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EDITORIALS

Association Between Postdischarge Emergency Department Visitation and Readmission Rates

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BACKGROUND: Hospital readmission rates are publicly reported by the Centers for Medicare & Medicaid Services (CMS); however, the implications of emergency department (ED) visits following hospital discharge on readmissions are uncertain. We describe the frequency, diagnoses, and hospital-level variation in ED visitation following hospital discharge, including the relationship between risk-standardized ED visitation and readmission rates.

METHODS: This is a cross-sectional analysis of Medicare beneficiaries hospitalized for acute myocardial infarction (AMI), heart failure, and pneumonia between July 2011 and June 2012. We used Medicare Standard Analytic Files to identify admissions, readmissions, and ED visits consistent with CMS measures. Postdischarge ED visits were defined as treat-and-discharge ED services within 30 days of hospitalization without readmission. We utilized hierarchical generalized linear models to calculate hospital risk–standardized postdischarge ED visit rates and readmission rates.

RESULTS: We included 157,035 patients hospitalized at 1,656 hospitals for AMI, 391,209 at 3,044 hospitals for heart failure, and 342,376 at 3,484 hospitals for pneumonia. After hospitalization for AMI, heart failure, and pneumonia, there were 14,714 (9%), 31,621 (8%), and 26,681 (8%) ED visits, respectively. Hospital-level variation in postdischarge ED visit rates was substantial: AMI (median: 8.3%; 5th and 95th percentile: 2.8%-14.3%), heart failure (median: 7.3%; 5th and 95th percentile: 3.0%-13.3%), and pneumonia (median: 7.1%; 5th and 95th percentile: 2.4%-13.2%). There was statistically significant inverse correlation between postdischarge ED visit rates and readmission rates: AMI (−0.23), heart failure (−0.29), and pneumonia (−0.18).

CONCLUSIONS: Following hospital discharge, ED treat-and-discharge visits are half as common as readmissions for Medicare beneficiaries. There is wide hospital-level variation in postdischarge ED visitation, and hospitals with higher ED visitation rates demonstrated lower readmission rates. *Journal of Hospital Medicine* 2018;13:589-594. Published online first March 15, 2018. © 2018 Society of Hospital Medicine

Hospital readmissions for acute myocardial infarction (AMI), heart failure, and pneumonia have become central to quality-measurement efforts by the Centers for Medicare & Medicaid Services (CMS), which seek to improve hospital care transitions through public reporting and payment programs.[1] Most current measures are limited to readmissions that require inpatient hospitalization and do not capture return visits to the emergency department (ED) that do not result in readmission but rather ED discharge. These visits may reflect important needs for acute, unscheduled care during the vulnerable posthospitalization period.[2-5] While previous research has suggested that nearly 10% of patients may return to the ED following hospital discharge without readmission, the characteristics of these visits among Medicare beneficiaries and the implications for national care-coordination quality-measurement initiatives have not been explored.[6,7]

As the locus of acute outpatient care and the primary portal of hospital admissions and readmissions, ED visits following hospital discharge may convey meaningful information about posthospitalization care transitions.[8,9] In addition, recent reviews and perspectives have highlighted the role of ED care-coordination services as interventions to reduce inpatient hospitalizations and improve care transitions,[10,11] yet no empirical studies have evaluated the relationship between these unique care-coordination opportunities in the ED and care-coordination outcomes, such as hospital readmissions. As policymakers seek to develop accountability measures that capture the totality of acute, unscheduled visits following hospital

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discharge, describing the relationship between ED visits and readmissions will be essential to providers for benchmarking and to policymakers and payers seeking to reduce the total cost of care.[12,13]

Accordingly, we sought to characterize the frequency, diagnoses, and hospital-level variation in treat-and-discharge ED visitation following hospital discharge for three conditions for which hospital readmission is publicly reported by the CMS: AMI, heart failure, and pneumonia. We also sought to evaluate the relationship between hospital-level ED visitation following hospital discharge and publicly reported, risk-standardized readmission rates (RSRRs).

METHODS

Study Design

This study was a cross-sectional analysis of Medicare beneficiaries discharged alive following hospitalization for AMI, heart failure, and pneumonia between July 2011 and June 2012.

Selection of Participants

We used Medicare Standard Analytic Files to identify inpatient hospitalizations for each disease cohort based on principal discharge diagnoses. Each condition-specific cohort was constructed to be consistent with the CMS's readmission measures using *International Classification of Diseases, 9th Revision-Clinical Modification* codes to identify AMI, heart failure, and pneumonia discharges.[1] We included only patients who were enrolled in fee-for-service (FFS) Medicare parts A and B for 12 months prior to their index hospitalization to maximize the capture of diagnoses for risk adjustment. Each cohort included only patients who were discharged alive while maintaining FFS coverage for at least 30 days following hospital discharge to minimize bias in outcome ascertainment. We excluded patients who were discharged against medical advice. All contiguous admissions that were identified in a transfer chain were considered to be a single admission. Hospitals with fewer than 25 condition-specific index hospital admissions were excluded from this analysis for consistency with publicly reported measures.[1]

Measurements

We measured postdischarge, treat-and-release ED visits that occurred at any hospital within 30 days of hospital discharge from the index hospitalization. ED visits were identified as a hospital outpatient claim for ED services using hospital outpatient revenue center codes 0450, 0451, 0452, 0456, and 0981. This definition is consistent with those of previous studies.[3,14] We defined postdischarge ED visits as treat-and-discharge visits or visits that did not result in inpatient readmission or observation stays. Similar to readmission measures, only one postdischarge ED visit was counted toward the hospital-level outcome in patients with multiple ED visits within the 30 days following hospital discharge. We defined readmission as the first unplanned, inpatient hospitalization occurring at any hospital within the 30-day period following discharge. Any subsequent inpatient admission following the 30-day period was considered a distinct index admission if it met the inclusion criteria. Consistent with CMS methods, unplanned, inpatient readmissions are from any source and are not limited to patients who were first evaluated in the ED.

Outcomes

We describe hospital-level, postdischarge ED visitation as the risk-standardized postdischarge ED visit rate. The general construct of this measure is consistent with those of prior studies that define postdischarge ED visitation as the proportion of index admissions followed by a treat-and-discharge ED visit without hospital readmission[2,3]; however, this outcome also incorporates a risk-standardization model with covariates that are identical to the risk-standardization approach that is used for readmission measurement.

We describe hospital-level readmission by calculating RSRRs consistent with CMS readmission measures, which are endorsed by the National Quality Forum and used for public reporting.[15-17] Detailed technical documentation, including the SAS code used to replicate hospital-level measures of readmission, are available publicly through the CMS QualityNet portal.[18]

We calculated risk-standardized postdischarge ED visit rates and RSRRs as the ratio of the predicted number of postdischarge ED visits or readmissions for a hospital given its observed case mix to the expected number of postdischarge ED visits or readmissions based on the nation's performance with that hospital's case mix, respectively. This approach estimates a distinct risk-standardized postdischarge ED visit rate and RSRR for each hospital using hierarchical generalized linear models (HGLMs) and using a logit link with a first-level adjustment for age, sex, 29 clinical covariates for AMI, 35 clinical covariates for heart failure, and 38 clinical covariates for pneumonia. Each clinical covariate is identified based on inpatient and outpatient claims during the 12 months prior to the index hospitalization. The second level of the HGLM includes a random hospital-level intercept. This approach to measuring hospital readmissions accounts for the correlated nature of observed readmission rates within a hospital and reflects the assumption that after adjustment for patient characteristics and sampling variability, the remaining variation in postdischarge ED visit rates or readmission rates reflects hospital quality.

Analysis

In order to characterize treat-and-discharge postdischarge ED visits, we first described the clinical conditions that were evaluated during the first postdischarge ED visit. Based on the principal discharge diagnosis, ED visits were grouped into clinically meaningful categories using the Agency for Healthcare Research and Quality Clinical Classifications Software (CCS).[19] We also report hospital-level variation in risk-standardized postdischarge ED visit rates for AMI, heart failure, and pneumonia.

Next, we examined the relationship between hospital characteristics and risk-standardized postdischarge ED visit rates. We linked hospital characteristics from the American Hospital Association (AHA) Annual Survey to the study dataset, including the following: safety-net status, teaching status, and urban

TABLE. **Postdischarge ED Visit Rates Based on Hospital Characteristics**

	AMI				Heart Failure				Pneumonia			
Hospital Characteristics	**Hospitals, N**	**Observed Postdischarge ED Visit Rate, % (95% CI)**	**Risk-Standardized Postdischarge ED Visit Rate, % (95% CI)**	**RSRR, % (95% CI)**	**Hospitals, N**	**Observed Postdischarge ED Visit Rate, % (95% CI)**	**Risk-Standardized Postdischarge ED Visit Rate, % (95% CI)**	**RSRR, % (95% CI)**	**Hospitals, N**	**Observed Postdischarge ED Visit Rate, % (95% CI)**	**Risk-Standardized Postdischarge ED Visit Rate, % (95% CI)**	**RSRR, % (95% CI)**
Teaching Status												
Nonteaching	978	8.7 (8.4 to 8.9)	8.6 (8.5 to 8.7)	17.5 (17.4 to 17.6)	2183	8.2 (8.1 to 8.4)	7.8 (7.7 to 7.9)	22.5 (22.4 to 22.5)	2634	7.9 (7.8 to 8)	7.6 (7.5 to 7.6)	17.2 (17.2 to 17.3)
Teaching	611	8.5 (8.2 to 8.7)	8.6 (8.5 to 8.7)	17.6 (17.5 to 17.7)	723	7.2 (7 to 7.4)	7.2 (7.1 to 7.3)	22.2 (22.1 to 22.4)	708	6.9 (6.7 to 7.1)	7.1 (7 to 7.2)	17.3 (17.2 to 17.4)
Location												
Rural	14	12.8 (10 to 15.6)	10.1 (9 to 11.2)	17.2 (16.7 to 17.7)	316	10.2 (9.6 to 10.8)	8.4 (8.2 to 8.6)	22.7 (22.5 to 22.8)	582	9.3 (8.9 to 9.6)	8.0 (7.9 to 8.1)	17.2 (17.2 to 17.3)
Urban	1,575	8.5 (8.4 to 8.7)	8.6 (8.5 to 8.7)	17.5 (17.5 to 17.6)	2590	7.7 (7.6 to 7.8)	7.5 (7.5 to 7.6)	22.4 (22.3 to 22.4)	2760	7.4 (7.3 to 7.5)	7.4 (7.3 to 7.4)	17.2 (17.2 to 17.3)
Ownership												
Public	158	8.8 (8.2 to 9.3)	8.6 (8.4 to 8.8)	17.6 (17.5 to 17.8)	422	8.7 (8.4 to 9)	8.0 (7.9 to 8.2)	22.2 (22.1 to 22.4)	591	8.4 (8 to 8.7)	7.7 (7.6 to 7.9)	17.2 (17.1 to 17.2)
Nonprofit	1,160	8.6 (8.4 to 8.8)	8.6 (8.5 to 8.7)	17.5 (17.5 to 17.6)	1936	7.7 (7.6 to 7.9)	7.5 (7.4 to 7.6)	22.3 (22.3 to 22.4)	2191	7.5 (7.4 to 7.6)	7.4 (7.3 to 7.4)	17.2 (17.2 to 17.3)
Private	271	8.1 (7.7 to 8.6)	8.4 (8.3 to 8.6)	17.6 (17.5 to 17.8)	548	7.7 (7.5 to 8)	7.5 (7.4 to 7.7)	22.6 (22.5 to 22.8)	560	7.3 (7 to 7.5)	7.3 (7.2 to 7.4)	17.3 (17.2 to 17.4)
Safety-Net Status												
Nonsafety net	1,324	8.6 (8.4 to 8.7)	8.6 (8.5 to 8.7)	17.5 (17.5 to 17.6)	2273	7.7 (7.6 to 7.8)	7.5 (7.4 to 7.6)	22.4 (22.3 to 22.4)	2505	7.5 (7.3 to 7.6)	7.3 (7.3 to 7.4)	17.3 (17.2 to 17.3)
Safety net	265	8.6 (8.2 to 9.1)	8.6 (8.4 to 8.7)	17.7 (17.6 to 17.8)	633	8.4 (8.1 to 8.7)	7.8 (7.7 to 8)	22.4 (22.2 to 22.5)	837	8.2 (8 to 8.5)	7.7 (7.6 to 7.8)	17.2 (17.1 to 17.2)

NOTE: Included are 1,564 of 1,656 hospitals (94%) for AMI, 2,839 of 3,044 hospitals (93%) for heart failure, and 3,266 of 3,484 of hospitals (94%) with hospital characteristics available. Abbreviations: AMI, acute myocardial infarction; CI, confidence interval; ED, emergency department.

or rural status. Consistent with prior work, hospital safety-net status was defined as a hospital Medicaid caseload greater than one standard deviation above the mean Medicaid caseload in the hospital's state. Approximately 94% of the hospitals included in the three condition cohorts in the dataset had complete data in the 2011 AHA Annual Survey to be included in this analysis.

We evaluated the relationship between postdischarge ED visit rates and hospital readmission rates in two ways. First, we calculated Spearman rank correlation coefficients between hospital-level, risk-standardized postdischarge ED visit rates and RSRRs. Second, we calculated hospital-level variation in RSRRs based on the strata of risk-standardized postdischarge ED visit rates. Given the normal distribution of postdischarge ED visit rates, we grouped hospitals by quartile of postdischarge ED visit rates and one group for hospitals with no postdischarge ED visits.

Based on preliminary analyses indicating a relationship between hospital size, measured by condition-specific index hospitalization volume, and postdischarge treat-and-discharge ED visit rates, all descriptive statistics and correlations reported are weighted by the volume of condition-specific index hospitalizations. The study was approved by the Yale University Human Research Protection Program. All analyses were conducted using SAS 9.1 (SAS Institute Inc, Cary, North Carolina). The analytic plan and results reported in this work are in compliance with the Strengthening the Reporting of Observational Studies in Epidemiology checklist.[20]

RESULTS

During the one-year study period, we included a total of 157,035 patients who were hospitalized at 1,656 hospitals for AMI, 391,209 at 3,044 hospitals for heart failure, and 342,376 at 3,484 hospitals for pneumonia. Details of study cohort creation are available in supplementary Table 1. After hospitalization for AMI, 14,714 patients experienced a postdischarge ED visit (8.4%) and 27,214 an inpatient readmissions (17.3%) within 30 days of discharge; 31,621 (7.6%) and 88,106 (22.5%) patients after hospitalization for heart failure; and 26,681 (7.4%) and 59,352 (17.3%) patients after hospitalization for pneumonia experienced a postdischarge ED visit and an inpatient readmission within 30 days of discharge, respectively.

Postdischarge ED visits were for a wide variety of conditions, with the top 10 CCS categories comprising 44% of postdischarge ED visits following AMI hospitalizations, 44% of following heart failure hospitalizations, and 41% following pneumonia hospitalizations (supplementary Table 2). The first postdischarge ED visit was rarely for the same condition as the index hospitalization in the AMI cohort (224 visits; 1.5%) as well as the pneumonia cohort (1,401 visits; 5.3%). Among patients who were originally admitted for heart failure, 10.6% of the first postdischarge ED visits were also for heart failure. However, the first postdischarge ED visit was commonly for associated conditions, such as coronary artery disease in the case of AMI or chronic obstructive pulmonary disease in the case of pneumonia, albeit these related conditions did not comprise the majority of postdischarge ED visitation.

We found wide hospital-level variation in postdischarge ED visit rates for each condition: AMI (median: 8.3%; 5th and 95th percentile: 2.8%-14.3%), heart failure (median: 7.3%; 5th and 95th percentile: 3.0%-13.3%), and pneumonia (median: 7.1%; 5th and 95th percentile: 2.4%-13.2%; supplementary Table 3). The variation persisted after accounting for hospital case mix, as evidenced in the supplementary Figure, which describes hospital variation in risk-standardized postdischarge ED visit rates. This variation was statistically significant ($P < .001$), as demonstrated by the isolated relationship between the random effect and the outcome (AMI: random effect estimate 0.0849 [95% confidence interval (CI), 0.0832 to 0.0866]; heart failure: random effect estimate 0.0796 [95% CI, 0.0784 to 0.0809]; pneumonia: random effect estimate 0.0753 [95% CI, 0.0741 to 0.0764]).

Across all three conditions, hospitals located in rural areas had significantly higher risk-standardized postdischarge ED visit rates than hospitals located in urban areas (10.1% vs 8.6% for AMI, 8.4% vs 7.5% for heart failure, and 8.0% vs 7.4% for pneumonia). In comparison to teaching hospitals, nonteaching hospitals had significantly higher risk-standardized postdischarge ED visit rates following hospital discharge for pneumonia (7.6% vs 7.1%). Safety-net hospitals also had higher risk-standardized postdischarge ED visitation rates following discharge for heart failure (8.4% vs 7.7%) and pneumonia (7.7% vs 7.3%). Risk-standardized postdischarge ED visit rates were higher in publicly owned hospitals than in nonprofit or privately owned hospitals for heart failure (8.0% vs 7.5% in nonprofit hospitals or 7.5% in private hospitals) and pneumonia (7.7% vs 7.4% in nonprofit hospitals and 7.3% in private hospitals; Table).

Among hospitals with RSRRs that were publicly reported by CMS, we found a moderate inverse correlation between risk-standardized postdischarge ED visit rates and hospital RSRRs for each condition: AMI ($r = -0.23$; 95% CI, −0.29 to −0.19), heart failure ($r = -0.29$; 95% CI, −0.34 to −0.27), and pneumonia ($r = -0.18$; 95% CI, −0.22 to −0.15; Figure).

DISCUSSION

Across a national cohort of Medicare beneficiaries, we found frequent treat-and-discharge ED utilization following hospital discharge for AMI, heart failure, and pneumonia, suggesting that publicly reported readmission measures are capturing only a portion of postdischarge acute-care use. Our findings confirm prior work describing a 30-day postdischarge ED visit rate of 8% to 9% among Medicare beneficiaries for all hospitalizations in several states.[3,6] While many of the first postdischarge ED visits were for conditions related to the index hospitalization, the majority represent acute, unscheduled visits for different diagnoses. These findings are consistent with prior work studying inpatient readmissions and observation readmissions that find similar heterogeneity in the clinical reasons for hospital return.[21,22]

We also described substantial hospital-level variation in risk-standardized ED postdischarge rates. Prior work by Vashi et al.[3] demonstrated substantial variation in observed postdischarge ED visit rates and inpatient readmissions following hospital discharge between clinical conditions in a population-level study. Our work extends upon this by demonstrating hospital-level variation for three conditions of high volume and substantial policy importance after accounting for differences in hospital case mix. Interestingly, our work also found similar rates of postdischarge ED treat-and-discharge visitation in recent work by Sabbatini et al.[23] analyzing an all-payer, adult population with any clinical condition. Taken together, these studies show the substantial volume of postdischarge acute-care utilization in the ED not captured by existing readmission measures.

We found several hospital characteristics of importance in describing variation in postdischarge ED visitation rates. Notably, hospitals located in rural areas and safety-net hospitals demonstrated higher postdischarge ED visitation rates. This may reflect a higher use of the ED as an acute, unscheduled care access point in rural communities without access to alternative acute diagnostic and treatment services.[24] Similarly, safety-net hospitals may be more likely to provide unscheduled care for patients with poor access to primary care in the ED setting. Yet, consistent with prior work, our results also indicate that these differences do not result in different readmission rates.[25] Regarding hospital teaching status, unlike prior work suggesting that teaching hospitals care for more safety-net Medicare beneficiaries,[26] our work found opposite patterns of postdischarge ED visitation between hospital teaching and safety-net status following pneumonia hospitalization. This may reflect differences in the organization of acute care as

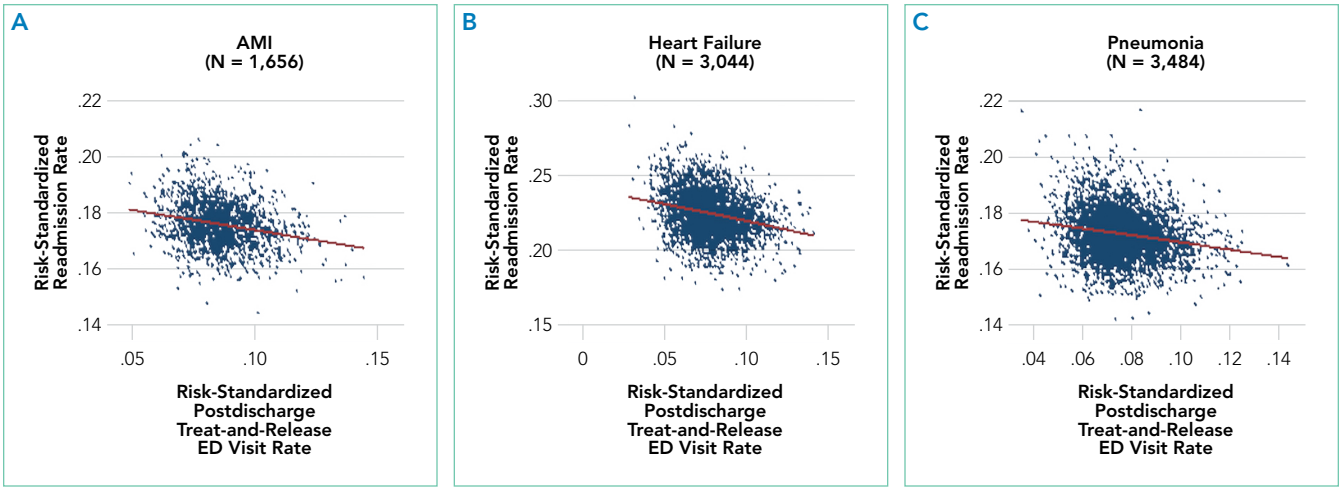

FIG. Association between Readmission Rates and Postdischarge ED Visit Rates for AMI, Heart Failure, and Pneumonia.

patients with limited access to unscheduled primary and specialty care in safety-net communities utilize the ED, whereas patients in teaching-hospital communities may be able to access hospital-based clinics for care.

Contrary to the expectations of many clinicians and policymakers, we found an inverse relationship between postdischarge ED visit rates and readmission rates. While the cross-sectional design of our study cannot provide a causal explanation, these findings merit policy attention and future exploration of several hypotheses. One possible explanation for this finding is that hospitals with high postdischarge ED visit rates provide care in communities in which acute, unscheduled care is consolidated to the ED setting and thereby permits the ED to serve a gatekeeper function for scarce inpatient resources. This hypothesis may also be supported by recent interventions demonstrating that the use of ED care coordination and geriatric ED services at higher-volume EDs can reduce hospitalizations. Also, hospitals with greater ED capacity may have easier ED access and may be able to see patients earlier in their disease courses postdischarge or more frequently in the ED for follow-up, therefore increasing ED visits but avoiding rehospitalization. Another possible explanation is that hospitals with lower postdischarge ED visit rates may also have a lower propensity to admit patients. Because our definition of postdischarge ED visitation did not include ED visits that result in hospitalization, hospitals with a lower propensity to admit from the ED may therefore appear to have higher ED visit rates. This explanation may be further supported by our finding that many postdischarge ED visits are for conditions that are associated with discretionary hospitalization in the ED.[27] A third explanation for this finding may be that poor access to outpatient care outside the hospital setting results in higher postdischarge ED visit rates without increasing the acuity of these revisits or increasing readmission rates[28]; however, given the validated, risk-standardized approach to readmission measurement, this is unlikely. This is also unlikely given recent work by Sabbatini et al.[23] demonstrating substantial acuity among patients who return to the ED following hospital discharge. Future work should seek to evaluate the relationship between the availability of ED care-coordination services and the specific ED, hospital, and community care-coordination activities undertaken in the ED following hospital discharge to reduce readmission rates.

This work should be interpreted within the confines of its design. First, it is possible that some of the variation detected in postdischarge ED visit rates is mediated by hospital-level variation in postdischarge observation visits that are not captured in this outcome. However, in previous work, we have demonstrated that almost one-third of hospitals have no postdischarge observation stays and that most postdischarge observation stays are for more than 24 hours, which is unlikely to reflect the intensity of care of postdischarge ED visits.[27] Second, our analyses were limited to Medicare FFS beneficiaries, which may limit the generalizability of this work to other patient populations. However, this dataset did include a national cohort of Medicare beneficiaries that is identical to those included in publicly reported CMS readmission measures; therefore, these results have substantial policy relevance. Third, this work was limited to three conditions of high illness severity of policy focus, and future work applying similar analyses to less severe conditions may find different degrees of hospital-level variation in postdischarge outcomes that are amenable to quality improvement. Finally, we assessed the rate of treat-and-discharge ED visits only after hospital discharge; this understates the frequency of ED visits since repeat ED visits and ED visits resulting in rehospitalization are not included. However, our definition was designed to mirror the definition used to assess hospital readmissions for policy purposes and is a conservative approach.

In summary, ED visits following hospital discharge are common, as Medicare beneficiaries have one treat-and-discharge ED visit for every two readmissions within 30 days of hospital discharge. Postdischarge ED visits occur for a wide variety of conditions, with wide risk-standardized, hospital-level variation. Hospitals with the highest risk-standardized postdischarge ED visitation rates demonstrated lower RSRRs, suggesting that poli-

cymakers and researchers should further examine the role of the hospital-based ED in providing access to acute care and supporting care transitions for the vulnerable Medicare population.

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The Burden of Guardianship: A Matched Cohort Study

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BACKGROUND: In cases where patients are unable to provide informed consent and have no surrogate decision-maker, a hospital must seek guardian appointment as a legally recognized surrogate decision-maker.

OBJECTIVE: The aim of this study was to examine the magnitudes of length of stay (LOS) beyond medical clearance and healthcare costs among patients referred for guardianship.

DESIGN, SETTING AND PATIENTS: This was a retrospective cohort study of all 61 adult inpatients in a single tertiary care hospital requiring guardianship between October 1, 2014, and September 30, 2015, matched with up to three controls from the same discharging services and hospitalized for at least as long as the date of clearance for referred patients.

MEASUREMENTS: The following parameters were measured using generalized estimating equations: total LOS, LOS beyond medical clearance (excess LOS), medical complications, and total charges among referred patients, and the LOS and costs were compared with those of matched controls.

RESULTS: Mean LOS for patients requiring guardianship was 31 ± 2 days, and the total charges averaged $179,243 ± 22,950. We documented 12 hospital-acquired complications in 10 (16%; 95% confidence interval [CI], 8%-28%) unique patients. Accounting for potential confounders, the process of obtaining guardianship was associated with a 37% longer total LOS (95% CI [12%-67%]; *P* = .002), 58% higher excess LOS (95% CI [2%-145%]; *P* = .04), and 23% higher total charges (95% CI [4%-46%]; *P* = .02).

CONCLUSION: In this single-center cohort study, the guardianship process was associated with prolonged hospital stay and higher total hospital charges even when compared with matched controls. Furthermore, one in six patients suffered from a hospital-associated complication after medical clearance. *Journal of Hospital Medicine* 2018;13:595-601. Published online first February 5, 2018.

A central tenet of modern medicine is that patients must provide fully informed consent to receive or refuse medical care offered by their clinical teams.[1–4] If a patient is unable to make and communicate a choice or clearly indicate an understanding of the information presented, then he or she is considered to lack the capacity to make medical decisions and the medical team must seek consent from the patient's surrogate decision-maker.[2-7] Every U.S. state recognizes a patient's healthcare proxy (HCP) and a court-appointed guardian as a legally recognized surrogate.[8,9] Most of the states also have statutes or regulations establishing a hierarchy of legally recognized surrogate decision-makers in the absence of a HCP or a court-appointed guardian, such as spouses, adult children, parents, siblings, and grandparents.[8,10] In states that do not have such a statute, hospitals develop their own institutional policies for surrogate decision-making.

However, there are important limitations on the authority of these surrogate decision-makers.[10] For instance, patients may not have a family member or a friend to serve as a surrogate decision-maker, often family members cannot override a patient's objection, even when that patient lacks decision-making capacity, and certain decisions require a guardian or a HCP.[8-10] In these circumstances, the hospital must petition a court to appoint a guardian as a legally recognized surrogate decision-maker. This can be an involved family member, if one exists, or an independent, typically volunteer, guardian.[11] The process of guardian appointment is complex[7,11] and can range from a few days to more than a month, largely dependent on court dates and finding a volunteer guardian. Much of the process occurs during the patient's hospital stay. This prolongation of hospitalization would be expected to increase health care costs and iatrogenic complications,[12–14] but data quantifying these for patients requiring guardianship are lacking.

The goal of this study was to describe the characteristics of patients who undergo the process of guardianship and measure the associated burdens. These burdens include the financial costs to the medical system, the prolonged length of stay beyond medical necessity, and the costs to the patient in the form of hospital-acquired complications. Investigating the bur-

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den of guardianship is an important first step in uncovering opportunities to improve the process. We hypothesized that patients requiring guardianship would have lengths of stay and healthcare costs that were at least as large as those for patients whose conditions required similar durations of hospitalization prior to medical clearance, in part due to iatrogenic complications that would accrue while awaiting guardian appointment.

METHODS

Setting

We conducted a retrospective matched cohort study of adult inpatients at Beth Israel Deaconess Medical Center (BIDMC), a 651-bed academic, tertiary care facility in Boston, Massachusetts. The study was approved by the BIDMC Institutional Review Board as a nonhuman subject research consistent with hospital operations.

Population

For this matched cohort study, we identified case patients as those hospitalized for any reason for whom guardianship proceedings were initiated and obtained; only the first hospitalization during which the guardianship was pursued was used. Cases were identified by obtaining the data of all patients for whom the BIDMC general counsel completed the process of guardianship between October 2014 and September 2015. At BIDMC, all the guardianship proceedings are referred to the general counsel.

To determine the postclearance experience for referred patients compared with that for other patients with similar lengths of stay up to those of the referred patients' point of clearance, we identified up to three matched controls for each case (Supplemental Figure 1). Medical clearance was defined as the date when the patient was medically stable to be discharged from the hospital, and it was determined in an iterative manner. We identified controls as hospitalized patients admitted for any cause and matched to the cases requiring guardianship on discharging service and length of stay prior to clearance. Specifically, we identified patients on the same service as the case whose length of stay was at least as long as the length of stay of the case patient until medical clearance, as defined below. We then determined the total and the excess length of stay, defined as the duration beyond clearance for each case referred for guardianship; for controls, the 'excess' length of stay was the number of hospitalized days beyond the corresponding time that a matched case had been provided clearance. To account for seasonal influences and the training level of house officers, we selected the three controls whose discharge date was closest (before or after) to the discharge date of their matched case.

From legal team files, we identified 61 patients hospitalized at BIDMC for whom new guardianship was pursued to completion. Of these 61 patients, 10 could not be matched to an appropriate control and were included in descriptive analyses but not in comparisons with controls.

Covariates and Outcomes

We collected the details regarding age, gender, primary language, highest level of education, marital status, insurance status, race, date of admission, date of discharge, discharge disposition, principal diagnosis, case mix index (CMI), and discharging service from our administrative and billing data. Outcomes of interest included length of stay and total hospital charges that were collected from the same databases. We used hospital charges, rather than payments, to ensure uniformity across payers.

Chart Review

Unique to cases, a team of two medical residents (J.P., R.P.) and a hospitalist (D.R.) determined the date of medical clearance and hospital-associated complications by a chart review. The date of medical clearance was then used to calculate excess length of stay, ie, the duration of stay beyond the date of medical clearance, by subtracting the time to medical clearance from the total inpatient length of stay.

We developed a novel algorithm to determine the date of medical clearance consistently (Figure 1). We first determined whether the discharge summary indicated a clear date of medical readiness for discharge. If the discharge summary was unclear, then a case management or a social work note was used. The date of medical clearance determined by the case management or the social work note was then confirmed with clinical data. The date was confirmed if there were no significant laboratory orders and major medication changes or procedures for 24 hours from the date identified. If notes were also inconclusive, then the medical clearance was determined by a review of provider order entry. Medical readiness for discharge was then defined as the first day when there were no laboratory orders for 48 hours and no significant medication changes, imaging studies, or microbiologic orders.

Hospital-acquired complications were determined to be related to the guardianship process if they occurred after the date of medical stability but prior to discharge. We did not investigate hospital-acquired complications among controls. Hospital-acquired complications were defined as follows:

- Catheter-associated urinary tract infection (CAUTI): active Foley catheter order and positive urine culture that resulted in antibiotic administration.
- Hospital-acquired pneumonia (HAP): chest X-ray or computed tomography (CT) scan showing a consolidation that resulted in antibiotic administration.
- Venous thromboembolism (VTE): positive venous ultrasound or CT angiography of the chest for deep venous thrombosis (DVT) or pulmonary embolism (PE).
- Decubitus ulcer: new wound care consultation for sacral decubitus ulceration.
- *Clostridium difficile* (*C. diff*) infection: positive stool polymerase chain reaction that resulted in antibiotic administration.

The algorithm for identifying the date of clearance and the presence of complications was piloted independently by three investigators (R.P., J.P., D.R.) using a single chart review and was redesigned until a consensus was obtained. The same three investigators then independently reviewed three additional charts, including all notes, laboratory results, imaging results, and orders, with complete agreement for both date

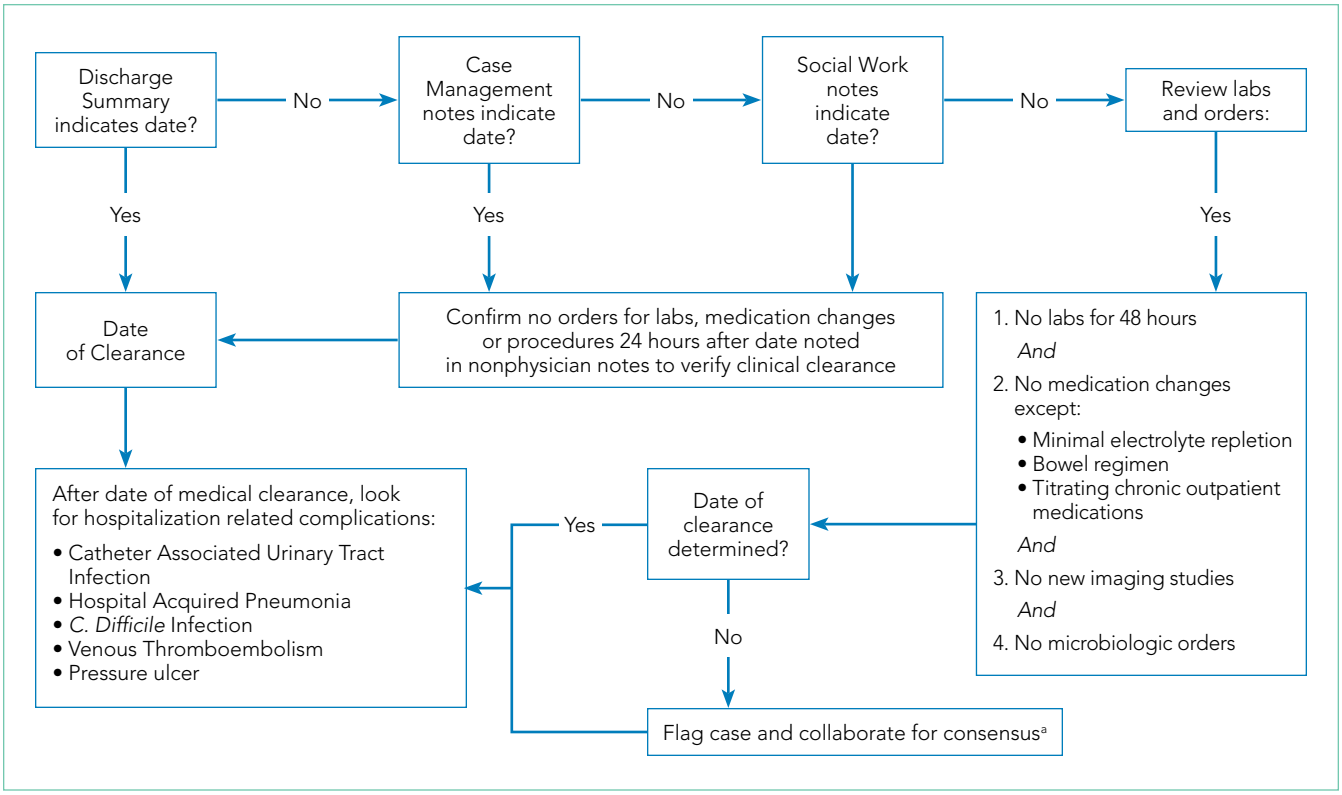

FIG 1. Algorithm for determining medical clearance. Algorithm used to determine date of medical clearance and presence of complications among patients referred for guardianship.
[a]No cases were flagged

of clearance and presence of complications. Two investigators (R.P., J.P.) then individually reviewed the remaining 57 charts. Of these, 10 were selected *a priori* for review by both investigators for interrater reliability, with a mean difference of 0.5 days in the estimated time to clearance and complete concordance in complications. In addition, a third investigator (DR) independently reread 5 of the 57 reviewed charts, with complete concordance in both time to clearance and presence of complications with the original readings.

Statistical Analysis

SAS 9.3 was used for all analyses (SAS Institute Inc., Cary, North Carolina).

We first examined the demographic and clinical characteristics of all 61 patients who underwent guardianship proceedings. Second, we described the primary outcomes of interest– length of stay, costs, and likelihood of complications – in this series of patients with associated 95% confidence intervals.

Third, we examined the associations between guardianship and length of stay and healthcare costs using generalized estimating equations with clustering by matched set and compound symmetry. For length of stay, we specifically assessed excess length of stay (the matching variable) to avoid immortal time bias; we also examined the total length of stay. For all regression analyses, we adjusted for the following covariates: age, gender, education, marital status, race/ethnicity, CMI, insurance status, discharging service, and principal diagnosis. To maximize normality of residuals, costs were log-transformed; length of stay beyond clearance was log-transformed after addition of one. For both outcomes, we back-transformed the regression coefficients and presented percent change between case and control patients. All reported tests are two-sided.

RESULTS

A total of 61 guardianship cases and 118 controls were included in the analysis.

General Characteristics

The characteristics of all cases prior to matching are included in Table 1. The department of internal medicine discharged the largest proportion of cases, followed by neurosurgery and neurology departments. More than 65% of cases were insured by Medicare or Medicaid. Three-quarters of cases were discharged from the hospital to another medical facility, with about half discharged to a skilled nursing facility (SNF) or a rehabilitation center and one-quarter to a long-term acute care hospital (LTACH).

The median length of stay for patients requiring guardianship was 28 (range, 23-36) days, and the median total charges were $171,083 ($106,897-$245,281), with a total cost approximating $10.9 million for these patients. Regarding hospital-acquired complications, 10 (16%; 95% confidence interval, 8%-28%) unique cases suffered from a complication, with HAP being the most frequently (n = 5) occurring complication.

TABLE 1. **Characteristics of Patients Referred for Guardianship**

Variable	N = 61
Age (years)	61 (52–72)
Case Mix Index	5.4 (1.7–10.9)
Total ICU Stay (days)	13 (2–22)
# Discharges in Last Year	1 (1–3)
Total Length of Stay (days)	28 (23–36)
Total Charges ($)	$171,083 ($106,897–$245,281)
Discharging Service	
Surgery	5 (8%)
Internal medicine	25 (41%)
Neurosurgery	19 (31%)
Neurology	11 (18%)
Psychiatry	1 (2%)
Gender	
F	35 (57%)
Complications	
CAUTI	3 (5%)
DVT	1 (2%)
Fall	1 (2%)
HAP	5 (8%)
Sacral Ulcer	2 (3%)
None	51 (84%)
Ethnicity	
White	31 (51%)
Black	4 (7%)
Hispanic	3 (5%)
Asian	3 (5%)
Other/Multiracial/Unknown	20 (33%)
Education	
College	14 (23%)
High School	24 (39%)
Unknown	23 (38%)
Primary Language	
English	56 (92%)
Non-English	5 (8%)
Marital Status	
Married	12 (20%)
Divorced	6 (10%)
Single	22 (36%)
Widowed	4 (7%)
Unknown	17 (28%)
Disposition	
Home	2 (3%)
Rehab/SNF	32 (52%)
LTACH	16 (26%)
Inpatient Psychiatry	5 (8%)
Expired	6 (10%)
Insurance Status	
Private	16 (26%)
Medicare	27 (44%)
Medicaid	13 (21%)
Other	5 (8%)

*Data are represented as median (IQR) for continuous variables and N (%) for nominal variables

Abbreviations: CAUTI, catheter-associated urinary tract infection; DVT, deep venous thrombosis; HAP, hospital-acquired pneumonia; ICU, intensive care unit; LTACH, long-term acute care hospital; SNF: skilled nursing facility.

Comparison with Matched Controls

No statistically significant differences were observed between cases and controls in terms of age, primary language, highest level of education, ethnicity, insurance status, or discharging service as shown in Table 2; discharging service was a matched variable and comparable by design. However, cases tended to be less likely to be married and had a higher CMI.

When compared with control patients in terms of similar services who stayed for at least as long as their duration to clearance, the cases had significantly longer lengths of stay compared to those of controls (29 total days compared to 18 days, $P < .001$; Figure 2). In addition, cases incurred significantly higher median total charges ($168,666) compared to those of controls ($104,190; $P = .02$).

After accounting for potential confounders, including age, gender, language, education, marital status, discharging service, ethnicity, insurance status, CMI, and principal diagnosis, guardianship was associated with 58% higher excess length of stay ($P = .04$, 95% CI [2%-145%]). Furthermore, guardianship was associated with 23% higher total charges ($P = .02$, 95% CI [4%-46%]) and 37% longer total length of stay ($P = .002$, 95% CI [12%-67%]).

DISCUSSION

In this cohort study of 61 inpatients from a single academic medical center who needed guardianship, patients who required this process had prolonged lengths of stay and substantial healthcare costs even when compared with matched controls who stayed at least as long as the cases' date of clearance. One in six patients suffered from hospital-associated complications after their date of medical clearance.

To our knowledge, this is among the first studies to investigate healthcare costs and harm to the patient in the form of hospital-associated complications as a result of guardianship proceedings. Other studies[15,16] have also demonstrated excessive length of stay attributed to nonclinical factors such as guardianship, though they did not quantify the excess stay or compare guardianship cases with a matched control. One study[17] demonstrated total charges of $150,000 per patient requiring guardianship, which are similar to our results. However, Chen et al. also observed an average of 27.8 medically unnecessary days, which are 16 more days than those in our study sample. This may reflect the difference in how excess days were determined, namely, statistical process control analysis in the previous study compared with a manual chart review in our study. To our knowledge, no other study has compared guardianship cases with matched controls to compare their experiences to patients with similarly prolonged stays prior to clearance.

After matching by service and the length of stay until medical clearance in each guardianship case, the subsequent length of stay was higher among cases than among controls, even after adjustment for differences in CMI and diagnosis. This suggests that the process of obtaining guardianship results in a particularly prolonged length of stay, which is presumably attributable to factors other than medical complexity or ongoing illness.

TABLE 2. **Characteristics of Patients Referred for Guardianship and Matched Controls**[a]

Variable		Cases (n=51)	Controls (n=118)	*P* Value[b]
Age (years)		61 (52-72)	61 (48-71)	.6
Case-Mix Index		5.9 (1.7-10.9)	3.0 (1.5-5.3)	.003
ICU Length of Stay (days)		13 (2-23)	4 (0-14)	.006
Length of Stay (days)		29 (23-37)	18 (12-32)	<.001
Excess Length of Stay (days)		12 (2-20)	4 (2-8)	<.001
Total Charges ($)		$168,666 (105,127 - 245,282)	$104,190 (40,318 - 217,307)	.02
Gender	Male	21 (41)	68 (57)	.06
	Female	30 (59)	50 (42)	
Language	English	46 (90)	99 (84)	.34
	Non-English	5 (10)	19 (16)	
Education	College	13 (25)	46 (39)	.08
	High School	20 (39)	48 (41)	
	Unknown	18 (35)	24 (20)	
Marital Status	Divorced	10 (20)	23 (19)	.002
	Married	9 (18)	50 (42)	
	Single	19 (37)	35 (30)	
	Unknown	13 (25)	10 (8)	
Discharging Service[c]	Medicine	23 (45)	58 (49)	.9
	Neurology	6 (12)	13 (11)	
	Psychiatry	1 (2)	3 (3)	
	Surgery	21 (41)	44 (37)	
Ethnicity	Asian	2 (4)	4 (3)	.5
	Black	4 (8)	13 (11)	
	Hispanic	2 (4)	4 (3)	
	Other	16 (31)	23 (19)	
	White	27 (53)	74 (63)	
Insurance Status	Medicaid	8 (16)	28 (24)	.6
	Medicare	22 (43)	46 (39)	
	Private	16 (31)	36 (31)	
	Other	5 (10)	8 (7)	
Principal Diagnosis	Neurosurgical Fracture	10 (20)	7 (6)	<.001
	Neurosurgical Hemorrhage	16 (31)	19 (16)	
	Neurosurgical Stroke	2 (4)	3 (3)	
	Medicine	27 (14)	56 (48)	
	Neurologic	5 (10)	17 (14)	
	Surgical	0 (0)	14 (12)	
	Psychiatric	4 (8)	2 (2)	

[a]Data are represented as median (IQR) for continuous variables and N (%) for nominal variables
[b]*P* values calculated using Wilcoxon two-sample t-test for continuous variables and Fisher's Exact for nominal variables
[c]Referred cases and controls matched on discharge service and length of stay prior to clearance.

It is probable that at least two interrelated mechanisms are responsible for the particularly high costs and the long stay of patients who require guardianship. First, the process of obtaining guardianship is itself protracted in several cases, necessitating long-term admissions well beyond the point of medical stability. Second, our results suggest that longer hospital stays are apt to grow further in a feed-forward cycle due to hospital-acquired complications that develop after the date of medical clearance. Indeed, in our series, 16% of patients sustained a complication that is readily attributable to hospital care after their date of clearance, and these types of complications are likely to lengthen the stay even further.

We compared cases referred for guardianship to control patients on the same services, at similar time points, whose length of stay was at least as long as the point of medical clearance as their corresponding case patient. Because cases were hospi-

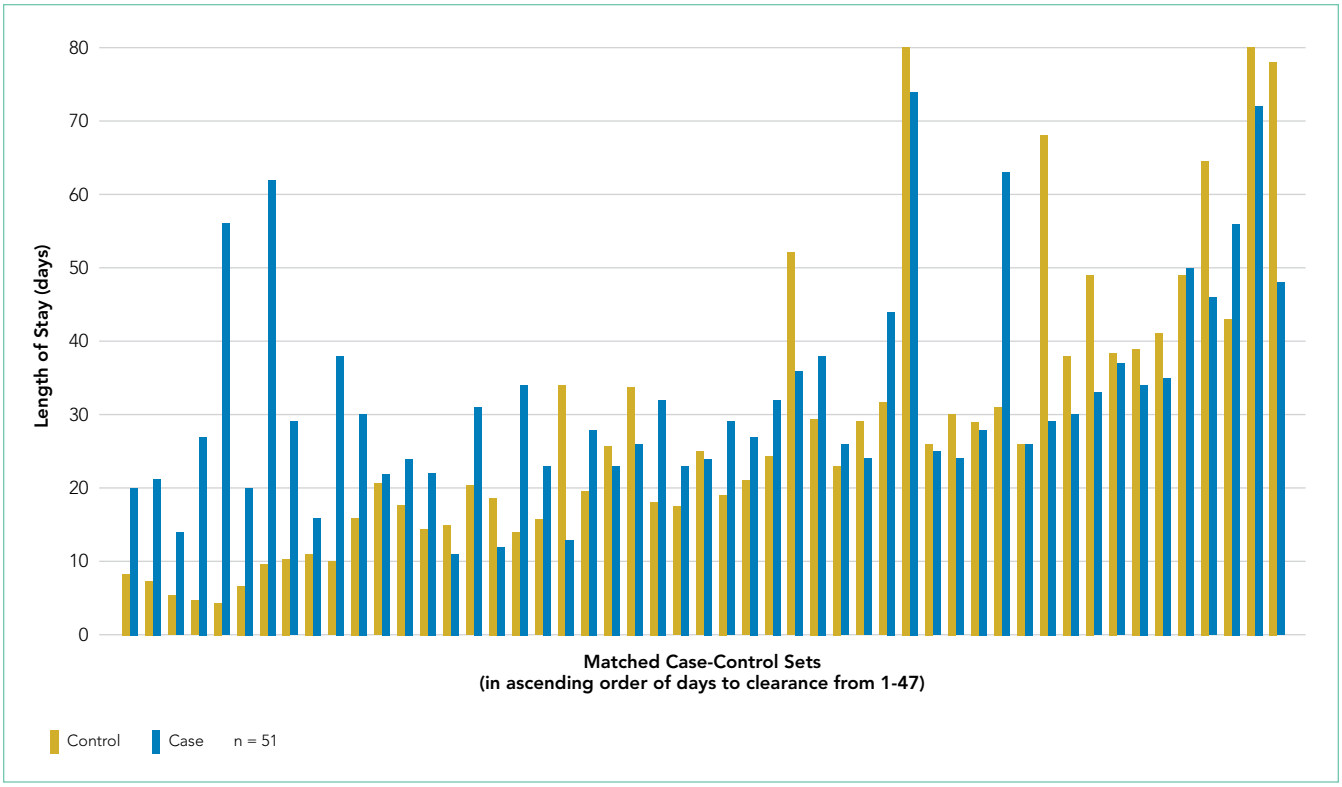

FIG 2. Total length of stay among patients referred for guardianship (n=51) and matched controls. Sets presented in ascending order of time to clearance among cases. Blue bars indicate case patients referred for guardianship, and gold bars indicate the mean among up to 3 matched controls.

talized with active medical needs to at least the point of clearance, we anticipated that costs might well be lower among cases, who had no medical necessity for hospitalization at the point of clearance, compared with controls who remained hospitalized presumably for active medical needs. Counter to this hypothesis, and accounting for potentially confounding variables, undergoing a guardianship proceeding was associated with nearly 25% higher costs of patient care. This may ultimately represent a substantial burden on the healthcare system. For example, in just one year in our hospital, the total hospital charges reached almost $11 million for the 61 patients who underwent guardianship proceedings. Considering that 65% of the patients requiring guardianship had Medicaid or Medicare coverage, there are significant financial implications for the hospital systems and to the public.

Limitations of our study relate to its retrospective nature at a single center. Investigating guardianship cases at a single center and with a small sample size of 61 patients limits generalizability. Nevertheless, we still had enough power to detect significant differences compared with matched controls, and, to our knowledge, this study remains the largest investigation into the cost associated with guardianship to date and the only study comparing guardianship cases with matched controls. Furthermore, we did not complete chart reviews of controls, which limits direct comparisons of complications and precluded our matching on variables that required detailed review.

The retrospective design may include confounders unaccounted for in our statistical design, though we attempted to match cases with controls to account for some of these potential differences and included a broad set of covariates that included measures of comorbidity and diagnosis. To this point, we included only CMI and principal diagnosis as the measures of severity, and adjustment for CMI, which includes features of the index hospitalization itself, may represent overadjustment. However, this type of overadjustment would tend to bias toward the null hypothesis.

Investigators only completed chart reviews for cases, which limits our ability to contrast the rate of hospital-associated complications for cases with that of controls. However, the rates of CAUTI and HAP complications among our cases were notably higher than national inpatient estimates, ie, 5% and 8% compared to 0.2%[18] and 0.5%-1%,[19] respectively. Furthermore, we demonstrated higher total costs and total lengths of stay among guardianship patients, analyses for which the attributed date of clearance for controls was not required, and the rate of complications among the case patients was sizable despite their being formally medically cleared. In other words, regardless of whether a complication rate of 16% is "typical" for inpatients hospitalized for these durations, this suggests that persistent hospitalization after clearance does not carry a benign prognosis.

In addition, to estimate healthcare costs, we relied on total hospital charges, which are readily available and reflect, at least in part, payer costs but do not reflect true costs to the medical center. Nonetheless, charges approximately reflect costs – with some variation across cost centers – and hence

provide a useful metric for comparing cases and controls. To provide context, for academic medical centers such as ours, costs are typically about half of charges.

Finally, each state has different statutes for surrogate decision making. The results of this study reflect the Massachusetts' experience, with no public guardianship program or hierarchy statute. That being said, while this presumably causes the need for more guardianships in Massachusetts, the mechanisms for guardianship are broadly similar nationwide and are likely to result in excessive length of stay and cost similar to those in our population, as demonstrated in studies from other states.[7,15–17]

Implications

At a time where medical systems are searching for opportunities to reduce the length of stay, prevent unnecessary hospitalization, and improve the quality of care, reevaluating the guardianship process is ripe with opportunity. In this single academic center, the process of guardianship was associated with 58% excess length of stay and 23% higher total hospital charges. Furthermore, one in six patients requiring guardianship suffered from hospital-associated complications.

This matched cohort study adds quantitative data demonstrating substantial burdens to the healthcare system as a result of the guardianship process and can be used as an impetus for hospital administration and legal systems to expedite the process. Potential improvements include increasing HCP form completions (which would eliminate the need to pursue guardianship for most of such patients), identifying patients who lack a legally recognized surrogate decision-maker earlier in their hospital stay (ideally upon admission), and providing resources to assist clinical teams in the completion of affidavits necessary to support the appointment of a guardian, so that paperwork can be filed with courts sooner. Further research that provides more generalizable prospective data could potentially improve the guardianship process and reduce its burden on hospitals and patients even further.

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Development of Hospitalization Resource Intensity Scores for Kids (H-RISK) and Comparison across Pediatric Populations

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BACKGROUND: In the Medicare population, measures of relative severity of illness (SOI) for hospitalized patents have been used in prospective payment models. Similar measures for pediatric populations have not been fully developed.

OBJECTIVE: To develop hospitalization resource intensity scores for kids (H-RISK) using pediatric relative weights (RWs) for SOI and to compare hospital types on case-mix index (CMI).

DESIGN/METHODS: Using the 2012 Kids' Inpatient Database (KID), we developed RWs for each All Patient Refined Diagnosis Related Group (APR-DRG) and SOI level. RW corresponded to the ratio of the adjusted mean cost for discharges in an APR-DRG SOI combination over adjusted mean cost of all discharges in the dataset. RWs were applied to every discharge from 3,117 hospitals in the database with at least 20 discharges. RWs were then averaged at the hospital level to provide each hospital's CMI. CMIs were compared by hospital type using Kruskal–Wallis tests.

RESULTS: The overall adjusted mean cost of weighted discharges in Healthcare Cost and Utilization Project KID 2012 was $6,135 per discharge. Solid organ and bone marrow transplantations represented 4 of the 10 highest procedural RWs (range: 35.5 to 91.7). Neonatal APR-DRG SOIs accounted for 8 of the 10 highest medical RWs (range: 19.0 to 32.5). Free-standing children's hospitals yielded the highest median (interquartile range [IQR]) CMI (2.7 [2.2–3.1]), followed by urban teaching hospitals (1.8 [1.3–2.6]), urban nonteaching hospitals (1.1 [0.9–1.5]), and rural hospitals (0.8 [0.7–0.9]; $P < .001$).

CONCLUSION: H-RISK for populations of pediatric admissions are sensitive to detection of substantial differences in SOI by hospital type. *Journal of Hospital Medicine* 2018;13:602-608. Published online first April 25, 2018. © 2018 Society of Hospital Medicine

Hospitals are increasingly assessed comparatively in terms of costs and quality for benchmarking purposes. These comparisons can be used by patients and families to determine where to seek care, to report compliance and grant certifications by oversight organizations (eg, Leapfrog, Magnet, Joint Commission), and by payers, to determine reimbursement models and/or to assess financial penalty or bonuses for underperforming or overperforming hospitals. As these efforts can cause substantial reputational and financial consequences for hospitals, these metrics must be contextualized within the population of patients that each hospital serves.

In adult Medicare patient populations, methods have been developed to assess the relative severity of a hospital's full complement of patients.[1,2] These methods assume a relationship between severity and hospital resource intensity (ie, cost) and typically assume the form of relative weights (RWs), which are developed for clinically similar groups of patients (eg, Medicare Diagnosis Related Groups; MS-DRG) from a reference population. A RW for each MS-DRG is calculated as the average cost of patients within the group divided by the average cost for all patients in the reference population. These weights are then applied to a hospital's discharges over a specific time period and averaged to obtain a hospital-level case-mix index (CMI). A value of one indicates that a hospital serves a mix of patients with similar severity (or resource intensity) to that of an "average" hospital discharge in the reference population, whereas a value of 1.2 indicates that a hospital serves a population of patients with 20% more severity than that of an "average" hospital discharge. Since 1983, the Centers for Medicare and Medicaid Services (CMS) have used RWs in their inpatient prospective payment system.[3]

Similar pediatric methods are less developed and necessitate special consideration as the use of existing weights may be inappropriate for a pediatric population. First, MS-DRGs were developed primarily for the Medicare population and lack sufficient granularity for pediatric populations, specifically newborns. Second, a severity stratification which incorporates

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important patient characteristics, such as age in pediatrics, does not exist in the MS-DRG system . Finally, although the reference populations that are used to develop MS-DRG weights do not explicitly exclude children, children typically account for approximately 15% of hospitalizations (6% excluding neonatal/maternal) and possibly feature different utilization patterns than adults with similar conditions. Thus, weights developed from a combined pediatric/adult reference population primarily reflect an adult population.

With valid pediatric RWs, stakeholders can assess a hospital's severity mix of patients in a comparable fashion and contextualize outcome metrics. Additionally, these same weights can be used to estimate expected costs for hospitalizations or for risk adjusting various outcomes at the discharge- or hospital-level. Thus, we sought to develop hospitalization resource intensity scores for kids (H-RISK) using pediatric-specific weights and compare hospital-level CMIs across various hospital types and locations as an example of the application of this novel methodology.

METHODS

Dataset

Data for this analysis were obtained from the 2012 Healthcare Cost and Utilization Project (HCUP) Kids' Inpatient Database (KID).[4] KID is the largest publicly available all-payer inpatient administrative database in the United States and is sponsored by the Agency for Healthcare Research and Quality as part of the HCUP. The 2012 KID included a sample of approximately 3.2 million discharge records of children <21 years old from 44 states and 4,179 community, nonrehabilitation hospitals weighted for national estimates.

Hospital discharge costs were estimated from charges using cost-to-charge ratios (CCR) provided by HCUP as a supplement to the 2012 KID.[5] Cost estimates associated with a specific discharge were estimated by multiplying the total charges reported in the data by the appropriate hospital-specific CCR and then adjusted for price factors beyond a hospital's control using the area wage index also provided by HCUP as a supplement.

H-RISK and Case-Mix Index Calculations

We calculated H-RISK as pediatric-specific RWs based on version 30 of 3M's All Patient Refined DRG (APR-DRG; 3M Health Information Systems, Salt Lake City, Utah) system as a measure of resource intensity. The APR-DRG system classifies hospital discharges into over 300 base DRGs based on demographic, diagnostic, and therapeutic characteristics. Each APR-DRG is further subdivided into four subclasses of severity of illness (SOI; eg, minor, moderate, major, and extreme) to indicate the intensity of resource utilization during hospitalization. However, SOI levels for differing APR-DRGs are not comparable.

For every APR-DRG SOI combinations available in the 2012 KID, calculation of RW was based on the ratio of the mean cost for patients assigned to a particular APR-DRG SOI compared with the mean cost for all patients in the database. Inpatient costs less than $0.50 were set to missing and removed from analysis. Mortalities and discharges with missing CCR and wage index values were also excluded from analysis. We required that estimates for RWs be based on a reasonable set of data (ie, 10 or more discharges) for each APR-DRG SOI, and that estimates across the four SOI levels within an APR-DRG be monotonically nondecreasing (ie, as SOI level increases, weights must either be the same or increasing). Winsorized means were used as point estimates for mean cost in both the numerator and denominator of RW computation. Winsorizing refers to an analytic transformation by which the influence of outliers (eg, values beyond a certain threshold) is mitigated by replacing the value of outliers with the value of the threshold. We used the 5th and 95th percentiles as thresholds for Winsorizing our point estimates.

Winsorized point estimates failing to meet the minimum sample size of 10 or nondecreasing monotonicity requirement were modified by one of the two following methods:

- Cost data were modeled using a generalized linear model assuming an exponential distribution. Covariates in the model included APR-DRG and SOI within APR-DRG as a continuous variable. Where applicable, Winsorized estimates of the mean were replaced with modeled estimates.
- Data from an APR-DRG SOI in question were combined with other SOIs within the same APR-DRG with the closest Winsorized mean value. Once data were combined, a common Winsorized value was re-computed and values across SOIs were checked to ensure that nondecreasing monotonicity was maintained. In some APR-DRGs with sparse data, this involved combining pairs of severity levels; in others, it involved combining three or four severity levels together.

For APR-DRGs in which no discharges at any SOI were recorded in the 2012 KID, we used the Winsorized mean of all encounters with a common major diagnostic category (MDC) as the missing APR-DRG as point estimate for all four SOI levels.

To calculate the CMI for a set of discharges (eg, discharges at a hospital in a year), RWs were assigned to each discharge based on APR-DRG SOI designation. Consequently, all discharges from a specific APR-DRG SOI were assigned the same RW. Once RWs were assigned, CMI was calculated as the mean RW across all discharges. To compare hospital types based on acute-care hospital stays which are usually considered with the realm of pediatric care, we excluded RWs for normal newborns, defined as APR-DRG 626 (neonate birthweight of 2,000–2,499 g, normal newborn or neonate with other problems) and 640 (neonate birthweight >2,499 g, normal newborn or neonate with other problems), and maternal hospitalizations, defined as APR-DRG 540 (cesarean delivery) and 560 (vaginal delivery), from our CMI calculations.

Statistical Methodology

Categorical variables were summarized using frequencies and percentages; continuous variables were summarized using medians and interquartile ranges. Differences between hospital types (eg, rural, urban nonteaching, urban teaching, and free-standing) were assessed using a Chi-square test for association for categorical variables. Differences in continuous

TABLE 1. **Demographic and Clinical Characteristics of Hospitalizations by Hospital Type.**

Characteristic[a]	Overall (N = 6,675,222)	Rural Hospital (N = 710,470)	Urban Nonteaching Hospital (N = 2,098,993)	Urban Teaching Hospital (N = 3,266,209)	Free-Standing Children's Hospital (N = 599,550)
Age, years					
<1	4,269,984 (64.1)	487,464 (68.6)	1,526,815 (72.9)	2,090,160 (64.1)	165,545 (27.6)
1–2	321,402 (4.8)	27,033 (3.8)	53,232 (2.5)	148,129 (4.5)	93,008 (15.5)
3–5	228,995 (3.4)	17,069 (2.4)	31,910 (1.5)	112,937 (3.5)	67,079 (11.2)
6–11	361,628 (5.4)	22,759 (3.2)	53,294 (2.5)	173,530 (5.3)	112,044 (18.7)
12–18	865,214 (13.0)	75,553 (10.6)	208,789 (10.0)	432,021 (13.2)	148,850 (24.9)
19–20	618,934 (9.3)	80,332 (11.3)	221,515 (10.6)	304,868 (9.3)	12,219 (2.0)
Male	3,194,495 (47.9)	320,765 (45.2)	975,987 (46.5)	1,575,426 (48.2)	322,317 (53.8)
Race					
White	3,138,004 (47.0)	447,829 (63.0)	1,034,281 (49.3)	1,405,849 (43.0)	250,046 (41.7)
Black	1,001,246 (15.0)	65,469 (9.2)	255,745 (12.2)	593,149 (18.2)	86,882 (14.5)
Hispanic	1,290,955 (19.3)	65,483 (9.2)	474,878 (22.6)	617,899 (18.9)	132,696 (22.1)
Asian or Pacific Islander	257,994 (3.9)	12,536 (1.8)	85,229 (4.1)	141,718 (4.3)	18,512 (3.1)
Native American	58,343 (0.9)	14,735 (2.1)	13,760 (0.7)	27,584 (0.8)	2,265 (0.4)
Other	378,468 (5.7)	20,257 (2.9)	117,251 (5.6)	215,408 (6.6)	25,552 (4.3)
Missing	549,932 (8.2)	84,114 (11.8)	117,668 (5.6)	264,557 (8.1)	83,593 (13.9)
Payer					
Public	330,6003 (51.6)	398,950 (59.1)	996,876 (49.5)	1,606,001 (51.0)	304,175 (53.6)
Private	2,836,105 (44.3)	242,793 (36.0)	926,629 (46.0)	1,422,135 (45.1)	244,548 (43.1)
Other	265,200 (4.1)	33,149 (4.9)	90,111 (4.5)	122,964 (3.9)	18,976 (3.3)
Region					
Northeast	1,129,265 (16.9)	71,247 (10.0)	210,787 (10.0)	771,675 (23.6)	75,556 (12.6)
Midwest	1,450,111 (21.7)	211,752 (29.8)	363,050 (17.3)	713,391 (21.8)	161,918 (27.0)
South	2,563,243 (38.4)	316,281 (44.5)	832,584 (39.7)	123,3023 (37.8)	181,355 (30.2)
West	1,532,604 (23.0)	111,190 (15.7)	692,572 (33.0)	548,120 (16.8)	180,722 (30.1)
Number of Chronic Conditions					
0	4,545,579 (68.1)	567,091 (79.8)	1,651,235 (78.7)	2,151,751 (65.9)	175,502 (29.3)
1	1,079,510 (16.2)	91,005 (12.8)	267,857 (12.8)	558,132 (17.1)	162,515 (27.1)
2	450,687 (6.8)	26,433 (3.7)	87,618 (4.2)	238,233 (7.3)	98,403 (16.4)
3+	599,446 (9.0)	25,941 (3.7)	92,283 (4.4)	318,093 (9.7)	163,129 (27.2)
Hospital Birth	3,733,760 (55.9)	447,564 (63.0)	142,8279 (68.0)	1,844,866 (56.5)	13,051 (2.2)
Medical APR-DRG	6,084,913 (91.2)	669,985 (94.3)	1,979,566 (94.3)	2,977,217 (91.2)	458,145 (76.4)

[a]All comparisons between hospital types were significant at $P < .001$.

NOTE: Abbreviations: APR-DRGs, all patient refined diagnosis related group; H-RISK, hospitalization resource intensity scores for kids, SOI, severity of illness.

variables including comparisons of neonatal (MDC 15) and nonneonatal discharges, and medical versus procedural discharges as defined by the APR-DRG grouper were assessed using a Kruskal–Wallis test. All analyses were performed using SAS, Version 9.4 (SAS Institute, Cary, North Carolina); *P* values <.05 were considered statistically significant.

This study was considered nonhuman subjects research by the Institutional Review Board of Vanderbilt University Medical Center.

RESULTS

Patient Population

Table 1 summarizes the patient characteristics for all four hospital types. All comparisons of patient characteristics across the four hospital types are significant ($P < .001$). Of the 6,675,222 weighted discharges in HCUP KID 2012, almost two-thirds were less than one year old (4,269,984). Three-quarters of those infant discharges (3,733,760) were in-hospital births. The South was the Census region with the most number of discharges (38.8%), and over half of discharges (53.2%) included patients who lived in metro areas with more than 1 million residents. Patients disproportionately originated from lower-income areas with 30.9% living in zip codes with median incomes in the first quartile.

More than 80% of discharges were classified by a medical APR-DRG. The most common medical APR-DRG SOI was APR-DRG 640 SOI 1, "Neonate birthweight >2,499 g, normal newborn or neonate with other problem," which accounted for almost half of medical APR-DRG discharges (44.5%, Table 2). Of the 10 most common medical APR-DRG SOIs, the only non-

TABLE 2. **Top 10 Medical and Procedural APR-DRG SOIs by Discharge Volume, with relative weights (H-RISK).**

Rank	APR-DRG	Severity	Volume, N (%[a])	H-RISK
Medical APR-DRGs				
1	640: Neonate birthweight >2499 g, normal newborn or neonate w other problem	1: Minor	2,708,958 (44.5)	0.18
2	640: Neonate birthweight >2499 g, normal newborn or neonate w other problem	2: Moderate	492,991 (8.1)	0.26
3	560: Vaginal delivery	1: Minor	225,114 (3.7)	0.51
4	640: Neonate birthweight >2499 g, normal newborn or neonate w other problem	3: Major	120,458 (2.0)	0.65
5	560: Vaginal delivery	2: Moderate	119,230 (2.0)	0.60
6	141: Asthma	1: Minor	88,758 (1.5)	0.55
7	138: Bronchiolitis and RSV pneumonia	1: Minor	71,591 (1.2)	0.49
8	639: Neonate birthweight >2499 g w other significant condition	1: Minor	60,433 (1.0)	0.83
9	626: Neonate birthweight 2000–2499 g, normal newborn or neonate w other problem	1: Minor	55,828 (0.9)	0.26
10	139: Pneumonia NEC	1: Minor	55,318 (0.9)	0.49
Procedural APR-DRGs				
1	540: Cesarean delivery	1: Minor	62,127 (10.5)	0.83
2	225: Appendectomy	1: Minor	53,914 (9.1)	1.23
3	540: Cesarean delivery	2: Moderate	39,779 (6.7)	1.02
4	225: Appendectomy	2: Moderate	30,389 (5.1)	1.88
5	315: Shoulder, upper arm, and forearm procedures	1: Minor	11,425 (1.9)	1.05
6	313: Knee & lower leg procedures except foot	1: Minor	10,541 (1.8)	1.73
7	540: Cesarean delivery	3: Major	10,248 (1.7)	1.42
8	97: Tonsil & adenoid procedures	1: Minor	9,928 (1.7)	0.78
9	222: Other stomach, esophageal, & duodenal procedures	1: Minor	9,175 (1.6)	1.02
10	315: Shoulder, upper arm, & forearm procedures	2: Moderate	8,106 (1.4)	1.63

[a]Percentages listed are percent of discharge type (medical vs. procedural).
NOTE: Abbreviations: APR-DRGs, all patient refined diagnosis related group; H-RISK, hospitalization resource intensity scores for kids, NEC, not elsewhere classified; SOI, severity of illness.

neonate, nonvaginal delivery APR-DRG SOIs included Asthma SOI 1, Bronchiolitis & RSV pneumonia SOI 1, and Pneumonia NEC SOI 1. Caesarian delivery and appendectomy represented half of the 10 most common procedural APR-DRG SOIs.

H-RISK Generation

Of the 1,258 APR-DRG SOI cost-based RWs (H-RISK), 1,119 (89.0%) met the minimum sample size and adhered to the monotonicity requirement. Thus, the Winsorized mean within the APR-DRG SOI was used. Modeling was used for 112 (8.9%) APR-DRG SOIs, and 23 (1.8%) were grouped with others to ensure that results were monotonically nondecreasing. For one APR-DRG, 482–Transurethral Prostatectomy, the dataset contained no discharges. Thus, Winsorized mean of all encounters within MDC 12, Diseases and Disorders of Male Reproductive System, was used.

The weighted Winsorized mean cost of all discharges was $6,135 per discharge. The majority of cost-based H-RISK were higher than 1, with 1,038 (82.5%) of APR-DRG SOIs incurring an estimated cost higher than $6,135. Solid organ and bone marrow transplantations represented 4 of the 10 highest cost-based RWs for procedural APR-DRG SOIs (Table 3). Neonatal APR-DRG SOIs accounted for 8 of the 10 highest medical RWs. A list of all APR-DRG SOIs and H-RISK can be found in Appendix A.

Hospital-Level Case-Mix Index for Acute Hospitalizations

After excluding normal newborn and maternal hospitalizations, median CMI of the 3,117 hospitals with at least 20 unweighted discharges was 1.0 (interquartile range [IQR]: 0.8, 1.7). CMI varied significantly across hospital types ($P < .001$). Free-standing children's hospitals exhibited the highest cost-based CMI (median: 2.7, IQR: 2.2–3.1), followed by urban teaching hospitals (median: 1.8, IQR: 1.3–2.6), urban nonteaching hospitals (median: 1.1, IQR:

TABLE 3. **Top 10 Medical and Procedural APR-DRG SOIs by Relative Weight (H-RISK).**

Rank	APR-DRG	Severity	Volume, N (%*)	H-RISK
Medical APR-DRGs				
1	589: Neonate birthweight <500 G or GA <24 weeks	3: Major	1,926 (0.0)	32.50
2	591: Neonate birthweight 500–749 g w/o major procedure	4: Extreme	3,404 (0.1)	32.44
3	589: Neonate birthweight <500G or GA <24 weeks	2: Moderate	303 (0.0)	30.44
4	593: Neonate birthweight 750–999 g w/o major procedure	4: Extreme	4,174 (0.1)	27.22
5	281: Malignancy of hepatobiliary system & pancreas	4: Extreme	30 (0.0)	22.53
6	591: Neonate birthweight 500–749 g w/o major procedure	3: Major	964 (0.0)	21.64
7	602: Neonate birthweight 1000–1249 g w RDS, other major respiratory or major anomaly	4: Extreme	2,283 (0.0)	21.53
8	40: Spinal disorders & injuries	4: Extreme	38 (0.0)	19.74
9	603: Neonate birthweight 1000–1249 g w or w/o other significant condition	4: Extreme	201 (0.0)	19.46
10	593: Neonate birthweight 750–999 g w/o major procedure	3: Major	3,358 (0.1)	18.98
Procedural APR-DRGs				
1	2: Heart &/or lung transplant	4: Extreme	293 (0.0)	91.66
2	583: Neonate, w ECMO	4: Extreme	623 (0.1)	66.12
3	161: Cardiac defibrillator & heart assist implant	4: Extreme	66 (0.0)	58.98
4	3: Bone marrow transplant	4: Extreme	597 (0.1)	56.55
5	588: Neonate birthweight <1500 g w major procedure	4: Extreme	4,062 (0.7)	48.72
6	1: Liver transplant &/or intestinal transplant	4: Extreme	333 (0.1)	45.95
7	841: Extensive 3rd degree burns w skin graft	4: Extreme	143 (0.0)	41.25
8	4: Tracheostomy w MV 96+ h w extensive procedure or ECMO	4: Extreme	2,379 (0.4)	40.23
9	162: Cardiac valve procedures w cardiac catheterization	4: Extreme	80 (0.0)	38.33
10	3: Bone marrow transplant	3: Major	566 (0.1)	35.54

*Percentages listed are percent of discharge type (medical vs. procedural).

Abbreviations: APR-DRGs, all patient refined diagnosis related group; ECMO, Extracorporeal membrane oxygenation; H-RISK, hospitalization resource intensity scores for kids; MV, mechanical ventilation; RDS, respiratory distress syndrome; SOI, severity of illness.

0.9–1.5), and rural hospitals (median: 0.9, IQR: 0.7–0.9).

These differences in CMI persist when analyzing specific subpopulations. Significant differences in CMI were observed across the four hospital types for both procedural ($P < .001$) and medical APR-DRGs ($P < .001$), with free-standing children's hospitals demonstrating the highest CMI of all hospital types (Figure). Similarly, within both neonatal and nonneonatal populations, significant variation in CMI was noted across hospital types ($P < .001$) with free-standing children's hospitals incurring the highest CMIs (Figure).

DISCUSSION

Currently, no widely available measures can compare the relative intensity of hospital care specific for inpatient pediatric populations. To meet this important need, we have developed a methodology to determine valid pediatric RWs (H-RISK) which can be used to estimate the intensity of care for applications across entire hospital patient populations and specific subpopulations. H-RISK allow calculation of CMIs for risk adjustment of various outcomes at the discharge- or hospital-level and for comparisons among hospitals and populations. Using this methodology, we demonstrated that the CMI for free-standing children's hospitals was significantly higher than those of rural, urban, nonteaching, and urban teaching hospitals for all discharges and medical or procedural subgroups.

CMS has used RWs based on DRGs since the inception of the prospective payment system in 1983. The sequence of DRGs used by CMS has purposely focused on older adult Medicare population, and CMS itself recommends applying Medicare-focused DRGs (MS-DRGs being the current iteration) only for the >65 years population.[6] Nevertheless, many payers, both government and commercial, utilize MS-DRGs and their RWs for

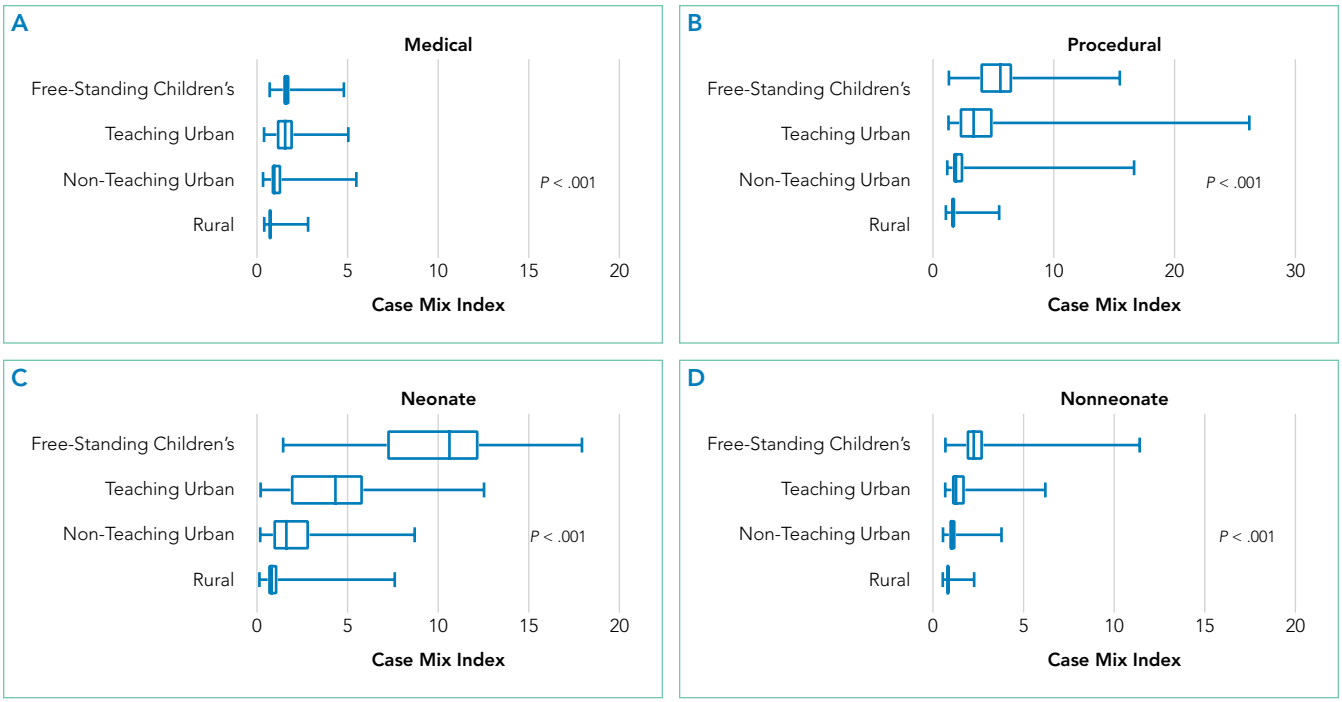

FIG. Case mix index by hospital type for: (A) medical, (B) procedural, (C) neonate, and (D) nonneonate discharges. The *P*-value indicates the level of significance comparing case-mix index across the four hospital types.

payment purposes when reimbursing children's hospitals. The validity of using weights developed using this grouper in hospitals treating large numbers of pediatric patients and childhood illnesses has been called into question, particularly when such weights are used in reimbursement of children's hospitals.[7]

Several factors contribute to the validity of a model for developing RWs. First, the system used to describe patient hospitalizations and illnesses should be appropriate to the population in question. As described above, the original DRG system and its subsequent iterations were designed to describe hospitalizations for adults >65 years of age.[8,9] Over the years, CMS DRGs incorporated rudimentary categories for neonatal and obstetrical hospitalizations. Still, the current MS-DRGs lack sufficient focus on common inpatient pediatric conditions to adequately describe pediatric hospitalizations, particularly those in free-standing children's hospitals delivering tertiary and quaternary care. Thus, a more appropriate classification schema for developing RWs specific for pediatric hospitalization should include patients across the entire age spectrum. APR-DRGs represent one such classification system.

Once an appropriate patient classification system is selected, then the population of hospitalized patients to be used as the reference group becomes important. For a system targeting a pediatric inpatient population, a hospital discharge database representing a broad sample of pediatric hospitalizations offers the best basis for developing a system of weights applicable to different types of hospitals providing care for children. For this purpose, we selected the 2012 KID database, a nationally representative dataset containing data on newborn and pediatric discharges from the majority of states within the Unietd States. This choice assured that the RWs developed were based on and applicable to pediatric hospitalizations across the entire spectrum of SOI and resource intensity.

A number of measures of hospital performance and quality have been developed and are used by various entities, including individual hospitals, CMS, Leapfrog, Magnet, Joint Commission, and payers, for purposes ranging from benchmarking for improvement to payment models to reimbursement penalties. However, SOI of a hospital's patient population influences not only the intensity of care that a hospital provides but also presents a potential impact on process and outcome measures. Thus, fair and appropriate measures must consider differences in SOI when comparing hospital performances. Using the weights derived in this paper, these adjustments can be possibly made at either the discharge- or hospital-level, depending on the application, and may include comparisons by hospital location, ownership, payer mix, or socioeconomic strata.

It is also common for hospitals to quantitatively express the uniqueness of services that they deliver to payers or the general public. A hospital-level CMI (derived as the average discharge weight for patients within a hospital) is one way that hospitals may differentiate themselves. This can be accomplished by considering the ratio of one hospital's CMI to another hospital's (or an average of a group of hospitals) as an expression of the relative intensity of services. For example, if hospital x has a CMI of 2.3, and hospital y has a CMI of 1.4, the population of children hospitalized at hospital x was 64.3% (1–2.3/1.4) more resource intensive than the children seen at hospital y.

This study should be considered in terms of several limitations. We used costs as the basis for determining intensity of service. Thus, the difference in cost structure among children's

hospitals and between children's hospitals and other hospital types in the KID could have affected the final calculated weights. Also, the RWs calculated in this study rely on hospital discharge data. Thus, complications which were not "present on admission" and occurred during a hospitalization could have reflected poor quality of care yet still increase resource intensity as measured by total costs. Future studies should examine the potential impact of using present-on-admission diagnoses only for the APR-DRG grouping on the values of RWs. Significant variation may have existed among hospitals in resource utilization, and some hospitals may have exhibited significant overutilization of resources for the same conditions. However, as we used Winsorized means, the impact of potential outliers should have been reduced. Some APR-DRG-SOI combinations were seen mainly at children's hospitals. Thus, cost structure and resource utilization practices of this subset of hospitals would have been the only contributors to weights for these patients. Given that the 2012 KID contained a broad representation of pediatric hospitalizations, with age 0–20 years, newborns accounted for the majority of total cases in the database. While providing a full range of pediatric weights, inclusion of these patients lowered the overall average RW. For this reason, we excluded normal newborn categories and maternal categories from analysis of CMI across hospital types and focused on acute-care hospitalizations. Lastly, as with any study relying on administrative data, there is always the possibility of coding errors or data entry errors in the reference dataset.

CONCLUSIONS

H-RISK can be used to risk adjust measures to account for severity differences across populations. These weights can also be averaged across hospitals' patient populations to compare relative resource intensities of the patients served.

Disclosures: The authors have nothing to disclose.

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Safety Huddle Intervention for Reducing Physiologic Monitor Alarms: A Hybrid Effectiveness-Implementation Cluster Randomized Trial

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BACKGROUND: Monitor alarms occur frequently but rarely warrant intervention.

OBJECTIVE: This study aimed to determine if a safety huddle-based intervention reduces unit-level alarm rates or alarm rates of individual patients whose alarms are discussed, as well as evaluate implementation outcomes.

DESIGN: Unit-level, cluster randomized, hybrid effectiveness-implementation trial with a secondary patient-level analysis.

SETTING: Children's hospital.

PATIENTS: Unit-level: all patients hospitalized on four control (n = 4177) and four intervention (n = 7131) units between June 15, 2015 and May 8, 2016. Patient-level: 425 patients on randomly selected dates postimplementation.

INTERVENTION: Structured safety huddle review of alarm data from the patients on each unit with the most alarms, with a discussion of ways to reduce alarms.

MEASUREMENTS: Unit-level: change in unit-level alarm rates between baseline and postimplementation periods in intervention versus control units. Patient-level: change in individual patients' alarm rates between the 24 hours leading up to huddles and the 24 hours after huddles in patients who were discussed versus not discussed in huddles.

RESULTS: Alarm data informed 580 huddle discussions. In unit-level analysis, intervention units had 2 fewer alarms/patient-day (95% CI: 7 fewer to 6 more, $P = .50$) compared with control units. In patient-level analysis, patients discussed in huddles had 97 fewer alarms/patient-day (95% CI: 52–138 fewer, $P < .001$) in the posthuddle period compared with patients not discussed in huddles. Implementation outcome analysis revealed a low intervention dose of 0.85 patients/unit/day.

CONCLUSIONS: Safety huddle-based alarm discussions did not influence unit-level alarm rates due to low intervention dose but were effective in reducing alarms for individual children. *Journal of Hospital Medicine* 2018:13:609-615. Published online first February 27, 2018.

Physiologic monitor alarms occur frequently in the hospital environment, with average rates on pediatric wards between 42 and 155 alarms per monitored patient-day.[1] However, average rates do not depict the full story, because only 9%-25% of patients are responsible for most alarms on inpatient wards.[1,2] In addition, only 0.5%-1% of alarms on pediatric wards warrant action.[3,4] Downstream consequences of high alarm rates include interruptions[5,6] and alarm fatigue.[3,4,7]

Alarm customization, the process of reviewing individual patients' alarm data and using that data to implement patient-specific alarm reduction interventions, has emerged as a potential approach to unit-wide alarm management.[8-11] Potential customizations include broadening alarm thresholds, instituting delays between the time the alarm condition is met and the time the alarm sounds, and changing electrodes.[8-11] However, the workflows within which to identify the patients who will benefit from customization, make decisions about how to customize, and implement customizations have not been delineated.

Safety huddles are brief structured discussions among physicians, nurses, and other staff aiming to identify and mitigate threats to patient safety.[11-13] In this study, we aimed to evaluate

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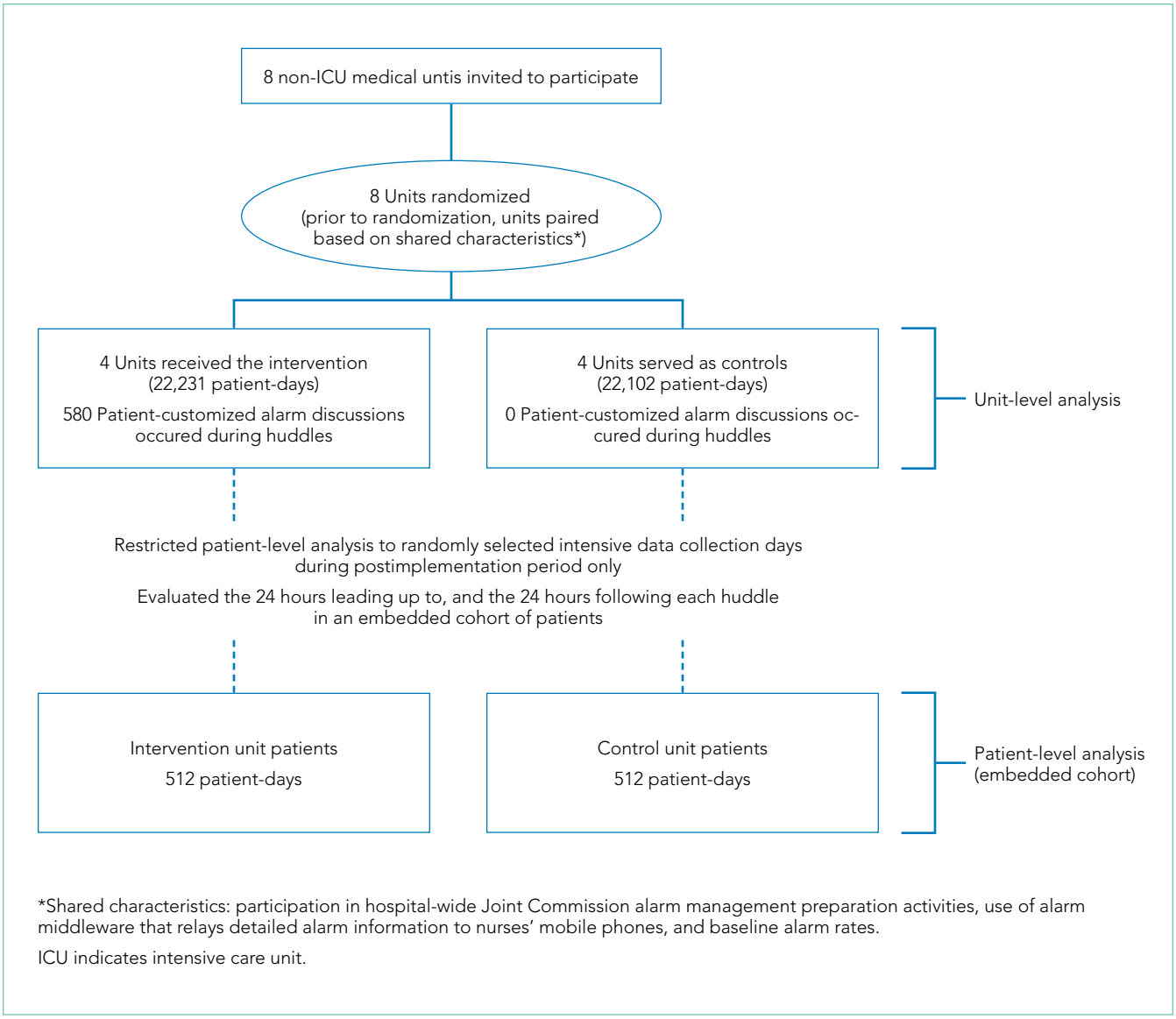

FIG 1. CONSORT flow diagram.

the influence of a safety huddle-based alarm intervention strategy targeting high alarm pediatric ward patients on (a) unit-level alarm rates and (b) patient-level alarm rates, as well as to (c) evaluate implementation outcomes. We hypothesized that patients discussed in huddles would have greater reductions in alarm rates in the 24 hours following their huddle than patients who were not discussed. Given that most alarms are generated by a small fraction of patients,[1,2] we hypothesized that patient-level reductions would translate to unit-level reductions.

METHODS

Human Subject Protection

The Institutional Review Board of Children's Hospital of Philadelphia approved this study with a waiver of informed consent. We registered the study at ClinicalTrials.gov (identifier NCT02458872). The original protocol is available as an Online Supplement.

Design and Framework

We performed a hybrid effectiveness-implementation trial at a single hospital with cluster randomization at the unit level (CONSORT flow diagram in Figure 1). Hybrid trials aim to determine the effectiveness of a clinical intervention (alarm customization) and the feasibility and potential utility of an implementation strategy (safety huddles).[14] We used the Consolidated Framework for Implementation Research[15] to theoretically ground and frame our implementation and drew upon the work of Proctor and colleagues[16] to guide implementation outcome selection.

For our secondary effectiveness outcome evaluating the effect of the intervention on the alarm rates of the individual patients discussed in huddles, we used a cohort design embedded within the trial to analyze patient-specific alarm data collected only on randomly selected "intensive data collection days," described below and in Figure 1.

Setting and Subjects

All patients hospitalized on eight units that admit general pediatric and medical subspecialty patients at Children's Hospital of Philadelphia between June 15, 2015 and May 8, 2016 were included in the primary (unit-level) analysis. Every patient's bedside included a General Electric Dash 3000 physiologic monitor. Decisions to monitor patients were made by physicians and required orders. Default alarm settings are available in Supplementary Table 1; these settings required orders to change.

All eight units were already convening scheduled safety huddles led by the charge nurse each day. All nurses and at least one resident were expected to attend; attending physicians and fellows were welcome but not expected to attend. Huddles focused on discussing safety concerns and patient flow. None of the preexisting huddles included alarm discussion.

Intervention

For each nonholiday weekday, we generated customized paper-based alarm huddle data "dashboards" (Supplementary Figure 1) displaying data from the patients (up to a maximum of four) on each intervention unit with the highest numbers of high-acuity alarms ("crisis" and "warning" audible alarms, see Supplementary Table 2 for detailed listing of alarm types) in the preceding four hours by reviewing data from the monitor network using BedMasterEx v4.2 (Excel Medical Electronics, Jupiter, Florida). Dashboards listed the most frequent types of alarms, alarm settings, and included a script for discussing the alarms with checkboxes to indicate changes agreed upon by the team during the huddle. Patients with fewer than 20 alarms in the preceding four hours were not included; thus, sometimes fewer than four patients' data were available for discussion. We hand-delivered dashboards to the charge nurses leading huddles, and they facilitated the multidisciplinary alarm discussions focused on reviewing alarm data and customizing settings to reduce unnecessary alarms.

Study Periods

The study had 3 periods as shown in Supplementary Figure 2: (1) 16-week baseline data collection, (2) phased intervention implementation during which we serially spent 2-8 weeks on each of the four intervention units implementing the intervention, and (3) 16-week postimplementation data collection.

Outcomes

The primary effectiveness outcome was the change in unit-level alarms per patient day between the baseline and postimplementation periods in intervention versus control units, with all patients on the units included. The secondary effectiveness outcome (analyzed using the embedded cohort design) was the change in individual patient-level alarms between the 24 hours leading up to a huddle and the 24 hours following huddles in patients who were versus patients who were not discussed in huddles.

Implementation outcomes included adoption and fidelity measures. To measure adoption (defined as "intention to try" the intervention),[16] we measured the frequency of discussions attended by patients' nurses and physicians. We evaluated three elements of fidelity: adherence, dose, and quality of delivery.[17] We measured adherence as the incorporation of alarm discussion into huddles when there were eligible patients to discuss. We measured dose as the average number of patients discussed on each unit per calendar day during the postimplementation period. We measured quality of delivery as the extent to which changes to monitoring that were agreed upon in the huddles were made at the bedside.

Safety Measures

To surveil for unintended consequences of reduced monitoring, we screened the hospital's rapid response and code blue team database weekly for any events in patients previously discussed in huddles that occurred between huddle and hospital discharge. We reviewed charts to determine if the events were related to the intervention.

Randomization

Prior to randomization, the eight units were divided into pairs based on participation in hospital-wide Joint Commission alarm management activities, use of alarm middleware that relayed detailed alarm information to nurses' mobile phones, and baseline alarm rates. One unit in each pair was randomized to intervention and the other to control by coin flip.

Data Collection

We used Research Electronic Data Capture (REDCap)[18] database tools.

Data for Unit-Level Analyses

We captured all alarms occurring on the study units during the study period using data from BedMasterEx. We obtained census data accurate to the hour from the Clinical Data Warehouse.

Data Captured in All Huddles

During each huddle, we collected the number of patients whose alarms were discussed, patient characteristics, presence of nurses and physicians, and monitoring changes agreed upon. We then followed up four hours later to determine if changes were made at the bedside by examining monitor settings.

Data Captured Only During Intensive Data Collection Days

We randomly selected one day during each of the 16 weeks of the postimplementation period to obtain additional patient-level data. On each intensive data collection day, the four monitored patients on each intervention and control unit with the most high-acuity alarms in the four hours prior to huddles occurring – regardless of whether or not these patients were later discussed in huddles – were identified for data collection. On these dates, a member of the research team reviewed each patient's alarm counts in four-hour blocks during the 24 hours before and after the huddle. Given that the huddles were not always at the same time every day (ranging between 10:00 AM and 1:00 PM), we operationally set the huddle time as 12:00 PM for all units.

TABLE 1. **Alarm Rates for Intervention and Control Units Across All Study Periods from Interrupted Time Series Piecewise Regression Analysis**

	Control Units	Intervention Units	Difference in Rate Differences	Difference in Differences *P* Value
Units (clusters)	4	4		
Patient-days	22,102	22,231		
Unique patients	4177	7131		
Baseline alarms/patient-day (95% CI)	77 (49–115)	46 (32–59)		
Phased implementation alarms/patient-day (95% CI)	76 (51–107)	53 (37–71)		
Postimplementation alarms/patient-day (95% CI)	85 (57–117)	52 (40–65)		
Rate difference in alarms/patient-day (95% CI): Baseline versus postimplementation	+8 (+2 to +14)	+6 (+5 to +9)	−2 (−7 to +6)	.50

Abbreviation: CI, confidence interval.

Data Analysis

We used Stata/SE 14.2 for all analyses.

Unit-Level Alarm Rates

To compare unit-level rates, we performed an interrupted time series analysis using segmented (piecewise) regression to evaluate the impact of the intervention.[19,20] We used a multivariable generalized estimating equation model with the negative binomial distribution[21] and clustering by unit. We bootstrapped the model and generated percentile-based 95% confidence intervals. We then used the model to estimate the alarm rate difference in differences between the baseline data collection period and the postimplementation data collection period for intervention versus control units.

Patient-Level Alarm Rates

In contrast to unit-level analysis, we used an embedded cohort design to model the change in individual patients' alarms between the 24 hours leading up to huddles and the 24 hours following huddles in patients who were versus patients who were not discussed in huddles. The analysis was restricted to the patients included in intensive data collection days. We performed bootstrapped linear regression and generated percentile-based 95% confidence intervals using the difference in four-hour block alarm rates between pre- and posthuddle as the outcome. We clustered within patients. We stratified by unit and preceding alarm rate. We modeled the alarm rate difference between the 24-hour prehuddle and the 24-hour posthuddle for huddled and nonhuddled patients and the difference in differences between exposure groups.

Implementation Outcomes

We summarized adoption and fidelity using proportions.

RESULTS

Alarm dashboards informed 580 structured alarm discussions during 353 safety huddles (huddles often included discussion of more than one patient).

Unit-Level Alarm Rates

A total of 2,874,972 alarms occurred on the eight units during the study period. We excluded 15,548 alarms that occurred during the same second as another alarm for the same patient because they generated a single alarm. We excluded 24,700 alarms that occurred during 4 days with alarm database downtimes that affected data integrity. Supplementary Table 2 summarizes the characteristics of the remaining 2,834,724 alarms used in the analysis.

Visually, alarm rates over time on each individual unit appeared flat despite the intervention (Supplementary Figure 3). Using piecewise regression, we found that intervention and control units had small increases in alarm rates between the baseline and postimplementation periods with a nonsignificant difference in these differences between the control and intervention groups (Table 1).

Patient-Level Alarm Rates

We then restricted the analysis to the patients whose data were collected during intensive data collection days. We obtained data from 1974 pre-post pairs of four-hour time periods.

Patients on intervention and control units who were not discussed in huddles had 38 fewer alarms/patient-day (95% CI: 23–54 fewer, $P < .001$) in the posthuddle period than in the prehuddle period. Patients discussed in huddles had 135 fewer alarms/patient-day (95% CI: 93–178 fewer, $P < .001$) in the posthuddle 24-hour period than in the prehuddle period. The pairwise comparison reflecting the difference in differences showed that huddled patients had a rate of 97 fewer alarms/patient-day (95% CI: 52–138 fewer, $P < .001$) in the posthuddle period compared with patients not discussed in huddles.

To better understand the mechanism of reduction, we analyzed alarm rates for the patient categories shown in Table 2 and

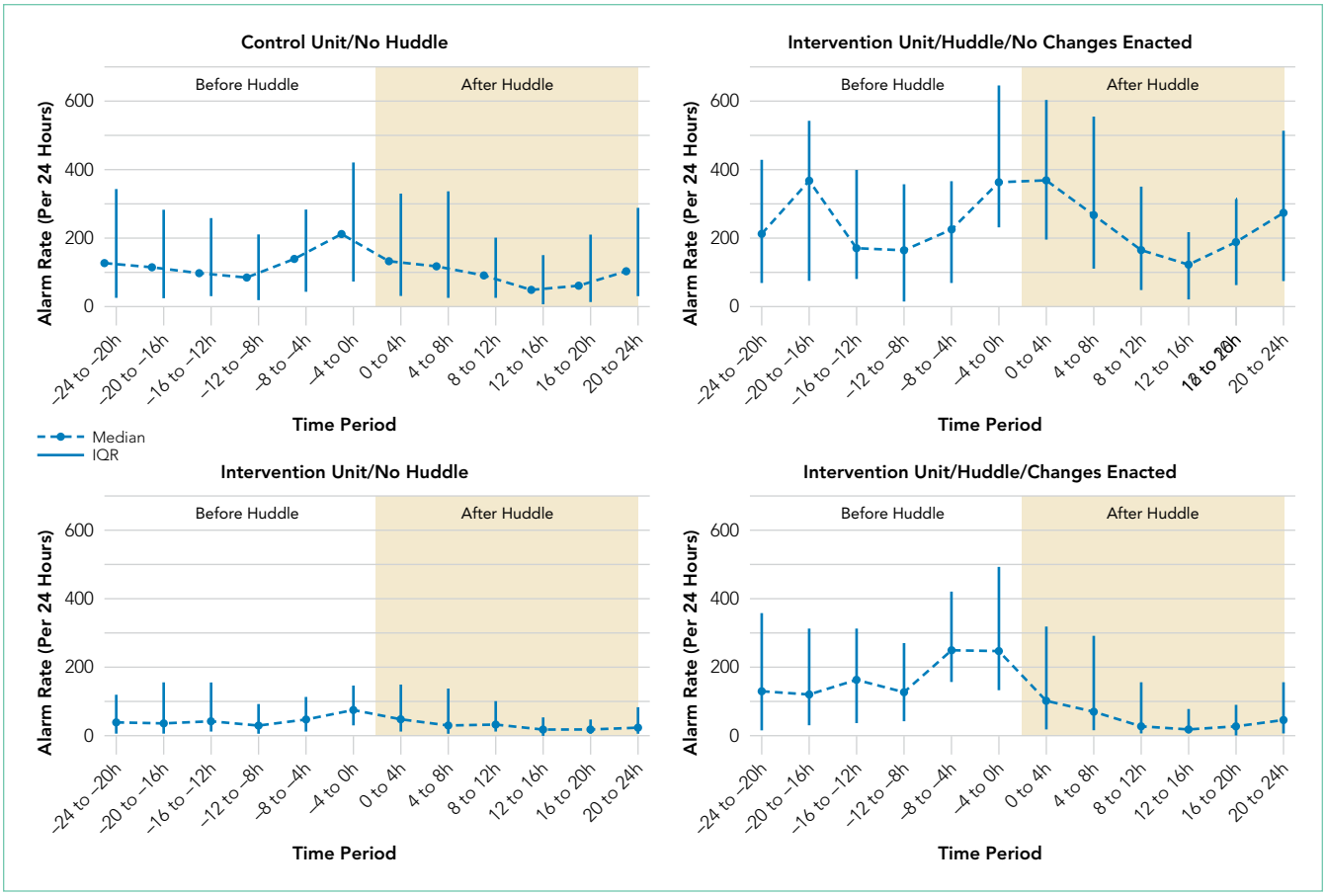

FIG 2. Patient-level alarm rates in the 24 hours leading up to safety huddles and the 24 hours after huddles. Abbreviation: IQR, interquartile range.

visually evaluated how average alarm rates changed over time (Figure 2). When analyzing the six potential pairwise comparisons between each of the four categories separately, we found that the following two comparisons were statistically significant: (1) patients whose alarms were discussed in huddles and had changes made to monitoring had greater alarm reductions than patients on control units, and (2) patients whose alarms were discussed in huddles and had changes made to monitoring had greater alarm reductions than patients who were also on intervention units but whose alarms were not discussed (Table 2).

Implementation Outcomes

Adoption

The patient's nurse attended 482 of the 580 huddle discussions (83.1%), and at least one of the patient's physicians (resident, fellow, or attending) attended 394 (67.9%).

Fidelity: Adherence

In addition to the 353 huddles that included alarm discussion, 123 instances had no patients with ≥20 high acuity alarms in the preceding 4 hours therefore, no data were brought to the huddle. There were an additional 30 instances when a huddle did not occur or there was no alarm discussion in the huddle despite data being available. Thus, adherence occurred in 353 of 383 huddles (92.2%).

Fidelity: Dose

During the 112 calendar day postimplementation period, 379 patients' alarms were discussed in huddles for an average intervention dose of 0.85 discussions per unit per calendar day.

Fidelity: Quality of Delivery

In 362 of the 580 huddle discussions (62.4%), changes were agreed upon. The most frequently agreed upon changes were discontinuing monitoring (32.0%), monitoring only when asleep or unsupervised (23.8%), widening heart rate parameters (12.7%), changing electrocardiographic leads/wires (8.6%), changing the pulse oximetry probe (8.0%), and increasing the delay time between when oxygen desaturation was detected and when the alarm was generated (4.7%). Of the huddle discussions with changes agreed upon, 346 (95.6%) changes were enacted at the bedside.

Safety Measures

There were zero code blue events and 26 rapid response team activations for patients discussed in huddles. None were related to the intervention.

DISCUSSION

Our main finding was that the huddle strategy was effective in safely reducing the burden of alarms for the high alarm pedi-

TABLE 2. **Alarm Rate Differences Based on Patient Category**

	Category 1. Control Unit, Not Discussed in Huddle	Category 2. Intervention Unit, Not Discussed in Huddle	Category 3. Intervention Unit, Discussed in Huddle, But No Changes Made in 4 h After Huddle	Category 4. Intervention Unit, Discussed in Huddle, Monitor Changes Made in 4 h After Huddle
Huddles or huddle opportunities, n[a]	256	135	34	87
Unique patients, n	201	126	27	71
Patient age in years, median (IQR)	4.1 (0.5–14.3)	4.1 (1.0–12.4)	0.6 (0.3–4.9)	1.4 (0.3–7.0)
Pre/post-huddle difference in alarms/patient-day (95% CI)	49 fewer (29 to 70 fewer)	14 fewer (35 fewer to 11 more)	54 fewer (155 fewer to 31 more)	168 fewer (125 to 217 fewer)
Versus Category 1:				
Difference in differences contrast in alarms/patient-day (95% CI, P)[b]		35 more (7 fewer to 78 more, $P = .17$)	5 fewer (130 fewer to 121 more, $P = .99$)	119 fewer (186 fewer to 52 fewer, $P < .001$)
Versus Category 2:				
Difference in differences contrast in alarms/patient-day (95% CI, P)[b]			40 fewer (165 fewer to 85 more, $P = .99$)	154 fewer (220 fewer to 89 fewer, $P < .001$)
Versus Category 3:				
Difference in differences contrast in alarms/patient-day (95% CI, P)[b]				114 fewer (253 fewer to 24 more, $P = .17$)

[a]Patients who were not discussed in huddles (Groups 1 and 2) but whose data we obtained for comparison on intensive data collection days are enumerated here as "huddle opportunities."

[b]CI and *P* value adjusted for 6 pairwise comparisons using Bonferroni method.

Abbreviations: CI, confidence interval; IQR, interquartile range.

atric ward patients whose alarms were discussed, but it did not reduce unit-level alarm rates. Implementation outcomes explained this finding. Although adoption and adherence were high, the overall dose of the intervention was low.

We also found that 36% of alarms had technical causes, the majority of which were related to the pulse oximetry probe detecting that it was off the patient or searching for a pulse. Although these alarms are likely perceived differently by clinical staff (most monitors generate different sounds for technical alarms), they still represent a substantial contribution to the alarm environment. Minimizing them in patients who must remain continuously monitored requires more intensive effort to implement other types of interventions than the main focus of this study, such as changing pulse oximetry probes and electrocardiographic leads/wires.

In one-third of huddles, monitoring was simply discontinued. We observed in many cases that, while these patients may have had legitimate indications for monitoring upon admission, their conditions had improved; after brief multidisciplinary discussion, the team concluded that monitoring was no longer indicated. This observation may suggest interventions at the ordering phase, such as prespecifying a monitoring duration.[22,23]

This study's findings were consistent with a quasi-experimental study of safety huddle-based alarm discussions in a pediatric intensive care unit that showed a patient-level reduction of 116 alarms per patient-day in those discussed in huddles relative to controls.[11] A smaller quasi-experimental study of implementing a nighttime alarm "ward round" in an adult intensive care unit showed a significant reduction in unit-level alarms/patient-day from 168 to 84.[9] In a quality improvement report, a monitoring care process bundle that included discussion of alarm settings showed a reduction in unit-level alarms/patient-day from 180 to 40.[10] Our study strengthens the body of literature using a cluster-randomized design, measuring patient- and unit-level outcomes, and including implementation outcomes that explain effectiveness findings.

On a hypothetical unit similar to the ones we studied with 20 occupied beds and 60 alarms/patient-day, an average of 1,200 alarms would occur each day. We delivered the intervention to 0.85 patients per day. Changes were made at the bedside in 60% of those with the intervention delivered, and those patients had a difference in differences of 119 fewer alarms compared with the comparison patients on control units. In this scenario, we could expect a relative reduction of 0.85 x 0.60 x 119 = 61 fewer alarms/day total on the unit or a 5% reduction. However, that estimated reduction did not account for the arrival of new patients with high alarm rates, which certainly occurred in this study and explained the lack of effect at the unit level.

As described above, the intervention dose was low, which translated into a lack of effect at the unit level despite a strong effect at the patient level. This result was partly due to the manual process required to produce the alarm dashboards that restricted their availability to nonholiday weekdays. The study was performed at one hospital, which limited generalizability. The study hospital was already convening daily safety huddles that were well attended by nurses and physicians. Other hos-

pitals without existing huddle structures may face challenges in implementing similar multidisciplinary alarm discussions. In addition, the study design was randomized at the unit (rather than patient) level, which limited our ability to balance potential confounders at the patient level.

CONCLUSION

A safety huddle intervention strategy to drive alarm customization was effective in safely reducing alarms for individual children discussed. However, unit-level alarm rates were not affected by the intervention due to a low dose. Leaders of efforts to reduce alarms should consider beginning with passive interventions (such as changes to default settings and alarm delays) and use huddle-based discussion as a second-line intervention to address remaining patients with high alarm rates.

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A Matter of Urgency: Reducing Clinical Text Message Interruptions During Educational Sessions

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BACKGROUND: Text messaging is increasingly replacing paging as a tool to reach physicians on medical wards. However, this phenomenon has resulted in high volumes of nonurgent messages that can disrupt the learning climate.

OBJECTIVE: Our objective was to reduce nonurgent educational interruptions to residents on general internal medicine.

DESIGN, SETTING, PARTICIPANTS: This was a quality improvement project conducted at an academic hospital network. Measurements and interventions took place on eight general internal medicine inpatient teaching teams.

INTERVENTION: Interventions included (1) refining the clinical communication process in collaboration with nursing leadership; (2) disseminating guidelines with posters at nursing stations; (3) introducing a noninterrupting option for message senders; (4) audit and feedback of messages; (5) adding an alert for message senders advising if a message would interrupt educational sessions; and (6) training and support to nurses and residents.

MEASUREMENTS: Interruptions (text messages, phone calls, emails) received by institution-supplied team smartphones were tracked during educational hours using statistical process control charts. A one-month record of text message content was analyzed for urgency at baseline and following the interventions.

RESULTS: The interruption frequency decreased from a mean of 0.92 (95% CI, 0.88 to 0.97) to 0.59 (95% CI, 0.51 to0.67) messages per team per educational hour from January 2014 to December 2016. The proportion of nonurgent educational interruptions decreased from 223/273 (82%) messages over one month to 123/182 (68%; $P < .01$).

CONCLUSIONS: Creation of communication guidelines and modification of text message interface with feedback from end-users were associated with a reduction in nonurgent educational interruptions. Continuous audit and feedback may be necessary to minimize nonurgent messages that disrupt educational sessions. *Journal of Hospital Medicine* 2018;13:616-622. Published online first April 25, 2018. © 2018 Society of Hospital Medicine

On general medical wards, effective interprofessional communication is essential for high-quality patient care. Hospitals increasingly adopt secure text-messaging systems for healthcare team members to communicate with physicians in lieu of paging.[1-3] Text messages facilitate bidirectional communication[4,5] and increase perceived efficiency[6-8] and are thus preferred over paging by nurses and trainees. However, this novel technology unintentionally causes high volumes of interruptions.[9,10] Compared to paging, sending text messages and calling smartphones are more convenient and encourage communication of issues in real time, regardless of urgency.[11] Interrupting messages are often perceived as nonurgent by physicians.[6,12] In particular, 73%-93% of pages or messages sent to physicians are found to be nonurgent.[13-17]

Pages, text messages, or calls not only interrupt day-to-day tasks on the ward[6,7,10,11,17,18] but also educational sessions,[18-21] which are essential to the clinical teaching unit (CTU). Interruptions reduce learning and retention[22] and are disruptive to the medical learning climate.[18-20,23]

Internal medicine CTUs at our large urban academic hospital network utilize a smartphone-based text messaging tool for interdisciplinary communication. Nonurgent interruptions are frequent during educational seminars, which occur at our institution between 8 AM and 9 AM and 12 PM and 1 PM on weekdays.[10,11,19] In a preliminary analysis at one hospital site, an average of three text messages (range 1-11), two calls (range 0-8), and three emails (range 0-13) interrupted each educational session. Physicians and nurses can disagree on the urgency of messages or calls for the purposes of patient care and workflow.[6,11,12,24] Nurses have expressed a desire for guidance

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FIG 1. Example of a poster displaying the recommended clinical communication process, developed through interdisciplinary consensus.

regarding what constitutes an urgent clinical communication.[6]

This project aimed to reduce nonurgent text message interruptions during educational rounds. We hypothesized that improved decision support around clinical prioritization and reminders about educational hours could reduce unnecessary interruptions.

METHODS

This study was approved by the institution's Research Ethics Board and conducted across eight general medical CTU teams at an academic hospital network (Sites 1 and 2). Each CTU team provides 24-hour coverage of approximately 20–28 patients. The most responsible resident from each team carries an institution-provided smartphone, which receives secure texts, phone calls, and emails from nurses, social workers, physiotherapists, speech language pathologists, dieticians, pharmacists, and other physicians. Close collaboration with the platform developer permitted changes to be made to the system when needed. Prior to our interventions, a nurse could send a text message as either an "immediate interrupt" or a "delayed interrupt" message. Messages sent via the "delayed interrupt" option would be added to a queue and would eventually lead to an interrupting message if not replied to after a defined period. Direct phone calls were reserved for especially urgent or emergent communications.

Meetings were held with physicians and nursing managers at Site 1 (August 2014) and Site 2 (January 2015) to establish consensus on the communication process and determine clinical scenarios, regardless of time of day, that warrant a phone call, an "immediate interrupt" text, or a "delayed interrupt" text. In March 2015, resident feedback led to the addition of a third option to the sender interface. This option allowed messages to be sent as "For Your Information (FYI)" only, which would not lead to an interruption. "FYI" messages (for example, to notify that an ambulance had been booked for a patient), were instead placed in an electronic message board that could be viewed by the resident through the application. This change relied upon interdisciplinary trust and a commitment from residents to ensure that "FYI" messages were reviewed regularly.

Communication guidelines were transformed into poster format and displayed as a reference at nursing stations in July 2015 (Site 2) and February 2016 (Site 1; Figure 1). Nurse managers audited messages from nurses and provided feedback. In March 2016, a focused intervention was piloted across both sites to specifically limit nonurgent text messages during educational hours. First, educational hours were emphasized within the interface to make senders aware of their potential for interruption. In June 2016, the interface was further modified. Once the message application was opened during a defined educational time, an imbedded notification advised the

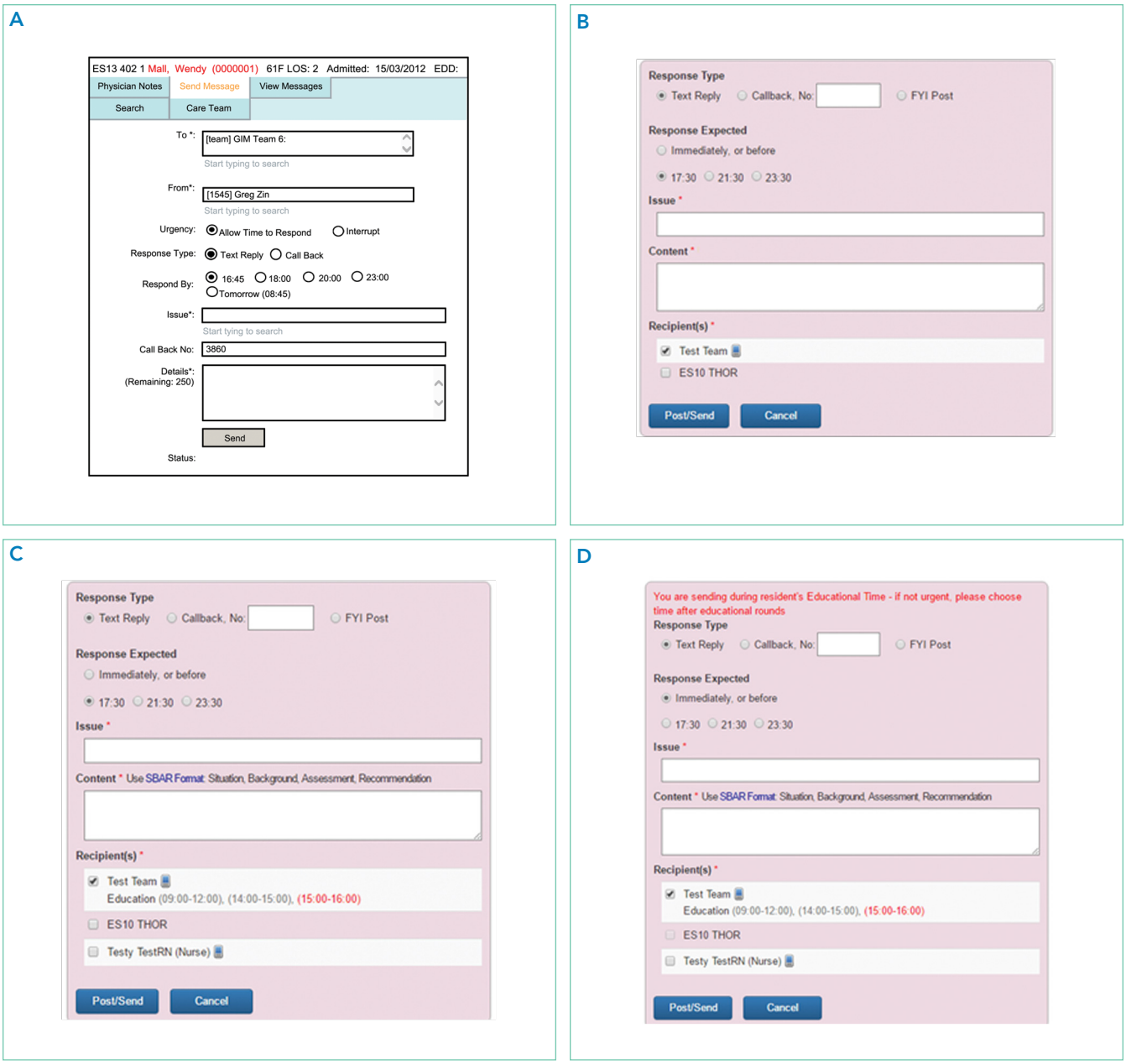

FIG 2. (A) Original text message interface. (B) March 2015: "FYI Post" option created. (C) March 2016: educational times defined in message interface. (D) June 2016: alert in message interface regarding educational hours.

sender to reevaluate the urgency of the communication and if appropriate, to delay sending the message until educational rounds were over or send an "FYI" message. This "alert" did not impede senders from sending a message through the system at any time (Figure 2A-D illustrates the evolution of the message interface).

Text interruptions (January 2014 to December 2016), phone calls (April 2015-December 2016), and emails (October 2014 to December 2016) received by team smartphones during educational hours were tracked. Total text messages sent over a 24-hour period and the type of message ("immediate interrupt," "delayed interrupt," and "FYI") were also monitored. Calls were encouraged only in the case of emergent patient care matters, and monitoring calls would thus help identify whether senders bypass the message system due to deterioration in patient status or confusion surrounding the new message interface. Emails sent to team smartphones came from a variety of sources, including hospital administration, physicians, and patient flow coordinators who are not involved in direct patient care. Emails served as a "negative control" because of the predicted random variability in the email interruption frequency. Additional balancing measures included tracking Critical Care Outreach Team consultations and "Code Blue" (cardiac arrest) announcements over the same period to ensure that limiting educational interruptions did not result in increased deterioration of patient status.

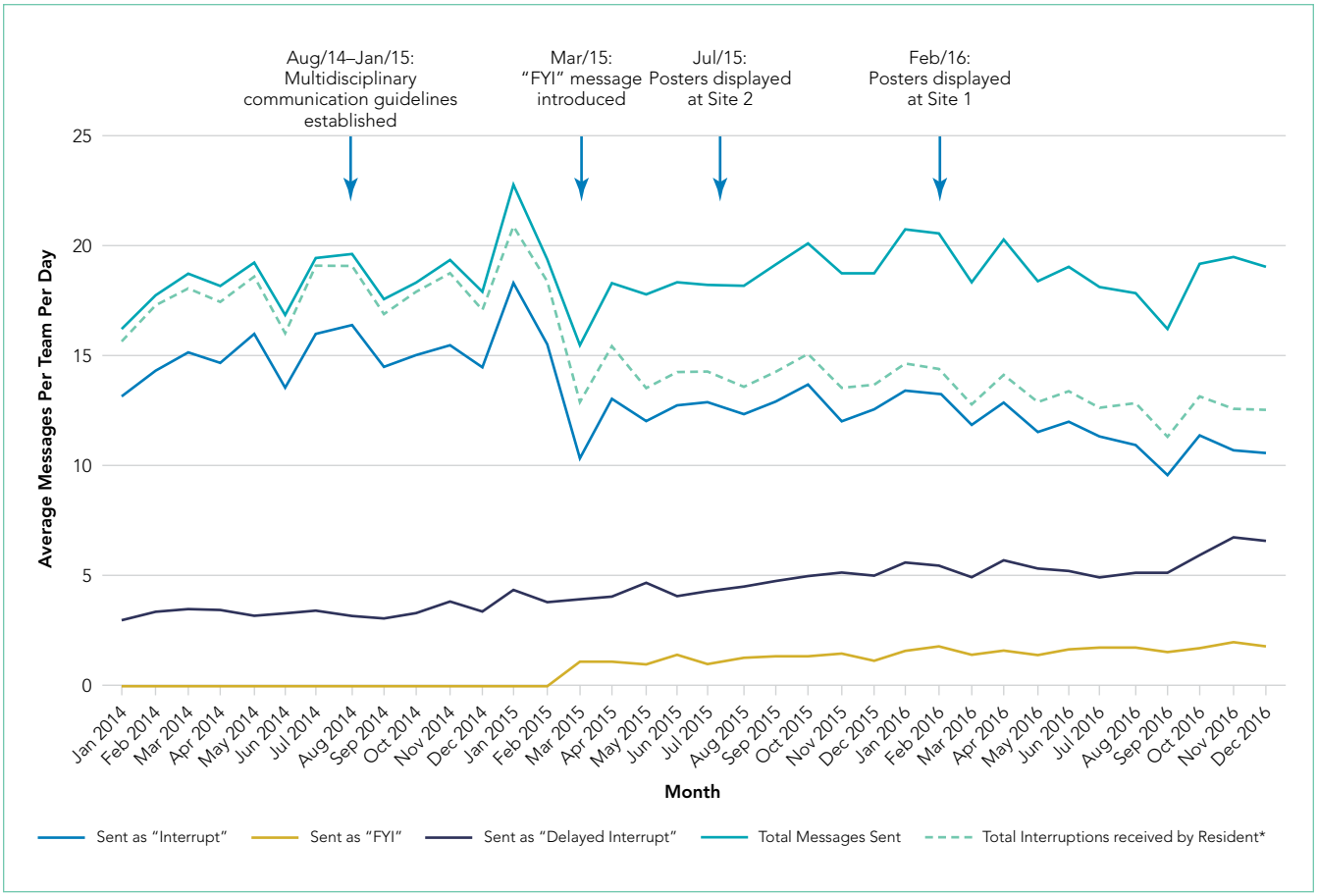

FIG 3. Total text messages sent to team smartphones according to message type, January 2014-December 2016.
*comprises messages sent as "interrupt" plus a portion of those sent as "delayed interrupt" that were not responded to by the time limit, triggering an interruption

Statistical process control charts (u charts) assessed the frequency of each type of educational interruption (text, call, or email) per team on a monthly basis. The total educational interruptions per month were divided by the number of educational hours per month to account for variation in educational hours each month (for example, during holidays when educational rounds do not take place). If call logs or email data were unavailable for individual teams or time periods, then the denominator was adjusted to reflect the number of teams and educational hours in the sample for that month.

Two four-week samples of interrupting text messages received by the eight teams during educational hours were deidentified, analyzed, and compared in terms of content and urgency. A preintervention sample (November 17 to December 14, 2014) was compared to a postintervention sample (November 14 to December 11, 2016). Messages from the 2014 and 2016 samples were randomized, deidentified for date and time, and analyzed for urgency by three independent adjudicators (two senior residents and one staff physician) to avoid biasing the postintervention analysis toward improvement. Messages were classified as "urgent" if the adjudicator felt a response or action was required within one hour. Messages not meeting these criteria were classified as "nonurgent" or "indeterminate" if the urgency of the message could not be assessed because it required further context. Fleiss kappa statistic evaluated agreement among adjudicators. Individual urgency designations were compared for each message, and discrepant rankings were addressed through repeated joint assessments. Disagreements were resolved through discussion and comparison against communication guidelines. In addition, messages reporting a "critical lab," requiring physician notification as per institutional policy, were reclassified as "urgent." The proportion of "nonurgent" messages sent during educational hours was compared between baseline and post-intervention periods using the Chi-square test.

"FYI" messages sent from November 14 to December 11, 2016 were audited using the same adjudication process to determine if "FYI" designations were appropriate and did not contain urgent patient care communications.

RESULTS

Total text messages sent to team smartphones, the type of message the sender intended ("immediate interrupt," "delayed interrupt," or "FYI"), and total text interruptions received by the resident over the study period are illustrated in Figure 3. The introduction of the "FYI" message in March 2015 was associated with reduced text message interruptions, from a mean of 18.0 (95% CI, 17.2 to18.8) interrupting messages per team per day to 14.1 (95% CI, 13.6 to14.5) in March 2015 and

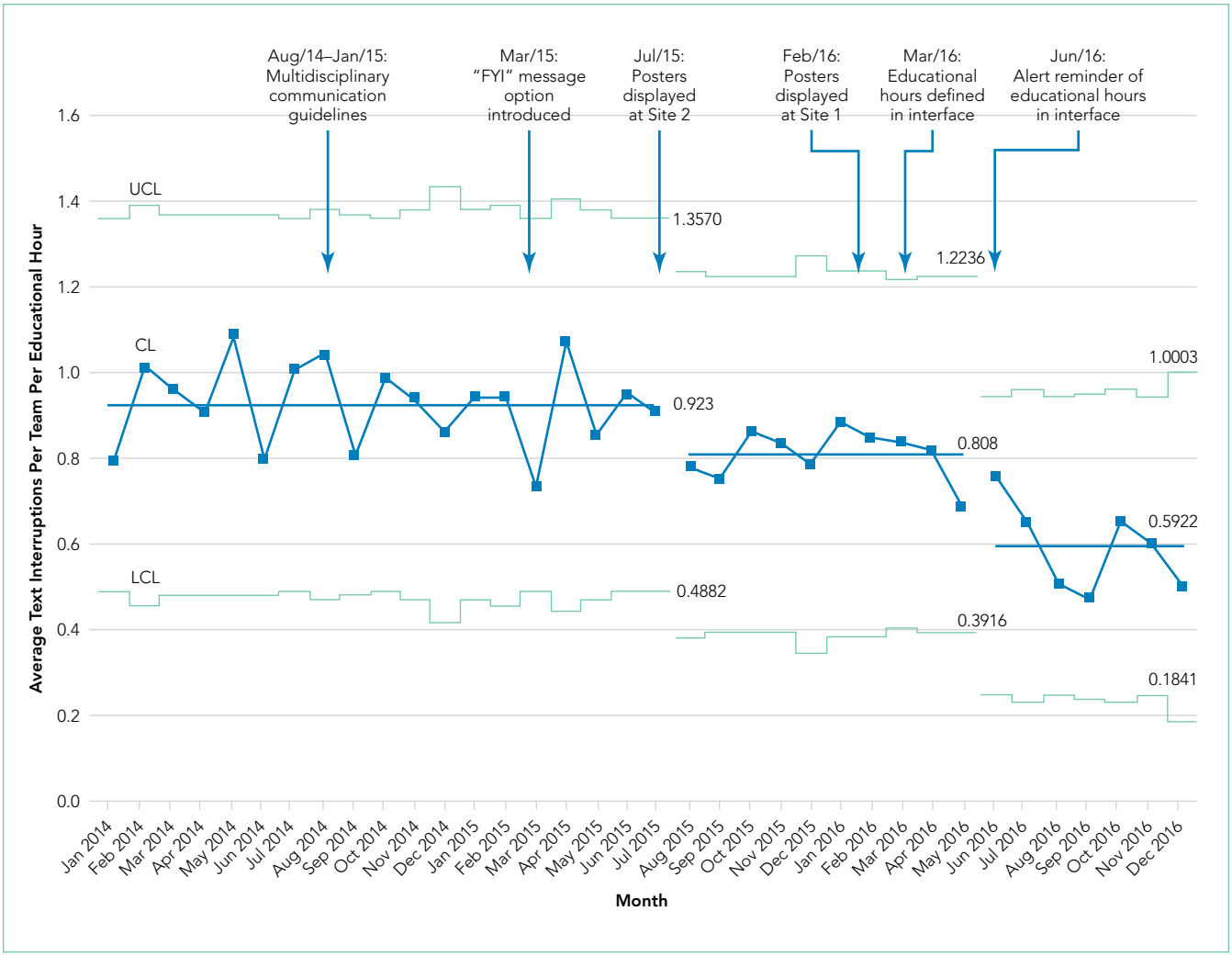

FIG 4. U Chart: text message interruptions per team per educational hour, January 2014-December 2016

12.7 (95% CI, 12.2 to 13.2) after May 2016 (Supplemental Figure 1). The numbers of "delayed interrupt" and "FYI" messages increased over time.

Analysis of text interruptions during educational hours indicated three distinct phases (Figure 4). A mean of 0.92 (95% CI 0.88 to 0.97) text interruptions per team per educational hour was found during the first phase (January 2014 to July 2015). The message frequency decreased to a mean of 0.81 (95% CI, 0.77 to 0.84) messages per team per educational hour starting August 2015, following the implementation of the "FYI" message option for senders (March 2015) and dissemination of communication guidelines (July 2015). Finally, a further reduction to a mean of 0.59 (95% CI, 0.51 to 0.67) messages per team per educational hour began in June 2016 after the creation of the alert message that reminded senders of educational hours (March 2016, modified June 2016). Change in the interruption frequency was sustained over the following six months to the end of the observation period in December 2016.

Incoming phone call logs were available from April 2015 to December 2016, with a mean of 0.62 (95% CI, 0.56 to 0.67) calls per team per educational hour, which did not change over the study period (Supplementary Figure 2). The overall number of calls to team smartphones also did not change during the measurement period. Incoming email data were available from October 2014 to December 2016, with a mean of 0.94 (95% CI, 0.88 to 1.0) emails per team per educational hour, which did not change over the study period (Supplementary Figure 3). Internal medicine service discharges, "Code Blue" announcements, and Critical Care Outreach Team consultations remained stable over the measurement period.

Independent ranking of the combined four-week samples of educational text interruptions from 2014 and 2016 revealed an initial three-way agreement on 257/455 (56%) messages (Fleiss Kappa 0.298, fair agreement), which increased to 405/455 (89%) messages after the first joint assessment and reached full consensus after a third joint assessment that included classifying all messages that communicated institution-defined "critical lab" values as "urgent."

Overall, 71 (16%) messages were classified as "urgent," 346 (76%) as "nonurgent," and 38 (8%) as "indeterminate." After unblinding of the message date and time, 273 text messages

were received during the baseline measurement period (November 17 to December 14, 2014) and 182 messages were received during the equivalent time period two years later (November 14 to December 11, 2016), consistent with the reduced volume of educational interruptions observed (Figure 4). A total of 426 (94%) messages were sent by nurses, and the remaining ones were sent by pharmacists (n = 20), ward clerks (n = 3), social workers (n = 4), speech language pathologist (n = 1), or device administrator (n = 1).

The proportion of "nonurgent" messages decreased from 223/273 (82%) in 2014 to 123/182 (68%) in 2016 ($P \leq .01$). Although the absolute number of urgent messages remained similar (33 in 2014 and 38 in 2016), the proportion of "urgent" messages increased from 12% to 21% of the total messages received ($P = .02$). Seventeen (6%) messages had indeterminate frequency in 2014 compared to 21 (11.5%) in 2016 (NS).

An audit of consecutive "FYI" messages (November 14-December 11, 2016) revealed an initial agreement in 384/431 (89%), reaching full consensus after repeated joint assessments. A total of 406 (94%) "FYI" messages were appropriately sent, while 10 (2%) represented urgent communications that should have been sent as interruptions. In 15 (4%) cases, the appropriateness of the message was indeterminate.

DISCUSSION

Sequential interventions over a 36-month period were associated with reduced nonurgent text message interruptions during educational hours. A clinical communication process was formally defined to accurately match message urgency with communication modality. A "noninterrupt" option allowed nonurgent text messages to be posted to an electronic message board, rather than causing real-time interruption, thereby reducing the overall volume of interrupting text messages. Modifying the interface to alert potential senders to protected educational hours was associated with reductions in educational interruptions. Through a blinded analysis of the text message content between 2014 and 2016, we determined that nonurgent educational interruptions were significantly reduced, and the number of urgent communications remained constant. Reduced nonurgent interruptions have the potential to improve the learning climate on the medical teaching unit during protected educational hours.

At baseline, 82% of the sampled text messages sent during educational hours across both sites were considered nonurgent. The estimated proportion of urgent messages varies in the literature (5%-34%)[13-18] possibly due to center-specific methods of defining and measuring urgent messages. For example, different assessor training backgrounds, different numbers of assessors, and varying institutional policies are described.[13-17] We considered an urgent message to require a response or action within one hour or to represent an established "critical lab value" as per the institution. The high proportion of nonurgent interruptions found in this study and other works demonstrates the widespread nature of this problem within inpatient hospital settings; this phenomenon could potentially lead to unintended consequences on efficiency and medical education.

Few other initiatives have aimed to reduce interruptions to medical trainees during educational sessions. At one center, replacing numeric pagers with alphanumeric pagers decreased the need to return pages during educational sessions but did not decrease the overall number of pages.[21] Another center implemented an inbox tool that reduced daytime nonurgent numeric pages.[15] Similar to our center's previous experience,[11] the total number of communications increased with the creation of the inbox tool.[15] Unexpectedly, the introduction of an "FYI" option for senders in March 2015 did not increase the total number of messages.

Increasing use of text messages for communication between physicians and allied health professions has resulted in higher volumes of interruptions compared with conventional paging.[6,7,9] Excessive interruptions create a "crisis mode" work climate,[10] which could compromise patient safety[25-27] and hamper trainees' attainment of educational objectives.[18-20,23] During educational sessions, audible text, phone call, and email interruptions disrupt all learners in addition to the resident receiving the message. The creation of the "FYI" message option in March 2015 was associated with reduced overall daily interruptions, which may improve efficiency in residents' clinical duties[17,18] and minimize multi-tasking that could lead to errors.[28] However, adding a real-time notification during educational hours (March 2016, modified June 2016) exerted the greatest impact specifically on educational interruptions. Engaging physicians in the creation and ongoing modification of instant-messaging interfaces can help customize technology to meet the needs of users.[15,29] Our work provides a strategy for improving communication between nurses and physicians in a teaching hospital setting, by achieving consensus on levels of urgency of different messages, providing a non-interrupting message option, and providing nurses with real-time information about educational hours.

Potential unintended consequences of the interventions require consideration. Discouraging interruptions may have reduced urgent patient care communications but were mitigated by enabling senders to ignore/override interruption warnings. We did not observe an increase in the number of overall calls to team devices, "Code Blues," or critical care team consultations. However, we found that a very small (2%) but important group of "FYI" messages should have been sent as urgent interrupting messages, thereby underscoring the necessity for continuous feedback to senders on the clinical communication process.

Our study has limitations. Although educational interruptions can cause fragmented learning at our institution,[19] the impact of reduced interruptions on the quality of educational sessions can only be inferred because we did not formally assess resident or staff physician perceptions on this outcome during the interventions. Moreover, we were unable to quantify interruptions received through personal smartphones, a frequent method of physician-physician communication.[30] Phone calls are the most intrusive of interruptions but were not the focus of interventions. Future work must consider documenting perceived appropriateness of calls in real time, similar to

previous studies assessing paging urgency.[13,14,18] Biased ranking of message urgency was minimized by utilizing three independent adjudicators blinded to message date throughout the adjudication process and by applying established communication guidelines where available. Nevertheless, retrospective assessment of message urgency could be limited by a lack of clinical context, which may have been more apparent to the original sender and the recipient. Finally, at our center, a close relationship with the communication platform programmer made sequential modifications possible, while other institutions may have limited ability to make such changes. A different approach may be useful in some cases, such as modifying academic teaching times to limit interruptions.[23]

In a large academic center, a high number of interrupting smartphone messages cause unnecessary distractions and reduce learning during educational hours. "Nonurgent" educational interruptions were reduced through successive improvement cycles, and ultimately by modifying the program interface to alert senders of educational hours. Further reduction in interruptions and sustainability may be achieved by studying phone call interruptions and by formalizing audit and feedback of sender's adherence to standardized clinical communication methods.

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Training Residents in Hospital Medicine: The Hospitalist Elective National Survey

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As the field of hospital medicine expands, internal medicine residency programs can play a role in preparing future hospitalists. To date, little is known of the prevalence and characteristics of hospitalist-focused resident rotations. We surveyed the largest 100 Internal Medicine Residency Programs to better understand the prevalence, objectives, and structure of hospitalist-focused rotations in the United States. Residency leaders from 82 programs responded (82%). The prevalence of hospitalist-focused rotations was 50% (41/82) with an additional 9 programs (11%) planning to start one. Of these 41 rotations, 85% were elective rotations and 15% were mandatory rotations. Rotations involved clinical responsibilities, and most programs incorporated nonclinical curricular activities such as teaching, research, and work on quality improvement and patient safety. Respondents noted that their programs promoted autonomy, mentorship, and "real-world" hospitalist experience. Hospitalist-focused rotations may supplement traditional inpatient rotations and teach skills that facilitate the transition from residency to a career in hospital medicine. *Journal of Hospital Medicine* 2018;13: 623-625. Published online first March 26, 2018.

Hospital medicine has become the fastest growing medicine subspecialty, though no standardized hospitalist-focused educational program is required to become a practicing adult medicine hospitalist.[1] Historically, adult hospitalists have had little additional training beyond residency, yet, as residency training adapts to duty hour restrictions, patient caps, and increasing attending oversight, it is not clear if traditional rotations and curricula provide adequate preparation for independent practice as an adult hospitalist.[2-5] Several types of training and educational programs have emerged to fill this potential gap. These include hospital medicine fellowships, residency pathways, early career faculty development programs (eg, Society of Hospital Medicine/Society of General Internal Medicine sponsored Academic Hospitalist Academy), and hospitalist-focused resident rotations.[6-10] These activities are intended to ensure that residents and early career physicians gain the skills and competencies required to effectively practice hospital medicine.

Hospital medicine fellowships, residency pathways, and faculty development have been described previously.[6-8] However, the prevalence and characteristics of hospital medicine-focused resident rotations are unknown, and these rotations are rarely publicized beyond local residency programs. Our study aims to determine the prevalence, purpose, and function of hospitalist-focused rotations within residency programs and explore the role these rotations have in preparing residents for a career in hospital medicine.

METHODS

Study Design, Setting, and Participants

We conducted a cross-sectional study involving the largest 100 Accreditation Council for Graduate Medical Education (ACGME) internal medicine residency programs. We chose the largest programs as we hypothesized that these programs would be most likely to have the infrastructure to support hospital medicine focused rotations compared to smaller programs. The UCSF Committee on Human Research approved this study.

Survey Development

We developed a study-specific survey (the Hospitalist Elective National Survey [HENS]) to assess the prevalence, structure, curricular goals, and perceived benefits of distinct hospitalist rotations as defined by individual resident programs. The survey prompted respondents to consider a "hospitalist-focused" rotation as one that is different from a traditional inpatient "ward" rotation and whose emphasis is on hospitalist-specific training, clinical skills, or career development. The 18-question survey (Appendix 1) included fixed choice, multiple choice, and open-ended responses.

Data Collection

Using publicly available data from the ACGME website (www.acgme.org), we identified the largest 100 medicine programs

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TABLE 1. **Activities and Curricular Elements of Hospital Medicine-Specific Rotations (n = 41)**

	n (%)
Clinical activities	
See medicine consults	13 (32)
Comanage patients on non-medicine services	16 (39)
Take holdover admissions	19 (46)
Admit new patients (not holdovers)	29 (71)
Perform common IM procedures	17 (41)
Work off site at SNF or post acute care	4 (10)
Non-clinical activities	
Teach students	7 (17)
Teach house staff	3 (7)
Engage in research and scholarship	5 (12)
Work on QI and patient safety	15 (37)
Other	15 (37)
Curricular elements	
Evidence-based practice in hospital medicine	20 (49)
Career mentorship	20 (49)
Quality improvement	20 (49)
Patient safety	15 (37)
Patient satisfaction	3 (7)
Healthcare finances	2 (5)
Leadership development	3 (7)
Value in healthcare	11 (27)
Billing and compliance	19 (46)
Palliative and end-of-life care	3 (7)

Abbreviations: IM, internal medicine, QI, quality improvement, SNF, skilled nursing facility

based on the total number of residents. This included programs with 81 or more residents. An electronic survey was e-mailed to the leadership of each program. In May 2015, surveys were sent to Residency Program Directors (PD), and if they did not respond after 2 attempts, then Associate Program Directors (APD) were contacted twice. If both these leaders did not respond, then the survey was sent to residency program administrators or Hospital Medicine Division Chiefs. Only one survey was completed per site.

Data Analysis

We used descriptive statistics to summarize quantitative data. Responses to open-ended qualitative questions about the goals, strengths, and design of rotations were analyzed using thematic analysis.[11] During analysis, we iteratively developed and refined codes that identified important concepts that emerged from the data. Two members of the research team trained in qualitative data analysis coded these data independently (S.L. and J.H.).

RESULTS

Eighty-two residency program leaders (53 PD, 19 APD, 10 chiefs/admin) responded to the survey (82% total response rate). Among all responders, the prevalence of hospitalist-focused rotations was 50% (41/82). Of these 41 rotations, 85% (35/41) were elective rotations and 15% (6/41) were mandatory rotations. Hospitalist rotations ranged in existence from 1 to 15 years with a mean duration of 4.78 years (S.D. 3.5).

Of the 41 programs that did not have a hospital medicine-focused rotation, the key barriers identified were a lack of a well-defined model (29%), low faculty interest (15%), low resident interest (12%), and lack of funding (5%). Despite these barriers, 9 of these 41 programs (22%) stated they planned to start a rotation in the future – of which, 3 programs (7%) planned to start a rotation within the year.

Of the 41 established rotations, most were one month in duration (31/41, 76%) and most of the participants included second-year residents (30/41, 73%), and/or third-year residents (32/41, 78%). In addition to clinical work, most rotations had a nonclinical component that included teaching, research/scholarship, and/or work on quality improvement or patient safety (Table 1). Clinical activities, nonclinical activities, and curricular elements varied across institutions (Table 1).

Most programs with rotations (39/41, 95%) reported that their hospitalist rotation filled at least one gap in traditional residency curriculum. The most frequently identified gaps the rotation filled included: allowing progressive clinical autonomy (59%, 24/41), learning about quality improvement and high value care (41%, 17/41), and preparing to become a practicing hospitalist (39%, 16/41). Most respondents (66%, 27/41) reported that the rotation helped to prepare trainees for their first year as an attending.

Results of thematic analysis related to the goals, strengths, and design of rotations are shown in Table 2. Five themes emerged relating to autonomy, mentorship, hospitalist skills, real-world experience, and training and curriculum gaps. These themes describe the underlying structure in which these rotations promote career preparation and skill development.

DISCUSSION

The Hospital Elective National Survey provides insight into a growing component of hospitalist-focused training and preparation. Fifty percent of ACGME residency programs surveyed in this study had a hospitalist-focused rotation. Rotation characteristics were heterogeneous, perhaps reflecting both the homegrown nature of their development and the lack of national study or data to guide what constitutes an "ideal" rotation. Common functions of rotations included providing career mentorship and allowing for trainees to get experience "being a hospitalist." Other key elements of the rotations included providing additional clinical autonomy and teaching material outside of traditional residency curricula such as quality improvement, patient safety, billing, and healthcare finances.

Prior research has explored other training for hospitalists such as fellowships, pathways, and faculty development.[6-8] A hospital medicine fellowship provides extensive training but without a practice requirement in adult medicine (as now exists in pediatric hospital medicine), the impact of fellowship training may be limited by its scale.[12,13] Longitudinal hospitalist residency

TABLE 2: **Results of Thematic Analysis Describing Goals, Strengths, and Design of Rotations**

Theme	Representative quotes
Autonomy	"No team…resident works one-on-one with a hospitalist doing direct patient care. More resident autonomy"
	"Autonomy, opportunity to direct patient care responsibility"
Mentorship	"One-on-one mentorship for QI projects with experienced academic hospitalists"
	"Work directly one-on-one with a hospitalist attending with focused curriculum…"
Fills training and curricula gaps	"Gives residents greater exposure to consultative medicine and comanagement of patients with physicians, mid-level practitioners, pharmacy, therapists, etc."
	"Exposes residents to hospital medicine at a different hospital with a different patient population than they would otherwise experience on the teaching service"
Hospitalist skills	"Concentration on QI, patient safety, and project leadership skills"
	"Increases patient management skills, specifically in the entire spectrum from admission all the way to discharge. Increases focus of discharge planning"
Real-world experience	"Job 'try-out' – in other words, residents get to see if they like the hospitalist model"
	"Real-world hospital medicine experience, time and opportunities for quality improvement/patient safety projects"

pathways provide comprehensive skill development and often require an early career commitment from trainees.[7] Faculty development can be another tool to foster career growth, though requires local investment from hospitalist groups that may not have the resources or experience to support this.[8] Our study has highlighted that hospitalist-focused rotations within residency programs can train physicians for a career in hospital medicine. Hospitalist and residency leaders should consider that these rotations might be the only hospital medicine-focused training that new hospitalists will have. Given the variable nature of these rotations nationally, developing standards around core hospitalist competencies within these rotations should be a key component to career preparation and a goal for the field at large.[14,15]

Our study has limitations. The survey focused only on internal medicine as it is the most common training background of hospitalists; however, the field has grown to include other specialties including pediatrics, neurology, family medicine, and surgery. In addition, the survey reviewed the largest ACGME Internal Medicine programs to best evaluate prevalence and content—it may be that some smaller programs have rotations with different characteristics that we have not captured. Lastly, the survey reviewed the rotations through the lens of residency program leadership and not trainees. A future survey of trainees or early career hospitalists who participated in these rotations could provide a better understanding of their achievements and effectiveness.

CONCLUSION

We anticipate that the demand for hospitalist-focused training will continue to grow as more residents in training seek to enter the specialty. Hospitalist and residency program leaders have an opportunity within residency training programs to build new or further develop existing hospital medicine-focused rotations. The HENS survey demonstrates that hospitalist-focused rotations are prevalent in residency education and have the potential to play an important role in hospitalist training.

Disclosure: The authors declare no conflicts of interest in relation to this manuscript.

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Update in Hospital Medicine: Practical Lessons from the Literature

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BACKGROUND: Hospital Medicine has a widening scope of practice. This article provides a summary of recent high-impact publications for busy clinicians who provide care to hospitalized adults.

METHODS: The authors reviewed articles published between March 2016 and March 2017 for the Update in Hospital Medicine presentations at the 2017 Society of Hospital Medicine and Society of General Internal Medicine annual meetings. Nine of the 20 articles presented were selected for this review based on the article quality and potential to influence practice.

RESULTS: The key insights gained include: pulmonary embolism may be a more common cause of syncope and acute exacerbation of COPD than previously recognized; nonthoracic low-tesla MRI is safe following a specific protocol for patients with cardiac devices implanted after 2001; routine inpatient blood cultures for fever are of a low yield with a false positive rate similar to the true positive rate; chronic opioid use after surgery occurs more frequently than in the general population; high-sensitivity troponin and a negative ECG performed 3 hours after an episode of chest pain can rule out acute myocardial infarction; sitting at patients' bedsides enhances patients' perception of provider communication; 5 days of antibiotics for community-acquired pneumonia is equivalent to longer courses; oral proton pump inhibitors (PPI) are as effective as IV PPIs after an esophagogastroduodenoscopy (EGD) for the treatment of bleeding peptic ulcers.

CONCLUSIONS: Recent research provides insight into how we approach common medical problems in the care of hospitalized adults. These articles have the potential to change or confirm current practices. *Journal of Hospital Medicine* 2018;13:626-630. Published online first February 27, 2018. © 2018 Society of Hospital Medicine

The practice of hospital medicine continues to grow in its scope and complexity. The authors of this article conducted a review of the literature including articles published between March 2016 and March 2017. The key articles selected were of a high methodological quality, had clear findings, and had a high potential for an impact on clinical practice. Twenty articles were presented at the Update in Hospital Medicine at the 2017 Society of Hospital Medicine (SHM) and Society of General Internal Medicine (SGIM) annual meetings selected by the presentation teams (B.A.S., A.B. at SGIM and R.E.T., C.M. at SHM). Through an iterative voting process, nine articles were selected for inclusion in this review. Each author ranked their top five articles from one to five. The points were tallied for each article, and the five articles with the most points were included. A second round of voting identified the remaining four articles for inclusion. Each article is summarized below, and the key points are highlighted in Table 1.

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ESSENTIAL PUBLICATIONS

Prevalence of Pulmonary Embolism among Patients Hospitalized for Syncope. Prandoni P et al. *New England Journal of Medicine*, 2016;375(16):1524-31.[1]

Background

Pulmonary embolism (PE), a potentially fatal disease, is rarely considered as a likely cause of syncope. To determine the prevalence of PE among patients presenting with their first episode of syncope, the authors performed a systematic workup for pulmonary embolism in adult patients admitted for syncope at 11 hospitals in Italy.

Findings

Of the 2,584 patients who presented to the emergency department (ED) with syncope during the study, 560 patients were admitted and met the inclusion criteria. A modified Wells Score was applied, and a D-dimer was measured on every hospitalized patient. Those with a high pretest probability, a Wells Score of 4.0 or higher, or a positive D-dimer underwent further testing for pulmonary embolism by a CT scan, a ventilation perfusion scan, or an autopsy. Ninety-seven of the 560 patients admitted to the hospital for syncope were found to have a PE (17%). One in four patients (25%) with no clear cause for syncope was found

TABLE. **Nine articles, 9 practical implications.**

Practical Implications
1. Consider PE in patients admitted for syncope without a clear cause
2. 1.5 Tesla nonthoracic MRIs done on a protocol are safe in patients with non-MRI conditional cardiac devices implanted after 2001
3. Routine blood cultures for fever in hospitalized patients is of a low yield, with a significant potential for false positives
4. Developing chronic opioid use is more common in the postoperative year than in a matched nonsurgical cohort
5. A negative high-sensitivity troponin test performed at least 3 hours after an episode of chest pain, in conjunction with a negative ECG, can rule out acute myocardial infarction
6. Consider PE in patients with acute exacerbations of COPD without other exacerbation triggers
7. Patients perceive better communication from physicians who sit, compared to those who stand, at the bedside
8. A shorter course of antibiotics (5 days) is as effective as a longer course (10 days) for inpatient treatment of community-aquired pneumonia
9. Oral PPI treatment after EGD for bleeding peptic ulcers is as effective as IV PPI

Abbreviations: COPD, Chronic Obstructive Pulmonary Disease; EGD, Esophagogastroduodenoscopy; PE, Pulmonary embolism; PPI, proton pump inhibitors.

to have a PE, and one in four patients with PE had no tachycardia, tachypnea, hypotension, or clinical signs of DVT.

Cautions

Nearly 72% of the patients with common explanations for syncope, such as vasovagal, drug-induced, or volume depletion, were discharged from the ED and not included in the study. The authors focused on the prevalence of PE. The causation between PE and syncope is not clear in each of the patients. Of the patients' diagnosis by a CT, only 67% of the PEs were found to be in a main pulmonary artery or lobar artery. The other 33% were segmental or subsegmental. Of those diagnosed by a ventilation perfusion scan, 50% of the patients had 25% or more of the area of both lungs involved. The other 50% involved less than 25% of the area of both lungs. Also, it is important to note that 75% of the patients admitted to the hospital in this study were 70 years of age or older.

Implications

After common diagnoses are ruled out, it is important to consider pulmonary embolism in patients hospitalized with syncope. Providers should calculate a Wells Score and measure a D-dimer to guide the decision making.

Assessing the Risks Associated with MRI in Patients with a Pacemaker or Defibrillator. Russo RJ et al. *New England Journal of Medicine*, 2017;376(8):755-64.[2]

Background

Magnetic resonance imaging (MRI) in patients with implantable cardiac devices is considered a safety risk due to the potential of cardiac lead heating and subsequent myocardial injury or alterations of the pacing properties. Although manufacturers have developed "MRI-conditional" devices designed to reduce these risks, still 2 million people in the United States and 6 million people worldwide have "non-MRI-conditional" devices. The authors evaluated the event rates in patients with "non-MRI-conditional" devices undergoing an MRI.

Findings

The authors prospectively followed up 1,500 adults with cardiac devices placed since 2001 who received nonthoracic MRIs according to a specific protocol available in the supplemental materials published with this article in the *New England Journal of Medicine*. Of the 1,000 patients with pacemakers only, they observed five atrial arrhythmias and six electrical resets. Of the 500 patients with implantable cardioverter defibrillators (ICDs), they observed one atrial arrhythmia and one generator failure (although this case had deviated from the protocol). All of the atrial arrhythmias were self-terminating. No deaths, lead failure requiring an immediate replacement, a loss of capture, or ventricular arrhythmias were observed.

Cautions

Patients who were pacing dependent were excluded. No devices implanted before 2001 were included in the study, and the MRIs performed were only 1.5 Tesla (a lower field strength than the also available 3 Tesla MRIs).

Implications

It is safe to proceed with 1.5 Tesla nonthoracic MRIs in patients, following the protocol outlined in this article, with non–MRI -conditional cardiac devices implanted since 2001.

Culture If Spikes? Indications and Yield of Blood Cultures in Hospitalized Medical Patients. Linsenmeyer K et al. *Journal of Hospital Medicine*, 2016;11(5):336-40.[3]

Background

Blood cultures are frequently drawn for the evaluation of an inpatient fever. This "culture if spikes" approach may lead to unnecessary testing and false positive results. In this study, the authors evaluated rates of true positive and false positive blood cultures in the setting of an inpatient fever.

Findings

The patients hospitalized on the general medicine or cardiology floors at a Veterans Affairs teaching hospital were prospectively followed over 7 months. A total of 576 blood cultures were ordered among 323 unique patients. The patients were older (average age of 70 years) and predominantly male (94%). The true-positive rate for cultures, determined by a consensus among the microbiology and infectious disease departments based on a review of clinical and laboratory data, was 3.6% compared with a false-positive rate of 2.3%. The clinical characteristics associated with a higher likelihood of a true positive included: the indication for a culture as a follow-up from a previous culture (likelihood ratio [LR] 3.4), a working diagnosis of bacteremia or endocarditis (LR 3.7), and the constellation

of fever and leukocytosis in a patient who has not been on antibiotics (LR 5.6).

Cautions
This study was performed at a single center with patients in the medicine and cardiology services, and thus, the data is representative of clinical practice patterns specific to that site.

Implications
Reflexive ordering of blood cultures for inpatient fever is of a low yield with a false-positive rate that approximates the true positive rate. A large number of patients are tested unnecessarily, and for those with positive tests, physicians are as likely to be misled as they are certain to truly identify a pathogen. The positive predictive value of blood cultures is improved when drawn on patients who are not on antibiotics and when the patient has a specific diagnosis, such as pneumonia, previous bacteremia, or suspected endocarditis.

Incidence of and Risk Factors for Chronic Opioid Use among Opioid-Naive Patients in the Postoperative Period. Sun EC et al. *JAMA Internal Medicine*, 2016;176(9):1286-93.[4]

Background
Each day in the United States, 650,000 opioid prescriptions are filled, and 78 people suffer an opiate-related death. Opioids are frequently prescribed for inpatient management of postoperative pain. In this study, authors compared the development of chronic opioid use between patients who had undergone surgery and those who had not.

Findings
This was a retrospective analysis of a nationwide insurance claims database. A total of 641,941 opioid-naive patients underwent 1 of 11 designated surgeries in the study period and were compared with 18,011,137 opioid-naive patients who did not undergo surgery. Chronic opioid use was defined as the filling of 10 or more prescriptions or receiving more than a 120-day supply between 90 and 365 days postoperatively (or following the assigned faux surgical date in those not having surgery). This was observed in a small proportion of the surgical patients (less than 0.5%). However, several procedures were associated with the increased odds of postoperative chronic opioid use, including a simple mastectomy (Odds ratio [OR] 2.65), a cesarean delivery (OR 1.28), an open appendectomy (OR 1.69), an open and laparoscopic cholecystectomy (ORs 3.60 and 1.62, respectively), and a total hip and total knee arthroplasty (ORs 2.52 and 5.10, respectively). Also, male sex, age greater than 50 years, preoperative benzodiazepines or antidepressants, and a history of drug abuse were associated with increased odds.

Cautions
This study was limited by the claims-based data and that the nonsurgical population was inherently different from the surgical population in ways that could lead to confounding.

Implications
In perioperative care, there is a need to focus on multimodal approaches to pain and to implement opioid reducing and sparing strategies that might include options such as acetaminophen, NSAIDs, neuropathic pain medications, and Lidocaine patches. Moreover, at discharge, careful consideration should be given to the quantity and duration of the postoperative opioids.

Rapid Rule-out of Acute Myocardial Infarction with a Single High-Sensitivity Cardiac Troponin T Measurement below the Limit of Detection: A Collaborative Meta-Analysis. Pickering JW et al. *Annals of Internal Medicine*, 2017;166:715-24.[5]

Background
High-sensitivity cardiac troponin testing (hs-cTnT) is now available in the United States. Studies have found that these can play a significant role in a rapid rule-out of acute myocardial infarction (AMI).

Findings
In this meta-analysis, the authors identified 11 studies with 9,241 participants that prospectively evaluated patients presenting to the emergency department (ED) with chest pain, underwent an ECG, and had hs-cTnT drawn. A total of 30% of the patients were classified as low risk with negative hs-cTnT and negative ECG (defined as no ST changes or T-wave inversions indicative of ischemia). Among the low risk patients, only 14 of the 2,825 (0.5%) had AMI according to the Global Task Forces definition.[6] Seven of these were in patients with hs-cTnT drawn within three hours of a chest pain onset. The pooled negative predictive value was 99.0% (CI 93.8%–99.8%).

Cautions
The heterogeneity between the studies in this meta-analysis, especially in the exclusion criteria, warrants careful consideration when being implemented in new settings. A more sensitive test will result in more positive troponins due to different limits of detection. Thus, medical teams and institutions need to plan accordingly. Caution should be taken for any patient presenting within three hours of a chest pain onset.

Implications
Rapid rule-out protocols—which include clinical evaluation, a negative ECG, and a negative high-sensitivity cardiac troponin—identify a large proportion of low-risk patients who are unlikely to have a true AMI.

Prevalence and Localization of Pulmonary Embolism in Unexplained Acute Exacerbations of COPD: A Systematic Review and Meta-analysis. Aleva FE et al. *Chest*, 2017;151(3):544-54.[7]

Background
Acute exacerbations of chronic obstructive pulmonary disease (AE-COPD) are frequent. In up to 30%, no clear trigger is found. Previous studies suggested that one in four of these patients

may have a pulmonary embolus (PE).[7] This study reviewed the literature and meta-data to describe the prevalence, the embolism location, and the clinical predictors of PE among patients with unexplained AE-COPD.

Findings

A systematic review of the literature and meta-analysis identified seven studies with 880 patients. In the pooled analysis, 16% had PE (range: 3%–29%). Of the 120 patients with PE, two-thirds were in lobar or larger arteries and one-third in segmental or smaller. Pleuritic chest pain and signs of cardiac compromise (hypotension, syncope, and right-sided heart failure) were associated with PE.

Cautions

This study was heterogeneous leading to a broad confidence interval for prevalence ranging from 8%-25%. Given the frequency of AE-COPD with no identified trigger, physicians need to attend to risks of repeat radiation exposure when considering an evaluation for PE.

Implications

One in six patients with unexplained AE-COPD was found to have PE; the odds were greater in those with pleuritic chest pain or signs of cardiac compromise. In patients with AE-COPD with an unclear trigger, the providers should consider an evaluation for PE by using a clinical prediction rule and/or a D-dimer.

Sitting at Patients' Bedsides May Improve Patients' Perceptions of Physician Communication Skills. Merel SE et al. *Journal of Hospital Medicine,* 2016;11(12):865-8.[9]

Background

Sitting at a patient's bedside in the inpatient setting is considered a best practice, yet it has not been widely adopted. The authors conducted a cluster-randomized trial of physicians on a single 28-bed hospitalist only run unit where physicians were assigned to sitting or standing for the first three days of a seven-day workweek assignment. New admissions or transfers to the unit were considered eligible for the study.

Findings

Sixteen hospitalists saw on an average 13 patients daily during the study (a total of 159 patients were included in the analysis after 52 patients were excluded or declined to participate). The hospitalists were 69% female, and 81% had been in practice three years or less. The average time spent in the patient's room was 12:00 minutes while seated and 12:10 minutes while standing. There was no difference in the patients' perception of the amount of time spent—the patients overestimated this by four minutes in both groups. Sitting was associated with higher ratings for "listening carefully" and "explaining things in a way that was easy to understand." There was no difference in ratings on the physicians interrupting the patient when talking or in treating patients with courtesy and respect.

Cautions

The study had a small sample size, was limited to English-speaking patients, and was a single-site study. It involved only attending-level physicians and did not involve nonphysician team members. The physicians were not blinded and were aware that the interactions were monitored, perhaps creating a Hawthorne effect. The analysis did not control for other factors such as the severity of the illness, the number of consultants used, or the degree of health literacy.

Implications

This study supports an important best practice highlighted in *etiquette-based medicine*[10]: sitting at the bedside provided a benefit in the patient's perception of communication by physicians without a negative effect on the physician's workflow.

The Duration of Antibiotic Treatment in Community-Acquired Pneumonia: A Multi-Center Randomized Clinical Trial. Uranga A et al. *JAMA Intern Medicine,* 2016;176(9):1257-65.[11]

Background

The optimal duration of treatment for community-acquired pneumonia (CAP) is unclear; a growing body of evidence suggests shorter and longer durations may be equivalent.

Findings

At four hospitals in Spain, 312 adults with a mean age of 65 years and a diagnosis of CAP (non-ICU) were randomized to a short (5 days) versus a long (provider discretion) course of antibiotics. In the short-course group, the antibiotics were stopped after 5 days *if* the body temperature had been 37.8° C or less for 48 hours, and no more than one sign of clinical instability was present (SBP < 90 mmHg, HR >100/min, RR > 24/min, O_2Sat < 90%). The median number of antibiotic days was five for the short-course group and 10 for the long-course group (P < .01). There was no difference in the resolution of pneumonia symptoms at 10 days or 30 days or in 30-day mortality. There were no differences in in-hospital side effects. However, 30-day readmissions were higher in the long-course group compared with the short-course group (6.6% vs 1.4%; P = .02). The results were similar across all of the Pneumonia Severity Index (PSI) classes.

Cautions

Most of the patients were not severely ill (~60% PSI I-III), the level of comorbid disease was low, and nearly 80% of the patients received fluoroquinolone. There was a significant crossover with 30% of patients assigned to the short-course group receiving antibiotics for more than 5 days.

Implications

Inpatient providers should aim to treat patients with community-acquired pneumonia (regardless of the severity of the illness) for five days. At day five, if the patient is afebrile and has no signs of clinical instability, clinicians should be comfortable stopping antibiotics.

Is the Era of Intravenous Proton Pump Inhibitors Coming to an End in Patients with Bleeding Peptic Ulcers? A Meta-Analysis of the Published Literature. Jian Z et al. *British Journal of Clinical Pharmacology,* 2016;82(3):880-9.[12]

Background

Guidelines recommend intravenous proton pump inhibitors (PPI) after an endoscopy for patients with a bleeding peptic ulcer. Yet, acid suppression with oral PPI is deemed equivalent to the intravenous route.

Findings

This systematic review and meta-analysis identified seven randomized controlled trials involving 859 patients. After an endoscopy, the patients were randomized to receive either oral or intravenous PPI. Most of the patients had "high-risk" peptic ulcers (active bleeding, a visible vessel, an adherent clot). The PPI dose and frequency varied between the studies. Re-bleeding rates were no different between the oral and intravenous route at 72 hours (2.4% vs 5.1%; $P = .26$), 7 days (5.6% vs 6.8%; $P = .68$), or 30 days (7.9% vs 8.8%; $P = .62$). There was also no difference in 30-day mortality (2.1% vs 2.4%; $P = .88$), and the length of stay was the same in both groups. Side effects were not reported.

Cautions

This systematic review and meta-analysis included multiple heterogeneous small studies of moderate quality. A large number of patients were excluded, increasing the risk of a selection bias.

Implications

There is no clear indication for intravenous PPI in the treatment of bleeding peptic ulcers following an endoscopy. Converting to oral PPI is equivalent to intravenous and is a safe, effective, and cost-saving option for patients with bleeding peptic ulcers.

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Interventions to Improve Follow-Up of Laboratory Test Results Pending at Discharge: A Systematic Review

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Failure to follow up test results pending at discharge (TPAD) from hospitals or emergency departments is a major patient safety concern. The purpose of this review is to systematically evaluate the effectiveness of interventions to improve follow-up of laboratory TPAD.

We conducted literature searches in PubMed, CINAHL, Cochrane, and EMBASE using search terms for relevant health care settings, transition of patient care, laboratory tests, communication, and pending or missed tests. We solicited unpublished studies from the clinical laboratory community and excluded articles that did not address transitions between settings, did not include an intervention, or were not related to laboratory TPAD. We also excluded letters, editorials, commentaries, abstracts, case reports, and case series.

Of the 9,592 abstracts retrieved, eight met the inclusion criteria and reported the successful communication of TPAD. A team member abstracted predetermined data elements from each study, and a senior scientist reviewed the abstraction. Two experienced reviewers independently appraised the quality of each study using published Laboratory Medicine Best Practices (LMBP™) A-6 scoring criteria.

We assessed the body of evidence using the A-6 methodology, and the evidence suggested that electronic tools or one-on-one education increased documentation of pending tests in discharge summaries. We also found that automated notifications improved awareness of TPAD.

The interventions were supported by suggestive evidence; this type of evidence is below the level of evidence required for LMBP™ recommendations. We encourage additional research into the impact of these interventions on key processes and health outcomes. *Journal of Hospital Medicine*. 2018:13:631-636. Published online first February 27, 2018. © 2018 Society of Hospital Medicine

The 2015 National Academy of Sciences (NAS; formerly the Institute of Medicine [IOM]) report, *Improving Diagnosis in Health Care,* attributes up to 10% of patient deaths and 17% of hospital adverse events to diagnostic errors,[1] one cause of which is absent or delayed follow-up of laboratory test results.[2] Poor communication or follow-up of laboratory tests with abnormal results has been cited repeatedly as a threat to patient safety.[1,3,4] In a survey of internists, 83% reported at least one unacceptably delayed laboratory test result during the previous 2 months.[5]

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Care transitions magnify the risk of missed test results.[6,7] Up to 16% of all emergency department (ED) and 23% of all hospitalized patients will have pending laboratory test results at release or discharge.[6] The percentage of tests that received follow-up ranged from 1% to 75% for tests done in the ED and from 20% to 69% for tests ordered on inpatients. In one study, 41% of all surveyed medical inpatients had at least one test result pending at discharge (TPAD). When further studied, over 40% of the results were abnormal and 9% required action, but the responsible physicians were unaware of 62% of the test results.[8] Many examples of morbidity from such failure have been reported. One of many described by El-Kareh et al., for example, is that of an 81-year-old man on total parenteral nutrition who was treated for suspected line infection and discharged without antibiotics, but whose blood cultures grew *Klebsiella pneumoniae* after his discharge.[9] Another example, presented on the Agency for Healthcare Research and Quality (AHRQ) Patient Safety Network, reported a patient admitted for a urinary tract infection and then discharged from the hospital on trimethoprim–sulfamethoxazole. He returned to the hospital 11 days later with severe sepsis. Upon review, the urine culture results from his previous admission, which were

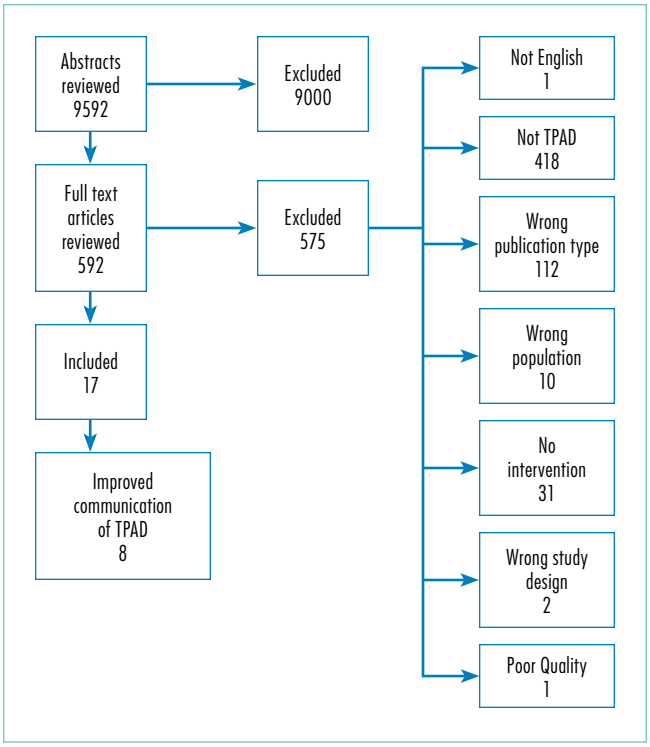

FIG 1. Literature Search Results

returned two days after his discharge, indicated that the infectious agent was not sensitive to trimethoprim–sulfamethoxazole. The results had not been reviewed by hospital clinicians or forwarded to the patient's physician, so the patient continued on the ineffective treatment. His second hospital admission lasted seven days, but he made a complete recovery with the correct antibiotic.[10]

Several barriers impede the follow-up of TPAD. First, who should receive test results or who is responsible for addressing them may be unclear. Second, even if responsibility is clear, communication between the provider who ordered the test and the provider responsible for follow-up may be suboptimal.[11] Finally, providers who need to follow up on abnormal results may not appreciate the urgency or significance of pending results.

The hospitalist model of care increases efficiency during hospitalization but further complicates care coordination.[12] The hospitalist who orders a test may not be on duty at discharge or when test results are finalized. Primary care providers may have little contact with their patients during their admission.[12] Effective communication between providers is key to ensuring appropriate follow-up care, but primary care physicians and hospital physicians communicate directly in 20% or fewer admissions.[13] The hospital discharge summary is the primary method of communication with the next provider, but 65%-84% of all discharge summaries lack information on TPAD.[13,14]

In this work, we sought to identify and evaluate interventions aimed at improving documentation, communication, and follow-up of TPAD. This review was conducted through the Laboratory Medicine Best Practices (LMBP™) initiative, which is sponsored by the Centers for Disease Control and Prevention's (CDC's) Division of Laboratory Systems (https://wwwn.cdc.gov/labbestpractices/). The LMBP™ was initiated as the CDC's response to the IOM report *To Err is Human: Building a Safer Health System*.[15]

METHODS

We applied the first four phases of the LMBP™-developed A-6 Cycle methodology to evaluate quality improvement practices as described below.[16] Our report follows the Meta-analysis Of Observational Studies in Epidemiology (MOOSE) guidelines.[17]

Asking the Question

The full review, which is available from the corresponding author, assessed the evidence that the interventions improved (1) the timeliness of follow-up of TPAD or reduced adverse health events; (2) discharge planning, documentation, or communication with the outpatient care provider regarding TPAD; and (3) health outcomes. In this article, we present the impact of interventions to improve the documentation, communication, and follow-up of TPAD. The review protocol, which is also available from the corresponding author, was developed with the input of a panel of experts (Appendix A) in laboratory medicine, systematic reviews, informatics, and patient safety. The analytic framework (Appendix B) describes the scope of the review. The inclusion criteria for papers reporting on interventions to improve communication of TPAD are the following:

- **Population**: Patients who were admitted to an inpatient facility or who visited an ED (including patients released from the ED) and who had one or more TPADs.
- **Interventions**: Practices that explicitly aimed to improve the documentation, communication, or follow-up of TPAD, alone or as part of a broader quality improvement effort.
- **Comparators**: Standard practice, pre-intervention practice, or any other valid comparator.
- **Outcomes**: Documentation completeness, physician awareness of pending tests, or follow-up of TPAD.

Acquire the Evidence

A professional librarian conducted literature searches in PubMed, CINAHL, Cochrane, and EMBASE using terms that captured relevant health care settings, transition of patient care, laboratory tests, communication, and pending or missed tests (Appendix C). Citations were also identified by expert panel members and by manual searches of bibliographies of relevant studies. We included studies published in English in 2005 or later. We sought unpublished studies through expert panelists and queries to relevant professional organizations.

Appraise the Studies

Two independent reviewers evaluated each retrieved citation for inclusion. We excluded articles that (1) did not explicitly address laboratory TPAD; (2) were letters, editorials, commentaries, or abstracts; (3) did not address transition between settings; (4) did not include an intervention; (5) were case reports or case series; or (6) were not published in English. A team member

TABLE. **Summary of Evidence on Interventions to Improve Communication of Tests Pending at Discharge**

Intervention	Citation: Author (Year)	Effect Size Rating	Quality Appraisal Score	Consistency Across Body of Evidence	Strength of the Evidence
Education to Improve Documentation of TPAD in Discharge Summaries	Dinescu (2011)	Moderate	Fair	Consistent	Suggestive
	Gandara (2010)	Moderate	Fair		
	Key-Solle (2010)	Moderate	Fair		
Electronic Aids to Improve Documentation of TPAD in Discharge Summaries	Kantor (2014)	Substantial	Fair	Consistent	Suggestive
	O'Leary (2009)	Substantial	Good		
Electronic Notifications to Physician Responsible for Follow-up	Dalal (2014)	Substantial	Fair	Consistent	Suggestive
	El-Kareh (2012)	Moderate	Good		
Report of Test Results to Parent	Goldman	Moderate	Good	Not Applicable	Insufficient

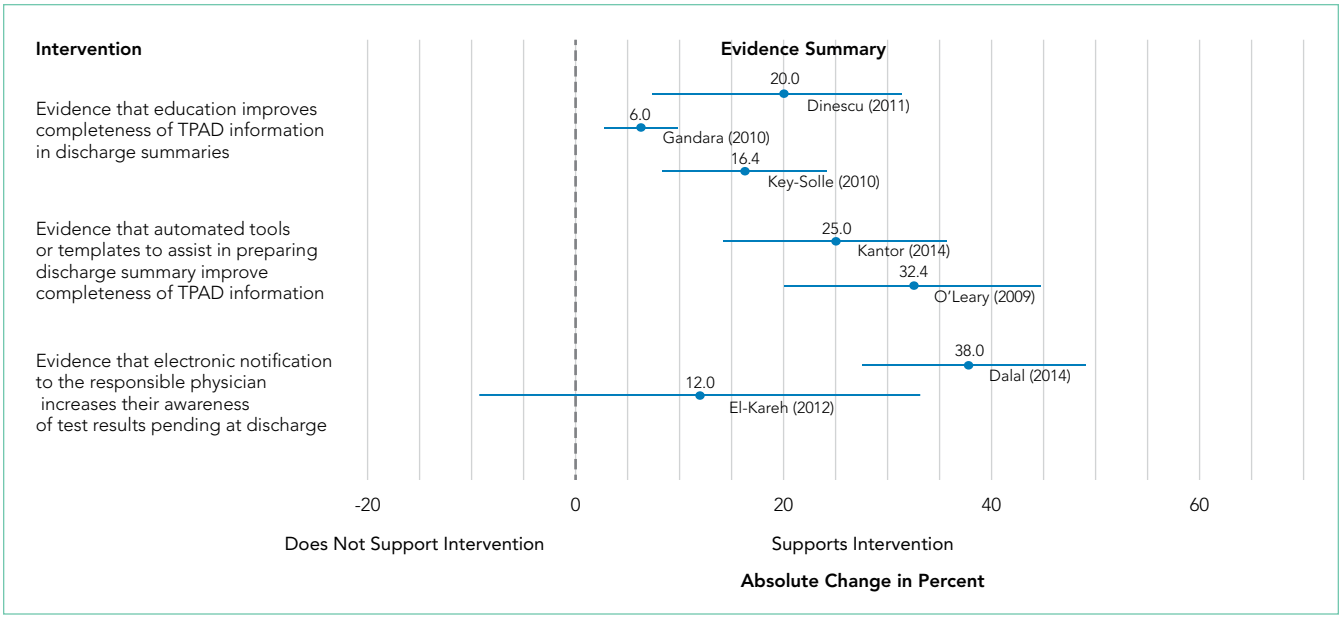

FIG 2. Impact of Interventions to Improve Communication and Follow-up of Tests Pending at Discharge

abstracted predetermined data elements (Appendix D) from each included study, and a senior scientist reviewed the abstraction. Two senior scientists independently scored the quality of the eligible studies on the A-6 domains of study characteristics, practice description, outcome measures, and results and findings; studies scored below 4 points on a 10-point scale were excluded. Based on this appraisal, studies were classified as good, fair, or poor; poor studies were excluded.

Analyze the Evidence

We synthesized the evidence by intervention type and outcome. The strength of the evidence that each intervention improved the desired outcome was rated in accordance with the A-6 methodology as high, moderate, suggestive, or insufficient based on the number of studies, the study ratings, and the consistency and magnitude of the effect size.

RESULTS

We retrieved 9,592 abstracts and included 17 articles after full-text review and study-quality appraisal; of these, eight provided evidence on communication of TPAD (Figure 1). These eight studies examined four types of interventions: (1) education to improve discharge summaries, (2) electronic tools to aid in preparation of discharge summaries, (3) electronic notification to physicians of pending tests, and (4) online access of test results for patients or parents. The Table and Figure 2 summarize the evidence for each intervention. The appendices provide detailed information on the characteristics of the included studies (Appendix E), the study interventions (Appendix F), and evidence tables (Appendix G).

Education to Improve Discharge Summaries

Three studies[18-20] examined educational interventions to improve the completeness of discharge summaries, and all three

were of fair quality with moderate effects. Two studies[18,19] evaluated educational inventions for first-year residents or fellows and included individual instruction alone[18] or in combination with a group session.[19] Dinescu et al.[18] found a 20% increase in the documentation of ordered tests, and a 39% increase in documented test results in discharge summaries (81% vs. 42%, $P = .02$) after the intervention. Key-Solle[19] reported that individual sessions resulted in a 16.4% ($P = .004$) increase in the documentation of pending laboratory results in the discharge summary compared with that of the controls; the group session increased documentation by only 5% ($P = .403$).

Gandara et al.[20] conducted a multi-site, multi-intervention study to improve completeness of information in discharge summaries, including documentation of TPAD. All sites implemented physician and nurse education. A significant trend ($P < .001$) toward more complete information overall was found after implementation; improvement in documentation of TPAD was not provided.

Electronic Tools for Preparation of Discharge Summaries

Two studies [21,22] investigated tools to aid preparation of discharge summaries. Kantor et al.,[21] rated fair, evaluated an EMR-generated list of TPAD, and O'Leary et al.,[22] rated good, evaluated an electronic discharge summary template. The EMR-generated list resulted in an absolute increase of 25% in the proportion of TPAD documented and of 18% in the percentage of discharge summaries with complete information on TPAD. An electronic discharge summary template increased the percentage of discharge summaries with complete information on TPAD by 32.4%.[22] O'Leary et al.[22] was the only study that reported a negative effect of an intervention. The authors found a 10% ($P = .04$) reduction in the documentation of clinically significant laboratory results after implementation of the electronic discharge summary.

Electronic Notifications to Physicians

One good study, El-Kareh et al.,[23] and one fair study, Dalal et al.,[24] examined the impact of electronic notification of pending laboratory tests or test results to physicians. El-Kareh et al.[23] also provided evidence on improved follow-up of test results. Physicians in intervention clusters were three times more likely (OR 3.2; 95% CI 1.3-8.4) to have documented follow-up of test results than those in control clusters.[23] The absolute increase in awareness of TPAD was 20%,[23,24] among primary care physicians and 12%[23] or 38%[24] among inpatient attending physicians in the intervention clusters.

Notification of Patients or Parents

One study evaluated the impact of online parental access to the results of laboratory tests ordered during a child's ED visit.[25] The intervention indirectly increased physician awareness of the test results: 36 parents (12% of enrolled families) reported informing their physician of the test results. Therapy changed for seven children (5% of 141 whose parents retrieved the child's test results and completed the follow-up survey).

DISCUSSION

Evidence Summary

We identified four interventions aimed at improving follow-up of TPAD and found suggestive evidence indicating that individual education for preparers of discharge summaries improved the quality of discharge summary documentation of TPAD; however, this type of evidence is below the level of evidence required by the LMBP™ to issue a recommendation. Site variations in the type and timing of interventions,[20] small sample size,[18] short follow-up,[18,19] lack of detail on educational content,[18-20] and differences in evaluated interventions limited the evidence quality. The long-term impact of educational interventions is also a concern. Oluma et al., for example, found that the benefits of education interventions were not sustained over time.[26]

Two studies[21,22] evaluated aids to completing discharge summaries. The aids, which include a list of TPADs[21] and an electronic template,[22] resulted in a substantial increase in the completeness of the documentation of TPAD. Because of the differences in the interventions and the limited number of studies obtained, the evidence was rated as suggestive.

Suggestive evidence that automated e-mail notifications increased awareness of TPAD results by inpatient attending physicians and primary care providers was found. A limitation of this evidence is that both studies[23,24] retrieved were conducted at the same institution; thus, the findings may not be generalizable to other institutions. Only one paper[25] examined the impact of patient or parental access to laboratory tests results on the primary care physician's awareness and follow-up of TPAD; as such, we consider the available evidence insufficient to evaluate the intervention.

Limitations

The evidence regarding interventions to improve follow-up of TPAD is limited. The interventions evaluated varied considerably in design and implementation. Most studies were conducted at a single medical center. Few studies had concurrent controls, and even fewer were randomized trials. Some studies included multiple interventions, thereby rendering the isolation of the impact of any single intervention difficult to accomplish.

Comparison to Other Literature

We found no other reviews of interventions to improve follow-up of TPAD. A review of interventions to improve information transfer found that computer-generated discharge summaries improved the timeliness and, less consistently, completeness of the summary.[13] The authors of this review[13] recommended computer-generated structured summaries that highlight the most pertinent information for follow-up care, as supported by a recent qualitative exploration of care coordination between hospitalists and primary care physicians.[27]

CONCLUSIONS

Successful follow-up of TPAD during care transition is a multistep process requiring identification and documentation of TPAD, notification of person responsible for follow-up, and their recognition and execution of the appropriate follow-up

actions. We found suggestive evidence that individual education and tools, such as automated templates or abstraction, can improve documentation of TPADs and that automated alerts to the physician responsible for follow-up can improve awareness of TPAD results. The interventions were distinct; evidence from one intervention and outcome should be applied cautiously to other interventions and outcomes.

None of the interventions completely resolved the problems of documentation, awareness, or follow-up of TPAD. New interventions should consider the barriers to coordination identified by Jones et al.[27] and Callen et al.[7] Both studies identified a lack of systems, policies, and practices to support communication across different settings, including lack of access or difficulty navigating electronic medical records at other institutions; unclear or varied accountability for follow-up care; and inconsistent receipt of discharge documents after initial follow-up visit. These systemic problems were exacerbated by a lack of personal relationships between the community physicians, hospital, and ED clinicians, and between acute care clinicians and patients. In EDs, high patient throughput and short length of stay were found to contribute to these barriers. Although laboratories have a responsibility, required by CLIA regulations, to ensure the accurate and complete transmission of test reports,[28] none of the interventions appeared to include laboratorians as stakeholders during the design, implementation, or evaluation of the interventions. Incorporating laboratory personnel and processes into the design of follow-up solutions may increase their effectiveness.

Medical informatics tools have the potential to improve patient safety during care transitions. Unfortunately, the evidence regarding informatics interventions to improve follow-up of TPAD was limited by both the number and the quality of the published studies. In addition, better-designed studies in this area are needed. Studies of interventions to improve follow-up of TPAD need to include well-chosen comparator populations and single, well-defined interventions. Evaluation of the interventions would be strengthened if the studies measured both the targeted outcome of the intervention, such as physician awareness of TPAD, and its impact on patient outcomes. Evaluation of the generalizability of the interventions would be strengthened by multi-site studies and, where appropriate, application of the same intervention to multiple study populations. As failure to communicate or follow up on abnormal laboratory tests is a critical threat to patient safety, more research and interventions to address this problem are urgently needed.

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Things We Do For No Reason: The Default Use of Hypotonic Maintenance Intravenous Fluids in Pediatrics

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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.

Hypotonic intravenous (IV) fluids have historically been the maintenance IV fluid of choice for hospitalized children. Iatrogenic hyponatremia is a common phenomenon among hospitalized patients and hypotonic IV fluids significantly increase the risk for hyponatremia. Although infrequent, hyponatremic encephalopathy can have catastrophic complications, making the avoidance of iatrogenic hyponatremia a priority in the hospital. Multiple studies have demonstrated that compared with hypotonic IV fluids, isotonic IV fluids decrease the risk of hyponatremia without significant untoward side effects. Therefore, clinicians should preferentially treat most children with isotonic maintenance IV fluids instead of hypotonic IV fluids.

CASE PRESENTATION

A 12-month-old female is admitted for acute bronchiolitis with increased work of breathing and decreased oral intake. She is mildly dehydrated upon exam with a sodium level of 139 mEq/L and is given a 20 mL/kg bolus of 0.9% saline. Given the patient's poor oral intake, the admitting intern orders maintenance intravenous (IV) fluids and asks her senior resident which IV fluid should be used. The medical student on the team wonders if a different IV fluid would be selected for a 2-week-old with a similar presentation.

INTRODUCTION

Maintenance IV fluids are continuously infused to preserve extracellular volume and electrolyte balance when fluids cannot be taken orally. In contrast, resuscitation IV fluids are given as a bolus to patients in states of hypoperfusion to restore extracellular volume. The given IV fluid concentration can be categorized as approximately equal to (isotonic) or less than (hypotonic) the plasma sodium concentration. Refer to Table 1 for the electrolyte composition of commonly used IV fluids. Dextrose is rapidly metabolized upon infusion and does not affect tonicity.

WHY YOU MIGHT THINK HYPOTONIC MAINTENANCE IV FLUIDS ARE THE RIGHT CHOICE

A 1957 publication by Holliday and Segar laid the foundation for maintenance IV fluid and electrolyte requirements in children and was the initial catalyst for the use of hypotonic maintenance IV fluids.[1] This manuscript contended that hypotonic IV fluids could supply the water and sodium needed to meet maintenance dietary requirements. This claim led to the predominant use of hypotonic maintenance IV fluids in children. By contrast, isotonic IV fluids have been avoided given the apprehension over electrolytes exceeding maintenance needs.

Concerns about the unintended consequences of fluid overload – edema, hypernatremia, and hypertension secondary to increased sodium load – have led some to avoid isotonic IV fluids.[2] When presented with common clinical scenarios of patients at risk for excess antidiuretic hormone (ADH; also known as arginine vasopressin), pediatric residents chose hypotonic (instead of isotonic) IV fluids 78% of the time.[3]

WHY ISOTONIC MAINTENANCE IV FLUIDS ARE USUALLY THE RIGHT CHOICE FOR CHILDREN

General recommendations for hypotonic IV fluids are primarily based on theoretical calculations from the fluid and electrolyte requirements of healthy individuals, and studies have not validated the use of hypotonic IV fluids in clinical practice.[1] Acutely ill patients are at risk for excessive levels of ADH from numerous causes (see Table 2).[2] As a result, nearly every hospitalized patient is at risk for excess ADH release, thus making them vulnerable to the development of hyponatremia. The syndrome of inappropriate secretion of ADH (SIADH) occurs when nonosmotic/nonhemodynamic stimuli trigger ADH release, which leads to excessive free-water retention and resultant hyponatremia. Schwartz and Bartter reported the first two cases of SIADH in 1957 when hyponatremia developed in the setting of bronchogenic carcinoma.[4] Although the publication by Holliday and Seger did acknowledge the potential for water intoxication, it was written before this report and before the

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TABLE 1. **Composition of Commonly Used Maintenance Intravenous Fluids**

IV Fluid	Sodium	Chloride	Potassium	Calcium	Magnesium	Buffer	Osmolarity[a]
	mmol/L						mOsm/L
Human Plasma	135-144	95-105	3.5-5.3	2.2-2.6	0.8-1.2	23-30 bicarbonate	308[b]
Isotonic/Near Isotonic Solutions							
5% dextrose in 0.9% Saline	154	154	0	0	0	0	308
Plasma-Lyte	140	98	5	0	1.5	27 acetate & 23 gluconate	294
5% dextrose in Ringer's Lactate	130	109	4	1.5	0	28 lactate	273
Hypotonic Solutions							
5% dextrose in 0.45% Saline	77	77	0	0	0	0	154
5% dextrose in 0.2% Saline	34	34	0	0	0	0	78

[a]This osmolarity calculation excludes the dextrose in the solutions as dextrose is rapidly metabolized upon infusion.
[b]The osmolality for plasma is 275-295 mOsm/kg.

effects of ADH on the sodium levels of hospitalized patients were clearly understood.[2] SIADH is now recognized as one of the most common causes of hyponatremia in hospitalized patients.[5, 6]

Numerous studies have demonstrated that patients who receive hypotonic IV fluids have a significantly higher risk of developing hyponatremia than patients who receive isotonic IV fluids.[7,8] An infrequent, yet serious, complication of iatrogenic hyponatremia is hyponatremic encephalopathy, which carries a high rate of morbidity or mortality.[9] The prevention of hyponatremia is essential as the early symptoms of hyponatremic encephalopathy are nonspecific and can be easily missed.[2]

More than 15 prospective randomized controlled trials (RCTs) involving over 2,000 children have demonstrated that isotonic IV fluids are more effective in preventing hospital-acquired hyponatremia than hypotonic IV fluids and are not associated with the development of fluid overload or hypernatremia. A 2014 metaanalysis comprising 10 RCTs and involving over 800 children found that when compared with isotonic IV fluids, hypotonic IV fluids present a relative risk of 2.37 for sodium levels to drop below 135 mEq/L and a relative risk of 6.1 for levels to drop below 130 mEq/L. The numbers needed to treat (NNT) with isotonic IV fluids to prevent hyponatremia in each group were 6 and 17, respectively.[7] A Cochrane review published in 2014 presented comparable findings, demonstrating that hypotonic IV fluids had a 34% risk of causing hyponatremia; by comparison, isotonic IV fluids had a 17% risk of causing hyponatremia and a NNT of six to prevent hyponatremia.[8] In a large RCT conducted in 2015 with 676 pediatric patients, McNabb et al. found that when compared with patients receiving isotonic IV fluids, those receiving hypotonic IV fluids had a higher incidence of developing hyponatremia (10.9% versus 3.8%) with a NNT of 15 to prevent hyponatremia with the use of isotonic fluids.[10] Published trials have likely been underpowered to detect a difference in the infrequent adverse hyponatremia outcomes of seizures and mortality.

On the basis of these data, patient safety alerts have recommended the avoidance of hypotonic IV fluids in the United Kingdom (UK) and Australia, and the 2015 UK guidelines for children now recommend isotonic IV fluids for maintenance needs.[11] Although many of the aforementioned studies included predominantly critically ill or surgical pediatric patients, the risk of hyponatremia with hypotonic IV fluids seems similarly increased in nonsurgical and noncritically ill pediatric patients.[10]

For patients at risk for excess ADH release, some have supported the use of hypotonic IV fluids at a lower than maintenance rate to theoretically decrease the risk of hyponatremia, but this practice has not been effective in preventing hyponatremia.[2,12] Unless a patient is in a fluid overload state, such as in congestive heart failure, cirrhosis, or renal failure; isotonic maintenance IV fluids should not result in fluid overload.[3] Available evidence for guiding maintenance IV fluid choice in neonates or young infants is limited. Nevertheless, given the aforementioned reasons, we generally recommend the prescription of isotonic IV fluids for most in this population.

WHICH ISOTONIC IV FLUID SHOULD BE USED?

The sodium concentration (154 mmol/L) of 0.9% saline, an isotonic IV fluid, is approximately equal to the tonicity of the aqueous phase of plasma. The majority of studies evaluating the risk of hyponatremia with maintenance IV fluids have used 0.9% saline as the studied isotonic IV fluid. Plasma-Lyte and Ringer's lactate are low-chloride, buffered/balanced solutions. Plasma-Lyte ([Na] = 140 mmol/L) has been demonstrated to be effective in preventing hyponatremia. Ringers' lactate is slightly hypotonic ([Na] = 130 mmol/L), and its administration is associated with a decrease in serum sodium.[13] A resultant dilutional and hyperchloremic metabolic acidosis is more likely to develop with the use of large volumes of 0.9% saline in resuscitation than with the use of balanced solutions.[2] Whether the

TABLE 2. **Nonosmotic Stimuli for ADH (AVP) Release**

Hemodynamic	Non-hemodynamic stimuli
Hypovolemia	Nausea and vomiting
Hypotension	Pain and stress
Congestive heart failure	Perioperative state
Nephrotic syndrome	Pulmonary disease
Cirrhosis	Central nervous system disease
Adrenal insufficiency	Cancer and inflammation
	Hypoxemia and hypercapnia
	Hypoglycemia
	Medications, including: SSRIs, amitriptyline, haloperidol, NSAIDS, opiates, carbamazepine, cyclophosphamide, methotrexate + many more

Abbreviations: ADH , anti-diuretic hormone; AVP, arginine vasopressin; NSAIDS, nonsteroidal anti-inflammatory drugs; SSRIs, selective serotonin reuptake inhibitors.

prolonged use of 0.9% saline maintenance IV fluids can lead to this same side effect remains unknown given insufficient evidence.[2] Retrospective studies using balanced solutions have shown an association with decreased rates of acute kidney injury (AKI) and mortality when compared with 0.9% saline. However, a RCT with over 2,000 adult ICU patients showed no change in rates of AKI in those that received Plasma-Lyte compared with those who received 0.9% saline.[14]

Two recent, single-center, prospective studies compared the use of Ringer's lactate or Plasma-Lyte for resuscitation with that of 0.9% saline. One study was comprised of 15,802 critically ill adults, and the other was comprised of 13,347 noncritically adults. Both studies showed that balanced solutions decreased the rate of major adverse kidney events (defined as a composite of death from any cause, new renal-replacement therapy, or persistent renal injury) within 30 days.[15,16] Available published pediatric studies indicate that 0.9% saline is an effective maintenance IV fluid for the prevention of hyponatremia that is not associated with hypernatremia or fluid overload. Further pediatric studies comparing 0.9% saline with balanced solutions are needed.

WHEN SHOULD WE USE HYPOTONIC IV FLUIDS?

Hypotonic IV fluids may be needed for patients with hypernatremia and a free-water deficit or a renal-concentrating defect with ongoing urinary free-water losses.[2] Special care should be taken when choosing maintenance IV fluids for patients with renal disease, liver disease, or heart failure given that these groups have been excluded from some studies.[12] These patients may be at risk for increased salt and fluid retention with any IV fluid, and fluid rates need to be restricted. The fluid intake of patients with hyponatremia secondary to SIADH needs close management; these patients benefit from total fluid restriction instead of standard maintenance IV fluid rates.[2]

WHAT WE SHOULD DO INSTEAD?

Maintenance IV fluids should only be used when necessary and should be stopped as soon as they are no longer required, especially in light of the recent shortages in 0.9% saline.[17] Similar to all medications, maintenance IV fluids should be individualized to the patient's needs on the basis of the indication for IV fluids and the patient's comorbidities.[2] Consideration should be given to checking the patient's electrolyte levels to monitor response to IV fluids, especially during the first 24 hours of admission when risk of hyponatremia is highest. Isotonic IV fluids with 5% dextrose should be used as the maintenance IV fluid in the majority of hospitalized children given its proven benefit in decreasing the rate of hospital-acquired hyponatremia.[7,8] Hypotonic IV fluids should be avoided as the default maintenance IV fluid and should only be utilized under specific circumstances.

RECOMMENDATIONS

- When needed, maintenance IV fluids should always be tailored to each individual patient.
- For most acutely ill hospitalized children, isotonic IV fluids should be the maintenance IV fluid of choice.
- Consider monitoring electrolytes to determine the effects of maintenance IV fluids.

CONCLUSION

Enteral maintenance fluids should be used first-line if possible. Although hypotonic IV fluids have historically been the maintenance IV fluid of choice, this class of IV fluids should be avoided for most hospitalized children to decrease the significant risk of iatrogenic hyponatremia, which can be severe and have catastrophic complications. When necessary, isotonic IV fluids should be used for the majority of hospitalized children given that these fluids present a significantly decreased risk for causing hyponatremia. Returning to our case presentation, to decrease the risk of hyponatremia, the senior resident should recommend starting isotonic IV fluids in the 12-month-old and theoretical 2-week-old until oral intake can be maintained.

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.

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A Tough Egg to Crack

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. Similar 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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A 68-year-old woman presented to the emergency department with altered mental status. On the morning prior to admission, she was fully alert and oriented. Over the course of the day, she became more confused and somnolent, and by the evening, she was unarousable to voice. She had not fallen and had no head trauma.

Altered mental status may arise from metabolic (eg, hyponatremia), infectious (eg, urinary tract infection), structural (eg, subdural hematoma), or toxin-related (eg, adverse medication effect) processes. Any of these categories of encephalopathy can develop gradually over the course of a day.

One year prior, the patient was admitted for a similar episode of altered mental status. Asterixis and elevated transaminases prompted an abdominal ultrasound, which revealed a nodular liver and ascites. Paracentesis revealed a high serum-ascites albumin gradient. The diagnosis of cirrhosis was made based on these findings. Testing for viral hepatitis, autoimmune hepatitis, hemochromatosis, and Wilson's disease were negative. Although steatosis was not detected on ultrasound, nonalcoholic fatty liver disease (NAFLD) was suspected based on the patient's risk factors of hypertension and type 2 diabetes mellitus. She had four additional presentations of altered mental status with asterixis; each episode resolved with lactulose.

Other medical history included end-stage renal disease (ESRD) requiring hemodialysis. Her medications were labetalol, amlodipine, insulin, propranolol, lactulose, and rifaximin. She was originally from China and moved to the United States 10 years earlier. Given concerns about her ability to consistently take medications, she had moved to a long-term facility. She did not use alcohol, tobacco, or illicit substances.

The normalization of the patient's mental status after lactulose treatment, especially in the context of recurrent episodes, is characteristic of hepatic encephalopathy, in which ammonia and other substances bypass hepatic metabolism and impair cerebral function. Hepatic encephalopathy is the most common cause of lactulose-responsive encephalopathy, and may recur in the setting of infection or nonadherence with lactulose and rifaximin. Other causes of lactulose-responsive encephalopathy include hyperammonemia caused by urease-producing bacterial infection (eg, *Proteus*), valproic acid toxicity, and urea cycle abnormalities.

Other causes of confusion with a self-limited course should be considered for the current episode. A postictal state is possible, but convulsions were not reported. The patient is at risk of hypoglycemia from insulin use and impaired gluconeogenesis due to cirrhosis and ESRD, but low blood sugar would have likely been detected at the time of hospitalization. Finally, she might have experienced episodic encephalopathy from ingestion of unreported medications or toxins, whose effects may have resolved with abstinence during hospitalization.

The patient's temperature was 37.8°C, pulse 73 beats/minute, blood pressure 133/69 mmHg, respiratory rate 12 breaths/minute, and oxygen saturation 98% on ambient air. Her body mass index (BMI) was 19 kg/m^2. She was somnolent but was moving all four extremities spontaneously. Her pupils were symmetric and reactive. There was no facial asymmetry. Biceps and patellar reflexes were 2+ bilaterally. Babinski sign was absent bilaterally. The patient could not cooperate with the assessment for asterixis. Her sclerae were anicteric. The jugular venous pressure was estimated at 13 cm of water. Her heart was regular with no murmurs. Her lungs were clear. She had a distended, nontender abdomen with caput medusae. She had symmetric pitting edema in her lower extremities up to the shins.

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The elevated jugular venous pressure, lower extremity edema, and distended abdomen suggest volume overload. Jugular venous distention with clear lungs is characteristic of right ventricular failure from pulmonary hypertension, right ventricular myocardial infarction, tricuspid regurgitation, or constrictive pericarditis. However, chronic biventricular heart failure often presents in this manner and is more common than the aforementioned conditions. ESRD and cirrhosis may be contributing to the hypervolemia.

Although Asian patients may exhibit metabolic syndrome and NAFLD at a lower BMI than non-Asians, her BMI is uncharacteristically low for NAFLD, especially given the increased weight expected from volume overload. There are no signs of infection to account for worsening of hepatic encephalopathy.

Laboratory tests demonstrated a white blood cell count of 4400/μL with a normal differential, hemoglobin of 10.3 g/dL, and platelet count of 108,000 per cubic millimeter. Mean corpuscular volume was 103 fL. Basic metabolic panel was normal with the exception of blood urea nitrogen of 46 mg/dL and a creatinine of 6.4 mg/dL. Aspartate aminotransferase was 34 units/L, alanine aminotransferase 34 units/L, alkaline phosphatase 289 units/L (normal, 31-95), gamma-glutamyl transferase 104 units (GGT, normal, 12-43), total bilirubin 0.8 mg/dL, and albumin 2.5 g/dL (normal, 3.5-4.5). Pro-brain natriuretic peptide was 1429 pg/mL (normal, <100). The international normalized ratio (INR) was 1.0. Urinalysis showed trace proteinuria. The chest x-ray was normal. A non-contrast computed tomography (CT) of the head demonstrated no intracranial pathology. An abdominal ultrasound revealed a normal-sized nodular liver, a nonocclusive portal vein thrombus (PVT), splenomegaly (15 cm in length), and trace ascites. There was no biliary dilation, hepatic steatosis, or hepatic mass.

The evolving data set presents a mixed picture about the state of the liver. The distended abdominal wall veins, thrombocytopenia, and splenomegaly are commonly observed in advanced cirrhosis, but these findings reflect the associated portal hypertension and not the liver disease itself. The normal bilirubin and INR suggest preserved liver function and decrease the likelihood of cirrhosis being responsible for the portal hypertension. However, the elevated alkaline phosphatase and GGT levels suggest an infiltrative liver disease, such as lymphoma, sarcoidosis, or amyloidosis.

Furthermore, while a nodular liver on imaging is consistent with cirrhosis, no steatosis was noted to support the presumed diagnosis of NAFLD. One explanation for this discrepancy is that fatty infiltration may be absent when NAFLD-associated cirrhosis develops. In summary, there is evidence of liver disease, and there is evidence of portal hypertension, but there is no evidence of liver parenchymal failure. The key features of the latter – spider angiomata, palmar erythema, hyperbilirubinemia, and coagulopathy – are absent.

Noncirrhotic portal hypertension (NCPH) is an alternative explanation for the patient's findings. NCPH is an elevation in the portal venous system pressure that arises from intrahepatic (but noncirrhotic) disease or from extrahepatic disease. Hepatic schistosomiasis is an example of intrahepatic but noncirrhotic portal hypertension. PVT that arises on account of a hypercoagulable condition (eg, abdominal malignancy, pancreatitis, or myeloproliferative disorders) is a prototype of extrahepatic NCPH. At this point, it is impossible to know if the PVT is a complication of NCPH or a cause of NCPH. PVT as a complication of cirrhosis is less likely.

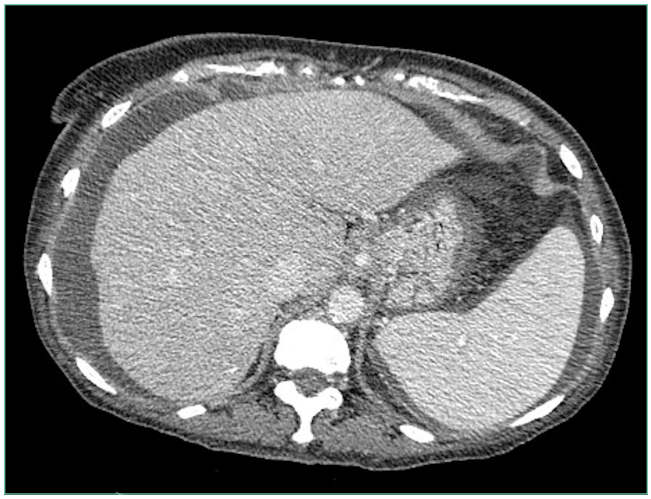

FIG 1. CT of the abdomen and pelvis with contrast demonstrating a nodular liver, ascites, and splenomegaly

An abdominal CT scan would better assess the hepatic parenchyma and exclude abdominal malignancies such as pancreatic adenocarcinoma. An echocardiogram is indicated to evaluate the cause of the elevated jugular venous pressure. A liver biopsy and measurement of portal venous pressure would help distinguish between cirrhotic and noncirrhotic portal hypertension.

Hepatitis A, B, and C serologies were negative as were antinuclear and antimitochondrial antibodies. Ferritin and ceruloplasmin levels were normal. A CT scan of the abdomen with contrast demonstrated a nodular liver contour, splenomegaly, and a nonocclusive PVT (Figure 1). A transthoracic echocardiogram showed normal biventricular systolic function and size, normal diastolic function, a pulmonary artery systolic pressure of 57 mmHg (normal, < 25), moderate tricuspid regurgitation, and no pericardial effusion or thickening. The patient's confusion and somnolence resolved after two days of lactulose therapy. She denied the use of other medications, supplements, or herbs.

Pulmonary hypertension is usually a consequence of cardiopulmonary disease, but there is no exam or imaging evidence for left ventricular failure, mitral stenosis, obstructive lung disease, or interstitial lung disease. Portopulmonary hypertension (a form of pulmonary hypertension) can develop as a consequence of end-stage liver disease. The most common cause of hepatic encephalopathy due to portosystemic shunting is

cirrhosis, but such shunting also arises in NCPH.

Schistosomiasis is the most common cause of NCPH worldwide. Parasite eggs trapped within the terminal portal venules cause inflammation, leading to fibrosis and intrahepatic portal hypertension. The liver becomes nodular on account of these changes, but the overall hepatic function is typically preserved. Portal hypertension, variceal bleeding, and pulmonary hypertension are common complications. The latter can arise from portosystemic shunting, which leads to embolization of schistosome eggs into the pulmonary circulation, where a granulomatous reaction ensues.

A percutaneous liver biopsy showed granulomatous inflammation and dilated portal venules consistent with increased resistance to venous inflow (Figure 2). There was no sinusoidal congestion to indicate impaired hepatic venous outflow. Mild sinusoidal and portal fibrosis and increased iron in Kupffer cells were noted. There was no evidence of cirrhosis or steatohepatitis. Stains for acid-fast bacilli and fungi were negative. 16S rDNA (a test assessing for bacterial DNA) and *Mycobacterium tuberculosis* polymerase chain reactions were negative. The biopsy confirmed the diagnosis of noncirrhotic portal hypertension.

Hepatic granulomas can arise from infectious, immunologic, toxic, and malignant diseases. In the United States, immunologic disorders, such as sarcoidosis and primary biliary cholangitis, are the most common causes of granulomatous hepatitis. The patient lacks extrahepatic features of the former. The absence of bile duct injury and negative antimitochondrial antibody exclude the latter. None of the listed medications are commonly associated with hepatic granulomas. The ultrasound, CT scan, and biopsy did not reveal a granulomatous malignancy such as lymphoma.

Infections, such as brucellosis, Q fever, and tuberculosis, are common causes of granulomatous hepatitis in the developing world. Tuberculosis is prevalent in China, but the test results do not support tuberculosis as a unifying diagnosis.

Schistosomiasis accounts for the major clinical features (portal and pulmonary hypertension and preserved liver function) and hepatic pathology (ie, portal venous fibrosis with granulomatous inflammation) in this case and is prevalent in China, where the patient emigrated from. The biopsy specimen should be re-examined for schistosome eggs and serologic tests for schistosomiasis pursued.

Antibodies to human immunodeficiency virus, *Brucella*, *Bartonella quintana*, *Bartonella henselae*, *Coxiella burnetii*, *Francisella tularensis,* and *Histoplasma* were negative. Cryptococcal antigen and rapid plasma reagin were negative. IgG antibodies to *Schistosoma* were 0.21 units (normal, < 0.19 units). Based on the patient's epidemiology, biopsy findings, and serology results, hepatic schistosomiasis was diagnosed. Praziquantel was prescribed. She continues to receive daily lactulose and rifaximin and has not had any episodes of encephalopathy in the year after discharge.

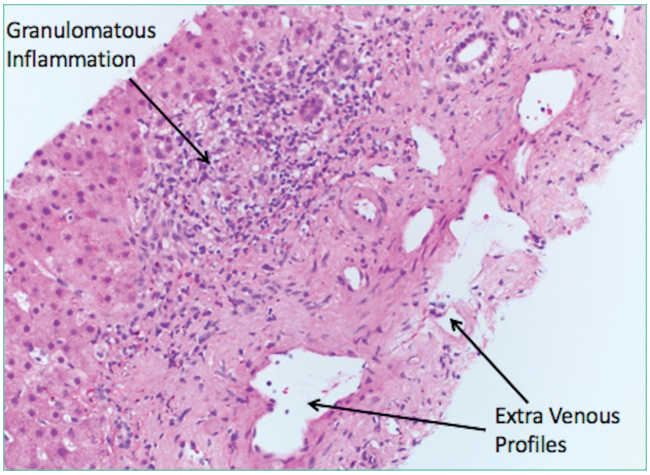

FIG 2. Liver biopsy specimen demonstrating granulomatous inflammation and dilated portal venules in the absence of hepatic congestion suggests an intrahepatic portal venous inflow disorder.

COMMENTARY

Portal hypertension arises when there is resistance to flow in the portal venous system. It is defined as a pressure gradient greater than 5 mmHg between the portal vein and the intra-abdominal portion of the inferior vena cava.[1] Clinicians are familiar with the manifestations of portal hypertension – portosystemic shunting leading to encephalopathy and variceal hemorrhage, ascites, and splenomegaly with thrombocytopenia – because of their close association with cirrhosis. In developed countries, cirrhosis accounts for over 90% of cases of portal hypertension.[1] In the remaining 10%, conditions such as portal vein thrombosis primarily affect the portal vasculature and increase resistance to portal blood flow while leaving hepatic synthetic function relatively spared (Figure 3). Therefore, cirrhosis cannot be inferred with certainty from signs of portal hypertension alone.

Liver biopsy is the gold standard for the diagnosis of cirrhosis, but this method is increasingly being replaced by noninvasive assessments of liver fibrosis, including imaging and scoring systems.[2] Clinicians often infer cirrhosis from the combination of a known cause of liver injury, abnormal liver biochemical tests, evidence of liver dysfunction, and signs of portal hypertension.[3] However, when signs of portal hypertension are present, but liver dysfunction cannot be established on physical exam (eg, palmar erythema, spider nevi, gynecomastia, and testicular atrophy) or laboratory testing (eg, low albumin, elevated INR, and elevated bilirubin), noncirrhotic causes of portal hypertension should be considered. In this case, the biopsy showed vascular changes that suggested impaired venous inflow without bridging fibrosis, which pointed to NCPH.

NCPH is categorized based on the location of resistance to blood flow: prehepatic (eg, portal vein thrombosis), intrahepatic (eg, schistosomiasis), and posthepatic (eg, right-sided heart failure).[1] In our patient, the dilated portal venules (inflow) in the presence of normal hepatic vein outflow suggested an increased intrahepatic resistance to blood flow. This finding excluded a causal role of the portal vein thrombosis and

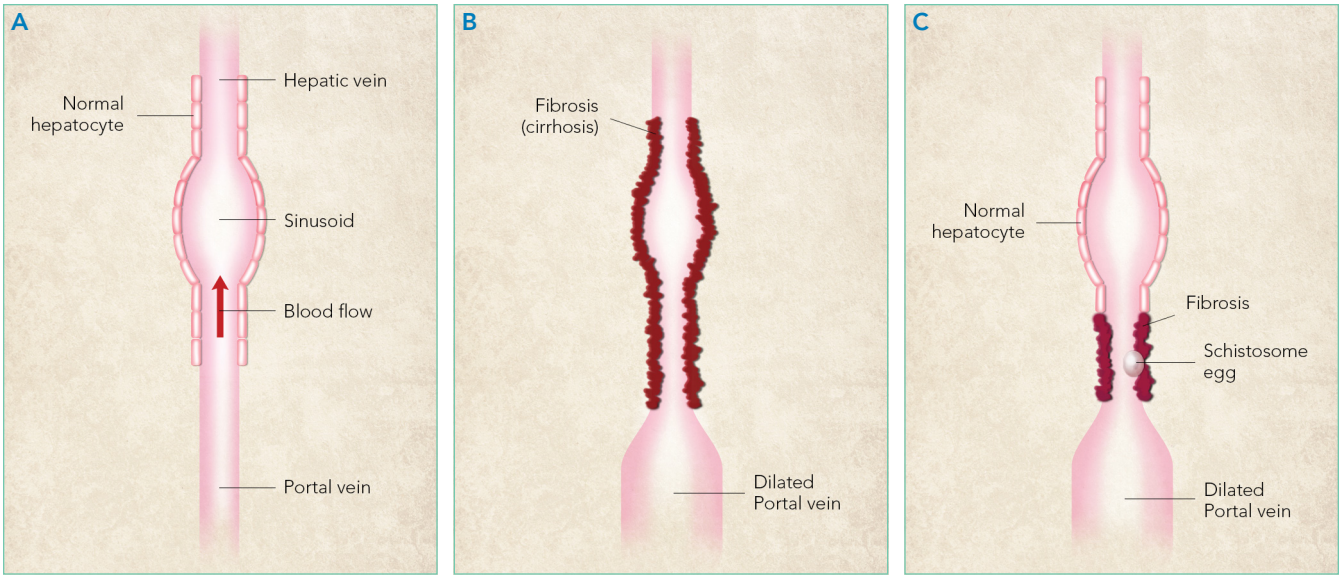

FIG 3. (A) In a normal liver, hepatocytes and adjacent connective tissue do not obstruct the blood flow of the portal venous system. (B) In cirrhosis, parenchymal fibrosis leads to loss of endothelial fenestrations and intrahepatic portal venous compression, which causes portal hypertension and proximal venous dilation. (C) In hepatic schistosomiasis, eggs that are lodged in the portal venous system cause granulomatous inflammation and portal venous fibrosis. The resultant obstruction to venous inflow leads to portal hypertension and proximal venous dilation. However, the hepatic architecture and function are usually maintained.

prompted testing for schistosomiasis.

Schistosomiasis affects more than 200 million people worldwide and is prevalent in Sub-Saharan Africa, South America, Egypt, China, and Southeast Asia.[4,5] Transmission occurs in fresh water, where the infectious form of the parasite is released from snails.[4,6] Schistosome worms are not found in the United States, but as a result of immigration and travel, more than 400,000 people in the United States are estimated to be infected.[5]

Chronic schistosomiasis develops from the host's granulomatous reaction to schistosome eggs whose location (depending on the species) leads to genitourinary, intestinal, hepatic, or rarely, neurologic disease.[6] Hepatic schistosomiasis arises when eggs released in the portal venous system lodge in small portal venules and cause granulomatous inflammation, periportal fibrosis, and microvascular obstruction.[6] The resultant portal hypertension develops insidiously, but the architecture and synthetic function of the liver is maintained until the very late stages of disease.[6,7] Pulmonary hypertension can arise from the embolization of eggs to the pulmonary arterioles via portosystemic collaterals.

The demonstration of eggs in stool is the gold standard for the diagnosis of hepatic schistosomiasis, which is most commonly caused by *Schistosoma mansoni* and *S. japonicum*.[7] Serologic assays provide evidence of infection or exposure but may cross-react with other helminths. Liver biopsy may reveal characteristic histopathologic findings, including granulomatous inflammation, distorted vasculature, and the deposition of collagen deposits in the periportal space, leading to "pipestem fibrosis."[8,9] If eggs cannot be detected on stool or histology, then serology, secondary histologic changes, and sometimes PCR are used to diagnose hepatic schistosomiasis. In our patient, the epidemiology, Schistosoma antibody titer, pulmonary hypertension, and liver biopsy with granulomatous inflammation, periportal fibrosis, and intrahepatic portal venule dilation were diagnostic of hepatic schistosomiasis.

The recurrent episodes of confusion which resolved with lactulose therapy were suggestive of hepatic encephalopathy, which results from shunting and accumulation of neurotoxic substances that would otherwise undergo hepatic metabolism.[10] Clinicians are most familiar with hepatic encephalopathy in cirrhosis, where multiple liver functions – synthesis, excretion, metabolism, and circulation – simultaneously fail. NCPH represents a scenario where only the circulation is impaired, but this is sufficient to cause the portosystemic shunting that leads to encephalopathy. Our patient's recurrent hepatic encephalopathy, despite adherence to lactulose and rifaximin and its resolution after praziquantel treatment, underscores the importance of addressing the underlying cause of portosystemic shunting.

Associating portal hypertension with cirrhosis is efficient and accurate in many cases. However, when specific manifestations of cirrhosis are lacking, clinicians must decouple this association and pursue an alternative explanation for portal hypertension. The presence of some intrahepatic pathology (from schistosomiasis) but no cirrhosis made this case a particularly tough egg to crack.

TEACHING POINTS

- In the developed world, 90% of portal hypertension is due to cirrhosis. Hepatic schistosomiasis is the most common cause of NCPH worldwide.
- Chronic schistosomiasis affects the gastrointestinal, hepatic, and genitourinary systems and causes significant global morbidity and mortality.
- Visualization of schistosome eggs is the diagnostic gold

standard. Indirect testing such as schistosoma antibodies and secondary histologic changes may be required for the diagnosis in patients with a low burden of eggs.

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Postdischarge Emergency Department Visits: Good, Bad, or Ugly?

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Once upon a time, discharges were easy to categorize: *good*, *bad*, or *ugly*. Good discharges allowed the patient to leave before noon, while bad discharges allowed the patient to leave without follow-up appointments. The worst discharges were defined by the two ugly cousins of acute care re-escalation: return emergency department (ED) visits and readmissions. Recently, however, much of this conventional wisdom has been turned on its head. For example, pre-noon discharges and provider-scheduled follow-up appointments may lead to unintended negative consequences and futility.[1,2] In contrast, weekend discharges, which were often viewed to be unsafe, may reduce lengths of stay without compromising care even in high-risk patients.[3]

Having obfuscated the line between good and bad, we can now turn our attention to the ugly. Comparing return ED visits with readmissions, hospitalists may be forgiven for judging the latter cousin as uglier – and not just for reimbursement reasons. Readmitted patients are sicker, more vulnerable, and have poorer outcomes. In our healthcare system's resultant quest to eliminate readmissions, return ED visits that do not end in readmission are generally either ignored or grouped with readmissions. Ignoring these treat-and-discharge ED visits is problematic because of their incidence, which rivals that of ED visits ending in readmission.[4] On the other hand, grouping these visits with readmissions only makes sense if the two are considered to be equally ugly outcomes. Is this a valid assumption to make?

In this issue of the *Journal of Hospital Medicine*, Venkatesh et al[5] tackle that question by studying Medicare beneficiaries hospitalized for acute myocardial infarction, heart failure, or pneumonia over a 1-year period. The authors differentiate 30-day treat-and-discharge ED visit rates from 30-day readmission rates before risk-standardizing these rates based on visit codes and hospital characteristics. Similar to the results of prior studies, the authors observe an 8%–9% overall incidence of treat-and-discharge ED visits within 30 days of hospital discharge.[6] Mapping treat-and-discharge ED visit rates versus readmission rates for each hospital, the authors detect modest but noticeable inverse correlations between the two. Among hospitals discharging heart failure patients, for example, every 10% increase in postdischarge ED visit rates corresponds to a roughly 2% decrease in readmission rates.

The authors are correct to tread cautiously with their interpretation of this correlation. Dispositions for ED patients exist on a continuum, so hospitals with higher propensities to discharge patients from EDs (whether directly or from observation units) will inherently have lower admission rates. The authors hint at a causal relationship nonetheless, suggesting that ED providers may be able to intervene on high-risk patients earlier before Readmission Road becomes a one-way street. Proving this hypothesis will require careful research that controls for patient, disease, and ED factors as well as their complex interactions in the postdischarge timeline. That being said, most analyses of outpatient follow-up visits (except for heart failure patients) have failed to find any anti-readmission correlation analogous to that identified by Venkatesh et al. What powers do ED providers have that outpatient providers lack? Many, admittedly: stat phlebotomy services, on-demand consultations, and observation units. Additionally, while ED visits invariably require a patient's presence in person, 25% of provider-scheduled posthospitalization outpatient visits end in no-shows.[2] Whether patient-triggered follow-up through rapid access clinics or even urgent care centers can replicate ED functionality in recently discharged patients is unknown and warrants further study.

Venkatesh et al[5] also find that reasons for postdischarge ED visits bear only a slight resemblance to reasons for index hospitalizations. For example, of all ED visits by patients recovering from hospitalizations for pneumonia, only 20% involve respiratory or pulmonary complaints. What explains the other 80%? Some variability may be attributable to the study's use of visit codes instead of chart reviews or stakeholder interviews; in surveys of patients and ED physicians during these postdischarge visits, the two groups may have very different perceptions of why the encounter is occurring and whether it is preventable.[7] Regardless of who is "right," the heterogeneity of reasons that prompt care re-escalation lends further credence to the existence of a distinct posthospitalization syndrome:[8] in the immediate postdischarge interval, patients experience many transient but real physiological risks for which they may identify the ED as their best recourse.

Whether the ED actually provides secondary prophylaxis against the posthospitalization syndrome is highly debatable, and Venkatesh et al wisely refrain from assigning a positive or negative valence to treat-and-discharge ED visits. Ultimately, postdischarge ED visits are neither inherently good nor bad (nor ugly, for that matter). Their unique nature is attracting

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newfound appreciation, and their potential ability to prevent readmission merits further research. If hospitals with high post-discharge ED visit rates can deliver high-quality care while truly arresting or reversing readmission-bound trajectories, then the strategies employed by these hospitals should inspire emulation, innovation, and dissemination.

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Relative Weights for Pediatric Inpatients: Children Now Have a Scale of Their Own

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For the last 35 years, Medicare's prospective payment system has transformed reimbursement for hospital-based care of patients. This "revolutionary" system shifted payment from being retrospective – the government paid hospitals for what they did – to prospective – the government paid hospitals against a predetermined fee schedule based on a patient's condition and other factors.[1] When the system started in 1983, the then-new payment system classified patients into 467 Diagnosis-Related Groups (DRGs). In those early days, Medicare paid hospitals "an average price for an average patient within the DRG."[2] Not surprisingly, early critics were concerned that this average payment would disadvantage hospitals that cared for more complex patients, such as teaching hospitals; studies then demonstrated that theoretical concern.[3] The Severity of Illness (SOI) index, which was developed in the 1980s, attempted to correct this problem by using SOI-stratified DRGs as a payment mechanism. By adding SOI to DRGs, the homogeneity of resource consumption in each group increased, resulting in more accurate comparisons about complexity, outcomes, resource utilization, and ultimately payment. Eventually, along with the risk of mortality, the SOI made its way into the All Patients Refined (APR) DRG system, which is more representative of non-Medicare populations and thus could be applied to children.

The ongoing challenge with SOI classification is that its 4-level categories (1-mild, 2-moderate, 3-severe, 4-extreme) is not comparable across DRGs; that is, a "moderate" patient in one DRG may be sicker and use more resources than an "extreme" patient in another DRG. For this reason, more than a decade ago, Medicare replaced the DRG/SOI approach with the Medicare Severity (MS)-DRG for Medicare payments to hospitals. The distinguishing feature of MS-DRGs is that they represent a complete relative scale; the relative weights are not categorical but can be lined up and payments assigned relative to the average Medicare patient. For example, a look at the 2015 tables shows that heart transplant has the highest relative weight and is the most expensive one, whereas false labor has the lowest relative weight and is the least expensive.[4] Due to its exclusive intent for use on Medicare patients, the system could not be used for pediatrics. Interestingly, New York State developed a Service Intensity Weight (SIW) in 2009 by using 3 years of Medicaid and commercial payer data to create a relative scale for payment within the state.[5]

Thanks to Richardson, et al, in this issue of *Journal of Hospital Medicine*, pediatrics has its first relative weight system for hospitalized children across the United States.[6] Similar to the MS-DRG system, those with the interest or need can line up the APR-DRGs into a relative scale and see that a normal newborn has a relative weight on their H-RISK scale of 0.18, while a heart transplant patient has a weight of 91.66. This is a welcome and much-needed addition to the world of pediatric health services and health service research. Stakeholders can use this system for comparative analyses, risk adjustment, resource utilization comparison, and payment. For those inclined, one can explore the comparisons of relative weights on different scales; for example, the ratio between simple pneumonia and heart transplant is 21 on the MS-DRG, 60 on the NY State SIW scale,[7] and 187 on H-RISK. A generation of health service researchers and economists may find great satisfaction in elucidating why this relativity in relative scales exists!

There are limitations to all weighting and relative weighting systems. The H-RISK is based on DRG and SOI, which rely on accurate coding. In addition, as the authors note, iatrogenic complications are not differentiated from naturally occurring ones. Thus, a hospital may obtain a higher relative weight applied to a patient who did not enter the hospital as sick as the final score suggests. Researchers noted this problem from the start of the DRG/SOI journey, and all systems that rely on *post hoc* scoring based on coded diagnoses and activities, without differentiation of presence on admission, have this limitation.[8] Furthermore, children's hospitals have far more variable use of observation status than in Medicare, and many DRG analyses exclude observation-status patients.

Despite these limitations, this is an important first step for children's hospitals to be better able to do comparative analyses and benchmarking with a true relative weight scale that is appropriate for use among hospitalized children.

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FYI: This Message Will Interrupt You – Texting Impact on Clinical Learning Environment

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Fifteen years ago, beepers with 5-digit call-back numbers were the norm. Pushing a call light button outside the patient's room to flag the desk clerk that a new order had been hand-written was all part of the lived experience of residency. Using that as our baseline, we have clearly come a long way in the way that we communicate with other clinicians in hospitals. Communication among the patient care team in the digital age predominantly involves bidirectional messaging using mobile devices. The approach is both immediate and convenient. Mobile devices can improve work efficiency, patient safety, and quality of care, but their main advantage may be real-time bedside decision support.[1,2] However, the widespread use of mobile devices for communication in healthcare is not without its concerns. First and foremost, there has been abundant literature around short message service (SMS) use in the healthcare setting, and there are concerns surrounding both threats to privacy and the prevalence and impact of interruptions in clinical care.

The first SMS was sent in 1992.[3] Text messaging since then has become ubiquitous, even in healthcare, raising concerns around the protection of patient health information under the Health Insurance Portability and Accountability Act (HIPAA). Interestingly, the United States Department of Health and Human Services Office for Civil Rights, enforcer of HIPAA, is tech neutral on the subject.[3] Multiple studies have assessed physician stances on SMS communication in the healthcare setting using routine, non-HIPAA-compliant mobile phones. Overall, 60%-80% of respondents admitted to using SMS in patient care, while in another study, 72% and 80% of Internal Medicine residents surveyed found SMS to be the most efficient form of communication and overall preferred method of communication, respectively.[3,4] Interestingly, 82.5% of those same residents preferred the hospital-based alphanumeric paging system for security purposes, even though Freundlich et al. make a compelling argument that unidirectional alphanumeric paging systems are most certainly less HIPAA compliant, lacking encryption and password protection.[5] Newer platforms that enable HIPAA-compliant messaging are promising, although they may not be fully adopted by clinical teams without full-scale implementation in hospitals.[6]

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In addition to privacy concerns with SMS applications on mobile phones, interruptions in healthcare – be it from phone calls, emails, text messages, or in-person conversations – are common. In fact, famed communication researcher Enrico Coeira has notoriously described healthcare communication as "interrupt-driven."[7] Prior work has shown that frequent interruptions in the healthcare setting can lead to medication prescription errors, errors in computerized physician order entry, and even surgical procedural errors.[8-10]

While studies have focused on interruptions in clinical care in the healthcare setting, little is known about how education may be compromised by interruptions due to mobile devices. Text messaging during dedicated conference time can lead to inadequate learning and a sense of frustration among residents. In this issue of the *Journal of Hospital Medicine*, Mendel et al. performed a quality improvement study involving eight academic inpatient clinical training units with the aim of reducing nonurgent text messages during education rounds.[11] Their unique interventions included learning sessions, posters, adding alerts to the digital communication platform, and alternative messaging options. Of four sequential interventions, a message alerting the sender that they will be interrupting educational rounds and suggesting a "delayed send" or "send as an FYI" showed the greatest impact, reducing the number of text interruptions per team per educational hour from 0.81 to 0.59 (95% CI 0.51-0.67). When comparing a four-week pre-intervention sample with a four-week end-intervention sample, the percentage of nonurgent messages decreased from 82% to 68% ($P < .01$).

While these results are promising, challenges to large-scale implementation of such a program exist. Buy-in from the ancillary healthcare team is critical for such interventions to succeed and be sustained. It also places a burden of "point triage" on the healthcare team members, who must assess the patient situation and determine the level of urgency and whether to immediately interrupt, delay interrupt or send an FYI message. For example, in the study by Mendel et al.,[11] it is noteworthy that urgent patient care issues were mislabeled as "FYI" in 2% of patients. While this is a seemingly low rate, even one of these mislabeled messages could result in significant adverse patient outcomes and should be considered a "never event." Finally, the study used a messaging platform with programming flexibility and IT personnel to assist. This could be cost prohibitive for some programs, especially if rolled out to an entire institution.

Communication is critical for effective patient care and unfortunately, the timing of such communication is often not

orderly but rather, chaotic. Text message communication can introduce interruptions into all aspects of patient care and education, not only dedicated learning conferences. If the goal is for all residents to attend all conferences, it seems impossible (and likely dangerous) to eliminate all messaging interruptions during conference hours. Nevertheless, it is worth noting that Mandel et al. have moved us creatively toward that goal with a multifaceted approach.[11] Future work should address more downstream outcomes, such as objective resident learning retention and adverse patient events relative to the number of interruptions per educational hour. If such studies showed improved learning outcomes and fewer adverse patient events, the next step would be to further strengthen and refine their protocol with real-time and scheduled feedback sessions between providers and other patient care team members in addition to the continued search for additional innovative approaches. In addition, combining artificial intelligence or predictive modeling may help us delineate when an interruption is warranted, for example, when a patient is at high clinical risk without intervention. Likewise, human factors research may help us understand the best way to time and execute an interruption to minimize the risk to clinical care or education. After all, the ideal system would not eliminate interruptions entirely but allow clinicians to know when someone should be interrupted and when they do not need to be interrupted.

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It Is What It Is…. For Now.

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This issue of the *Journal of Hospital Medicine* addresses an emerging trend in internal medicine graduate medical education: the hospitalist rotation.

In the article, Training Residents in Hospital Medicine: The Hospitalist Elective National Survey (HENS). by Ludwin et al., the authors present a descriptive overview of the composition of hospital medicine rotations, as described by program directors from some of the largest training programs. [1] It can be said for sure that hospital medicine rotations exist: half of the 82 programs that replied to the survey noted that a hospital medicine rotation was already in place. That is where the certainty ends. Although there are common themes across these rotations, there is no one clear definition of such a rotation. Like all good contributions to the medical literature, this study inspires more questions than it answers.

The Mark Twain-inspired cynic would be quick to make an interpretation of the hospital medicine rotation: Is this not just a clever way to coax residents into using their elective time to cover the service needs left over from Accreditation Council for Graduate Medical Education (ACGME)-mandated shift limits and admission caps? Seventy-one percent of these rotations were involved in "admitting new patients." And since forty-six percent were tasked with taking hold-over admissions, it is reasonable to surmise that these rotations are playing a role in covering patient care duties left over from traditional ward services.

But is there anything wrong with that? Within the confines of reasonable intensity, caring for more patients usually benefits a resident's education. And if the resident is learning knowledge, skills and attitudes that are unique from those that are acquired on a traditional ward service, painting the fence for free might not be that bad. The question is: "Does the hospitalist rotation help in the acquisition of those unique knowledge, skills and attitudes?" Although this study alludes to such unique components via its qualitative analysis (i.e., more autonomy, co-management of non-medicine services, etc.), it does not fully answer that question. It does, however, inspire the next study: How do residents perceive the unique and additional value (if any) of the hospital medicine rotation?

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For the sake of argument, let's say that residents' perception of the hospital medicine rotation is one of meaning and value. Does that matter? It is great if they do, but equally important is the question of whether or not hospital medicine rotations are effective in preparing resident graduates for a career in hospital medicine. This study suggests that those who have designed these rotations have tried to anticipate and address this need. Components such as quality, patient safety, co-management, and billing and compliance are all clearly a part of a hospitalist's practice, and all are elements that have not been traditionally emphasized in residency training. The question is: "Are these elements the knowledge, skills and attitudes that are most lacking in the residency graduate as he/she enters the practice of hospital medicine?" The unfortunate answer is that we do not know for sure, and this uncertainty has been the Achilles heel of our current residency-training infrastructure. Not unique to hospital medicine, there is simply not a well-defined feedback loop between practice requirements and residency training requirements. A structured and regular gap analysis comparing the residents' areas of competence at the end of training to what they need in practice, would go a long way in answering questions such as this one, and would most certainly inform the components of a hospital medicine elective going forward.

Even if the components of a hospital medicine rotation are valuable, and even if they do align with what the practice needs, there is still the question of whether a month-long hospital medicine rotation can even come close to closing the gap of what is needed versus what is delivered. One can surmise that the answer to that question is what has extended the "hospital medicine rotation" to the "hospital medicine track," comprised of a multiple of such rotations. Like all discussions on time-constrained medical education curricula, what will be discarded to make room for these rotations? In thirty-six months of training, there is opportunity cost: every month spent on a hospital medicine elective is a month that could have been spent on something else (rheumatology, nephrology, etc.). Again, this is not unique to hospital medicine; the same could be said of the resident who does too many cardiology electives at the exclusion of learning about endocrinology. It would be overly dramatic to say that devoting a month to a hospital medicine rotation, or any elective for that matter, meaningfully compromises the resident's overall competence as an internist. It is, instead, a question of degree: an excessive number of these electives would likely compromise the resident's overall competence. The likelihood of this happening is proportional to the size of the gap between what is required to effectively enter hospital medicine practice and what can be delivered in a month-long hospital medicine rotation. We return, then, to the question: How much

hospital medicine training in residency would be required to fully prepare a resident for the current practice of a hospitalist?

Whatever the answer might be, that question takes us to a difficult dilemma that has lurked in the background of residency training for some time now; one that is not at all unique to hospital medicine. Should residency training be "voc-tech" or "liberal arts"? A purist would argue that an understanding and appreciation of all things not hospital medicine is what truly makes for the great hospitalist. An understanding of primary care, for example, would seem to optimize a hospitalist's performance with respect to transitions of care. Adding to the gravity of such an argument is that residency might be the last time to acquire such "nonhospital-medicine" experiences.

Noting that the practice of hospital medicine being so dynamic and heterogeneous, the realist might pile on by saying that it is simply impossible to fully prepare a resident for the actual practice of hospital medicine. Further, many of these skills might be impossible to fully master outside of being fully immersed in the practice of hospital medicine (i.e., billing and coding). The best that can be done is to set a solid foundation that would enable them to learn further as they practice; there will be opportunities to learn the specific components of the field later on.

On the other hand, it is hard to justify residency training if the graduate is unprepared to practice, and without the fundamental knowledge, skills and attitudes specific to their career as they practice. For example, it is reasonable to suspect that a new hospitalist who has had no prior training in quality improvement will, because of the inertia that comes with engaging in any new and foreign skill, find it much harder to engage in quality improvement as a part of her career. It is also worth considering the role that mastery, autonomy and purpose have upon the overall residency experience. Engaging in electives that have a palpable purpose for the resident's eventual career, and engender an opportunity to begin developing a sense of mastery in that field, could be an effective antidote in mitigating the burn-out that is far too common in residency training today.

For residents engaged in a future practice of hospital medicine, the hospital medicine rotation seems like a promising way out of this dilemma. An effectively designed elective approach could enable maintaining a core foundational education, while getting an early start on the specific components necessary for a promising career in hospital medicine. The operative words, of course, are "effectively designed." What exactly does that entail? That is why this study is so important; even if we do not fully know what it should look like, we now have our first glimpse of what it is.

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Healthy Skepticism and Due Process

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For more than 75 years, pediatrics has sought sound guidelines for prescribing maintenance intravenous fluid (mIVF) for children. In 1957, Holliday and Segar (H&S)[1] introduced a breakthrough method for estimating mIVF needs. Their guidelines for calculating free-water and electrolyte needs for mIVF gained wide-spread acceptance and became the standard of care for decades.

Over the last two decades, awareness has grown around the occurrence of rare, life-threatening hyponatremic conditions, especially hyponatremic encephalopathy, in hospitalized children. Concomitantly, an increasing awareness shows that serum levels of antidiuretic hormone (ADH) are often elevated in sick children and triggered by nonosmotic conditions (pain, vomiting, perioperative state, meningitis, and pulmonary disease). This situation led to heightened concern of clinicians and investigators who assumed that hospitalized patients would exhibit reduced tolerance for hypotonic mIVF the mainstay of the H&S method. The possibility that the H&S method could be a significant contributing factor to the development of hyponatremic encephalopathy in hospitalized children became a research topic. This research speculated that even mildly reduced serum sodium levels might be a marker for the much rarer condition of hyponatremic encephalopathy. A number of hospitalists also switched from quarter-normal to half-normal saline in mIVF.

The substitution of hypotonic fluids with isotonic fluids (eg, 0.9% normal saline or lactated Ringer's) is the current front-runner alternative to increase sodium delivery. The hypothesis is that the delivery of additional sodium, while maintaining the same H&S method volume/rate of fluid delivery, will protect against life-threatening hyponatremic events.

The challenge we face is whether we are moving from mIVF therapy, which features a long track record of success and an excellent safety profile, to a safer or more effective therapeutic approach. We should consider the burden of proof which should be satisfied to support creating new guidelines which center on changing from hypotonic mIVF to isotonic mIVF.

Is there sufficient scientific proof that isotonic mIVF is safer and/or more effective than hypotonic mIVF in preventing life-threatening hyponatremic events?

Is there compelling biologic plausibility for this change for patients with risk factors that are associated with elevated serum ADH levels?

What is the magnitude of the benefit?

What is the magnitude of unintended harms?

We offer our perspective on each of these questions.

The primary difficulty with addressing the adverse events of catastrophic hyponatremia (encephalopathy, seizures, cerebral edema, and death) is their rarity. The events stand out when they occur, prompting mortality and morbidity (M&M) conferences to blunder into action. But that action is not evidence-based, even if a rationale mentions a meta-analysis, because the rationales lack estimates of the number needed to treat (NNT) to prevent one catastrophic event. Estimates of the NNT to prevent mild hypernatremia are not useful. Furthermore, estimates of the number needed to harm (NNH) via unintended consequences of infusing extra sodium chloride are unavailable. True evidence-based medicine (EBM) is rigorous in requiring NNT and NNH. Anything less is considered M&M-based medicine masquerading as EBM.

No technical jargon distinguishes the profound and catastrophic events from the common, mild hyponatremia frequently observed in ill toddlers upon admission. As an analogy, in dealing with fever, astute pediatricians recognize that a moderate fever of 103.4 °F is not halfway to a heatstroke of 108 °F. Fever is not a near miss for heatstroke. Physicians do not recommend acetaminophen to prevent heatstroke, although many parents act that way.

No published randomized controlled trials (RCTs) showed the incidence of these catastrophic hyponatremic events. In the meta-analysis of 10 disparate and uncoordinated trials in 2014,[2] no serious adverse events were noted among the 1,000 patients involved. Since then, newer RCTs have added another 1,000 patients to the meta-analysis pool, but still no serious adverse event has been observed.

The H&S method features 60 years of proven safety and remains the appropriate estimate when composing long-term parenteral nutrition. No recommendation is perfect for all situations. Many hospitalized children will exhibit an increased level of ADH. A very small fraction of those children will present a sufficiently elevated ADH level long enough to risk creating profound hyponatremia. An approximation is in the order of magnitude of 1 per 100,000 pediatric medical admissions and 1 per 10,000 postoperative patients. With 3 million pediatric admissions yearly in the United States, such numbers mean that large children's hospitals might see one or two catastrophic adverse events each decade due to mIVF in previously healthy children. The risk in chronically ill children and in the ICU will

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be higher. The potential for causing unintended greater harm amongst the other millions of patients is high, requiring application of the precautionary principle.

Thus, EBM and RCTs are poor methodologies for quality improvement of this issue. Assigning surrogate measures, such as moderate hyponatremia or even mild hyponatremia, to increase sensitivity and incidence for research purposes lacks a validated scientific link to the much rarer profound hyponatremic events. The resulting nonvalid extrapolation is precisely what true EBM seeks to avoid. A serum sodium of 132 mEq/L is not a near miss. The NNT to prevent the catastrophic events is unknown. Indeed, no paper advocating adoption of isotonic mIVF has even ventured an approximation.

The RCTs are also, therefore, underpowered to identify harms from using normal saline as a maintenance fluid. A few studies mention hypernatremia, but serum sodium is not a statistical variable. Renal physiology predicts that kidneys can easily handle excess infused sodium and can protect against hypernatremia. However, the extra chloride load risks creating hyperchloremic acidosis, particularly when a patient with respiratory insufficiency cannot compensate by lowering pCO_2 through increased minute ventilation. Edema is another risk. Both respiratory insufficiency and edema already occur more frequently (by orders of magnitude) in hospitalized patients on any mIVF than the profound hyponatremia events in hospitalized patients on hypotonic mIVF. For instance, about 1% of hospitalized infants with bronchiolitis are ventilated for respiratory failure. If hyperchloremic acidosis unintentionally caused by isotonic mIVF slightly increases the frequency of intubation, then such result far outweighs any benefit from reducing catastrophic hyponatremic events. Difficulty will also arise in detecting this unintended increase in the rate of intubation compared with the current background frequency. Detecting these unintended harms becomes impossible if the RCT is underpowered by 100-fold due to utilizing a surrogate measure, such as serum sodium <135 mEq/L, as the dependent variable instead of measuring serious hyponatremic adverse events.

All claims that "no evidence of harm" was found from using normal saline as mIVF are type II statistical errors. There is little chance of detecting any harm with a grossly underpowered study or a meta-analysis of 10 such studies. Simply put, EBM is impossible to use for events that occur less than 1 per 10,000 patients using RCTs with 1,000 patients. No usable safety data are available for normal saline as mIVF in any published RCT. As the RCTs are underpowered, one should rely on science to guide therapy, rather than on invalid statistics.

Using the precautionary principle, hypothetically, adding extra sodium chloride to maintenance fluids should be considered in the same manner as adding any other drug. Based on the current evidence, would the Food and Drug Administration approve the drug intravenous sodium chloride for the prevention of hyponatremia induced by maintenance fluids? An increasing evidence of a minimal beneficial effect is observed, but no evidence of safety nor physiology is available. A new drug application for using normal saline as a default maintenance fluid would be soundly rejected by an FDA panel, just as it has been rejected by the majority of pediatric hospitalists throughout the past 15 years since the idea was proposed in 2003.

With the lack of compelling statistical evidence to guide practice, clinicians often rely on biologic plausibility. Relatively recent studies have revealed that many sick children develop elevated blood levels of ADH due to nonosmotic and nonhemodynamic triggers. Fortunately, we also possess a strong body of knowledge around management of children with syndrome of inappropriate secretion of antidiuretic hormone (SIADH). We understand that elevated levels of ADH in the blood causes an increase in the resorption of free water from the renal collecting tubules. No increase in loss of renal sodium nor chloride is associated with this hormonal influence. The resultant hyponatremia is due to excess free-water retention and not the excess loss of sodium or chloride. To manage this condition, patients are not given a salt shaker and then allowed to drink ad libitum. The standard and well-accepted management of patients with SIADH is the restriction of free-water intake because this step addresses the dysfunctional renal process. Administering sodium chloride to a child with SIADH might possibly slow down the progression of hyponatremia but would also expand the total fluid volumes of the patient and would indirectly deal with a problem that could be addressed directly.

Understandably, in an intensive care setting, when hemodynamics is dicey, and when fluid-restriction could risk hypovolemia, employing a volume-expanding solution for mIVF therapy might be reasonable. However, in an ICU setting, SIADH is routinely treated with free-water restriction, and careful calculations of an individual patient's fluid and electrolyte losses and needs are made.

In conclusion, we recognize the motivation for questioning the H&S method for mIVF as our field surveilles more than a half-century of accumulated experience with this method and the advances in our understanding of physiology and pathophysiology. However, we believe that the current body of evidence fails to substantiate the proposed recommendations.[3] The avoidance of laboratory-detectable decreases in serum sodium levels is an unproven marker for the development of life-threatening hyponatremic events. Concerns for untoward effects (eg, excessive volume expansion and effects of hyperchloremia toward acidosis) and the exploration of alternative approaches (eg, modifications in volumes/rates of fluid delivery) have been inadequately explored. The proposed changes in practice may provide no mitigation in the rare events we hope to avoid, may fail to serve all subpopulations within the proposed scope of patients, and will likely create unintended new problems.

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