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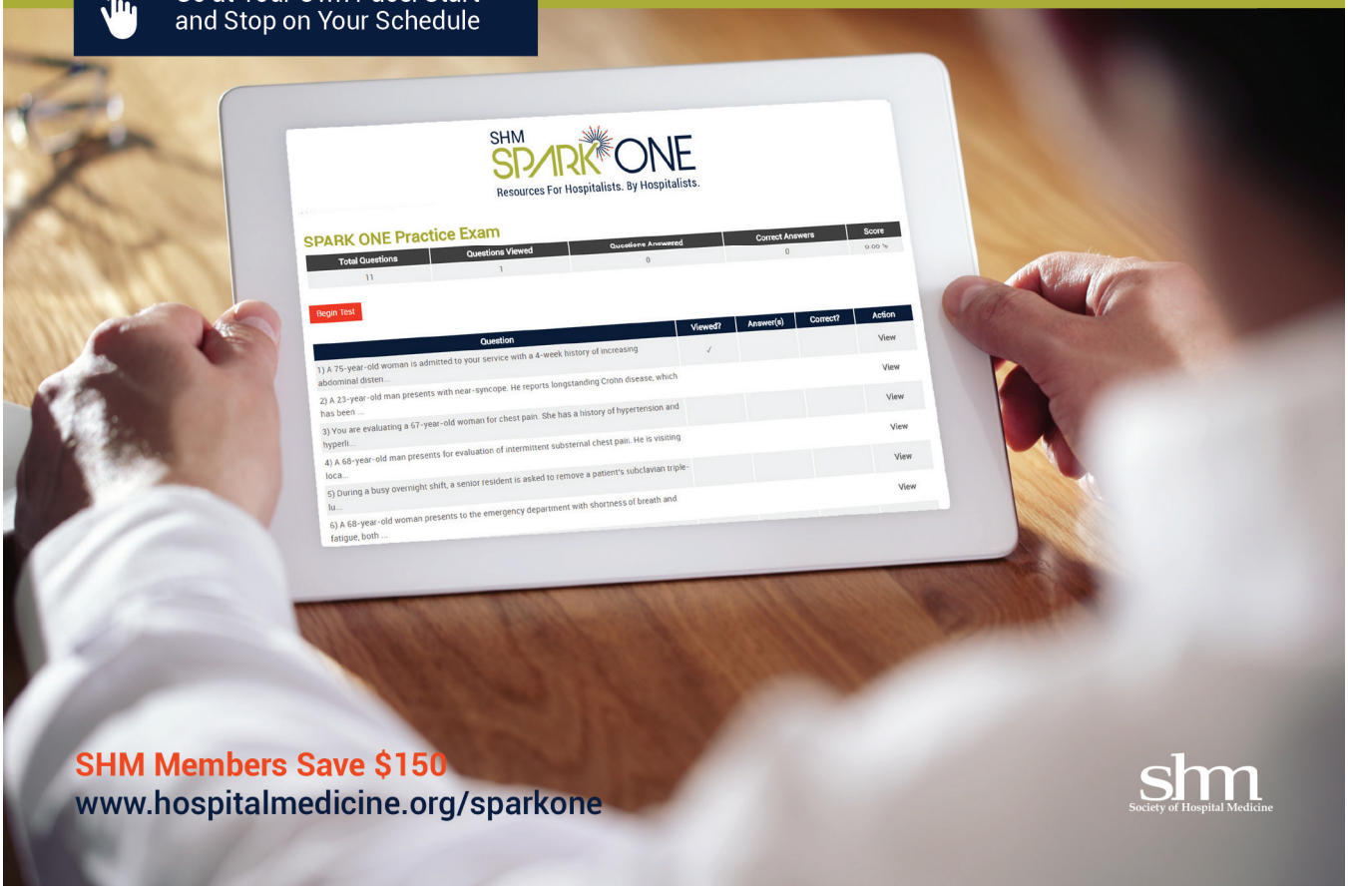

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SPECIAL ARTICLE

Predicting 30-Day Pneumonia Readmissions Using Electronic Health Record Data

Anil N. Makam, MD, MAS[1,2*] and Oanh Kieu Nguyen, MD, MAS[1,2], Christopher Clark, MPA[3], Song Zhang, PhD[2], Bin Xie, PhD[4], Mark Weinreich, MD[1], Eric M. Mortensen, MD, MSc[1,2,5], Ethan A. Halm, MD, MPH[1, 2]

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BACKGROUND: Readmissions after hospitalization for pneumonia are common, but the few risk-prediction models have poor to modest predictive ability. Data routinely collected in the electronic health record (EHR) may improve prediction.

OBJECTIVE: To develop pneumonia-specific readmission risk-prediction models using EHR data from the first day and from the entire hospital stay ("full stay").

DESIGN: Observational cohort study using stepwise-backward selection and cross-validation.

SUBJECTS: Consecutive pneumonia hospitalizations from 6 diverse hospitals in north Texas from 2009-2010.

MEASURES: All-cause nonelective 30-day readmissions, ascertained from 75 regional hospitals.

RESULTS: Of 1463 patients, 13.6% were readmitted. The first-day pneumonia-specific model included sociodemographic factors, prior hospitalizations, thrombocytosis, and a modified pneumonia severity index; the full-stay model included disposition status, vital sign instabilities on discharge, and an updated pneumonia severity index calculated using values from the day of discharge as additional predictors. The full-stay pneumonia-specific model outperformed the first-day model (C statistic 0.731 vs 0.695; P = 0.02; net reclassification index = 0.08). Compared to a validated multi-condition readmission model, the Centers for Medicare and Medicaid Services pneumonia model, and 2 commonly used pneumonia severity of illness scores, the full-stay pneumonia-specific model had better discrimination (C statistic range 0.604-0.681; $P < 0.01$ for all comparisons), predicted a broader range of risk, and better reclassified individuals by their true risk (net reclassification index range, 0.09-0.18).

CONCLUSIONS: EHR data collected from the entire hospitalization can accurately predict readmission risk among patients hospitalized for pneumonia. This approach outperforms a first-day pneumonia-specific model, the Centers for Medicare and Medicaid Services pneumonia model, and 2 commonly used pneumonia severity of illness scores. *Journal of Hospital Medicine* 2017;12:209-216. © 2017 Society of Hospital Medicine

Pneumonia is a leading cause of hospitalizations in the U.S., accounting for more than 1.1 million discharges annually.[1] Pneumonia is frequently complicated by hospital readmission, which is costly and potentially avoidable.[2,3] Due to financial penalties imposed on hospitals for higher than expected 30-day readmission rates, there is increasing attention to implementing interventions to reduce readmissions in this population.[4,5] However, because these programs are resource-intensive, interventions are thought to be most cost-effective if they are targeted to high-risk individuals who are most likely to benefit.[6-8]

Current pneumonia-specific readmission risk-prediction models that could enable identification of high-risk patients suffer from poor predictive ability, greatly limiting their use, and most were validated among older adults or by using data from single academic medical centers, limiting their generalizability.[9-14] A potential reason for poor predictive accuracy is the omission of known robust clinical predictors of pneumonia-related outcomes, including pneumonia severity of illness and stability on discharge.[15-17] Approaches using electronic health record (EHR) data, which include this clinically granular data, could enable hospitals to more accurately and pragmatically identify high-risk patients during the index hospitalization and enable interventions to be initiated prior to discharge.

An alternative strategy to identifying high-risk patients for readmission is to use a multi-condition risk-prediction model. Developing and implementing models for every condition may be time-consuming and costly. We have derived and validated 2 multi-condition risk-prediction models using EHR data—1 using data from the first day of hospital admission ('first-day' model), and the second incorporating data from the entire hospitalization ('full-stay' model) to reflect in-hospital complications and clinical stability at discharge.[18,19] However, it is unknown if a multi-condition model for pneumonia would perform as well as a disease-specific model.

This study aimed to develop 2 EHR-based pneumonia-specific readmission risk-prediction models using data routinely collected in clinical practice—a 'first-day' and a

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'full-stay' model—and compare the performance of each model to: 1) one another; 2) the corresponding multi-condition EHR model; and 3) to other potentially useful models in predicting pneumonia readmissions (the Centers for Medicare and Medicaid Services [CMS] pneumonia model, and 2 commonly used pneumonia severity of illness scores validated for predicting mortality). We hypothesized that the pneumonia-specific EHR models would outperform other models; and the full-stay pneumonia-specific model would outperform the first-day pneumonia-specific model.

METHODS

Study Design, Population, and Data Sources

We conducted an observational study using EHR data collected from 6 hospitals (including safety net, community, teaching, and nonteaching hospitals) in north Texas between November 2009 and October 2010, All hospitals used the Epic EHR (Epic Systems Corporation, Verona, WI). Details of this cohort have been published.[18,19]

We included consecutive hospitalizations among adults 18 years and older discharged from any medicine service with principal discharge diagnoses of pneumonia (ICD-9-CM codes 480-483, 485, 486-487), sepsis (ICD-9-CM codes 038, 995.91, 995.92, 785.52), or respiratory failure (ICD-9-CM codes 518.81, 518.82, 518.84, 799.1) when the latter 2 were also accompanied by a secondary diagnosis of pneumonia.[20] For individuals with multiple hospitalizations during the study period, we included only the first hospitalization. We excluded individuals who died during the index hospitalization or within 30 days of discharge, were transferred to another acute care facility, or left against medical advice.

Outcomes

The primary outcome was all-cause 30-day readmission, defined as a nonelective hospitalization within 30 days of discharge to any of 75 acute care hospitals within a 100-mile radius of Dallas, ascertained from an all-payer regional hospitalization database.

Predictor Variables for the Pneumonia-Specific Readmission Models

The selection of candidate predictors was informed by our validated multi-condition risk-prediction models using EHR data available within 24 hours of admission ('first-day' multi-condition EHR model) or during the entire hospitalization ('full-stay' multi-condition EHR model).[18,19] For the pneumonia-specific models, we included all variables in our published multi-condition models as candidate predictors, including sociodemographics, prior utilization, Charlson Comorbidity Index, select laboratory and vital sign abnormalities, length of stay, hospital complications (eg, venous thromboembolism), vital sign instabilities, and disposition status (see Supplemental Table 1 for complete list of variables). We also assessed additional variables specific to pneumonia for inclusion that were: (1) available in the EHR of all participating hospitals; (2) routinely collected or available at the time of admission or discharge; and (3) plausible predictors of adverse outcomes based on literature and clinical expertise. These included select comorbidities (eg, psychiatric conditions, chronic lung disease, history of pneumonia),[10,11,21,22] the pneumonia severity index (PSI),[16,23,24] intensive care unit stay, and receipt of invasive or noninvasive ventilation. We used a modified PSI score because certain data elements were missing. The modified PSI (henceforth referred to as PSI) did not include nursing home residence and included diagnostic codes as proxies for the presence of pleural effusion (ICD-9-CM codes 510, 511.1, and 511.9) and altered mental status (ICD-9-CM codes 780.0X, 780.97, 293.0, 293.1, and 348.3X).

Statistical Analysis

Model Derivation. Candidate predictor variables were classified as available in the EHR within 24 hours of admission and/or at the time of discharge. For example, socioeconomic factors could be ascertained within the first day of hospitalization, whereas length of stay would not be available until the day of discharge. Predictors with missing values were assumed to be normal (less than 1% missing for each variable). Univariate relationships between readmission and each candidate predictor were assessed in the overall cohort using a pre-specified significance threshold of $P \leq 0.10$. Significant variables were entered in the respective first-day and full-stay pneumonia-specific multivariable logistic regression models using stepwise-backward selection with a pre-specified significance threshold of $P \leq 0.05$. In sensitivity analyses, we alternately derived our models using stepwise-forward selection, as well as stepwise-backward selection minimizing the Bayesian information criterion and Akaike information criterion separately. These alternate modeling strategies yielded identical predictors to our final models.

Model Validation. Model validation was performed using 5-fold cross-validation, with the overall cohort randomly divided into 5 equal-size subsets.[25] For each cycle, 4 subsets were used for training to estimate model coefficients, and the fifth subset was used for validation. This cycle was repeated 5 times with each randomly-divided subset used once as the validation set. We repeated this entire process 50 times and averaged the C statistic estimates to derive an optimism-corrected C statistic. Model calibration was assessed qualitatively by comparing predicted to observed probabilities of readmission by quintiles of predicted risk, and with the Hosmer-Lemeshow goodness-of-fit test.

Comparison to Other Models. The main comparisons of the first-day and full-stay pneumonia-specific EHR model performance were to each other and the corresponding multi-condition EHR model.[18,19] The multi-condition EHR models were separately derived and validated within the larger parent cohort from which this study cohort was derived, and outperformed the CMS all-cause model, the HOSPITAL model, and the LACE index.[19] To further triangulate our findings, given the lack of other rigorously validated pneumonia-specific risk-prediction models for

readmission,[14] we compared the pneumonia-specific EHR models to the CMS pneumonia model derived from administrative claims data,[10] and 2 commonly used risk-prediction scores for short-term mortality among patients with community-acquired pneumonia, the PSI and CURB-65 scores.[16] Although derived and validated using patient-level data, the CMS model was developed to benchmark hospitals according to hospital-level readmission rates.[10] The CURB-65 score in this study was also modified to include the same altered mental status diagnostic codes according to the modified PSI as a proxy for "confusion." Both the PSI and CURB-65 scores were calculated using the most abnormal values within the first 24 hours of admission. The 'updated' PSI and the 'updated' CURB-65 were calculated using the most abnormal values within 24 hours prior to discharge, or the last known observation prior to discharge if no results were recorded within this time period. A complete list of variables for each of the comparison models are shown in Supplemental Table 1.

We assessed model performance by calculating the C statistic, integrated discrimination index, and net reclassification index (NRI) compared to our pneumonia-specific models. The integrated discrimination index is the difference in the mean predicted probability of readmission between patients who were and were not actually readmitted between 2 models, where more positive values suggest improvement in model performance compared to a reference model.[26] The NRI is defined as the sum of the net proportions of correctly reclassified persons with and without the event of interest.[27] Here, we calculated a category-based NRI to evaluate the performance of pneumonia-specific models in correctly classifying individuals with and without readmissions into the 2 highest readmission risk quintiles vs the lowest 3 risk quintiles compared to other models.[27] This pre-specified cutoff is relevant for hospitals interested in identifying the highest risk individuals for targeted intervention.[7] Finally, we assessed calibration of comparator models in our cohort by comparing predicted probability to observed probability of readmission by quintiles of risk for each model. We conducted all analyses using Stata 12.1 (StataCorp, College Station, Texas). This study was approved by the University of Texas Southwestern Medical Center Institutional Review Board.

RESULTS

Of 1463 index hospitalizations (Supplemental Figure 1), the 30-day all-cause readmission rate was 13.6%. Individuals with a 30-day readmission had markedly different sociodemographic and clinical characteristics compared to those not readmitted (Table 1; see Supplemental Table 2 for additional clinical characteristics).

Derivation, Validation, and Performance of the Pneumonia-Specific Readmission Risk-Prediction Models

The final first-day pneumonia-specific EHR model included 7 variables, including sociodemographic characteristics; prior hospitalizations; thrombocytosis, and PSI (Table 2). The first-day pneumonia-specific model had adequate discrimination (C statistic, 0.695; optimism-corrected C statistic 0.675, 95% confidence interval [CI], 0.667-0.685; Table 3). It also effectively stratified individuals across a broad range of risk (average predicted decile of risk ranged from 4% to 33%; Table 3) and was well calibrated (Supplemental Table 3).

The final full-stay pneumonia-specific EHR readmission model included 8 predictors, including 3 variables from the first-day model (median income, thrombocytosis, and prior hospitalizations; Table 2). The full-stay pneumonia-specific EHR model also included vital sign instabilities on discharge, updated PSI, and disposition status (ie, being discharged with home health or to a post-acute care facility was associated with greater odds of readmission, and hospice with lower odds). The full-stay pneumonia-specific EHR model had good discrimination (C statistic, 0.731; optimism-corrected C statistic, 0.714; 95% CI, 0.706-0.720), and stratified individuals across a broad range of risk (average predicted decile of risk ranged from 3% to 37%; Table 3), and was also well calibrated (Supplemental Table 3).

First-Day Pneumonia-Specific EHR Model vs First-Day Multi-Condition EHR Model

The first-day pneumonia-specific EHR model outperformed the first-day multi-condition EHR model with better discrimination (P = 0.029) and more correctly classified individuals in the top 2 highest risk quintiles vs the bottom 3 risk quintiles (Table 3, Supplemental Table 4, and Supplemental Figure 2A). With respect to calibration, the first-day multi-condition EHR model overestimated risk among the highest quintile risk group compared to the first-day pneumonia-specific EHR model (Figure 1A, 1B).

Full-Stay Pneumonia-Specific EHR Model vs Other Models

The full-stay pneumonia-specific EHR model comparatively outperformed the corresponding full-stay multi-condition EHR model, as well as the first-day pneumonia-specific EHR model, the CMS pneumonia model, the updated PSI, and the updated CURB-65 (Table 3, Supplemental Table 5, Supplemental Table 6, and Supplemental Figures 2B and 2C). Compared to the full-stay multi-condition and first-day pneumonia-specific EHR models, the full-stay pneumonia-specific EHR model had better discrimination, better reclassification (NRI, 0.09 and 0.08, respectively), and was able to stratify individuals across a broader range of readmission risk (Table 3). It also had better calibration in the highest quintile risk group compared to the full-stay multi-condition EHR model (Figure 1C and 1D).

Updated vs First-Day Modified PSI and CURB-65 Scores

The updated PSI was more strongly predictive of readmission than the PSI calculated on the day of admission (Wald test, 9.83; P = 0.002). Each 10-point increase in the updated PSI was associated with a 22% increased odds of readmission vs an 11% increase for the PSI calculated upon admission (Table 2). The improved predictive ability of the updated

TABLE 1. Baseline Characteristics of Patients Hospitalized with Pneumonia

	No Readmission n = 1,264	Readmission n = 199	*P* value
Sociodemographic characteristics			
Age in years, mean (SD)	64.5 (17.2)	70.3 (15.0)	≤0.001
Male, n (%)	549 (43.4)	101 (50.8)	0.054
Race/ethnicity			0.894
White	880 (69.6)	138 (69.6)	
Black	166 (13.1)	29 (14.6)	
Hispanic	165 (13.1)	23 (11.6)	
Other	53 (4.2)	9 (4.5)	
Marital status, n (%)			0.027
Single	295 (23.3)	30 (15.1)	
Married	493 (39.0)	81 (40.7)	
Other	476 (37.7)	88 (44.2)	
Primary payer, n (%)			≤0.001
Private	517 (40.9)	60 (30.2)	
Medicare	540 (42.7)	117 (58.8)	
Medicaid	72 (5.7)	15 (7.5)	
Charity, self-pay, or other	135 (10.7)	7 (3.5)	
Median income (<$30,000) per ZIP code, n (%)	102 (8.1)	26 (13.1)	0.022
Utilization history			
≥1 hospitalizations in past year, n (%)[a]	433 (33.4)	99 (50.0)	≤0.001
Clinical factors from first day of hospital stay			
Charlson Comorbidity Index, median [IQR][b]	0 [0-1]	0 [0-3]	≤0.001
Platelets >350 x 10^3/μL	142 (11.2)	43 (21.6)	≤0.001
PSI[c]			≤0.001
≤70	428 (33.9)	33 (16.6)	
71-90	318 (25.2)	50 (25.1)	
91-130	398 (31.5)	73 (36.7)	
>130	120 (9.5)	43 (21.6)	
Clinical factors from remainder of hospital stay			0.001
Length of stay in days, median [IQR]	5 [3-7]	6 [4-9]	
Updated pneumonia severity index[c]			≤0.001
≤70	561 (44.4)	43 (21.6)	
71-90	359 (28.4)	56 (28.1)	
91-130	301 (23.8)	83 (41.7)	
>130	43 (3.4)	17 (8.5)	
Vital sign instabilities on discharge, ≥1, n(%)[d]	310 (24.5)	68 (34.2)	0.004
Discharge location, n (%)			≤0.001
Home	889 (70.3)	106 (53.3)	
Home health	106 (8.4)	30 (15.1)	
Post-acute care[e]	237 (18.8)	60 (30.2)	
Hospice	32 (2.5)	3 (1.5)	

[a]Prior hospitalization at any of 75 acute care hospitals in the north Texas region within the past year.

[b]Calculated from diagnoses available within 1 year prior to index hospitalization.

[c]Omitted nursing home residence and included diagnostic codes as proxies for pleural effusion (ICD-9-CM codes 510, 511.1, and 511.9) and altered mental status (ICD-9-CM codes 780.0X, 780.97, 293.0, 293.1, and 348.3X).

[d]On day of discharge, or last known observation prior to discharge. Instabilities were defined as temperature ≥37.8°C, heart rate >100 beats/minute, respiratory rate > 24 breaths/minute, systolic blood pressure ≤90 mm Hg, or oxygen saturation <90%.[17]

[e]Includes discharges to nursing home, skilled nursing facility, or long-term acute care hospital.

NOTE: Abbreviations: IQR, interquartile range; PSI, pneumonia severity index.

PSI and CURB-65 scores was also reflected in the superior discrimination and calibration vs the respective first-day pneumonia severity of illness scores (Table 3).

DISCUSSION

Using routinely available EHR data from 6 diverse hospitals, we developed 2 pneumonia-specific readmission risk-prediction models that aimed to allow hospitals to identify patients hospitalized with pneumonia at high risk for readmission. Overall, we found that a pneumonia-specific model using EHR data from the entire hospitalization outperformed all other models—including the first-day pneumonia-specific model using data present only on admission, our own multi-condition EHR models, and the CMS pneumonia model based on administrative claims data—in all aspects of model performance (discrimination, calibration, and reclassification). We found that

TABLE 2. Final Pneumonia-Specific EHR Risk-Prediction Models for Readmissions

	Odds Ratio (95% CI)	
	Univariate	Multivariate[a]
First-day pneumonia-specific model		
Single	0.58 (0.39-0.88)	0.61 (0.40-0.95)
Medicare	1.91 (1.41-2.59)	1.72 (1.23-2.41)
Medicaid	1.35 (0.76-2.40)	2.16 (1.14-4.11)
Median income (<$30,000) per ZIP code	1.71 (1.08-2.71)	1.85 (1.14-3.02)
Prior hospitalizations in past year	1.35 (1.19-1.53)	1.18 (1.03-1.36)
Platelets >350 x 10^3/μL	2.18 (1.49-3.18)	2.18 (1.46-3.24)
PSI, per 10 points	1.15 (1.06-1.17)	1.11 (1.06-1.17)
Full-stay pneumonia-specific model		
Median income (<$30,000) per ZIP code	1.71 (1.08-2.71)	1.92 (1.18-3.12)
Platelets >350 x 10^3/μL	2.18 (1.49-3.18)	2.35 (1.57-3.52)
Prior hospitalizations in past year	1.35 (1.19-1.53)	1.26 (1.10-1.44)
Vital sign instabilities on discharge, ≥1	1.60 (1.16-2.20)	1.47 (1.05-2.07)
Updated PSI, per 10 points	1.23 (1.17-1.30)	1.22 (1.15-1.29)
Disposition status at hospital discharge		
Home	[Reference]	[Reference]
Home with home health	2.37 (1.51-3.73)	1.61 (0.99-2.62)
Post-acute care facility	2.12 (1.50-3.01)	1.39 (0.94-2.03)
Hospice	0.79 (0.24-2.61)	0.23 (0.07-0.83)

[a]Adjusted for all factors listed in the table for each respective model

NOTE: Abbreviations: CI, confidence interval; EHR, electronic health record; PSI, pneumonia severity index.

TABLE 3. Model Performance and Comparison of Pneumonia-Specific EHR Readmissions Models vs Other Models

Model	C Statistic	Comparison of C Statistic (*P* value)[a]	IDI (%) (95% CI)	Categorical NRI[b] (95% CI)	Average Predicted Risk (%)	
					Lowest Decile	Highest Decile
First-day pneumonia	0.695	[Reference]	[Reference]	[Reference]	0.04	0.33
First-day multi-condition	0.656	0.029	-0.01 (-0.03 to 0.01)	-0.06 (-0.15 to 0.02)	0.07	0.36
CMS pneumonia	0.640	0.014	-0.03 (-0.04 to -0.02)	-0.07 (-0.15 to 0.02)	0.08	0.29
PSI	0.638	<0.001	-0.03 (-0.04 to -0.02)	-0.09 (-0.17 to -0.01)	0.06	0.27
CURB-65	0.578	<0.001	-0.05 (-0.07 to -0.04)	-0.14 (-0.23 to -0.05)	0.10	0.18
Full-stay pneumonia	0.731	[Reference]	[Reference]	[Reference]	0.03	0.37
First-day pneumonia	0.695	0.018	-0.02 (-0.01 to -0.03)	-0.08 (-0.01 to -0.15)	0.04	0.33
Full-stay multi-condition	0.681	0.008	-0.01 (-0.03 to 0.01)	-0.09 (-0.17 to -0.01)	0.06	0.39
CMS pneumonia	0.640	<0.001	-0.05 (-0.04 to -0.07)	-0.15 (-0.23 to -0.06)	0.08	0.29
Updated PSI	0.673	<0.001	-0.04 (-0.06 to -0.03)	-0.09 (-0.16 to -0.01)	0.05	0.30
Updated CURB-65	0.604	<0.001	-0.07 (-0.08 to -0.05)	-0.18 (-0.27 to -0.09)	0.09	0.22

[a]*P* values are shown for each model compared to the respective reference model using the DeLong, DeLong, and Clarke-Pearson method.

[b]The categorical NRI compares reclassification between the highest 2 risk quintiles and the lowest 3 risk quintiles.

NOTE: Abbreviations: CI, confidence interval; CMS, Centers for Medicare and Medicaid Services; IDI, integrated discrimination improvement; NRI, net reclassification index; PSI, pneumonia severity index.

socioeconomic status, prior hospitalizations, thrombocytosis, and measures of clinical severity and stability were important predictors of 30-day all-cause readmissions among patients hospitalized with pneumonia. Additionally, an updated discharge PSI score was a stronger independent predictor of readmissions compared to the PSI score calculated upon admission; and inclusion of the updated PSI in our full-stay pneumonia model led to improved prediction of 30-day readmissions.

The marked improvement in performance of the full-stay pneumonia-specific EHR model compared to the first-day pneumonia-specific model suggests that clinical stability and trajectory during hospitalization (as modeled through disposition status, updated PSI, and vital sign instabilities at discharge) are important predictors of 30-day readmis-

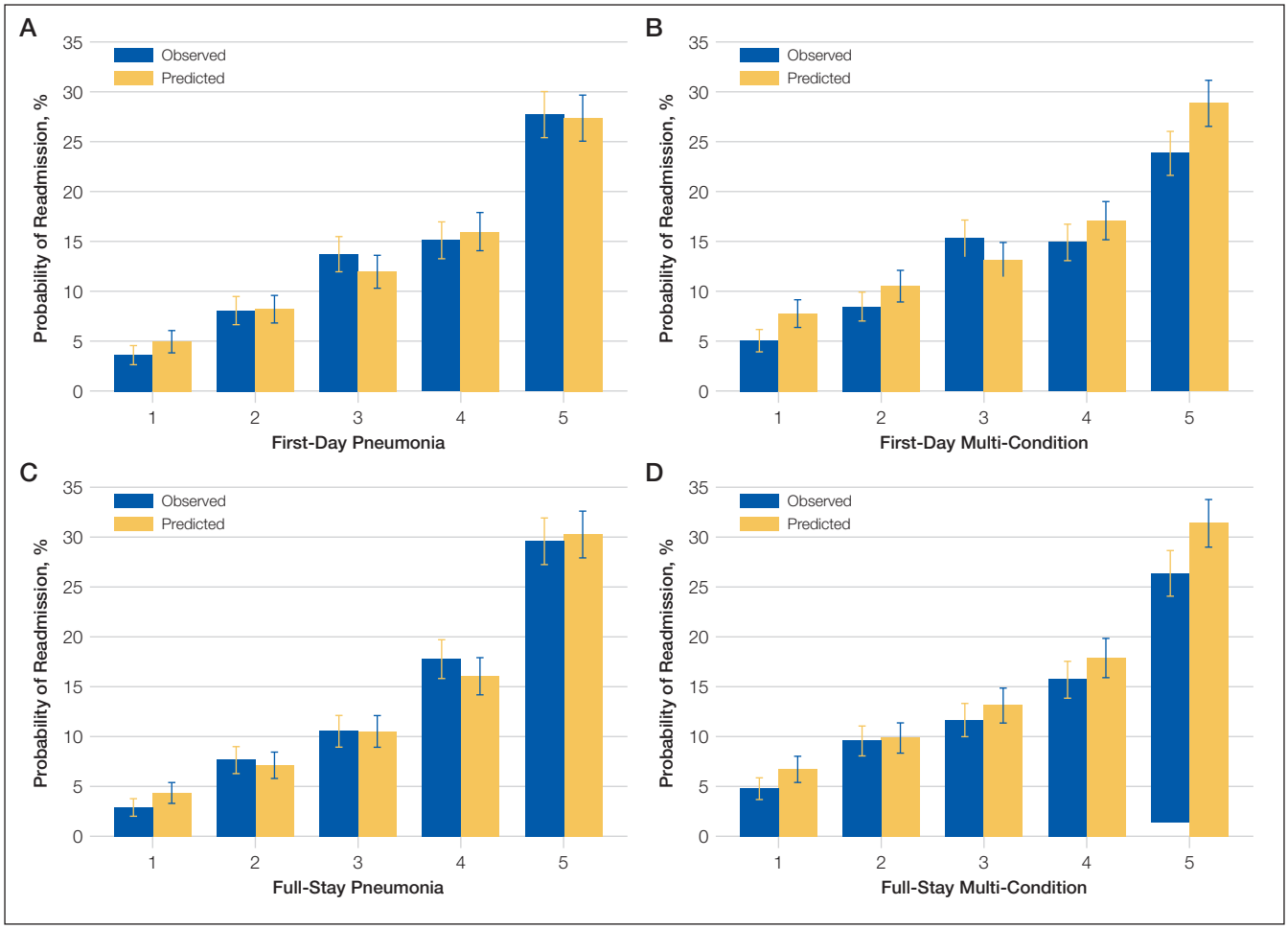

FIG. Comparison of the calibration of different readmission models. The Hosmer-Lemeshow goodness-of-fit test using deciles of predicted risk confirmed adequate model fit for the first-day and full-stay pneumonia-specific models (*P* value = 0.16 and 0.31, respectively)

sion among patients hospitalized for pneumonia, which was not the case for our EHR-based multi-condition models.[19] With the inclusion of these measures, the full-stay pneumonia-specific model correctly reclassified an additional 8% of patients according to their true risk compared to the first-day pneumonia-specific model. One implication of these findings is that hospitals interested in targeting their highest risk individuals with pneumonia for transitional care interventions could do so using the first-day pneumonia-specific EHR model and could refine their targeted strategy at the time of discharge by using the full-stay pneumonia model. This staged risk-prediction strategy would enable hospitals to initiate transitional care interventions for high-risk individuals in the inpatient setting (ie, patient education).[7] Then, hospitals could enroll both persistent and newly identified high-risk individuals for outpatient interventions (ie, follow-up telephone call) in the immediate post-discharge period, an interval characterized by heightened vulnerability for adverse events,[28] based on patients' illness severity and stability at discharge. This approach can be implemented by hospitals by building these risk-prediction models directly into the EHR, or by extracting EHR data in near real time as our group has done successfully for heart failure.[7]

Another key implication of our study is that, for pneumonia, a disease-specific modeling approach has better predictive ability than using a multi-condition model. Compared to multi-condition models, the first-day and full-stay pneumonia-specific EHR models correctly reclassified an additional 6% and 9% of patients, respectively. Thus, hospitals interested in identifying the highest risk patients with pneumonia for targeted interventions should do so using the disease-specific models, if the costs and resources of doing so are within reach of the healthcare system.

An additional novel finding of our study is the added value of an updated PSI for predicting adverse events. Studies of pneumonia severity of illness scores have calculated the PSI and CURB-65 scores using data present only on admission.[16,24] While our study also confirms that the PSI calculated upon admission is a significant predictor of readmission,[23,29] this study extends this work by showing that an updated PSI score calculated at the time of discharge is an even stronger predictor for readmission, and its inclusion in the model significantly improves risk stratification and prognostication.

Our study was noteworthy for several strengths. First, we

used data from a common EHR system, thus potentially allowing for the implementation of the pneumonia-specific models in real time across a number of hospitals. The use of routinely collected data for risk-prediction modeling makes this approach scalable and sustainable, because it obviates the need for burdensome data collection and entry. Second, to our knowledge, this is the first study to measure the additive influence of illness severity and stability at discharge on the readmission risk among patients hospitalized with pneumonia. Third, our study population was derived from 6 hospitals diverse in payer status, age, race/ethnicity, and socioeconomic status. Fourth, our models are less likely to be overfit to the idiosyncrasies of our data given that several predictors included in our final pneumonia-specific models have been associated with readmission in this population, including marital status,[13,30] income,[11,31] prior hospitalizations,[11,13] thrombocytosis,[32-34] and vital sign instabilities on discharge.[17] Lastly, the discrimination of the CMS pneumonia model in our cohort (C statistic, 0.64) closely matched the discrimination observed in 4 independent cohorts (C statistic, 0.63), suggesting adequate generalizability of our study setting and population.[10,12]

Our results should be interpreted in the context of several limitations. First, generalizability to other regions beyond north Texas is unknown. Second, although we included a diverse cohort of safety net, community, teaching, and nonteaching hospitals, the pneumonia-specific models were not externally validated in a separate cohort, which may lead to more optimistic estimates of model performance. Third, PSI and CURB-65 scores were modified to use diagnostic codes for altered mental status and pleural effusion, and omitted nursing home residence. Thus, the independent associations for the PSI and CURB-65 scores and their predictive ability are likely attenuated. Fourth, we were unable to include data on medications (antibiotics and steroid use) and outpatient visits, which may influence readmission risk.[2,9,13,35-40] Fifth, we included only the first pneumonia hospitalization per patient in this study. Had we included multiple hospitalizations per patient, we anticipate better model performance for the 2 pneumonia-specific EHR models since prior hospitalization was a robust predictor of readmission.

In conclusion, the full-stay pneumonia-specific EHR readmission risk-prediction model outperformed the first-day pneumonia-specific model, multi-condition EHR models, and the CMS pneumonia model. This suggests that: measures of clinical severity and stability at the time of discharge are important predictors for identifying patients at highest risk for readmission; and that EHR data routinely collected for clinical practice can be used to accurately predict risk of readmission among patients hospitalized for pneumonia.

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REFERENCES

1. Centers for Disease Control and Prevention. Pneumonia. http://www.cdc.gov/nchs/fastats/pneumonia.htm. Accessed January 26, 2016.
2. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. *N Engl J Med*. 2009;364(16):1582.
3. van Walraven C, Bennett C, Jennings A, Austin PC, Forster AJ. Proportion of hospital readmissions deemed avoidable: a systematic review. *CMAJ*. 2011;183(7):E391-E402.
4. Rennke S, Nguyen OK, Shoeb MH, Magan Y, Wachter RM, Ranji SR. Hospital-initiated transitional care interventions as a patient safety strategy: a systematic review. *Ann Intern Med*. 2013;158(5 pt 2):433-440.
5. Hansen LO, Young RS, Hinami K, Leung A, Williams MV. Interventions to reduce 30-day rehospitalization: a systematic review. *Ann Intern Med*. 2011;155(8):520-528.
6. Rennke S, Shoeb MH, Nguyen OK, Magan Y, Wachter RM, Ranji SR. *Interventions to Improve Care Transitions at Hospital Discharge*. Rockville, MD: Agency for Healthcare Research and Quality, US Department of Health and Human Services;March 2013.
7. Amarasingham R, Patel PC, Toto K, et al. Allocating scarce resources in real-time to reduce heart failure readmissions: a prospective, controlled study. *BMJ Qual Saf*. 2013;22(12):998-1005.
8. Amarasingham R, Patzer RE, Huesch M, Nguyen NQ, Xie B. Implementing electronic health care predictive analytics: considerations and challenges. *Health Aff (Millwood)*. 2014;33(7):1148-1154.
9. Hebert C, Shivade C, Foraker R, et al. Diagnosis-specific readmission risk prediction using electronic health data: a retrospective cohort study. *BMC Med Inform Decis Mak*. 2014;14:65.
10. Lindenauer PK, Normand SL, Drye EE, et al. Development, validation, and results of a measure of 30-day readmission following hospitalization for pneumonia. *J Hosp Med*. 2011;6(3):142-150.
11. Mather JF, Fortunato GJ, Ash JL, Davis MJ, Kumar A. Prediction of pneumonia 30-day readmissions: a single-center attempt to increase model performance. *Respir Care*. 2014;59(2):199-208.
12. O'Brien WJ, Chen Q, Mull HJ, et al. What is the value of adding Medicare data in estimating VA hospital readmission rates? *Health Serv Res*. 2015;50(1):40-57.
13. Tang VL, Halm EA, Fine MJ, Johnson CS, Anzueto A, Mortensen EM. Predictors of rehospitalization after admission for pneumonia in the veterans affairs healthcare system. *J Hosp Med*. 2014;9(6):379-383.
14. Weinreich M, Nguyen OK, Wang D, et al. Predicting the risk of readmission in pneumonia: a systematic review of model performance. *Ann Am Thorac Soc*. 2016;13(9):1607-1614.
15. Kwok CS, Loke YK, Woo K, Myint PK. Risk prediction models for mortality in community-acquired pneumonia: a systematic review. *Biomed Res Int*. 2013;2013:504136.
16. Loke YK, Kwok CS, Niruban A, Myint PK. Value of severity scales in predicting mortality from community-acquired pneumonia: systematic review and meta-analysis. *Thorax*. 2010;65(10):884-890.
17. Halm EA, Fine MJ, Kapoor WN, Singer DE, Marrie TJ, Siu AL. Instability on hospital discharge and the risk of adverse outcomes in patients with pneumonia. *Arch Intern Med*. 2002;162(11):1278-1284.
18. Amarasingham R, Velasco F, Xie B, et al. Electronic medical record-based multicondition models to predict the risk of 30 day readmission or death among adult medicine patients: validation and comparison to existing models. *BMC Med Inform Decis Mak*. 2015;15:39.
19. Nguyen OK, Makam AN, Clark C, et al. Predicting all-cause readmissions using electronic health record data from the entire hospitalization: Model development and comparison. *J Hosp Med*. 2016;11(7):473-480.
20. Lindenauer PK, Lagu T, Shieh MS, Pekow PS, Rothberg MB. Association of diagnostic coding with trends in hospitalizations and mortality of patients with pneumonia, 2003-2009. *JAMA*. 2012;307(13):1405-1413.
21. Ahmedani BK, Solberg LI, Copeland LA, et al. Psychiatric comorbidity and 30-day readmissions after hospitalization for heart failure, AMI, and pneumonia. *Psychiatr Serv*. 2015;66(2):134-140.
22. Jasti H, Mortensen EM, Obrosky DS, Kapoor WN, Fine MJ. Causes and risk fac-

tors for rehospitalization of patients hospitalized with community-acquired pneumonia. *Clin Infect Dis*. 2008;46(4):550-556.
23. Capelastegui A, España Yandiola PP, Quintana JM, et al. Predictors of short-term rehospitalization following discharge of patients hospitalized with community-acquired pneumonia. *Chest*. 2009;136(4):1079-1085.
24. Fine MJ, Auble TE, Yealy DM, et al. A prediction rule to identify low-risk patients with community-acquired pneumonia. *N Engl J Med*. 1997;336(4):243-250.
25. Vittinghoff E, Glidden D, Shiboski S, McCulloch C. *Regression Methods in Biostatistics: Linear, Logistic, Survival, and Repeated Measures Models (Statistics for Biology and Health)*. New York City, NY: Springer; 2012.
26. Pencina MJ, D'Agostino RB Sr, D'Agostino RB Jr, Vasan RS. Evaluating the added predictive ability of a new marker: from area under the ROC curve to reclassification and beyond. *Stat Med*. 2008;27(2):157-172; discussion 207-112.
27. Leening MJ, Vedder MM, Witteman JC, Pencina MJ, Steyerberg EW. Net reclassification improvement: computation, interpretation, and controversies: a literature review and clinician's guide. *Ann Intern Med*. 2014;160(2):122-131.
28. Krumholz HM. Post-hospital syndrome--an acquired, transient condition of generalized risk. *N Engl J Med*. 2013;368(2):100-102.
29. Micek ST, Lang A, Fuller BM, Hampton NB, Kollef MH. Clinical implications for patients treated inappropriately for community-acquired pneumonia in the emergency department. *BMC Infect Dis*. 2014;14:61.
30. Metersky ML, Fine MJ, Mortensen EM. The effect of marital status on the presentation and outcomes of elderly male veterans hospitalized for pneumonia. *Chest*. 2012;142(4):982-987.
31. Calvillo-King L, Arnold D, Eubank KJ, et al. Impact of social factors on risk of readmission or mortality in pneumonia and heart failure: systematic review. *J Gen Intern Med*. 2013;28(2):269-282.
32. Mirsaeidi M, Peyrani P, Aliberti S, et al. Thrombocytopenia and thrombocytosis at time of hospitalization predict mortality in patients with community-acquired pneumonia. *Chest*. 2010;137(2):416-420.
33. Prina E, Ferrer M, Ranzani OT, et al. Thrombocytosis is a marker of poor outcome in community-acquired pneumonia. *Chest*. 2013;143(3):767-775.
34. Violi F, Cangemi R, Calvieri C. Pneumonia, thrombosis and vascular disease. *J Thromb Haemost*. 2014;12(9):1391-1400.
35. Weinberger M, Oddone EZ, Henderson WG. Does increased access to primary care reduce hospital readmissions? Veterans Affairs Cooperative Study Group on Primary Care and Hospital Readmission. *N Engl J Med*. 1996;334(22):1441-1447.
36. Field TS, Ogarek J, Garber L, Reed G, Gurwitz JH. Association of early post-discharge follow-up by a primary care physician and 30-day rehospitalization among older adults. *J Gen Intern Med*. 2015;30(5):565-571.
37. Spatz ES, Sheth SD, Gosch KL, et al. Usual source of care and outcomes following acute myocardial infarction. *J Gen Intern Med*. 2014;29(6):862-869.
38. Brooke BS, Stone DH, Cronenwett JL, et al. Early primary care provider follow-up and readmission after high-risk surgery. *JAMA Surg*. 2014;149(8):821-828.
39. Adamuz J, Viasus D, Campreciós-Rodriguez P, et al. A prospective cohort study of healthcare visits and rehospitalizations after discharge of patients with community-acquired pneumonia. *Respirology*. 2011;16(7):1119-1126.
40. Shorr AF, Zilberberg MD, Reichley R, et al. Readmission following hospitalization for pneumonia: the impact of pneumonia type and its implication for hospitals. *Clin Infect Dis*. 2013;57(3):362-367.

Evaluating Automated Rules for Rapid Response System Alarm Triggers in Medical and Surgical Patients

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BACKGROUND: The use of rapid response systems (RRS), which were designed to bring clinicians with critical care expertise to the bedside to prevent unnecessary deaths, has increased. RRS rely on accurate detection of acute deterioration events. Early warning scores (EWS) have been used for this purpose but were developed using heterogeneous populations. Predictive performance may differ in medical vs surgical patients.

OBJECTIVE: To evaluate the performance of published EWS in medical vs surgical patient populations.

DESIGN: Retrospective cohort study.

SETTING: Two tertiary care academic medical center hospitals in the Midwest totaling more than 1500 beds.

PATIENTS: All patients discharged from January to December 2011.

INTERVENTION: None.

MEASUREMENTS: Time-stamped longitudinal database of patient variables and outcomes, categorized as surgical or medical. Outcomes included unscheduled transfers to the intensive care unit, activation of the RRS, and calls for cardiorespiratory resuscitation ("resuscitation call"). The EWS were calculated and updated with every new patient variable entry over time. Scores were considered accurate if they predicted an outcome in the following 24 hours.

RESULTS: All EWS demonstrated higher performance within the medical population as compared to surgical: higher positive predictive value ($P < .0001$ for all scores) and sensitivity ($P < .0001$ for all scores). All EWS had positive predictive values below 25%.

CONCLUSIONS: The overall poor performance of the evaluated EWS was marginally better in medical patients when compared to surgical patients. *Journal of Hospital Medicine* 2017;12:217-223. © 2017 Society of Hospital Medicine

Patients typically show signs and symptoms of deterioration hours to days prior to cardiorespiratory arrest.[1,2] The rate of inhospital cardiorespiratory arrest (CRA) requiring cardiopulmonary resuscitation is estimated to be 0.174 per bed per year in the United States.[3] After CRA, survival to discharge is estimated to be as low as 18%.[3,4] Efforts to predict and prevent arrest could prove beneficial.[1,2]

Rapid response systems (RRS) have been proposed as a means of identifying clinical deterioration and facilitating a timely response. These systems were designed to bring clinicians with critical care expertise to the bedside to prevent unnecessary deaths. They typically include an afferent limb (detects deteriorating patients), an efferent limb (responds to calls and acts to avoid further deterioration), and administrative and data analysis limbs.[5,6] Automatic provision of recommendations and computer-based systems are desirable components of the afferent limb of the detection system.[6] Both are independent predictors of improved clinical practices for clinical decision support systems.[7] However, the existing early warning scores (EWS) may not be ready for automation due to low positive predictive values (PPV) and sensitivities.[8]

It is possible that the low discriminatory accuracy of the published EWS may be secondary to the use of aggregate patient populations for derivation of scores. We hypothesized that these EWS perform differently in medical and in surgical subpopulations. Also, the EWS need to be tested in a time-dependent manner to serve as a realistic clinical support tool for hospitalized patients.

STUDY AIM

The aim of this study was to evaluate the differential performance of widely used EWS in medical vs surgical patients.

METHODS

Site

The study was conducted in an academic center with 2 hospitals in Southeastern Minnesota totaling approximately 1500 general care nonintensive care unit (ICU) beds. The Mayo Clinic Institutional Review Board approved the research proposal.

Subjects

Our retrospective cohort was comprised of all adult inpatients discharged from 2 academic hospitals between January 1, 2011 and December 31, 2011 who spent any time in a general care (non-ICU) unit. We excluded patients younger

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than 18 years, psychiatric or rehabilitation inpatients, those without research authorization, and patients admitted for research purposes.

Study patients were divided into medical and surgical cohorts. Hospitalizations were considered surgical if patients had surgery at any time during their hospital stay according to billing data. A trigger was an instance in which a patient met the conditions of a specific rule (score/vital sign exceeded the published/defined threshold).

A resuscitation call was defined as a call for cardiopulmonary resuscitation when a patient has a CRA.

An event was an occurrence of 1 of the following in a general care setting: unplanned transfer to the ICU, resuscitation call, or RRS activation.

The RRS activation criteria consisted of an "acute and persistent change" in any 1 or more of the following: oxygen saturations less than 90%, heart rate less than 40 or greater than 130 beats/minute, systolic blood pressure less than 90 mm Hg, or respiratory rate less than 10 or greater than 28 breaths/minute. The RRS activation requires health provider action; they are not electronically generated. Nurses and physicians may also activate the RRS if they are concerned about a patient, even if calling criteria are not met. This is in contrast to the EWS analyzed, which are aggregate composites of multiple parameters. However, whether or not a derangement in vital signs is considered an "acute and persistent change" still involves clinical judgment. Any movement from a general care bed to an ICU bed, or from a general care bed to a procedure area, and from there to an ICU, was considered unplanned. Transfers to the ICU directly from the emergency department or operating room (OR) were not considered as an unplanned transfer and were not included in the analyses.

Coverage time was the period observed for events after a rule was triggered. In this analysis, a coverage time of 24 hours was considered, with a 1-hour look-back. A trigger was counted as a true positive if an event occurred during the following 24 hours. The 1-hour look-back was included to take into account the nursing clinical process of prioritizing a call to the RRS followed by documentation of the altered vital signs that prompted the call.

An episode was the continuous time on the general care floor within a hospitalization, excluding times when a patient was in the OR or ICU. For example, if a patient was admitted to a general bed on a surgery floor, subsequently went to the OR, and then returned to the surgery floor, the 2 episodes were considered separate: the time on the floor before surgery, and the time on the floor after surgery.

Assessment of implementation of RRS in our hospitals showed a significant drop in the failure-to-rescue rate (issues considered related to delay or failure to identify or intervene appropriately when a patient was deteriorating, as identified through mortality review) and a decrease in non-ICU mortality.[9,10] This suggests that our current process captures many of the relevant episodes of acute deterioration when a rapid response team is needed and supports using RRS activation as outcomes.

Data Sources

We developed a time-stamped longitudinal database of patient data from the electronic health record, including vital signs, laboratory test results, demographics (age, sex), administrative data (including length of stay), comorbidities, resuscitation code status, location in hospital, and at the minute level throughout each patient's hospital stay. Physiologically impossible values (eg, blood pressures of 1200 mm Hg) were considered entered in error and eliminated from the database. Time spent in the OR or ICU was excluded because RRS activation would not be applied in these already highly monitored areas. SAS Statistical software (SAS Institute Inc. Cary, North Carolina) was used for database creation.

We applied the current RRS calling criteria in our institution and calculated the Kirkland score,[11] along with some of the most widely used early warning scores:[12] Modified Early Warning System (MEWS),[13] Standardized Early Warning Scoring System (SEWS),[14] Global Modified Early Warning Score (GMEWS),[15] Worthing physiologic scoring system,[16] National Early Warning Score (NEWS),[17] and VitaPAC Early Warning Score (ViEWS).[18] Published thresholds for these scores were used to create rule triggers in the data. Once a trigger was created to calculate the number of false positives and true positives, all subsequent triggers were ignored until the end of the episode or until 24 hours elapsed. We calculated triggers in a rolling fashion throughout the episodes of care. The EWS score was updated every time a new parameter was entered into the analytical electronic health record, and the most recent value for each was used to calculate the score. SAS statistical software was used for calculation of scores and identification of outcomes.

For our analysis, events were treated as dependent variables, and triggers were independent variables. We calculated the score for each EWS to the minute level throughout our retrospective database. If the score for a specific EWS was higher than the published/recommended threshold for that EWS, an alert was considered to have been issued, and the patient was followed for 24 hours. If the patient had an event in the subsequent 24 hours, or 1 hour before (1-hour look-back), the alert was considered a true positive; if not, a false positive. Events that were not preceded by an alert were false negatives, and 24-hour intervals without either an alert or an event were considered true negatives. This simulation exercise was performed for each EWS in both subcohorts (medical and surgical). Clusters of RRS calls followed by transfers to the ICU within 3 hours were considered as a single adverse event (RRS calls, as it was the first event to occur) to avoid double counting. We have described how well this simulation methodology,[8] correlates with results from prospective studies.[19]

Statistical Analysis

To calculate whether results were statistically significant for subgroups, a jackknife method of calculating variance[20] was used. The jackknife method calculates variance by repeating

TABLE 1. Patient Characteristics, Events, and Triggers

	All	Surgical	Medical
Patient characteristics			
Total patients (N[a])	34,898	20,176	14,722
Male patients (N [%])	17,001 (48.7%)	10,368 (51.4%)	6633 (45.1%)
Age (mean)	58.6	58.9	58.2
Total hospitalizations	46,366	23,831	22,535
Total episodes (N)	75,240	46,275	28,965
Total time points (N)	16,780,669	11,878,268	4902,401
LoS (d)[a]			
LOS, hospitalization (median, quartiles)			
25%	2	2	2
50%	3	3	3
75%	6	6	5
LOS, episode. (median, quartiles)			
25%	0	0	1
50%	2	2	2
75%	3	3	4
Events[b]			
Total events	3,517	1,820	1,697
RRS calls	1,865	786	1,079
Code 45	203	119	84
Unscheduled transfer to ICU	1,449	915	534
Event rate			
Total events/100 episodes	4.67	3.93	5.86
RRS calls/100 episodes	2.48	1.70	3.73
Code 45/100 episodes	0.27	0.26	0.29
Unscheduled transfers to ICU/100 episodes	1.93	1.98	1.84
Triggers by rule			
RRT	174,014	101,190	72,824
GMEWS	5,043	2,338	2,705
MEWS	51,693	27,386	24,307
SEWS	116,753	63,370	53,383
ViEWS	1,375,831	818,695	557,136
Worthing	1,175,736	685,693	490,043
Kirkland	602,441	321,605	280,836
Triggers/d/10 hospital beds			
RRT	3.0	3.1	2.9
GMEWS	0.1	0.1	0.1
MEWS	0.9	0.8	1.0
SEWS	2.0	1.9	2.1
ViEWS	23.8	24.9	22.4
Worthing	20.3	20.8	19.7
Kirkland	10.4	9.8	11.3

[a]Patients are classified as surgical if they had at least 1 surgical hospitalization during the study period. All other metrics shown here (eg, events, triggers) are calculated per hospitalization. Hence, the total number of events for the medical group is the total number of events for all medical hospitalizations.

[b]Events and triggers are assigned to the group where a patient was when the event took place. "Triggers" refers to the number of instances when a patient met the EWS' triggering criteria recommended by the authors.

NOTE: Abbreviations: GMEWS, Global Modified Early Warning Score; ICU, intensive care unit; LOS, length of stay; RRS, rapid response systems; RRT, rapid response team calling criteria; SEWS, Standardized Early Warning Scoring System; ViEWS, VitaPAC Early Warning Score.

the calculations of the statistic leaving out 1 sample at a time. In our case, we repeated the calculation of sensitivity and PPV leaving out 1 patient at a time. Once the simulation method had been run and the false/true positives/negatives had been assigned, calculation of each metric (PPV and sensitivity) was repeated for n subsamples, each leaving out 1 patient. The variance was calculated and 2 Student t tests were performed for each EWS: 1 for PPV and another for sensitivity. SAS statistical software v 9.3 was used for the simulation analysis; R statistical software v 3.0.2 (The R Foundation, Vienna, Austria) was used for the calculation of the statistical significance of results. A univariable analysis was also performed to assess the sensitivity and PPVs for the published thresholds of the most common variables in each EWS: respiratory rate, systolic blood pressure, heart rate, temperature, and mental status as measured by the modified Richmond Agitation Sedation Score.[21]

RESULTS

The initial cohort included 60,020 hospitalizations, of which the following were excluded: 2751 because of a lack of appropriate research authorization; 6433 because the patients

TABLE 2. Comparison of the Predictive Performance of Widely Used EWS in a Surgical and a Medical Population[a]

	Alerts (n)		Sensitivity				PPV			
	Medical	Surgical	Medical		Surgical		Medical		Surgical	
	N	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD
GMEWS	688	675	0.10	0.007	0.07	0.006	0.22	0.013	0.18	0.013
KIRKL	14,210	14,560	0.58	0.008	0.49	0.008	0.06	0.002	0.06	0.002
MEWS	4040	3957	0.37	0.009	0.29	0.009	0.14	0.005	0.13	0.005
NEWS	14,269	16,197	0.64	0.007	0.53	0.008	0.07	0.002	0.06	0.002
RRT	13,527	16,120	0.59	0.008	0.53	0.008	0.07	0.002	0.06	0.002
SEWS	7832	9116	0.51	0.008	0.40	0.009	0.10	0.003	0.08	0.003
ViEWS	26,034	35,856	0.78	0.005	0.70	0.006	0.05	0.001	0.03	0.001
WRTH	33,602	44,109	0.78	0.005	0.68	0.006	0.04	0.001	0.03	0.001

[a]All analyzed EWS sensitivity and PPV perform better in the medical than in the surgical subpopulation.

NOTE: Abbreviations: EWS, early warning scores; GMEWS, Global Modified Early Warning Score; KIRKL, Kirkland score; MEWS, Modified Early Warning Score; PPV, positive predictive value; RRT, rapid response team calling criteria; SD, standard deviation; SEWS, Standardized Early Warning Scoring System; ViEWS, VitaPAC Early Warning Score; WRTH, Worthington physiologic scoring system.

were younger than 18 years; 2129 as psychiatric admissions; 284 as rehabilitation admissions; 872 as research purposes-only admissions; and 1185 because the patient was never in a general care bed (eg, they were either admitted directly to the ICU, or they were admitted for an outpatient surgical procedure and spent time in the postanesthesia care unit).

Table 1 summarizes patient and trigger characteristics, overall and by subgroup. The final cohort included 75,240 total episodes in 46,366 hospitalizations, from 34,898 unique patients, of which 48.7% were male. There were 23,831 medical and 22,535 surgical hospitalizations. Median length of episode was 2 days both for medical and surgical patients. Median length of stay was 3 days, both for medical and for surgical patients.

There were 3332 events in total, of which 1709 were RRS calls, 185 were resuscitation calls, and 1438 were unscheduled transfers to the ICU. The rate of events was 4.67 events per 100 episodes in the aggregate adult population. There were 3.93 events per 100 episodes for surgical hospitalizations, and 5.86 events per 100 episodes for medical hospitalizations ($P < .001$). The number of CRAs in our cohort was 0.27 per 100 episodes, 0.128 per hospital bed per year, or 4.37 per 1000 hospital admissions, similar to other reported numbers in the literature.[3, 22,23]

The total number of EWS triggers varied greatly between EWS rules, with the volume ranging during the study year from 1363 triggers with the GMEWS rule to 77,711 triggers with the ViEWS score.

All scores had PPVs less than 25%. As seen in Table 2 and shown graphically in the Figure, all scores performed better on medical patients (blue) than on surgical patients (yellow). The *P* value was < .0001 for both PPV and sensitivity. The Worthing score had the highest sensitivity (0.78 for medical and 0.68 for surgical) but a very low PPV (0.04 for medical and 0.03 for surgical), while GMEWS was the opposite: low sensitivity (0.10 and 0.07) but the highest PPV (0.22 and 0.18).

The results of the univariable analysis can be seen in Table 3. Most of the criteria performed better (higher sensitivity and PPV) as predictors in the medical hospitalizations than in the surgical hospitalizations.

DISCUSSION

We hypothesized that EWS may perform differently when applied to medical rather than surgical patients. Studies had not analyzed this in a time-dependent manner,[24-26] which limited the applicability of the results.[8]

All analyzed scores performed better in medical patients than in surgical patients (Figure). This could reflect a behavioral difference by the teams on surgical and medical floors in the decision to activate the RRS, or a bias of the clinicians who designed the scores (mostly nonsurgeons). The difference could also mean that physiological deteriorations are intrinsically different in patients who have undergone anesthesia and surgery. For example, in surgical patients, a bleeding episode is more likely to be the cause of their physiological deterioration, or the lingering effects of anesthesia could mask underlying deterioration. Such patients would benefit from scores where variables such as heart rate, blood pressure, or hemoglobin had more influence.

When comparing the different scores, it was much easier for a patient to meet the alerting score with the Worthing score than with GMEWS. In the Worthing score, a respiratory rate greater than 22 breaths per minute, or a systolic blood pressure less than 100 mm Hg, already meet alerting criteria. Similar vital signs result in 0 and 1 points (respectively) in GMEWS, far from its alerting score of 5. This reflects the intrinsic tradeoff of EWS: as the threshold for considering a patient "at risk" drops, not only does the number of true positives (and the sensitivity) increase, but also the number of false positives, thus lowering the PPV.

However, none of the scores analyzed were considered to perform well based on their PPV and sensitivity, particularly in the surgical subpopulation. Focusing on another metric,

TABLE 3. Univariable analysis in the medical and surgical subpopulations[a]

Criteria	Sensitivity		PPV	
	Medical	Surgical	Medical	Surgical
RR <8	0.018	0.036	0.019	0.030
RR <15	0.218	0.323	0.023	0.016
RR >20	0.621	0.511	0.048	0.045
RR >22	0.546	0.427	0.060	0.055
RR >25	0.414	0.308	0.085	0.079
RR >30	0.229	0.162	0.124	0.110
RR >35	0.137	0.097	0.162	0.133
HR <40	0.078	0.077	0.041	0.003
HR <50	0.131	0.138	0.027	0.026
HR >100	0.599	0.558	0.040	0.031
HR >110	0.478	0.413	0.061	0.046
HR >120	0.332	0.288	0.087	0.066
HR >130	0.229	0.187	0.118	0.088
HR >140	0.137	0.114	0.139	0.103
SBP <70	0.069	0.085	0.162	0.139
SBP <80	0.165	0.175	0.111	0.092
SBP <90	0.290	0.290	0.057	0.048
SBP <100	0.432	0.421	0.031	0.025
SBP >180	0.078	0.091	0.042	0.054
SBP >200	0.034	0.027	0.085	0.090
SBP >220	0.011	0.008	0.131	0.107
SpO_2 <88	0.408	0.353	0.054	0.034
SpO_2 <90	0.522	0.452	0.043	0.028
SpO_2 <91	0.590	0.514	0.037	0.025
SpO_2 <92	0.657	0.605	0.031	0.022
SpO_2 <94	0.795	0.786	0.023	0.018
SpO_2 <95	0.844	0.848	0.020	0.016
SpO_2 <96	0.905	0.909	0.019	0.015
Temp <34.5°	0.008	0.008	0.052	0.076
Temp <35°	0.018	0.013	0.044	0.048
Temp <35.5°	0.032	0.020	0.035	0.038
Temp >38°	0.151	0.110	0.069	0.066
Temp >38.5°	0.103	0.078	0.082	0.110
Temp >39°	0.070	0.050	0.095	0.142
Temp >40°	0.004	0.003	0.291	0.400
mRASS ≠ 0	0.566	0.550	0.030	0.023
mRASS >1 or <-1	0.201	0.159	0.039	0.147
mRASS >2 or <-2	0.081	0.058	0.147	0.114
mRASS >3 or <-3	0.044	0.034	0.191	0.193

[a]Table shows the sensitivity and positive predictive value in the following 24 hours after a patient meets each of the criteria.

NOTE: Abbreviations: HR, heart rate (beats/minute); mRASS, modified Richmond Agitation Sedation Score (+4 to -5); RR, respiratory rate (breaths/minute); PPV, positive predictive value; SBP, systolic blood pressure (mm Hg); SpO_2, peripheral oxygen saturation (%); temp, temperature (C).

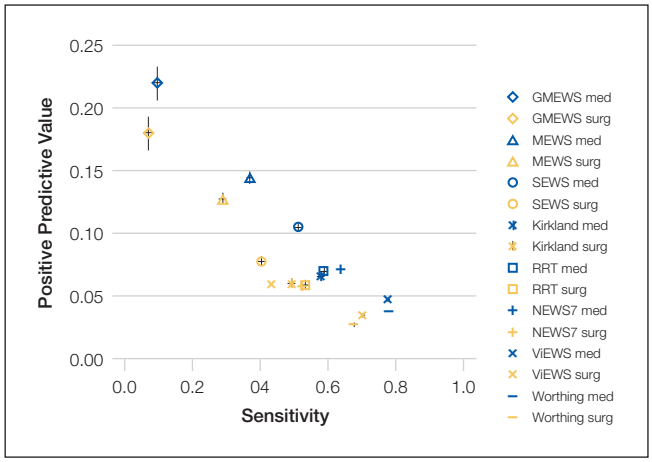

FIG. Performance of scores in medical and surgical patients.

NOTE: Abbreviations: GMEWS, Global Modified Early Warning Score; Kirkland, Kirkland score; med, medical; MEWS, Modified Early Warning Score; NEWS 7, National Early Warning Score 7; RRT, rapid response team; SEWS, Standardized Early Warning Scoring System; surg, surgical; ViEWS, VitaPAC Early Warning Score; Worthing, Worthington physiologic scoring system.

the area under the receiver operator curve can give misleadingly optimistic results.[24,27] However, the extremely low prevalence of acute physiological deterioration can produce low PPVs even when specificity seems acceptable, which is why it is important to evaluate PPV directly.[28]

To use EWS effectively to activate RRS, they need to be combined with clinical judgment to avoid high levels of false alerts, particularly in surgical patients. It has been reported that RRS is activated only 30% of the time a patient meets RRS calling criteria.[29] While there may be cultural characteristics inhibiting the decision to call,[30] our study hints at another explanation: if RRS was activated every time a patient met calling criteria based on the scores analyzed, the number of RRS calls would be very high and difficult to manage. So health providers may be doing the right thing when "filtering" RRS calls and not applying the criteria strictly, but in conjunction with clinical judgment.

A limitation of any study like this is how to define "acute physiological deterioration." We defined an event as recognized episodes of acute physiological deterioration that are signaled by escalations of care (eg, RRS, resuscitation calls, or transfers to an ICU) or unexpected death. By definition, our calculated PPV is affected by clinicians' recognition of clinical deteriorations. This definition, common in the literature, has the limitation of potentially underestimating EWS' performance by missing some events that are resolved by the primary care team without an escalation of care. However, we believe our interpretation is not unreasonable since the purpose of EWS is to trigger escalations of care in a timely fashion. Prospective studies could define an event in a way that is less affected by the clinicians' judgment.

Regarding patient demographics, age was similar between the 2 groups (average, 58.2 years for medical vs 58.9 years for surgical), and there was only a small difference in gender ratios (45.1% male in the medical vs 51.4% in the surgical group). These differences are unlikely to have affected the

results significantly, but unknown differences in demographics or other patient characteristics between groups may account for differences in score performance between surgical and medical patients.

Several of the EWS analyzed had overlapping trigger criteria with our own RRS activation criteria (although as single-parameter triggers and not as aggregate). To test how these potential biases could affect our results, we performed a post hoc sensitivity analysis eliminating calls to the RRS as an outcome (so using the alternative outcome of unexpected transfers to the ICU and resuscitation calls). The results are similar to those of our main analysis, with all analyzed scores having lower sensitivity and PPV in surgical hospitalizations when compared to medical hospitalizations.

Our study suggests that, to optimize detection of physiological deterioration events, EWS should try to take into account different patient types, with the most basic distinction being surgical vs medical. This tailoring will make EWS more complex, and less suited for paper-based calculation, but new electronic health records are increasingly able to incorporate decision support, and some EWS have been developed for electronic calculation only. Of particular interest in this regard is the score developed by Escobar et al,[31] which groups patients into categories according to the reason for admission, and calculates a different subscore based on that category. While the score by Escobar et al. does not split patients based on medical or surgical status, a more general interpretation of our results suggests that a score may be more accurate if it classifies patients into subgroups with different subscores. This seems to be confirmed by the fact that the score by Escobar et al performs better than MEWS.[28] Unfortunately, the paper describing it does not provide enough detail to use it in our database.

A recent systematic review showed increasing evidence that RRS may be effective in reducing CRAs occurring in a non-ICU setting and, more important, overall inhospital mortality.[32] While differing implementation strategies (eg, different length of the educational effort, changes in the frequency of vital signs monitoring) can impact the success of such an initiative, it has been speculated that the afferent limb (which often includes an EWS) might be the most critical part of the system.[33] Our results show that the most widely used EWS perform significantly worse on surgical patients, and suggest that a way to improve the accuracy of EWS would be to tailor the risk calculation to different patient subgroups (eg, medical and surgical patients). Plausible next steps would be to demonstrate that tailoring risk calculation to medical and surgical patients separately can improve risk predictions and accuracy of EWS.

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References

1. Buist MD, Jarmolowski E, Burton PR, Bernard SA, Waxman BP, Anderson J. Recognising clinical instability in hospital patients before cardiac arrest or unplanned admission to intensive care. A pilot study in a tertiary-care hospital. *Med J Aust*. 1999; 171(1):22-25.
2. Schein RM, Hazday N, Pena M, Ruben BH, Sprung CL. Clinical antecedents to in-hospital cardiopulmonary arrest. *Chest*. 1990;98(6):1388-1392.
3. Peberdy MA, Kaye W, Ornato JP, Larkin GL, Nadkarni V, Mancini ME, et al. Cardiopulmonary resuscitation of adults in the hospital: a report of 14720 cardiac arrests from the National Registry of Cardiopulmonary Resuscitation. *Resuscitation*. 2003; 58(3):297-308.
4. Nadkarni VM, Larkin GL, Peberdy MA, Carey SM, Kaye W, Mancini ME, et al. First documented rhythm and clinical outcome from in-hospital cardiac arrest among children and adults. *JAMA*. 2006;295(1):50-57.
5. Devita MA, Bellomo R, Hillman K, Kellum J, Rotondi A, Teres D, et al. Findings of the first consensus conference on medical emergency teams. *Crit Care Med*. 2006;34(9):2463-2478.
6. DeVita MA, Smith GB, Adam SK, Adams-Pizarro I, Buist M, Bellomo R, et al. "Identifying the hospitalised patient in crisis"--a consensus conference on the afferent limb of rapid response systems. *Resuscitation*. 2010;81(4):375-382.
7. Kawamoto K, Houlihan CA, Balas EA, Lobach DF. Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. *BMJ*. 2005;330(7494):765.
8. Romero-Brufau S, Huddleston JM, Naessens JM, Johnson MG, Hickman J, Morlan BW, et al. **W**idely used track and trigger scores: are they ready for automation in practice? *Resuscitation*. 2014;85(4):549-552.
9. Huddleston JM, Diedrich DA, Kinsey GC, Enzler MJ, Manning DM. Learning from every death. *J Patient Saf*. 2014;10(1):6-12.
10. Moriarty JP, Schiebel NE, Johnson MG, Jensen JB, Caples SM, Morlan BW, et al. Evaluating implementation of a rapid response team: considering alternative outcome measures. *Int J Qual Health Care*. 2014;26(1):49-57.
11. Kirkland LL, Malinchoc M, O'Byrne M, Benson JT, Kashiwagi DT, Burton MC, et al. A clinical deterioration prediction tool for internal medicine patients. *Am J Med Qual*. 2013;28(2):135-142.
12. Griffiths JR, Kidney EM. Current use of early warning scores in UK emergency departments. *Emerg Med J*. 2012;29(1):65-66.
13. Subbe CP, Kruger M, Rutherford P, Gemmel L. Validation of a modified Early Warning Score in medical admissions. *QJM*. 2001;94(10):521-526.
14. Paterson R, MacLeod DC, Thetford D, Beattie A, Graham C, Lam S, et al.. Prediction of in-hospital mortality and length of stay using an early warning scoring system: clinical audit. *Clin Med (Lond)*. 2006;6(3):281-284.
15. Harrison GA, Jacques T, McLaws ML, Kilborn G. Combinations of early signs of critical illness predict in-hospital death–the SOCCER study (signs of critical conditions and emergency responses). *Resuscitation*. 2006;71(3):327-334.
16. Duckitt RW, Buxton-Thomas R, Walker J, Cheek E, Bewick V, Venn R, et al. Worthing physiological scoring system: derivation and validation of a physiological early-warning system for medical admissions. An observational, population-based single-centre study. *Br J Anaesth*. 2007; 98(6):769-774.
17. Smith GB, Prytherch DR, Meredith P, Schmidt PE, Featherstone PI. The ability of the National Early Warning Score (NEWS) to discriminate patients at risk of early cardiac arrest, unanticipated intensive care unit admission, and death. *Resuscitation*. 2013;84(4):465-470.
18. Prytherch DR, Smith GB, Schmidt PE, Featherstone PI. ViEWS--Towards a national early warning score for detecting adult inpatient deterioration. *Resuscitation*. 2010;81(8):932-937.
19. Romero-Brufau S, Huddleston JM. Reply to letter: widely used track and trigger scores: are they ready for automation in practice? *Resuscitation*. 2014;85(10):e159.
20. Efron B, Stein C. The jackknife estimate of variance. *Annals of Statistics*. 1981;586-596.
21. Sessler CN, Gosnell MS, Grap MJ, Brophy GM, O'Neal PV, Keane KA, et al. The Richmond Agitation-Sedation Scale: validity and reliability in adult intensive care unit patients. *Am J Respir Crit Care Med*. 2002;166(10):1338-1344.
22. DeVita MA, Braithwaite RS, Mahidhara R, Stuart S, Foraida M, Simmons RL. Medical Emergency Response Improvement Team (MERIT). Use of medical emergency team responses to reduce hospital cardiopulmonary arrests. *Qual Saf Health Care*. 2004;13(4):251-254.
23. Goncales PD, Polessi JA, Bass LM, Santos Gde P, Yokota PK, Laselva CR, et al. Reduced frequency of cardiopulmonary arrests by rapid response teams. *Einstein (Sao Paulo)*. 2012;10(4):442-448.
24. Cuthbertson BH, Boroujerdi M, McKie L, Aucott L, Prescott G. Can physiological variables and early warning scoring systems allow early recognition of the deteriorating surgical patient? *Crit Care Med*. 2007;35(2):402-409.
25. Gardner-Thorpe J, Love N, Wrightson J, Walsh S, Keeling N. The value of Modified Early Warning Score (MEWS) in surgical in-patients: a prospective observational study. *Ann R Coll Surg Engl*. 2006;88(6):571-575.
26. Stenhouse C, Coates S, Tivey M, Allsop P, Parker T. Prospective evaluation of a modified Early Warning Score to aid earlier detection of patients developing critical illness on a general surgical ward. *British Journal of Anaesthesia*. 2000;84(5):663-663.

27. Smith GB, Prytherch DR, Schmidt PE, Featherstone PI. Review and performance evaluation of aggregate weighted 'track and trigger' systems. *Resuscitation*. 2008;77(2):170-179.
28. Romero-Brufau S, Huddleston JM, Escobar GJ, Liebow M. Why the C-statistic is not informative to evaluate early warning scores and what metrics to use. *Crit Care*. 2015; 19:285.
29. Hillman K, Chen J, Cretikos M, Bellomo R, Brown D, Doig G, et al. Introduction of the medical emergency team (MET) system: a cluster-randomised controlled trial. *Lancet*. 2005;365(9477):2091-2097.
30. Shearer B, Marshall S, Buist MD, Finnigan M, Kitto S, Hore T, et al. What stops hospital clinical staff from following protocols? An analysis of the incidence and factors behind the failure of bedside clinical staff to activate the rapid response system in a multi-campus Australian metropolitan healthcare service. *BMJ Qual Saf*. 2012;21(7):569-575.
31. Escobar GJ, LaGuardia JC, Turk BJ, Ragins A, Kipnis P, Draper D. Early detection of impending physiologic deterioration among patients who are not in intensive care: development of predictive models using data from an automated electronic medical record. *J Hosp Med*. 2012;7(5):388-395.
32. Winters BD, Weaver SJ, Pfoh ER, Yang T, Pham JC, Dy SM. Rapid-response systems as a patient safety strategy: a systematic review. *Ann Intern Med*. 2013;158(5 pt 2):417-425.
33. Jones DA, DeVita MA, Bellomo R. Rapid-response teams. *N Engl J Med*. 2011;365(2):139-146.

Prognosticating with the Hospitalized-patient One-year Mortality Risk Score Using Information Abstracted from the Medical Record

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BACKGROUND: Predicting death risk in patients with diverse conditions is difficult. The Hospitalized-patient One-year Mortality Risk (HOMR) score accurately determines death risk in adults admitted to hospital using health administrative data unavailable to clinicians and most researchers.

OBJECTIVE: Determine if HOMR is valid when calculated using data abstracted directly from the medical record.

DESIGN: Medical record review linked to population-based administrative data.

PARTICIPANTS: 4996 adults admitted in 2011 to a non-psychiatric service at a tertiary hospital.

MAIN MEASURES: From the chart, we abstracted information required to calculate the HOMR score and linked to population-based mortality data to determine vital status within 1 year of admission date.

KEY RESULTS: Patients had a mean age of 55.6 (standard deviation [SD], 20.7) with 563 (11.3%) dying. The mean chart HOMR score was 22 (SD, 12) and significantly predicted death risk; a 1-point increase in HOMR increased death odds by 19% (odds ratio, 1.192;, 95% confidence interval [CI], 1.175-1.210;, $P < 0.0001$). Chart HOMR was strongly discriminative (C statistic 0.888) and well calibrated (Hosmer-Lemeshow goodness-of-fit test, 12.9; $P = 0.11$). The observed death risk was *strongly* associated with expected death risk (calibration slope, 1.02; 95% CI, 0.89-1.16). Notation of delirium or falls on admitting notes or dependence for at least 1 activity of daily living were each associated with 1-year death risk independent of the HOMR score.

CONCLUSIONS: One-year mortality risk can be accurately determined in adults admitted to hospital with the HOMR score calculated using information abstracted from the medical record. Patient functional status was independently associated with death risk. *Journal of Hospital Medicine* 2017;12:224-230. © 2017 Society of Hospital Medicine

A patient's prognosis can strongly influence their medical care. Decisions about diagnostic modalities, treatment options, and the use of preventive therapies can all be affected by the likelihood of a patient's death in the near future. For example, patients with severely limited survival might forego prophylactic therapy, avoid interventions for asymptomatic issues, and cease screening interventions. Knowing survival probability would also be very helpful as a controlling variable in research analyses whenever death risk might be a possible confounder.

Sixteen indices that aim to predict patient death risk have been described by Yourman et al.[1] They were all created from secondary analyses of clinical and administrative datasets, were applicable to patients in a variety of settings (including the community, nursing home, or hospital), and predicted survival probabilities in time horizons ranging from 6 months to 5 years. Prognostic factors that were most commonly included in these indices were comorbidity and functional status. In validation populations, the discrimination of these indices for 1-year survival in hospitalized patients was moderate (with C statistics that ranged from 0.64 to 0.79) with good calibration for broad prognostic ranges.

In 2014, we published the Hospitalized-patient One-year Mortality Risk (HOMR) score.[2] This study used health administrative data for all adult Ontarians admitted in 2011 to hospital under nonpsychiatric services (n = 640,022) to estimate the probability of dying within 1 year of admission to hospital (which happened in 11.7% of people). The HOMR score included 12 patient and hospitalization factors (Table 1). It was highly discriminative (C statistic, 0.923; [0.922-0.924]) and well calibrated (the mean *relative* difference between observed and expected death risk was 2.0% [range, 0.0% to 7.0%]). It was externally validated in more than 3 million adults from Ontario, Alberta, and Boston in whom the C statistic ranged from 0.89 to 0.92 and calibration was excellent.[3] We concluded from these studies that the HOMR score is excellent for prognosticating a diverse group of patients using health administrative data.

However, we do not know whether the HOMR score can be applied to patients using primary data (ie, those taken directly from the chart). This question is important for 2 reasons. First, if HOMR accurately predicts death risk using data abstracted from the medical record, it could be used in the

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TABLE 1. Hospital-patient One-year Mortality Risk (HOMR) Scoring System[a]

Variable	Value	Points	Variable	Value	Points
Sex	Female	0	ED visits in previous yr	0	0
	Male	1		1+	1
Home oxygen	No	0	Admits by ambulance[c]	0	0
	Yes	4		1	3
Diagnostic risk score[b]		Same		2	4
				3+	5
Service	General medicine	10	Service	General surgery	8
	Cardiology	8		Cardiovascular surgery	9
	GI/nephrology/neurology	9		Neurosurgery	10
	Palliative care	28		Orthopedic, plastic surgery	7
	Hematology/oncology	14		Thoracic/transplant	7
	Ante-, intra-, postpartum	0		Trauma	8
	Gynecology	7		Urology	6

Variable	Level	Points					
		Charlson Comorbidity Index					
		0	1	2	3	4	5	6
Age	20-24.9	0	3	5	7	8	9	10
	25-29.9	2	5	7	9	10	11	11
	30-34.9	4	7	9	11	12	12	13
	35-39.9	7	9	11	12	13	14	15
	40-44.9	8	11	13	14	15	15	16
	45-49.9	10	13	14	15	16	17	17
	50-54.9	12	14	16	17	17	18	18
	55-59.9	14	16	17	18	19	19	20
	60-64.9	15	17	18	19	20	20	21
	65-69.9	17	19	20	21	21	22	22
	70-74.9	18	20	21	22	22	23	23
	75-79.9	20	21	22	23	23	24	24
	80-84.9	21	23	23	24	24	25	25
	85-89.9	23	24	25	25	25	26	26
	90-94.9	24	25	26	26	26	27	27
	95+	25	26	27	27	27	28	28

Variable	Level	Points			
		Admissions by ambulance[b]			
		0	1	2	3+
Living status	Independent	0	0	0	0
	Rehabilitation	3	3	2	2
	Home care	4	3	3	3
	Nursing home	4	4	4	3
	Chronic hospital	8	6	5	5
Admission urgency	Elective	0	0	0	0
	ED, no ambulance	3	1	0	0
	ED, ambulance	5	2	1	0

[a]To calculate the HOMR score for a particular patient, add the points associated with their values for all 12 variables above. For example, a previously healthy (1 point) 51-year-old male with no significant comorbidities (12 points) admitted to cardiology (8 points) through the ED by ambulance (5 points) with cardiac arrest (12 points, Appendix 2) would have a HOMR score of 42. This has an expected risk of death in 1 year of 46.2% (Appendix 1).

[b]See Appendix 2 for admission diagnoses and their associated diagnostic risk score.

[c]In the last year.

NOTE: Abbreviations: ED, emergency department; GI, gastrointestinal; HOMR, hospitalized-patient one-year mortality risk.

clinical setting to assist in clinical decision-making. Second, HOMR uses multiple administrative datasets that are difficult to access and use by most clinical researchers; it is, therefore, important to determine if HOMR is accurate for clinical research based on primary medical record review. The primary objective of this study was to determine the accuracy of the HOMR score when calculated using data abstracted from clinical notes that were available when patients were admitted to hospital. Secondary objectives included determining whether functional measures abstracted were significantly associated with death risk beyond the HOMR score and whether HOMR scores calculated from chart review deviated from those calculated from administrative data.

METHODS

Study Cohort

The study, which was approved by our local research ethics board, took place at the Ottawa Hospital, a 1000-bed teaching hospital that is the primary referral center in our region. We used the hospital admission registry to identify all people 18 years or older who were admitted to a nonpsychiatric service at our hospital between January 1, 2011 and December 31, 2011 (this time frame corresponds with the year used to derive the HOMR score). We excluded overnight patients in the same-day surgery or the bone-marrow transplant units (since they would not have been included in the original study) and those without a valid health card number (which was required to link to provincial data to identify outcomes). From this list, we randomly selected 5000 patients.

Primary Data Collection

For each patient, we retrieved all data required to calculate the HOMR score from the medical record (Table 1). Patient registration information in our electronic medical record was used to identify patient age, sex, admitting service, number of emergency department (ED) visits in the previous year, number of admissions in the previous year (the nursing triage note was reviewed for each admission to determine if it was by ambulance), and whether or not the patient had been discharged from hospital in the previous 30 days. The admitting service consult note was used to determine the admitting diagnosis and whether or not the patient was admitted directly to the intensive care unit. If they were present, the emergency nursing triage note, the ED record of treatment, the admission consult note, the pre-operative consult note, and consult notes were all used to determine the patient's comorbidities, living status, and home oxygen status. Admission urgency was determined using information from the patient registration information and the ED nursing triage note. All data were abstracted from information that had been registered *prior* to when the patient was physically transferred to their hospital bed. This ensured that we used only data available at the start of the admission.

Patient functional status has been shown to be strongly associated with survival[4] but HOMR only indirectly captures functional information (through the patient's living status). We, therefore, collected more detailed functional information from the medical record by determining if the patient was dependent for any activities of daily living (ADL) from the emergency nursing triage note, the ED record of treatment, the admission consult note, and the pre-operative consultation. We also collected information that might indicate frailty, which we defined per Clegg et al.[5] as "a state of increased vulnerability to poor resolution of homeostasis following a stress." This information included: delirium or more than 1 fall recorded on the emergency nursing triage note, the ED record of treatment, or the admission consultation note; or whether a geriatric nursing specialist assessment occurred in the ED in the previous 6 months. Finally, we recorded possible indicators of limited social support (no fixed address [from patient registration and nursing triage note], primary contact is not a family member [from the emergency notes, consult, and patient registration], and no religion noted in system [from patient registration]). Patients for whom religion status was missing were classified as having "no religion."

Analysis

These data were encrypted and linked anonymously to population-based databases to determine whether patients died within 1 year of admission to hospital. We calculated the chart-HOMR score using information from the chart review and determined its association with the outcome using bivariate logistic regression. We compared observed and expected risk of death within 1 year of admission to hospital for each chart-HOMR score value, with expected risks determined from the external validation study.[3] We regressed observed death risks on expected death risks for chart-HOMR scores (clustered into 22 groups to ensure adequate numbers in each group); and we gauged overall deviations from expected risk and the relationship between the observed and expected death risk (based on the chart-HOMR score) using the line's intercept and slope, respectively.[6] Next, we replicated methods from our studies[2,3] to calculate the administrative-HOMR score in our study cohort using administrative databases. We compared these chart-HOMR and administrative-HOMR scores (and scores for each of its components). Finally, we determined which of the socio-functional factors were associated with 1-year death risk independent of the chart-HOMR score. We used the likelihood ratio test to determine whether these additional socio-functional factors significantly improved the model beyond the chart-HOMR score.[7] This test subtracted the -2 logL value of the full model from that containing the chart-HOMR score alone, comparing its value to the χ^2 distribution (with degrees of freedom equivalent to the number of additional parameters in the nested model) to determine statistical significance. All analyses were completed using SAS v9.4 (SAS Institute Inc., Cary, North Carolina).

RESULTS

There were 43,883 overnight hospitalizations at our hospital in 2011, and 38,886 hospitalizations were excluded: 1883 hospitalizations were in the same-day surgery or the

TABLE 2. Description of Study Cohort by 1-Year Death Status

		Dead Within 1 Year of Admission		Overall
		No (n = 4433, 88.7%)	Yes (n = 563, 11.3%)	(N = 4996)
HOMR variables				
Mean age (SD)	Mean ± SD	53.1 ± 20.0	75.5 ± 13.5	55.6 ± 20.7
Male	Male	1709 (38.6%)	279 (49.6%)	1988 (39.8%)
Living status	Independent	4317 (97.4%)	466 (82.8%)	4783 (95.7%)
	Rehab facility	≤5 (0.1%)	≤5 (0.2%)	≤5 (0.1%)
	Home with home care	59 (1.3%)	37 (6.6%)	96 (1.9%)
	Nursing home	45 (1.0%)	53 (9.4%)	98 (2.0%)
	Chronic hospital	9 (0.2%)	6 (1.1%)	15 (0.3%)
Charlson Comorbidity Index	0	2743 (61.9%)	80 (14.2%)	2823 (56.5%)
	1	876 (19.8%)	187 (33.2%)	1063 (21.3%)
	2-3	449 (10.1%)	101 (17.9%)	550 (11.0%)
	4-5	218 (4.9%)	86 (15.3%)	304 (6.1%)
	6+	147 (3.3%)	109 (19.4%)	256 (5.1%)
Home oxygen		8 (0.2%)	9 (1.6%)	17 (0.3%)
ED visits[a]	0	3450 (77.8%)	353 (62.7%)	3803 (76.1%)
	1	568 (12.8%)	106 (18.8%)	674 (13.5%)
	2	415 (9.4%)	104 (18.5%)	519 (10.4%)
Admissions by ambulance[a]	0	4343 (98.0%)	510 (90.6%)	4853 (97.1%)
	1+	90 (2.0%)	53 (9.4%)	143 (2.9%)
Urgent 30-day readmission		145 (3.3%)	65 (11.5%)	210 (4.2%)
Admission urgency	Elective	2364 (53.3%)	64 (11.4%)	2428 (48.6%)
	Emergent, no ambulance	878 (19.8%)	120 (21.3%)	998 (20.0%)
	Emergent, by ambulance	1191 (26.9%)	379 (67.3%)	1570 (31.4%)
Admitted directly to ICU		68 (1.5%)	55 (9.8%)	123 (2.5%)
Admission diagnosis points	<0	1457 (32.9%)	157 (27.9%)	1614 (32.3%)
	0	2301 (51.9%)	118 (21.0%)	2419 (48.4%)
	1+	675 (15.2%)	288 (51.1%)	963 (19.3%)
Mean HOMR score (SD)		19.9 (12.2)	37.4 (7.5)	21.9 (13.0)
Additional socio-functional variables				
Delirium noted on admission		58 (1.3%)	55 (9.8%)	113 (2.3%)
Geriatrics consult in ED		46 (1.0%)	13 (2.3%)	59 (1.2%)
Falls noted on admission		88 (2.0%)	56 (9.9%)	144 (2.9%)
'No fixed address' listed as current domicile		7 (0.2%)	0 (0.0%)	7 (0.1%)
No religion noted on patient's hospital registration		1948 (43.9%)	224 (39.8%)	2172 (43.5%)
Primary contact is a family member		4103 (92.6%)	516 (91.7%)	4619 (92.5%)
Dependent for any ADL[b]		52 (1.2%)	53 (9.4%)	105 (2.1%)
Any frailty indicator[c]		183 (4.1%)	137 (24.3%)	320 (6.4%)

[a]In year prior to admission.

[b]Includes ambulation, feeding, bathing, dressing, and elimination.

[c]Patient had delirium or falls noted on admitting note or was dependent for any of the 5 ADL.

NOTE: Abbreviations: ADL, activities of daily living; ED, emergency department; HOMR, hospitalized-patient one-year mortality risk; ICU, intensive care unit; SD, standard deviation.

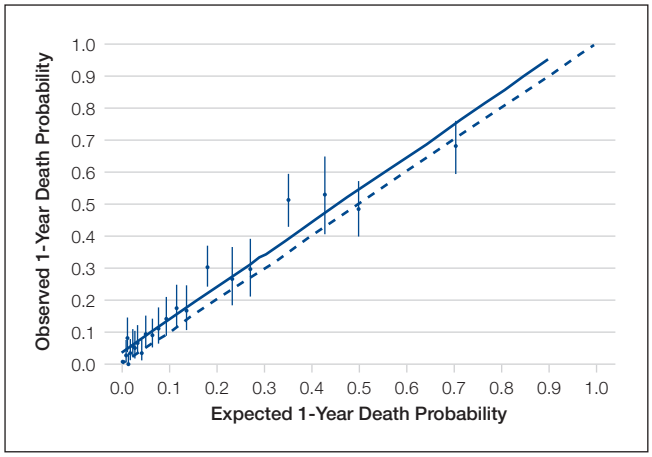

FIG. 1. Observed vs. expected 1-year death risk. The observed risk of death within 1 year of admission to hospital (vertical axis) is plotted against the expected 1-year death risk (horizontal axis). Expected 1-year death risk was determined from the patient's chart-HOMR score (Table 1 and Appendix 1). Observed risks are presented with 95% exact CIs so they can be compared to unity (dashed line); data points whose CIs exclude unity indicate a group whose observed risk deviates significantly from expected risk. The calibration line (solid line) has a significant positive intercept (0.035; 95% CI, 0.01-0.06) indicating that observed risk significantly exceeded predicted risk; however, the line's slope (1.02; 95% CI, 0.91-1.12) does not deviate significantly from 1 (indicating a consistent relationship between the expected death risk, based on the chart-HOMR score, and the observed risk).

NOTE: Abbreviations: CI, confidence interval; HOMR, hospitalized-patient one-year mortality risk.

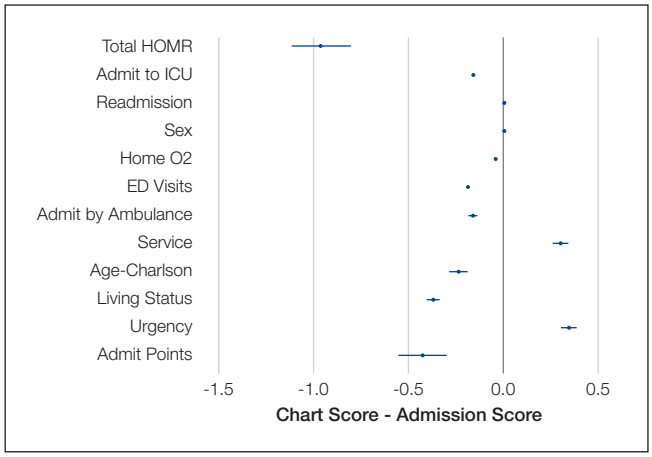

FIG. 2. HOMR-score values using data from medical record review and health administrative databases. This plot demonstrates differences in HOMR scores (and its components) when calculated using data from the chart or from health administrative databases. Each data point presents the mean difference for 4898 patients along with its 95% CI with data points with values below 0, indicating that HOMR scores were lower when calculated using information from the chart vs. information from the database. Point estimates whose 95% CI exclude 0 (vertical line) are statistically significant at an alpha level of 5%.

NOTE: Abbreviations: CI, confidence interval; ED, emergency department; HOMR, hospitalized-patient one-year mortality risk; ICU, intensive care unit.

bone-marrow transplant unit; 2485 did not have a valid health card number; 34,515 were not randomly selected; the records of 3 randomly selected patients had been blocked by our hospital's privacy department; and 1 patient could not be linked with the population-based administrative datasets.

The 4996 study patients were middle-aged and predominantly female (Table 2). The extensive majority of patients was admitted from the community, was independent for ADL, had a family member as the principal contact, and had no admissions by ambulance in the previous year. Most people had no significant comorbidities or ED visits in the year prior to their admission. The mean chart-HOMR score was 22 (standard deviation [SD], 12), which is associated with a 1.2% expected risk of death within 1 year of hospital admission (Appendix 1).[3]

A total of 563 patients (11.3%) died within 1 year of admission to hospital (Table 2). In the study cohort, each chart-HOMR component was associated with death status. People who died were older, more likely to be male, had a greater number of important comorbidities, had more ED visits and admissions by ambulance in the previous year, and were more likely to have been discharged in the previous 30 days, and were admitted urgently, directly to the intensive care unit, or with complicated diagnoses. The mean chart-HOMR score differed extensively by survival status (37.4 [SD, 7.5] in those who died vs. 19.9 [SD, 12.2] in those who survived). Three of the socio-functional variables (delirium and falls noted on admission documents, and dependent for any ADL) also varied with death status.

The chart-HOMR score was strongly associated with the likelihood of death within 1 year of admission. When included in a logistic regression model having 1-year death as the outcome, a 1-point increase in the chart-HOMR score was associated with a 19% increase in the odds of death ($P < 0.0001$). This model (with only the chart-HOMR score) was highly discriminative (C statistic, 0.888) and well calibrated (Hosmer-Lemeshow test, 12.9 [8 df, $P = 0.11$]).

Observed and expected death risks by chart-HOMR score were similar (Figure 1). The observed total number of deaths (n = 563; 11.3%) exceeded the expected number of deaths (n = 437, 8.7%). When we regressed observed death risks on expected death risks for chart-HOMR scores (clustered into 22 groups), the Hosmer-Lemeshow test was significant, indicating that differences between observed and expected risks were beyond that expected by chance (Hosmer-Lemeshow test, 141.9, 21 df, $P < 0.0001$). The intercept of this model (0.035; 95% CI, 0.01-0.06) was statistically significant ($P = 0.01$), indicating that the observed number of cases significantly exceeded the expected; however, its calibration slope (1.02; 95% CI, 0.89-1.16) did not deviate significantly from unity, indicating that the relationship between the observed and expected death risk (based on the chart-HOMR score) remained intact (Figure 1).

The deviations between observed and expected death risks reflected deviations between the c chart-HOMR score and the administrative-HOMR score, with the former being significantly lower than the latter (Figure 2). Overall, the chart-HOMR score was 0.96 points lower (95% CI, 0.81-1.12) than the administrative-HOMR score. The HOMR score components that were notably *under*estimated using chart data included those for the age-Charlson Comorbidity Index interaction, living status, and admit points. Points for only 2 components (admitting service and admission urgency) were higher when calculated using chart data.

Four additional socio-functional variables collected from medical record review were significantly associated with 1-year death risk *independent* of the chart-HOMR score (Table 3). Admission documentation noting either delirium or falls were both associated with a significantly increased death risk (adjusted odds ratio [OR], 1.92 [95% CI, 1.24-2.96] and OR 1.96 [95% CI, 1.29-2.99], respectively). An independently increased death risk was also noted in patients who were dependent for any ADL (adjusted OR, 1.99 [95% CI, 1.24-3.19]). The presence of an ED geriatrics consultation within the previous 6 months was associated with a significantly *decreased* death risk of 60% (adjusted OR, 0.40 [95% CI, 0.20-0.81]). Adding these covariates to the logistic model with the chart-HOMR score significantly improved predictions (likelihood ratio statistic = 33.569, 4df, $P < 0.00001$).

TABLE 3. Association of Additional Socio-functional Variables on 1-Year Death Risk[a]

Socio-functional Variable	Association of Variable With 1-year Death Risk, Odds Ratio (95% CI)	
	With chart HOMR	With chart HOMR and other socio-functional variables
Delirium noted on admission	2.10 (1.38, 3.21)	1.92 (1.24, 2.96)
Geriatrics consult in ED	0.52 (0.26, 1.03)	0.40 (0.20, 0.81)
Falls noted on admission	1.81 (1.21, 2.70)	1.96 (1.29, 2.99)
No religion noted on patient's hospital registration	1.18 (0.95, 1.46)	1.19 (0.96, 1.47)
Primary contact is a family member	0.85 (0.58, 1.24)	0.88 (0.60, 1.28)
Dependent for any ADL[b]	2.11 (1.32, 3.36)	1.99 (1.24, 3.19)

[a]The association of each variable with 1-year death risk after adjusting for chart-HOMR score is presented as adjusted odds ratios (with 95% confidence intervals in parentheses). The first result column ('With chart HOMR') presents results for logistic models having only chart-HOMR score and the socio-functional variable; the second result column ('With chart HOMR and other variables') presents results having chart HOMR and all socio-functional variables. No results are presented for the socio-functional variable "No fixed address listed as current domicile" since its parameter estimate could not be estimated likely because this condition was very infrequent (Table 2).

[b]Includes ambulation, feeding, bathing, dressing, and elimination.

NOTE: Abbreviations: ADL, activities of daily living; ED, emergency department; HOMR, hospitalized-patient one-year mortality risk.

DISCUSSION

In a large random sample of patients from our hospital, we found that the HOMR score using data abstracted from the medical record was significantly associated with 1-year death risk. The expected death risk based on the chart-HOMR score underestimated observed death risk but the relationship between the chart-HOMR score and death risk was similar to that in studies using administrative data. The HOMR score calculated using data from the chart was lower than that calculated using data from population-based administrative datasets; additional variables indicating patient frailty were significantly associated with 1-year death risk independent of the chart-HOMR score. Since the HOMR score was derived and initially validated using health administrative data, this study using data abstracted from the health record shows that the HOMR score has methodological generalizability.[8]

We think that our study has several notable findings. First, we found that data abstracted from the medical record can be used to calculate the HOMR score to accurately predict individual death risk. The chart-HOMR score discriminated very well between patients who did and did not die (C statistic, 0.88), which extensively exceeds the discrimination of published death risk indices (whose C statistics range between 0.69 and 0.82). It is also possible that chart abstraction for the HOMR score—without functional status—is simpler than other indices since its components are primarily very objective. (Other indices for hospital-based patients required factors that could be difficult to abstract reliably from the medical record including meeting more than 1 guideline for noncancer hospice care[9]; ambulation difficulties[10]; scales such as the Exton-Smith Scale or the Short Portable Mental Status Questionnaire[11]; weight loss[12]; functional status[4]; and pressure sore risk.[13]) Although expected risks for the chart-HOMR consistently underestimated observed risks (Figure 1), the mean deviation was small (with an absolute difference of 3.5% that can be used as a correction factor when determining expected risks with HOMR scores calculated from chart review), but it was an association between the chart-HOMR score and death risk that remained consistent through the cohort. Second, we found a small but significant decrease in the chart-HOMR score vs. the administrative-HOMR score (Figure 2). Some of these underestimates such as those for the number of ED visits or admissions by ambulance were expected since population-based health administrative databases would best capture such data. However, we were surprised that the comorbidity score was less when calculated using chart vs. database data (Figure 2). This finding is distinct from studies finding that particular comorbidities are documented in the chart are sometimes not coded.[14,15] However, we identified comorbidities in the administrative databases using a 1-year 'look-back' period so that diagnostic codes from multiple hospitalizations (and from multiple hospitals) could be used to calculate the Charlson Comorbidity Index for a particular patient; this has been shown to increase the capture of comorbidities.[16] Third, we found that variables from the chart review indicating frailty were predictive of 1-year death risk independent of the chart-HOMR score (Table 2). This illustrates that mortality risk prediction can be improved for particular patient groups by adding new covariates to the HOMR. Further work is required to determine how to incor-

porate these (and possibly other) covariates into the HOMR to create a unique chart-HOMR score. Finally, we found that a geriatrics assessment in the ED was associated with a significant (and notable) decrease in death risk. With these data, we are unable to indicate whether this association is causative. However, these findings indicate that the influence of emergency geriatric assessments on patient survival needs to be explored in more detail.

Several issues about our study should be considered when interpreting its results. First, this was a single-center study and the generalizability of our results to other centers is unknown. However, our study had the largest sample size of all primary data prognostic index validation studies[1] ensuring that our results are, at the very least, internally reliable. In addition, our simple random sample ensured that we studied a broad assortment of patients to be certain that our results are representative of our institution. Second, we used a single abstractor for the study, which could limit the generalizability of our results. However, almost all the data points that were abstracted for our study were very objective.

In summary, our study shows that the HOMR score can be used to accurately predict 1-year death risk using data abstracted from the patient record. These findings will aid in individual patient prognostication for clinicians and researchers.

Disclosure: The authors report no financial conflicts of interest.

References

1. Yourman LC, Lee SJ, Schonberg MA, Widera EW, Smith AK. Prognostic indices for older adults: a systematic review. *JAMA*. 2012;307(2):182-192.
2. van Walraven C. The Hospital-patient One-year Mortality Risk score accurately predicts long term death risk in hospitalized patients. *J Clin Epidemiol*. 2014;67(9):1025-1034.
3. van Walraven C, McAlister FA, Bakal JA, Hawken S, Donzé J. External validation of the Hospital-patient One-year Mortality Risk (HOMR) model for predicting death within 1 year after hospital admission. *CMAJ*. 2015;187(10):725-733.
4. Walter LC, Brand RJ, Counsell SR, et al. Development and validation of a prognostic index for 1-year mortality in older adults after hospitalization. *JAMA*. 2001;285(23):2987-2994.
5. Clegg A, Young J, Iliffe S et al. Frailty in elderly people. The Lancet 2002;381:752-762.
6. Crowson CS, Atkinson EJ, Therneau TM. Assessing calibration of prognostic risk scores. *Stat Methods Med Res*. 2016;25(4):1692-1706.
7. Harrell FE Jr. *Overview of Maximum Likelihood Estimation*. *Regression Modeling Strategies*. New York, NY: Springer-Verlag; 2001: 179-212.
8. Justice AC, Covinsky KE, Berlin JA. Assessing the generalizability of prognostic information. *Ann Intern Med*. 1999;130(6):515-524.
9. Fischer SM, Gozansky WS, Sauaia A, Min SJ, Kutner JS, Kramer A. A practical tool to identify patients who may benefit from a palliative approach: the CARING criteria. *J Pain Symptom Manage*. 2006;31(4):285-292.
10. Inouye SK, Bogardus ST, Jr, Vitagliano G, et al. Burden of illness score for elderly persons: risk adjustment incorporating the cumulative impact of diseases, physiologic abnormalities, and functional impairments. *Med Care*. 2003;41(1):70-83.
11. Pilotto A, Ferrucci L, Franceschi M, et al. Development and validation of a multidimensional prognostic index for one-year mortality from comprehensive geriatric assessment in hospitalized older patients. *Rejuvenation Res*. 2008;11(1):151-161.
12. Teno JM, Harrell FE Jr, Knaus W, et al. Prediction of survival for older hospitalized patients: the HELP survival model. Hospitalized Elderly Longitudinal Project. *J Am Geriatr Soc*. 2000;48(5 suppl):S16-S24.
13. Dramé M, Novella JL, Lang PO, et al. Derivation and validation of a mortality-risk index from a cohort of frail elderly patients hospitalised in medical wards via emergencies: the SAFES study. *Eur J Epidemiol*. 2008;23(12):783-791.
14. Kieszak SM, Flanders WD, Kosinski AS, Shipp CC, Karp H. A comparison of the Charlson comorbidity index derived from medical record data and administrative billing data. *J Clin Epidemiol*. 1999;52(2):137-142.
15. Quan H, Parsons GA, Ghali WA. Validity of procedure codes in International Classification of Diseases, 9th revision, clinical modification administrative data. *Med Care*. 2004;42(8):801-809.
16. Zhang JX, Iwashyna TJ, Christakis NA. The performance of different lookback periods and sources of information for Charlson comorbidity adjustment in Medicare claims. *Med Care*. 1999;37(11):1128-1139.

Automating Venous Thromboembolism Risk Calculation Using Electronic Health Record Data Upon Hospital Admission: The Automated Padua Prediction Score

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BACKGROUND: Venous thromboembolism (VTE) risk scores assist providers in determining the relative benefit of prophylaxis for individual patients. While automated risk calculation using simpler electronic health record (EHR) data is feasible, it lacks clinical nuance and may be less predictive. Automated calculation of the Padua Prediction Score (PPS), requiring more complex input such as recent medical events and clinical status, may save providers time and increase risk score use.

OBJECTIVE: We developed the Automated Padua Prediction Score (APPS) to auto-calculate a VTE risk score using EHR data drawn from prior encounters and the first 4 hours of admission. We compared APPS to standard practice of clinicians manually calculating the PPS to assess VTE risk.

DESIGN: Cohort study of 30,726 hospitalized patients. APPS was compared to manual calculation of PPS by chart review from 300 randomly selected patients.

MEASUREMENTS: Prediction of hospital-acquired VTE not present on admission.

RESULTS: Compared to manual PPS calculation, no significant difference in average score was found (5.5 vs. 5.1, $P = 0.073$), and area under curve (AUC) was similar (0.79 vs. 0.76). Hospital-acquired VTE occurred in 260 (0.8%) of 30,726 patients. Those without VTE averaged APPS of 4.9 (standard deviation [SD], 2.6) and those with VTE averaged 7.7 (SD, 2.6). APPS had AUC = 0.81 (confidence interval [CI], 0.79-0.83) in patients receiving no pharmacologic prophylaxis and AUC = 0.78 (CI, 0.76-0.82) in patients receiving pharmacologic prophylaxis.

CONCLUSION: Automated calculation of VTE risk had similar ability to predict hospital-acquired VTE as manual calculation despite differences in how often specific scoring criteria were considered present by the 2 methods. *Journal of Hospital Medicine* 2017;12:231-237. © 2017 Society of Hospital Medicine

Hospital-acquired venous thromboembolism (VTE) continues to be a critical quality challenge for U.S. hospitals,[1] and high-risk patients are often not adequately prophylaxed. Use of VTE prophylaxis (VTEP) varies as widely as 26% to 85% of patients in various studies, as does patient outcomes and care expenditures.[2-6] The 9th edition of the American College of Chest Physicians (CHEST) guidelines[7] recommend the Padua Prediction Score (PPS) to select individual patients who may be at high risk for venous thromboembolism (VTE) and could benefit from thromboprophylaxis. Use of the manually calculated PPS to select patients for thromboprophylaxis has been shown to help decrease 30-day and 90-day mortality associated with VTE events after hospitalization to medical services.[8] However, the PPS requires time-consuming manual calculation by a provider, who may be focused on more immediate aspects of patient care and several other risk scores competing for his attention, potentially decreasing its use.

Other risk scores that use only discrete scalar data, such as vital signs and lab results to predict early recognition of sepsis, have been successfully automated and implemented within electronic health records (EHRs).[9-11] Successful automation of scores requiring input of diagnoses, recent medical events, and current clinical status such as the PPS remains difficult.[12] Data representing these characteristics are more prone to error, and harder to translate clearly into a single data field than discrete elements like heart rate, potentially impacting validity of the calculated result.[13] To improve usage of guideline based VTE risk assessment and decrease physician burden, we developed an algorithm called Automated Padua Prediction Score (APPS) that automatically calculates the PPS using only EHR data available within prior encounters and the first 4 hours of admission, a similar timeframe to when admitting providers would be entering orders. Our goal was to assess if an automatically calculated version of the PPS, a score that depends on criteria more complex than vital signs and labs, would accurately assess risk for hospital-acquired VTE when compared to

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traditional manual calculation of the Padua Prediction Score by a provider.

METHODS

Site Description and Ethics

The study was conducted at University of California, San Francisco Medical Center, a 790-bed academic hospital; its Institutional Review Board approved the study and collection of data via chart review. Handling of patient information complied with the Health Insurance Portability and Accountability Act of 1996.

Patient Inclusion

Adult patients admitted to a medical or surgical service between July 1, 2012 and April 1, 2014 were included in the study if they were candidates for VTEP, defined as: length of stay (LOS) greater than 2 days, not on hospice care, not pregnant at admission, no present on admission VTE diagnosis, no known contraindications to prophylaxis (eg, gastrointestinal bleed), and were not receiving therapeutic doses of warfarin, low molecular weight heparins, heparin, or novel anticoagulants prior to admission.

Data Sources

Clinical variables were extracted from the EHR's enterprise data warehouse (EDW) by SQL Server query (Microsoft, Redmond, Washington) and deposited in a secure database. Chart review was conducted by a trained researcher (Mr. Jacolbia) using the EHR and a standardized protocol. Findings were recorded using REDCap (REDCap Consortium, Vanderbilt University, Nashville, Tennessee). The specific ICD-9, procedure, and lab codes used to determine each criterion of APPS are available in the Appendix.

Creation of the Automated Padua Prediction Score (APPS)

We developed APPS from the original 11 criteria that comprise the Padua Prediction Score: active cancer, previous VTE (excluding superficial vein thrombosis), reduced mobility, known thrombophilic condition, recent (1 month or less) trauma and/or surgery, age 70 years or older, heart and/or respiratory failure, acute myocardial infarction and/or ischemic stroke, acute infection and/or rheumatologic disorder, body mass index (BMI) 30 or higher, and ongoing hormonal treatment.[13] APPS has the same scoring methodology as PPS: criteria are weighted from 1 to 3 points and summed with a maximum score of 20, representing highest risk of VTE. To automate the score calculation from data routinely available in the EHR, APPS checks pre-selected structured data fields for specific values within laboratory results, orders, nursing flowsheets and claims. Claims data included all ICD-9 and procedure codes used for billing purposes. If any of the predetermined data elements are found, then the specific criterion is considered positive; otherwise, it is scored as negative. The creators of the PPS were consulted in the generation of these data queries to replicate the original standards for deeming a criterion positive. The automated calculation required no use of natural language processing.

Characterization of Study Population

We recorded patient demographics (age, race, gender, BMI), LOS, and rate of hospital-acquired VTE. These patients were separated into 2 cohorts determined by the VTE prophylaxis they received. The risk profile of patients who received pharmacologic prophylaxis was hypothesized to be inherently different from those who had not. To evaluate APPS within this heterogeneous cohort, patients were divided into 2 major categories: pharmacologic vs. no pharmacologic prophylaxis. If they had a completed order or medication administration record on the institution's approved formulary for pharmacologic VTEP, they were considered to have received pharmacologic prophylaxis. If they had only a completed order for usage of mechanical prophylaxis (sequential compression devices) or no evidence of any form of VTEP, they were considered to have received no pharmacologic prophylaxis. Patients with evidence of both pharmacologic and mechanical were placed in the pharmacologic prophylaxis group. To ensure that automated designation of prophylaxis group was accurate, we reviewed 40 randomly chosen charts because prior researchers were able to achieve sensitivity and specificity greater than 90% with that sample size.[14]

The primary outcome of hospital-acquired VTE was defined as an ICD-9 code for VTE (specific codes are found in the Appendix) paired with a "present on admission = no" flag on that encounter's hospital billing data, abstracted from the EDW. A previous study at this institution used the same methodology and found 212/226 (94%) of patients with a VTE ICD-9 code on claim had evidence of a hospital-acquired VTE event upon chart review.[14] Chart review was also completed to ensure that the primary outcome of newly discovered hospital-acquired VTE was differentiated from chronic VTE or history of VTE. Theoretically, ICD-9 codes and other data elements treat chronic VTE, history of VTE, and hospital-acquired VTE as distinct diagnoses, but it was unclear if this was true in our dataset. For 75 randomly selected cases of presumed hospital-acquired VTE, charts were reviewed for evidence that confirmed newly found VTE during that encounter.

Validation of APPS through Comparison to Manual Calculation of the Original PPS

To compare our automated calculation to standard clinical practice, we manually calculated the PPS through chart review within the first 2 days of admission on 300 random patients, a subsample of the entire study cohort. The largest study we could find had manually calculated the PPS of 1,080 hospitalized patients with a mean PPS of 4.86 (standard deviation [SD], 2.26).[15] One researcher (Mr. Jacolbia) accessed the EHR with all patient information available to physicians, including admission notes, orders, labs, flowsheets, past medical history, and all prior encounters to calculate and record the PPS. To limit potential score bias, 2 authors (Drs. Elias and Davies) assessed 30 randomly selected charts from the cohort of 300.

The standardized chart review protocol mimicked a physician's approach to determine if a patient met a criterion, such as concluding if he/she had active cancer by examining medication lists for chemotherapy, procedure notes for radiation, and recent diagnoses on problem lists. After the original PPS was manually calculated, APPS was automatically calculated for the same 300 patients. We intended to characterize similarities and differences between APPS and manual calculation prior to investigating APPS' predictive capacity for the entire study population, because it would not be feasible to manually calculate the PPS for all 30,726 patients.

Statistical Analysis

For the 75 randomly selected cases of presumed hospital-acquired VTE, the number of cases was chosen by powering our analysis to find a difference in proportion of 20% with 90% power, $\alpha = 0.05$ (two-sided). We conducted χ^2 tests on the entire study cohort to determine if there were significant differences in demographics, LOS, and incidence of hospital-acquired VTE by prophylaxis received. For both the pharmacologic and the no pharmacologic prophylaxis groups, we conducted 2-sample Student t tests to determine significant differences in demographics and LOS between patients who experienced a hospital-acquired VTE and those who did not.

For the comparison of our automated calculation to standard clinical practice, we manually calculated the PPS through chart review within the first 2 days of admission on a subsample of 300 random patients. We powered our analysis to detect a difference in mean PPS from 4.86 to 4.36, enough to alter the point value, with 90% power and $\alpha = 0.05$ (two-sided) and found 300 patients to be comfortably above the required sample size. We compared APPS and manual calculation in the 300-patient cohort using: 2-sample Student t tests to compare mean scores, χ^2 tests to compare the frequency with which criteria were positive, and receiver operating characteristic (ROC) curves to determine capacity to predict a hospital-acquired VTE event. Pearson's correlation was also completed to assess score agreement between APPS and manual calculation on a per-patient basis. After comparing automated calculation of APPS to manual chart review on the same 300 patients, we used APPS to calculate scores for the entire study cohort (n = 30,726). We calculated the mean of APPS by prophylaxis group and whether hospital-acquired VTE had occurred. We analyzed APPS' ROC curve statistics by prophylaxis group to determine its overall predictive capacity in our study population. Lastly, we computed the time required to calculate APPS per patient. Statistical analyses were conducted using SPSS Statistics (IBM, Armonk, New York) and Python 2.7 (Python Software Foundation, Beaverton, Oregon); 95% confidence intervals (CI) and (SD) were reported when appropriate.

RESULTS

Among the 30,726 unique patients in our entire cohort (all patients admitted during the time period who met the study criteria), we found 6574 (21.4%) on pharmacologic (with or without mechanical) prophylaxis, 13,511 (44.0%) on mechanical only, and 10,641 (34.6%) on no prophylaxis. χ^2 tests found no significant differences in demographics, LOS, or incidence of hospital-acquired VTE between the patients who received mechanical prophylaxis only and those who received no prophylaxis (Table 1). Similarly, there were no differences in these characteristics in patients receiving pharmacologic prophylaxis with or without the addition of mechanical prophylaxis. Designation of prophylaxis group by manual chart review vs. our automated process was found to agree in categorization for 39/40 (97.5%) sampled encounters. When comparing the cohort that received pharmacologic prophylaxis against the cohort that did not, there were significant differences in racial distribution, sex, BMI, and average LOS as shown in Table 1. Those who received pharmacologic prophylaxis were found to be significantly older than those who did not (62.7 years versus 53.2 years, $P < 0.001$), more likely to be male (50.6% vs, 42.4%, $P < 0.001$), more likely to have hospital-acquired VTE (2.2% vs. 0.5%, $P < 0.001$), and to have a shorter LOS (7.1 days vs. 9.8, $P < 0.001$).

Within the cohort group receiving pharmacologic prophylaxis (n = 6574), hospital-acquired VTE occurred in patients who were significantly younger (58.2 years vs. 62.8

TABLE 1. Distribution of Patient Characteristics in Cohort

	No Pharmacologic Prophylaxis (n = 24,152)	Pharmacologic Prophylaxis (n = 6574)	*P* value
Race or Ethnicity (%)			0.001
White	13,765 (57.0)	3652 (55.6)	
Hispanic or Latino	3766 (15.6)	908 (13.8)	
Asian	3072 (12.7)	993 (15.1)	
Black or African American	1685 (7.0)	745 (11.3)	
Other/declined	1447 (6.0)	140 (2.1)	
Pacific Islander	319 (1.3)	103 (1.6)	
American Indian	98 (0.4)	33 (0.5)	
Male (%)	10,236 (42.4)	3327 (50.6)	<0.001
Age (SD)	53.2 (17.7)	62.7 (17.1)	<0.001
BMI (SD)	27.7 (6.7)	27.3 (7.4)	<0.001
LOS, d (SD)	9.8 (11.8)	7.1 (10.1)	<0.001
Hospital-acquired VTE (%)	113 (0.5)	147 (2.2)	<0.001

NOTE: Abbreviations: BMI, body mass index; LOS, length of stay; SD, standard deviation; VTE, venous thromboembolism.

TABLE 2. Comparison of APPS to Manual Calculation of PPS

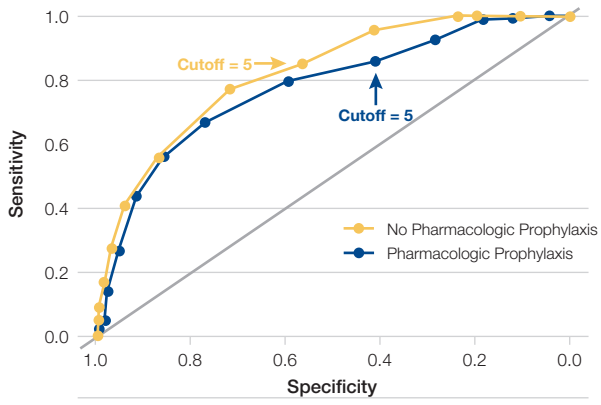
	Manual Calculation (n = 300)	APPS (n = 300)	*P*
Score criteria (%)			
Active cancer[3]	96 (32.0)	39 (13.0)	<0.001
Prior VTE[3]	25 (8.3)	48 (16.0)	<0.001
Reduced mobility[3]	198 (66.0)	223 (74.3)	<0.001
Thrombophilia[3]	0	17 (5.7)	<0.001
Recent trauma or surgery[2]	163 (54.3)	117 (39.0)	<0.001
Age ≥70 y[1]	76 (25.3)	77 (25.7)	0.655
Heart or respiratory failure[1]	27 (9.0)	66 (22.0)	<0.001
Acute MI/stroke[1]	16 (5.3)	54 (18.0)	<0.001
Acute infection/rheumatic flare[1]	75 (25.0)	57 (19.0)	0.036
Obese[1]	42 (14.0)	124 (41.3)	<0.001
Ongoing hormonal treatment[1]	1 (0.3)	5 (1.7)	0.103
Total score (SD)	5.1 (2.6)	5.5 (2.9)	0.073
Hospital-acquired VTE (%)	6 (2.0)		

[3,2,1]Corresponds to the point value of each criterion in the original PPS and APPS.

NOTE: Abbreviations: APPS, Automated Padua Prediction Score; MI, myocardial infarction; PPS, Padua Prediction Score; SD, standard deviation; VTE, venous thromboembolism.

years, *P* = 0.003) with a greater LOS (23.8 days vs. 6.7, *P* < 0.001) than those without. Within the group receiving no pharmacologic prophylaxis (n = 24,152), hospital-acquired VTE occurred in patients who were significantly older (57.1 years vs. 53.2 years, *P* = 0.014) with more than twice the LOS (20.2 days vs. 9.7 days, *P* < 0.001) compared to those without. Sixty-six of 75 (88%) randomly selected patients in which new VTE was identified by the automated electronic query had this diagnosis confirmed during manual chart review.

As shown in Table 2, automated calculation on a subsample of 300 randomly selected patients using APPS had a mean of 5.5 (SD, 2.9) while manual calculation of the original PPS on the same patients had a mean of 5.1 (SD, 2.6). There was no significant difference in mean between manual calculation and APPS (*P* = 0.073). There were, however, significant differences in how often individual criteria were considered present. The largest contributors to the difference in scores between APPS and manual calculation were "prior VTE" (positive, 16% vs. 8.3%, respectively) and "reduced mobility" (positive, 74.3% vs. 66%, respectively) as shown in Table 2. In the subsample, there were a total of 6 (2.0%) hospital-acquired VTE events. APPS' automated calculation had an AUC = 0.79 (CI, 0.63-0.95) that was significant (*P* = 0.016) with a cutoff value of 5. Chart review's manual calculation of the PPS had an AUC = 0.76 (CI 0.61-0.91) that was also significant (*P* = 0.029).



	No Pharmacologic Prophylaxis (n = 24,152)	Pharmacologic Prophylaxis (n = 6574)	Overall (n = 30,736)
Cut point	5	5	5
Sensitivity (%)	85.0	85.7	85.4
Specificity (%)	56.5	41.1	53.3
PPV (%)	0.9	3.2	1.5
NPV (%)	99.8	99.2	99.8
C statistic (SD)	0.811 (0.2)	0.78 (0.3)	0.81 (0.1)

FIG. (Left) ROC curves of the APPS predicting hospital-acquired VTE of patients receiving no pharmacologic prophylaxis (yellow line, n = 24,152) vs pharmacologic prophylaxis (blue line, n = 6574). (Right) Predictive characteristics of APPS based on prophylaxis received and for entire cohort. Each AUC was significantly greater than reference of 0.5 (*P* < 0.001).

NOTE: Abbreviations: APPS, Automated Padua Prediction Score; AUC, area under the curve; NPV, negative predictive value; PPV, positive predictive value; ROC, receiver operating characteristic; SD, standard deviation; VTE, venous thromboembolism.

Our entire cohort of 30,726 unique patients admitted during the study period included 260 (0.8%) who experienced hospital-acquired VTEs (Table 3). In patients receiving no pharmacologic prophylaxis, the average APPS was 4.0 (SD, 2.4) for those without VTE and 7.1 (SD, 2.3) for those with VTE. In patients who had received pharmacologic prophylaxis, those without hospital-acquired VTE had an average APPS of 4.9 (SD, 2.6) and those with hospital-acquired VTE averaged 7.7 (SD, 2.6). APPS' ROC curves for "no pharmacologic prophylaxis" had an AUC = 0.81 (CI, 0.79 – 0.83) that was significant ($P < 0.001$) with a cutoff value of 5. There was similar performance in the pharmacologic prophylaxis group with an AUC = 0.79 (CI, 0.76 – 0.82) and cutoff value of 5, as shown in the Figure. Over the entire cohort, APPS had a sensitivity of 85.4%, specificity of 53.3%, positive predictive value (PPV) of 1.5%, and a negative predictive value (NPV) of 99.8% when using a cutoff of 5. The average APPS calculation time was 0.03 seconds per encounter. Additional information on individual criteria can be found in Table 3.

TABLE 3. APPS Criteria by Prophylaxis and VTE Occurrence

	No Pharmacologic Prophylaxis			Pharmacologic Prophylaxis		
	No VTE (n = 24,039)	Hospital-Acquired VTE (n = 113)	*P*	No VTE (n = 6,427)	Hospital-Acquired VTE (n = 147)	*P*
APPS criteria (%)						
Active cancer[3]	3801 (15.8)	39 (34.5)	<0.001	527 (8.2)	21 (14.3)	0.014
Prior VTE[3]	1255 (5.2)	88 (77.9)	<0.001	836 (13.0)	106 (72.1)	<0.001
Reduced mobility[3]	13,791 (57.4)	67 (59.3)	0.702	4371 (68.0)	119 (81.0)	<0.001
Thrombophilia[3]	602 (2.5)	7 (6.2)	0.024	342 (5.3)	18 (12.2)	<0.001
Recent trauma/surgery[2]	9305 (38.7)	36 (31.9)	0.148	2266 (35.3)	72 (49.0)	<0.001
Age ≥70 y[1]	4537 (18.9)	26 (23.0)	0.278	2349 (36.5)	27 (18.4)	<0.001
Heart/respiratory failure[1]	1531 (6.4)	26 (23.0)	<0.001	1523 (23.7)	40 (27.2)	0.327
Acute MI/stroke[1]	1049 (4.4)	5 (4.4)	0.819	833 (13.0)	14 (9.5)	0.262
Acute infection/ rheumatic flare[1]	3179 (13.2)	20 (17.7)	0.164	1403 (21.8)	41 (27.9)	0.086
Obese[1]	8848 (36.8)	51 (45.1)	0.077	2540 (39.5)	72 (49.0)	0.021
Hormonal therapy[1]	407 (1.7)	3 (2.7)	0.445	81 (1.3)	2 (1.4)	0.709
Total score (SD)	4.0 (2.4)	7.1 (2.3)	<0.001	4.9 (2.6)	7.7 (2.6)	<0.001
C statistic (SD)	0.81 (0.79 - 0.83)		<0.001	0.78 (0.76 - 0.82)		<0.001

[3,2,1]Corresponds to the point value of each criterion in the original PPS and APPS.

NOTE: Abbreviations: APPS, Automated Padua Prediction Score; MI, myocardial infarction; PPS, Padua Prediction Score; SD, standard deviation; VTE, venous thromboembolism.

DISCUSSION

Automated calculation of APPS using EHR data from prior encounters and the first 4 hours of admission was predictive of in-hospital VTE. APPS performed as well as traditional manual score calculation of the PPS. It was able to do so with no physician input, significantly lessening the burden of calculation and potentially increasing frequency of data-driven VTE risk assessment.

While automated calculation of certain scores is becoming more common, risk calculators that require data beyond vital signs and lab results have lagged,[16-19] in part because of uncertainty about 2 issues. The first is whether EHR data accurately represent the current clinical picture. The second is if a machine-interpretable algorithm to determine a clinical status (eg, "active cancer") would be similar to a doctor's perception of that same concept. We attempted to better understand these 2 challenges through developing APPS. Concerning accuracy, EHR data correctly represent the clinical scenario: designations of VTEP and hospital-acquired VTE were accurate in approximately 90% of reviewed cases. Regarding the second concern, when comparing APPS to manual calculation, we found significant differences ($P < 0.001$) in how often 8 of the 11 criteria were positive, yet no significant difference in overall score and similar predictive capacity. Manual calculation appeared more likely to find data in the index encounter or in structured data. For example, "active cancer" may be documented only in a physician's note, easily accounted for during a physician's calculation but missed by APPS looking only for structured data. In contrast, automated calculation found historic criteria, such as "prior VTE" or "known thrombophilic condition," positive more often. If the patient is being admitted for a problem unrelated to blood clots, the physician may have little time or interest to look through hundreds of EHR documents to discover a 2-year-old VTE. As patients' records become larger and denser, more historic data can become buried and forgotten. While the 2 scores differ on individual criteria, they are similarly predictive and able to bifurcate the at-risk population to those who should and should not receive pharmacologic prophylaxis.

The APPS was found to have near-equal performance in the pharmacologic vs. no pharmacologic prophylaxis cohorts. This finding agrees with a study that found no sig-

nificant difference in predicting 90-day VTE when looking at 86 risk factors vs. the most significant 4, none of which related to prescribed prophylaxis.[18] The original PPS had a reported sensitivity of 94.6%, specificity 62%, PPV 7.5%, and NPV 99.7% in its derivation cohort.[13] We matched APPS to the ratio of sensitivity to specificity, using 5 as the cutoff value. APPS performed slightly worse with sensitivity of 85.4%, specificity 53.3%, PPV 1.5%, and NPV 99.8%. This difference may have resulted from the original PPS study's use of 90-day follow-up to determine VTE occurrence, whereas we looked only until the end of current hospitalization, an average of 9.2 days. Furthermore, the PPS had significantly poorer performance (AUC = 0.62) than that seen in the original derivation cohort in a separate study that manually calculated the score on more than 1000 patients.[15]

There are important limitations to our study. It was done at a single academic institution using a dataset of VTE-associated, validated research that was well-known to the researchers.[20] Another major limitation is the dependence of the algorithm on data available within the first 4 hours of admission and earlier; thus, previous encounters may frequently play an important role. Patients presenting to our health system for the first time would have significantly fewer data available at the time of calculation. Additionally, our data could not reliably tell us the total doses of pharmacologic prophylaxis that a patient received. While most patients will maintain a consistent VTEP regimen once initiated in the hospital, 2 patients with the same LOS may have received differing amounts of pharmacologic prophylaxis. This research study did not assess how much time automatic calculation of VTE risk might save providers, because we did not record the time for each manual abstraction; however, from discussion with the main abstracter, chart review and manual calculation for this study took from 2 to 14 minutes per patient, depending on the number of previous interactions with the health system. Finally, although we chose data elements that are likely to exist at most institutions using an EHR, many institutions' EHRs do not have EDW capabilities nor programmers who can assist with an automated risk score.

The EHR interventions to assist providers in determining appropriate VTEP have been able to increase rates of VTEP and decrease VTE-associated mortality.[16,21] In addition to automating the calculation of guideline-adherent risk scores, there is a need for wider adoption for clinical decision support for VTE. For this reason, we chose only structured data fields from some of the most common elements within our EHR's data warehouse to derive APPS (Appendix 1). Our study supports the idea that automated calculation of scores requiring input of more complex data such as diagnoses, recent medical events, and current clinical status remains predictive of hospital-acquired VTE risk. Because it is calculated automatically in the background while the clinician completes his or her assessment, the APPS holds the potential to significantly reduce the burden on providers while making guideline-adherent risk assessment more readily accessible. Further research is required to determine the exact amount of time automatic calculation saves, and, more important, if the relatively high predictive capacity we observed using APPS would be reproducible across institutions and could reduce incidence of hospital-acquired VTE.

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References

1. Galson S. The Surgeon General's call to action to prevent deep vein thrombosis and pulmonary embolism. 2008. http://www.surgeongeneral.gov/library/calls/deepvein/call-to-action-on-dvt-2008.pdf. Accessed February 11, 2016.
2. Borch KH, Nyegaard C, Hansen JB, et al. Joint effects of obesity and body height on the risk of venous thromboembolism: the Tromsø study. *Arterioscler Thromb Vasc Biol*. 2011;31(6):1439-44.
3. Braekkan SK, Borch KH, Mathiesen EB, Njølstad I, Wilsgaard T, Hansen JB.. Body height and risk of venous thromboembolism: the Tromsø Study. *Am J Epidemiol*. 2010;171(10):1109-1115.
4. Bounameaux H, Rosendaal FR. Venous thromboembolism: why does ethnicity matter? *Circulation*. 2011;123(200:2189-2191.
5. Spyropoulos AC, Anderson FA Jr, Fitzgerald G, et al; IMPROVE Investigators. Predictive and associative models to identify hospitalized medical patients at risk for VTE. *Chest*. 2011;140(3):706-714.
6. Rothberg MB, Lindenauer PK, Lahti M, Pekow PS, Selker HP. Risk factor model to predict venous thromboembolism in hospitalized medical patients. *J Hosp Med*. 2011;6(4):202-209.
7. Perioperative Management of Antithrombotic Therapy: Prevention of VTE in Nonsurgical Patients: Antithrombotic Therapy and Prevention of Thrombosis, 9th ed: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines. *Chest*. 2012;141(6):1645.
8. Subbe CP, Kruger M, Rutherford P, Gemmel L. Validation of a modified Early Warning Score in medical admissions. *QJM*. 2001;94(10):521-526.
9. Alvarez CA, Clark CA, Zhang S, et al. Predicting out of intensive care unit cardiopulmonary arrest or death using electronic medical record data. *BMC Med Inform Decis Mak*. 2013;13:28.
10. Escobar GJ, LaGuardia JC, Turk BJ, Ragins A, Kipnis P, Draper D. Early detection of impending physiologic deterioration among patients who are not in intensive care: development of predictive models using data from an automated electronic medical record. *J Hosp Med*. 2012;7(5):388-395.
11. Umscheid CA, Hanish A, Chittams J, Weiner MG, Hecht TE. Effectiveness of a novel and scalable clinical decision support intervention to improve venous thromboembolism prophylaxis: a quasi-experimental study. *BMC Med Inform Decis Mak*. 2012;12:92.
12. Tepas JJ 3rd, Rimar JM, Hsiao AL, Nussbaum MS. Automated analysis of electronic medical record data reflects the pathophysiology of operative complications. *Surgery*. 2013;154(4):918-924.
13. Barbar S, Noventa F, Rossetto V, et al. A risk assessment model for the identification of hospitalized medical patients at risk for venous thromboembolism: the Padua Prediction Score. *J Thromb Haemost*. 2010; 8(11):2450-2457.
14. Khanna R, Maynard G, Sadeghi B, et al. Incidence of hospital-acquired venous thromboembolic codes in medical patients hospitalized in academic medical centers. *J Hosp Med*. 2014; 9(4):221-225.
15. Vardi M, Ghanem-Zoubi NO, Zidan R, Yurin V, Bitterman H. Venous thromboembolism and the utility of the Padua Prediction Score in patients with sepsis admit-

ted to internal medicine departments. *J Thromb Haemost*. 2013;11(3):467-473.

16. Samama MM, Dahl OE, Mismetti P, et al. An electronic tool for venous thromboembolism prevention in medical and surgical patients. *Haematologica*. 2006;91(1):64-70
17. Mann DM, Kannry JL, Edonyabo D, et al. Rationale, design, and implementation protocol of an electronic health record integrated clinical prediction rule (iCPR) randomized trial in primary care. *Implement Sci*. 2011;6:109.
18. Woller SC, Stevens SM, Jones JP, et al. Derivation and validation of a simple model to identify venous thromboembolism risk in medical patients. *Am J Med*. 2011;124(10):947-954.
19. Huang W, Anderson FA, Spencer FA, Gallus A, Goldberg RJ. Risk-assessment models for predicting venous thromboembolism among hospitalized non-surgical patients: a systematic review. *J Thromb Thrombolysis*. 2013;35(1):67-80.
20. Khanna RR, Kim SB, Jenkins I, et al. Predictive value of the present-on-admission indicator for hospital-acquired venous thromboembolism. *Med Care*. 2015;53(4):e31-e36.
21. Kucher N, Koo S, Quiroz R, et al. Electronic alerts to prevent venous thromboembolism among hospitalized patients. *N Engl J Med*. 2005;352(10):969-977.

Impact of a Connected Care Model on 30-Day Readmission Rates from Skilled Nursing Facilities

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BACKGROUND: About one-fifth of hospitalized Medicare beneficiaries are discharged to skilled nursing facilities (SNFs) for post-acute care. Readmissions are common but interventions to reduce readmissions are scarce.

OBJECTIVE: To assess the impact of a connected care model on 30-day hospital readmission rates among patients discharged to SNFs.

DESIGN: Retrospective cohort.

SETTING: SNFs that receive referrals from an academic medical center in Cleveland, Ohio.

PARTICIPANTS: All patients admitted to Cleveland Clinic main campus between January 1, 2011 and December 31, 2014 and subsequently discharged to 7 intervention SNFs or 103 control SNFs.

INTERVENTION: Hospital-employed physicians and advanced practice professionals (nurse practitioners and physician assistants) visited SNF patients 4 to 5 times per week.

RESULTS: During the study period, 13,544 patients were discharged to SNFs within a 25-miles radius of Cleveland Clinic main campus. Of these, 3334 were discharged to 7 intervention SNFs and 10,201 were discharged to 103 usual-care SNFs. During the intervention phase (2013-2014), adjusted 30-day readmission rates declined at the intervention SNFs (28.1% to 21.7%, $P < 0.001$), while there was a slight increase at control SNFs (27.1 % to 28.5%, $P < 0.001$). The absolute reductions ranged from 4.6% for patients at low risk for readmission to 9.1% for patients at high risk, and medical patients benefited more than surgical patients.

CONCLUSION: A program of frequent visits by hospital employed physicians and advanced practice professionals at SNFs can reduce 30-day readmission rates. *Journal of Hospital Medicine* 2017;12:238-244. © 2017 Society of Hospital Medicine

Approximately 20% of hospitalized Medicare beneficiaries in the U.S. are discharged to skilled nursing facilities (SNFs) for post-acute care,[1,2] and 23.5% of these patients are readmitted within 30 days.[3] Because hospital readmissions are costly and associated with worse outcomes,[4,5] 30-day readmission rates are considered a quality indicator,[6] and there are financial penalties for hospitals with higher than expected rates.[7] As a result, hospitals invest substantial resources in programs to reduce readmissions.[8-10] The SNFs represent an attractive target for readmission reduction efforts, since SNFs contribute a disproportionate share of readmissions.[3,4] Because SNF patients are in a monitored environment with high medication adherence, risk factors for readmission likely differ between patients discharged to SNFs and those sent home. For example, 1 study showed that among heart failure patients with cognitive impairment, those discharged to SNFs had lower readmissions during the first 20 days, likely due to better medication adherence.[11] Patients discharged to SNFs generally have more complex illnesses, lower functional status, and higher 1-year mortality than patients discharged to the community.[12,13] Despite this, SNF patients might have infrequent contact with physicians. Federal regulations require only that patients discharged to SNFs need to be seen within 30 days and then at least once every 30 days thereafter.[14] According to the 2014 Office of Inspector General report, one-third of Medicare beneficiaries in SNFs experience adverse events from substandard treatment, inadequate resident monitoring and failure or delay of necessary care, most of which are thought to be preventable.[15]

To address this issue, the Cleveland Clinic developed a program called "Connected Care SNF," in which hospital-employed physicians and advanced practice professionals visit patients in selected SNFs 4 to 5 times per week, for the purpose of reducing preventable readmissions. The aim of this study was to assess whether the program reduced 30-day readmissions, and to identify which patients benefited most from the program.

METHODS

Setting and Intervention

The Cleveland Clinic main campus is a tertiary academic medical center with 1400 beds and approximately 50,000

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admissions per year. In late 2012, the Cleveland Clinic implemented the Connected Care SNF program, wherein Cleveland Clinic physicians regularly visited patients who were discharged from the Cleveland Clinic main campus to 7 regional SNFs. Beginning in December 2012, these 7 high-volume referral SNFs that were not part of the Cleveland Clinic Health System (CCHS) agreed to participate in the program, which focused on reducing avoidable hospital readmissions and delivering quality care (Table 1). The Connected Care team, comprised of 2 geriatricians (1 of whom was also a palliative medicine specialist), 1 internist, 1 family physician, and 5 advanced practice professionals (nurse practitioners and physician assistants), provided medical services at the participating SNFs. These providers aimed to see patients 4 to 5 times per week, were available on site during working hours, and provided telephone coverage at nights and on weekends. All providers had access to hospital electronic medical records and could communicate with the discharging physician and with specialists familiar with the patient as needed. Prior to the admission, providers were informed about patient arrival and, at the time of admission to the SNF, providers reviewed medications and discussed goals of care with patients and their families. In the SNF, providers worked closely with staff members to deliver medications and timely treatment. They also met monthly with multidisciplinary teams for continuous quality improvement and to review outcomes. Patients at Connected Care SNFs who had their own physicians, including most long-stay and some short-stay residents, did not receive the Connected Care intervention. They constituted less than 10% of the patients discharged from Cleveland Clinic main campus.

TABLE 1. Connected Care SNF Program

Connected Care providers:
Have access to hospital EMR and review of patient information prior to admission to SNFs
Round daily during weekday and within 48 hours visit for weekend admissions
Provide on call coverage to reduce readmissions during off hours
Communicate with subspecialists, hospital team and ED physicians
Conduct goals-of-care discussion on admission
Lead monthly meeting to review 30-day readmission outcome and other quality measures
Are evaluated on 30-day readmission performances rather than productivity
Emphasize timely medication administration and physician communication at SNFs

NOTE: Abbreviations: ED, emergency department; EMR, electronic medical records; SNF, skilled nursing facility.

Study Design and Population

We reviewed administrative and clinical data from a retrospective cohort of patients discharged to SNF from the Cleveland Clinic main campus from January 1, 2011 to December 31, 2014. We included all patients who were discharged to an SNF during the study period. Our main outcome measure was 30-day all-cause readmissions to any hospital in the Cleveland Clinic Health System (CCHS), including the main campus and 8 regional community hospitals. Study patients were followed until January 30, 2015 to capture 30-day readmissions. According to 2012 Medicare data, of CCHS patients who were readmitted within 30 days, 83% of pneumonia, 81% of major joint replacement, 72% of heart failure and 57% of acute myocardial infarction patients were readmitted to a CCHS facility. As the Cleveland Clinic main campus attracts cardiac patients from a 100+-mile radius, they may be more likely to seek care readmission near home and are not reflective of CCHS patients overall. Because we did not have access to readmissions data from non-CCHS hospitals, we excluded patients who were discharged to SNFs beyond a 25-mile radius from the main campus, where they may be more likely to utilize non-CCHS hospitals for acute hospitalization. We also excluded patients discharged to non-CCHS hospital-based SNFs, which may refer readmissions to their own hospital system. Because the Connected Care program began in December 2012, the years 2011-2012 served as the baseline period. The intervention was conducted at 7 SNFs. All other SNFs within the 25-mile radius were included as controls, except for 3 hospital-based SNFs that would be unlikely to admit patients to CCHS. We compared the change in all-cause 30-day readmission rates after implementation of Connected Care, using all patients discharged to SNFs within 25 miles to control for temporal changes in local readmission rates. Discharge to specific SNFs was determined solely by patient choice.

Data Collection

For each patient, we collected the following data that has been shown to be associated with readmissions:[16-18] demographics (age, race, sex, ZIP code), lab values on discharge (hemoglobin and sodium); hemodialysis status; medicine or surgical service; elective surgery or nonelective surgery; details of the index admission index (diagnosis-related group [DRG], Medicare severity-diagnosis-related groups [MS-DRG] weight, primary diagnosis code; principal procedure code; admission date; discharge date, length of stay, and post-acute care provider); and common comorbidities, as listed in Table 2**.** We also calculated each patient's HOSPITAL[19,20] score. The HOSPITAL score was developed to predict risk of preventable 30-day readmissions,[19] but it has also been validated to predict 30-day all-cause readmission rates for patients discharged to SNF.[21] The model contains 7 elements (*h*emoglobin, *o*ncology service, *s*odium, *p*rocedure, *i*ndex *t*ype, *a*dmissions within the last year, *l*ength of stay) (supplemental Table). Patients with a high score (7 or higher) have a 41% chance of readmission, while those with a low score (4 or lower) have only a 15% chance. [21] We assessed all cause 30-day readmission status from CCHS administrative data. Observation patients and outpatient

TABLE 2. Characteristics of Patients Discharged in 2011-2012 vs. 2013-2014 to 7 Intervention SNFs and 103 Usual-Care SNFs

	Intervention 7 SNFs			Usual-Care 103 SNFs		
	2011-2012 (n = 1547)	2013-2014 (n = 1787)	*P* value	2011-2012 (n = 5095)	2013-2014 (n = 5115)	*P* value
	N (%) or mean (SD)	N (%) or mean (SD)		N (%) or mean (SD))	N (%) or mean (SD)	
Age, y (SD)	75.6 (12.3)	75.6 (12.0)	0.99	70.2 (14.3)	69.4 (14.2)	0.006
Race						
White	749 (48.4)	853 (47.7)	0.69	2982(58.5)	2943 (57.5)	0.14
African American	704 (45.5)	779 (43.6)		1826(35.9)	1918 (37.5)	
Other	94 (6.0)	155 (8.7)		287(5.6)	254 (5.0)	
Male sex	603 (39.0)	711 (39.8)	0.63	2272 (44.6)	2370 (46.3)	0.07
Hemoglobin on discharge (g/dL)	9.9 (1.9)	9.9 (1.9)	0.82	9.9 (2.0)	9.9 (2.0)	0.14
Sodium on discharge(mmol/L)	136.3 (13.1)	136.4 (14.2)	0.82	135.8 (15.5)	136.3 (14.2)	0.06
Elective surgery	337 (21.8)	455 (25.5)	0.01	1177 (23.1)	1261 (24.7)	0.07
Hemodialysis	164 (10.6)	157 (8.8)	0.07	482 (9.5)	577 (11.3)	0.002
Last 1 y admissions	1.6 (2.2)	1.6 (2.2)	0.46	1.8 (2.4)	2.0 (2.6)	0.01
Oncology discharge	48 (3.1)	57 (3.2)	0.88	171 (3.4)	194 (3.8)	0.23
HOSPITAL score	5.9 (2.1)	5.8 (2.0)	0.10	6.0 (2.0)	6.1 (2.1)	0.14
HOSPITAL score						
High	435 (42.8)	431(41.5)		1414 (44.3)	1292 (44.9)	
Intermediate	349 (34.3)	344(33.1)	0.43	1061 (33.3)	945 (32.9)	0.89
Low	233 (22.9)	263(25.3)		716 (22.4)	639 (22.2)	
Service						
Medicine	1017 (65.7)	1038 (58.1)	<0.001	3191 (62.6)	2876 (56.2)	<0.001
Surgical	530 (34.3)	749 (41.9)		1904 (37.4)	2239 (43.8)	
MS-DRG weight	2.4 (2.1)	2.5 (2.2)	0.22	2.4 (2.2)	2.5 (2.2)	0.33
Index length of stay	9.3 (7.9)	9.4 (7.7)	0.56	9.6 (8.9)	9.8 (8.6)	0.29
Payer						
Medicare	1318 (85.2)	1549 (86.7)	0.81	3638 (71.4)	3580 (70.0)	<0.001
Medicaid	19 (1.2)	24 (1.3)		668 (13.1)	842 (16.5)	
Other	210 (13.6)	214 (12.0)		789 (15.5)	693 (13.5)	
MI	174 (11.2)	242 (13.5)	0.05	525 (10.3)	629 (12.3)	0.002
CHF	557 (36.0)	652 (36.5)	0.77	1484 (29.1)	1548 (30.3)	0.21
PVD	255 (16.5)	363 (20.3)	0.004	771 (15.1)	928 (18.1)	<0.001
CVA	349 (22.6)	447 (25.0)	0.10	1092 (21.4)	1143 (22.4)	0.25
Dementia	183 (11.8)	241 (13.5)	0.15	557 (10.9)	605 (11.8)	0.15
COPD	364 (23.5)	442 (24.7)	0.41	1109 (21.8)	1301 (25.4)	<0.001
Connective tissue disease	61 (3.9)	67 (3.7)	0.77	169 (3.3)	176 (3.4)	0.73
Peptic ulcer	73 (4.7)	111 (6.2)	0.06	224 (4.4)	296 (5.8)	<0.001
DM	617 (39.9)	760 (42.5)	0.12	1945 (38.2)	1984 (38.8)	0.51
CKD	432 (27.9)	506 (28.3)	0.80	1157 (22.7)	1306 (25.5)	<0.001
Hemiplegia	92 (5.9)	84 (4.7)	0.13	263 (5.2)	253 (4.9)	0.62
Leukemia	10 (0.6)	23 (1.3)	0.06	76 (1.5)	100 (2.0)	0.07
Lymphoma	39 (2.5)	41 (2.3)	0.67	93 (1.8)	115 (2.2)	0.13
Solid tumor	486 (31.4)	559 (31.3)	0.93	1295 (25.4)	1334 (26.1)	0.46
Liver disease	292 (18.9)	422 (23.6)	<0.001	1131 (22.2)	1317 (25.7)	<0.001
AIDS	0 (0)	2 (0.1)	0.18	38 (0.7)	27 (0.5)	0.17

NOTE: Abbreviations: AIDS, acquired immunodeficiency syndrome; CHF, congestive heart failure; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; DM, diabetes mellitus; HOSPITAL, *h*emoglobin, *o*ncology service, *s*odium, *p*rocedure, *i*ndex *t*ype, *a*dmissions within the last year, *l*ength of stay; MI, myocardial infarction; MS-DRG, Medicare severity-diagnosis-related group; PVD, peripheral vascular disease; SNF, skilled nursing facility; SD, standard deviation.

TABLE 3. Adjusted 30-Day Readmission Rates, 2011-2012 vs. 2013-2014 from 7 Intervention SNFs and 103 Usual-Care SNFs

	Intervention 7 SNFs			Usual-Care 103 SNFs		
	2011-2012 (n = 1547), rate (95% CI)	2013-2014 (n = 1787), rate (95% CI)	*P* value	2011-2012 (n = 5095), rate (95% CI)	2013-2014 (n = 5115), rate (95% CI)	*P* value
Overall	28.1% (23.6-33.0)	21.7% (18.0-25.8)	<0.001	27.1% (23.8-30.7)	28.5% (25.1-32.2)	<0.001
Services						
Medical	31.0% (26.3-36.1)	24.6% (20.6-29.0)	<0.001	30.2% (26.8-33.9)	31.8% (28.3-35.6)	<0.001
Surgical	22.4% (18.4-27.0)	17.7% (14.4-21.4)	<0.001	21.9% (18.9 -25.4)	24.2% (21.1-27.7)	<0.001
HOSPITAL score						
High (≥7)	37.3% (32.0-42.9)	30.0% (25.3-35.0)	<0.001	36.6% (32.6-40.7)	39.1% (35.0-43.4)	<0.001
Intermediate (5-6)	27.1% (22.7-31.9)	21.7% (17.9-25.9)	<0.001	26.2% (23.0%-29.7)	27.2% (23.9%-30.8)	0.001
Low (0-4)	25.2% (21.2-29.6)	19.5% (16.2-23.3)	<0.001	23.7% (20.9-26.7)	24.1% (21.3-27.2)	0.15

NOTE: Abbreviations: CI, confidence interval; HOSPITAL, *h*emoglobin, *o*ncology service, *s*odium, *p*rocedure, *i*ndex *t*ype, *a*dmissions within the last year, *l*ength of stay; SNF, skilled nursing facility.

same-day surgeries were not considered to be admissions. For patients with multiple admissions, each admission was counted as a separate index hospitalization. Cleveland Clinic's Institutional Review Board approved the study.

Statistical Analysis

For the 7 intervention SNFs, patient characteristics were summarized as means and standard deviations or frequencies and percentages for the periods of 2011-2012 and 2013-

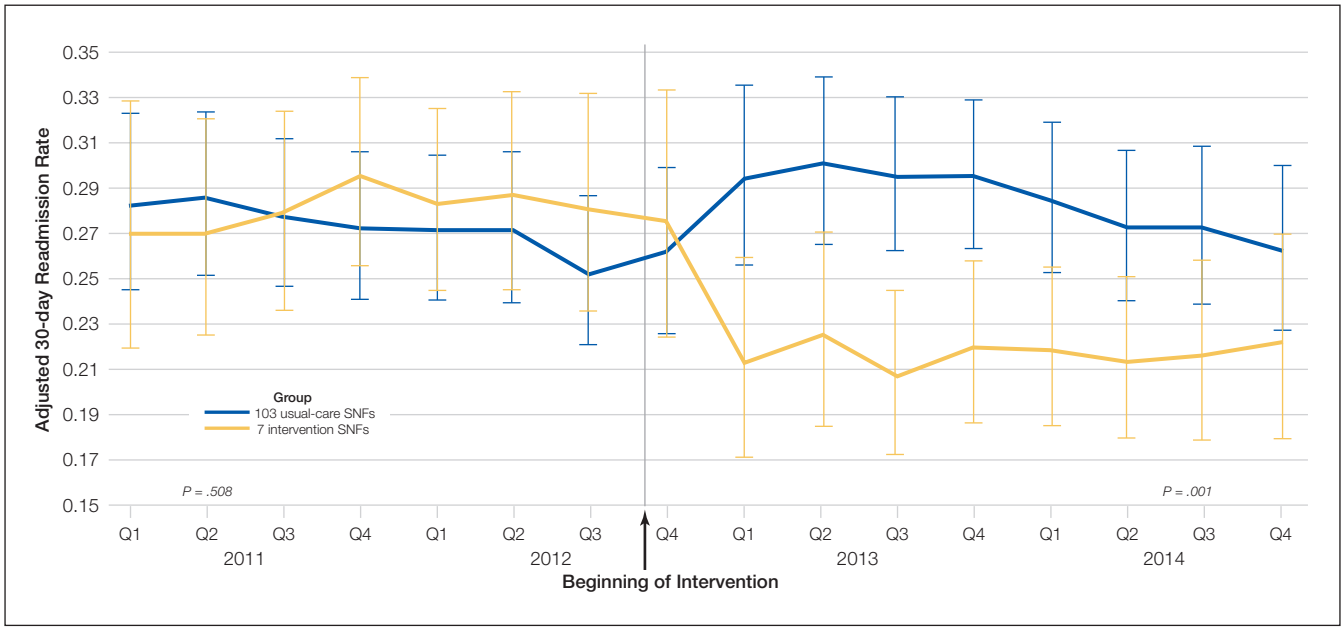

FIG. Adjusted 30-day readmission rates on 7 intervention SNF discharged patients by quarters from 2011 to 2014 and yearly 30-day readmission rates on all SNF discharged patients. *P* is for comparing readmission rates of 7 intervention SNFs before and after intervention.

2014, respectively, and the 2 periods were compared using the Student t test or χ^2 test as appropriate.

Mixed-effects logistic regression models were used to model 30-day readmission rates. Since the intervention was implemented in the last quarter of 2012, we examined the difference in readmission rates before and after that time point. The model included the following fixed effects: SNF type (intervention or usual care), time points (quarters of 2011-2014), whether the time is pre- or postintervention (binary), and the 3-way interaction between SNF type, pre- or postintervention and time points, and patient characteristics. The model also contained a Gaussian random effect at the SNF level to account for possible correlations among the outcomes of patients from the same SNF. For each quarter, the mean adjusted readmission rates of 2 types of SNFs were calculated from the fitted mixed models and plotted over time. Furthermore, we compared the mean readmission rates of the 2 groups in the pre- and postintervention periods. Subgroup analyses were performed for medical and surgical patients, and for patients in the low, intermediate and high HOSPITAL score groups.

All analyses were performed using RStudio (Boston, Massachusetts). Statistical significance was established with 2-sided *P* values less than 0.05.

RESULTS

We identified 119 SNFs within a 25-mile radius of the hospital. Of these, 6 did not receive any referrals. Three non-CCHS hospital-based SNFs were excluded, leaving a total of 110 SNFs in the study sample: 7 intervention SNFs and 103 usual-care SNFs. Between January 2011 and December 2014, there were 23,408 SNF discharges from Cleveland Clinic main campus, including 13,544 who were discharged to study SNFs (Supplemental Figure). Of these, 3334 were discharged to 7 intervention SNFs and 10,210 were discharged to usual care SNFs. Characteristics of patients in both periods appear in Table 2. At baseline, patients in the intervention and control SNFs varied in a number of ways. Patients at intervention SNFs were older (75.6 vs. 70.2 years; $P < 0.001$), more likely to be African American (45.5% vs. 35.9%; $P < 0.001$), female (61% vs. 55.4%; $P < 0.001$) and to be insured by Medicare (85.2% vs. 71.4%; $P < 0.001$). Both groups had similar proportions of patients with high, intermediate, and low readmission risk as measured by HOSPITAL score. Compared to the 2011-2012 pre-intervention period, during the 2013-2014 intervention period, there were more surgeries (34.3% vs. 41.9%; $P < 0.001$), more elective surgeries (21.8% vs. 25.5%; $P = 0.01$), fewer medical patients (65.7% vs. 58.1%; $P < 0.001$), and an increase in comorbidities, including myocardial infarction, peripheral vascular disease, and liver disease (Table 2).

Table 3 shows adjusted 30-day readmissions rates, before and during the intervention period at the intervention and usual care SNFs. Compared to the pre-intervention period, 30-day all-cause adjusted readmission rates declined in the intervention SNFs (28.1% to 21.7%, $P < 0.001$), while it increased slightly at control sites (27.1% to 28.5%, $P < 0.001$). The Figure shows the adjusted 30-day readmission rates by quarter throughout the study period.

Declines in 30-day readmission rates were greater for medical patients (31.0% to 24.6%, $P < 0.001$) than surgical patients (22.4% to 17.7%, $P < 0.001$). Patients with high HOSPITAL scores had the greatest decline, while those with low HOSPITAL scores had smaller declines.

DISCUSSION

In this retrospective study of 4 years of discharges to 110 SNFs, we report on the impact of a Connected Care program, in which a physician visited patients on admission to the SNF and 4 to 5 times per week during their stay. Introduction of the program was followed by a 6.8% absolute reduction in all-cause 30-day readmission rates compared to usual care. The absolute reductions ranged from 4.6% for patients at low risk for readmission to 9.1% for patients at high risk, and medical patients benefited more than surgical patients.

Most studies of interventions to reduce hospital readmissions have focused on patients discharged to the community setting.[7-9] Interventions have centered on discharge planning, medication reconciliation, and close follow-up to assess for medication adherence and early signs of deterioration. Because patients in SNFs have their medications administered by staff and are under frequent surveillance, such interventions are unlikely to be helpful in this population. We found no studies that focus on short-stay or skilled patients discharged to SNF. Two studies have demonstrated that interventions can reduce hospitalization from nursing homes.[22,23] Neither study included readmissions. The Evercare model consisted of nurse practitioners providing active primary care services within the nursing home, as well as offering incentive payments to nursing homes for not hospitalizing patients.[22] During a 2-year period, long term residents who enrolled in Evercare had an almost 50% reduction in incident hospitalizations compared to those who did not.[22] INTERACT II was a quality improvement intervention that provided tools, education, and strategies to help identify and manage acute conditions proactively.[23] In 25 nursing homes employing INTERACT II, there was a 17% reduction in self-reported hospital admissions during the 6-month project, with higher rates of reduction among nursing homes rated as more engaged in the process.[23] Although nursing homes may serve some short-stay or skilled patients, they generally serve long-term populations, and studies have shown that short-stay patients are at higher risk for 30-day readmissions.[24]

There are a number of reasons that short-term SNF patients are at higher risk for readmission. Although prior to admission, they were considered hospital level of care and received a physician visit daily, on transfer to the SNF, relatively little medical care is available. Current federal regulations regarding physician services at a SNF require the

resident to be seen by a physician at least once every 30 days for the first 90 days after admission, and at least once every 60 days thereafter.[25]

The Connected Care program physicians provided a smooth transition of care from hospital to SNF as well as frequent reassessment. Physicians were alerted prior to hospital discharge and performed an initial comprehensive visit generally on the day of admission to the SNF and always within 48 hours. The initial evaluation is important because miscommunication during the handoff from hospital to SNF may result in incorrect medication regimens or inaccurate assessments. By performing prompt medication reconciliation and periodic reassessments of a patient's medical condition, the Connected Care providers recreate some of the essential elements of successful outpatient readmissions prevention programs.

They also worked together with each SNF's interdisciplinary team to deliver quality care. There were monthly meetings at each participating Connected Care SNF. Physicians reviewed monthly 30-day readmissions and performed root-cause analysis. When they discovered challenges to timely medication and treatment delivery during daily rounds, they provided in-services to SNF nurses.

In addition, Connected Care providers discussed goals of care—something that is often overlooked on admission to a SNF. This is particularly important because patients with chronic illnesses who are discharged to SNF often have poor prognoses. For example, Medicare patients with heart failure who are discharged to SNFs have 1-year mortality in excess of 50%.[13] By implementing a plan of care consistent with patient and family goals, inappropriate readmissions for terminal patients may be avoided.

Reducing readmissions is important for hospitals because under the Hospital Readmissions Reduction Program, hospitals now face substantial penalties for higher than expected readmissions rates. Hospitals involved in bundled payments or other total cost-of-care arrangements have additional incentive to avoid readmissions. Beginning in 2019, SNFs will also receive incentive payments based on their 30-day all-cause hospital readmissions as part of the Skilled Nursing Facility Value-Based Purchasing program.[25] The Connected Care model offers 1 means of achieving this goal through partnership between hospitals and SNFs.

Our study has several limitations. First, our study was observational in nature, so the observed reduction in readmissions could have been due to temporal trends unrelated to the intervention. However, no significant reduction was noted during the same time period in other area SNFs. There was also little change in the characteristics of patients admitted to the intervention SNFs. Importantly, the HOSPITAL score, which can predict 30-day readmission rates,[20] did not change throughout the study period. Second, the results reflect patients discharged from a single hospital and may not be generalizable to other geographic areas. However, because the program included 7 SNFs, we believe it could be reproduced in other settings. Third, our readmissions measure included only those patients who returned to a CCHS facility. Although we may have missed some readmissions to other hospital systems, such leakage is uncommon—more than 80% of CCHS patients are readmitted to CCHS facilities—and would be unlikely to differ across the short duration of the study. Finally, at the intervention SNFs, most long-stay and some short-stay residents did not receive the Connected Care intervention because they were cared for by their own physicians who did not participate in Connected Care. Had these patients' readmissions been excluded from our results, the intervention might appear even more effective.

CONCLUSION

A Connected Care intervention reduced 30-day readmission rates among patients discharged to SNFs from a tertiary academic center. While all subgroups had substantial reductions in readmissions following the implementation of the intervention, patients who are at the highest risk of readmission benefited the most. Further study is necessary to know whether Connected Care can be reproduced in other health care systems and whether it reduces overall costs.

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References

1. Medicare Payment Advisory Commission. Report to the Congress: Medicare Payment Policy. Chapter 8. Skilled Nursing Facility Services. March 2013. http://www.medpac.gov/docs/default-source/reports/mar13_entirereport.pdf?sfvrsn=0. Accessed March 1, 2017.
2. Kim DG, Messinger-Rapport BJ. Clarion call for a dedicated clinical and research approach to post-acute care. *J Am Med Dir Assoc*. 2014;15(8):607. e1-e3.
3. Mor V, Intrator O, Feng Z, Grabowski D. The revolving door of rehospitalization from skilled nursing facilities. *Health Aff*. 2010;29(1):57-64.
4. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. *N Engl J Med*. 2009;360(14):1418-1428.
5. Creditor MC. Hazards of hospitalization of the elderly. *Ann Intern Med* 1993;118(3):219-223.
6. Van Walraven C, Bennett C, Jennings A, Austin PC, Forester AJ. Proportion of hospital readmissions deemed avoidable: a systematic review. *CMAJ*. 2011;183(7):E391-E402.
7. Brenson RA, Paulus RA, Kalman NS. Medicare's readmissions-reduction program – a positive alternative. *N Engl J Med* 2012;366(15):1364-1366.
8. Jack BW, Chetty VK, Anthony D, et al. A reengineered hospital discharge program to decrease rehospitalization: a randomized trial. *Ann Intern Med*. 2009;150(3):178-187.
9. Naylor MD, Brooten D, Campbell R, et al. Comprehensive discharge planning and home follow-up of hospitalized elders: a randomized clinical trial. *JAMA*. 1999;281(7):613-620.
10. Coleman EA, Parry C, Chalmers S, Min SJ. The care transition intervention: results of a randomized controlled trial. *Arch Intern Med*. 2006;166(17):1822-1828.
11. Patel A, Parikh R, Howell EH, Hsich E, Landers SH, Gorodeski EZ. Mini-cog performance: novel marker of post discharge risk among patients hospitalized for heart failure. *Circ Heart Fail*. 2015;8(1):8-16.
12. Walter LC, Brand RJ, Counsell SR, et al. Development and validation of a prog-

nostic index for 1-year mortality in older adults after hospitalization. *JAMA*. 2001;285(23):2987-2994.
13. Allen LA, Hernandez AF, Peterson ED, et al. Discharge to a skilled nursing facility and subsequent clinical outcomes among older patients hospitalized for heart failure. *Circ Heart Fail*. 2011;4(3):293-300.
14. 42 CFR 483.40 – Physician services. US government Publishing Office. https://www.gpo.gov/fdsys/granule/CFR-2011-title42-vol5/CFR-2011-title42-vol5-sec483-40. Published October 1, 2011. Accessed August 31, 2016.
15. Office of Inspector General. Adverse Events in Skilled Nursing Facilities: National Incidence among Medicare Beneficiaries. OEI-06-11-00370. February 2014. http://oig.hhs.gov/oei/reports/oei-06-11-00370.pdf. Accessed March 22, 2016.
16. Hasan O, Meltzer DO, Shaykevich SA, et al. Hospital readmission in general medicine patients: a prediction model. *J Gen Intern Med*. 2010;25(3):211-219.
17. Boult C, Dowd B, McCaffrey D, Boult L, Hernandez R, Krulewitch H. Screening elders for risk of hospital admission. *J Am Geriatr Soc*. 1993;41(8):811-817.
18. Silverstein MD, Qin H, Mercer SQ, Fong J, Haydar Z. Risk factors for 30-day hospital readmission in patients ≥65 years of age. *Proc (Bayl Univ Med Cent)*. 2008;21(4):363-372.
19. Donzé J, Aujesky D, Williams D, Schnipper JL. Potentially avoidable 30-day hospital readmissions in medical patients: derivation and validation of a prediction model. *JAMA Intern Med*. 2013;173(8):632-638.
20. Donzé JD, Williams MV, Robinson EJ, et al. International validity of the HOSPITAL score to predict 30-day potentially avoidable hospital readmissions. JAMA Intern Med. 2016;176(4):496-502.
21. Kim LD, Kou L, Messinger-Rapport BJ, Rothberg MB. Validation of the HOSPITAL score for 30-day all-cause readmissions of patients discharged to skilled nursing facilities. *J Am Med Dir Assoc*. 2016;17(9):e15-e18.
22. Kane RL, Keckhafer G, Flood S, Bershardsky B, Siadaty MS. The effect of Evercare on hospital use. *J Am Geriatr Soc*. 2003;51(10):1427-1434.
23. Ouslander JG, Lamb G, Tappen R, et al. Interventions to reduce hospitalizations from nursing homes: Evaluation of the INTERACT II collaboration quality improvement project. *J Am Geriatr Soc*. 2011;59(4):745-753.
24. Cost drivers for dually eligible beneficiaries: Potentially avoidable hospitalizations from nursing facility, skilled nursing facility, and home and community based service waiver programs. http://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/Reports/downloads/costdriverstask2.pdf. Accessed August 31, 2016.
25. H.R. 4302 (113th), Section 215, Protecting Access to Medicare Act of 2014 (PAMA). April 2, 2014. https://www.govtrack.us/congress/bills/113/hr4302/text. Accessed August 31, 2016.

Family Report Compared to Clinician-Documented Diagnoses for Psychiatric Conditions Among Hospitalized Children

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BACKGROUND: Psychiatric comorbidity is common in pediatric medical and surgical hospitalizations and is associated with worse hospital outcomes. Integrating medical or surgical and psychiatric hospital care depends on accurate estimates of which hospitalized children have psychiatric comorbidity.

OBJECTIVE: We conducted a study to determine agreement of family report (FR) and clinician documentation (CD) identification of psychiatric diagnoses in hospitalized children.

DESIGN AND SETTING: This was a cross-sectional study at a tertiary-care children's hospital.

PATIENTS: The patients were children and adolescents (age, 4-21 years) who were hospitalized for medical or surgical indications.

MEASUREMENTS: Psychiatric diagnoses were identified from structured interviews (FR) and from inpatient notes and *International Classification of Diseases* codes in medical records (CD). We compared estimates of point prevalence of any comorbid psychiatric diagnosis using each method, and estimated FR–CD agreement in identifying psychiatric comorbidity in hospitalized children.

RESULTS: Of 119 study patients, 26 (22%; 95% confidence interval [CI], 14%-29%) had a psychiatric comorbidity identified by FR, 30 (25%; 95% CI, 17%-34%) had it identified by CD, and 37 (23%-40%) had it identified by FR or CD. Agreement between FR and CD was low overall (κ = .46; 95% CI, .27-.66), highest for attention-deficit/hyperactivity disorder (κ = .78; 95% CI, .59-.97), and lowest for anxiety disorders (κ = .11; 95% CI, –.16 to .56).

CONCLUSIONS: Current methods may underestimate the prevalence of psychiatric conditions in hospitalized children. Information from multiple sources may be needed to develop accurate estimates of the scope of the population in need of services so that mental health resources can be appropriately allocated. *Journal of Hospital Medicine* 2017;12:245-250.

Psychiatric conditions affect 1 in 5 children,[1,2] and having a comorbid psychiatric condition is associated with worse outcomes in children hospitalized for medical or surgical indications.[3-7] Although little is known about interventions for improving outcomes for hospitalized children with psychiatric conditions,[8] several interventions that integrate medical and psychiatric care are known to improve ambulatory patient outcomes.[9-14] The success of initiatives that test whether integrated medical and psychiatric care models can improve pediatric hospital outcomes depends on reliable identification of comorbid psychiatric conditions and family and clinician having a shared understanding of a patient's psychiatric diagnoses.

Mental health care system fragmentation, stigma, and privacy issues[15-20] may contribute to clinical teams and families having disparate views of psychiatric comorbidities. Evidence suggests that hospital clinicians caring for pediatric medical and surgical inpatients are often unaware of a psychiatric condition that has been diagnosed or managed in the ambulatory setting,[3,6] even in cases in which the patient and family are aware of the diagnosis. Conversely, for other patients, clinicians may be aware of a psychiatric diagnosis, but patient and family may not share that understanding or reliably report a psychiatric diagnosis.[21-23] Although hospitalization may not be the ideal setting for identifying a new psychiatric diagnosis, given the short-term relationship between patient and clinical care team, addressing and managing a psychiatric comorbidity that is known to family or clinician are important elements of patient-centered hospital care.

The success of interventions in improving hospital outcomes for hospitalized children with psychiatric comorbidity depends on patients, families, and clinicians having a shared understanding of which patients have psychiatric conditions, and on accurate estimates of the scope of the population in need of psychiatric care during pediatric hospitalization.

We conducted a study to compare estimates of point prevalence of psychiatric comorbidity identified by family report (FR) or clinician documentation (CD) and to determine the degree of FR–CD agreement regarding the presence of psychiatric comorbidity in hospitalized children.

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METHODS

We estimated point prevalence and determined FR–CD agreement regarding diagnosed psychiatric comorbidities in a cross-sectional sample of pediatric medical and surgical hospitalizations at Children's Hospital of Philadelphia (CHOP). CHOP is a free-standing 535-bed children's hospital that serves as a community hospital for the city of Philadelphia; a regional referral center for eastern Pennsylvania, Delaware, and southern New Jersey; and a national and international quaternary referral center. This study was approved by CHOP's institutional review board.

Patients eligible for inclusion in the study were 4 to 21 years old and hospitalized for a medical or surgical indication. Patients were ineligible if they were hospitalized for a primary psychiatric indication, were medically unstable (eg, received end-of-life care or escalating interventions for a life-threatening condition), had significant cognitive impairment precluding communication (eg, history of severe hypoxic-ischemic encephalopathy), or did not speak English (pertains to consenting parent, guardian, or patient).

The cross-sectional patient sample was selected using a point prevalence recruitment strategy. All eligible patients on each of CHOP's 20 inpatient medical, surgical, and critical care units were approached for study participation on 2 dates between July 2015 and March 2016. To avoid enrolling the same patient multiple times for a single hospitalization, we separated recruitment dates on each unit by at least 3 months. A goal sample size of 100 to 150 patients was selected to provide precision sufficient to achieve a confidence interval (CI) of 10% around an estimate of the point prevalence of any mental health condition.

To obtain family report of prior psychiatric diagnoses, we interviewed patients and/or their parents during the hospitalization. For 18- to 21-year-old patients, the adolescent patient completed the interview. For patients under 18 years old, parents completed the interview, and for 14- to 17-year-old adolescents,either the parent, the patient, or both could complete the interview. Adolescents were asked to complete the interview confidentially without a parent present. The structured interview included questions derived from the National Survey of Children's Health[24] and the Services Assessment for Children and Adolescents[22] to report the patient's active psychiatric conditions. Interviewees reported whether the patient had ever been diagnosed with any psychiatric disorder, whether the condition was ongoing in the year prior to hospitalization, and whether the patient received any mental health services in clinical settings or school in the 12 months prior to hospitalization.

For CD, we identified a psychiatric diagnosis associated with the index hospitalization if a psychiatric diagnosis was noted in the patient's admission note, discharge summary, or hospital problem list, or if an *International Classification of Diseases* (*ICD*) code for a psychiatric diagnosis was submitted for billing for the index hospitalization. The Healthcare Cost and Utilization Project condition classification system was used to sort psychiatric condition codes[25-27] into 5 categories: attention-deficit/hyperactivity disorder (ADHD), anxiety disorders, depression, disruptive behavior disorders, and autism spectrum disorders. A residual category of other, less common psychiatric conditions included eating disorders, attachment disorders, and bipolar disorder.

For each condition category, we determined the point prevalence of having a psychiatric diagnosis identified by FR and having a diagnosis identified by CD. We used McNemar tests to compare point prevalence estimates, the Clopper-Pearson method to calculate CIs around the estimates,[28] and Cohen κ statistics to estimate FR–CD agreement regarding psychiatric diagnoses, grouping patients by type of psychiatric diagnosis and by clinical and demographic characteristics. All statistical tests were 2-sided, and $P < 0.05$ was used for statistical significance. All statistical analyses were performed with Stata Version 13.1 (StataCorp, College Station, Texas).

RESULTS

Of 640 patients hospitalized on study recruitment dates, 411 were ineligible for the study (282 were <4 or >21 years old, 42 were not English speakers, 37 had cognitive impairment, 30 were not medically stable, and 20 were admitted for a primary psychiatric diagnosis). Of the 229 eligible patients, 119 (52%) enrolled. Included patients were 57% female; 9% Hispanic; and 35% black, 55% white, and 15% other race. Forty-eight percent of the enrollees had Medicaid (48%), and 52% had private health insurance. Mean age was 12.3 years. Of enrolled patients, 38% were admitted to subspecialty medical services. Enrollee demographics were representative of hospital-level demographics for the study-eligible population; there were no significant differences in age, sex, race, ethnicity, payer type, or hospital service admission type between enrollees and patients who declined to participate (all *P*s > 0.05). Table 1 lists demographic and clinical characteristics of the complete study sample and of the groups with FR- or CD-identified psychiatric diagnosis.

Of 119 enrollees, 26 (22%; 95% CI, 15%-30%) had at least 1 FR-identified comorbid psychiatric diagnosis, and 30 (25%; 95% CI, 17%-33%) had at least 1 CD-identified diagnosis. In 13 cases, adolescents (age, 14-17 years) and their parents both completed the structured interview; there were no discrepancies between interview results.

In total, 39 of 119 patients (33%, 95% CI: 24-42%) had either a family-reported or clinician-documented psychiatric diagnosis at the time of hospitalization. For 17 of 119 patients (14%; 95% CI: 9-22%), family-report and clinician-documentation both identified the patient as having a comorbid psychiatric diagnosis. For 9 of 119 patients (8%; 95% CI: 4-14%) families reported a psychiatric diagnosis, but clinicians did not document one. Conversely, for another 13 of 119 patients (11%; 95% CI: 6-18%), a clinician documented a psychiatric diagnosis but the family did not report one. The Figure shows the point prevalence of family-reported psychiatric diagnoses and clinician-documented psychiatric diagnoses for 5 common psychiatric condition categories.

TABLE 1. Demographic and Clinical Characteristics of Children and Adolescents Hospitalized With Family-Reported or Clinician-Documented Psychiatric Comorbidity at 1 Tertiary-Care Children's Hospital

Characteristic	All Patients	Psychiatric Comorbidity Group		
		Family-Reported	Clinician-Documented	Family-Reported or Clinician-Documented
n	119	26	30	39
Mean (SD) age, y	12.3 (4.9)	12.8 (4.9)	14.7 (4.7)	14.0 (4.9)
Sex, %				
Male	43	38	33	33
Female	57	62	67	66
Hispanic, %	9	8	7	8
Private insurance, %	52	65	53	56
Race, %				
Black	30	23	26	28
White	55	77	60	62
Other	15	0	13	10
Admission indication, %				
General medical	19	31	20	26
Subspecialty medical	38	38	47	41
Surgical	26	23	17	15
Critical care	17	8	17	18

NOTE: Abbreviation: SD, standard deviation.

The most common psychiatric conditions reported by families or documented by clinicians were ADHD (n=16, 13%), anxiety (n=19, 16%), and depression (n=15, 13%). Estimates of the point prevalence of psychiatric conditions were similar when using either family report or clinician documentation alone to identify patients with psychiatric conditions. However, when family report and clinician documentation were used together to identify patients with psychiatric comorbidity, the estimated point prevalence of psychiatric comorbidity was significantly higher for depression, anxiety, and autism. Table 2 displays the point prevalence of patient- and parent-reported psychiatric diagnoses and clinician-documented psychiatric diagnoses.

Although point prevalence estimates were similar for FR- and CD-identified comorbid psychiatric conditions, FR–CD agreement was modest. It was fair for any psychiatric diagnosis (κ = .49; 95% CI, .30-.67), highest for ADHD (κ = .79; 95% CI, .61-.96), and fair or poor for other psychiatric conditions (κ range, .11-.48). Table 3 lists the FR–CD agreement data for psychiatric diagnoses for hospitalized children and adolescents.

We compared the distribution of FR and CD psychiatric diagnoses with FR use of mental health services. Of the 119 patients, 47 (39%; 95% CI, 31%-49%) had used mental health services within the year before hospitalization. Of these 47 patients, 15 (32%; 95% CI, 19%-47%) had a psychiatric diagnosis identified by both FR and CD, 6 (13%; 95% CI, 5%-26%) had a diagnosis identified only by FR, 8 (17%; 95% CI, 8%-30%) had a diagnosis identified only by CD, and 18 (38%; 95% CI, 25%-54%) had no FR- or CD-identified diagnosis. For 5 (38%; 95% CI, 14%-68%) of the 13 patients with a CD-only diagnosis, the family reported no use of mental health services within the year before hospitalization.

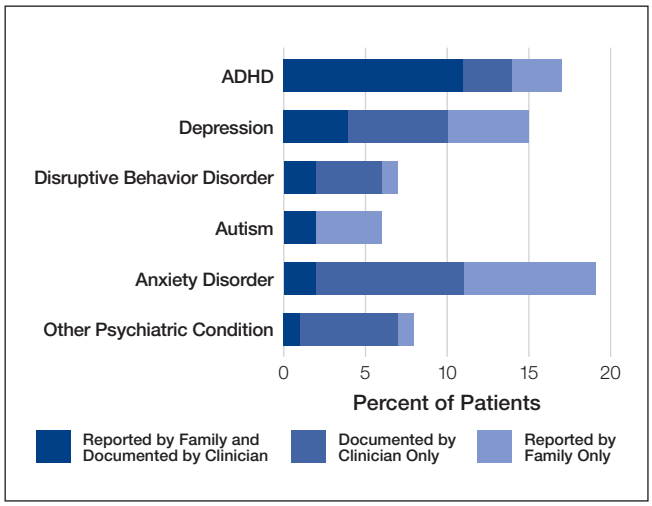

FIG. Point prevalence of family-reported psychiatric diagnoses and clinician-documented psychiatric diagnoses for 5 common psychiatric condition categories.
NOTE: Abbreviation: ADHD, attention-deficit/hyperactivity disorder.

DISCUSSION

At a tertiary-care children's hospital, we found high point prevalence of comorbid psychiatric conditions and low agreement between FR- and CD-identified psychiatric conditions. Estimates of the prevalence of psychiatric comorbidity among pediatric medical and surgical inpatients were sim-

TABLE 2. Point Prevalence of Family Report and Clinician Documentation of Comorbid Psychiatric Diagnoses for 119 Children and Adolescents Hospitalized at 1 Tertiary-Care Children's Hospital

Condition	Point Prevalence, % (95% CI)		
	Family Report	Clinician Documentation	Family Report or Clinician Documentation
Anxiety	8 (3-13)	9 (4-15)	16 (9-23)[b]
ADHD	12 (6-18)	11 (5-17)	13 (7-19)
Depression	8 (3-12)	8 (3-13)	13 (7-19)[b]
Autism	5 (1-9)[b]	2 (0-4)	5 (1-9)[b]
Disruptive behavior disorder	3 (0-5)	5 (1-9)	6 (2-10)
Other[a]	2 (0-4)	5 (1-9)	7 (2-11)
Any psychiatric condition	22 (14-29)	25 (17-33)	33 (24-41)[b]

[a]Includes attachment disorder, eating disorder, and bipolar disorder.

[b]Statistically significant ($P < 0.05$) difference from clinician documentation prevalence estimates.

NOTE: Abbreviations: ADHD, attention-deficit/hyperactivity disorder; CI, confidence interval.

TABLE 3. Agreement of Family Report and Clinician Documentation of Comorbid Psychiatric Diagnoses by Patient Characteristics

Characteristic	Family Report or Clinician Documentation of Psychiatric Diagnosis, n	κ (95% CI)
Sex		
Female	26	.39 (.15 to .64)
Male	13	.63 (.35 to .90)
Race		
White	24	.63 (.42 to .84)
Other	15	.21 (–.09 to .52)
Age, y		
>12	27	.30 (.04 to .56)
≤12	12	.69 (.43 to .94)
Insurance		
Private	22	.54 (.31 to .78)
Public	17	.41 (.13 to .69)
Service		
General medical	10	.39 (–.01 to .79)
Subspecialty medical	16	.55 (.28 to .82)
Surgical	6	.89 (.68 to 1.0)
Critical care	7	–.17 (–.39 to .05)
Psychiatric diagnosis		
ADHD	16	.79 (.61 to .96)
Depression	15	.37 (.08 to .67)
Autism	6	.48 (.06 to .91)
Disruptive behavior disorder	7	.43 (.02 to .84)
Anxiety	19	.11 (–.16 to .56)
Other[a]	8	.20 (–.16 to .56)
Any psychiatric condition	39	.49 (.30 to .67)

[a]Includes attachment disorder, eating disorder, and bipolar disorder.

NOTE: Abbreviations: ADHD, attention-deficit/hyperactivity disorder; CI, confidence interval.

ilar for FR- and CD-identified psychiatric conditions, though each method missed about one third of the cases identified by the other method. FR only and CD only each identified about 1 in 4 or 5 hospitalized children and adolescents with a psychiatric comorbidity. When FR and CD were combined, a comorbid psychiatric diagnosis was identified in about 1 in 3 medical and surgical inpatients aged 4 to 21 years. FR–CD agreement was substantial only for ADHD and was fair to slight for most other psychiatric conditions, including autism, depression, anxiety, and disruptive behavior disorders (eg, conduct disorder, oppositional defiant disorder).

Our finding that psychiatric conditions were more commonly reported by families and documented by clinicians for white patients is consistent with a large body of evidence showing that racial or ethnic minority patients experience more stigma related to mental health diagnoses and use mental health services less.[29-33] Families were more likely to report use of mental health services than a known mental health diagnosis. This finding may reflect families' willingness to use services even if they do not understand or experience stigma related to psychiatric diagnoses. Alternatively, use of mental health services without a diagnosis may reflect clinicians' willingness to refer a child for services when the child is perceived to have an impairment even in the absence of a clear psychiatric diagnosis.

The low FR–CD agreement regarding psychiatric conditions in hospitalized children and adolescents raises 3 issues for pediatric hospital care. First, earlier studies likely underestimated the prevalence of these conditions. A 2014 study of a national sample found that 13% of children hospitalized for a physical health condition had psychiatric comorbidity.[25] That study and other large-scale studies showing a high and increasing prevalence of primary psychiatric conditions in hospitalized children and adolescents have relied on administrative data derived from clinician-documented diagnoses.[25-27] Our study findings suggest that reliance on administrative data could result in underestimation of the prevalence of psychiatric comorbidity in hospitalized children by as much as 40%. Pediatric hospitals are reporting a shortage of pediatric mental health specialists.[34] Augmenting estimates of the prevalence of psychiatric comorbidity in hospitalized children with reports from other sources, including families or outpatient administrative records, may aid health systems in allocating mental health resources for pediatric inpatients.

The second issue is that the present data suggest that families and clinicians do not share the same information about a child's psychiatric diagnoses when the child is hospitalized for a medical condition or surgical procedure. Low FR–CD agreement regarding psychiatric diagnoses suggests families and clinical teams are not always "on the same page" about psychiatric needs during hospitalization. Implications of this finding are relevant to inpatient and ambulatory care settings. In cases in which a clinician recognizes a psychiatric condition but the family does not, the family may not seek outpatient treatment. In the present study, one third of patients with a psychiatric diagnosis identified by CD but not FR were not engaged in ambulatory treatment for the condition. Conversely, a psychiatric diagnosis identified by FR but not CD suggests clinical teams lack the skills and knowledge

needed to elicit information about psychiatric conditions and their potential relevance to inpatient care. As a result, clinicians may miss opportunities to provide interventions that may improve physical or mental health outcomes. For example, clinical teams with information about a patient's anxiety disorder may be better able to provide brief interventions to prevent medical treatments from triggering anxiety symptoms and to mitigate the risk for traumatic stress symptoms related to the hospitalization.

The third issue is that anxiety disorders were most likely to be the subject of FR–CD disagreement. This finding identifies children with anxiety disorders as a priority population for research into differences between families and clinicians in understanding patients' psychiatric diagnoses. Our findings suggest families and clinicians have different views of patients' anxiety symptoms. Anxiety disorders are a risk factor for worse outcomes in children with chronic physical conditions,[3,35-37] and acute hospitalization is associated with posthospital anxiety symptoms.[38,39] Thus, anxiety disorders are particularly relevant to hospital care and are a priority for research on the differences between families' and clinicians' perspectives on children's psychiatric diagnoses.

Our findings should be interpreted in the context of study limitations. First, because of resource limitations, we did not obtain psychiatric diagnostic evaluations or records to confirm FR- and CD-identified psychiatric diagnoses. Although this lack of clinical confirmation could have resulted in misclassification bias, the risk of bias was no higher than in many other studies that have successfully used hospital records[21,25] and family reports to identify psychiatric comorbidity.[40] Second, because the study included only English-speaking patients and families, results cannot be generalized to non-English-speaking populations. Third, this was a single-center study, conducted in a free-standing tertiary-care children's hospital. Sample size was small, particularly for estimating the prevalence of individual psychiatric conditions. Patient characteristics and clinical practice patterns may differ at other types of hospitals. Larger multicenter studies are warranted. Despite these limitations, our results provide important new information that can further our understanding of the epidemiology of psychiatric conditions in hospitalized children. This information should interest clinical teams caring for children with comorbid physical and mental health conditions.

CONCLUSIONS

Low FR–CD agreement regarding hospitalized children's psychiatric comorbidities suggests that patients and their families and clinicians do not always share the same information about these comorbidities, and that the prevalence of psychiatric comorbidity in hospitalized children is likely underestimated. To allocate adequate resources for these children, health systems may need to obtain information from multiple sources. Furthermore, we need to better our understanding of strategies for communicating about hospitalized children's psychiatric conditions so that we can develop interventions to improve hospital outcomes for this vulnerable population.

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References

1. Perou R, Bitsko RH, Blumberg SJ, et al; Centers for Disease Control and Prevention (CDC). Mental health surveillance among children—United States, 2005-2011. *MMWR Suppl*. 2013;62(2):1-35.
2. Merikangas KR, Nakamura EF, Kessler RC. Epidemiology of mental disorders in children and adolescents. *Dialogues Clin Neurosci*. 2009;11(1):7-20.
3. Doupnik SK, Mitra N, Feudtner C, Marcus SC. The influence of comorbid mood and anxiety disorders on outcomes of pediatric patients hospitalized for pneumonia. *Hosp Pediatr*. 2016;6(3):135-142.
4. Snell C, Fernandes S, Bujoreanu IS, Garcia G. Depression, illness severity, and healthcare utilization in cystic fibrosis. *Pediatr Pulmonol*. 2014;49(12):1177-1181.
5. Garrison MM, Katon WJ, Richardson LP. The impact of psychiatric comorbidities on readmissions for diabetes in youth. *Diabetes Care*. 2005;28(9):2150-2154.
6. Myrvik MP, Campbell AD, Davis MM, Butcher JL. Impact of psychiatric diagnoses on hospital length of stay in children with sickle cell anemia. *Pediatr Blood Cancer*. 2012;58(2):239-243.
7. Myrvik MP, Burks LM, Hoffman RG, Dasgupta M, Panepinto JA. Mental health disorders influence admission rates for pain in children with sickle cell disease. *Pediatr Blood Cancer*. 2013;60(7):1211-1214.
8. Bujoreanu S, White MT, Gerber B, Ibeziako P. Effect of timing of psychiatry consultation on length of pediatric hospitalization and hospital charges. *Hosp Pediatr*. 2015;5(5):269-275.
9. Archer J, Bower P, Gilbody S, et al. Collaborative care for depression and anxiety problems. *Cochrane Database Syst Rev*. 2012;10:CD006525.
10. Aupont O, Doerfler L, Connor DF, Stille C, Tisminetzky M, McLaughlin TJ. A collaborative care model to improve access to pediatric mental health services. *Adm Policy Ment Health*. 2013;40(4):264-273.
11. Kolko DJ, Campo J, Kilbourne AM, Hart J, Sakolsky D, Wisniewski S. Collaborative care outcomes for pediatric behavioral health problems: a cluster randomized trial. *Pediatrics*. 2014;133(4):e981-e992.
12. Richardson L, McCauley E, Katon W. Collaborative care for adolescent depression: a pilot study. *Gen Hosp Psychiatry*. 2009;31(1):36-45.
13. Richardson LP, Ludman E, McCauley E, et al. Collaborative care for adolescents with depression in primary care: a randomized clinical trial. *JAMA*. 2014;312(8):809-816.
14. Huffman JC, Mastromauro CA, Beach SR, et al. Collaborative care for depression and anxiety disorders in patients with recent cardiac events: the Management of Sadness and Anxiety in Cardiology (MOSAIC) randomized clinical trial. *JAMA Intern Med*. 2014;174(6):927-935.
15. Henderson C, Noblett J, Parke H, et al. Mental health-related stigma in health care and mental health-care settings. *Lancet Psychiatry*. 2014;1(6):467-482.
16. Pescosolido BA, Perry BL, Martin JK, McLeod JD, Jensen PS. Stigmatizing attitudes and beliefs about treatment and psychiatric medications for children with mental illness. *Psychiatr Serv*. 2007;58(5):613-618.
17. Pescosolido BA. Culture, children, and mental health treatment: special section on the National Stigma Study–Children. *Psychiatr Serv*. 2007;58(5):611-612.
18. Britt TW, Greene-Shortridge TM, Brink S, et al. Perceived stigma and barriers to care for psychological treatment: implications for reactions to stressors in different contexts. *J Soc Clin Psychol*. 2008;27(4):317-335.
19. Thornicroft G, Mehta N, Clement S, et al. Evidence for effective interventions to reduce mental-health-related stigma and discrimination. *Lancet*. 2016;387(10023):1123-1132.
20. Health Insurance Portability and Accountability Act of 1996. Washington, DC: US Government Publishing Office; 1996. https://www.gpo.gov/fdsys/pkg/CRPT-104hrpt736/pdf/CRPT-104hrpt736.pdf. Accessed January 21, 2017.
21. Frayne SM, Miller DR, Sharkansky EJ, et al. Using administrative data to identify mental illness: what approach is best? *Am J Med Qual*. 2010;25(1):42-50.
22. Horwitz SM, Hoagwood K, Stiffman AR, et al. Reliability of the Services Assessment for Children and Adolescents. *Psychiatr Serv*. 2001;52(8):1088-1094.
23. Ascher BH, Farmer EM, Burns BJ, Angold A. The Child and Adolescent Services Assessment (CASA): description and psychometrics. *J Emot Behav Disord*. 1996;4(1):12-20.

24. Data Resource Center for Child & Adolescent Health, Child and Adolescent Health Measurement Initiative, Oregon Health & Science University. National Survey of Children's Health (NSCH), 2011/12. http://childhealthdata.org/docs/drc/2011-12-guide-to-topics-questions-draft.pdf?sfvrsn=4. Accessed January 21, 2017.
25. Bardach NS, Coker TR, Zima BT, et al. Common and costly hospitalizations for pediatric mental health disorders. *Pediatrics*. 2014;133(4):602-609.
26. Torio CM, Encinosa W, Berdahl T, McCormick MC, Simpson LA. Annual report on health care for children and youth in the United States: national estimates of cost, utilization and expenditures for children with mental health conditions. *Acad Pediatr*. 2015;15(1):19-35.
27. Zima BT, Rodean J, Hall M, Bardach NS, Coker TR, Berry JG. Ten year national trends in pediatric hospitalizations by psychiatric complexity. Abstract presented at: 62nd Annual Meeting of the American Academy of Child and Adolescent Psychiatry; October 2015; San Antonio, TX.
28. Clopper CJ, Pearson ES. The use of confidence or fiducial limits illustrated in the case of the binomial. *Biometrika*. 1934;26:404-413.
29. Wu CH, Erickson SR, Piette JD, Balkrishnan R. Mental health resource utilization and health care costs associated with race and comorbid anxiety among Medicaid enrollees with major depressive disorder. *J Nat Med Assoc*. 2012;104(1-2):78-88.
30. Mapelli E, Black T, Doan Q. Trends in pediatric emergency department utilization for mental health-related visits. *J Pediatr*. 2015;167(4):905-910.
31. Berdahl T, Owens PL, Dougherty D, McCormick MC, Pylypchuk Y, Simpson LA. Annual report on health care for children and youth in the United States: racial/ethnic and socioeconomic disparities in children's health care quality. *Acad Pediatr*. 2010;10(2):95-118.
32. Flores G; Committee on Pediatric Research. Technical report—racial and ethnic disparities in the health and health care of children. *Pediatrics*. 2010;125(4):e979-e1020.
33. Turner EA, Jensen-Doss A, Heffer RW. Ethnicity as a moderator of how parents' attitudes and perceived stigma influence intentions to seek child mental health services. *Cultur Divers Ethnic Minor Psychol*. 2015;21(4):613-618.
34. Shaw RJ, Wamboldt M, Bursch B, Stuber M. Practice patterns in pediatric consultation-liaison psychiatry: a national survey. *Psychosomatics*. 2006;47(1):43-49.
35. Benton TD, Ifeagwu JA, Smith-Whitley K. Anxiety and depression in children and adolescents with sickle cell disease. *Curr Psychiatry Rep*. 2007;9(2):114-121.
36. Chavira DA, Garland AF, Daley S, Hough R. The impact of medical comorbidity on mental health and functional health outcomes among children with anxiety disorders. *J Dev Behav Pediatr*. 2008;29(5):394-402.
37. Knight A, Weiss P, Morales K, et al. Depression and anxiety and their association with healthcare utilization in pediatric lupus and mixed connective tissue disease patients: a cross-sectional study. *Pediatr Rheumatol Online J*. 2014;12:42.
38. Marsac ML, Kassam-Adams N, Delahanty DL, F. Widaman K, Barakat LP. Posttraumatic stress following acute medical trauma in children: a proposed model of bio-psycho-social processes during the peri-trauma period. *Clin Child Fam Psychol Rev*. 2014;17(4):399-411.
39. Marsac ML, Hildenbrand AK, Kohser KL, Winston FK, Li Y, Kassam-Adams N. Preventing posttraumatic stress following pediatric injury: a randomized controlled trial of a web-based psycho-educational intervention for parents. *J Pediatr Psychol*. 2013;38(10):1101-1111.
40. Petersen MC, Kube DA, Whitaker TM, Graff JC, Palmer FB. Prevalence of developmental and behavioral disorders in a pediatric hospital. *Pediatrics*. 2009;123(3):e490-e495.

Hospitalizations With Observation Services and the Medicare Part A Complex Appeals Process at Three Academic Medical Centers

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Hospitalists and other providers must classify hospitalized patients as *inpatient* or *outpatient*, the latter of which includes all *observation* stays. These orders direct hospital billing and payment, as well as patient out-of-pocket expenses. The Centers for Medicare & Medicaid Services (CMS) audits hospital billing for Medicare beneficiaries, historically through the Recovery Audit program. A recent U.S. Government Accountability Office (GAO) report identified problems in the hospital appeals process of Recovery Audit program audits to which CMS proposed reforms. In the context of the GAO report and CMS's proposed improvements, we conducted a study to describe the time course and process of complex Medicare Part A audits and appeals reaching Level 3 of the 5-level appeals process as of May 1, 2016 at 3 academic medical centers. Of 219 appeals reaching Level 3, 135 had a decision—96 (71.1%) successful for the hospitals. Mean total time since date of service was 1663.3 days, which includes mean days between date of service and audit (560.4) and total days in appeals (891.3). Government contractors were responsible for 70.7% of total appeals time. Overall, government contractors and judges met legislative timeliness deadlines less than half the time (47.7%), with declining compliance at successive levels (discussion, 92.5%; Level 1, 85.4%; Level 2, 38.8%; Level 3, 0%). Most Level 1 and Level 2 decision letters (95.2%) cited time-based (24-hour) criteria for determining inpatient status, despite 70.3% of denied appeals meeting the 24-hour benchmark. These findings suggest that the Medicare appeals system merits process improvement beyond current proposed reforms. *Journal of Hospital Medicine* 2017;12:251-255.

Hospitalists and other inpatient providers are familiar with hospitalizations classified *observation*. The Centers for Medicare & Medicaid Services (CMS) uses the "2-midnight rule" to distinguish between outpatient services (which include all observation stays) and inpatient services for most hospitalizations. The rule states that "inpatient admissions will generally be payable … if the admitting practitioner expected the patient to require a hospital stay that crossed two midnights and the medical record supports that reasonable expectation."[1]

Hospitalization under inpatient versus outpatient status is a billing distinction that can have significant financial consequences for patients, providers, and hospitals. The inpatient or outpatient observation orders written by hospitalists and other hospital-based providers direct billing based on CMS and other third-party regulation. However, providers may have variable expertise writing such orders. To audit the correct use of the visit-status orders by hospital providers, CMS uses recovery auditors (RAs), also referred to as recovery audit contractors.[2,3]

Historically, RAs had up to 3 years from date of service (DOS) to perform an audit, which involves asking a hospital for a medical record for a particular stay. The audit timeline includes 45 days for hospitals to produce such documentation, and 60 days for the RA either to agree with the hospital's billing or to make an "overpayment determination" that the hospital should have billed Medicare Part B (outpatient) instead of Part A (inpatient).[3,4] The hospital may either accept the RA decision, or contest it by using the pre-appeals discussion period or by directly entering the 5-level Medicare administrative appeals process.[3,4] Level 1 and Level 2 appeals are heard by a government contractor, Level 3 by an administrative law judge (ALJ), Level 4 by a Medicare appeals council, and Level 5 by a federal district court. These different appeal types have different deadlines (Appendix 1). The deadlines for hospitals and government responses beyond Level 1 are set by Congress and enforced by CMS,[3,4] and CMS sets discussion period timelines. Hospitals that miss an appeals deadline automatically default their appeals request, but there are no penalties for missed government deadlines.

Recently, there has been increased scrutiny of the audit-and-appeals process of outpatient and inpatient status determinations.[5] Despite the 2-midnight rule, the *Medicare Benefit Policy Manual* (*MBPM*) retains the passage: "Physicians should use a 24-hour period as a benchmark, i.e.,

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they should order admission for patients who are expected to need hospital care for 24 hours or more, and treat other patients on an outpatient basis."[6] Auditors often cite "medical necessity" in their decisions, which is not well defined in the *MBPM* and can be open to different interpretation. This lack of clarity likely contributed to the large number of status determination discrepancies between providers and RAs, thereby creating a federal appeals backlog that caused the Office of Medicare Hearings and Appeals to halt hospital appeals assignments[7] and prompted an ongoing lawsuit against CMS regarding the lengthy appeals process.[4] To address these problems and clear the appeals backlog, CMS proposed a "$0.68 settlement offer."[4] The settlement "offered an administrative agreement to any hospital willing to withdraw their pending appeals in exchange for timely partial payment (68% of the net allowable amount)"[8] and paid out almost $1.5 billion to the third of eligible hospitals that accepted the offer.[9] CMS also made programmatic improvements to the RA program.[10]

Despite these efforts, problems remain. On June 9, 2016, the U.S. Government Accountability Office (GAO) published *Medicare Fee-for-Service: Opportunities Remain to Improve Appeals Process*, citing an approximate 2000% increase in hospital inpatient appeals during the period 2010–2014 and the concern that appeals requests will continue to exceed adjudication capabilities.[11] On July 5, 2016, CMS issued its proposed rule for appeals reform that allows the Medicare Appeals Council (Level 4) to set precedents which would be binding at lower levels and allows senior attorneys to handle some cases and effectively increase manpower at the Level 3 (ALJ). In addition, CMS proposes to revise the method for calculating dollars at risk needed to schedule an ALJ hearing, and develop methods to better adjudicate similar claims, and other process improvements aimed at decreasing the more than 750,000 current claims awaiting ALJ decisions.[12]

We conducted a study to better understand the Medicare appeals process in the context of the proposed CMS reforms by investigating all appeals reaching Level 3 at Johns Hopkins Hospital (JHH), University of Wisconsin Hospitals and Clinics (UWHC), and University of Utah Hospital (UU). Because relatively few cases nationally are appealed beyond Level 3, the study focused on most-relevant data.[3] We examined time spent at each appeal Level and whether it met federally mandated deadlines, as well as the percentage accountable to hospitals versus government contractors or ALJs. We also recorded the overturn rate at Level 3 and evaluated standardized text in de-identified decision letters to determine criteria cited by contractors in their decisions to deny hospital appeal requests.

METHODS

The JHH, UWHC, and UU Institutional Review Boards did not require a review. The study included all complex Part A appeals involving DOS before October 1, 2013 and reaching Level 3 (ALJ) as of May 1, 2016.

Our general methods were described previously.[2] Briefly, the 3 academic medical centers are geographically diverse. JHH is in region A, UWHC in region B, and UU in region D (3 of the 4 RA regions are represented). The hospitals had different Medicare administrative contractors but the same qualified independent contractor until March 1, 2015 (Appendix 2).

For this paper, time spent in the discussion period, if applicable, is included in appeals time, except as specified (Table 1). The term *partially favorable* is used for UU cases only, based on the *O'Connor Hospital* decision[13] (Table 1). Reflecting ambiguity in the *MBPM*, for time-based encounter length of stay (LOS) statements, JHH and UU used time between admission order and discharge order, whereas UWHC used time between decision to admit (for emergency department patients) or time care began (direct admissions) and time patient stopped receiving care (Table 2). Although CMS now defines when a hospital encounter begins under the 2-midnight rule,[14] there was no standard definition when the cases in this study were audited.

We reviewed de-identified standardized text in Level 1 and Level 2 decision letters. Each hospital designated an analyst to search letters for *Medicare Benefit Policy Manual chapter 1*, which references the 24-hour benchmark, or the *MBPM* statement regarding use of the 24-hour period as a benchmark to guide inpatient admission orders.[6] Associated paragraphs that included these terms were coded and reviewed by Drs. Sheehy, Engel, and Locke to confirm that the 24-hour time-based benchmark was mentioned, as per the *MBPM* statement (Table 2, Appendix 3).

Descriptive statistics are used to describe the data, and representative de-identified standardized text is included.

RESULTS

Of 219 Level 3 cases, 135 (61.6%) concluded at Level 3. Of these 135 cases, 96 (71.1%) were decided in favor of the hospital, 11 (8.1%) were settled in the CMS $0.68 settlement offer, and 28 (20.7%) were unfavorable to the hospital (Table 1).

Mean total days since DOS was 1,663.3 (536.8) (mean [SD]), with median 1708 days. This included 560.4 (351.6) days between DOS and audit (median 556 days) and 891.3 (320.3) days in appeal (median 979 days). The hospitals were responsible for 29.3% of that time (260.7 [68.2] days) while government contractors were responsible for 70.7% (630.6 [277.2] days). Government contractors and ALJs met deadlines 47.7% of the time, meeting appeals deadlines 92.5% of the time for Discussion, 85.4% for Level 1, 38.8% for Level 2, and 0% for Level 3 (Table 1).

All "redetermination" (level 1 appeals letters) received at UU and UWHC, and all "reconsideration" (level 2 appeals letters) received by UU, UWHC, and JHH contained standardized time-based 24–hour benchmark text directly or referencing the MBPM containing such text, to describe criteria for inpatient status (Table 2 and Appendix 3).[6] In total, 417 of 438 (95.2%) of Level 1 and Level 2 appeals results letters contained time-based 24-hour benchmark criteria for

TABLE 1. Complex Part A Appeals Reaching Administrative Law Judge (Level 3) at 3 Academic Medical Centers

	Academic Medical Center			
	JHH (n = 21)	UU (n = 116)	UWHC (n = 82)	Total (N = 219)
Total Time in Days Since Date of Service (mean, SD)[a]	2,377.9 (117.9)	1,391.1 (487.9)	1,865.3 (392.6)	1,663.3 (536.8)
Time between Date of Service (Discharge Date) and Audit	946.5 (105.8)	499.1 (357.6)	548.2 (323.0)	560.4 (351.6)
Time between Audit and Denial	394.5 (20.0)	120.6 (18.8)	108.2 (43.5)	142.2 (88.0)
Time between Denial and Appeal/Contested Denial[b]	49.3 (17.7)	97.9 (26.0)	34.3 (7.2)	69.4 (36.6)
Time in Appeals	987.6 (15.5)	673.5 (257.2)	1,174.7 (174.7)	891.3 (320.3)
Time in Appeals Attributable to Hospital (%)	26.6%	31.9%	27.7%	29.3%
Government Contractor Compliance with Deadlines (number, %)				
Discussion (30 day contractor deadline)[c]	9/9 (100%)	2/2 (100%)	75/82 (91.5%)	86/93 (92.5%)
Level 1 (60)	12/21 (57.1%)	95/116 (81.9%)	80/82 (97.6%)	187/219 (85.4%)
Level 2 (60)	18/21 (85.7%)	4/116 (3.4%)	63/82 (76.8%)	85/219 (38.8%)
Level 3 (90)	0/21 (0%)	0/116 (0%)	0/82 (0%)	0/219 (0%)
All Levels	39/72 (54.2%)	101/350 (28.9%)	218/328 (66.5%)	358/750 (47.7%)
Level 3 Appeals with ALJ Decisions or Settlement[d] Prior to ALJ Decision (number, %)	0/21 (0%)[f]	116/116 (100%)	19/82 (23.2%)	135/219 (61.6%)
Favorable/Partially Favorable Decisions for Hospital[e]	n/a	83/116 (71.6%)	13/19 (68.4%)	96/135 (71.1%)
CMS Settlement Prior to ALJ Decision	n/a	11/116 (9.5%)	0/19 (0%)	11/135 (8.1%)
Unfavorable Decisions for Hospital	n/a	22/116 (19.0%)	6/19 (31.6%)	28/135 (20.7%)

[a]Indicates total time (days) between date of service (defined as day of discharge) and Level 3 decision or settlement. For cases still awaiting Level 3 decision, indicates total time between date of service and censor date of 5/1/2016.

[b]Reflects most accurate timepoint at each institution where contested denial started for purposes of this study. At UWHC, this was Discussion for 79 cases and Level 1 appeal for 3; for UU and JHH, this was Level 1. Discussion request date could not be used for 14 cases because MAC demand letter (official start of payment denial) was received after the hospital's Discussion request. For these 14 cases, the Appeal/Contested Denial date is the Level 1 Appeal letter date even though Discussion was used. All timepoints used were based on dates on level appeal results/decision letters.

[c]As Discussion is optional, not all cases went through Discussion. All UWHC cases, 9 JHH cases, and 2 UU cases had Discussion. All cases reaching Level 3 went through Level 1 and 2.

[d]Settlement refers to the Centers for Medicare and Medicaid Services "$0.68 on the dollar" settlement offer in 2014. For purposes of this study, included settlement cases were waiting for an ALJ hearing at the time of the settlement. Of the three hospitals, only UU accepted the settlement.

[e]52 of the 83 favorable decisions at UU are considered 'partially favorable' and are the result of legal negotiation for Part B payment at the ALJ level based on the O'Connor case. In some individual cases, UU argued for full inpatient payment, but also requested that the judge consider partial payment for the medically necessary hospitalization based on the Medicare Appeal Council's decision In re O'Connor Hospital.13 Argued on a legal basis only, the ALJ awarded UU partial payment under Part B. UU considers these 52 decisions to be favorable (noted as "partially favorable" to distinguish).

[f]JHH is a Periodic Interim Payment (PIP) program, which likely delayed the start of RA audits and the subsequent appeals process timeline.

NOTE: Abbreviations: ALJ, administrative law judge; CMS, Centers for Medicare & Medicaid Services; DOS, date of service; JHH, Johns Hopkins Hospital; MAC, Medicare administrative contractor; PIP, periodic interim payment; SD, standard deviation; UU, University of Utah Hospital; UWHC, University of Wisconsin Hospitals and Clinics.

inpatient status despite 154 of 219 (70.3%) of denied cases exceeding a 24-hour LOS.

DISCUSSION

This study demonstrated process and timeliness concerns in the Medicare RA program for Level 3 cases at 3 academic medical centers. Although hospitals forfeit any appeal for which they miss a filing deadline, government contractors and ALJs met their deadlines less than half the time without default or penalty. Average time from the rendering of services to the conclusion of the audit-and-appeals process exceeded 4.5 years, which included an average 560 days between hospital stay and initial RA audit, and almost 900 days in appeals, with more than 70% of that time attributable to government contractors and ALJs.

Objective time-based 24-hour inpatient status criteria were referenced in 95% of decision letters, even though LOS exceeded 24 hours in more than 70% of these cases, suggesting that objective LOS data played only a small role in contractor decisions, or that contractors did not actually audit for LOS when reviewing cases. Unclear criteria likely contributed to payment denials and improper payments, despite admitting providers' best efforts to comply with Medicare rules when writing visit-status orders. There was also a significant cost to hospitals; our prior study found that navigating the appeals process required 5 full-time equivalents per institution.[2]

At the 2 study hospitals with Level 3 decisions, more than two thirds of the decisions favored the hospital, suggesting the hospitals were justified in appealing RA Level 1 and Level 2 determinations. This proportion is consistent with the 43% ALJ overturn rate (including RA- and non-RA-derived appeals) cited in the recent U.S. Court of Appeals for the DC Circuit decision.[9]

This study potentially was limited by contractor and hospital use of the nonstandardized LOS calculation during the study period. That the majority of JHH and UU cases cited

TABLE 2. Sample Time-Based Text Excerpts From Level 1 and Level 2 Decision Letters, Number of Letters That Included Time-Based Text, and Number of Cases That Exceeded 24 Hours,[a] for Appeals Reaching Level 3 at 3 Academic Medical Centers

	Academic Medical Center		
Measure	JHH (n = 21)	UWHC (n = 82)	UU (n = 116)
Exceeded 24-hour LOS,[b] n (%)	13 (61.9%)	72 (87.8%)	69 (59.5%)
Level 1 (MAC)	No time-based text in decision letters	Our review of the records was based on the Internet-Only Manuals (IOM) Pub 100-2 *Medicare Benefit Policy Manual* Chapter 1 Section 10[c] and 100-8 *Medicare Program Integrity Manual* Chapter 6 Section 6.5. Inpatient care rather than outpatient care is required only if the patient's medical condition, safety, or health would be significantly and directly threatened if care was provided in a less intensive setting. The patient's (or "beneficiary's") signs and symptoms must be severe enough to warrant the need for medical care and must be severe enough to warrant the need for medical care and must receive services of such intensity that they can be furnished safely and effectively only on an inpatient basis.	The records did not support more intensive monitoring or extended nursing or physician care that would require an inpatient stay. Observation hospital care rather than inpatient admission was appropriate…The requirements for observation care, appropriate for this patient, are the same as for inpatient care with the exception that inpatient care is considerably more intense in terms of resource utilization (eg, ICU/CCU) and/or duration (commonly more than two days), entailing more extensive resource utilization. The policies used to help make this decision were: • *Medicare Benefit Policy Manual,* Chapter 1, "Inpatient Hospital Services Covered Under Part A"[c] • *Medicare Claims Processing Manual*, Chapter 3, "Inpatient Hospital Billing" • *Medicare Program Integrity Manual*, Chapter 6, Section 6.5, "Medical Review of Inpatient Hospital Claims" and Chapter 3, Section 3.4.5.C "Complex Prepayment/Postpayment Review"
Level 1 letters with time-based standardized text, n (%)	0 (0%)	82 (100%)	116 (100%)
Level 2 (QIC)[d]	For inpatient hospital care, admitting physicians or other practitioners should use a 24-hour period as a benchmark, ie, they should order inpatient admission for patients who are expected to need such care for 24 hours or more, and treat other patients on an outpatient basis. However, the decision whether to admit as an inpatient is a complex medical judgment, which includes consideration of a variety of factors, including: • The patient's medical history and current medical needs • The types of facilities available to inpatients and outpatients, the hospital's bylaws and admission policies, and the relative appropriateness of treatment in each setting • The severity of the signs and symptoms exhibited by the beneficiary • The medical probability of something adverse happening to the beneficiary • The need for diagnostic studies that are appropriately outpatient services to assist in assessing the need for inpatient admission • The availability of diagnostic procedures at the time when and at the location where the beneficiary presents (*Medicare Benefit Policy Manual*, Publication 100-2, Chapter 1, Section 10).		
Level 2 letters with time-based standardized text, n (%)	21 (100%)	82 (100%)	116 (100%)

[a]There was no standard method of defining LOS at the time of these cases. At UWHC, LOS was time between emergency department decision to admit and time patient arrived on floor for direct admission; at JHH and UU, LOS was based on admit order. Discharge time was based on time patient stopped receiving care (UWHC) or on discharge order (JHH, UU). With this measurement method, LOS was shorter at JHH and UU than at UWHC.

[b]Of 219 cases, 154 (70.3%) exceeded the 24-hour benchmark; of 438 letters, 417 (95.2%) included time-based text.

[c]Referenced Chapter 1 contains text, "Physicians should use a 24-hour benchmark when deciding whether a beneficiary should be admitted as an inpatient. When a beneficiary is expected to need hospital care for 24 hours or more, the beneficiary should be admitted as an inpatient. Other patients should be admitted on an outpatient basis."

[d]The 3 hospitals had the same QIC for letters received in this study; therefore, Level 2 text was similar among hospitals.

NOTE: Abbreviations: CCU, cardiac/coronary care unit; ICU, intensive care unit; JHH, Johns Hopkins Hospital; LOS, length of stay; MAC, Medicare administrative contractor; QIC, qualified independent contractor; UU, University of Utah Hospital; UWHC, University of Wisconsin Hospitals and Clinics.

the 24-hour benchmark in their letters but nevertheless exceeded 24-hour LOS (using the most conservative definition of LOS) suggests contractors did not audit for or consider LOS in their decisions.

Our results support recent steps taken by CMS to reform the appeals process, including shortening the RA "look-back period" from 3 years to 6 months,[10] which will markedly shorten the 560-day lag between DOS and audit found in this study. In addition, CMS has replaced RAs with beneficiary and family-centered care quality improvement organizations (BFCC-QIOs)[1,8] for initial status determination audits. Although it is too soon to tell, the hope is that BFCC-QIOs will decrease the volume of audits and denials that have overwhelmed the system and most probably contributed to process delays and the appeals backlog.

However, our data demonstrate several areas of concern not addressed in the recent GAO report[11] or in the rule proposed by CMS.[12] Most important, CMS could consider an appeals deadline missed by a government contractor as a decision for the hospital, in the same way a hospital's missed deadline defaults its appeal. Such equity would ensure due process and prevent another appeals backlog. In addition, the large number of Level 3 decisions favoring hospitals suggests a need for process improvement at the Medicare administrative contractor and qualified independent contractor Level of appeals—such as mandatory review of Level 1 and Level 2 decision letters for appeals overturned at Level 3, accountability for Level 1 and Level 2 contractors with high rates of Level 3 overturn, and clarification of criteria used to judge determinations.

Medicare fraud cannot be tolerated, and a robust auditing process is essential to the integrity of the Medicare program. CMS's current and proposed reforms may not be enough to eliminate the appeals backlog and restore a timely and fair appeals process. As CMS explores bundled payments and other reimbursement reforms, perhaps the need to distinguish observation hospital care will be eliminated. Short of that, additional actions must be taken so that a just and efficient Medicare appeals system can be realized for observation hospitalizations.

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References

1. Centers for Medicare & Medicaid Services, US Dept of Health and Human Services. Fact sheet: 2-midnight rule. https://www.cms.gov/Newsroom/MediaReleaseDatabase/Fact-sheets/2015-Fact-sheets-items/2015-07-01-2.html. Published July 1, 2015. Accessed August 9, 2016.
2. Sheehy AM, Locke C, Engel JZ, et al. Recovery Audit Contractor audits and appeals at three academic medical centers. *J Hosp Med*. 2015;10(4):212-219.
3. Centers for Medicare & Medicaid Services, US Dept of Health and Human Services. Recovery auditing in Medicare for fiscal year 2014. https://www.cms.gov/Research-Statistics-Data-and-Systems/Monitoring-Programs/Medicare-FFS-Compliance-Programs/Recovery-Audit-Program/Downloads/RAC-RTC-FY2014.pdf. Accessed August 9, 2016.
4. American Hospital Association vs Burwell. No 15-5015. Circuit court decision. https://www.cadc.uscourts.gov/internet/opinions.nsf/CDFE9734F0D36C2185257F540052A39D/$file/15-5015-1597907.pdf. Decided February 9, 2016. Accessed August 9, 2016
5. AMA news: Payment recovery audit program needs overhaul: Doctors to CMS. https://wire.ama-assn.org/ama-news/payment-recovery-audit-program-needs-overhaul-doctors-cms. Accessed March 17, 2017.
6. Centers for Medicare & Medicaid Services, US Dept of Health and Human Services. Inpatient hospital services covered under Part A. In: *Medicare Benefit Policy Manual*. Chapter 1. Publication 100-02. https://www.cms.gov/Regulations-and-Guidance/Guidance/Manuals/downloads/bp102c01.pdf. Accessed August 9, 2016.
7. Griswold NJ; Office of Medicare Hearings and Appeals, US Dept of Health and Human Services. Memorandum to OMHA Medicare appellants. http://www.modernhealthcare.com/assets/pdf/CH92573110.pdf. Accessed August 9, 2016.
8. Centers for Medicare & Medicaid Services, US Dept of Health and Human Services. Inpatient hospital reviews. https://www.cms.gov/Research-Statistics-Data-and-Systems/Monitoring-Programs/Medicare-FFS-Compliance-Programs/Medical-Review/InpatientHospitalReviews.html. Accessed August 9, 2016.
9. Galewitz P. CMS identifies hospitals paid nearly $1.5B in 2015 Medicare billing settlement. *Kaiser Health News*. http://khn.org/news/cms-identifies-hospitals-paid-nearly-1-5b-in-2015-medicare-billing-settlement/. Published August 23, 2016. Accessed October 14, 2016.
10. Centers for Medicare & Medicaid Services, US Dept of Health and Human Services. Recovery audit program improvements. https://www.cms.gov/research-statistics-data-and-systems/monitoring-programs/medicare-ffs-compliance-programs/recovery-audit-program/downloads/RAC-program-improvements.pdf. Accessed August 9, 2016.
11. US Government Accountability Office. Medicare Fee-for-Service: Opportunities Remain to Improve Appeals Process. http://www.gao.gov/assets/680/677034.pdf. Publication GAO-16-366. Published May 10, 2016. Accessed August 9, 2016.
12. Centers for Medicare & Medicaid Services, US Dept of Health and Human Services. Changes to the Medicare Claims and Entitlement, Medicare Advantage Organization Determination, and Medicare Prescription Drug Coverage Determination Appeals Procedures. https://www.gpo.gov/fdsys/pkg/FR-2016-07-05/pdf/2016-15192.pdf. Accessed August 9, 2016..
13. Departmental Appeals Board, US Dept of Health and Human Services. Action and Order of Medicare Appeals Council: in the case of O'Connor Hospital. http://www.hhs.gov/dab/divisions/medicareoperations/macdecisions/oconnorhospital.pdf. Accessed August 9, 2016.
14. Centers for Medicare & Medicaid Services, US Dept of Health and Human Services. Frequently asked questions: 2 midnight inpatient admission guidance & patient status reviews for admissions on or after October 1, 2013. https://www.cms.gov/Research-Statistics-Data-and-Systems/Monitoring-Programs/Medical-Review/Downloads/QAsforWebsitePosting_110413-v2-CLEAN.pdf. Accessed August 9, 2016.

Detecting Sepsis: Are Two Opinions Better Than One?

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The diagnosis of sepsis requires that objective criteria be met with a corresponding subjective suspicion of infection. We conducted a study to characterize the agreement between different providers' suspicion of infection and the correlation with patient outcomes using prospective data from a general medicine ward. Registered nurse (RN) suspicion of infection was collected every 12 hours and compared with medical doctor or advanced practice professional (MD/APP) suspicion, defined as an existing order for antibiotics or a new order for blood or urine cultures within the 12 hours before nursing screen time. During the study period, 1386 patients yielded 11,489 screens, 3744 (32.6%) of which met at least 2 systemic inflammatory response syndrome (SIRS) criteria. Infection was suspected by RN and MD/APP in 5.8% of cases, by RN only in 22.2%, by MD/APP only in 7.2%, and by neither provider in 64.7%. Overall agreement rate was 80.7% for suspicion of infection ($\kappa = 0.11$, $P < 0.001$). Progression to severe sepsis or shock was highest when both providers suspected infection in a SIRS-positive patient (17.7%), was substantially reduced with single-provider suspicion (6.0%), and was lowest when neither provider suspected infection (1.5%) ($P < 0.001$). Provider disagreement regarding suspected infection is common, with RNs suspecting infection more often, suggesting that a collaborative model for sepsis detection may improve timing and accuracy. *Journal of Hospital Medicine* 2017;12:256-258. © 2017 Society of Hospital Medicine

Sepsis is a leading cause of hospital mortality in the United States, contributing to up to half of all deaths.[1] If the infection is identified and treated early, however, its associated morbidity and mortality can be significantly reduced.[2] The 2001 sepsis guidelines define sepsis as the suspicion of infection plus meeting 2 or more systemic inflammatory response syndrome (SIRS) criteria.[3] Although the utility of SIRS criteria has been extensively debated, providers' accuracy and agreement regarding suspicion of infection are not yet fully characterized. This is very important, as the source of infection is often not identified in patients with severe sepsis or septic shock.[4]

Although much attention recently has been given to ideal objective criteria for accurately identifying sepsis, less is known about what constitutes ideal *subjective* criteria and who can best make that assessment.[5-7] We conducted a study to measure providers' agreement regarding this subjective assessment and the impact of that agreement on patient outcomes.

METHODS

We performed a secondary analysis of prospectively collected data on consecutive adults hospitalized on a general medicine ward at an academic medical center between April 1, 2014 and March 31, 2015. This study was approved by the University of Chicago Institutional Review Board with a waiver of consent.

A sepsis screening tool was developed locally as part of the Surviving Sepsis Campaign Quality Improvement Learning Collaborative[8] (Supplemental Figure). This tool was completed by bedside nurses for each patient during each shift. Bedside registered nurse (RN) suspicion of infection was deemed positive if the nurse answered yes to question 2: "Does the patient have evidence of an active infection?" We compared RN assessment with assessment by the ordering provider, a medical doctor or advanced practice professionals (MD/APP), using an existing order for antibiotics or a new order for either blood or urine cultures placed within 12 hours before nursing screen time to indicate MD/APP suspicion of infection.

All nursing screens were transcribed into an electronic database, excluding screens not performed, or missing RN suspicion of infection. For quality purposes, screening data were merged with electronic health record data to verify SIRS criteria at the time of the screens as well as the presence of culture and/or antibiotic orders preceding the screens. Outcome data were obtained from an administrative database and confirmed by chart review using the 2001 sepsis definitions.[6] Data were de-identified and time-shifted before this analysis. SIRS-positive criteria were defined as meeting 2 or more of the following: temperature higher than 38°C or lower than 36°C; heart rate higher than 90 beats per minute; respiratory rate more than 20 breaths per minute; and white blood cell count more than 2,000/mm^3 or less than 4,000/mm^3.

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The primary clinical outcome was progression to severe sepsis or septic shock. Secondary outcomes included transfer to intensive care unit (ICU) and in-hospital mortality. Given that RN and MD/APP suspicion of infection can vary over time, only the initial screen for each patient was used in assessing progression to severe sepsis or septic shock and in-hospital mortality. All available screens were used to investigate the association between each provider's suspicion of infection over time and ICU transfer.

Demographic characteristics were compared using the χ^2 test and analysis of variance, as appropriate. Provider agreement was evaluated with a weighted κ statistic. Fisher exact tests were used to compare proportions of mortality and severe sepsis/septic shock, and the McNemar test was used to compare proportions of ICU transfers. The association of outcomes based on provider agreement was evaluated with a nonparametric test for trend.

RESULTS

During the study period, 1386 distinct patients had 13,223 screening opportunities, with a 95.4% compliance rate. A total of 1127 screens were excluded for missing nursing documentation of suspicion of infection, leaving 1192 first screens and 11,489 total screens for analysis. Of the completed screens, 3744 (32.6%) met SIRS criteria; suspicion of infection was noted by both RN and MD/APP in 5.8% of cases, by RN only in 22.2%, by MD/APP only in 7.2%, and by neither provider in 64.7% (Figure 1). Overall agreement rate was 80.7% for suspicion of infection ($\kappa = 0.11$, $P < 0.001$). Demographics by subgroup are shown in the Supplemental Table. Progression to severe sepsis or shock was highest when both providers suspected infection in a SIRS-positive patient (17.7%), was substantially reduced with single-provider suspicion (6.0%), and was lowest when neither provider suspected infection (1.5%) ($P < 0.001$). A similar trend was found for in-hospital mortality (both providers, 6.3%; single provider, 2.7%; neither provider, 2.5%; $P = 0.01$). Compared with MD/APP-only suspicion, SIRS-positive patients in whom only RNs suspected infection had similar frequency of progression to severe sepsis or septic shock (6.5% vs 5.6%; $P = 0.52$) and higher mortality (5.0% vs 1.1%; $P = 0.32$), though these findings were not statistically significant.

For the 121 patients (10.2%) transferred to ICU, RNs were more likely than MD/APPs to suspect infection at all time points (Figure 2). The difference was small ($P = 0.29$) 48 hours before transfer (RN, 12.5%; MD/APP, 5.6%) but became more pronounced ($P = 0.06$) by 3 hours before transfer (RN, 46.3%; MD/APP, 33.1%). Nursing assessments were not available after transfer, but 3 hours after transfer the proportion of patients who met MD/APP suspicion-of-infection criteria (44.6%) was similar ($P = 0.90$) to that of the RNs 3 hours before transfer (46.3%).

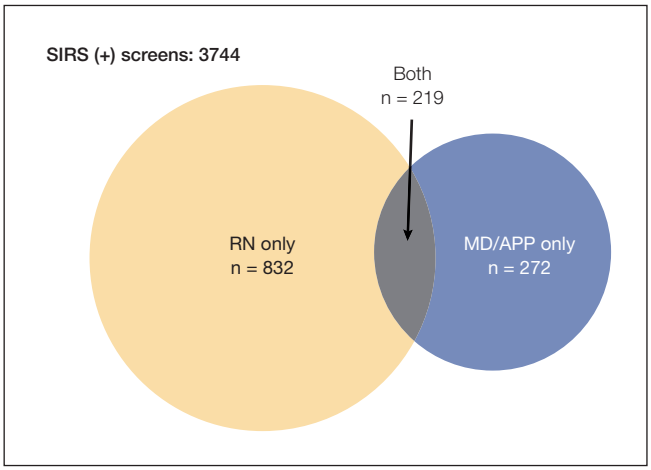

FIG. 1. Provider agreement on suspicion of infection in patients meeting 2 of 4 SIRS criteria.

NOTE: Abbreviations: APP, advanced practice professional; MD, medical doctor; RN, registered nurse; SIRS, systemic inflammatory response syndrome.

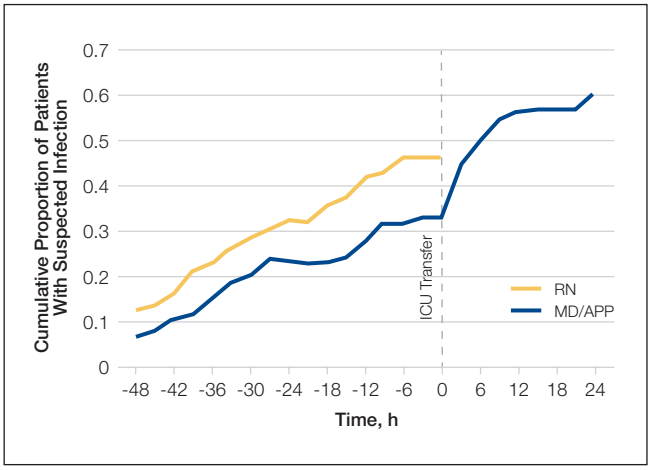

FIG. 2. Cumulative suspicion of infection by provider over time in patients transferred to ICU.

NOTE: Abbreviations: APP, advanced practice professional; ICU, intensive care unit; MD, medical doctor; RN, registered nurse.

DISCUSSION

Our findings reveal that bedside nurses and ordering providers routinely have discordant assessments regarding presence of infection. Specifically, when RNs are asked to screen patients on the wards, they are suspicious of infection more often than MD/APPs are, and they suspect infection earlier in ICU transfer patients. These findings have significant implications for patient care, compliance with the new national SEP-1 Centers for Medicare & Medicaid Services quality measure, and identification of appropriate patients for enrollment in sepsis-related clinical trials.

To our knowledge, this is the first study to explore agreement between bedside RN and MD/APP suspicion of infection in sepsis screening and its association with patient outcomes. Studies on nurse and physician concordance in other domains have had mixed findings.[9-11] The high discordance rate found in our study points to the highly subjective nature of suspicion of infection.

Our finding that RNs suspect infection earlier in patients

transferred to ICU suggests nursing suspicion has value above and beyond current practice. A possible explanation for the higher rate of RN suspicion, and earlier RN suspicion, is that bedside nurses spend substantially more time with their patients and are more attuned to subtle changes that often occur before any objective signs of deterioration. This phenomenon is well documented and accounts for why rapid response calling criteria often include "nurse worry or concern."[12,13] Thus, nurse intuition may be an important signal for early identification of patients at high risk for sepsis.

That about one third of all screens met SIRS criteria and that almost two thirds of those screens were not thought by RN or MD/APP to be caused by infection add to the literature demonstrating the limited value of SIRS as a screening tool for sepsis.[14] To address this issue, the 2016 sepsis definitions propose using the quick Sepsis-Related Organ Failure Assessment (qSOFA) to identify patients at high risk for clinical deterioration; however, the Surviving Sepsis Campaign continues to encourage sepsis screening using the SIRS criteria.[15]

Limitations of this study include its lack of generalizability, as it was conducted with general medical patients at a single center. Second, we did not specifically ask the MD/APPs whether they suspected infection; instead, we relied on their ordering practices. Third, RN and MD/APP assessments were not independent, as RNs had access to MD/APP orders before making their own assessments, which could bias our results.

Discordance in provider suspicion of infection is common, with RNs documenting suspicion more often than MD/APPs, and earlier in patients transferred to ICU. Suspicion by either provider alone is associated with higher risk for sepsis progression and in-hospital mortality than is the case when neither provider suspects infection. Thus, a collaborative method that includes both RNs and MD/APPs may improve the accuracy and timing of sepsis detection on the wards.

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References

1. Liu V, Escobar GJ, Greene JD, et al. Hospital deaths in patients with sepsis from 2 independent cohorts. *JAMA*. 2014;312(1):90-92.
2. Rivers E, Nguyen B, Havstad S, et al; Early Goal-Directed Therapy Collaborative Group. Early goal-directed therapy in the treatment of severe sepsis and septic shock. *N Engl J Med*. 2001;345(19):1368-1377.
3. Levy MM, Fink MP, Marshall JC, et al; SCCM/ESICM/ACCP/ATS/SIS. 2001 SCCM/ESICM/ACCP/ATS/SIS International Sepsis Definitions Conference. *Crit Care Med*. 2003;31(4):1250-1256.
4. Vincent JL, Sakr Y, Sprung CL, et al; Sepsis Occurrence in Acutely Ill Patients Investigators. Sepsis in European intensive care units: results of the SOAP study. *Crit Care Med*. 2006;34(2):344-353.
5. Kaukonen KM, Bailey M, Pilcher D, Cooper DJ, Bellomo R. Systemic inflammatory response syndrome criteria in defining severe sepsis. *N Engl J Med*. 2015;372(17):1629-1638.
6. Vincent JL, Opal SM, Marshall JC, Tracey KJ. Sepsis definitions: time for change. *Lancet*. 2013;381(9868):774-775.
7. Singer M, Deutschman CS, Seymour CW, et al. The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3). *JAMA*. 2016;315(8):801-810.
8. Surviving Sepsis Campaign (SSC) Sepsis on the Floors Quality Improvement Learning Collaborative. Frequently asked questions (FAQs). Society of Critical Care Medicine website. http://www.survivingsepsis.org/SiteCollectionDocuments/About-Collaboratives.pdf. Published October 8, 2013.
9. Fiesseler F, Szucs P, Kec R, Richman PB. Can nurses appropriately interpret the Ottawa ankle rule? *Am J Emerg Med*. 2004;22(3):145-148.
10. Blomberg H, Lundström E, Toss H, Gedeborg R, Johansson J. Agreement between ambulance nurses and physicians in assessing stroke patients. *Acta Neurol Scand*. 2014;129(1):4955.
11. Neville TH, Wiley JF, Yamamoto MC, et al. Concordance of nurses and physicians on whether critical care patients are receiving futile treatment. *Am J Crit Care*. 2015;24(5):403410.
12. Odell M, Victor C, Oliver D. Nurses' role in detecting deterioration in ward patients: systematic literature review. *J Adv Nurs*. 2009;65(10):1992-2006.
13. Howell MD, Ngo L, Folcarelli P, et al. Sustained effectiveness of a primary-team-based rapid response system. *Crit Care Med*. 2012;40(9):2562-2568.
14. Churpek MM, Zadravecz FJ, Winslow C, Howell MD, Edelson DP. Incidence and prognostic value of the systemic inflammatory response syndrome and organ dysfunctions in ward patients. *Am J Respir Crit Care Med*. 2015;192(8):958-964.
15. Antonelli M, DeBacker D, Dorman T, Kleinpell R, Levy M, Rhodes A; Surviving Sepsis Campaign Executive Committee. Surviving Sepsis Campaign responds to Sepsis-3. Society of Critical Care Medicine website. http://www.survivingsepsis.org/SiteCollectionDocuments/SSC-Statements-Sepsis-Definitions-3-2016.pdf. Published March 1, 2016. Accessed May 11, 2016.

The Value of Using Ultrasound to Rule Out Deep Vein Thrombosis in Cases of Cellulitis

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The "Things We Do for No Reason" series reviews practices which have become common parts of hospital care but which may provide little value to our patients. Practices reviewed in the TWDFNR series do not represent "black and white" conclusions or clinical practice standards, but are meant as a starting place for research and active discussions among hospitalists and patients. We invite you to be part of that discussion.

Because of overlapping clinical manifestations, clinicians often order ultrasound to rule out deep vein thrombosis (DVT) in cases of cellulitis. Ultrasound testing is performed for 16% to 73% of patients diagnosed with cellulitis. Although testing is common, the pooled incidence of DVT is low (3.1%). Few data elucidate which patients with cellulitis are more likely to have concurrent DVT and require further testing. The Wells clinical prediction rule with D-dimer testing overestimates DVT risk in patients with cellulitis and is of little value in this setting. Given the overall low incidence, routine ultrasound testing is unnecessary for most patients with cellulitis. ultrasound should be reserved for patients with a history of venous thromboembolism (VTE), immobility, thrombophilia, congestive heart failure (CHF), cerebrovascular accident (CVA) with hemiparesis, trauma, or recent surgery, and for patients who do not respond to antibiotics.

CASE REPORT

A 50-year-old man presented to the emergency department with a 3-day-old cut on his anterior right shin. Associated redness, warmth, pain, and swelling had progressed. The patient had no history of prior DVT or pulmonary embolism (PE). His temperature was 38.5°C, and his white blood cell count of 18,000. On review of systems, he denied shortness of breath and chest pain. He was diagnosed with cellulitis and administered intravenous fluids and cefazolin. The clinician wondered whether to perform lower extremity ultrasound to rule out concurrent DVT.

WHY YOU MIGHT THINK ULTRASOUND IS HELPFUL IN RULING OUT DVT IN CELLULITIS

Lower extremity cellulitis, a common infection of the skin and subcutaneous tissues, is characterized by unilateral erythema, pain, warmth, and swelling. The infection usually follows a skin breach that allows bacteria to enter. DVT may present similarly, and symptoms can include mild leukocytosis and elevated temperature. Because of the clinical similarities, clinicians often order compression ultrasound of the extremity to rule out concurrent DVT in cellulitis. Further impetus for testing stems from fear of the potential complications of untreated DVT, including post-thrombotic syndrome, chronic venous insufficiency, and venous ulceration. A subsequent PE can be fatal, or can cause significant morbidity, including chronic VTE with associated pulmonary hypertension. An estimated quarter of all PEs present as sudden death.[1]

WHY ULTRASOUND IS NOT HELPFUL IN THIS SETTING

Studies have shown that ultrasound is ordered for 16% to 73% of patients with a cellulitis diagnosis.[2,3] Although testing is commonly performed, a meta-analysis of 9 studies of cellulitis patients who underwent ultrasound testing for concurrent DVT revealed a low pooled incidence of total DVT (3.1%) and proximal DVT (2.1%).[4] Maze et al.[2] retrospectively reviewed 1515 cellulitis cases (identified by *International Classification of Diseases, Ninth Revision* codes) at a single center in New Zealand over 3 years. Of the 1515 patients, 240 (16%) had ultrasound performed, and only 3 (1.3%) were found to have DVT. Two of the 3 had active malignancy, and the third had injected battery acid into the area. In a 5-year retrospective cohort study at a Veterans Administration hospital in Connecticut, Gunderson and Chang[3] reviewed the cases of 183 patients with cellulitis and found ultrasound testing commonly performed (73% of cases) to assess for DVT. Only 1 patient (<1%) was diagnosed with new DVT in the ipsilateral leg, and acute DVT was diagnosed in the contralateral leg of 2 other patients. Overall, these studies indicate the incidence of concurrent DVT in cellulitis is low, regardless of the frequency of ultrasound testing.

Although the cost of a single ultrasound test is not prohibitive, annual total costs hospital-wide and nationally are large. In the United States, the charge for a unilateral duplex ultrasound of the extremity ranges from $260 to $1300, and there is an additional charge for interpretation by a radiologist.[5] In a retrospective study spanning 3.5 years and involving 2 community hospitals in Michigan, an estimated $290,000 was spent on ultrasound tests defined as unnecessary for patients with cellulitis.[6] A limitation of the study was defining a test as unnecessary based on its result being negative.

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DOES WELLS SCORE WITH D-DIMER HELP DEFINE A LOW-RISK POPULATION?

The Wells clinical prediction rule is commonly used to assess the pretest probability of DVT in patients presenting with unilateral leg symptoms. The Wells score is often combined with D-dimer testing to help determine whether ultrasound is necessary. Studies of patients with suspected DVT have found that those considered low risk according to the Wells criteria had a 6.5% incidence of DVT.[7] However, the predictive value is lower in the setting of presumed cellulitis. In a prospective cohort study of 200 patients with cellulitis, Maze et al.[8] reported that use of the Wells score with D-dimer testing overestimated the DVT risk. D-dimer level was elevated for 74% of patients, and 20.5% were high-risk by Wells criteria. An algorithm determined that—among patients with a high-risk Wells score, a positive D-dimer result, or both—only 1 (0.5%) was diagnosed with ipsilateral DVT after ultrasound testing. Two patients were diagnosed with DVT in the contralateral leg. These results suggest that a strategy that incorporates the Wells score and D-dimer testing in the setting of acute cellulitis provides little value. The authors concluded that, in the absence of a known hypercoagulable state, ultrasound is not warranted. However, their study did not assess whether there are any specific hypercoagulable states for which further testing may be indicated.

WHEN MIGHT ULTRASOUND BE HELPFUL IN CELLULITIS?

Investigators have described possible DVT risk factors in patients with cellulitis, but definitive associations are lacking because of the insufficient number of patients studied.[8,9] The most consistently identified DVT risk factor is history of previous thromboembolism. In a retrospective analysis of patients with cellulitis, Afzal et al.[6] found that, of the 66.8% who underwent ultrasound testing, 5.5% were identified as having concurrent DVT. The authors performed univariate analyses of 15 potential risk factors, including active malignancy, oral contraceptive pill use, recent hospitalization, and surgery. A higher incidence of DVT was found for patients with history of VTE (odds ratio [OR], 5.7; 95% confidence interval [CI], 2.3-13.7), calf swelling (OR, 4.5; 95% CI, 1.3-15.8), CVA (OR, 3.5; 95% CI, 1.2-10.1), or hypertension (OR, 3.5; 95% CI, 0.98-12.2). Given the wide confidence intervals, paucity of studies, and lack of definitive data in the setting of cellulitis, clinicians may want to consider the risk factors established in larger trials in other settings, including known immobility (OR, <2); thrombophilia, CHF, and CVA with hemiparesis (OR, 2-9); and trauma and recent surgery (OR, >10).[10]

WHAT YOU SHOULD DO INSTEAD

As the incidence of concurrent VTE in patients with cellulitis is low, the essential step is to make a clear diagnosis of cellulitis based on its established signs and symptoms. A 2-center trial of 145 patients found that cellulitis was diagnosed accurately by general medicine and emergency medicine physicians 72% of the time, with evaluation by dermatologists and infectious disease specialists used as the gold standard. Only 5% of the misdiagnosed patients were diagnosed with DVT; stasis dermatitis was the most common alternative diagnosis. Taking a thorough history may elicit risk factors consistent with cellulitis, such as a recent injury with a break in the skin. On examination, cellulitis should be suspected for patients with fever and localized pain, redness, swelling, and warmth—the cardinal signs of dolor, rubor, tumor, and calor. An injury or entry site and leukocytosis also support the diagnosis of cellulitis. Distinct margins of erythema on the skin are highly suspicious for erysipelas.[11] Other physical findings (eg, laceration, purulent drainage, lymphangitic spread, fluctuating mass) also are consistent with a diagnosis of cellulitis.

The patient's history is also essential in determining whether any DVT risk factors are present. Past medical history of VTE or CVA, or recent history of surgery, immobility, or trauma, should alert the clinician to the possibility of DVT. Family history of VTE increases the likelihood of DVT. Acute shortness of breath or chest pain in the setting of concerning lower extremity findings for DVT should raise concern for DVT and concurrent PE.

If the classic features of cellulitis are present, empiric antibiotics should be initiated. Routine ultrasound testing for all patients with cellulitis is of low value. However, as the incidence of DVT in this population is not negligible, those with VTE risk factors should be targeted for testing. Studies in the setting of cellulitis provide little guidance regarding specific risk factors that can be used to determine who should undergo further testing. Given this limitation, we suggest that clinicians incorporate into their decision making the well-established VTE risk factors identified for large populations studied in other settings, such as the postoperative period. Specifically, clinicians should consider ultrasound testing for patients with cellulitis and prior history of VTE; immobility; thrombophilia, CHF, and CVA with hemiparesis; or trauma and recent surgery.[10-12] Ultrasound should also be considered for patients with cellulitis that does not improve and for patients whose localized symptoms worsen despite use of antibiotics.

RECOMMENDATIONS

- Do not routinely perform ultrasound to rule out concurrent DVT in cases of cellulitis.
- Consider compression ultrasound if there is a history of VTE; immobility; thrombophilia, CHF, and CVA with hemiparesis; or trauma and recent surgery. Also consider it for patients who do not respond to antibiotics.
- In cases of cellulitis, avoid use of the Wells score alone or with D-dimer testing, as it likely overestimates the DVT risk.

CONCLUSION

The current evidence shows that, for most patients with cellulitis, routine ultrasound testing for DVT is unnecessary.

Ultrasound should be considered for patients with potent VTE risk factors. If symptoms do not improve, or if they worsen despite use of antibiotics, clinicians should be alert to potential anchoring bias and consider DVT. The Wells clinical prediction rule overestimates the incidence of DVT in cellulitis and has little value in this setting.

Disclosure: Nothing to report.

Do you think this is a low-value practice? Is this truly a "Thing We Do for No Reason"? Let us know what you do in your practice and propose ideas for other "Things We Do for No Reason" topics. Please join in the conversation online at Twitter (#TWDFNR)/ Facebook and don't forget to "Like It" on Facebook or retweet it on Twitter. We invite you to propose ideas for other "Things We Do for No Reason" topics by emailing TWDFNR@ hospitalmedicine.org.

References

1. Heit JA. The epidemiology of venous thromboembolism in the community: implications for prevention and management. *J Thromb Thrombolysis*. 2006;21(1): 23-29.
2. Maze MJ, Pithie A, Dawes T, Chambers ST. An audit of venous duplex ultrasonography in patients with lower limb cellulitis. *N Z Med J*. 2011;124(1329):53-56.
3. Gunderson CG, Chang JJ. Overuse of compression ultrasound for patients with lower extremity cellulitis. *Thromb Res*. 2014;134(4):846-850.
4. Gunderson CG, Chang JJ. Risk of deep vein thrombosis in patients with cellulitis and erysipelas: a systematic review and meta-analysis. *Thromb Res*. 2013;132(3):336-340.
5. Extremity ultrasound (nonvascular) cost and procedure information. http://www.newchoicehealth.com/procedures/extremity-ultrasound-nonvascular. Accessed February 15, 2016.
6. Afzal MZ, Saleh MM, Razvi S, Hashmi H, Lampen R. Utility of lower extremity Doppler in patients with lower extremity cellulitis: a need to change the practice? *South Med J*. 2015;108(7):439-444.
7. Goodacre S, Sutton AJ, Sampson FC. Meta-analysis: the value of clinical assessment in the diagnosis of deep venous thrombosis. *Ann Intern Med*. 2005;143(2): 129-139.
8. Maze MJ, Skea S, Pithie A, Metcalf S, Pearson JF, Chambers ST. Prevalence of concurrent deep vein thrombosis in patients with lower limb cellulitis: a prospective cohort study. *BMC Infect Dis*. 2013;13:141.
9. Bersier D, Bounameaux H. Cellulitis and deep vein thrombosis: a controversial association. *J Thromb Haemost*. 2003;1(4):867-868.
10. Anderson FA Jr, Spencer FA. Risk factors for venous thromboembolism. *Circulation*. 2003;107(23 suppl 1):I9-I16.
11. Rabuka CE, Azoulay LY, Kahn SR. Predictors of a positive duplex scan in patients with a clinical presentation compatible with deep vein thrombosis or cellulitis. *Can J Infect Dis*. 2003;14(4):210-214.
12. Samama MM. An epidemiologic study of risk factors for deep vein thrombosis in medical outpatients: the Sirius Study. *Arch Intern Med*. 2000;160(22):3415-3420.

What Are the Chances?

The approach to clinical conundrums by an expert clinician is revealed through the presentation of an actual patient's case in an approach typical of a morning report. Similarly to patient care, sequential pieces of information are provided to the clinician, who is unfamiliar with the case. The focus is on the thought processes of both the clinical team caring for the patient and the discussant.

This icon represents the patient's case. Each paragraph that follows represents the discussant's thoughts.

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Two weeks after undergoing a below-knee amputation (BKA) and 10 days after being discharged to a skilled nursing facility (SNF), an 87-year-old man returned to the emergency department (ED) for evaluation of somnolence and altered mental state. In the ED, he was disoriented and unable to provide a detailed history.

The differential diagnosis for acute confusion and altered consciousness is broad. Initial possibilities include toxic-metabolic abnormalities, medication side effects, and infections. Urinary tract infection, pneumonia, and surgical-site infection should be assessed for first, as they are common causes of postoperative altered mentation. Next to be considered are subclinical seizure, ischemic stroke, and infectious encephalitis or meningitis, along with hemorrhagic stroke and subdural hematoma.

During initial assessment, the clinician should ascertain baseline mental state, the timeline of the change in mental status, recent medication changes, history of substance abuse, and concern about any recent trauma, such as a fall. Performing the physical examination, the clinician should assess vital signs and then focus on identifying localizing neurologic deficits.

First steps in the work-up include a complete metabolic panel, complete blood cell count, urinalysis with culture, and a urine toxicology screen. If the patient has a "toxic" appearance, blood cultures should be obtained. An electrocardiogram should be used to screen for drug toxicity or evidence of cardiac ischemia. If laboratory test results do not reveal an obvious infectious or metabolic cause, a noncontrast computed tomography (CT) of the head should be obtained. In terms of early interventions, a low glucose level should be treated with thiamine and then glucose, and naloxone should be given if there is any suspicion of narcotic overdose.

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More history was obtained from the patient's records. The BKA was performed to address a nonhealing transmetatarsal amputation. Two months earlier, the transmetatarsal amputation had been performed as treatment for a diabetic forefoot ulcer with chronic osteomyelitis. The patient's post-BKA course was uncomplicated. He was started on intravenous (IV) ertapenem on postoperative day 1, and on postoperative day 4 was discharged to the SNF to complete a 6-week course of antibiotics for osteomyelitis. Past medical history included paroxysmal atrial fibrillation, coronary artery disease, congestive heart failure (ejection fraction 40%), and type 2 diabetes mellitus. Medications given at the SNF were oxycodone, acetaminophen, cholecalciferol, melatonin, digoxin, ondansetron, furosemide, gabapentin, correctional insulin, tamsulosin, senna, docusate, warfarin, and metoprolol. While there, the patient's family expressed concern about his diminishing "mental ability." They reported he had been fully alert and oriented on arrival at the SNF, and living independently with his wife before the BKA. Then, a week before the ED presentation, he started becoming more somnolent and forgetful. The gabapentin and oxycodone dosages were reduced to minimize their sedative effects, but he showed no improvement. At the SNF, a somnolence work-up was not performed.

Several of the patient's medications can contribute to altered mental state. Ertapenem can cause seizures as well as profound mental status changes, though these are more likely in the setting of poor renal function. The mental status changes were noticed about a week into the patient's course of antibiotics, which suggests a possible temporal correlation with the initiation of ertapenem. An electroencephalogram is required to diagnose nonconvulsive seizure activity. Narcotic overdose should still be considered, despite the recent reduction in oxycodone dosage. Digoxin toxicity, though less likely when the dose is stable and there are no changes in renal function, can cause a confused state. Concurrent use of furosemide could potentiate the toxic effects of digoxin.

Non-medication-related concerns include hypoglycemia, hyperglycemia, and, given his history of atrial fibrillation, cardioembolic stroke. Although generalized confusion is

not a common manifestation of stroke, a thalamic stroke can alter mental state but be easily missed if not specifically considered. Additional lab work-up should include a digoxin level and, since he is taking warfarin, a prothrombin time/international normalized ratio (PT/INR). If the initial laboratory studies and head CT do not explain the altered mental state, magnetic resonance imaging (MRI) of the brain should be performed to further assess for stroke.

On physical examination in the ED, the patient was resting comfortably with eyes closed, and arousing to voice. He obeyed commands and participated in the examination. His Glasgow Coma Scale score was 13; temperature, 36.8°C, heart rate, 80 beats per minute; respiratory rate, 16 breaths per minute; blood pressure, 90/57 mm Hg; and 100% peripheral capillary oxygen saturation while breathing ambient air. He appeared well developed. His heart rhythm was irregularly irregular, without murmurs, rubs, or gallops. Respiratory and abdominal examination findings were normal. The left BKA incision was well approximated, with no drainage, dehiscence, fluctuance, or erythema. On neurologic examination, the patient was intermittently oriented only to self. Pupils were equal, round, and reactive to light; extraocular movements were intact; face was symmetric; tongue was midline; sensation on face was equal bilaterally; and shoulder shrug was intact. Strength was 5/5 and symmetric in the elbow and hip and 5/5 in the right knee and ankle (not tested on left because of BKA). Deep tendon reflexes were 3+ and symmetrical at the biceps, brachioradialis, and triceps tendons and 3+ in the right patellar and Achilles tendons. Sensation was intact and symmetrical in the upper and lower extremities. The patient's speech was slow and slurred, and his answers were unrelated to the questions being asked.

The patient's mental state is best described as lethargic. As he is only intermittently oriented, he meets the criteria for delirium. He is not obtunded or comatose, and his pupils are at least reactive, not pinpoint, so narcotic overdose is less likely. Thalamic stroke remains in the differential diagnosis; despite the seemingly symmetrical sensation examination, hemisensory deficits cannot be definitively ruled out given the patient's mental state. A rare entity such as carcinomatosis meningitis or another diffuse, infiltrative neoplastic process could be causing his condition. However, because focal deficits other than abnormal speech and diffuse hyperreflexia are absent, toxic, infectious, or metabolic causes are more likely than structural abnormalities. Still possible is a medication toxicity, such as ertapenem toxicity or, less likely, digoxin toxicity. In terms of infectious possibilities, urinary tract infection could certainly present in this fashion, especially if the patient had a somewhat low neurologic reserve at baseline, and hypotension could be secondary to sepsis. Encephalitis or meningitis remains in the differential diagnosis, though the patient appears nontoxic, and therefore a bacterial etiology is very unlikely.

The patient's hyperreflexia may be an important clue. Although the strength of his reflexes at baseline is unknown, seizures can cause transiently increased reflexes as well as a confused, lethargic mental state. Reflexes can also be increased by a drug overdose that has caused serotonin syndrome. Of the patient's medications, only ondansetron can cause this reaction. Hyperthyroidism can cause brisk reflexes and confusion, though more typically it causes agitated confusion. A thyroid-stimulating hormone level should be added to the initial laboratory panel.

A complete blood count revealed white blood cell count 11.86 K/uL with neutrophilic predominance and immature granulocytes, hemoglobin 11.5 g/dL, and platelet count 323 K/uL. Serum sodium was 141 mEq/L, potassium 4.2 mEq/L, chloride 103 mEq/L, bicarbonate 30 mEq/L, creatinine 1.14 mg/dL (prior baseline of 0.8-1.0 mg/dL), blood urea nitrogen 26 mg/dL, blood glucose 159 mg/dL, and calcium 9.1 mg/dL. His digoxin level was 1.3 ng/mL (reference range 0.5-1.9 mg/mL) and troponin was undetectable. INR was 2.7 and partial thromboplastin time (PTT) 60 seconds. Vitamin B_{12} level was 674 pg/mL (reference range >180). A urinalysis had 1+ hyaline casts and was negative for nitrites, leukocyte esterase, blood, and bacteria. An ECG revealed atrial fibrillation with a ventricular rate of 80 beats per minute. A chest radiograph showed clear lung fields. A CT of the head without IV contrast had no evidence of an acute intracranial abnormality. In the ED, 1 liter of IV normal saline was given and blood pressure improved to 127/72 mm Hg.

The head CT does not show intracranial bleeding, and, though it is reassuring that INR is in the therapeutic range, ischemic stroke must remain in the differential diagnosis. Sepsis is less likely given that the criteria for systemic inflammatory response syndrome are not met, and hypotension was rapidly corrected with administration of IV fluids. Urinary tract infection was ruled out with the negative urinalysis. Subclinical seizures remain possible, as does medication-related or other toxicity. A medication overdose, intentional or otherwise, should also be considered.

The patient was admitted to the hospital. On reassessment by the inpatient team, he was oriented only to self, frequently falling asleep, and not recalling earlier conversations when aroused. His speech remained slurred and difficult to understand. Neurologic examination findings were unchanged since the ED examination. On additional cerebellar examination, he had dysmetria with finger-to-nose testing bilaterally and dysdiadochokinesia (impaired rapid alternating movements) of the left hand.

His handedness is not mentioned; the dysdiadochokinesia of the left hand may reflect the patient's being right-handed, or may signify a focal cerebellar lesion. The cerebellum is also implicated by the bilateral dysmetria. Persistent som-

TABLE. Naranjo Adverse Drug Reaction Questionnaire

Questions	Yes	No	Don't Know
1. Are there previous conclusive reports on this reaction?	+1	0	0
2. Did the adverse events appear after the suspected drug was given?	+2	-1	0
3. Did the adverse reaction improve when the drug was discontinued or a specific antagonist was given?	+1	0	0
4. Did the adverse reaction reappear when the drug was readministered?	+2	-1	0
5. Are there alternative causes that could have caused the reaction?	-1	+2	0
6. Did the reaction reappear when a placebo was given?	-1	+1	0
7. Was the drug detected in any body fluid in toxic concentrations?	+1	0	0
8. Was the reaction more severe when the dose was increased, or less severe when the dose was decreased?	+1	0	0
9. Did the patient have a similar reaction to the same or similar drugs in any previous exposure?	+1	0	0
10. Was the adverse event confirmed by any objective evidence?	+1	0	0

Score: ≥9, definite; 5-8, probable; 1-4, possible; ≤0, doubtful.

nolence in the absence of CT findings suggests a metabolic or infectious process. Metabolic processes that can cause bilateral cerebellar ataxia and somnolence include overdose of a drug or medication. Use of alcohol or a medication such as phenytoin, valproic acid, or a benzodiazepine can cause the symptoms in this case, but was not reported by the family, and there was no documentation of it in the SNF records. Wernicke encephalopathy is rare and is not well supported by the patient's presentation but should be considered, as it can be easily treated with thiamine. Meningoencephalitis affecting the cerebellum remains possible, but infection is less likely. Both electroencephalogram and brain MRI should be performed, with a specific interest in possible cerebellar lesions. If the MRI is unremarkable, a lumbar puncture should be performed to assess opening pressure and investigate for infectious etiologies.

MRI of the brain showed age-related volume loss and nonspecific white matter disease without acute changes. Lack of a clear explanation for the neurologic findings led to suspicion of a medication side effect. Ertapenem was stopped on admission because it has been reported to rarely cause altered mental status. IV moxifloxacin was started for the osteomyelitis. Over the next 2 days, symptoms began resolving; within 24 hours of ertapenem discontinuation, the patient was awake, alert, and talkative. On examination, he remained dysarthric but was no longer dysmetric. Within 48 hours, the dysarthria was completely resolved, and he was returned to the SNF to complete a course of IV moxifloxacin.

DISCUSSION

Among elderly patients presenting to the ED, altered mental status is a common complaint, accounting for 10% to 30% of visits.[1] Medications are a common cause of altered mental status among the elderly and are responsible for 40% of delirium cases.[1] The risk of adverse drug events (ADEs) rises with the number of medications prescribed.[1-3] Among patients older than 60 years, the incidence of polypharmacy (defined as taking >5 prescription medications) increased from roughly 20% in 1999 to 40% in 2012.[4,5] The most common ADEs in the ambulatory setting (25%) are central nervous system (CNS) symptoms, including dizziness, sleep disturbances, and mood changes.[6] A medication effect should be suspected in any elderly patient presenting with altered mental state.

The present patient developed a constellation of neurologic symptoms after starting ertapenem, one of the carbapenem antibiotics, which is a class of medications that can cause CNS ADEs. Carbapenems are renally cleared, and adjustments must be made for acute or chronic changes in kidney function. Carbapenems are associated with increased risk of seizure; the incidence of seizure with ertapenem is 0.2%.[7,8] Food and Drug Administration postmarketing reports have noted ertapenem can cause somnolence and dyskinesia,[9] and several case reports have described ertapenem-associated CNS side effects, including psychosis and encephalopathy.[10-13] Symptoms and examination findings can include confusion, disorientation, garbled speech, dysphagia, hallucinations, miosis, myoclonus, tremor, and agitation.[10-13] Although reports of dysmetria and dysdiadochokinesia are lacking, suspicion of an ADE in this case was heightened by the timing of the exposure and the absence of alternative infectious, metabolic, and vascular explanations for bilateral cerebellar dysfunction.

The Naranjo Adverse Drug Reaction (ADR) scale may help clinicians differentiate ADEs from other etiologies of symptoms. It uses 10 weighted questions (Table) to estimate the probability that an adverse clinical event is caused by a drug reaction.[14] The present case was assigned 1 point for prior reports of neurologic ADEs associated with ertapenem, 2 for the temporal association, 1 for resolution after medication withdrawal, 2 for lack of alternative causes, and 1 for objective evidence of neurologic dysfunction—for a total of 7

points, indicating ertapenem was probably the cause of the patient's neurologic symptoms. Of 4 prior cases in which carbapenem toxicity was suspected and the Naranjo scale was used, 3 found a probable relationship, and the fourth a highly probable one.[10,12] Confusion, disorientation, hallucinations, tangential thoughts, and garbled speech were reported in the 3 probable cases of ADEs. In the highly probable case, tangential thoughts, garbled speech, and miosis were noted on examination, and these findings returned after re-exposure to ertapenem. Of note, these ADEs occurred in patients with normal and abnormal renal function, and in middle-aged and elderly patients.[10,11,13]

Most medications have a long list of low-frequency and rarely reported adverse effects. The present case reminds clinicians to consider rare adverse effects, or variants of previously reported adverse effects, in a patient with unexplained symptoms. To estimate the probability that a drug is causing harm to a patient, using a validated tool such as the Naranjo scale helps answer the question, *What are the chances?*

KEY TEACHING POINTS

- Clinicians should include rare adverse effects of common medications in the differential diagnosis.
- The Naranjo score is a validated tool that can be used to systematically assess the probability of an adverse drug effect at the bedside.
- The presentation of ertapenem-associated neurotoxicity may include features of bilateral cerebellar dysfunction.

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References

1. Inouye SK, Fearing MA, Marcantonio ER. Delirium. In: Halter JB, Ouslander JG, Tinetti ME, Studenski S, High KP, Asthana S, eds. *Hazzard's Geriatric Medicine and Gerontology*. 6th ed. New York, NY: McGraw-Hill; 2009.
2. Sarkar U, López A, Maselli JH, Gonzales R. Adverse drug events in U.S. adult ambulatory medical care. *Health Serv Res*. 2011;46(5):1517-1533.
3. Chrischilles E, Rubenstein L, Van Gilder R, Voelker M, Wright K, Wallace R. Risk factors for adverse drug events in older adults with mobility limitations in the community setting. *J Am Geriatr Soc*. 2007;55(1):29-34.
4. Kaufman DW, Kelly JP, Rosenberg L, Anderson TE, Mitchell AA. Recent patterns of medication use in the ambulatory adult population of the United States: the Slone survey. *JAMA*. 2002;287(3):337-344.
5. Kantor ED, Rehm CD, Haas JS, Chan AT, Giovannucci EL. Trends in prescription drug use among adults in the United States from 1999-2012. *JAMA*. 2015;314(17):1818-1831.
6. Thomsen LA, Winterstein AG, Søndergaard B, Haugbølle LS, Melander A. Systematic review of the incidence and characteristics of preventable adverse drug events in ambulatory care. *Ann Pharmacother*. 2007;41(9):1411-1426.
7. Zhanel GG, Wiebe R, Dilay L, et al. Comparative review of the carbapenems. *Drugs*. 2007;67(7):1027-1052.
8. Cannon JP, Lee TA, Clark NM, Setlak P, Grim SA. The risk of seizures among the carbapenems: a meta-analysis. *J Antimicrob Chemother*. 2014;69(8):2043-2055.
9. US Food and Drug Administration. Invanz (ertapenem) injection [safety information]. http://www.fda.gov/Safety/MedWatch/SafetyInformation/ucm196605.htm. Published July 2013. Accessed July 6, 2015.
10. Oo Y, Packham D, Yau W, Munckhof WJ. Ertapenem-associated psychosis and encephalopathy. *Intern Med J*. 2014;44(8):817-819.
11. Wen MJ, Sung CC, Chau T, Lin SH. Acute prolonged neurotoxicity associated with recommended doses of ertapenem in 2 patients with advanced renal failure. *Clin Nephrol*. 2013;80(6):474-478.
12. Duquaine S, Kitchell E, Tate T, Tannen RC, Wickremasinghe IM. Central nervous system toxicity associated with ertapenem use. *Ann Pharmacother*. 2011;45(1):e6.
13. Kong V, Beckert L, Awunor-Renner C. A case of beta lactam-induced visual hallucination. *N Z Med J*. 2009;122(1298):76-77.
14. Naranjo CA, Busto U, Sellers EM, et al. A method for estimating the probability of adverse drug reactions. *Clin Pharmacol Ther*. 1981;30(2):239-245.

Safe and Effective Bedside Thoracentesis: A Review of the Evidence for Practicing Clinicians

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BACKGROUND: Physicians often care for patients with pleural effusion, a condition that requires thoracentesis for evaluation and treatment. We aim to identify the most recent advances related to safe and effective performance of thoracentesis.

METHODS: We performed a narrative review with a systematic search of the literature. Two authors independently reviewed search results and selected studies based on relevance to thoracentesis; disagreements were resolved by consensus. Articles were categorized as those related to the pre-, intra- and postprocedural aspects of thoracentesis.

RESULTS: Sixty relevant studies were identified and included. Pre-procedural topics included methods for physician training and maintenance of skills, such as simulation with direct observation. Additionally, pre-procedural topics included the finding that moderate coagulopathies (international normalized ratio less than 3 or a platelet count greater than 25,000/μL) and mechanical ventilation did not increase risk of postprocedural complications. Intraprocedurally, ultrasound use was associated with lower risk of pneumothorax, while pleural manometry can identify a nonexpanding lung and may help reduce risk of re-expansion pulmonary edema. Postprocedurally, studies indicate that routine chest X-ray is unwarranted, because bedside ultrasound can identify pneumothorax.

CONCLUSIONS: While the performance of thoracentesis is not without risk, clinicians can incorporate recent advances into practice to mitigate patient harm and improve effectiveness. *Journal of Hospital Medicine* 2017;12:266-276.

Pleural effusion can occur in myriad conditions including infection, heart failure, liver disease, and cancer.[1] Consequently, physicians from many disciplines routinely encounter both inpatients and outpatients with this diagnosis. Often, evaluation and treatment require thoracentesis to obtain fluid for analysis or symptom relief.

Although historically performed at the bedside without imaging guidance or intraprocedural monitoring, thoracentesis performed in this fashion carries considerable risk of complications. In fact, it has 1 of the highest rates of iatrogenic pneumothorax among bedside procedures.[2] However, recent advances in practice and adoption of newer technologies have helped to mitigate risks associated with this procedure. These advances are relevant because approximately 50% of thoracenteses are still performed at the bedside.[3] In this review, we aim to identify the most recent key practices that enhance the safety and the effectiveness of thoracentesis for practicing clinicians.

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METHODS

Information Sources and Search Strategy

With the assistance of a research librarian, we performed a systematic search of PubMed-indexed articles from January 1, 2000 to September 30, 2015. Articles were identified using search terms such as *thoracentesis*, *pleural effusion*, *safety*, *medical error*, *adverse event*, and *ultrasound* in combination with Boolean operators. Of note, as *thoracentesis* is indexed as a subgroup of *paracentesis* in PubMed, this term was also included to increase the sensitivity of the search. The full search strategy is available in the Appendix. Any references cited in this review outside of the date range of our search are provided only to give relevant background information or establish the origin of commonly performed practices.

Study Eligibility and Selection Criteria

Studies were included if they reported clinical aspects related to thoracentesis. We defined clinical aspects as those strategies that focused on operator training, procedural techniques, technology, management, or prevention of complications. Non-English language articles, animal studies, case reports, conference proceedings, and abstracts were excluded. As our intention was to focus on the contemporary advances related to thoracentesis performance, (eg, ultrasound [US]), our search was limited to studies published after the year 2000. Two authors, Drs. Schildhouse and Lai independently screened studies to determine inclusion, excluding studies with weak methodology, very small sample sizes, and those

only tangentially related to our aim. Disagreements regarding study inclusion were resolved by consensus. Drs. Lai, Barsuk, and Mourad identified additional studies by hand review of reference lists and content experts (Figure 1).

Conceptual Framework

All selected articles were categorized by temporal relationship to thoracentesis as pre-, intra-, or postprocedure. Pre-procedural topics were those outcomes that had been identified and addressed before attempting thoracentesis, such as physician training or perceived risks of harm. Intraprocedural considerations included aspects such as use of bedside US, pleural manometry, and large-volume drainage. Finally, postprocedural factors were those related to evaluation after thoracentesis, such as follow-up imaging. This conceptual framework is outlined in Figure 2.

RESULTS

The PubMed search returned a total of 1170 manuscripts, of which 56 articles met inclusion criteria. Four additional articles were identified by experts and included in the study.[4-7] Therefore, 60 articles were identified and included in this review. Study designs included cohort studies, case control studies, systematic reviews, meta-analyses, narrative reviews, consensus guidelines, and randomized controlled trials. A summary of all included articles by topic can be found in the Table.

PRE-PROCEDURAL CONSIDERATIONS

Physician Training

Studies indicate that graduate medical education may not adequately prepare clinicians to perform thoracentesis.[8] In

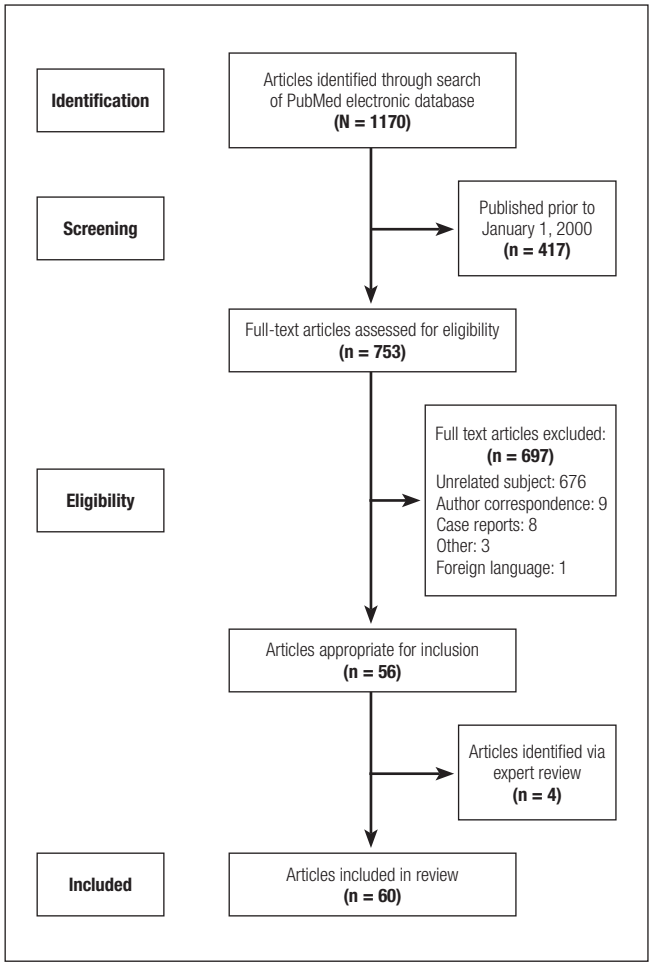

FIG. 1. Study eligibility and selection criteria.

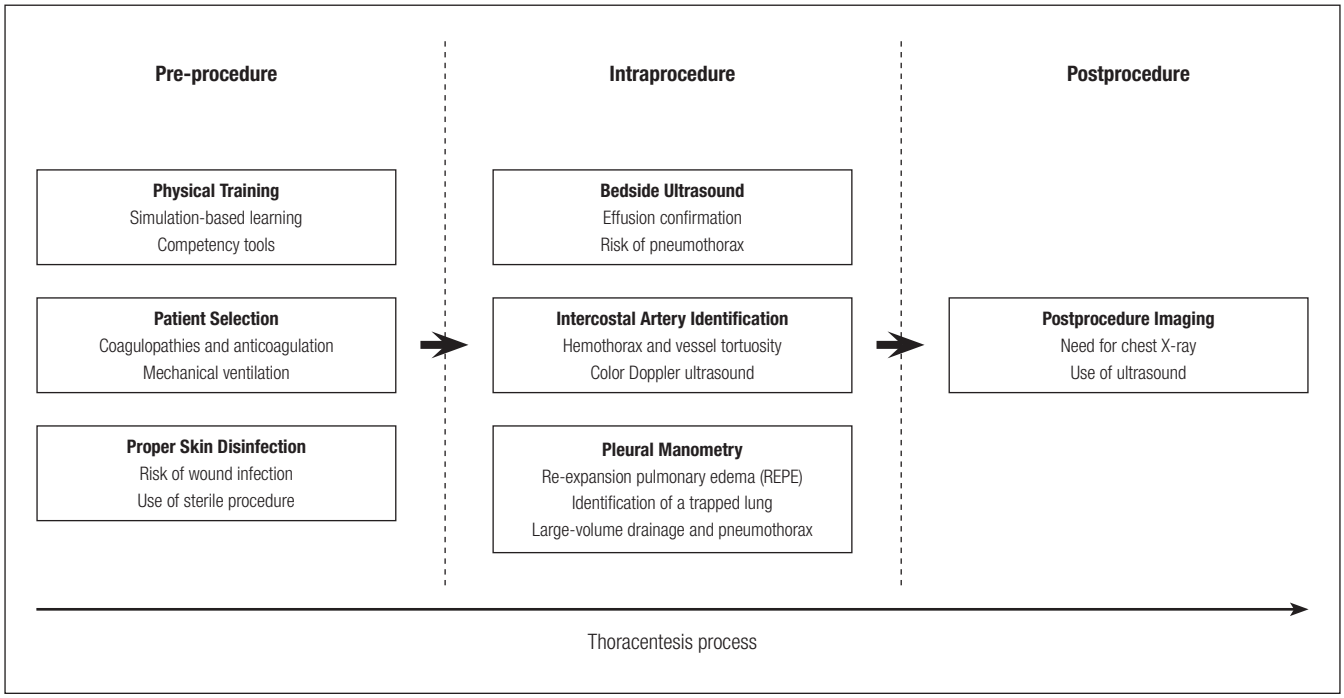

FIG. 2. Conceptual framework.

fact, residents have the least exposure and confidence in performing thoracentesis when compared to other bedside procedures.[9,10] In 1 survey, 69% of medical trainees desired more exposure to procedures, and 98% felt that procedural skills were important to master.[11] Not surprisingly, then, graduating internal medicine residents perform poorly when assessed on a thoracentesis simulator.[12]

Supplemental training outside of residency is useful to develop and maintain skills for thoracentesis, such as simulation with direct observation in a zero-risk environment. In 1 study, "simulation-based mastery learning" combined an educational video presentation with repeated, deliberate practice on a simulator until procedural competence was acquired, over two 2-hour sessions. In this study, 40 third-year medicine residents demonstrated a 71% improvement in clinical skills performance after course completion, with 93% achieving a passing score. The remaining 7% also achieved passing scores with extra practice time.[12] Others have built upon the concept of simulation-based training. For instance, 2 studies suggest that use of a simulation-based curriculum improved both thoracentesis knowledge and performance skills in a 3-hour session.[13,14] Similarly, 1 prospective study reported that a half-day thoracentesis workshop using simulation and 1:1 direct observation successfully lowered pneumothorax rates from 8.6% to 1.8% in a group of practicing clinicians. Notably, additional interventions including use of bedside US, limiting operators to a focused group, and standardization of equipment were also a part of this quality improvement initiative.[7] Although repetition is required to gain proficiency when using a simulator, performance and confidence appear to plateau with only 4 simulator trials. In medical students, improvements derived through simulator-based teaching were sustained when retested 6 months following training.[15]

An instrument to ensure competency is necessary, given variability in procedural experience among both new graduates and practicing physicians,. Our search did not identify any clinically validated tools that adequately assessed thoracentesis performance. However, some have been proposed[16] and 1 validated in a simulation environment.[12] Regarding the incorporation of US for effusion markup, 1 validated tool used an 11-domain assessment covering knowledge of US machine manipulation, recognition of images with common pleural effusion characteristics, and performance of thoracic US with puncture-site marking on a simulator. When used on 22 participants, scores with the tool could reliably differentiate between novice, intermediate, and advanced groups ($P < 0.0001$).[17]

Patient Selection

Coagulopathies and Anticoagulation. Historically, the accepted cutoff for performing thoracentesis is an international normalized ratio (INR) less than 1.5 and a platelet count greater than 50,000/μL. McVay et al.[18] first showed in 1991 that use of these cutoffs was associated with low rates of periprocedural bleeding, leading to endorsement in the British Thoracic Society (BTS) Pleural Disease Guideline 2010.[19] Other recommendations include the 2012 Society for Interventional Radiology guidelines that endorse correction of an INR greater than 2, or platelets less than 50,000/μL, based almost exclusively on expert opinion.[5]

However, data suggest that thoracentesis may be safely performed outside these parameters. For instance, a prospective study of approximately 9000 thoracenteses over 12 years found that patients with an INR of 1.5-2.9 or platelets of 20,000 - 49,000/μL experienced rates of bleeding complications similar to those with normal values.[20] Similarly, a 2014 review[21] found that the overall risk of hemorrhage during thoracentesis in the setting of moderate coagulopathy (defined as an INR of 1.5 - 3 or platelets of 25,000-50,000/μL), was not increased. In 1 retrospective study of more than 1000 procedures, no differences in hemorrhagic events were noted in patients with bleeding diatheses that received prophylactic fresh frozen plasma or platelets vs. those who did not.[22] Of note, included studies used a variety of criteria to define a hemorrhagic complication, which included: an isolated 2 g/dL or more decrement in hemoglobin, presence of bloody fluid on repeat tap with associated hemoglobin decrement, rapid re-accumulation of fluid with a hemoglobin decrement, or transfusion of 2 units or more of whole blood.

Whether it is safe to perform thoracentesis on patients taking antiplatelet therapy is less well understood. Although data are limited, a few small-scale studies[23,24] suggest that hemorrhagic complications following thoracentesis in patients receiving clopidogrel are comparable to the general population. We found no compelling data regarding the safety of thoracentesis in the setting of direct oral anticoagulants, heparin, low-molecular weight heparin, or intravenous direct thrombin inhibitors. Current practice is to generally avoid thoracentesis while these therapeutic anticoagulants are used.

Invasive mechanical ventilation. Pleural effusion is common in patients in the intensive care unit, including those requiring mechanical ventilation.[25] Thoracentesis in this population is clinically important: fluid analysis in 1 study was shown to aid the diagnosis in 45% of cases and changes in treatment in 33%.[26] However, clinicians may be reluctant to perform thoracentesis on patients who require mechanical ventilation, given the perception of a greater risk of pneumothorax from positive pressure ventilation.

Despite this concern, a 2011 meta-analysis including 19 studies and more than 1100 patients revealed rates of pneumothorax and hemothorax comparable to nonventilated patients.[25] Furthermore, a 2015 prospective study that examined thoracentesis in 1377 mechanically ventilated patients revealed no difference in complication rates as well.[20] Therefore, evidence suggests that performance of thoracentesis in mechanically ventilated patients is not contraindicated.

Skin Disinfection and Antisepsis Precautions

The 2010 BTS guidelines list empyema and wound infection as possible complications of thoracentesis.[19] However, no

data regarding incidence are provided. Additionally, an alcohol-based skin cleanser (such as 2% chlorhexidine gluconate/70% isopropyl alcohol), along with sterile gloves, field, and dressing are suggested as precautionary measures.[19] In 1 single-center registry of 2489 thoracenteses performed using alcohol or iodine-based antiseptic and sterile drapes, no postprocedure infections were identified.[27] Of note, we did not find other studies (including case reports) that reported either incidence or rate of infectious complications such as wound infection and empyema. In an era of modern skin antiseptics that have effectively reduced complications such as catheter-related bloodstream infection,[28] the incidence of this event is thus likely to be low.

INTRAPROCEDURAL CONSIDERATIONS

Use of Bedside Ultrasound

Portable US has particular advantages for evaluation of pleural effusion vs other imaging modalities. Compared with computerized tomography (CT), bedside US offers similar performance but is less costly, avoids both radiation exposure and need for patient transportation, and provides results instantaneously.[29,30] Compared to chest x-ray (CXR), US is more sensitive at detecting the presence, volume, and characteristics of pleural fluid[30,31] and can be up to 100% sensitive for effusions greater than 100 mL.[29] Furthermore, whereas CXR typically requires 200 mL of fluid to be present for detection of an effusion, US can reliably detect as little as 20 mL of fluid.[29] When US was used to confirm thoracentesis puncture sites in a study involving 30 physicians of varying experience and 67 consecutive patients, 15% of sites found by clinical exam were inaccurate (less than 10 mm fluid present), 10% were at high risk for organ puncture, and a suitable fluid pocket was found 54% of times when exam could not.[4]

A 2010 meta-analysis of 24 studies and 6605 thoracenteses estimated the overall rate of pneumothorax at 6%; however, procedures performed with US guidance were associated with a 70% reduced risk of this event (odds ratio, 0.30; 95% confidence interval, 0.20 - 0.70).[32] In a 2014 randomized control trial of 160 patients that compared thoracentesis with US guidance for site marking vs no US use, 10 pneumothoraces occurred in the control group vs 1 in the US group (12.5% vs 1.25%, $P = 0.009$).[33] Similarly, another retrospective review of 445 consecutive patients with malignant effusions revealed a pneumothorax rate of 0.97% using US in real time during needle insertion compared to 8.89% for unguided thoracenteses ($P < 0.0001$).[34] Several other studies using US guidance for either site markup or in real time reported similar pneumothorax rates, ranging from 1.1% - 4.8%.[35-37] However, it is unclear if real-time US specifically provides an additive effect vs site marking alone, as no studies directly comparing the 2 methods were found.

Benefits of US also include a higher rate of procedural success, with 1 study demonstrating a 99% success rate when using US vs. 90% without ($P = 0.030$).[33] A larger volume of fluid removed has been observed with US use as well, and methods have been described using fluid-pocket depth to guide puncture site localization and maximize drainage.[38] Finally, US use for thoracentesis has been associated with lower costs and length of stay.[39,40]

Intercostal Artery Localization

Although rare (incidence, 0.18%-2%[20,21,39]), the occurrence of hemothorax following thoracentesis is potentially catastrophic. This serious complication is often caused by laceration of the intercostal artery (ICA) or 1 of its branches during needle insertion.[41]

While risk of injury is theoretically reduced by needle insertion superior to the rib, studies using cadaver dissection and 3D angiography show significant tortuosity of the ICA.[6,41-43] The degree of tortuosity is increased within 6 cm of the midline, in more cephalad rib spaces, and in the elderly (older than 60 years).[41-43] Furthermore, 1 cadaveric study also demonstrated the presence of arterial collaterals branching off the ICA at multiple intercostal spaces, ranging between 8 cm and 11 cm from the midline.[41] This anatomic variability may explain why some have observed low complication and hemothorax rates with an extreme lateral approach.[35] Bedside US with color flow Doppler imaging has been used to identify the ICA, with 88% sensitivity compared to CT imaging while adding little to exam time.[44,45] Of note, a 37% drop in the rate of hemothorax was observed in 1 study with routine US guidance alone.[39]

Pleural Pressure Monitoring and Large-Volume Thoracentesis

While normal intrapleural pressures are approximately -5 to -10 cm H_2O,[46] the presence of a pleural effusion creates a complex interaction between fluid, compressed lung, and chest wall that can increase these pressures.[47] During drainage of an effusion, pleural pressures may rapidly drop, provoking re-expansion pulmonary edema (REPE). While rare (0 -1%), clinically-diagnosed REPE is a serious complication that can lead to rapid respiratory failure and death.[20,48] REPE is postulated to be caused by increased capillary permeability resulting from inflammation, driven by rapid re-inflation of the lung when exposed to highly negative intrapleural pressures.[47,49]

Measurement of intrapleural pressure using a water manometer during thoracentesis may minimize REPE by terminating fluid drainage when intrapleural pressure begins to drop rapidly.[50,51] A cutoff of -20 cm H_2O has been cited repeatedly as safe since being suggested by Light in 1980, but this is based on animal models.[50,52] In 1 prospective study of 185 thoracenteses in which manometry was performed, 15% of patients had intrapleural pressure drop to less than -20 cm H_2O (at which point the procedure was terminated) but suffered no REPE.[50]

Manometry is valuable in the identification of an unexpandable or trapped lung when pleural pressures drop rapidly with only minimal fluid volume removal.[47,53] Other findings

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TABLE. Summary of Studies in Review, Organized by Topic

Topic	Author (Year)	Study Design	Participants (n)	Study Description or Intervention	Results and Authors' Conclusions
Physician training	Grover S, et al (2009)[8]	Cohort survey	188 IM residents	Assess resident knowledge of 3 core medical procedures; 32-item multiple choice test developed and given to students, residents, and clinicians	The instrument was reliable ($\alpha = 0.79$); resident median score was 53%; overall knowledge of procedures was poor
	Promes S, et al (2009)[9]	Cohort survey	256 1st y IM residents at 3 training sites	Self-reported survey to evaluate attitudes, competency, and exposure to common medical procedures in medical school	New medical interns report having the least experience and confidence with thoracentesis of all procedures
	Huang G, et al (2006)[10]	Prospective cohort	106 IM residents	Residents logged procedures performed, answering questions evaluating their comfort with 9 aspects of 4 medical procedures	Many residents are uncomfortable performing bedside procedures, especially when unsupervised (37%); thoracentesis associated with less comfort (OR, 0.40; CI, 0.20-0.80)
	Lagan J, et al (2015)[11]	Online survey	156 medical trainees	Online survey given to trainees regarding attitudes and experience related to medicine procedures	Majority of trainees felt procedures were important and wanted more exposure; trainees did not feel competent in independent US use; thoracentesis confidence positively correlated with exposure ($P < 0.003$).
	Wayne D, et al (2008)[12]	Pretest-posttest design with no control	40 3rd y IM residents	Baseline knowledge and skills assessment followed by video instruction and deliberate practice on thoracentesis simulator until competence attained	Simulation with deliberate practice led to a 71% improvement in clinical skills exam, with 100% reaching the mastery standard; amount of practice time required was a negative predictor of posttest performance
	Lenchus J (2010)[13]	Case cohort before and after	56 residents and 4 medical students	Procedural instruction curriculum (including thoracentesis) and pilot developed consisting of instruction with videos, simulation, and deliberate practice; knowledge, and skills assessed before and after	Standardized course resulted in significantly increased knowledge scores for all procedures ($P < 0.001$), along with increased technical skills rated on first patient performance ($P < 0.001$)
	Lenchus J, et al (2011)[14]	Case cohort before and after	85 IM residents	Residents completed 4 wk multimodal procedure course including simulation; assessed with a knowledge and skills test before and after	All participants demonstrated an improvement in medical knowledge and technical skills ($P < 0.05$); a blended, standardized procedure curriculum has potential to address shortcomings of traditional training
	Duncan D, et al (2009)[7]	Prospective cohort	244 procedures	Institution of a training system to reduce pneumothorax rate including focused group of operators, ultrasound, and standardization of methods and equipment	Institution of improvement program with simulation and US reduced rates of pneumothorax from 8.6% to 1.1% ($P = 0.0034$); effect sustained for 2 y
	Jiang G, et al (2011)[15]	Case cohort before and after	52 medical students	Students performed repeated trials on a thoracentesis simulator, and performance was recorded	Performance score, time, and confidence were maximized after trial number 4 ($P < 0.05$); effect persisted at 6 mo on retest and 12 mo on first live patient
	Berg D, et al (2013)[16]	NA	8 physician experts	Checklist developed to aid in the standardization of thoracentesis training and competence evaluation	Developed a 23-point checklist with a high level of agreement between experts ($\alpha = 0.94$); requires implementation for validation in simulation and clinical environment
	Salamonsen M, et al (2013)[17]	NA	22 trainees	11-domain, 100-point scoring tool developed to gauge thoracic US competence; used to score participant performance on simulator	The tool reliably predicted experience level (novice, intermediate, expert) regarding thoracic US use and effusion markup ($P < 0.0001$); can be used to document adequacy of US training
Coagulopathies and anticoagulation	Havelock T, et al (2010)[19]	Consensus guidelines	NA	Literature review and expert opinion regarding the preparation, technique, and complications related to bedside thoracentesis	Thoracentesis can be safely performed in most patients with INR <1.5 and platelets >50,000/μL, US guidance is recommended; routine postprocedure chest X-ray (CXR) not indicated unless concern for complication
	Patel I, et al (2012)[5]	Consensus guidelines	NA	Literature review and expert opinion used to determine best practices related to the hematologic management of patients undergoing percutaneous interventions	Thoracentesis is a low-risk bleeding procedure; recommend performance if INR <2.0 and platelets >50,000/μL; benefit of prophylactic transfusion unclear and risk/benefit should be weighed by physician
	Ault M, et al 2015)[20]	Prospective cohort	9320 thoracenteses	To evaluate specific demographic and clinical factors that have been associated with complications of thoracentesis	Low rate of complications with experienced operator; no increase in risk with moderate coagulopathy ($P = 0.97$ INR category, $P = 0.55$ platelet category); risk factors for complications included >1 needle pass ($P = 0.002$) and >1.5L fluid removed ($P = 0.0001$)
	Puchalski J (2014)[21]	Literature review	8 studies, 2600 procedures	Review of the literature regarding the risk of bleeding complications after thoracentesis in patients with baseline coagulopathy and the practice of prophylactic reversal	Thoracentesis appears to be safe to perform despite significant coagulation abnormalities (INR <3, platelets >25,000/μL); prophylactic reversal of coagulation abnormalities not beneficial
	Hibbert R, et al (2013)[22]	Retrospective chart review	1009 procedures	Chart review of US-guided thoracenteses done with INR >1.6 or platelets <50,000/μL; patients separated by whether or not coagulopathy corrected prior with blood products	Despite the presence of coagulopathy, the risk of hemorrhagic complication is very low (0.40%; CI 0.15%-1.02%); prophylactic transfusion of blood products did not alter this risk
	Zalt M, et al (2012)[23]	Prospective cohort	30 patients, 45 thoracenteses	US-guided thoracentesis performed in patients on clopidogrel with symptomatic effusion, assessed for bleeding complications postprocedure	No clinically significant bleeding complications observed; unnecessary to hold clopidogrel before US-guided thoracentesis for symptomatic effusion as bleeding risk is low; larger studies required to confirm results
	Mahmood K, et al (2014)[24]	Prospective cohort with control group	75 patients	25 patients underwent US-guided percutaneous pleural intervention without cessation of clopidogrel; bleeding rates compared with control group	1 patient on clopidogrel developed a hemothorax requiring transfusion (overall rate, 4%); clinically significant bleeding risk is low and comparable to control group ($P = 0.15$)

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TABLE. Summary of Studies in Review, Organized by Topic (continued)

Topic	Author (Year)	Study Design	Participants (n)	Study Description or Intervention	Results and Authors' Conclusions
Invasive mechanical ventilation	Goligher E, et al (2011)[25]	Systematic review and meta-analysis	19 studies, 1124 thoracenteses	Review of studies relevant to the utility and safety of draining pleural effusions in patients on mechanical ventilation	Rates of pneumothorax (3.4%; CI, 1.7-6.5%) and hemothorax (1.6%; CI, 0.8-3.3%) were low; drainage of pleural effusions in mechanically ventilated patients is safe and appears to improve oxygenation
	Fartoukh M, et al (2002)[26]	Prospective cohort	113 patients, 68 on mechanical ventilation	MICU patients with effusion underwent thoracentesis; clinicians queried on both pre- and post-tap diagnosis	8.4% of MICU patients had an effusion; thoracentesis aided treatment in 56% of cases and altered the final diagnosis in 45% of cases; pneumothorax noted in 6 patients (7%)
Skin disinfection and antisepsis precautions	Cervini P, et al (2010)[27]	Retrospective chart review	2489 thoracenteses	Chart review of patients who underwent US-guided thoracentesis to evaluate for infectious complications and determine infection rate	US-guided thoracentesis confers an extremely low risk of infectious complication when aseptic technique is used; no infections were observed
Use of bedside ultrasound	Soni N, et al (2015)[29]	Literature review	NA	Review of the literature related to the use of point-of-care US to evaluate and mange pleural effusions	Regarding pleural effusion characterization US performs similarly to CT and is more sensitive than CXR; US guidance reduces thoracentesis complications and increases success rates
	Feller-Kopman D (2006)[30]	Literature review	NA	Review of the basic techniques of bedside US related to evaluation of pleural disease and performance of thoracentesis	US guidance improves patient outcomes by reducing the risk of complication, and is especially helpful in the setting of small effusions and mechanical ventilation
	Shojaee S and Argento A (2014)[31]	Literature review	NA	Literature reviewed pertaining to basic US physiology, common thoracic exam findings, and utility related to pleural access	Bedside US during thoracentesis is recommended because it provides immediate results, improved site selection, fewer complications, and high accuracy even when done by trainees
	Diacon A, et al (2003)[4]	Prospective comparative	67 consecutive patients	To assess the value of thoracentesis puncture sites identified by clinical examination alone; clinician-proposed locations were evaluated for accuracy against thoracic US	US found that 15% of clinician exam-proposed puncture sites to be inaccurate (<10 mm fluid depth) with 10% of sites overlying solid organs; US able to identify accurate pocket in 54% of cases where exam could not; US increases procedure yield and potentially reduces complications
	Gordon C, et al (2010)[32]	Systematic review and meta-analysis	24 studies, 6605 thoracenteses	Literature reviewed to determine the baseline rate of pneumothorax related to thoracentesis and identify influencing factors	Overall calculated risk of pneumothorax was 6% (95% CI, 4.6%-7.8%); US guidance associated with lower risk (OR, 0.3; CI, 0.2-0.7); factors increasing this risk were therapeutic indication (OR, 2.6; CI, 1.8-3.8) and periprocedural symptoms (OR, 26.6; CI, 2.7-262.5)
	Perazzo A, et al (2014)[33]	Randomized control trial	160 patients	Patients randomized to thoracentesis with or without US use prior to identifying fluid pocket; measured rate of procedure success, fluid yield, and pneumothorax	Use of US prior to thoracentesis resulted in a significantly lower rate of pneumothorax (1.25% vs 12.5%, $P = 0.009$), higher procedure success (99% vs 90%, $P = 0.03$) and higher fluid yield ($P > 0.014$)
	Cavanna L, et al (2014)[34]	Retrospective chart review	445 patients with malignant pleural effusions	Chart review of patients status post-thoracentesis with or without real-time US guidance; procedure success, yield, and complication rates compared	US guidance used in 310 (69%) thoracenteses; use of real-time US guidance during thoracentesis for malignant effusions resulted in drastically lower pneumothorax rates (0.89% vs 8.89%, $P = 0.0001$)
	Soldati G, et al (2013)[35]	Prospective cohort	106 patients, 131 procedures	Evaluate efficacy and safety of thoracentesis or pigtail catheter placement in the supine or lateral recumbent position under real-time US guidance	97% of all procedures successful; pneumothorax rate was 1.4% with no bleeding complications observed; pleural procedures in the supine or lateral recumbent positions are safe, comfortable, and conducive to real-time US guidance
	Pihlajamaa K, et al (2004)[36]	Retrospective chart review	212 patients, 264 thoracenteses	Chart review performed to determine the incidence of pneumothorax and contributing variables after US-guided thoracentesis	Post-thoracentesis pneumothorax rates were low (4.2%) with no increase in risk in mechanical ventilation or based on operator experience; recommend against routine CXR postprocedure
	Barnes T, et al (2005)[37]	Retrospective chart review	450 thoracenteses	Charts reviewed of all thoracenteses performed over 1-year period, assessing for use of US and relation to pneumothorax rates	Use of US prior to thoracentesis resulted in a significantly lower rate of pneumothorax (4.9% vs 10.3%, $P < 0.05$); recommend US use be considered in all patients
	Hooper C, et al (2015)[3]	Retrospective review	1252 thoracenteses	British Thoracic Society pleural procedures audit of 90 hospitals over a 2-mo period outlining complication rates, consent rates, and use of bedside US	Rates of pneumothorax (1.3%) and hemothorax (1.1%) are low; use of US guidance is rising since 2010 (69% vs 52%); 50% of thoracenteses are still performed at bedside
	Zanforlin A, et al (2013)[38]	Prospective cohort	45 thoracenteses	Assessment of safety and efficacy of thoracentesis performed over the area of effusion with maximum depth between lung and diaphragm as identified on bedside US ("V-point")	The "V point" is an easy-to-identify US landmark that provides a safe area for needle puncture; no pneumothoraces observed; measurement of maximum pocket depth provides a rough estimation of effusion volume
	Patel P, et al (2012)[39]	Retrospective chart review	19,339 thoracenteses	Premier hospital database queried for thoracenteses performed over 1-y period; cost analysis performed to determine if use of US led to a change in outcomes and cost	US guidance was used in 46% of thoracenteses; associated with a decrease in pneumothorax of 16.3% (OR, 0.837; CI, 0.73-0.96, $P = 0.014$) and hemothorax by 38.7% (OR, 0.613; CI, 0.36-1.04; $P = 0.071$); US use was associated with a lower cost of hospitalization ($P < 0.0001$) and shorter length of stay ($P < 0.0001$)
	Mercaldi C and Lanes S (2013)[40]	Retrospective chart review	61,261 thoracenteses	Claims data reviewed over 2-y period on thoracenteses with analysis of US use, pneumothorax, length of stay, and hospitalization cost	Use of US during thoracentesis resulted in a reduction in pneumothorax by 19% (OR, 0.81; CI, 0.74-0.90); pneumothorax occurrence found to increase hospital cost by $2801 ($P < 0.001$) and length of stay by 1.5 days ($P > 0.001$)
	Celik B, et al (2009)[2]	Retrospective chart review	12,010 invasive procedures	Records of patients treated for iatrogenic pneumothorax reviewed to determine causal procedure, location, service, treatment required, and consequences	164 cases of iatrogenic pneumothorax were identified (1.36%); highest risk procedures included central venous catheter insertion (43.8% of cases) and thoracentesis (20.1% of cases); 56.7% of procedures causing pneumothorax were performed under emergency conditions

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TABLE. Summary of Studies in Review, Organized by Topic (continued)

Topic	Author (Year)	Study Design	Participants (n)	Study Description or Intervention	Results and Authors' Conclusions
Intercostal artery localization	Shurtleff E and Olinger A (2012)[41]	Observational cohort	29 cadavers	Identify the course and tortuosity of the posterior intercostal coronary artery (ICA) and its collaterals in elderly cadavers using dissection	The ICA is unshielded and most tortuous in its course near the posterior midline, also demonstrating collaterals within the first 120 mm; age >60 was associated with higher rates of tortuosity; recommend tall pleural procedures be performed ≥120 mm from midline
	Helm E, et al (2013)[42]	Retrospective review	47 patients, 298 arteries	Thoracic CT angiograms reformatted and analyzed to describe the course and variability in the ICAs and the factors that may influence them	The ICA is often exposed in the IC space within the first 6 cm lateral to the spine; artery course is more variable when age >60 (coefficient 0.91, $P < 0.001$) and more cephalad rib spaces (coefficient -2.60, $P < 0.001$); recommend all procedures be performed lateral to 6 cm from the spine
	Yoneyama H, et al (2010)[43]	Observational cohort	33 patients	3D CT angiography was performed in elderly patients to identify the ICA with calculation of the "percent safe space" to quantify vulnerability of laceration during thoracentesis	The ICA "percent safe space" was significantly higher at the lateral position versus medial position (79.8% vs 61.2%; $P < 0.0001$); ICA tortuosity increased with age, but correlation was low ($P = 0.0378$; r = -0.3631)
	Salamonsen M, et al (2012)[44]	Prospective cohort	22 patients	Describe a method to visualize the ICA prior to thoracentesis using US, and calculate its location relative to the overlying rib to identify a "vulnerable" vessel	US was able to identify the ICA in 74 of 88 positions examined; the ICA was noted to be most central within the IC space near the spine and migrated to lie under the rib more laterally; ICA location is variable and may be vulnerable even with a lateral approach
	Salamonsen M, et al (2013)[45]	Prospective cohort	50 patients	Physicians evaluate the reliability of bedside US to identify the ICA in patients prior to planned CT thoracic angiography as gold standard	The sensitivity and specificity of portable US compared to CT was 0.86 (0.18-0.91) and 0.30 (0.13-0.54) respectively; bedside US with color flow Doppler is a reliable method for detection of a vulnerable IC artery; exam added 42 seconds to the procedure time
	Wraight W, et al (2005)[6]	Observational cohort	38 cadavers, 62 rib blocks	Rib blocks dissected to identify the neurovascular bundle and measure its relation to the inferior rib border and attempt to describe a "safe zone" for drain insertion	The "safe zone" in the IC space is narrower than thought, and is approximately 50%-70% of the way down an interspace to avoid the variably positioned IC neurovascular bundle and collaterals
Pleural pressure monitoring and large-volume thoracentesis	Huggins J and Doelken P (2006)[47]	Literature review	NA	This review discusses pleural mechanics and pleural manometry including its role in re-expansion pulmonary edema (REPE) and diagnosing of a nonexpandable lung	Pleural pressure can be helpful in diagnosing pleural pathologies and may improve safely by avoiding REPE performing thoracentesis
	Echevarria C, et al (2008)[48]	Systematic review	13 studies	Literature review performed to determine the prevalence of REPE after thoracentesis and associated risk factors	The incidence of REPE is 0%-1%; patients who have a lung collapsed >7 days, >3 L fluid drained, or are young appear to be at higher risk for this complication
	Sue R, et al (2004)[49]	Retrospective	7 patients on mechanical ventilation	To investigate if clinical REPE is due to increased permeability of the alveolar capillary barrier through analysis of pulmonary edema fluid and plasma	The average edema to plasma-fluid protein ratio was 0.58, which supports increased alveolar permeability and a hydrostatic mechanism as the cause of REPE
	Feller-Kopman D, et al (2007)[50]	Prospective cohort	185 thoracenteses	Patients undergoing thoracentesis with >1 L removed had volume drained, pleural pressure, elastance, and presence of symptoms recorded; parameters compared with those who developed REPE	1 patient developed REPE (0.5%); both clinical and radiographic REPE are rare and independent of volume removed, elastance, and pleural pressure; no need to stop drainage at 1 L if pleural pressure is > -20 cm H_2O or symptoms absent
	Villena V, et al (2000)[51]	Prospective cohort	61 patients	During therapeutic thoracentesis, pleural pressures were measured to determine if they could predict the amount of fluid that could be safely removed or effusion etiology	Measuring intrapleural pressure can allow large amounts of fluid to be safely removed and reinforce a diagnosis of trapped lung; neither initial pressure nor pleural elastance after the first 500 mL removed were predictive of fluid removed
	Doelken P, et al (2004)[52]	Prospective cohort	40 patients	To compare the agreement between an electronic transducer and water manometer in measuring pleural pressures during thoracentesis	Pleural manometry during lar-volume thoracentesis can prevent the development of excessively negative pleural pressures; a simple water manometer correlated well with an electronic transducer (r = 0.97;$P < 0.001$)
	Feller-Kopman D (2007)[53]	Literature review	NA	This review summarizes the relevant data for the use of US and manometry, and their use during therapeutic thoracentesis	The data regarding pleural US are sound enough to suggest its use should become standard of care; further research is required to define the role of formal manometry
	Boshuizen R, et al (2013)[54]	Prospective cohort	30 patients, 34 procedures	Manometry used to explore the relationship between pleural pressure and a nonexpanded lung in patients with malignant effusions; compared with imaging to check lung expansion	4 patients were identified as having a nonexpanding lung; total drop in pleural pressure ($P = 0.009$), difference in pleural pressure with respiration ($P = 0.007$), and pleural elastance ($P = 0.002$) were all significantly associated with a nonexpanding lung
	Pannu J, et al (2014)[55]	Retrospective chart review	214 patients	Chart review of thoracenteses performed with and without manometry to assess for a correlation between intrapleural pressure and patient discomfort	The use of manometry did not reliably predict the change in chest pain ($P = 0.12$) or dyspnea ($P = 0.24$) during thoracentesis; similar results found in large-volume thoracentesis group
	Feller-Kopman D, et al (2006)[56]	Prospective cohort	169 patients	Serial manometry performed during therapeutic thoracentesis to explore the correlation between intrapleural pressure changes and symptom onset	Symptoms developed in 17% of patients; chest discomfort was significantly associated with large drops in pleural pressure ($P = 0.001$), but opening pressure and total volume removed were not
	Abunasser J. and Brown R (2010)[57]	Retrospective chart review	237 patients, 300 thoracenteses	Charts reviewed of thoracenteses performed to assess the risk of large-volume drainage (>1 L) without manometry	137 thoracenteses performed were large volume; no statistically significant difference in the risk of pneumothorax, hypotension, or bleeding

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TABLE. Summary of Studies in Review, Organized by Topic (continued)

Topic	Author (Year)	Study Design	Participants (n)	Study Description or Intervention	Results and Authors' Conclusions
	Mynarek G, et al (2004)[58]	Retrospective chart review	711 procedures in 371 patients	Chart review performed of patients who underwent US-guided thoracentesis to assess type and frequency of complications and associated risk factors	US-guided thoracentesis is a safe procedure with a 2.8% rate of pneumothorax; no association with the amount of fluid removed (P = 0.096); authors recommend against postprocedure CXR in the absence of symptoms
	Josephson T, et al (2009)[59]	Prospective cohort	471 patients, 735 thoracenteses	US-guided therapeutic thoracenteses performed and effusions drained with no upper limit and without manometry; stratified by amount of fluid removed and pneumothorax rates analyzed	A steep increase in pneumothorax rate noted when > 1.8 L fluid (OR, 3.8; CI 1.28-11.2) and >2.3 L fluid (OR, 5.7; CI, 1.30-24.7) removed; amount of fluid removed also associated with higher risk for chest tube placement ($P < 0.0001$)
	Heidecker J, et al (2006)[60]	Retrospective chart review	367 patients	Charts reviewed of US-guided thoracenteses performed with goal of explaining mechanism of pneumothoraces that occurred	Authors propose that the majority of pneumothoraces observed were found to be related to unexpanded lung as opposed to direct trauma or entranced air, and cannot be avoided with manometry
Postprocedure imaging	Jones P, et al (2003)[62]	Prospective cohort	605 patients, 941 thoracenteses	Thoracenteses performed in the radiology department under US guidance were analyzed to determine the incidence of complications	The complication rates of pneumothorax (2.5%), hemothorax (0.2%), and REPE (0.5%) were low for US-guided thoracenteses performed by interventional radiologists; these rates are less than the reported rates for nonguided thoracentesis
	Petersen W, et al (2000)[63]	Prospective cohort	199 patients, 251 thoracenteses	Physicians given questionnaire postprocedure rating their concern for complication with CXR obtained at doctor discretion; rate of pneumothorax	Pneumothorax rate was 2.7% when there was no concern for complication vs 30% when complication suspected; only procedural risk factor associated with pneumothorax was aspiration of air; recommend no CXR obtained unless clinical suspicion for complication suspected
	Sachdeva A, et al (2014)[64]	Literature review	NA	Review of relevant literature pertaining to US exam techniques, thoracentesis, and an US-based procedure service	Bedside US has utility throughout the pre-, intra-, and postprocedure process. It is a viable option for use to detect postprocedure pneumothorax and is more sensitive than CXR
	Shostak E, et al (2013)[65]	Prospective cohort	185 patients	Bedside US exam performed on patients prior to and after pleural procedures to detect pneumothorax	8 pneumothoraces identified by CXR, 7 of which were seen on bedside US; sensitivity was 88% and specificity 97%; bedside US is a valuable tool to detect pneumothorax when a good quality scan is obtained

NOTE: Abbreviations: CI, confidence interval; CT, computed tomography; CXR, chest x-ray; ICA, intercostal artery; IM, internal medicine; INR, international normalized ratio; MICU, medical intensive care unit; OR, odds ratio; REPE, re-expansion pulmonary edema; US, ultrasound.

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correlated with an unexpandable lung include a negative opening pressure[47] and large fluctuations in pressure during the respiratory cycle.[54]

While development of symptoms (eg, chest pain, cough, or dyspnea) is often used as a surrogate, the correlation between intrapleural pressure and patient symptoms is inconsistent and not a reliable proxy.[55] One study found that 22% of patients with chest pain during thoracentesis had intrapleural pressures lower than -20 cm H_2O compared with 8.6% of asymptomatic patients,[56] but it is unclear if the association is causal.

Thoracentesis is often performed for symptomatic relief and removal of large fluid volume. However, it remains common to halt fluid removal after 1.5 L, a threshold endorsed by BTS.[19] While some investigators have suggested that removal of 2 L or more of pleural fluid does not compromise safety,[57,58] a 4- to 5-fold rise in the risk of pneumothorax was noted in 2 studies.[20,59] when more than 1.5 L of fluid was removed. The majority of these may be related to pneumothorax *ex vacuo*, a condition in which fluid is drained from the chest, but the lung is unable to expand and fill the space (eg, "trapped lung"), resulting in a persistent pneumothorax. This condition generally does not require treatment.[60] When manometry is employed at 200-mL intervals with termination at an intrapleural pressure of less than 20 mm H_2O, drainage of 3 L or more has been reported with low rates of pneumothorax and very low rates of REPE.[50,51] However, whether this is cause and effect is unknown because REPE is rare, and more work is needed to determine the role of manometry for its prevention.

POSTPROCEDURAL CONSIDERATIONS

Postprocedure Imaging

Performing an upright CXR following thoracentesis is a practice that remains routinely done by many practitioners to monitor for complications. Such imaging was also endorsed by the American Thoracic Society guidelines.[61] However, more recent data question the utility of this practice. Multiple studies have confirmed that post-thoracentesis CXR is unnecessary unless clinical suspicion for pneumothorax or REPE is present.[36,58,62,63] The BTS guidelines also advocate this approach.[19] Interestingly, a potentially more effective way to screen for postprocedure complications is through bedside US, which has been shown to be more sensitive than CXR in detecting pneumothorax.[64] In 1 study of 185 patients, bedside US demonstrated a sensitivity of 88% and a specificity of 97% for diagnosing pneumothorax in patients with adequate quality scans, with positive and negative likelihood ratios of 55 and 0.17, respectively.[65]

DISCUSSION

Thoracentesis remains a core procedural skill for hospitalists, critical care physicians, and emergency physicians. It is the foundational component when investigating and treating pleural effusions. When the most current training, techniques, and technology are used, data suggest this procedure is safe to perform at the bedside. Our review highlights these

strategies and evaluates which aspects might be most applicable to clinical practice.

Our findings have several implications for those who perform this procedure. First, appropriate training is central to procedural safety, and both simulation and direct observation by procedural experts have been shown by multiple investigators to improve knowledge and skill. This training should integrate the use of US in performing a focused thoracic exam.

Second, recommendations regarding coagulopathy and a "safe cutoff" of an INR less than 1.5 or platelets greater than 50,000/μL had limited evidentiary support. Rather, multiple studies suggest no difference in bleeding risk following thoracentesis with an INR as high as 3.0 and platelets greater than 25,000/μL. Furthermore, prophylactic transfusion with fresh frozen plasma or platelets before thoracentesis did not alter bleeding risk and exposes patients to transfusion complications. Thus, routine use of this practice can no longer be recommended. Third, further research is needed to understand the bleeding risk for patients on antiplatelet medications, heparin products, and also direct oral anticoagulants, given the growing popularity in their use and the potential consequences of even temporary cessation. Regarding patients on mechanical ventilation, thoracentesis demonstrated no difference in complication rates vs. the general population, and its performance in this population is encouraged when clinically indicated.

Intraprocedural considerations include the use of bedside US. Due to multiple benefits including effusion characterization, puncture site localization, and significantly lower rates of pneumothorax, the standard of care should be to perform thoracentesis with US guidance. Both use of US to mark an effusion immediately prior to puncture or in real time during needle insertion demonstrated benefit; however, it is unclear if 1 method is superior because no direct comparison studies were found. Further work is needed to investigate this potential.

Our review suggests that the location and course of the ICA is variable, especially near the midline, in the elderly, and in higher intercostal spaces, leaving it vulnerable to laceration. We recommend physicians only attempt thoracentesis at least 6 cm lateral to the midline due to ICA tortuosity and, ideally, 12 cm lateral, to avoid the presence of collaterals. Although only 2 small-scale studies were found pertaining to the use of US in identifying the ICA, we encourage physicians to consider learning how to screen for its presence as a part of their routine thoracic US exam in the area underlying the planned puncture site.

Manometry is beneficial because it can diagnose a nonexpandable lung and allows for pleural pressure monitoring.[52,53] A simple U-shaped manometer can be constructed from intravenous tubing included in most thoracentesis kits, which adds little to overall procedure time. While low rates of REPE have been observed when terminating thoracentesis if pressures drop below -20 cm H_2O or chest pain develops, neither measure appears to have reliable predictive value, limiting clinical utility. Further work is required to determine if a "safe pressure cutoff" exists. In general, we recommend the use of manometry when a nonexpandable (trapped) lung is suspected, because large drops in intrapleural pressure, a negative opening pressure, and respiratory variation can help confirm the diagnosis and avoid pneumothorax *ex vacuo* or unnecessary procedures in the future. As this condition appears to be more common in the setting of larger effusions, use of manometry when large-volume thoracenteses are planned is also reasonable.

Postprocedurally, routine imaging after thoracentesis is not recommended unless there is objective concern for complication. When indicated, bedside US is better positioned for this role compared with CXR, because it is more sensitive in detecting pneumothorax, provides instantaneous results, and avoids radiation exposure.

Our review has limitations. First, we searched only for articles between defined time periods, restricted our search to a single database, and excluded non-English articles. This has the potential to introduce selection bias, as nonprimary articles that fall within our time restrictions may cite older studies that are outside our search range. To minimize this effect, we performed a critical review of all included studies, especially nonprimary articles. Second, despite the focus of our search strategy to identify any articles related to patient safety and adverse events, we cannot guarantee that all relevant articles for any particular complication or risk factor were captured given the lack of more specific search terms. Third, although we performed a systematic search of the literature, we did not perform a formal systematic review or formally grade included studies. As the goal of our review was to categorize and operationalize clinical aspects, this approach was necessary, and we acknowledge that the quality of studies is variable. Lastly, we aimed to generate clinical recommendations for physicians performing thoracentesis at the bedside; others reviewing this literature may find or emphasize different aspects relevant to practice outside this setting.

In conclusion, evaluation and treatment of pleural effusions with bedside thoracentesis is an important skill for physicians of many disciplines. The evidence presented in this review will help inform the process and ensure patient safety. Physicians should consider incorporating these recommendations into their practice.

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References

1. Kasper DL. *Harrison's Principles of Internal Medicine*. 19th ed. New York, NY: McGraw Hill Education; 2015.
2. Celik B, Sahin E, Nadir A, Kaptanoglu M. Iatrogenic pneumothorax: etiology, incidence and risk factors. *Thorac Cardiovasc Surg*. 2009;57(5):286-290.
3. Hooper CE, Welham SA, Maskell NA, Soc BT. Pleural procedures and patient

safety: a national BTS audit of practice. *Thorax*. 2015;70(2):189-191.
4. Diacon AH, Brutsche MH, Soler M. Accuracy of pleural puncture sites: a prospective comparison of clinical examination with ultrasound. *Chest*. 2003;123(2):436-441.
5. Patel IJ, Davidson JC, Nikolic B, et al. Consensus guidelines for periprocedural management of coagulation status and hemostasis risk in percutaneous image-guided interventions. *J Vasc Interv Radiol*. 2012;23(6):727-736.
6. Wraight WM, Tweedie DJ, Parkin IG. Neurovascular anatomy and variation in the fourth, fifth, and sixth intercostal spaces in the mid-axillary line: a cadaveric study in respect of chest drain insertion. *Clin Anat*. 2005;18(5):346-349.
7. Duncan DR, Morgenthaler TI, Ryu JH, Daniels CE. Reducing iatrogenic risk in thoracentesis: establishing best practice via experiential training in a zero-risk environment. *Chest*. 2009;135(5):1315-1320.
8. Grover S, Currier PF, Elinoff JM, Mouchantaf KJ, Katz JT, McMahon GT. Development of a test to evaluate residents' knowledge of medical procedures. *J Hosp Med*. 2009;4(7):430-432.
9. Promes SB, Chudgar SM, Grochowski CO, et al. Gaps in procedural experience and competency in medical school graduates. *Acad Emerg Med*. 2009;16 Suppl 2:S58-62.
10. Huang GC, Smith CC, Gordon CE, et al. Beyond the comfort zone: residents assess their comfort performing inpatient medical procedures. *Am J Med*. 2006;119(1):71 e17-24.
11. Lagan J, Cutts L, Zaidi S, Benton I, Rylance J. Are we failing our trainees in providing opportunities to attain procedural confidence? *Br J Hosp Med (Lond)*. 2015;76(2):105-108.
12. Wayne DB, Barsuk JH, O'Leary KJ, Fudala MJ, McGaghie WC. Mastery learning of thoracentesis skills by internal medicine residents using simulation technology and deliberate practice. *J Hosp Med*. 2008;3(1):48-54.
13. Lenchus JD. End of the "see one, do one, teach one" era: the next generation of invasive bedside procedural instruction. *J Am Osteopath Assoc*. 2010;110(6):340-346.
14. Lenchus J, Issenberg SB, Murphy D, et al. A blended approach to invasive bedside procedural instruction. *Med Teach*. 2011;33(2):116-123.
15. Jiang G, Chen H, Wang S, et al. Learning curves and long-term outcome of simulation-based thoracentesis training for medical students. *BMC Med Educ*. 2011;11:39.
16. Berg D, Berg K, Riesenberg LA, et al. The development of a validated checklist for thoracentesis: preliminary results. *Am J Med Qual*. 2013;28(3):220-226.
17. Salamonsen M, McGrath D, Steiler G, Ware R, Colt H, Fielding D. A new instrument to assess physician skill at thoracic ultrasound, including pleural effusion markup. *Chest*. 2013;144(3):930-934.
18. McVay PA, Toy PT. Lack of increased bleeding after paracentesis and thoracentesis in patients with mild coagulation abnormalities. *Transfusion*. 1991;31(2):164-171.
19. Havelock T, Teoh R, Laws D, Gleeson F, Group BTSPDG. Pleural procedures and thoracic ultrasound: British Thoracic Society Pleural Disease Guideline 2010. *Thorax*. 2010;65 Suppl 2:ii61-76.
20. Ault MJ, Rosen BT, Scher J, Feinglass J, Barsuk JH. Thoracentesis outcomes: a 12-year experience. *Thorax*. 2015;70(2):127-132.
21. Puchalski J. Thoracentesis and the risks for bleeding: a new era. *Curr Opin Pulm Med*. 2014;20(4):377-384.
22. Hibbert RM, Atwell TD, Lekah A, et al. Safety of ultrasound-guided thoracentesis in patients with abnormal preprocedural coagulation parameters. *Chest*. 2013;144(2):456-463.
23. Zalt MB, Bechara RI, Parks C, Berkowitz DM. Effect of routine clopidogrel use on bleeding complications after ultrasound-guided thoracentesis. *J Bronchology Interv Pulmonol*. 2012;19(4):284-287.
24. Mahmood K, Shofer SL, Moser BK, Argento AC, Smathers EC, Wahidi MM. Hemorrhagic complications of thoracentesis and small-bore chest tube placement in patients taking clopidogrel. *Ann Am Thorac Soc*. 2014;11(1):73-79.
25. Goligher EC, Leis JA, Fowler RA, Pinto R, Adhikari NK, Ferguson ND. Utility and safety of draining pleural effusions in mechanically ventilated patients: a systematic review and meta-analysis. *Crit Care*. 2011;15(1):R46.
26. Fartoukh M, Azoulay E, Galliot R, et al. Clinically documented pleural effusions in medical ICU patients: how useful is routine thoracentesis? *Chest*. 2002;121(1):178-184.
27. Cervini P, Hesley GK, Thompson RL, Sampathkumar P, Knudsen JM. Incidence of infectious complications after an ultrasound-guided intervention. *AJR Am J Roentgenol*. 2010;195(4):846-850.
28. Mimoz O, Chopra V, Timsit JF. What's new in catheter-related infection: skin cleansing and skin antisepsis. *Intensive Care Med*. 2016;42(11):1784-1786.
29. Soni NJ, Franco R, Velez MI, et al. Ultrasound in the diagnosis and management of pleural effusions. *J Hosp Med*. 2015;10(12):811-816.
30. Feller-Kopman D. Ultrasound-guided thoracentesis. *Chest*. 2006;129(6):1709-1714.
31. Shojaee S, Argento AC. Ultrasound-guided pleural access. *Semin Respir Crit Care Med*. 2014;35(6):693-705.
32. Gordon CE, Feller-Kopman D, Balk EM, Smetana GW. Pneumothorax following thoracentesis: a systematic review and meta-analysis. *Arch Intern Med*. 2010;170(4):332-339.
33. Perazzo A, Gatto P, Barlascini C, Ferrari-Bravo M, Nicolini A. Can ultrasound guidance reduce the risk of pneumothorax following thoracentesis? *J Bras Pneumol*. 2014;40(1):6-12.
34. Cavanna L, Mordenti P, Berte R, et al. Ultrasound guidance reduces pneumothorax rate and improves safety of thoracentesis in malignant pleural effusion: report on 445 consecutive patients with advanced cancer. *World J Surg Oncol*. 2014;12:139.
35. Soldati G, Smargiassi A, Inchingolo R, Sher S, Valente S, Corbo GM. Ultrasound-guided pleural puncture in supine or recumbent lateral position - feasibility study. *Multidiscip Respir Med*. 2013;8(1):18.
36. Pihlajamaa K, Bode MK, Puumalainen T, Lehtimaki A, Marjelund S, Tikkakoski T. Pneumothorax and the value of chest radiography after ultrasound-guided thoracocentesis. *Acta Radiol*. 2004;45(8):828-832.
37. Barnes TW, Morgenthaler TI, Olson EJ, Hesley GK, Decker PA, Ryu JH. Sonographically guided thoracentesis and rate of pneumothorax. *J Clin Ultrasound*. 2005;33(9):442-446.
38. Zanforlin A, Gavelli G, Oboldi D, Galletti S. Ultrasound-guided thoracenthesis: the V-point as a site for optimal drainage positioning. *Eur Rev Med Pharmacol Sci*. 2013;17(1):25-28.
39. Patel PA, Ernst FR, Gunnarsson CL. Ultrasonography guidance reduces complications and costs associated with thoracentesis procedures. *J Clin Ultrasound*. 2012;40(3):135-141.
40. Mercaldi CJ, Lanes SF. Ultrasound guidance decreases complications and improves the cost of care among patients undergoing thoracentesis and paracentesis. *Chest*. 2013;143(2):532-538.
41. Shurtleff E, Olinger A. Posterior intercostal artery tortuosity and collateral branch points: a cadaveric study. *Folia Morphol (Warsz)*. 2012;71(4):245-251.
42. Helm EJ, Rahman NM, Talakoub O, Fox DL, Gleeson FV. Course and variation of the intercostal artery by CT scan. *Chest*. 2013;143(3):634-639.
43. Yoneyama H, Arahata M, Temaru R, Ishizaka S, Minami S. Evaluation of the risk of intercostal artery laceration during thoracentesis in elderly patients by using 3D-CT angiography. *Intern Med*. 2010;49(4):289-292.
44. Salamonsen M, Ellis S, Paul E, Steinke K, Fielding D. Thoracic ultrasound demonstrates variable location of the intercostal artery. *Respiration*. 2012;83(4):323-329.
45. Salamonsen M, Dobeli K, McGrath D, et al. Physician-performed ultrasound can accurately screen for a vulnerable intercostal artery prior to chest drainage procedures. *Respirology*. 2013;18(6):942-947.
46. Grippi MA. *Fishman's pulmonary diseases and disorders*. 5th ed. New York, NY: McGraw-Hill Education; 2015.
47. Huggins JT, Doelken P. Pleural manometry. *Clin Chest Med*. 2006;27(2):229-240.
48. Echevarria C, Twomey D, Dunning J, Chanda B. Does re-expansion pulmonary oedema exist? *Interact Cardiovasc Thorac Surg*. 2008;7(3):485-489.
49. Sue RD, Matthay MA, Ware LB. Hydrostatic mechanisms may contribute to the pathogenesis of human re-expansion pulmonary edema. *Intensive Care Med*. 2004;30(10):1921-1926.
50. Feller-Kopman D, Berkowitz D, Boiselle P, Ernst A. Large-volume thoracentesis and the risk of reexpansion pulmonary edema. *Ann Thorac Surg*. 2007;84(5):1656-1661.
51. Villena V, Lopez-Encuentra A, Pozo F, De-Pablo A, Martin-Escribano P. Measurement of pleural pressure during therapeutic thoracentesis. *Am J Respir Crit Care Med*. 2000;162(4 Pt 1):1534-1538.
52. Doelken P, Huggins JT, Pastis NJ, Sahn SA. Pleural manometry: technique and clinical implications. *Chest*. 2004;126(6):1764-1769.
53. Feller-Kopman D. Therapeutic thoracentesis: the role of ultrasound and pleural manometry. *Curr Opin Pulm Med*. 2007;13(4):312-318.
54. Boshuizen RC, Sinaasappel M, Vincent AD, Goldfinger V, Farag S, van den Heuvel MM. Pleural pressure swing and lung expansion after malignant pleural effusion drainage: the benefits of high-temporal resolution pleural manometry. *J Bronchology Interv Pulmonol*. 2013;20(3):200-205.
55. Pannu J, DePew ZS, Mullon JJ, Daniels CE, Hagen CE, Maldonado F. Impact of pleural manometry on the development of chest discomfort during thoracentesis: a symptom-based study. *J Bronchology Interv Pulmonol*. 2014;21(4):306-313.
56. Feller-Kopman D, Walkey A, Berkowitz D, Ernst A. The relationship of pleural pressure to symptom development during therapeutic thoracentesis. *Chest*. 2006;129(6):1556-1560.
57. Abunasser J, Brown R. Safety of large-volume thoracentesis. *Conn Med*. 2010;74(1):23-26.
58. Mynarek G, Brabrand K, Jakobsen JA, Kolbenstvedt A. Complications following ultrasound-guided thoracocentesis. *Acta Radiol*. 2004;45(5):519-522.
59. Josephson T, Nordenskjold CA, Larsson J, Rosenberg LU, Kaijser M. Amount

drained at ultrasound-guided thoracentesis and risk of pneumothorax. *Acta Radiol*. 2009;50(1):42-47.
60. Heidecker J, Huggins JT, Sahn SA, Doelken P. Pathophysiology of pneumothorax following ultrasound-guided thoracentesis. *Chest*. 2006;130(4):1173-1184.
61. Sokolowski JW Jr, Burgher LW, Jones FL Jr, Patterson JR, Selecky PA. Guidelines for thoracentesis and needle biopsy of the pleura. This position paper of the American Thoracic Society was adopted by the ATS Board of Directors, June 1988. *Am Rev Respir Dis*. 1989;140(1):257-258.
62. Jones PW, Moyers JP, Rogers JT, Rodriguez RM, Lee YC, Light RW. Ultrasound-guided thoracentesis: is it a safer method? *Chest*. 2003;123(2):418-423.
63. Petersen WG, Zimmerman R. Limited utility of chest radiograph after thoracentesis. *Chest*. 2000;117(4):1038-1042.
64. Sachdeva A, Shepherd RW, Lee HJ. Thoracentesis and thoracic ultrasound: state of the art in 2013. *Clin Chest Med*. 2013;34(1):1-9.
65. Shostak E, Brylka D, Krepp J, Pua B, Sanders A. Bedside sonography for detection of postprocedure pneumothorax. *J Ultrasound Med*. 2013;32(6):1003-1009.

Hospital Medicine and Perioperative Care: A Framework for High-Quality, High-Value Collaborative Care

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BACKGROUND: Hospitalists have long been involved in optimizing perioperative care for medically complex patients. In 2015, the Society of Hospital Medicine organized the Perioperative Care Work Group to summarize this experience and to develop a framework for providing optimal perioperative care.

METHODS: The work group, which consisted of perioperative care experts from institutions throughout the United States, reviewed current hospitalist-based perioperative care programs, compiled key issues in each perioperative phase, and developed a framework to highlight essential elements to be considered. The framework was reviewed and approved by the board of the Society of Hospital Medicine.

RESULTS: The Perioperative Care Matrix for Inpatient Surgeries was developed. This matrix characterizes perioperative phases, coordination, and metrics of success. Additionally, concerns and potential risks were tabulated. Key questions regarding program effectiveness were drafted, and examples of models of care were provided.

CONCLUSIONS: The Perioperative Care Matrix for Inpatient Surgeries provides an essential collaborative framework hospitalists can use to develop and continually improve perioperative care programs. *Journal of Hospital Medicine* 2017;12:277-282. © 2017 Society of Hospital Medicine

Of the 36 million US hospitalizations each year, 22% are surgical.[1] Although less frequent than medical hospitalizations, surgical hospitalizations are more than twice as costly.[2] Additionally, surgical hospitalizations are on average longer than medical hospitalizations.[2] Given the increased scrutiny on cost and efficiency of care, attention has turned to optimizing perioperative care. Hospitalists are well positioned to provide specific expertise in the complex interdisciplinary medical management of surgical patients.

In recent decades, multiple models of hospitalist involvement in perioperative care have evolved across the United States.[3-19] To consolidate knowledge and experience and to develop a framework for providing the best care for surgical patients, the Society of Hospital Medicine organized the Perioperative Care Work Group in 2015. This framework was designed for interdisciplinary collaboration in building and strengthening perioperative care programs.

METHODS

The Society of Hospital Medicine recognized hospital medicine programs' need for guidance in developing collaborative care in perioperative medicine and appointed the Perioperative Care Work Group in May 2015. Work group members are perioperative medicine experts from US medical centers. They have extensive knowledge of the literature as well as administrative and clinical experience in a variety of perioperative care models.

Topic Development. Initial work was focused on reviewing and discussing multiple models of perioperative care and exploring the roles that hospital medicine physicians have within these models. Useful information was summarized to guide hospitals and physicians in designing, implementing, and expanding patient-centric perioperative medicine services with a focus on preoperative and postoperative care. A final document was created; it outlines system-level issues in perioperative care, organized by perioperative phases.

Initial Framework. Group members submitted written descriptions of key issues in each of 4 phases: (1) preoperative, (2) day of surgery, (3) postoperative inpatient, and (4) postdischarge. These descriptions were merged and reviewed by the content experts. Editing and discussion from the entire group were incorporated into the final matrix, which highlighted (1) perioperative phase definitions, (2) requirements for patients to move to next phase, (3) elements of care coordination typically provided by surgery, anesthesiology, and medicine disciplines, (4) concerns and risks particular to each phase, (5) unique considerations for each phase, (6) suggested metrics of success, and (7) key questions for determining the effectiveness of perioperative care in an institution. All members provided final evaluation and editing.

Final Approval. The Perioperative Care Matrix for Inpatient Surgeries (PCMIS) was presented to the board of the Society of Hospital Medicine in fall 2015 and was approved

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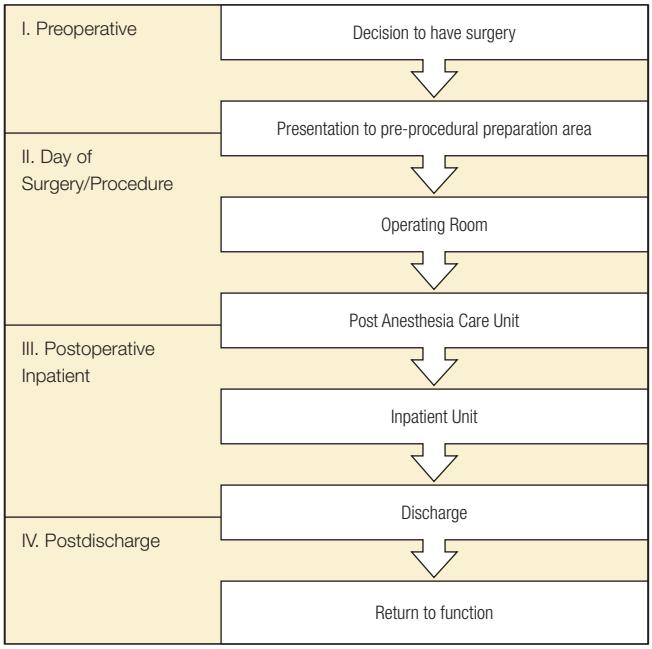

FIG. Phases of perioperative period.

for use in centering and directing discussions regarding perioperative care.

Models of Care. The Perioperative Care Work Group surveyed examples of hospitalist engagement in perioperative care and synthesized these into synopses of existing models of care for the preoperative, day-of-surgery, postoperative-inpatient, and postdischarge phases.

RESULTS

Defining Key Concepts and Issues

Hospitalists have participated in a variety of perioperative roles for more than a decade. Roles include performing in-depth preoperative assessments, providing oversight to presurgical advanced practice provider assessments, providing inpatient comanagement and consultation both before and after surgery, and providing postdischarge follow-up within the surgical period for medical comorbidities.

Although a comprehensive look at the entire perioperative period is important, 4 specific phases were defined to guide this work (Figure). The phases identified were based on time relative to surgery, with unique considerations as to the overall perioperative period. Concerns and potential risks specific to each phase were considered (Table 1).

The PCMIS was constructed to provide a single coherent vision of key concepts in perioperative care (Table 2). Also identified were several key questions for determining the effectiveness of perioperative care within an institution (Table 3).

Models of Care

Multiple examples of hospitalist involvement were collected to inform the program development guidelines. The specifics noted among the reviewed practice models are described here.

Preoperative. In some centers, all patients scheduled for surgery are required to undergo evaluation at the institution's preoperative clinic. At most others, referral to the preoperative clinic is at the discretion of the surgical specialists,

TABLE 1. Concerns and Potential Risks Specific to Each Phase of Perioperative Period

Phase	Concerns and Risks
Preoperative	Inadequate or nonstandardized communication and handoffs among providers
	Unclear or contradictory information provided to patients before surgery
	Failed communication regarding needs for additional testing or optimization
	Unknown or incomplete medical history from patient or in records
	Determination that patient is not optimized
	Determination that surgery is not best option
	Patient needs direction regarding alternatives
	Inability to medically optimize patient in given time—send patient to surgery with increased risk or postpone surgery
	Disagreement among providers as to whether patient is truly optimized
Day of surgery	Patient not medically optimized by time of arrival in operating room
	Identification of previously unrecognized or new medical condition that requires further evaluation
	Several transitions occur this day—careful attention to handoffs is essential
Postoperative inpatient	Clinical concerns, including surgical wound (dehiscence, inadequate healing, infection), bleeding (evaluation for hemostasis, need for reoperation), pain, nausea/vomiting/constipation/ileus, venous thromboembolism, delirium, electrolyte derangement, atelectasis, hyperglycemia, hypoglycemia, anemia
	Chronic disease decompensation
	Unmasking of underlying disease
	Inadequate or nonstandardized communication and handoffs among providers regarding patient's progress and ongoing needs
	Unclear follow-up instructions, including which team member is expected to manage abnormal findings or complications
	Situations that require change in service (surgery to medicine) or level of service (floor to intensive care unit)
Postdischarge	Poor postoperative recovery
	Poor coordination of care
	Ongoing or postdischarge postoperative complications
	Hospital readmissions
	Triaging management of postoperative or postdischarge complications to appropriate providers (surgical vs medical)

TABLE 2. Perioperative Care Matrix for Inpatient Surgeries[a]

	Phases in the Perioperative Continuum			
	Preoperative	Day of Surgery	Postoperative Inpatient	Postdischarge
Phase definitions	From time of decision to have surgery through arrival in preoperative preparation area	From preoperative preparation, through OR to PACU, to transfer to inpatient unit	From arrival in inpatient unit (acute care floor, telemetry, or ICU) through hospital discharge	From hospital discharge through return to function (includes time in nursing care or rehabilitation facility until return to preoperative living arrangement)
Requirements for passing to next phase	Standardized preoperative medical assessment (may differ for elective, urgent, and emergent surgeries) Optimization of chronic medical conditions to degree possible Appropriate patient and family education with shared decision-making Guideline-based testing, financial stewardship	Appropriate level of care identified for post-PACU (ICU vs acute care floor) Clinical stability confirmed for appropriate care level Crucial information is communicated	Protocol-driven early interventions focused on return to function (pain control, physical/occupational therapy, bowel/bladder function) Standardized approach to preventing complications (eg, venous thromboembolism, surgical site infection, delirium, bleeding) Tailored patient/family education (anticipatory guidance for recovery, management of expectations) As needed, assessment for home safety (per physical/occupational therapy) and for skilled nursing/rehabilitation facility Discharge planning coordination	Resolution of any postoperative complications Transfer of information back to medical home and primary medical providers
Elements of care coordination by discipline	*Surgical Team:* determines if surgery is an appropriate option, conducts consent process, and provides education on surgical process/expectations *Anesthesiology:* conducts airway assessment, reviews readiness for surgery, and reviews anesthesia options (may be performed day of surgery) *Hospital Medicine:* identifies medical issues that affect perioperative risk, ensures optimization of underlying medical conditions, and provides anticipatory guidance	*Surgical Team:* evaluates readiness for OR and implements postoperative orders, including hospital admission orders *Anesthesiology:* evaluates readiness for OR, intraoperative monitoring and interventions, PACU care to ensure hemodynamic stability, and adequate pain control *Hospital Medicine:* available to evaluate and manage acute decompensation or new medical conditions that may arise	*Surgical Team:* provides general postoperative care, including routine pain management, surgical site care, surgery-specific postoperative recovery, and discharge planning *Hospital Medicine:* manages chronic disease, acute decompensation, or new medical conditions; may serve as comanager, traditional consultant, or, in some cases, primary service *Anesthesiology:* follows up intraoperative or PACU complications, provides advanced postoperative pain management, and, in some settings, provides intensive care in surgical intensive care unit	*Surgical Team:* postoperative follow-up appointment *Hospital Medicine:* ensures appropriate medical follow-up, as needed, by primary care physician, skilled nursing facility team, or hospital medicine postdischarge clinic
Metrics of success	Adequate patient preparation (patient report, measures of patient understanding) Use of preoperative services Timely scheduling of preoperative clinic appointment Clinic efficiency (no-show rates, information flow) Judicious preoperative testing (no unnecessary tests) Patient-reported experience Surgeon/provider satisfaction	OR efficiency (turnover time, time from patient presentation to OR start) OR delays and cancellations OR complications Reintubation rate Floor transfer to ICU within 24 hours of surgery Patient-reported experience	Complication rates Rate of unanticipated return to OR Length of stay (observed-to-expected ratio) Mortality index Surgical Care Improvement Project and Value-Based Purchasing metrics University HealthSystem Consortium patient safety indicators Patient satisfaction Clarity of patient education and discharge instructions (patient report, measures of patient understanding)	30-day rate of readmissions (related and unrelated) Postacute care needs and expenses Surgery-specific metric (infection rate) Timeliness of return to prior physical function and/or return to work

[a]The perioperative care continuum encompasses care from the time the decision is made to have surgery to the time function returns after surgery. A myriad of transitions and complicated handoffs among several disciplines is involved in every phase. Thus, it is imperative to have clear plans for coordination of and communication about services throughout the care continuum. This matrix is structured by phases of the perioperative continuum. It outlines requirements for passing from one phase to the next, elements of care coordination, potential risks, unique considerations, and metrics associated with each phase. It concludes with suggested key questions that assist in designing perioperative programs.

NOTE: Abbreviations: ICU, intensive care unit; OR, operating room; PACU, postanesthesia care unit.

who have been informed of the clinic's available resources. Factors determining whether a patient has an in-person clinic visit, undergoes a telephone-based medical evaluation, or has a referral deferred to the primary care physician (PCP) include patient complexity and surgery-specific risk. Patients who have major medical comorbidities (eg, chronic lung or heart disease) or are undergoing higher risk procedures (eg, those lasting >1 hour, laparotomy) most often undergo a formal clinic evaluation. Often, even for a patient whose preoperative evaluation is completed by a PCP, the preoperative nursing staff will call before surgery to provide instructions and to confirm that preoperative planning is complete. Confirmation includes ensuring that the surgery consent and preoperative history and physical examination documents are in the medical record, and that all recommended tests have been performed. If deficiencies are found, surgical and preoperative clinic staff are notified.

During a typical preoperative clinic visit, nursing staff complete necessary regulatory documentation requirements and ensure that all items on the preoperative checklist are completed before day of surgery. Nurses or pharmacists perform complete medication reconciliation. For medical evaluation at institutions with a multidisciplinary preoperative clinic, patients are triaged according to comorbidity and procedure. These clinics often have anesthesiology and hospital medicine clinicians collaborating with interdisciplinary colleagues and with patients' longitudinal care providers (eg, PCP, cardiologist). Hospitalists evaluate patients with comorbid medical diseases and address uncontrolled conditions and newly identified symptomatology. Additional testing is

TABLE 3. Key Questions for Determining Effectiveness of Perioperative Care in an Institution

Phase	Key Questions
Preoperative	How extensive a preoperative evaluation is medically necessary, and how is that determined?
	What is the current process for preparing patients for surgery? Who is involved or should be involved? How will underlying medical issues be assessed and optimized?
	How is patient care coordinated, and how is communication ensured among providers? How are disagreements managed?
	What is the rate or frequency of last-minute operating room cancellations and delays? What strategies are in place to optimize the preoperative process? How else might the institution measure the value of preoperative assessments?
	What planning can and should be done in anticipation of the perioperative course? How is this plan communicated to the patient, family members, and providers?
Day of surgery	How will pertinent information from the operating room be transferred to the intensive care unit or the acute care floor?
	Is there a need for inpatient comanagement? How will this be determined?
	What clinical conditions or situations determine whether the hospital medicine team or the surgical team should provide primary services once the patient is out of the operating room?
	For urgent cases, what methods are used to address preoperative medical stability and to implement risk reduction strategies?
	Who is responsible for immediate care or triage when a new or an acute medical issue is identified during preoperative preparation or in the postanesthesia care unit?
Postoperative inpatient	What process is or should be in place for accurate and efficient communication and handoffs?
	What are the provider roles after surgery? How can the surgical team, anesthesiology, and medicine best collaborate and coordinate to provide optimal inpatient care?
	Regarding length of stay for the top 10 surgical procedures, how well does this hospital compare with its "peer" hospitals?
	What other performance metrics are in most need of refinement?
	How can discharge planning begin in the preoperative phase and be coordinated across the perioperative period? What elements of transition programs (eg, BOOST [Better Outcomes by Optimizing Safe Transitions]) should be incorporated, and how?
	What effective and innovative inpatient postoperative processes has the institution endorsed and actively supported?
Postdischarge	What standardized process and protocols are needed for communication and handoffs among providers?
	What are the provider roles after surgery? How can the surgical team, anesthesiology, and medicine best collaborate and coordinate to provide optimal patient care?
	What instructions are provided to the patient? How and by whom?
	What is the 30-day readmission rate for surgical patients? What are common causes? How can these be anticipated and prevented?

determined by evidence- and guideline-based standards. Patients receive preoperative education, including simple template-based medication management instructions. Perioperative clinicians follow up on test results, adjust therapy, and counsel patients to optimize health in preparation for surgery.

Patients who present to the hospital and require urgent surgical intervention are most often admitted to the surgical service, and hospital medicine provides timely consultation for preoperative recommendations. At some institutions, protocols may dictate that certain surgical patients (eg, elderly with hip fracture) are admitted to the hospital medicine service. In these scenarios, the hospitalist serves as the primary inpatient care provider and ensures preoperative medical optimization and coordination with the surgical service to expedite plans for surgery.

Day of Surgery. On the day of surgery, the surgical team verifies all patient demographic and clinical information, confirms that all necessary documentation is complete (eg, consents, history, physical examination), and marks the surgical site. The anesthesia team performs a focused review and examination while explaining the perioperative care plan to the patient. Most often, the preoperative history and physical examination, completed by a preoperative clinic provider or the patient's PCP, is used by the anesthesiologist as the basis for clinical assessment. However, when information is incomplete or contradictory, surgery may be delayed for further record review and consultation.

Hospital medicine teams may be called to the pre-anesthesia holding area to evaluate acute medical problems (eg, hypertension, hyperglycemia, new-onset arrhythmia) or to give a second opinion in cases in which the anesthesiologist disagrees with the recommendations made by the provider who completed the preoperative evaluation. In either scenario, hospitalists must provide rapid service in close collaboration with anesthesiologists and surgeons. If a patient is found to be sufficiently optimized for surgery, the hospitalist clearly documents the evaluation and recommendation in the medical record. For a patient who requires further medical intervention before surgery, the hospitalist often coordinates the immediate disposition (eg, hospital admission or discharge home) and plans for optimization in the timeliest manner possible.

Occasionally, hospitalists are called to evaluate a patient in the postanesthesia care unit (PACU) for a new or chronic medical problem before the patient is transitioned to the next level of care. At most institutions, all PACU care is provided under the direction of anesthesiology, so it is imperative to collaborate with the patient's anesthesiologist for all recommendations. When a patient is to be discharged home, the hospitalist coordinates outpatient follow-up plans for any medical issues to be addressed postoperatively. Hospitalists also apply their knowledge of the limitations of non–intensive care unit hospital care to decisions regarding appropriate triage of patients being admitted after surgery.

Postoperative Inpatient. Hospitalists provide a 24/7 model of care that deploys a staff physician for prompt assessment and management of medical problems in surgical patients. This care can be provided as part of the duties of a standard hospital medicine team or can be delivered by a dedicated perioperative medical consultation and comanagement service. In either situation, the type of medical care, comanagement or consultation, is determined at the outset. As consultants, hospitalists provide recommendations for medical care but do not write orders or take primary responsibility for management. Comanagement agreements are common, especially for orthopedic surgery and neurosurgery; these agreements delineate the specific circumstances and responsibilities of the hospitalist and surgical teams. Indications for comanagement, which may be identified during preoperative clinic evaluation or on admission, include uncontrolled or multiple medical comorbidities or the development of nonsurgical complications in the perioperative period. In the comanagement model, care of most medical issues is provided at the discretion of the hospitalist. Although this care includes order-writing privileges, management of analgesics, wounds, blood products, and antithrombotics is usually reserved for the surgical team, with the hospitalist only providing recommendations. In some circumstances, hospitalists may determine that the patient's care requires consultation with other specialists. Although it is useful for the hospitalist to speak directly with other consultants and coordinate their recommendations, the surgical service should agree to the involvement of other services.

In addition to providing medical care throughout a patient's hospitalization, the hospitalist consultant is crucial in the discharge process. During the admission, ideally in collaboration with a pharmacist, the hospitalist reviews the home medications and may change chronic medications. The hospitalist may also identify specific postdischarge needs of which the surgical team is not fully aware. These medical plans are incorporated through shared responsibility for discharge orders or through a reliable mechanism for ensuring the surgical team assumes responsibility. Final medication reconciliation at discharge, and a plan for prior and new medications, can be formulated with pharmacy assistance. Finally, the hospitalist is responsible for coordinating medically related hospital follow-up and handover back to the patient's longitudinal care providers. The latter occurs through inclusion of medical care plans in the discharge summary completed by the surgical service and, in complex cases, through direct communication with the patient's outpatient providers.

For some patients, medical problems eclipse surgical care as the primary focus of management. Collaborative discussion between the medical and surgical teams helps determine if it is more appropriate for the medical team to become the primary service, with the surgical team consulting. Such triage decisions should be jointly made by the attending physicians of the services rather than by intermediaries.

Postdischarge. Similar to their being used for medical problems after hospitalization, hospitalist-led postdischarge and extensivist clinics may be used for rapid follow-up of medical concerns in patients discharged after surgical admissions. A key benefit of this model is increased availability over what primary care clinics may be able to provide on short notice, particularly for patients who previously did not have a PCP. Additionally, the handover of specific follow-up items is more streamlined because the transition of care is between hospitalists from the same institution. Through the postdischarge clinic, hospitalists can provide care through either clinic visits or telephone-based follow-up. Once a patient's immediate postoperative medical issues are fully stabilized, the patient can be transitioned to long-term primary care follow-up.

DISCUSSION

The United States is focused on sensible, high-value care. Perioperative care is burgeoning with opportunities for improvement, including reducing avoidable complications, developing systems for early recognition and treatment of complications, and streamlining processes to shorten length of stay and improve patient experience. The PCMIS provides the needed platform to catalyze detailed collaborative work between disciplines engaged in perioperative care.

As average age and level of medical comorbidity increase among surgical patients, hospitalists will increasingly be called on to assist in perioperative care. Hospitalists have long been involved in caring for medically complex surgical patients, through comanagement, consultation, and preoperative evaluations. As a provider group, hospitalists have comprehensive skills in quality and systems improvement, and in program development across hospital systems nationwide. Hospitalists have demonstrated their value by focusing on improving patient outcomes and enhancing patient engagement and experiences. Additionally, the perioperative period is fraught with multiple and complicated handoffs, a problem area for which hospital medicine has pioneered solutions and developed unique expertise. Hospital medicine is well prepared to provide skilled and proven leadership in the timely development, improvement, and expansion of perioperative care for this increasingly older and chronically ill population.

Hospitalists are established in multiple perioperative roles for high-risk surgical patients and have the opportunity to expand optimal patient-centric perioperative care systems working in close concert with surgeons and anesthesiologists. The basics of developing these systems include (1) assessing risk for medical complications, (2) planning for perioperative care, (3) developing programs aimed at risk reduction for preventable complications and early identification and intervention for unavoidable complications, and (4) guiding quality improvement efforts, including planning for frequent handoffs and transitions.

As a key partner in developing comprehensive programs in perioperative care, hospital medicine will continue to shape the future of hospital care for all patients. The PC-

MIS, as developed with support from the Society of Hospital Medicine, will aid efforts to achieve the best perioperative care models for our surgical patients.

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References

1. Colby SL, Ortman JM. *Projections of the Size and Composition of the U.S. Population: 2014 to 2060* (Current Population Reports, P25-1143). Washington, DC: US Census Bureau; 2014. https://www.census.gov/content/dam/Census/library/publications/2015/demo/p25-1143.pdf. Published March 2015. Accessed May 26, 2016.
2. Steiner C, Andrews R, Barrett M, Weiss A. *HCUP Projections: Cost of Inpatient Discharges 2003 to 2013* (Rep 2013-01). Rockville, MD: US Dept of Health and Human Services, Agency for Healthcare Research and Quality; 2013. http://www.hcup-us.ahrq.gov/reports/projections/2013-01.pdf. Published December 11, 2013. Accessed May 26, 2016.
3. Auerbach AD, Wachter RM, Cheng HQ, et al. Comanagement of surgical patients between neurosurgeons and hospitalists. *Arch Intern Med*. 2010;170(22):2004-2010.
4. Batsis JA, Phy MP, Melton LJ 3rd, et al. Effects of a hospitalist care model on mortality of elderly patients with hip fractures. *J Hosp Med*. 2007;2(4):219-225.
5. Carr AM, Irigoyen M, Wimmer RS, Arbeter AM. A pediatric residency experience with surgical co-management. *Hosp Pediatr*. 2013;3(2):144-148.
6. Della Rocca GJ, Moylan KC, Crist BD, Volgas DA, Stannard JP, Mehr DR. Comanagement of geriatric patients with hip fractures: a retrospective, controlled, cohort study. *Geriatr Orthop Surg Rehabil*. 2013;4(1):10-15.
7. Fisher AA, Davis MW, Rubenach SE, Sivakumaran S, Smith PN, Budge MM. Outcomes for older patients with hip fractures: the impact of orthopedic and geriatric medicine cocare. *J Orthop Trauma*. 2006;20(3):172-178.
8. Friedman SM, Mendelson DA, Kates SL, McCann RM. Geriatric co-management of proximal femur fractures: total quality management and protocol-driven care result in better outcomes for a frail patient population. *J Am Geriatr Soc*. 2008;56(7):1349-1356.
9. Huddleston JM, Long KH, Naessens JM, et al; Hospitalist-Orthopedic Team Trial Investigators. Medical and surgical comanagement after elective hip and knee arthroplasty: a randomized, controlled trial. *Ann Intern Med*. 2004;141(1):28-38.
10. Mendelson DA, Friedman SM. Principles of comanagement and the geriatric fracture center. *Clin Geriatr Med*. 2014;30(2):183-189.
11. Merli GJ. The hospitalist joins the surgical team. *Ann Intern Med*. 2004;141(1):67-69.
12. Phy MP, Vanness DJ, Melton LJ 3rd, et al. Effects of a hospitalist model on elderly patients with hip fracture. *Arch Intern Med*. 2005;165(7):796-801.
13. Pinzur MS, Gurza E, Kristopaitis T, et al. Hospitalist-orthopedic co-management of high-risk patients undergoing lower extremity reconstruction surgery. *Orthopedics*. 2009;32(7):495.
14. Rappaport DI, Adelizzi-Delany J, Rogers KJ, et al. Outcomes and costs associated with hospitalist comanagement of medically complex children undergoing spinal fusion surgery. *Hosp Pediatr*. 2013;3(3):233-241.
15. Rappaport DI, Cerra S, Hossain J, Sharif I, Pressel DM. Pediatric hospitalist preoperative evaluation of children with neuromuscular scoliosis. *J Hosp Med*. 2013;8(12):684-688.
16. Roy A, Heckman MG, Roy V. Associations between the hospitalist model of care and quality-of-care-related outcomes in patients undergoing hip fracture surgery. *Mayo Clin Proc*. 2006;81(1):28-31.
17. Sharma G, Kuo YF, Freeman J, Zhang DD, Goodwin JS. Comanagement of hospitalized surgical patients by medicine physicians in the United States. *Arch Intern Med*. 2010;170(4):363-368.
18. Simon TD, Eilert R, Dickinson LM, Kempe A, Benefield E, Berman S. Pediatric hospitalist comanagement of spinal fusion surgery patients. *J Hosp Med*. 2007;2(1):23-30.
19. Whinney C, Michota F. Surgical comanagement: a natural evolution of hospitalist practice. *J Hosp Med*. 2008;3(5):394-397.

Updating the Core Competencies in Hospital Medicine—2017 Revision: Introduction and Methodology

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In 2006, the Society of Hospital Medicine (SHM) first published *The Core Competencies in Hospital Medicine: A Framework for Curricular Development* (henceforth described as the Core Competencies) to help define the role and expectations of hospitalists.[1,2] The Core Competencies provided a framework for evaluating clinical skills and professional expertise within a rapidly developing field and highlighted opportunities for growth. Since the initial development and publication of the Core Competencies, changes in the healthcare landscape and hospitalist practice environment have prompted this revision.

Over the past decade, the field of hospital medicine has experienced exponential growth. In 2005, just over 16,000 hospitalists were practicing in the United States. By 2015, that number had increased to an estimated 44,000 hospitalists, accounting for approximately 6% of the physician workforce.[3] Hospitalists have expanded the scope of hospital medicine in many ways. In their roles, hospitalists lead and participate in hospital-based care models that emphasize interprofessional collaboration and a focus on the delivery of high-quality and cost-effective care across a variety of clinical domains (eg, the Choosing Wisely initiative).[4] They are also engaged in patient safety and quality initiatives that are increasingly being used as benchmarks to rate hospitals and as factors for hospital payment (eg, Hospital Inpatient Value-Based Purchasing Program).[5] In fact, the American Board of Internal Medicine (ABIM) created a Focused Practice in Hospital Medicine Maintenance of Certification program in response to the growing number of internists choosing to concentrate their practice in the hospital setting. This decision by the ABIM underscores the value that hospitalists bring to improving patient care in the hospital setting. The ABIM also recognizes the Core Competencies as a curricular framework for a focused practice in hospital medicine.[6]

Changes within the educational environment have demanded attentive and active participation by many hospitalists. For example, in 2012, the Accreditation Council for Graduate Medical Education (ACGME) introduced the Milestones Project, a new outcomes-based framework designed to more effectively assess learner performance across the 6 core competencies.[7] These milestones assessments create intentional opportunities to guide the development of physicians during their training, including in the inpatient environments in which hospitalists practice. Where applicable, existing Core Competencies learning objectives were compared with external sources such as the individual ACGME performance milestones for this revision.

THE CORE COMPETENCIES

The Core Competencies focus on adult hospital medicine. The Pediatric Hospital Medicine Core Competencies are published separately.[8] Importantly, the Core Competencies document is not intended to define an absolute set of clinical, procedural, or system-based topics described in textbooks or used by graduate medical education training programs. It does not define or limit the scope of the practice of hospital medicine. Rather, the Core Competencies serve as measurable learning objectives that encourage teaching faculty, practicing hospitalists, and administrators to develop individual skill sets and programs to improve patient care contextualized to the needs of an individual, care setting, or institution. To permit this flexibility, individual chapter-specific objectives are intentionally general in nature. Finally, the Core Competencies document is not a set of practice guidelines, nor does it offer any representation of a "standard of care." Readers are encouraged to explore the article by McKean et al.[9] to review examples of application of the Core Competencies and suggestions for curricular development.

The purpose of this article is to describe the criteria for inclusion of new chapters in the Core Competencies and the methodology of the review and revision process. It outlines the process of initial review and editing of the existing chapters; needs assessment for new topics; new chapter production; and the process of review and revision of individual chapters to create the complete document. The revised Core Competencies document is available online at http://www.journalofhospitalmedicine.com.

REVIEW AND REVISION PROCESS

In 2012, the Society of Hospital Medicine (SHM) Education Committee created a Core Competencies Task Force (CCTF) in response to the SHM Board of Directors' charge

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TABLE 1. Topics Considered for Inclusion in the 2017 Revision of the Core Competencies in Hospital Medicine

Section 1: Clinical Conditions
1. Acute Diarrhea
2. Acute Pancreatitis
3. Acute Poisoning and Drug Toxicity
4. Anemia and Transfusion Medicine
5. Cirrhosis
6. Depression and Suicidal Attempt
7. Fever of Unknown Origin
8. Hypertensive Crisis
9. Hyponatremia
10. Sickle Cell Disease
11. Syncope
Section 2: Procedures
1. Arterial Blood Gas Interpretation
2. Nasogastric Intubation
3. Point-of-Care Ultrasonography
4. Urinary Catheterization
5. Urine Microscopy Interpretation
Section 3: Healthare Systems
1. Remote Monitoring and Evaluation (Telemedicine)
2. Research

that it review and update the initial Core Competencies document. The CCTF comprised of 5 physician SHM Education Committee members and one SHM staff representative. CCTF membership included hospitalists with an interest and familiarity with the Core Competencies document. The SHM Education Committee nominated the CCTF chair, who determined the optimal size, qualifications, and composition of the task force with approval from the Committee. The CCTF communicated through frequent conference calls and via e-mail correspondence to conduct an initial review of the existing chapters and to perform a needs assessment for new topics.

Individual Chapter Review

The SHM Education Committee provided critical input and approved the chapter review process designed by the CCTF (Figure). The CCTF reviewed each chapter of the Core Competencies document to assess its continuing relevance to the field of hospital medicine with a standardized tool (Appendix 1). The process required that at least 2 CCTF members reviewed each chapter. Preliminary reviewers assessed the current relevance of each chapter, determined whether individual learning objectives required additional investigation or modification, and developed new learning objectives to fill any educational gaps. All CCTF members then discussed assimilated feedback from the initial CCTF review, using consensus decision making to determine chapter changes and modifications. The CCTF found each of the existing chapters to be relevant to the field and identified none for removal.

The CCTF rewrote all chapters. It then disseminated proposed chapter changes to a panel of diverse independent reviewers to solicit suggestions and comments to ensure a multidisciplinary and balanced review process. Independent reviewers included authors of the original Core Competencies chapters, invited content experts, and members of the SHM Education Committee. When appropriate, corresponding SHM Committees reviewed individual chapters for updates and revisions. For example, the SHM Hospital Quality and Patient Safety Committee reviewed the chapters on patient safety and quality improvement, and the SHM Practice Management Committee reviewed the chapter on management practices. Four CCTF section editors managed an independent portfolio of chapters. Each CCTF section editor assimilated the various draft versions, corresponded with individual reviewers when necessary, and compiled the changes into a subsequent draft. This process ensured that the final version of every chapter reflected the thoughtful input from all parties involved in the review. Throughout the process, the CCTF used consensus decision making to adjudicate chapter changes and modifications. The 2006 Core Competencies Editorial team also reviewed the revision and provided critical input. The SHM Education Committee and the SHM Board of Directors reviewed and approved the final version of the Core Competencies document.

Needs Assessment and Selection of New Core Competency Chapters

The CCTF issued a call for new topics to the members of the SHM Education Committee for inclusion in the Core Competencies. Topics were also identified from the following sources: the top 100 adult medical diagnoses at hospital discharge in the Healthcare Cost and Utilization Project database in 2010; topics in hospital medicine textbooks; curricula presented at the 3 most recent SHM annual meetings; and responses from SHM annual meeting surveys. Table 1 lists the topics considered for addition.

Members of the SHM Education Committee rated each of the potential topics considered for inclusion based on the following characteristics: relevance to the field of hospital medicine; intersection of the topic with medical subspecialties; and its appropriateness as a separate, stand-alone chapter. In addition, topics more frequently encountered by hospitalists, those deemed clinically important with a known risk of complications or management inconsistencies, and those with significant opportunities for quality improvement initiatives carried more weight. Syncope and hyponatremia were the only 2 clinical conditions identified that met all of the inclusion criteria. No additional topics met the criteria for new chapter development in the Procedures or Healthcare Systems sections. The SHM Education Committee identified the use of point-of-care ultrasonography as an important advancement in the field. Where appropriate, the individual procedure chapters now include a new competency-

based objective highlighting its role. In addition, a separate SHM task force is working to develop a practice guideline for the use of point-of-care ultrasonography by hospitalists.

Contributors

The SHM Education Committee determined authorship for the new chapters (syncope and hyponatremia). It assigned 2 CCTF members with content expertise and familiarity with the Core Competencies to each author one chapter. Given the limited number of new chapters, it made a decision to develop the content internally rather than through an open-call for authorship nominations to practicing SHM members. The authors made an effort to maintain consistency with the educational theory used to develop the initial Core Competencies. Each of the new topics underwent rigorous review as previously described, including additional independent reviews by hospitalists with content expertise in these areas.

CHAPTER FORMAT AND CONTENT CHANGES

Following the same format as the earlier version, the 2017 Core Competencies revision contains 53 chapters, divided into 3 sections—Clinical Conditions, Procedures, and Healthcare Systems (Table 2) —all integral components of the practice of hospital medicine. The design allows individual chapters to stand alone. However, each chapter should be considered in the context of the entire document because a particular concept may be only briefly discussed in one chapter, but described in greater depth in another given the potential overlap across topics.

The chapters maintain the same content structure as the original version. Each chapter begins with an introductory paragraph followed by a list of competency-based objectives grouped in subsections according to the educational theory of learning domains: cognitive (knowledge), psychomotor (skills), and affective (attitudes).[10] In addition, a subsection for System Organization and Improvement is included in the Clinical Conditions and Procedure chapters to emphasize the importance of interprofessional collaboration for optimal patient care. These subsections were not included in the Healthcare Systems chapters, as system organization and improvement is intrinsic to these subjects.

The introductory paragraph provides background information and describes how the chapter remains relevant to the current practice of hospital medicine. Individual competency-based objectives outline a relevant concept and expected level of proficiency as defined by Bloom's taxonomy.[10] New objectives reflect changes in the healthcare landscape over the past decade or further enhance each chapter's concepts. Chapter authors made an effort to develop chapter

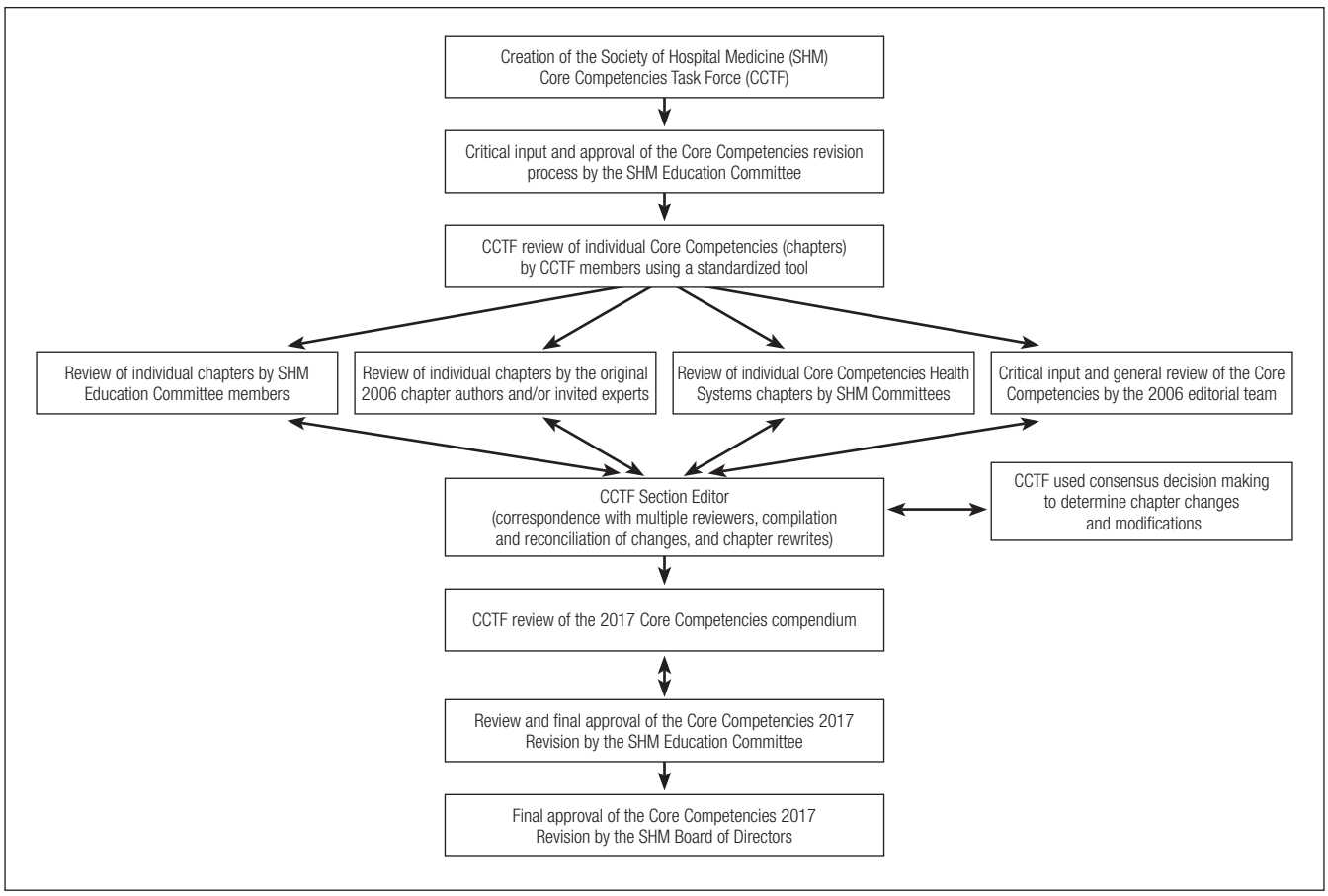

FIG. The chapter review process.

TABLE 2. The Core Competencies in Hospital Medicine—2017 Revision: List of Chapters[a]

Section 1: Clinical Conditions	Section 2: Procedures	Section 3: Healthcare Systems
1. Acute Coronary Syndrome	1. Arthrocentesis	1. Care of the Older Patient
2. Acute Kidney Injury	2. Chest Radiograph Interpretation	2. Care of Vulnerable Populations
3. Alcohol and Drug Withdrawal	3. Electrocardiogram Interpretation and Telemetry Monitoring	3. Communication
4. Asthma	4. Emergency Procedures	4. Diagnostic Decision Making
5. Cardiac Arrhythmia	5. Lumbar Puncture	5. Drug Safety, Pharmacoeconomics, and Pharmacoepidemiology
6. Chronic Obstructive Pulmonary Disease	6. Paracentesis	6. Equitable Allocation of Resources
7. Community-Acquired Pneumonia	7. Thoracentesis	7. Evidence-Based Medicine
8. Heart Failure	8. Vascular Access	8. Hospitalist as Educator
9. Delirium and Dementia		9. Information Management
10. Diabetes Mellitus		10. Leadership
11. Gastrointestinal Bleed		11. Management Practices
12. Hospital-Acquired Pneumonia		12. Medical Consultation and Comanagement
13. *Hyponatremia*		13. Nutrition and the Hospitalized Patient
14. Pain Management		14. Palliative Care
15. Perioperative Medicine		15. Patient Education
16. Sepsis Syndrome		16. Patient Handoff
17. Skin and Soft Tissue Infections		17. Patient Safety
18. Stroke		18. Practice-Based Learning and Improvement
19. *Syncope*		19. Prevention of Healthcare–Associated Infections and Antimicrobial Resistance
20. Urinary Tract Infection		20. Professionalism and Medical Ethics
21. Venous Thromboembolism		21. Quality Improvement
		22. Risk Management
		23. Team Approach and Multidisciplinary Care
		24. Transitions of Care

[a]New topics are italicized.

TABLE 3. Highlighted Changes in the 2017 Revision of the Core Competencies in Hospital Medicine

Two additional clinical chapters
• Hyponatremia
• Syncope
Chapters with more substantive updates compared to the others
• Delirium and Dementia
• Hospital-Acquired Pneumonia
• Palliative Care
• Quality Improvement
• Transitions of Care

Chapter name changes	
New Name	**Previous Name**
Acute Kidney Injury	Acute Renal Failure
Skin and Soft Tissue Infections	Cellulitis
Heart Failure	Congestive Heart Failure
Electrocardiogram Interpretation and Telemetry Monitoring	Electrocardiogram Interpretation
Care of the Older Patient	Care of the Elderly Patient
Medical Consultation and Comanagement	Hospitalist as Consultant
Hospitalist as Educator	Hospitalist as Teacher

and learning objective concepts that are consistent with external resources such as the ACGME Milestones Project and practice guideline objectives developed by a variety of professional organizations.

SUMMARY AND FUTURE DIRECTIONS

The Core Competencies document serves as a resource for hospitalists and hospital medicine programs to evaluate, develop, and improve individual and collective skills and the practice environment. The Core Competencies also provide a framework for medical school clerkship directors and residency and fellowship program directors, as well as course directors of Continuing Medical Education programs, to develop curricula to enhance educational experiences for trainees and hospital medicine providers. The updates in every chapter in this revision to the Core Competencies reflects the changes in the healthcare landscape and hospitalist practice environment over the past decade, and we encourage readers to revisit the entire compendium. Table 3 highlights some of the salient changes in this revision.

Hospital medicine continues to evolve as a specialty. The Core Competencies define hospitalists as agents of change and foster the development of a culture of safe and effective patient care within the hospital environment. Although the

CCTF hopes that the Core Competencies will preserve their relevance over time, it recognizes the importance of their periodic reevaluation and adaptation. Additionally, SHM developed the Core Competencies primarily for physicians practicing as hospitalists. As the number of physician assistants and nurse practitioners engaged in the practice of hospital medicine increases, and hospital medicine expands into nontraditional specialties such as surgical comanagement, it may be necessary to consider the development of additional or separate Hospital Medicine Core Competencies tailored to the needs of these subsets of clinicians.

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References

1. The core competencies in hospital medicine: a framework for curriculum development by the society of hospital medicine. *J Hosp Med*. 2006;1 Suppl 1:2-95.
2. Dressler DD, Pistoria MJ, Budnitz TL, McKean SCW, Amin AN. Core competencies in hospital medicine: development and methodology. *J Hosp Med*. 2006;1(1):48-56.
3. Hospital Medicine News, Society of Hospital Medicine. http://www.hospitalmedicine.org/press. Accessed June 16, 2016.
4. Bulger J, Nickel W, Messler J, et al. Choosing wisely in adult hospital medicine: five opportunities for improved healthcare value. *J Hosp Med*. 2013;8(9):486-492.
5. Conway PH. Value-driven health care: implications for hospitals and hospitalists. *J Hosp Med*. 2009;4(8):507-511.
6. American Board of Internal Medicine. Questions and Answers Regarding ABIM's Maintenance of Certification in Internal Medicine with a Focused Practice in Hospital Medicine Program. 2009. http://www.abim.org/news/focused-practice-hospital-medicine-questions-answers.aspx. Accessed November 11, 2016.
7. The Internal Medicine Milestone Project. http://www.acgme.org/acgmeweb/portals/0/pdfs/milestones/internalmedicinemilestones.pdf. Accessed February 29, 2016.
8. Stucky ER, Ottolini MC, Maniscalco J. Pediatric hospital medicine core competencies: development and methodology. *J Hosp Med*. 2010;5(6):339-343.
9. McKean SC, Budnitz TL, Dressler DD, Amin AN, Pistoria MJ. How to use the core competencies in hospital medicine: a framework for curriculum development. *J Hosp Med*. 2006;1 Suppl 1:57-67.
10. Anderson LW, Krathwohl DR (eds). *A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Outcomes. Complete edition*. New York, NY: Longman; 2001.


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