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The Journal of Hospital Medicine in 2019 and Beyond

Samir S Shah, MD, MSCE

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With this issue, I officially assume the role of Editor-in-Chief of the *Journal of Hospital Medicine*. I am honored and humbled to serve as the third editor for this journal and thankful to my predecessors, Drs. Mark V. Williams and Andrew D. Auerbach, for establishing it as the premier forum for publication of research in hospital medicine.

The journal has always taken a broad view of its mission. Our focus on improving value and quality of healthcare for children and adults will continue. We are also well-positioned to expand our scope and publish the highest quality research and commentary on the evolving healthcare system, including adoption of new technology, population health management, and regionalization in healthcare, and our role within it. There is also increasing recognition that these trends have implications for patient experience and outcomes, healthcare professional well-being, and the learning environment. We welcome qualitative and quantitative research that provides insight into understanding and addressing these new challenges. We also seek your Perspectives in Hospital Medicine to highlight innovations or controversies in healthcare delivery or policy.

The journal landscape has evolved. We consume medical information in many different formats with a rapidly diminishing reliance on paper and ink. Rather than perusing a journal at the end of a busy workday, we now capitalize on small increments of time in between meetings or other activities. The journal has taken a leading role in engaging readers through social media (@JHospMedicine) with Twitter-based features such as journal clubs (#JHMChat) to discuss recently published research as well as visual abstracts to efficiently share scientific advances.[1] We will extend these efforts to include "tweetorials," video abstracts, and a redesigned web presence, allowing us to transcend the constraints of traditional written articles. Our goals are to increase the visibility of authors and accessibility of their research, allow readers to engage with the journal in formats that best meet their needs, and enhance knowledge retention and knowledge translation to improve healthcare systems and patient outcomes.

The Journal of Hospital Medicine also strives to remain relevant to clinical practice through columns that seek to improve diagnostic reasoning (Clinical Care Conundrums), value and innovation in healthcare (Choosing Wisely: Things We Do For No Reason, Choosing Wisely: Next Steps in Improving Healthcare Value), and, through our long-form reviews, core medical knowledge. While in-depth reviews provide an important synthesis of a topic, our work environment and schedules are not always conducive to reading in this manner; busy clinicians may benefit from focused updates. We will introduce new shorter format reviews addressing clinical content, including practice guidelines, and research methodology.

Finally, we are invested in developing a leadership pipeline for academic medicine. Our Editorial Fellowship will provide educational experiences, professional development, and academic and networking opportunities for a cadre of young physicians.[2] A new column will highlight leadership and professional development lessons from renowned leaders from a broad range of disciplines. We also value diversity and inclusion. Disparities in academic medical leadership, though well-recognized, persist. For example, women now comprise more than half of all incoming medical students[3] and 41% of faculty, yet only 24% of full professors, 18% of department chairs, and 17% of deans.[4] This journal will play an important role in creating a diverse pipeline of academic leaders. We will lead by example and, in the coming year, develop approaches to create equity in all facets of journal leadership and authorship.

I am grateful to Dr. Auerbach for his visionary stewardship of the journal. As I take the helm, the journal will continue to evolve with the changing landscape of healthcare. I am fortunate to work with an exceptionally talented team, and I look forward to serving the journal and the field together to accomplish these goals.

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Announcing the *Journal of Hospital Medicine* Editorial Fellowship

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The peer review and editorial processes are integral activities in academic medicine that provide ethical, independent, and unbiased critical assessment of submitted manuscripts to academic journals. Recognizing that few trainees or junior faculty are formally exposed to these processes,[1] the *Journal of Hospital Medicine* aims to fill this opportunity gap through the launch of a one-year Editorial Fellowship.

The Fellowship is open to chief residents, hospital medicine fellows, and junior faculty (eg, Assistant Professor or Clinical Instructor). Starting in July of each year, a group of four to six applicants are paired with editorial mentors who are current JHM Deputy or Associate Editors. Structured as a distance-learning program, this program aims to allow Fellows the ability to continue in their full time professional roles while also allowing the opportunity to engage with national leaders in hospital medicine. Regular communication and interactions take place through both synchronous and asynchronous means. Fellows' responsibilities during the 12-month experience include: completion of six guided peer reviews, preparation of one or two editorials, participation in monthly editorial meetings, and quarterly educational videoconferences. Interested Fellows may also have an opportunity to co-lead the journal's online journal club, #JHMChat.[2] Fellows are expected to attend the editorial staff meeting at the annual Society of Hospital Medicine Conference.

With this program, JHM aims to accomplish several tasks. First, we hope to offer a unique educational experience that allows for further growth, development, inspiration, and experience in academic medicine—specifically around the manuscript review and editorial processes. Second, recognizing that a journal's quality is frequently a product of its reviewers, JHM hopes to build a cadre of well-trained and experienced reviewers and, hopefully, future members of the JHM editorial leadership team. Third, the program hopes to act as a networking experience, allowing editorial Fellows to learn from, collaborate with, and become academic leaders in the field. Finally, we hope to provide an opportunity for Fellows to be academically productive in their composition of editorial content—an output that will help catalyze their professional development.

We believe that in working closely with the JHM editorial staff, this program will help develop the next generation of leaders in academic hospital medicine. We strongly encourage applications from physicians who have been historically under-represented in leadership in academic medicine. Further details and the application can be found in the appendix and on the JHM website (www.journalofhospitalmedicine.com). It will be announced annually through the @JHospMedicine twitter handle.

Disclosures: The authors have nothing to disclose.

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Predicting the Future: Using Simulation Modeling to Forecast Patient Flow on General Medicine Units

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BACKGROUND: Hospitals are complex adaptive systems within which multiple components such as patients, practitioners, facilities, and technology interact. A careful approach to optimization of this complex system is needed because any change can result in unexpected deleterious effects. One such approach is discrete event simulation, in which what-if scenarios allow researchers to predict the impact of a proposed change on the system. However, studies illustrating the application of simulation in optimization of general internal medicine (GIM) team inpatient operations are lacking.

METHODS: Administrative data about admissions and discharges, data from a time-motion study, and expert opinion on workflow were used to construct the simulation model. Then, the impact of four changes – aligning medical teams with nursing units, adding a hospitalist team, adding a nursing unit, and adding both a nursing unit and hospitalist team with higher admission volume – were modeled on key hospital operational metrics.

RESULTS: Aligning medical teams with nursing units improved team metrics for aligned teams but shifted patients to unaligned teams. Adding a hospitalist team had little benefit, but adding a nursing unit improved system metrics. Both adding a hospitalist team and a nursing unit would be required to maintain operational metrics with increased patient volume.

CONCLUSION: Using simulation modeling, we provided data on the implications of four possible strategic changes on GIM inpatient units, providers, and patient throughput. Such analyses may be a worthwhile investment to study strategic decisions and make better choices with fewer unintended consequences. Journal of Hospital Medicine 2018;14:9-15. Published online first November 28, 2018.

Hospitals are complex adaptive systems within which practitioners, technology, physical resources, and other components adapt interdependently to attempt to best meet the needs of patients.[1] Hospitals must provide a stable, dependable level of care while also surging to respond to times of high demand, such as patient emergencies or swells in patient volume. Given the critical and resource-intensive nature of this work, optimizing the system is essential; however, because of the complexity of the system, making changes can result in unexpected and possibly deleterious effects. We need to approach change in hospital processes carefully and thoughtfully.

The Institute of Medicine, the National Academy of Engineering, and the President's Council of Advisors on Science and Technology have recommended the application of systems engineering approaches to improve health care delivery.[2,3] Systems engineering seeks to coordinate, synchronize, and integrate complex systems of people, information, materials, technology, and financial resources.[4,5] To determine how complex systems can be improved, engineers apply analytic methods to describe how such systems operate and what the impact of changes might be. These methodologies have improved patient care and reduced costs at several hospitals.[6] For example, a decision support system that combined simulation, optimization, and machine learning methods in an emergency department (ED) resulted in a 33% reduction in length of stay (LOS) and a 28% decrease in ED readmissions.[7] Other strategies to improve patient flow include shaping demand (decreasing variation in surgical scheduling, relocating low acuity care ED visits to primary care, etc.), redesigning systems (early discharges, improving efficiency, and coordination of hospital discharge process, decreasing care variation, etc.), or aligning capacity and demand. Another approach, real-time demand capacity (RTDC), is based on management principles

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and queuing and constraint theory and has been implemented successfully in a variety of healthcare organizations. RTDC represents a promising approach to improve hospitalwide patient flow and can be integrated into current bed management processes.[8] Unfortunately, many of these approaches are not well known to clinicians and would benefit from greater awareness and input from healthcare practitioners.

One systems engineering tool that can be used to describe, analyze, and evaluate proposed changes in care is simulation.[9] Simulation creates a model within which what-if scenarios (ie, adjusting various inputs into the simulation) allow researchers to define the likelihood of consequences from various courses of action and determine the optimal change to a system. Such analyses can predict the impact of a proposed change on patients and healthcare practitioners.[10-13]

A critical concern for hospitals that simulation may help address is managing the volume of inpatients. A high inpatient census is necessary for financial solvency, yet too high a census of inpatients or an unexpected surge in acuity can overwhelm hospital resources. Many hospitals, pressured by growing numbers of increasingly complex patients, have seen medical inpatients spread across multiple nonmedical nursing units (NUs) of their institution such that a particular medical team may have only a couple patients assigned to each nursing unit.[14] This dispersion may hinder communication between physicians and nurses and limits the time physicians have to interact with patients.[15] Additionally, coordination of care may become more challenging for discharge planning.[16] Aligning medical teams with NUs may benefit the quality and efficiency of care or may create a barrier to patient flow, which worsens these problems.[15,17] Alternatively, hospitals might meet the increasing demands for care by choosing to add capacity by opening new NUs or hiring additional healthcare providers. We identified no studies in the literature that applied simulation modeling to general medicine inpatients to evaluate the impact of these different decisions.

This article describes the application of simulation to model the interconnected variables and subsequent future states created by several possible strategic decisions around the care of general medicine inpatients. Through the application of systems engineering techniques, we modeled four future states that illustrate the following: (1) the complexities of a large health delivery system, (2) the intended and unintended consequences of implementing different changes in the process of care delivery, and (3) how the simulation modeling might be used to inform decision making.

METHODS

Setting and Present State

Virginia Commonwealth University (VCU) is a 865-bed tertiary academic medical center, with inpatient care activities spread between four connected buildings and 50 different NUs. The occupancy rate had been over 92% during the time period of this project with admission volume limited primarily by the capacity of the facility. Three of the NUs were primarily allocated to general medicine (GIM) patients. However, over the years, GIM inpatients grew to over 7,500 admissions annually, resulting in nearly 50% of GIM patients being admitted to a non-GIM nursing unit.

Additionally, patients on each medical team had a high degree of spread across NUs due to several factors. Admissions and discharges from the hospital did not align across the day. While discharges clumped in the late afternoon, admission occurred throughout the day with a surge in the later afternoon. This mismatch frequently led to patients waiting in the ED for a bed, medical team, or both, and patients were typically assigned to the first available bed and team. For medical team assignments, newly admitted patients were distributed relatively equally across five hospitalist teams and five housestaff teams (that include residents, interns, and medical students). This steady distribution of patients through the day supported meeting housestaff work-hour restrictions of 80 hours each week.[18] Yet, as a result of the high occupancy rate, the patterns of patient admissions and discharges, and the distribution of patients among medical teams and across NUs, medical teams and NUs rarely shared more than a few patients.

Leaders at our institution outlined several possible options to address these challenges, including aligning medical teams with NUs, adding an additional hospitalist team, or adding an additional nursing unit. In addition, institutional leaders were concerned about the impact of continued growth in admission volume and the impact of patient dispersion on trainees and students. The overall goal of creating a simulation model was to determine the impact of an increased volume of patients and these possible strategic decisions on operational metrics, including number of patients waiting in the ED, ED boarding time per patient, time in system per patient (ED boarding time plus inpatient LOS), team utilization, and rounding travel time.

Simulation Modeling

To model the impact of some possible system changes on patient care, we applied Kelton and Law's simulation study framework;[19] including data collection, model building and validation, and what-if scenario testing (Figure 1).

Data Collection

Process Flow Map

We created a complex process flow map of patient care activities on medical teams. The map was developed by four general medicine physicians (R.C., H.M., V.M., and S.P.T.) who all provided medical care on the hospital-based services and ensured expert input on the patient care activities captured by the simulation modeling.

Time and Motion Studies

Time and motion study is a well-established technique used to evaluate the efficiency of work processes.[20,21] Originally applied to increase productivity in manufacturing, this technique uses first-hand observations to measure the time allotted to different work tasks to systematically analyze workflow.[22] Workflow in healthcare, like manufacturing tasks, tends to have a repetitive pattern, making time and motion studies a highly applicable tool.

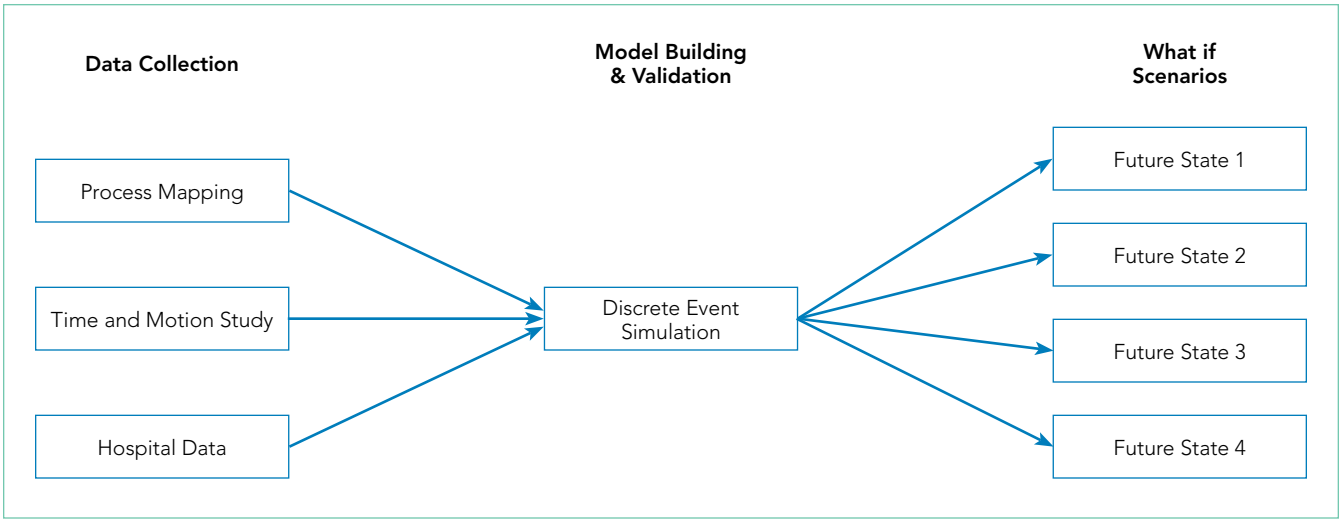

FIG 1. Model of Study Design

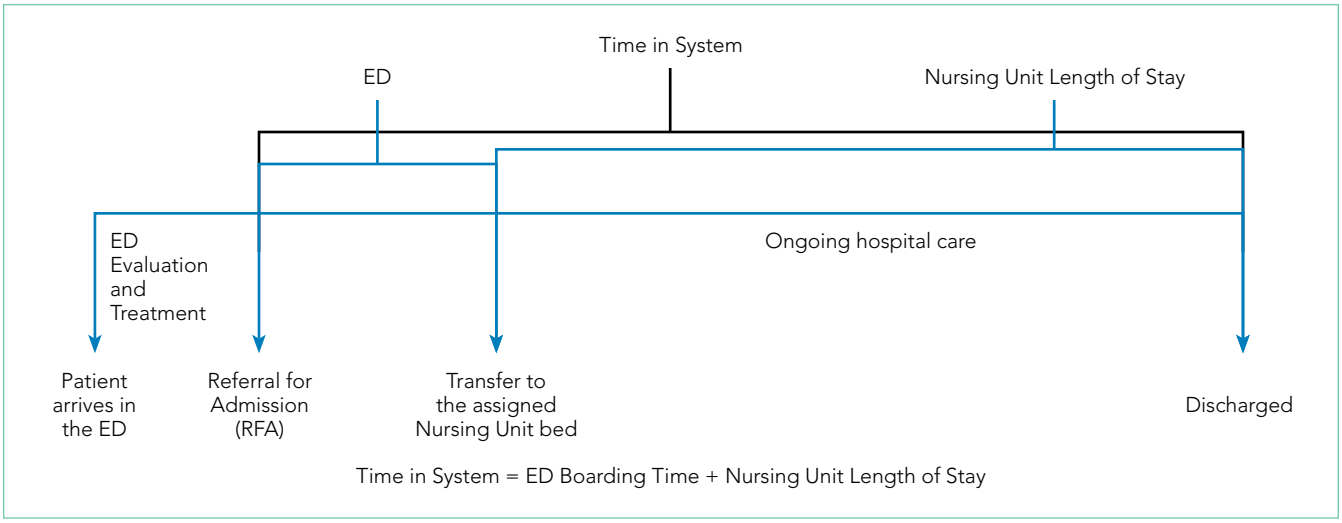

FIG 2. Simulation Model.

A research assistant observed a total of 30 hospitalist work cycles to describe the work of our inpatient clinicians. A work cycle, defined as one complete process flow,[23] began when the hospitalist started a daytime shift of patient care and concluded after the physician "signed out" to the physician who was assuming responsibility for ongoing medical care of the patients (ie, cross-coverage). Time spent on different activities identified by the process flow map was captured throughout the cycle. These activities included time spent traveling to evaluate patients located on different NUs. To minimize disruptions in patient care and adhere to privacy standards, no observations were conducted in patient rooms, and details of computer work were not recorded. To ensure stable estimates of the mean and standard deviation of the time spent at each step, at least 30 cycles of observation are recommended. Thus, 300 hours of observations over the course of 30 separate days were collected.

Hospital Data

We extracted admission and discharge data from the electronic health records (EHR) for general medicine patients admitted from the ED for the calendar year 2013. These records were used to establish means and standard deviations for admission date and time, distribution of patients across NUs, and LOS.

Model Building and Internal Validation

On the basis of these data inputs and using SIMIO® Simulation Software version 7, we constructed a discrete event simulation (DES) model representing the patient care activities of general medicine teams. Each patient was assigned a bed on a nursing unit through a probability distribution based on prior EHR data and then randomly assigned to a general medicine team. We replicated the model 200 times, and each model ran for 365 days. Each team was limited to 16 assigned patients, the maximum number of patients per housestaff team allowed by VCU protocol; henceforth, this number is referred to as team-patient

TABLE 1. **Simulation Models Input Data**

	Present State	Future State 1 Geography	Future State 2 + 26 beds	Future State 3 + Team 6	Future State 4 + 26 beds + Team 6 + ↑ Admit Rate
No. of Teams	10	10	10	11	11
Team Assignment	Random	Geographic assignment*	Random	Random	Random
Patient Generator	Actual admission data (ADD) ~21.6 pts/day	ADD ~21.6 pts/day	ADD ~21.6 pts/day	ADD ~21.6 pts/day	Derived admission 25 pts/day
Duration of Run (days)	365	365	365	365	365
Nursing Unit Distribution of Patients	Probability distribution from dataset (PDD)	PDD	PDD + added unit	PDD	PDD + added unit
Nursing Unit Length of Stay (hrs. per original data)	Random exponential with mean of 133 hrs.	Random exponential with mean of 133 hrs.	Random exponential with mean of 133 hrs.	Random exponential with mean of 133 hrs.	Random exponential with mean of 133 hrs.

*Constraining patients on housestaff (but not hospitalist) teams to the three general medicine nursing units

capacity. The model assumed patients remained on the assigned nursing unit and medical team for the entirety of their hospital stay and that each patient was seen by their assigned medical team every day. The results of the present state model, including mean number of patients on each nursing unit, mean team census, patient dispersion (ie, the number of NUs on which each medical team had patients), and team utilization (ie, mean team census divided by team patient capacity), were compared with actual data from 2013 to internally validate the model.

What-If Scenario Testing

We constructed four what-if scenarios based on possible strategic directions identified by leadership. These models evaluated:

- constraining patients on housestaff (but not hospitalist) teams to the three general medicine NUs (Future State 1),
- increasing bed capacity for general medicine patients by adding one additional nursing unit of 26 beds (Future State 2),
- increasing the number of general medicine teams by adding one additional hospitalist team of up to 16 patients (Future State 3),
- modeling the impact of increased patient admissions from 21 per day to 25 per day while also adding a nursing unit and an additional medical team (Future State 4).

For Future States 1-3, admission volume was held constant. The model generated nursing unit LOS using a random continuous exponential probability distribution with a mean of 133 hours to match the LOS distribution derived from health system data. As patients entered the system for admission, the model assigned a bed to the patient, but the patient could not move to the assigned bed until a bed and care team were both available. We were only interested in the steady-state behavior of the system, so collecting performance statistics only after the model had been populated and steady state had been achieved was important.

Table 1 summarizes the input data and the fixed and dynamic variable for each future state model.

We examined the impact of these scenarios on the following variables (Table 2): (1) average time in system; (2) average number of patients waiting for a bed; (3) average ED boarding time; (4) total daily general medicine census; (5) average housestaff team census per team; (6) average hospitalist team census per team; (7) average combined housestaff and hospitalist team census per team; (8) average housestaff team utilization (ie, mean team census divided by team patient capacity of 16); (9) average hospitalist team utilization (ie, mean team census divided by team patient capacity of 16); (10) average nursing unit utilization (ie, mean nursing unit census divided by maximum number of patients that can be cared for on each nursing unit); (11) patient dispersion to NUs (ie, average number of NUs on which each general medicine team has patients); 12) estimated average rounding time per general medicine team.

Of note, the average time in the system included time patients spent waiting for bed and team assignments (ED boarding time) in addition to the time they spent in the assigned nursing unit (nursing LOS). The difference between the nursing LOS (ie, time on the nursing unit) and total time in the system is one indicator of system efficiency around hospital admission.

The Institutional Review Board of Virginia Commonwealth University approved this study.

RESULTS

Time and Motion Data

The mean time spent with each patient was nine minutes. The mean time traveling between NUs Healthcare Quality for Children and Adolescents with Suicidality Admitted to Acute Care Hospitals in the United States was five minutes. Average rounding time was noted to be two hours, 53 minutes. Thirty-seven minutes, about ~21% of the time, was wasted in traveling. Each team, on average, traveled to seven different NUs to round on their daily census, averaging 1.6 patients in each nursing unit.

Hospital Data

Between January 1, 2011 to December 31, 2013, a total of 7,902 patients were admitted to the general medicine teams,

TABLE 2. **Summary of Results from Simulation Model**

	Present State	Future State 1 Geography[a] (95% CI)	Future State 2 + 26 beds (95% CI)	Future State 3 + Team 6 (95% CI)	Future State 4 + 26 beds + Team 6 + Increase Admit Rate[b] (95% CI)
Total Pt Admissions[c] per Year	7222.00	7222.00	7222.00	7222.00	8301.68 (8314.14–8289.02)
Average Time in System[d] Hrs./Pt	147.37	149.72 (148.35–151.09)	137.51* (137.22–137.80)	147.34 (146.16–148.52)	144.89* (144.28–145.50)
Average Number of Pts waiting for a bed	11.31	13.18 (12.03–14.37)	1.99* (1.85–2.13)	11.30 (10.30–12.29)	9.94 (9.33–10.54)
Average ED Boarding Time (Hrs.)	12.39	14.42 (13.14–15.71)	2.19* (2.03–2.34)	12.37 (11.28–13.46)	9.49* (8.93–10.06)
Total Daily General Medicine Census Pts/Day	119.26	119.01* (118.98–119.05)	119.59* (119.57–119.60)	119.25 (119.23–119.27)	137.19* (137.17–137.22)
Average House Staff Team Census (Pt/Team)	12.17	9.96* (9.58–10.34)	12.20 (12.00–12.39)	11.11* (10.93–11.29)	12.73* (12.56–12.90)
Average Hospitalist Team Census (Pt/Team)	11.68	13.85* (13.46–14.18)	11.72 (11.53–11.91)	10.66* (10.49–10.84)	12.30* (12.05–12.47)
Average Internal Medicine Team Census (Pt/Team)	11.93	11.90 (9.58–14.18)	11.96 (11.53–12.39)	10.84* (10.40–11.29)	12.47 (12.05–12.90)
Average House Staff Team Utilization % of max # Pts/Team	76.06	62.22* (62.02–62.42)	76.22 (76.10–76.35)	69.42* (69.30–69.54)	79.56* (79.41–79.71)
Average Hospitalist Team Utilization % of max # Pts/Team	73.02	86.55* (86.31–86.79)	73.26 (73.14–73.38)	66.65* (66.52–66.77)	76.87* (76.72–77.02)
Nursing Unit Utilization % of max # Pts/NU	62.29	62.19 (61.82–62.55)	51.75* (51.41–52.09)	62.28 (61.93–62.63)	59.49* (59.11–59.86)
Patient Dispersion (NU)[e,f]	7.30	4.27	7.40	6.95	7.65
Rounding Travel Time (min)/day[f]	36.50	21.35	37	34.75	38.25

*Statistically significant difference from present state at the 0.05 level
[a]Geography = Pts selectively assigned to 3 NUs for Housestaff Teams
[b]Increased admission rate = from 21 Pts/day to 25 Pts/day
[c]Sum of all patients admitted to general internal medicine team (housestaff as well as hospitalists)
[d]Average Time in System = Average ED boarding time + Average Nursing Unit length of stay
[e]Distribution of patients among medical teams across nursing unit
[f]Values were averages of the collection of teams, so confidence intervals were not available. These were calculated values and not direct results of the simulation model.
Abbreviations: Dept, department; Hrs, hours; min, minute; NU, nursing unit; Pt, patient; Pts, patients.

spanning 23 NUs. The average number of admissions per day was 21.6, and the average nursing unit LOS was 133 hours. Average team census was derived from historical data across all GIM teams for 2013 and was noted to be 11.5 patients per team, and these patients were spread over seven NUs.

Model Validation

The mean number of patients admitted to different NUs was estimated from the simulation model then compared with the EHR data from 2013. None were statistically different ($P > .05$), which signified that the validated simulation model is similar to the EHR data from 2013 despite the underlying assumptions.

Model Outputs

Analysis of the models indicated that steady-state (based upon hospital census) was realized at approximately 800 hours or after 680 patients were admitted to the GIM teams. Statistics collection, therefore, was started after 800 hours of simulated time and reflected the admission of the remaining 7,222 patients in the model validation sample (Table 2).

In the model, the total daily general medicine patient census was 119.26. Average time in the system per patient was noted to be 147.37 hours, which was 14.37 hours more than the average nursing unit LOS of 133 hours. Average number of patients waiting for a bed was noted to be 11.31, while the

average wait time for a patient to get a bed was 12.39 hours.

Average housestaff team and hospitalist team utilization were 76.06% and 73.02%, respectively, with average team utilization of 74.54% (range: 72.88%-76.19%). Housestaff teams and hospitalist teams averaged 12.17 and 11.68 patients per care team, respectively. General medicine teams had patients on 7.30 NUs on average. GIM teams rounding travel time was 36.5 minutes.

What-If Scenario Testing

Simulation outputs for the four future states are summarized in Table 2. With Future State 1, through which patients were selectively assigned to housestaff teams aligned with three NUs, the average time in the system per patient increased by 2.35 hours, with 1.87 more patients waiting for a bed and waiting for 2.03 more hours as compared with the present state. A marked disparity was observed in hospitalist and housestaff team utilization of 62.22% and 86.55% respectively. Patient dispersion to various NUs significantly decreased, and rounding time correspondingly decreased by approximately 41%.

Future State 2, adding a nursing unit, decreased average time in the system per patient by 9.86 hours, with 9.32 fewer patients waiting for a bed as compared with the present state. A slight increase in patient dispersion and rounding time was observed. Overall, patients spent 137.51 hours in the system, which demonstrated improved efficiency of the system.

Future State 3, adding an additional medical team, interestingly did not have a significant effect on patients' average time in system or the number of patients waiting for a bed even though a decrease occurred in average team census, team utilization, and patient dispersion.

Finally, Future State 4, increasing admissions while also adding a nursing unit and a hospitalist team, resulted in an increase in admission volume while maintaining similar utilization rates for teams and NUs. Patients spent about 2.48 hours less in the system, while only 9.94 patients were noted to be waiting for a bed as compared with 11.21 patients in the present state model. The total daily general medicine patient census was noted to be 137.19. Average team census and average team utilization were noted to be similar to those of the present state model, while admissions were up by approximately 1,080 per year. Both patient dispersion and rounding were slightly worsened.

Sensitivity Analysis

Overall, average time in system was most affected by the number of patient arrivals. This became particularly significant as the volume of patient arrivals approached and exceeded the capacity of the rounding teams. Adding a nursing unit had more impact on decreasing average time in the system than adding a medical team or aligning teams with NUs under the conditions defined by the model. However, under different conditions, such as increasing admission volume, the relative benefit of different approaches may vary.

DISCUSSION

Given that hospitals are large, complex systems,[2] the impact of system-level changes can have unpredictable and potentially deleterious effects. Simulation provides a technique for modeling the impact of changes to understand the ramifications of these interventions more thoroughly.[3] In this study, we describe the process of building a simulation model for the admission and discharge of patients from general medicine services in a tertiary care hospital, internally validating this model, and examining the outcomes from several potential changes to the system.

The outcomes for these what-if scenarios provided some important insights about the secondary effect of system changes and the need for multiple, simultaneous interventions. Given that hospitals often function at near capacity, adding a hospitalist team or nursing unit might be seen as a reasonable strategy to improve the system metrics, number of patient discharges, or average LOS. On the basis of our analysis, adding a nursing unit would have more benefit than adding a hospitalist team. Leaders who want to increase capacity may need to consider both adding a hospitalist team and a nursing unit, and model the impact of each choice as described with a simulation.

Additionally, assigning patients to medical teams aligned with NUs seems theoretically appealing to improve interprofessional communication and decrease the time spent in transit between patients by physicians. While our findings supported a decrease in rounding time and patient dispersion, the teams not aligned with a nursing unit (ie, the hospitalists) exceeded 80% utilization, the threshold at which efficiency is known to decrease.[24] Potentially, benefits resulting from teams being aligned with NUs were offset by decrements in performance of the teams not aligned with NUs. If medical teams and NUs become aligned, then a higher number of teams may be necessary to maintain patient throughput.

Simulation models identify these unexpected consequences prior to investing resources in a significant change; however, modeling is not simple. Simulation models depend on the characteristics of the model and the quality of the input data. For example, we used an expert approach to map physician workflow as an underpinning of the model, but we may have missed an important variation in physician workflow. Understanding this variation could strengthen the model and provide some testable variables for future study. Likewise, understanding nursing workflow and how variation in physician workflow shapes nursing workflow, and vice versa, is worth exploring.

Other data could also be added to, and help interpret, the outputs of this model. For example, the impact of various levels of team and unit utilization on diversion time for the hospital ED may help determine whether adding team capacity or unit capacity is more beneficial for the system. Likewise, aligning medical teams with NUs seems to hinder patient throughput on this analysis, but benefits in patient satisfaction or decreased readmissions might improve reimbursement and outweigh the revenue lost from throughput. Underpinning each of these types of decisions is a need to model the system well and thoughtfully choose the inputs, processes, and outputs. Pursuing a new strategic decision usually involves cost; simulation modeling provides data to help leaders weigh the benefits in terms of the needed investment.

The major limitations of the study stem from these choices. Our study focused on matching capacity and demand while limiting other changes in the system, such as changes in nursing unit LOS. Future work to quantify the relationship of other variables on parameters, such as the impact of decreased team dispersion on LOS, early discharges, and decreasing care variation, would make future models more robust. This model does not consider other strategies to improve patient flow, such as shaping demand, adaptive team assignment algorithms, or creating surge capacity. We also used only hospitalist time and motion data in our model; housestaff workflow is likely different. In addition, we modeled all patients as having a general level of nursing care and did not account for admissions or transfers to intensive care units or other services. These parameters could be added in future iterations. Finally, the biggest limitation in any simulation is the underlying assumptions made to construct the model. While we validated the model retrospectively, prospective validation and refinement should also be performed with attention to how the model functions under extreme conditions, such as a very high patient load.

CONCLUSION

Major system changes are expensive and must be made carefully. Systems engineering techniques, such as DES, provide techniques to estimate the impact of changes on pertinent care delivery variables. Results from this study underscore the complexity of patient care delivery and how simulation models can integrate multiple system components to provide a data-driven approach to inform decision making in a complex system.

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Association between Hospitalist Productivity Payments and High-Value Care Culture

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BACKGROUND: Given the national emphasis on affordability, healthcare systems expect that their clinicians are motivated to provide high-value care. However, some hospitalists are reimbursed with productivity bonuses and little is known about the effects of these reimbursements on the local culture of high-value care delivery.

OBJECTIVE: To evaluate if hospitalist reimbursement models are associated with high-value culture in university, community, and safety-net hospitals.

DESIGN, PATIENTS, AND SETTINGS: Internal medicine hospitalists from 12 hospitals across California completed a cross-sectional survey assessing their perceptions of high-value care culture within their institutions. Sites represented university, community, and safety-net centers with different performances as reflected by the Centers of Medicare and Medicaid Service's Value-based Purchasing (VBP) scores.

MEASUREMENT: Demographic characteristics and High-Value Care Culture Survey (HVCCS™) scores were evaluated using descriptive statistics, and associations were assessed through multilevel linear regression.

RESULTS: Of the 255 hospitalists surveyed, 147 (57.6%) worked in university hospitals, 85 (33.3%) in community hospitals, and 23 (9.0%) in safety-net hospitals. Across all 12 sites, 166 (65.1%) hospitalists reported payment with salary or wages, and 77 (30.2%) with salary plus productivity adjustments. The mean HVCCS score was 50.2 (SD 13.6) on a 0-100 scale. Hospitalists reported lower mean HVCCS scores if they reported payment with salary plus productivity ($\beta = -6.2$, 95% CI −9.9 to −2.5) than if they reported payment with salary or wages.

CONCLUSIONS: Hospitalists paid with salary plus productivity reported lower high-value care culture scores for their institutions than those paid with salary or wages. High-value care culture and clinician reimbursement schemes are potential targets of strategies for improving quality outcomes at low cost. *Journal of Hospital Medicine* 2019;14:16-21. Published online first October 31, 2018.

The Centers of Medicare and Medicaid Services (CMS) has introduced new payment models that tie quality and value incentives to 90% of fee-for-service payments and provide 50% of Medicare payments through alternative payment models.[1] The push toward value comes after productivity-based physician reimbursement (ie, fee for service) has been associated with poor quality care, including delayed diagnoses, complications, readmissions, increased length of stay, and high costs of care.[2-5] The method of physician payment is widely believed to affect clinical behavior by incentivizing doing more, coding for more, and billing for more.[6-7] Although payment systems may be used to achieve policy objectives,[8] little is known about the association of different payment systems with the culture of delivering value-based care among frontline clinicians.

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Culture is defined as a system of shared assumptions, values, beliefs, and norms within an environment and has a powerful role in shaping clinician practice patterns.[9-12] The culture within medicine currently contributes to the overuse of resources[11,13] and a culture for improvement is correlated with clinical outcomes. A systematic review found a consistent association between positive organization culture and improved outcomes including mortality.[14] Across health systems, institutions with high scores on patient safety culture surveys have shown improvements in clinical behaviors and patient outcomes.[15-18]

In this study, we aim to describe high-value care culture among internal medicine hospitalists across diverse hospitals and evaluate the relationship between physician reimbursement and high-value care culture.

METHODS

Study Design

This study is an observational, cross-sectional survey-based study of hospitalists from 12 hospitals in California between January and June 2016.

Study Population

A total of 12 hospitals with hospitalist programs in California

were chosen to represent three types of hospitals (ie, four university, four community, and four safety net). Safety-net hospitals, which traditionally serve low-income and medically and socially vulnerable patients were defined as those in the top quartile (ie, greater than 0.5) of their Disproportionate Share Index (DSH), which measures Medicaid patient load.[19-20]

To select hospitals with varying value-based care performance, we stratified using CMS value-based purchasing (VBP) scores from fiscal year 2015; these scores have been used to adjust reimbursement for just over 3,000 hospitals in the VBP program of CMS.[22,23] CMS calculates the VBP total performance score as a composite of four domains: (1) clinical processes of care (20% of total performance); (2) patient satisfaction (30%); (3) patient outcomes, including mortality and complications (30%); and (4) cost defined by Medicare payment per beneficiary (20%).[21] Established quality measures are based on data reported by participating hospitals and chart abstraction during 2011-2014.[22] Although other clinical measures of care intensity have been used as proxies of value-based care,[23,24] we used the measure of value that has been publically reported by the CMS VBP given its wide use and effects on reimbursements for 80% of hospitals in the CMS VBP program in 2015.[25] We obtained institution-level data from the CMS VBP Program and Hospital Compare files. Each of the three types of hospitals represented institutions with low, middle, and high VBP performance (split in tertiles) as reported by the CMS VBP program. To increase the number of participants in tertiles with fewer hospitalists, a fourth hospital was selected for each hospital type.

We excluded individual hospitalists who primarily identified as working in subspecialty divisions and those who spent less than eight weeks during the last year providing direct patient care on inpatient internal medicine services at the studied institution.

Measurement

Hospitalists were asked to complete the High-Value Care Culture Survey (HVCCS™), which measures the culture of value-based decision making among frontline clinicians.[26] Similar to other validated surveys for the assessment of patient safety culture,[27,28] the HVCCS can be used to identify target areas for improvement. The survey includes four domains: (1) leadership and health system messaging, (2) data transparency and access, (3) comfort with cost conversations, and (4) blame-free environment. This tool was developed by using a two-phase national modified Delphi process. It was evaluated at two academic centers to complete factor analysis and assess internal consistency, reliability, and validity among internal medicine hospitalists and residents. Validation included estimating product-moment correlation of overall HVCCS scores and domain scores with the CMS institutional VBP scores. HVCCS scores are standardized to a 0-100 point scale for each of the four domains and are then averaged to obtain an overall score.[26]

In the survey, value was defined as the quality of care provided to patients in relation to the costs required to deliver that care, and high-value care was defined as care that tried to maximize quality while minimizing costs. Quality was defined as the degree to which health services increased the likelihood of desired health outcomes that are safe, effective, patient centered, timely, equitable, and consistent with current professional knowledge. Cost was defined as the negative financial, physical, and emotional effects on patients and the health system.[26]

Data Analysis

We described the overall institutional mean high-value care culture and domain scores measured by the HVCCS, hospitalist demographics and training experiences, and hospital characteristics. We also described individual survey items. Descriptive statistics were stratified and compared on the basis of hospital type (ie, safety net, community, or university). We assessed the relationship between the clinician perception of reimbursement structure within their divisions and individually reported high-value care culture scores using bivariate and multilevel linear regression. We hypothesized that compared with hospitalists who were paid with salaries or wages, those who reported reimbursement with productivity adjustments may report lower HVCCS scores and those who reported reimbursement with quality or value adjustments may report higher HVCCS scores. We adjusted for physician- and hospital-level characteristics, including age, gender, and training track, and considered hospital type and size as random effects.

This study was approved by the Institutional Review Board at all 12 sites. All analyses were conducted using STATA® 13.0 (College Station, Texas).

RESULTS

Hospitalist Characteristics

A total of 255 (68.9%, 255/370) hospitalists across all sites completed the survey. Of these respondents, 135 were female (50.6%). On average, hospitalists were 39 years of age (SD 6.8), trained in categorical tracks (221; 86.7%), and had previously trained for 14.3 months at a safety-net hospital (SD 14.2). In total, 166 hospitalists (65.1%) reported being paid with salary or wages, 77 (30.2%) with salary plus productivity adjustments, and 12 (4.7%) with salary plus quality or value adjustments. Moreover, 123 (48.6%) hospitalists agreed that funding for their group depended on the volume of services they delivered. Community-based hospitalists reported higher rates of reimbursement with salary plus productivity (47; 32.0%) compared with their counterparts from university-based (24; 28.2%) and safety-net based programs (6; 26.1%). Among the three different hospital types, significant differences exist in hospitalist mean age ($P < .001$), gender ($P = .01$), and the number of months training in a safety-net hospital ($P = .02$; Table 1).

Hospital Characteristics

Of the 12 study sites, four from each type of hospital (ie, safety-net based, community based, and university based) and four representing each value-based purchasing performance tertile (ie, high, middle, and low) were included. Eleven (91.7%) sites were located in urban areas with an average DSH index of 0.40 (SD 0.23), case mix index of 1.97 (SD 0.28), and bed size of 435.5 (SD 146.0; Table 1).

TABLE 1. **Characteristics of Medical Centers (N = 12) and Hospitalist Participants (N = 255)**

	Overall (N = 255) n (%), Mean (SD)	University (n = 147) n (%), Mean (SD)	Community (n = 85) n (%), Mean (SD)	Safety-net (n = 23) n (%), Mean (SD)	*P* Value
Outcomes					
HVCCS Overall Score	50.18 (13.60)	51.71 (14.69)	47.31 (11.57)	50.58 (11.71)	.06
Leadership and health system messaging	65.35 (15.59)	67.43 (16.90)	64.02 (13.34)	56.84 (10.53)	**.006****
Data transparency and access	32.35 (22.84)	33.59 (24.69)	30.59 (19.91)	30.98 (20.94)	.60
Comfort with cost conversations	52.12 (19.73)	54.14 (20.12)	47.94 (17.49)	54.71 (23.28)	.06
Blame-free environment	50.74 (21.42)	51.70 (20.67)	46.62 (21.77)	59.78 (22.28)	**.02***
Participant Level Characteristics					
Age	39.05 (6.81)	38.10 (6.42)	41.35 (6.67)	36.68 (7.71)	**<.001*****
Gender: Male	125 (49.41)	83 (56.85)	31 (36.47)	11 (50.00)	**.01***
Categorical track	221 (86.67)	128 (87.07)	72 (84.71)	21 (91.30)	.70
Number of Months Training in Safety-Net Medical Centers	14.33 (14.18)	14.66 (13.98)	11.95 (13.81)	21.09 (15.12)	**.02***
Perception of Payment Structure					.80
Salary or wages only	166 (65.10)	93 (63.27)	56 (65.88)	17 (73.92)	
Fee-for-service only	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	
Salary + productivity	77 (30.20)	47 (31.97)	24 (28.24)	6 (26.09)	
Salary + quality or value adj.	12 (4.71)	7 (4.76)	5 (5.88)	0 (0.00)	
Institution-Level Characteristics					
Bed Size	435.50 (145.99)	545.75 (81.32)	339.50 (124.88)	421.25 (164.83)	.13
Disproportionate Share Index[a]	0.40 (0.23)	0.43 (0.05)	0.12 (0.10)	0.64 (0.10)	**<.001*****
Case Mix Index[b]	1.97 (0.28)	2.16 (0.19)	1.99 (0.25)	1.77 (0.26)	0.19

*$P < .05$, **$P < .01$, ***$P < .001$

[a]The Disproportionate Share Index measures Medicaid patient load.

[b]The Case Mix Index describes the medical complexity of patients.

Abbreviation: HVCCS, High-Value Care Culture Survey™

In multilevel regression modeling across all 12 sites, hospitalists from community-based hospitalist programs reported lower mean HVCCS scores (β = −4.4, 95% CI −8.1 to −0.7) (Table 2) than those from other hospital types.

High-Value Care Culture Survey Scores

The mean HVCCS score was 50.2 (SD 13.6), and mean domain scores across all sites were 65.4 (SD 15.6) for leadership and health system messaging, 32.4 (SD 22.8) for data transparency and access, 52.1 (SD 19.7) for comfort with cost conversations, and 50.7 (SD 21.4) for blame-free environment (Table 1). For the majority (two-thirds) of individual HVCCS items, more than 30% of hospitalists across all sites agreed or strongly agreed that components of a low-value care culture exist within their institutions. For example, over 80% of hospitalists reported low transparency and limited access to data (see Appendix I for complete survey responses).

Hospitalists reported different HVCCS domains as strengths or weaknesses within their institutions in accordance with hospital type. Compared with university-based and safety-net-based hospitalists, community-based hospitalists reported lower scores in having a blame-free environment (466, SD 21.8). Nearly 50% reported that the clinicians' fear of legal repercussions affects their frequency of ordering unneeded tests or procedures, and 30% reported that individual clinicians are blamed for complications. Nearly 40% reported that clinicians are uncomfortable discussing the costs of tests or treatments with patients and reported that clinicians do not feel that physicians should discuss costs with patients. Notably, community-based hospitalists uniquely differed in how they reported components of leadership and health system messaging. Over 60% reported a work climate or role modeling supportive of delivering quality care at lower costs. Only 48%, however, reported success seen from implemented efforts, and 45% reported weighing costs in clinical decision making (Table 1, Appendix 1).

University-based hospitalists had significantly higher scores in leadership and health system messaging (67.4, SD 16.9) than community-based and safety-net-based hospitalists. They reported that their institutions consider their suggestions to improve quality care at low cost (75%), openly discuss ways to deliver this care (64%), and are actively implementing projects

TABLE 2. **Perception of Payment by Salary with Productivity Adjustments is Associated with Lower Institutional High-Value Care Culture Scores: Multilevel Regression Model among 12 Hospitalist Groups (n = 234)**

	Unadjusted β (95% CI)	Adjusted for Participant and Institution Level Covariates β (95% CI)
Age	–0.0 (–0.3 to –0.2)	0.02 (–0.2 to –0.3)
Gender: Male	0.0 (–3.3 to –3.4)	–0.8 (–4.2 to –2.7)
Categorical Track	1.9 (–5.0 to –1.3)	2.3 (–2.9 to –7.4)
Perception of Payment Structure		
Salary or wages only	—	—
Salary + productivity	**–5.7(–9.3 to –2.0)***	**–6.2 (–9.9 to –2.5)****
Salary + quality or value adj.	3.9 (–4.0 to –11.7)	3.9 (–4.0 –11.7)
Hospital Type		
University	—	
Community	**–4.4 (–8.1 to –0.7)***	
County	–1.1 (–7.1 to –4.8)	
Bed Size	–1.8 (–5.2 to –1.7)	

*$P < .05$, **$P < .01$

There was 3% or less missing data for any survey item leaving 234 participants in regression modeling.

(73%). However, only 54% reported seeing success from implemented high-value care efforts (Table 1, Appendix 1).

Safety-net hospitalists reported lower scores in leadership and health system messaging (56.8, SD 10.5) than university-based and community-based hospitalists. Few hospitalists reported a work climate (26%) or role modeling (30%) that is supportive of delivering quality care at low costs, openly discusses ways to deliver this care (35%), encourages frontline clinicians to pursue improvement projects (57%), or actively implements projects (26%). They also reported higher scores in the blame-free environment domain (59.8, SD 22.3; Table 1; Appendix 1).

Productivity Adjustments and High-Value Care Culture

In multilevel regression modeling, hospitalists who reported reimbursement with salary plus productivity adjustments had a lower mean HVCCS score (β = −6.2, 95% CI −9.9 to –2.5) than those who reported payment with salary or wages alone. Further multilevel regression modeling for each HVCCS domain revealed that hospitalists who reported reimbursement with salary plus productivity adjustments had lower scores in the leadership and health system messaging domain (β = −4.9, 95% CI −9.3 to −0.6) and data transparency and access domain (β = −10.7, 95% CI −16.7 to −4.6). No statistically significant difference was found between hospitalists who reported reimbursement with quality or value adjustments.

DISCUSSION

Understanding the drivers that are associated with a high-value care culture is necessary as payment models for hospitals transition from volume-based to value-based care. In this study, we found a meaningful association (β = −6.2) between clinician reimbursement schemes and measures of high-value care culture. A six-point change in the HVCCS score would correspond with a hospital moving from the top quartile to the median, which represents a significant change in performance. The relationship between clinician reimbursement schemes and high-value care culture may be a bidirectional relationship. Fee for service, the predominant payment scheme, places pressure on clinicians to maximize volume, focus on billing, and provide reactive care.[7,29] Conversely, payment schemes that avoid these incentives (ie, salary, wages, and adjustments for quality or value), especially if incentives are felt by frontline clinicians, may better align with goals for long-term health outcomes for patient populations and reduce excess visits and services.[2-6,8,30-34] At the same time, hospitals with a strong high-value care culture may be more likely to introduce shared savings programs and alternative payment models than those without. Through these decisions, the leadership can play an important role in creating an environment for change.[34] Similar to the study sites, hospitals in California have a higher percentage of risk-based payments than hospitals in other states (>22%)[35] and may also provide incentives to promote a high-value care culture or affect local physician compensation models.

Hospitals have options in how they choose to pay their clinicians, and these decisions may have downstream effects, such as building or eroding high-value care culture among clinicians or staff. A dose-response relationship between physician compensation models and value culture is plausible (salary with productivity < salary only < salary with value incentive). However, we did not find a statistically significant difference for salary with value incentive. This result may be attributed to the relatively small sample size in this study.

Hospitals can also improve their internal processes, organiza-

tional structure, and align their institutional payment contracts with those that emphasize value over fee-for-service-based incentives to increase value in care delivery.[36] The operation of hospitals is challenging when competing payment incentives are used at the same time,[7] and leadership will likely achieve more success in improving a high-value care culture and value performance when all efforts, including clinician and institutional payment, are aligned.[37-38]

Enduring large systems redesign will require directing attention to local organizational culture. For the majority of individual HVCCS items, 30% or more hospitalists across all sites agreed or strongly agreed that components of low-value care culture exist within their institutions. This response demonstrates a lack of focus on culture to address high-value care improvement among the study sites. Division and program leaders can begin measuring culture within their groups to develop new interventions that target culture change and improve value.[34] No single panacea exists for the value improvement of hospitalist programs in California across all hospital types and sites.

Unique trends, however, emerge among each hospital type that could direct future improvements. In addition to all sites requiring increased transparency and access to data, community-based hospitalists identified the need for improvement in the creation of a blame-free environment, comfort with cost conversations, and aspects of leadership and health system messaging. While a high proportion of these hospitalists reported a work culture and role modeling that support the delivery of quality care at low costs, opportunities to create open discussion and frontline involvement in improvement efforts, weigh costs into clinical decision making, and cost conversations with patients exist. We hypothesize that these opportunities exist because community-based hospitals create infrastructure and technology to drive improvement that is often unseen by frontline providers. University-based hospitalists performed higher on three of the four domains compared with their counterparts but may have opportunities to promote a blame-free environment. A great proportion of these hospitalists reported the occurrence of open discussion and active projects within their institutions but also identified opportunities for the improvement of project implementation. Safety-net hospitalists reported the need to improve leadership and health system messaging across most domain items. Further study is required to evaluate reasons for safety-net hospitalists' responses. We hypothesize that these responses may be related to having limited institutional resources to provide data and coordinated care and different institutional payment models. Each of these sites could identify trends in specific questions identified by the HVCCS for improvement in the high-value care culture.[25]

Our study evaluated 12 hospitalist programs in California that represent hospitals of different sizes and institutional VBP performance. A large multisite study that evaluates HVCCS across other specialties and disciplines in medicine, all regions of the country, and ambulatory care settings may be conducted in the future. Community-based hospitalist programs also reported low mean HVCCS scores, and further studies could better understand this relationship.

The limitations of the study include its small subgroup sample size and the lack of a gold standard for the measurement of high-value care. As expected, hospitalist groups among safety-net hospitals in California are small, and we may have been underpowered to determine some correlations presented by safety-net sites when stratifying by hospital type. Other correlations also may have been limited by sample size, including differences in HVCCS scores based on reimbursement and hospital type and the correlation between a blame-free environment and reimbursement type. Additionally, the field lacks a gold standard for the measurement of high-value care to help stratify institutional value performance for site selection. The VBP measure presents policy implications and is currently the best available measure with recent value data for over 3,000 hospitals nationally and representing various types of hospitals. This study is also cross-sectional and may benefit from the further evaluation of organizational culture over time and across other settings.

CONCLUSION

The HVCCS can identify clear targets for improvement and has been evaluated among internal medicine hospitalists. Hospitalists who are paid partly based on productivity reported low measures of high-value care culture at their institutions. As the nation moves toward increasingly value-based payment models, hospitals can strive to improve their understanding of their individual culture for value and begin addressing gaps.

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Improving Patient Flow: Analysis of an Initiative to Improve Early Discharge

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BACKGROUND: Discharge delays adversely affect hospital bed availability and thus patient flow.

OBJECTIVE: We aimed to increase the percentage of early discharges (EDCs; before 11 AM). We hypothesized that obtaining at least 25% EDCs would decrease emergency department (ED) and postanesthesia care unit (PACU) hospital bed wait times.

DESIGN: This study used a pre/postintervention retrospective analysis.

SETTING: All acute care units in a quaternary care academic children's hospital were included in this study.

PATIENTS: The patient sample included all discharges from the acute care units and all hospital admissions from the ED and PACU from January 1, 2014, to December 31, 2016.

INTERVENTION: A multidisciplinary team identified EDC barriers, including poor identification of EDC candidates, accountability issues, and lack of team incentives. A total of three successive interventions were implemented using Plan–Do-Check-Act (PDCA) cycles over 10 months between 2015 and 2016 addressing these barriers. Interventions included EDC identification and communication, early rounding on EDCs, and modest incentives.

MEASUREMENTS: Calendar month EDC percentage, ED (from time bed requested to the time patient left ED) and PACU (from time patient ready to leave to time patient left PACU) wait times were measured.

RESULTS: EDCs increased from an average 8.8% before the start of interventions (May 2015) to 15.8% after interventions (February 2016). Using an interrupted time series, both the jump and the slope increase were significant (3.9%, $P = .02$ and 0.48%, $P < .01$, respectively). Wait times decreased from a median of 221 to 133 minutes ($P < .001$) for ED and from 56 to 36 minutes per patient ($P = .002$) for PACU.

CONCLUSION: A multimodal intervention was associated with more EDCs and decreased PACU and ED bed wait times. *Journal of Hospital Medicine* 2019;14:22-27.

Patient flow throughout the hospital has been shown to be adversely affected by discharge delays.[1] When hospitals are operating at peak capacity, these delays impact throughput, length of stay (LOS), and cost of care and block patients from the emergency department (ED), postanesthesia recovery unit (PACU), or home awaiting inpatient beds.[2-5] As patients wait in locations not ideal for inpatient care, they may suffer from adverse events and poor satisfaction.[3,6] Several studies have analyzed discharge timing as it relates to ED boarding of admitted patients and demonstrated that early discharges (EDCs) can impact boarding times.[7-9] A number of recent improvement efforts directed at moving discharges earlier in the day have been published.[10-15] However, these improvements are often targeted at specific units or teams within a larger hospital setting and only one is in the pediatric setting.

Lucile Packard Children's Hospital Stanford (LPCHS) is a 311-bed quaternary care academic women and children's hospital in Northern California. As our organization expanded, the demand for hospital beds often exceeded capacity. The challenge of overall demand was regularly compounded by a mismatch in bed availability timing – bed demand is early in the day and bed availability is later. This mismatch results in delays for admitted patients waiting in the ED and PACU. Organization leaders identified increasing early discharges (EDCs) as one initiative to contribute to improved patient flow.

Our organization aimed to increase the number of discharges before 11 AM across the acute care units from an average of 8% in the 17 months prior to May 2015 to 25% by December 2016. Based on the average number and timing of planned admissions, they hypothesized that 25% of EDCs would decrease ED and PACU wait times.

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METHODS

Setting

We focused our EDC interventions on the 87 acute care beds at LPCHS. All patients discharged from these beds were included in the study. We excluded patients discharged from intensive care, maternity, and nursery. Acute care includes five units, one focused on hematology/oncology (Unit A), one focused on cardiology (Unit B), and the others with a surgical and medical pediatric patient mix (Units C, D, and E). Although physician teams have primary units, due to unit size, patients on teams other than cardiology and hematology/oncology are often spread across multiple units wherever there is a bed (including Units A and B). Most of the frontline care physicians are residents supervised by attendings; however, a minority of patients are cared for by nurse practitioners (NPs) or physician assistants (PAs).

Improvement Team

In early 2015, we formed a multidisciplinary group inclusive of a case manager, frontline nurses, nurse management, pediatric residents, and hospitalist physicians with support from performance improvement. We periodically included physician leaders from other specialties to help initiate changes within their own clinical areas. Our group used Lean A3 thinking[16] to gather information about the current state, formulate the problem statement, analyze the problem, and consider interventions implemented in three Plan–Do-Check-Act (PDCA) cycles. The A3 is a structured tool to analyze problems before jumping to solutions and communicate with stakeholders. We interviewed leaders, nurses, residents, case managers, etc. and observed work processes around discharge. We met weekly to follow data, assess results of interventions, and problem solve.

Barriers and Interventions

The first barrier we identified and addressed was poor identification and shared team mental model of potential EDC patients and lack of preparation when an EDC was identified. In intervention one starting May 2015, charge nurses on Units C, D, and E were each asked to identify one EDC for the following day. The identified patient was discussed at the previously existing afternoon daily unit huddle[17] attended by nurse management, case management, and hospitalist leaders. Following the huddle, the resident, NP, or PA responsible for the patient was paged regarding the EDC plan and tasked with medication reconciliation and discharge paperwork. Others were asked to address their specific area of patient care for discharge (eg, case manager–supplies, nursing–education). The patient was identified on the unit white board with a yellow magnet (use of a visual control[18]), so that all would be aware of the EDC. An e-mail was sent to case management, nurse leaders, and patient placement coordinators regarding the planned EDCs. Finally, the EDCs were discussed during regularly scheduled huddles throughout the evening and into the next day.[17]

Despite this first intervention, we noted that progress toward increased EDCs was slow. Thus, we spent approximately seven days (spread over one month) further observing the work processes.[19] Over five days, we asked each unit's charge nurse every hour which patients were waiting to be discharged and the primary reason for waiting. From this information, we created a *pareto* chart demonstrating that rounds were the highest contributor to waiting (Appendix A). Thus, our second intervention was a daily physician morning huddle that the four nonsurgical physician teams (excluding cardiology, hematology/oncology) implemented one team at a time between November 2015 and February 2016. At the huddle, previously identified EDCs (located on any of the five units) were confirmed and preparatory work was completed (inclusive of the discharge order) before rounds. Further, the attending and resident physicians were to see the patient before or at the start of rounds.

Our working group still observed slow EDC improvement and sought feedback from all providers. EDC was described as "extra" work, apart from routine practices and culture. In addition, our interventions had not addressed most discharges on Units A and B. Consequently, our third intervention in February 2016 aimed to recognize and incentivize teams, units, and individuals for EDC successes. Units and/or physician teams that met 25% of EDCs the previous week were acknowledged through hospital-wide screensavers and certificates of appreciation signed by the Chief Nursing Officer. Units and/or physician teams that met 25% of EDC the previous month were acknowledged with a trophy. Residents received coffee cards for each EDC (though not without controversy among the improvement group as we acknowledged that all providers contributed to EDCs). Finally, weekly, we shared an EDC dashboard displaying unit, team, and organization performance at the hospital-wide leader huddle. We also e-mailed the dashboard regularly to division chiefs, medical directors, and nursing leaders.

Measures

Our primary outcome was percentage of EDCs (based on the time the patient left the room) across acute care. Secondary outcome measures were median wait times for an inpatient bed from the ED (time bed requested to the time patient left the ED) and the average PACU wait time (time the patient is ready to leave the PACU to time the patient left the PACU) per admitted patient. We also assessed balancing measures, including discharge satisfaction, seven-day readmission rates, and LOS. We obtained the mean discharge satisfaction score from the organization's Press Ganey survey results across acute care (the three discharge questions' mean – "degree … you felt ready to have your child discharged," "speed of discharge process …," and "instructions… to care for your child…"). We obtained seven-day readmission rates from acute care discharges using the hospital's regularly reported data. We assessed patient characteristics, including sex, age, case mix index (CMI; >2 vs <2), insurance type (nongovernment vs government), day of discharge (weekend vs weekday), and LOS from those patients categorized as inpatients. Complete patient characteristics were not available for observation (InterQual® criteria) status patients.

Analysis

We used descriptive statistics to describe the inpatient population characteristics by analyzing differences when EDC did

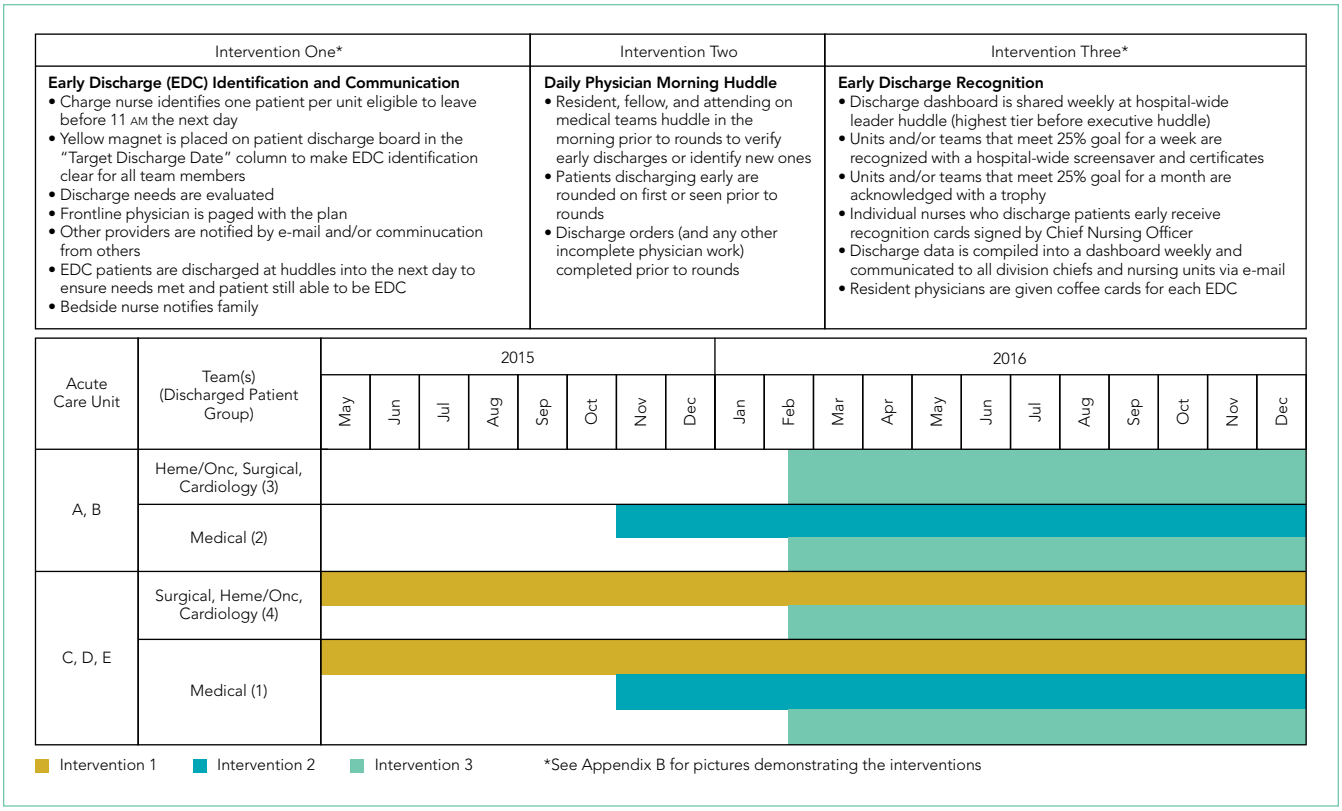

FIG 1. Descriptions of Interventions and Timeline.

and did not occur using chi-square and the Mann–Whitney U tests. Patients with missing data were removed from analyses that incorporated patient factors.

To assess our primary outcome, we used an interrupted time series analysis assessing the percentage of EDC in the total population before any intervention (May 2015) and after the last intervention (March 2016). We used the Durbin–Watson statistic to assess autocorrelation of errors in our regression models. As we had only patient characteristics for the inpatient population, we repeated the analysis including only inpatients and accounting for patient factors significantly associated with EDC.

As units and physician teams had differential exposure to the interventions, we performed a subanalysis (using interrupted time series) creating groups based on the combination of interventions to which a patient's discharge was exposed (based on unit and physician team at discharge). Patient discharges from group 1 (medical patients on Units C, D, and E) were exposed to all three interventions, group 2 patient discharges (medical patients on Units A and B) were exposed to interventions 2 and 3, group 3 (cardiology, hematology/oncology, surgical patients on Units A and B) were exposed to intervention 3, and group 4 (surgical, cardiology, hematology/oncology patients on Units C, D, and E) were exposed to interventions 1 and 3 (Figure 1). Interrupted time series models were fit using the R Statistical Software Package.[20]

Because of seasonal variation in admissions, we compared secondary outcomes and balancing measures over similar time frames in the calendar year (January to September 2015 vs January to September 2016) using the Mann–Whitney U test and the unpaired t-test, respectively.

The project's primary purpose was to implement a practice to improve the quality of care, and therefore, the Stanford Institutional Review Board determined it to be nonresearch.

RESULTS

There were 16,175 discharges on acute care from January 2014 through December 2016. Across all acute care units, EDCs increased from an average of 8.8% before the start of interventions (May 2015) to 15.8% after all interventions (February 2016). From the estimated trend in the preintervention period, there was a jump of 3.9% to the start of the postintervention trend (P = .02; Figure 2). Furthermore, there was an increase of 0.48% (95% CI 0.15-0.82%; P < .01) per month in the trend of the slope between the pre- and postintervention. The autocorrelation function and the Durbin–Watson test did not show evidence of autocorrelation (P = .85). Lack of evidence for autocorrelation in this and each of our subsequent fitted models led to excluding an autocorrelation parameter from our models.

From 16,175 discharges, 1,764 (11%) were assigned to observation status. Among inpatients (14,411), patients with missing values (CMI, insurance status) were also excluded (n = 66, 0.5%). Among the remaining 14,345 inpatients, 54% were males, 50% were government-insured, and 1,645 (11.5%) were discharged early. The average age was 8.5 years, the average LOS was seven days, and the median CMI was 2.2. Children

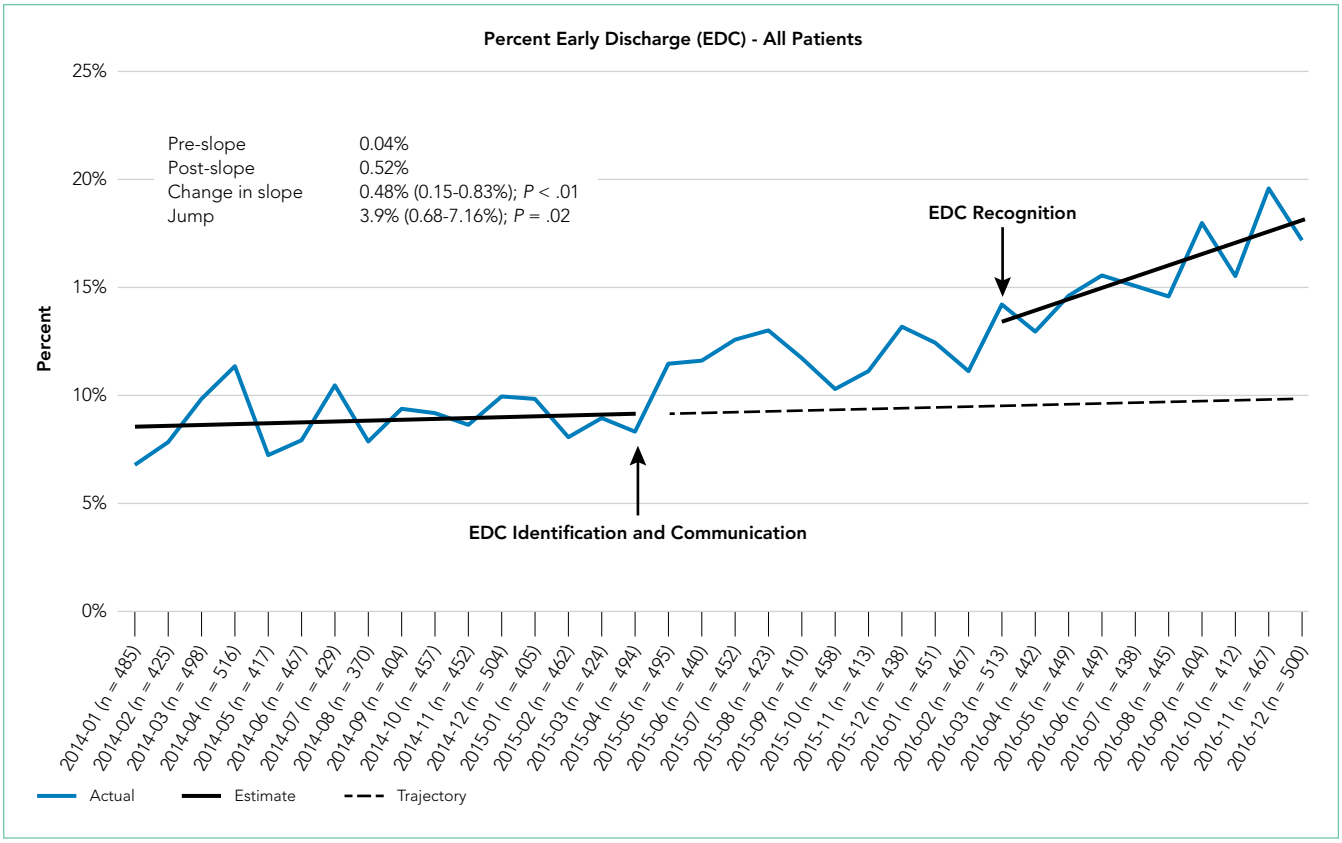

FIG 2. Percentage of Early Discharge Trajectory for all Discharges on Acute Care Pre- and Postimplementation of the Interventions.

who were younger, had shorter LOS, CMI <2, and nongovernment insurance were more likely to be discharged early ($P < .01$ for all). For each of these variables, F-tests were performed to determine whether there was a statistically significant reduction in variation by adding the variable to our initial model. None of the variables alone or in combination led to a statistically significant reduction in variation. Including these factors in the interrupted time series did not change the significance of the results (jump at postintervention start 3.6%, 95% CI 0.7%-7.2%; $P = .02$, slope increased by 0.59% per month, 95% CI 0.29-0.89%; $P < .01$).

In the subgroup analysis, we did not account for patient factors as they did not change the results in the analysis of total population. Though each group had a greater percentage of EDCs in the postintervention period, the changes in slopes and jumps were primarily nonsignificant (Figure 3). Only the change in slope in group 4 was significant (1.1%, 95% CI 0.3-1.9%; $P = .01$).

Between January to September 2015 and 2016, ED wait times decreased by 88 minutes ($P < .01$) and PACU wait times decreased by 20 minutes per patient admitted ($P < .01$; Table). There was no statistically significant change in seven-day readmissions ($P = .19$) or in families feeling ready to discharge ($P = .11$) or in general discharge satisfaction ($P = .48$) as measured by Press Ganey survey. Among all discharges (inpatient and observation), the average LOS significantly decreased by 0.6 days ($P = .02$).

DISCUSSION

The percentage of patients who left the hospital prior to 11 AM significantly improved after a number of interventions aimed at emphasizing EDC and discharge task completion earlier within the hospital stay. Our EDC improvement was associated with improved ED and PACU wait times without negatively impacting discharge satisfaction, seven-day readmissions, or LOS.

It is difficult to compare our EDC improvements to those of previous studies, as we are unaware of published data on pediatric EDC efforts across an entire hospital. In addition, studies have reported discharges prior to different times in the day (noon, 1 PM, etc).[12, 13] Our interventions were similar to those of Wertheimer et al.,[11] including the use of interdisciplinary rounds, identification of potential EDCs the afternoon before discharge, and "reward and recognition." Wertheimer also sent an e-mail about EDCs to a multidisciplinary group, which was then updated as conditions changed. Unlike Wertheimer, we did not include physicians in our e-mail due to the large number and frequently changing physician teams. Our EDC rate prior to 11 AM was lower than their achieved rate of 35% prior to 12 PM. When we assessed our discharges using 12 PM, our rate was still lower (22%-28%), but a direct comparison was complicated by different patient populations. Still, our study adds to the evidence that interdisciplinary rounds and reward and recognition lead to earlier discharge. In addition, this study builds upon Wertheimer's results as although they later assessed the timing of ED admissions as a result of their EDC

improvements, they did not directly assess inpatient bed wait times as we did in our study.[14]

As providers of all types were aware of the constant push for beds due to canceled surgeries, delayed admissions and intensive care transfers, and the inability to accept admission, it is difficult to compare the subgroups directly. Furthermore, although physician teams and units are distinct, individuals (nurses, case managers, trainees) may rotate through different units and teams and we cannot account for individual influences on EDCs depending on exposure to interventions over time. Although all groups improved, the improvement in slope in group 4 (exposed to interventions 1 and 3) was the only significant change. As group 4 contained a large number of surgical patients who often have more predictable hospital stays, perhaps this group was more responsive to the interventions.

Our EDC improvements were associated with a decrease in ED and PACU bed wait times. Importantly, we did not address potential confounding factors impacting these times such as total hospital admission volumes, ED and PACU patient complexity, and distribution of ED and PACU admission requests throughout the day. Modeling has suggested that EDCs could also improve ED flow,[7] but studies implementing EDC have not necessarily assessed this outcome.[10-15] One study retrospectively evaluated ED boarding times in the context of an EDC improvement effort and found a decrease in boarding times.[21] This decrease is important as ED boarders may be at a higher risk for adverse events, a longer LOS, and more readmissions.[3,7] Less is known about prolonged PACU wait times; however, studies have reported delays in receiving patients from the operating room (OR), which could presumably impact timeliness of other scheduled procedures and patient satisfaction.[22-24] It is worth noting that OR holds as a result of PACU backups happened more frequently at our institution before our EDC work.

Our limitations include that individual providers in the various groups were not completely blind to the interventions and groups often comprised distinct patient populations. Second, LPCHS has a high CMI and LOS relative to most other children's hospitals, complicating comparison with patient populations at other children's hospitals. In addition, our work was done at this single institution. However, since a higher CMI was associated with a lower probability of EDC, hospitals with a lower CMI may have a greater opportunity for EDC improvements. Third, hospital systems are more impacted by low EDCs when operating at high occupancy (as we were at LPCHS); thus, improvements in ED and PACU wait times for inpatient beds might not be noted for hospitals operating with a >10% inventory of beds.[25] Importantly, our hospital had multiple daily management structures in place, which we harnessed for our interventions, and better patient flow was a key hospital initiative garnering improvement of resources. Hospitals without these resources may have more difficulty implementing similar interventions. Finally, other work to improve patient flow was concurrently

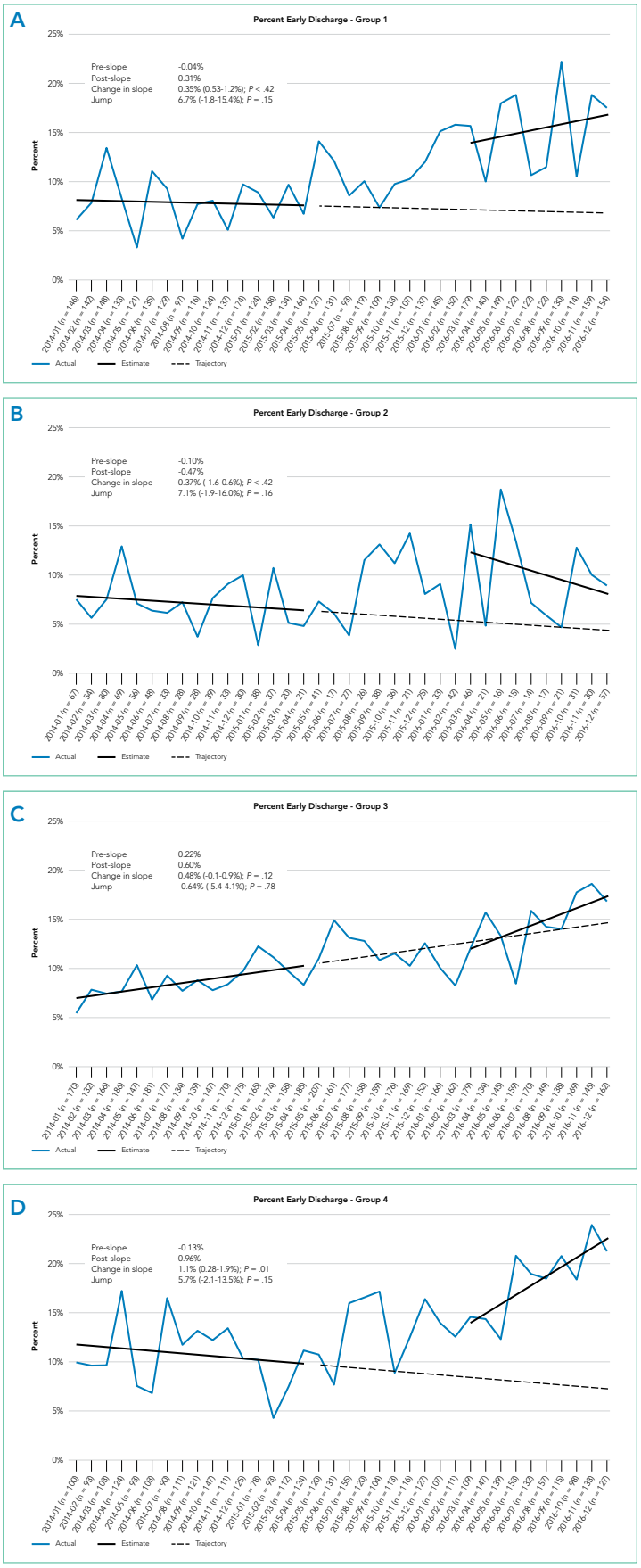

FIG 3. Percentage of Early Discharge Trajectory for Each Subgroup (based on unit and physician team at the time of patient discharge) Pre- and Postimplementation of the Interventions.

TABLE. **Secondary Outcomes and Balancing Measures**

	January to September 2015[1]	January to September 2016	*P* Value
Secondary Outcomes			
Emergency Department wait time	221 minutes	133 minutes	<.001
Postanesthesia Care Unit wait time/patient admitted	56 min/patient	36 min/patient	.002
Balancing Measures			
Press Ganey discharge satisfaction[2]	86.6	85.4	.48
Press Ganey felt ready for discharge[2]	89.6	86.9	.11
7-day readmission rates	5.5	5.0	.19
Length of stay	7.0 days	6.4 days	.02

[1]3,634 patients discharged January to September 2015, 3,657 patients discharged January to September 2016.
[2]402 responses January to September 2015, 391 responses January to September 2016

implemented, including matching numbers of scheduled OR admissions with anticipated capacity, which probably also contributed to the decrease in ED and PACU wait times.

CONCLUSIONS

We found that a multimodal intervention was associated with more EDCs and improved ED and PACU bed wait times. We observed no impact on discharge satisfaction or readmissions. Our EDC improvement efforts may guide institutions operating at high capacity and aiming to improve EDCs to improve patient flow.

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The Association of Discharge Before Noon and Length of Stay in Hospitalized Pediatric Patients

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BACKGROUND AND OBJECTIVES: To optimize patient throughput, many hospitals set targets for discharging patients before noon (DCBN). However, it is not clear whether DCBN is an appropriate measure for an efficient discharge. This study aims to determine whether DCBN is associated with shorter length of stay (LOS) in pediatric patients and whether that relationship is different between surgical and medical discharges.

METHODS: From May 2014 to April 2017, we performed a retrospective data analysis of pediatric medical and surgical discharges belonging to a single academic medical center. Patients were included if they were 21 years or younger with at least one night in the hospital. Propensity score weighted multivariate ordinary least squares models were used to evaluate the association between DCBN and LOS.

RESULTS: Of the 8,226 pediatric hospitalizations, 1,531 (18.61%) patients were DCBN. In our multivariate model of all the discharges, DCBN was associated with an average of 0.27 day (P = .014) shorter LOS when compared to discharge in the afternoon. In our multivariate medical discharge model, DCBN was associated with an average of 0.30 (P = .017) day decrease in LOS while the association between DCBN and LOS was not significant among surgical discharges.

CONCLUSIONS: On average, at a single academic medical center, DCBN was associated with a decreased LOS for medical but not surgical pediatric discharges. DCBN may not be an appropriate measure of discharge efficiency for all services. *Journal of Hospital Medicine* 2019;14:28-32. © 2019 Society of Hospital Medicine

Many hospitals and emergency departments (EDs) face challenges posed by overcrowding and hospital throughput. Slow ED throughput has been associated with worse patient outcomes.[1] One strategy increasingly employed to improve hospital throughput is to increase the rate of inpatient discharges earlier in the day, which is often defined as discharges before noon (DCBNs). The hypothesis behind DCBN is that earlier hospital discharges will allow for earlier ED admissions and thus mitigate ED overcrowding while optimizing inpatient hospital flow. Previous quality improvement efforts to increase the percentage of DCBNs have been successfully implemented. For example, Wertheimer et al. implemented a process for earlier discharges and reported a 27-percentage point (11% to 38%) increase in DCBN on general medicine units.[2] In a recent survey among leaders in hospital medicine programs, a majority reported early discharge as an important institutional goal.[3]

Studies of the effectiveness of DCBN initiatives on improving throughput and shortening length of stay (LOS) in adult patients have had mixed results. Computer modeling has supported the idea that earlier inpatient discharges would shorten ED patient boarding time.[4] Wertheimer et al. performed a retrospective analysis of a DCBN intervention on two inpatient medicine units and reported an association between slightly shorter observed versus expected inpatient LOS[2] and earlier arrival time of inpatient admissions from the ED.[5] In contrast, Rajkomar et al. conducted a retrospective analysis of the association of DCBN and LOS in a predominantly surgical services population and reported a longer LOS for DCBN patients when controlling for patient characteristics and comorbidities.[6] These mixed findings have led some authors to question the value of DCBN initiatives and created concern for the potential of prolonged patient hospitalizations as a result of institutional DCBN goals.[7] The impact of DCBN in pediatric patients is much less studied.

A question of interest for hospitals is if DCBN is a good indicator of shorter LOS, or is DCBN an arbitrary indicator, as morning discharges might just be the result of a delayed discharge of a patient ready for discharge the prior afternoon/evening. Our study objectives were: (1) to determine whether DCBN is associated with a shorter LOS in a pediatric population at an academic medical center, and (2) to examine separately this association in medical and surgical patients given the different provider workflow and patient clinical characteristics in those groups.

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PATIENTS AND METHODS

Patients and Settings

This retrospective cohort analysis included pediatric medical and surgical inpatient admissions from a single academic medical center from May 2014 to April 2017. The University of North Carolina (UNC) Children's Hospital is a 175-bed tertiary care 'hospital within a hospital' in an academic setting with multiple residencies. UNC Children's Hospital contains three units providing inpatient pediatric care. Each unit occupies a floor of the Children's hospital and are loosely regionalized, as follows: (1) Unit 7 is focused on surgical patients; (2) Unit 6 is focused on general, neurologic, and renal patients; and (3) Unit 5 is focused on hematology/oncology and pulmonary patients. Extending the entire study period, Unit 6 initiated a quality improvement effort to discharge patients earlier in the day, specifically before 1 PM; however, the initiative did not extend beyond this one unit.

We included patients 21 years or younger with an inpatient admission to any of the following pediatric medical or surgical services: cardiac surgery, cardiology, endocrinology, gastroenterology, general services, hematology/oncology, nephrology, orthopedics, otolaryngology, plastic surgery, pulmonology, and urology. Patients whose stay did not extend beyond one midnight were excluded because discharge time of day for these short stays was strongly related to the time of admission. We also excluded patients whose stay extended beyond two standard deviations of the average LOS for the discharge service under the assumption that these patients represented atypical circumstances. Finally, we excluded patients who died or left against medical advice. A consortium diagram of all exclusion criteria can be found in Supplemental Figure 1. Discharge data were extracted from the Carolina Database Warehouse, a data repository of the University of North Carolina Health System. The University of North Carolina Institutional Review Board reviewed and approved this study (IRB 17-0500).

Measures

The outcome of interest was LOS, defined as discharge date and time minus admission date and time, and thus a continuous measure of time in the hospital rather than a number of midnights. Rajkomar et al. used the same definition of LOS.[6] The independent variable of interest was whether the discharge occurred before noon. Because discharges between midnight and 8:00 AM are likely unplanned and not attributable to any particular workflow, we followed a similar definition of DCBN used by Rajkomer et al. and defined DCBN as a patient leaving between 8:00 AM and 11:59 AM (pre-8:00 AM discharges accounted for less than one half of one percent of discharges).[6]

All model covariates were collected at the patient level (Table 1), including demographic characteristics such as age, sex, race, and ethnicity. We also collected covariates describing the patient's hospitalization as follows: (1) whether the patient was discharged on a weekend versus weekday; (2) hospital service at time of discharge (dichotomized to a surgical or medical service); (3) whether the patient was discharged from the unit that had a DCBN quality improvement initiative; (4) discharge disposition (home with self-care, assisted living or home health, or other); (5) insurance type during hospitalization (commercial, Medicaid, no insurance, or other); and (6) case mix index (CMI), a measure of hospital resource intensity of a patient's principal diagnosis. Covariate selection was made on the basis of a priori knowledge of causal pathways.[8]

Statistical Analysis

Student *t* tests and χ^2 statistics were used to compare baseline characteristics of hospitalizations of patients DCBN and after noon. We used ordinary least squares (OLS) regression models to assess the association between DCBN and LOS. Because DCBN may be correlated with patient characteristics, we used propensity score weighted models. Propensity scores were estimated using a logistic regression predicting DCBN using the variables given in Table 1 (excluding the outcome variable LOS). To estimate the average treatment effect on the entire sample for each model, we weighted each observation by the inverse-probability of treatment as per recent propensity score methods detailed by Garrido et al.[9] In the inverse-probability weighted models, we clustered on attending physician to adjust for the autocorrelation caused by unobservable similarities of discharges by the same attending. We tested for multicollinearity using the variance inflation factor (VIF). To test our secondary hypothesis that there was a difference in the relationship between DCBN and LOS based on service type (medical versus surgical), we tested if the service type moderated any of the coefficients using a joint Wald test on the 10 coefficients interacted with the service type.

For our sensitivity analysis, we reran all surgical and medical discharges models changing the LOS outlier exclusion criteria to greater than three and then four standard deviations. Statistical modeling and analysis were completed using Stata version 14 (StataCorp, College Station, Texas).

RESULTS

Our study sample comprised 8,226 pediatric hospitalizations with a LOS mean of 5.10 and a median of 3.91 days respectively (range, 1.25-32.83 days). There were 1,531 (18.6%) DCBNs. Compared to those discharged after noon, patients with DCBN had a higher probability of being surgical patients, having commercial insurance, discharge home with self-care, discharge on the weekend, and discharge from a nonquality improvement unit (Table 1). Patients with DCBN were also more likely to be white, non-Hispanic, and male.

Our propensity score weighted ordinary least score (OLS) LOS regression results are presented in Table 2. In the bivariate analysis, DCBN was associated with an average 0.40 day, or roughly 10 hours, shorter LOS ($P < .001$). In the multivariate model of all discharges, we found that DCBN was associated with a mean of 0.27 day ($P = .010$) shorter LOS when compared to discharge in the afternoon when controlling for age, race, ethnicity, weekend discharge, discharge from quality improvement unit, discharge service type, CMI, insurance type, and discharge disposition. In the multivariate analysis, weekend discharge, surgical discharge, and discharge disposition

TABLE 1. **Baseline Characteristics for Patients Discharged Before and After Noon.**

	Discharged before Noon	Discharged after Noon	*P* Value
N	1,531	6,695	
LOS (days), mean (SD)	4.78 (3.7)	5.17 (4.0)	<.001
Age (years), mean (SD)	7.71 (6.2)	8.32 (6.2)	<.001
Race			
White (%)	882 (57.6)	3,460 (51.7)	<.001
Non-white (%)	649 (42.4)	3,235 (48.3)	
Ethnicity			
Hispanic (%)	200 (13.1)	1,087 (16.2)	.002
Non-Hispanic (%)	1,331 (86.9)	5,608 (83.8)	
Male (%)	859 (56.1)	3,502 (52.3)	.007
Discharge day of week			
Weekday (%)	1,036 (68.7)	5,192 (77.5)	<.001
Weekend (%)	495 (32.3)	1,504 (22.5)	
CMI, mean (SD)	1.80 (1.5)	1.71 (1.5)	.037
Discharge service type			
Surgical discharges (%)	401 (26.2)	1,387 (20.7)	<.001
Medical discharges (%)	1,130 (73.8)	5,308 (79.3)	
DCBN QI			
DC from QI unit (%)	523 (34.2)	2,672 (39.9)	<.001
DC from non-QI unit (%)	1,008 (65.8)	4,023 (60.1)	
Insurance type (%)			
Commercial	517 (33.8)	2,013 (30.1)	.04
Medicaid	852 (55.6)	3,904 (58.3)	
No insurance	18 (1.2)	87 (1.3)	
Other insurance	144 (9.4)	691 (10.3)	
Discharge disposition (%)			
Asst. living or HH	76 (5.0)	577 (8.6)	<.001
Home with self-care	1,421 (92.8)	5,985 (89.4)	
Other disposition	34 (2.2)	133 (2.0)	

Abbreviations: CMI, case mix index; DC, discharge; HH, home health; LOS, length of stay; QI, quality improvement; SD, standard deviation.

TABLE 2. **Propensity Score Weighted Ordinary Least Square Coefficient Estimates of the Effect of Discharge Before Noon on Length of Stay.**

	Bivariate	Multivariate		
	All Discharges	All Discharges	Surgical Discharges	Medical Discharges
N	8,226	8,226	1,788	6,438
DCBN	-0.4[a]	-0.3[b]	-0.2	-0.3[c]
	(.1)	(.1)	(.1)	(.1)

Standard error in parentheses; significance denoted, [a]$P < .001$; [b]$P < .01$, [c]$P < .05$
Abbreviations: DCBN, discharge before noon.

of home with self-care, compared to assisted living or home health were associated with shorter LOS.

There was no evidence of multicollinearity (mean VIF of 1.14). The Wald test returned an F statistic of 27.50 ($P < .001$) indicating there was a structural difference in the relationship between LOS and DCBN dependent on discharge service type; thus, we ran separate surgical and medical discharge models to interpret model coefficients for both service types. When we analyzed surgical and medical discharges in separate models, the effect of DCBN on LOS in the medical discharges model was significantly associated with a 0.30 day ($P = .017$) shorter LOS (Table 2). The association was not significant in the surgical discharges model.

To further test the analysis, we increased the LOS outlier exclusion criteria to three and four standard deviations. Being more inclusive with LOS outliers in the sample resulted in a larger DCBN effect size that was significant in all three multivariate models (Supplemental Table 1).

DISCUSSION

In our study of over 8,000 pediatric discharges during a three-year period, DCBN was associated with shorter LOS for medical pediatric patients, but this finding was not consistent for surgical patients. Among medical discharges, DCBN was associated with shorter LOS, an effect robust enough to include or exclude outliers (for LOS, outliers are an important subset because there are always, in general, a few patients with very long lengths of stay). Discharge before noon showed no association with LOS for surgical patients unless we included outlier values.

The differential effect of DCBN on LOS in surgical and medical discharges suggests that the relationship between DCBN and LOS may be related to provider team workflow. For example, surgical teams may tend to round one time per day early in the morning before spending the entire day in the operating room, and thus completing more early morning discharge orders compared to medical teams. However, if a patient on a surgical service is not ready for discharge first thing in the morning, the patient may be more likely to wait until the following morning for a discharge order. On medical services, physician schedules may allow for more flexibility for rounding and responding with a discharge order when a patient becomes ready; however, medical services may round later in the day compared to surgeons and for a longer period of time, delaying discharges beyond noon that could have been made earlier. Another possibility, given UNC pediatric services are loosely regionalized with surgical patients concentrated more in one unit, is that unit-level differences in how staff processed discharges could have contributed to the difference observed between medical and surgical patients, particularly as there was a unit-level quality improvement effort for decreasing discharge time on one of two medical floors. However, we analyzed for differences based on the discharging unit and found no association. The influence of outliers on the association between DCBN and LOS increases also suggests that this group of children who have extremely long hospital stays might need further exploration.

Our study has some similar and some contrasting results with prior studies in adult patients. Our findings support the modeling literature that suggests DCBN may improve discharge efficiency by shortening patient LOS for some discharges.[4] These findings contrast with Rajkomar et al., who reported that DCBN was associated with a longer LOS in adult patients.[6] The contrasting findings could be due to differences in pediatric versus adult patients. Additionally, the population Rajkomar et al. studied was predominantly surgical patients, whose discharges may differ from medical patients' in many aspects. Another possible explanation is that the Rajkomar et al. study was performed in a setting with clearly set institutional targets for DCBN, whereas, our institution lacked any hospital-wide DCBN initiatives or standards to which providers were held accountable. Some authors have argued setting DCBN as a measure of hospital quality perhaps creates the unintended consequence of providers holding potential afternoon or evening discharges until the next day so that they can be DCBN.[7,10] In that scenario, perhaps there would be a relationship between DCBN and longer LOS compared to patients who are re-evaluated in the afternoon or evening and discharged. We did not find evidence of these effects in our analysis, however, understanding the potential for this is important when designing quality improvement efforts aimed at increasing discharge efficiency.

While shorter LOS can be an indicator of high-value care, the relationship between LOS, DCBN, and efficiency of discharge processes remains unclear. Prior studies have found evidence that multidisciplinary care teams with frequent care coordination rounds and integration of electronic admission order sets can be effective in improving discharge efficiency as measured by discharge within two hours of meeting discharge goals.[11,12] Measuring discharge efficiency on an ongoing basis is very difficult; however, easy-to-measure targets such as discharge before noon may be used as a proxy measure of efficiency. These targets also have "face validity," and because of these two factors, measures like DCBN have been widely implemented even though evidence to support their validity is minimal.

Our study has several limitations. While we controlled for observable characteristics using covariates and propensity score weighted analyses, there are likely unobservable characteristics that confound our analysis. We did not measure other factors that may affect discharge time of day such as high occupancy, staffing levels, patient transportation availability, and patient and family preferences. Given these limitations, we caution against interpreting a causal relationship between independent variables and the outcome. Finally, this analysis was conducted at a single tertiary care, academic medical center. The majority of pediatric admissions at this institution are either transferred from other hospitals or scheduled admissions for medical or surgical care. A smaller proportion of discharges are acute, unplanned admissions through our emergency

department in children with or without underlying medical complexity. These factors plus the exclusion of observation, extended recovery, and all the less than two-day stays in this study contribute to a relatively higher average LOS. These factors potentially limit generalizability to other care settings. Additionally, the majority of the care teams involve care by resident physicians, and they are often the primary caregivers and write the majority of orders in patient charts such as discharge orders. While we were not able to control for within resident physician similarities between patients, we did control for autocorrelation at the attending level.

CONCLUSION

The results of our study suggest that DCBN is associated with a decreased LOS for medical but not surgical pediatric patients. DCBN may not be an appropriate measure for all services. Further research should be done to identify other feasible but more valid indicators for shorter LOS.

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Screening for Humoral Immunodeficiency in Patients with Community-Acquired Pneumonia

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BACKGROUND: Immunodeficiency is an underrecognized risk factor for infections, such as community-acquired pneumonia (CAP).

OBJECTIVE: We evaluated patients admitted with CAP for humoral immunodeficiency.

DESIGN: Prospective cohort study

SETTING: Inpatients

PATIENTS, INTERVENTION, AND MEASUREMENTS: We enrolled 100 consecutive patients admitted with a diagnosis of CAP from February 2017 to April 2017. Serum IgG, IgM, IgA, and IgE levels were obtained within the first 24 hours of admission. CURB-65 score and length of hospital stay were calculated. The Wilcoxon rank-sum test, Kruskal-Wallis test, and simple linear regression analysis were used in data analysis.

RESULTS: The prevalence of hypogammaglobinemia in patients with CAP was 38% (95% CI: 28.47% to 48.25%). Twenty-seven of 100 patients had IgG hypogammaglobinemia (median: 598 mg/dL, IQ range: 459-654), 23 of 100 had IgM hypogammaglobinemia (median: 38 mg/dL, IQ range: 25-43), and 6 of 100 had IgA hypogammaglobinemia (median: 36 mg/dL, IQ range: 18-50). The median hospital length of stay for patients with IgG hypogammaglobinemia was significantly higher when compared to patients with normal IgG levels (five days, IQ range [3-10] vs three days, IQ range [2-5], P = .0085). Fourteen patients underwent further immune evaluation, resulting in one diagnosis of multiple myeloma, three patients diagnosed with specific antibody deficiency, and one patient diagnosed with selective IgA deficiency.

CONCLUSION: There is a high prevalence of hypogammaglobinemia in patients hospitalized with CAP, with IgG and IgM being the most commonly affected classes. IgG hypogammaglobinemia was associated with an increased length of hospitalization. Screening immunoglobulin levels in CAP patients may also uncover underlying humoral immunodeficiency or immunoproliferative disorders. *Journal of Hospital Medicine* 2019;14:33-37. Published online first November 28, 2018.

Community-acquired pneumonia (CAP) is the most common infection in hospitalized patients and the eighth most common cause of death in the United States.[1] Mortality from CAP is estimated to be 5.1% in the outpatient population,13.6% in hospitalized patients, and 35.1% in patients admitted to the intensive care unit.[2,3] CAP accounts for more than 50,000 deaths annually in the United States.[2] There are multiple risk factors for CAP, including tobacco use, malnutrition, chronic obstructive pulmonary disease (COPD), bronchiectasis, cystic fibrosis, and mechanical bronchial obstruction. Underlying immunodeficiency, specifically humoral immunodeficiency, is also a risk factor for CAP.

Primary immunodeficiency (PIDD) is estimated to affect one in 1,800 individuals in the United States.[4] The National Institutes of Health (NIH) estimates that only one out of three individuals with PIDD are appropriately diagnosed. Based on probability calculations on known PIDD patients versus incidence of disease, the NIH estimates that more than 500,000 individuals with PIDD remain undiagnosed in the United States.[4] Further, there exists an average diagnostic delay of at least five years. This delay increases both morbidity and mortality and leads to increased healthcare utilization.[5,6]

The most common form of primary immunodeficiency is due to humoral immunodeficiency, including selective IgA deficiency, specific antibody deficiency, and common variable immunodeficiency. Specific antibody deficiency is defined as a lack of response to polysaccharide antigens in the setting of low to normal Ig levels and an intact response to peptide antigens.[7] Selective IgA deficiency is defined as the isolated deficiency of serum IgA in the setting of normal serum levels of IgG and IgM in an individual older than four years in whom other causes of hypogammaglobinemia have been excluded.[8] Common variable immunodeficiency (CVID) is defined as a decreased serum concentration of IgG in combination with low levels of IgA and/or IgM with a poor or absent response to immunization in the absence of other defined immunodeficiency

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state.[9] In addition to experiencing recurrent infections—namely bronchitis, sinusitis, otitis, and pneumonia—patients with CVID are also at increased risk of autoimmunity and malignancy. In adults, secondary immunodeficiency is more common than primary immunodeficiency. Secondary immunodeficiency occurs commonly with disease states like HIV infection, diabetes, cirrhosis, malnutrition, and autoimmune conditions.[10] Additional causes of secondary immune defects due to humoral immunodeficiency include immune-modulating drugs—such as rituximab and ibrutinib—and hematologic malignancies, including chronic lymphocytic leukemia and multiple myeloma. Recurrent infections remain the leading cause of morbidity and mortality in patients with both primary and secondary immunodeficiency.[11,12]

Evaluation of the humoral immune system begins with measurement of serum immunoglobulin (Ig) levels. Although abnormal Ig levels are not diagnostic of immunodeficiency, abnormal results may prompt additional evaluation. Screening strategies may assist in making an earlier diagnoses, potentially decreasing morbidity and mortality in patients with immunodeficiency.[13-15] To date, there have been no studies evaluating the utility of screening Ig levels to evaluate for underlying humoral immunodeficiency in patients hospitalized for CAP.

METHODS

Study Design

This was a prospective cohort study conducted at Rochester General Hospital, a 528-bed tertiary care medical center, from February 2017 to April 2017. We enrolled 100 consecutive patients admitted to the inpatient internal medicine service with a physician diagnosis of CAP. Written consent was obtained from each patient. The study was approved by the institutional review board at Rochester General Hospital.

Case Definition

The following criteria were used to diagnose CAP: (1) Respiratory symptoms of productive cough or pleuritic chest pain, (2) Fever >38°C before or at the time of admission, and (3) chest imaging with infiltrate. Exclusion criteria included a diagnosis of hospital-acquired pneumonia, prior diagnosis of primary immunodeficiency, immunosuppression due to an underlying condition, such as HIV or malignancy, therapy with immunosuppressive medications including chemotherapy, Ig replacement within the past six months, or treatment with >10 mg prednisone for greater than 14 days before hospital admission.

Patients underwent an additional evaluation by a clinical immunologist if they met one of the following criteria: any hypergammaglobinemia (elevated IgG, IgM, or IgA), IgG hypogammaglobinemia <550 mg/dL, undetectable IgM or IgA, or if IgG, IgM, and IgA were all below the lower limit of normal.

CURB-65 was used for estimation of the severity of illness with CAP. The components of the score include age ≥65, confusion, BUN >19 mg/dl, respiratory rate ≥30 breaths per minute and systolic blood pressure <90 mm Hg or diastolic blood pressure ≤60 mm Hg. Each component is scored zero if absent or one if present. Predicted mortality ranges from 0.6% for a score of zero to 27.8% for a score of 5.

Data Collection

Patient health information including age, race, gender, medical history, admission notes, results of chest imaging studies, and relevant laboratory studies including serum levels of IgG, IgM, IgA, IgE on admission was obtained from the electronic medical health record. An additional evaluation by the immunologist occurred within three months of hospital discharge and included repeat Ig levels, pre- and postvaccination titers of polysaccharide and peptide antigens, serum protein electrophoresis, and B & T cell panels.

Description of Normal Levels

The normal levels of immunoglobulins were defined based on standard reference ranges at the laboratory at Rochester General Hospital; IgG (700-1,600 mg/dl), IgM (50-300 mg/dl), IgA (70-400 mg/dl), and IgE (0-378 IU/ml). Although there is no established classification regarding the degree of IgG hypogammaglobinemia,[16] clinical immunologists commonly classify the severity of IgG hypogammaglobinemia as follows: mild (550-699 mg/dL), moderate (400-549 mg/dL), and severe (<400 mg/dL) IgG hypogammaglobinemia.

Statistical Analysis

Statistical analysis was performed using STATA software (StataCorp LLC, College Station, Texas). We conducted a Wilcoxon rank-sum test to compare the median difference in length of stay between groups with a low versus normal range of immunoglobulins. A Kruskal–Wallis test was performed to check for the median difference in IgG levels across degrees of illness severity (CURB-65 score categories). We conducted a simple linear regression analysis using the logarithmic data of the length of stay and IgG level variables. A chi-square test was used to determine the association between comorbidities and Ig levels.

RESULTS

Baseline Characteristics

There were 100 patients with CAP enrolled in this study with a median age of 65.04 ± 18.8, and 53% were female. Forty-seven patients reported a previous history of pneumonia and 18 reported a history of recurrent sinusitis or otitis media. Of the 100 enrolled patients, 46 had received pneumococcal polysaccharide vaccine (PPV23), 26 had received the 13-valent pneumococcal conjugate vaccine (PCV13), and 22 had received both (Table 1). The mean white blood cell count on admission was $12.9 \pm 7 \times 10^3$/uL with 75 ± 12.5% neutrophils. Total protein (6.5 ± 0.8) and albumin (3.7 ± 0.5) were within the normal range for the study population.

Immunoglobulin Analyses

The prevalence of hypogammaglobinemia in the study was 38% (95% CI: 28.47% to 48.25%). The median values of Ig levels

for the entire study population and in patients with hypogammaglobinemia are summarized in Table 2.

- *IgG hypogammaglobinemia* (<700 mg/dl) was found in 27/100 patients, with a median level of 598 mg/dL, IQ range: 459-654. The median age in this group was 76.5 years, and 13 were female. Of these 27 patients, 10 had low IgM, four had low IgA, and four had an elevated IgE. In this group, 11 patients had received PPSV23, nine had received PCV13, and six had received both PPV23 and PCV13 before the index hospital admission.
- *IgG hypergammaglobinemia* (>1,600 mg/dl) was found in 9/100 patients, with a median level of 1,381 mg/dL, IQ range: 1,237-1,627. The median age was 61 years, and six were female. Of these nine patients, three had low IgM, one had low IgA, and four had elevated IgE.
- *IgM hypogammaglobinemia* (<50 mg/dl) was found in 23/100 patients with a median level of 38 mg/dL, IQ range: 25-43. In this group, the median age was 69 years, and 10 were female. Of these 23 patients, 10 had low IgG, and three had an elevated IgG.
- *IgM hypergammaglobinemia* (>300 mg/dl) was noted in two patients, with a median level of 491 mg/dL, IQ range: 418-564. Both patients were female, and one had elevated IgG.
- *IgA hypogammaglobinemia* (<70 mg/dl) was discovered in six patients, with a median level of 36 mg/dL, IQ range: 18-50. In this group, four patients had low IgG, four had low IgM, one had elevated IgE, and one had elevated IgG.
- *IgA hypergammaglobinemia* (>400 mg/dl) was noted in five patients, with a median level of 561 mg/dL, IQ range: 442-565: Two patients were female. Of these five patients, one had high IgG, and one had low IgG.

TABLE1. **Characteristics of Patients**

Total participants (n)	**100**
Age- years	65.04 ± 18.71
Female—no (%)	53 (53%)
Race—no (%)	
White	67 (67%)
African-American	20 (20%)
Hispanic	10 (10%)
Asian	2 (2%)
Indian	1 (1%)
Medical History—no (%)	
COPD	25 (25%)
Asthma	29 (29%)
Bronchiectasis	1 (1%)
Obesity (BMI ≥30)	38 (38%)
Diabetes	27 (27%)
History of physician-diagnosed pneumonia	47 (47%)
History of recurrent sinusitis/otitis	18 (18%)
Current smoker	38 (38%)
Vaccination Status—no (%)	
PPV13 vaccination	26 (26%)
PPV23 vaccination	46 (46%)
History of PPSV 23 + PPV 13 vaccination	22 (22%)
CURB65—no (%)	
0	24 (24%)
1	25 (25%)
2	24 (24%)
3	20 (20%)
4	7 (7%)

Abbreviations: COPD; chronic obstructive pulmonary disease; PPSV; pneumococcal polysaccharide vaccine, PPV, pneumococcal conjugate vaccine.

Length of Stay and Severity of Pneumonia

The median length of stay in the hospital for the entire study population was three days (IQ range: 2-5.5 days). Among patients with IgG hypogammaglobinemia, the median length of stay was two days longer as compared with patients who had IgG levels in the normal range (5 days, IQ range [3-10] vs 3days, IQ range [2-5], $P = .0085$).

The median CURB-65 score for the entire study population was two (IQ range: 1-3). The median CURB-65 score did not differ between patients with low and normal ranges of IgG levels (Median: 2, IQ range [1-3] vs Median: 1, IQ range [0-3], $P = .2922$). The CURB-65 score was not correlated with IgG levels ($\rho = -0.0776$, $P = .4428$). Length of stay, however, was positively correlated with CURB-65 score ($\rho = .4673$, $P = .000$)

A simple linear regression analysis using the logarithmic transformation of both length of stay and IgG level revealed a linear relationship between serum IgG levels and hospital length of stay ($P = .0335$, [$R^2 = .0453$]).

TABLE 2. **Serum Immunoglobulin Levels in the Study Population**

Type	**Total Number of Patients**	**Median (mg/dl)**	**IQ Range in mg/dl**
IgG (700-1,600 mg/dl))	100	941	684.5 -1223
Low IgG (<700 mg/dl)	27	598	459-654
IgA (70-400 mg/dl)	100	228	164-292.5
Low IgA (<70 mg/dl)	6	36	18-50
IgM (50-300 mg/dl)	100	76.5	52-114
Low IgM (<50 mg/dl)	23	38	25-43

TABLE 3. **Serum Immunoglobulin Levels in Patients with Diagnosis of Antibody Deficiency**

Age in Years	IgG (700-1,600)	IgM (50-300 mg/dl)	IgA (70 -400 mg/dl)	Diagnosis
79	1,904	8	18	Multiple myeloma
77	359	23	30	Selective antibody deficiency
54	680	24	42	Selective antibody deficiency
90	337	79	77	Selective antibody deficiency
56	1,321	100	<18	Selective IgA deficiency

Comorbidities and New Diagnoses

No significant association was found between smoking status, obesity, COPD, asthma, diabetes mellitus, and hypogammaglobinemia.

Fourteen patients with abnormal Ig levels as defined by (1) the presence of hypergammaglobinemia (elevated IgG, IgM, or IgA), (2) IgG levels <550, (3) undetectable IgA or IgM, and (4) either IgG or both IgM and IgA below the lower limit of normal underwent further evaluation. Of these 14 patients, one was diagnosed with multiple myeloma, one with selective IgA deficiency, and three with specific antibody deficiency (Table 3).

DISCUSSION

Previous research has evaluated the humoral immune system during an episode of CAP.[17-20] Studies on Ig levels in patients with CAP have shown hypogammaglobinemia to be associated with ICU admission and increased ICU mortality.[17,20] Additionally, patients with CAP have been shown to have lower IgG_2 levels than healthy controls. The goal of our study was to evaluate patients with CAP for humoral immunodeficiency.

In our study, the prevalence of low Ig levels in CAP was 38%, with IgG hypogammaglobinemia being the most common class of hypogammaglobinemia. This rate is slightly higher than that found in a previous work by de la Torri et al.,[21] who reported a prevalence of 28.9% in the inpatient population. The lower prevalence in the de la Torri et al. study was likely secondary to the exclusion of patients who did not have recorded Ig levels.[21] Additionally, de la Torri et al. noted an inverse relationship between serum IgG levels and CURB-65. These results were not replicated in our analysis. This is likely due to the relatively low number of patients in each category of CURB-65 score in our study focusing only on inpatients. However, low IgG levels were associated with increased length of stay (5 days, IQ range [3-10] vs 3 days, IQ range [2-5]).

Sepsis can cause hypogammaglobinemia.[22,23] The mechanism behind this phenomenon remains unclear, but several theories have been proposed. Sepsis results in endothelial dysfunction, vascular leakage, lymphopenia, and quantitative and qualitative defects in T and B cells.[23] This potentially leads to impaired production and increased catabolism of immunoglobulins. Immunoglobulins play an essential role in recovery from sepsis, and there may be increased consumption during acute illness.[24-28] Regardless of the mechanism, hypogammaglobinemia with SIRS, sepsis, and septic shock has been shown to be a risk factor for increased mortality in these patients.[22,23] There is currently no consensus on the optimal time to screen for humoral immunodeficiency or evaluate the immune system after infection, such as CAP. Some would argue that Ig levels are lower during an active illness and, therefore, this may not be an appropriate time to evaluate Ig levels. However, we believe that inpatient hospitalization for CAP provides a window of opportunity to selectively screen these patients at higher risk for PIDD for underlying immune defects. A hospital-based approach as demonstrated in this study may be more productive than relying on an outpatient evaluation, which often may not occur due to patient recall and/or fragmentation of care, thus leading to the well-recognized delay in diagnosis of immunodeficiency.[5,6]

In our study, one patient was diagnosed with multiple myeloma, three were diagnosed with specific antibody deficiency, and one was diagnosed with selective IgA deficiency. The patient with multiple myeloma was a 79-year old male who presented with his first ever episode of CAP, along with modest anemia and a creatinine of 1.6. His only other infectious history included an episode of sinusitis and one episode of pharyngitis. Additional evaluation included serum and urine electrophoresis, followed by bone marrow biopsy. This patient's multiple myeloma diagnoses may have been missed if Ig levels had not been evaluated. Three patients were diagnosed with specific antibody deficiency. All these patients were above 50 years of age; two out of the three patients in this group had experienced a previous episode of pneumonia, and one had a history of recurrent sinusitis. Lastly, one patient was diagnosed with selective IgA deficiency as defined by undetectable IgA in the setting of normal IgG and IgM. This 56-year-old patient had a history of multiple episodes of sinusitis and three previous episodes of pneumonia, one requiring inpatient hospitalization. Earlier diagnosis of patients with specific antibody deficiency and selective IgA deficiency can guide management, which focuses on appropriate vaccination, the use of prophylactic antibiotics, and the possible role of Ig replacement in patients with specific antibody deficiency.

Of the 100 patients who underwent screening for immunodeficiency in the setting of CAP, five were found to have clinically significant humoral immunodeficiency, resulting in a number needed to screen of 20 to detect a clinically meaningful immunodeficiency in the setting of CAP. The number needed

to screen by colonoscopy to detect one large bowel neoplasm in patients >50 years of age is 23.[29] The number needed to screen to diagnose one occult cancer after an unprovoked DVT is 91.[30] Based on this information, we feel that future, larger studies are required to evaluate the utility and cost-effectiveness of routine Ig screening for CAP requiring inpatient hospital admission.

We acknowledge limitations to this study. First, this study only evaluated adults in the inpatient floor setting, and therefore the results cannot be applied to the pediatric population or patients in the outpatient or ICU setting. Second, rather than completing a follow-up evaluation in all patients with abnormal immunoglobulins, we selected patients for additional evaluation based on criteria predefined by an immunologist. Although our rationale was to minimize additional diagnostic testing in individuals with mild hypogammaglobinemia, we acknowledge that this could have led to missing subtler humoral defects, such as a patient with near-normal Ig levels but a suboptimal response to vaccination. Third, due to the design of the study, we did not have a healthy matched control group. Despite these limitations, we believe our results are clinically meaningful and warrant future, larger scale investigation.

In conclusion, there is a high prevalence of hypogammaglobinemia in patients admitted with the diagnosis of CAP. IgG hypogammaglobinemia is the most commonly decreased class of Ig, and hospital length of stay is significantly longer in patients with low levels of IgG during admission for CAP. Additional immune evaluation of patients with CAP and abnormal Ig levels may also result in the identification of underlying antibody deficiency or immunoproliferative disorders.

Disclosures: The authors have nothing to disclose

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Effectiveness of SIESTA on Objective and Subjective Metrics of Nighttime Hospital Sleep Disruptors

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We created Sleep for Inpatients: Empowering Staff to Act (SIESTA), which combines electronic "nudges" to forgo nocturnal vitals and medications with interprofessional education on improving patient sleep. In one "SIESTA-enhanced unit," nurses received coaching and integrated SIESTA into daily huddles; a standard unit did not. Six months pre- and post-SIESTA, sleep-friendly orders rose in both units (foregoing vital signs: SIESTA unit, 4% to 34%; standard, 3% to 22%, $P < .001$ both; sleep-promoting VTE prophylaxis: SIESTA, 15% to 42%; standard, 12% to 28%, $P < .001$ both). In the SIESTA-enhanced unit, nighttime room entries dropped by 44% (−6.3 disruptions/room, $P < .001$), and patients were more likely to report no disruptions for nighttime vital signs (70% vs 41%, $P = .05$) or medications (84% vs 57%, $P = .031$) than those in the standard unit. The standard unit was not changed. Although sleep-friendly orders were adopted in both units, a unit-based nursing empowerment approach was associated with fewer nighttime room entries and improved patient experience. *Journal of Hospital Medicine* 2019;14:38-41. © 2019 Society of Hospital Medicine

Although sleep is critical to patient recovery in the hospital, hospitalization is not restful,[1,2] and inpatient sleep deprivation has been linked to poor health outcomes.[1-4] The American Academy of Nursing's *Choosing Wisely*® campaign recommends nurses reduce unnecessary nocturnal care.[5] However, interventions to improve inpatient sleep are not widely implemented.[6] Targeting routine disruptions, such as overnight vital signs, by changing default settings in the electronic health record (EHR) with "nudges" could be a cost-effective strategy to improve inpatient sleep.[4,7]

We created Sleep for Inpatients: Empowering Staff to Act (SIESTA), which pairs nudges in the EHR with interprofessional education and empowerment,[8] and tested its effectiveness on objectively and subjectively measured nocturnal sleep disruptors.

METHODS

Study Design

Two 18-room University of Chicago Medicine general-medicine units were used in this prospective study. The SIESTA-enhanced unit underwent the full sleep intervention: nursing education and empowerment, physician education, and EHR changes. The standard unit did not receive nursing interventions but received all other forms of intervention. Because physicians simultaneously cared for patients on both units, all internal medicine residents and hospitalists received the same education. The study population included physicians, nurses, and awake English-speaking patients who were cognitively intact and admitted to these two units. The University of Chicago Institutional Review Board approved this study (12-1766; 16685B).

Development of SIESTA

To develop SIESTA, patients were surveyed, and focus groups of staff were conducted; overnight vitals, medications, and phlebotomy were identified as major barriers to patient sleep.[9] We found that physicians did not know how to change the default vital signs order "every 4 hours" or how to batch-order morning phlebotomy at a time other than 4:00 AM. Nurses reported having to wake patients up at 1:00 AM for q8h subcutaneous heparin.

Behavioral Nudges

The SIESTA team worked with clinical informaticists to change the default orders in Epic™ (Epic Systems Corporation, 2017, Verona, Wisconsin) in September 2015 so that physicians would be asked, "Continue vital signs throughout the night?"[10] Previously, this question was marked "Yes" by default and hidden. While the default protocol for heparin q8h was maintained, heparin q12h (9:00 AM and 9:00 PM) was introduced as an op-

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TABLE. **Demographics of Patients (N = 1,083)**

Characteristic	SIESTA-Enhanced Unit		Standard Unit	
	Pre n = 329, 30.3%	**Post n = 293, 27.1%**	**Pre n = 252, 23.3%**	**Post n = 209, 19.3%**
Age (years) Mean, SD	54.3, 19.1	55.1, 20.8	59.0, 19.2	62.3, 16.1
Gender (% female)	58.6%	60.1%	57.9%	54.6%
Length of Stay (days) Median (IQR)	4 (2-7)	5 (2-8)	4 (2-8)	5 (3-8)
Race (% African- American)	64.4%	62.8%	67.1%	75.1%
Outcomes				
Sleep-Promoting Order Set Usage				
Vital Signs n = 168 uses	11, 6.5%	104, 62%	7, 4.2%	46, 27.4%
Heparin n = 147 uses	23, 15.6%	73, 49.7%	16, 10.9%	35, 23.8%
Patients Reporting a Sleep Disruption n = 201 surveyed	48, 59%	11, 34%	27, 56.3%	21, 56.7%

No major differences in demographics among patients admitted before and after SIESTA in each unit were observed. Although the difference is clinically small, patients admitted to the standard unit were older than those admitted to the SIESTA-enhanced unit in both periods ($P < .05$).

tion, since q12h heparin is equally effective for VTE prophylaxis.[11] Laboratory ordering was streamlined so that physicians could batch-order laboratory draws at 6:00 AM or 10:00 PM.

SIESTA Physician Education

We created a 20-minute presentation on the consequences and causes of in-hospital sleep deprivation and evidence-based behavioral modification. We distributed pocket cards describing the mnemonic SIESTA (Screen patients for sleep disorders, Instruct patients on sleep hygiene, Eliminate disruptions, Shut doors, Treat pain, and Alarm and noise control). Physicians were instructed to consider forgoing overnight vitals, using clinical judgment to identify stable patients, use a sleep-promoting VTE prophylaxis option, and order daily labs at 10:00 PM or 6:00 AM. An online educational module was sent to staff who missed live sessions due to days off.

SIESTA-Enhanced Unit

In the SIESTA-enhanced unit, nurses received education using pocket cards and were coached to collaborate with physicians to implement sleep-friendly orders. Customized signage depicting empowered nurses advocating for patients was posted near the huddle board. Because these nurses suggested adding SIESTA to the nurses' ongoing daily huddles at 4:00 PM and 3:00 AM, beginning on January 1, 2016, nurses were asked to identify at least two stable patients for sleep-friendly orders at the huddle. Night nurses incorporated SIESTA into their handoff to day nurses for eligible patients. Day nurses would then call physicians to advocate changing of orders.

Data Collection

Objectively Measured Sleep Disruptors

Adoption of SIESTA orders from March 2015 to March 2016 was assessed with a monthly Epic™ Clarity report. From August 1, 2015 to April 1, 2016, nocturnal room entries were recorded using the GOJO SMARTLINK™ Hand Hygiene system (GOJO Industries Inc., 2017, Akron, Ohio). This system includes two components: the hand-sanitizer dispensers, which track dispenses (numerator), and door-mounted Activity Counters, which use heat sensors that react to body heat emitted by a person passing through the doorway (denominator for hand-hygiene compliance). For our analysis, we only used Activity Counter data, which count room entries and exits, regardless of whether sanitizer was dispensed.

Patient-Reported Nighttime Sleep Disruptions

From June 2015 to March 2016, research assistants administered a 10-item Potential Hospital Sleep Disruptions and Noises Questionnaire (PHSDNQ) to patients in both units. Responses to this questionnaire correlate with actigraphy-based sleep measurements.[9,12,13] Surveys were administered every other weekday to patients available to participate (eg, willing to participate, on the unit, awake). Survey data were stored on the REDCap Database (Version 6.14.0; Vanderbilt University, 2016, Nashville, Tennessee). Pre- and post-intervention Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) "top-box ratings" for percent quiet at night and percent pain well controlled were also compared.

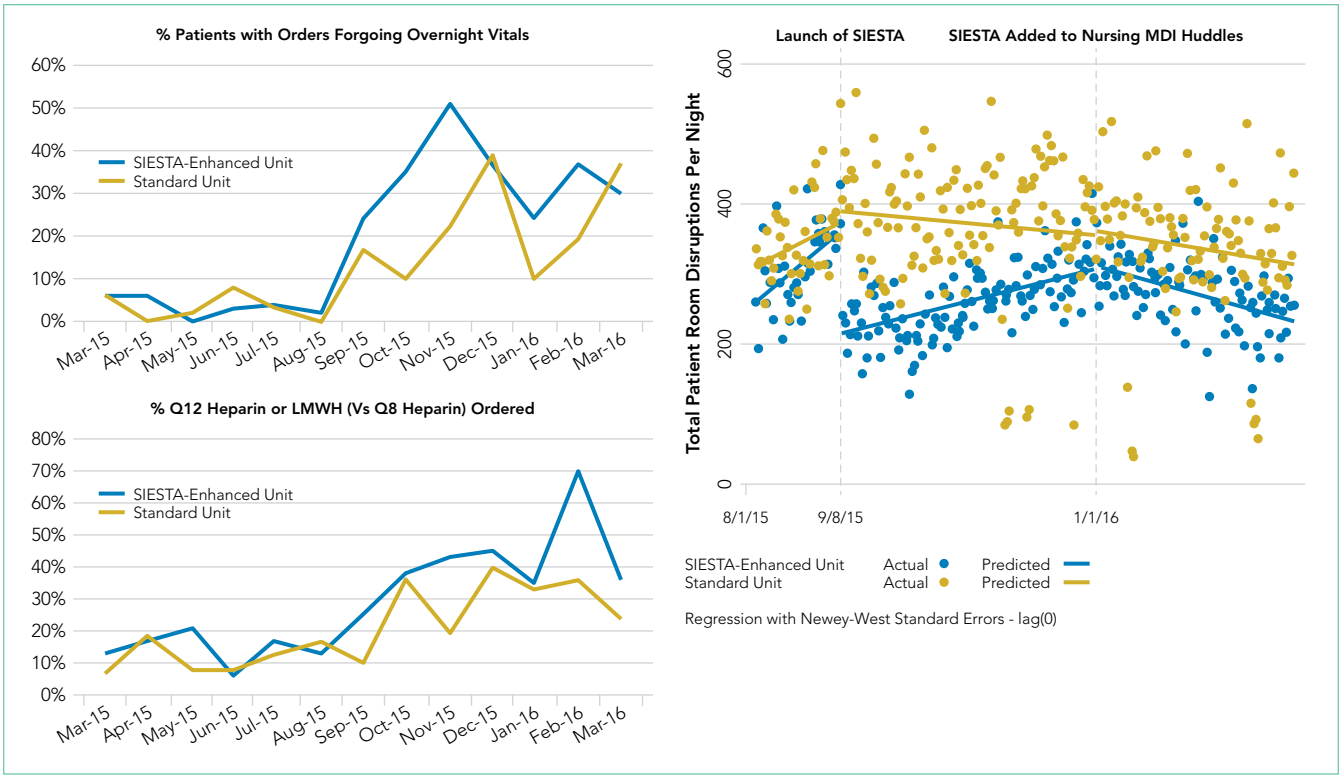

FIG. Sleep-promoting admission orders in EpicTM before and after SIESTA and interrupted time-series showing disruptions per night in SIESTA-enhanced and standard units.

Left: From admit orders with thromboembolism prophylaxis, the monthly percent of orders with q12h heparin or daily enoxaparin was calculated (vs q8h heparin). Patients who were not receiving for thromboembolism prophylaxis are excluded (ie, ongoing anticoagulation, bleeding, allergy, not indicated). From all admit orders per unit, the monthly percent of orders with discontinued overnight vitals was calculated.

Right: Using GOJO Activity Counters to measure entries into patient rooms over 244 nights, total disruptions per night were summed across the SIESTA-enhanced unit (18 patient rooms) and standard unit (18 patient rooms). Both the dotted and dashed lines are best-fit lines from regression models. In contrast to the standard unit (yellow), there were significant deceases in nocturnal room entries after the launch of SIESTA and implementation of the nursing huddle in the SIESTA-enhanced unit (blue).

Data Analysis

Objectively Measured Potential Sleep Disruptors

The proportion of sleep-friendly orders was analyzed using a two-sample test for proportions pre-post for the SIESTA-enhanced and standard units. The difference in use of SIESTA orders between units was analyzed via multivariable logistic regression, testing for independent associations between post-period, SIESTA-enhanced unit, and an interaction term (post-period × SIESTA unit) on use of sleep-friendly orders.

Room entries per night (11:00 PM–7:00 AM) were analyzed via single-group interrupted time-series. Multiple Activity Counter entries within three minutes were counted as a single room entry. In addition, the pre-post cutoff was set to 7:00 AM, September 8, 2015; after the SIESTA launch, a second cutoff marking when SIESTA was added to the nurses' MDI Huddle was added at 7:00 AM, January 1, 2016.

Patient-Reported Nighttime Sleep Disruptions

Per prior studies, we defined a score 2 or higher as "sleep disruption."[9] Differences between units were evaluated via multivariable logistic regression to examine the association between the interaction of post-period × SIESTA-enhanced unit and odds of not reporting a sleep disruption. Significance was denoted as $P = .05$.

RESULTS

Between March 2015 and March 2016, 1,083 general-medicine patients were admitted to the SIESTA-enhanced and standard units (Table).

Nocturnal Orders

From March 2015 to March 2016, 1,669 Epic™ general medicine orders were reviewed (Figure). In the SIESTA-enhanced unit, the mean percentage of sleep-friendly orders rose for both vital signs (+31% [95% CI = 25%, 36%]; $P < .001$, $n_{pre} = 306$, $n_{post} = 306$] and VTE prophylaxis (+28% [95% CI = 18%, 37%]; $P < .001$, $n_{pre} = 158$, $n_{post} = 173$]. Similar changes were observed in the standard unit for sleep-friendly vital signs (+20% [95% CI = 14%, 25%]; $P < .001$, $n_{pre} = 252$, $n_{post} = 219$) and VTE prophylaxis (+16% [95% CI = 6%, 25%]; $P = .002$, $n_{pre} = 130$, $n_{post} = 125$). Differences between the two units were not statistically significant, and no significant change in timing of laboratory orders postintervention was found.

Nighttime Room Entries

Immediately after SIESTA launch, an average decrease of 114 total entries/night were noted in the SIESTA-enhanced unit, ([95% CI = −138, −91]; $P < .001$), corresponding to a 44% reduction (−6.3 entries/room) from the mean of 14.3 entries per patient room at baseline (Figure). No statistically significant

change was seen in the standard unit. After SIESTA was incorporated into nursing huddles, total disruptions/night decreased by 1.31 disruptions/night ([95% CI = −1.64, −0.98]; $P < .001$) in the SIESTA-enhanced unit; by comparison, no significant changes were observed in the standard unit.

Patient-Reported Nighttime Sleep Disruptions

Between June 2015 and March 2016, 201 patient surveys were collected. A significant interaction was observed between the SIESTA-enhanced unit and post-period, and patients in the SIESTA-enhanced unit were more likely to report not being disrupted by medications (OR 4.08 [95% CI = 1.13–14.07]; $P = .031$) and vital signs (OR 3.35 [95% CI = 1.00–11.2]; $P = .05$) than those in the standard unit. HCAHPS top-box scores for the SIESTA unit increased by 7% for the "Quiet at night" category and 9% for the "Pain well controlled" category; by comparison, no major changes (>5%) were observed in the standard unit.

DISCUSSION

The present SIESTA intervention demonstrated that physician education coupled with EHR default changes are associated with a significant reduction in orders for overnight vital signs and medication administration in both units. However, addition of nursing education and empowerment in the SIESTA-enhanced unit was associated with fewer nocturnal room entries and improvements in patient-reported outcomes compared with those in the standard unit.

This study presents several implications for hospital initiatives aiming to improve patient sleep.[14] Our study is consistent with other research highlighting the hypothesis that altering the default settings of EHR systems can influence physician behavior in a sustainable manner.[15] However, our study also finds that, even when sleep-friendly orders are present, creating a sleep-friendly environment likely depends on the unit-based nurses championing the cause. While the initial decrease in nocturnal room entries post-SIESTA eventually faded, sustainable changes were observed only after SIESTA was added to nursing huddles, which illustrates the importance of using multiple methods to nudge staff.

Our study includes a number of limitations. It is not a randomized controlled trial, we cannot assume causality, and contamination was assumed, as residents and hospitalists worked in both units. Our single-site study may not be generalizable. Low HCAHPS response rates (10%-20%) also prevent demonstration of statistically significant differences. Finally, our convenience sampling strategy means not all inpatients were surveyed, and objective sleep duration was not measured.

In summary, at the University of Chicago, SIESTA could be associated with adoption of sleep-friendly vitals and medication orders, a decrease in nighttime room entries, and improved patient experience.

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Less Lumens-Less Risk: A Pilot Intervention to Increase the Use of Single-Lumen Peripherally Inserted Central Catheters

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To reduce risk of complications, existing guidelines recommend use of peripherally inserted central catheters (PICCs) with the minimal number of lumens. This recommendation, however, is difficult to implement in practice. We conducted a pilot study to increase the use of single-lumen PICCs in hospitalized patients. The intervention included (1) education for physicians, pharmacists, and nurses; (2) changes to the electronic PICC order-set that set single lumen PICCs as default; and (3) criteria defining when use of multilumen PICCs is appropriate. The intervention was supported by real-time monitoring and feedback. Among 226 consecutive PICCs, 64.7% of preintervention devices were single lumen versus 93.6% postintervention ($P < .001$). The proportion of PICCs with an inappropriate number of lumens decreased from 25.6% preintervention to 2.2% postintervention ($P < .001$). No cases suggesting inadequate venous access or orders for the placement of a second PICC were observed. Implementing a single-lumen PICC default and providing education and indications for multilumen devices improved PICC appropriateness. *Journal of Hospital Medicine* 2019;14:42-46. Published online first October 31, 2018.

Vascular access is a cornerstone of safe and effective medical care. The use of peripherally inserted central catheters (PICCs) to meet vascular access needs has recently increased.[1,2] PICCs offer several advantages over other central venous catheters. These advantages include increased reliability over intermediate to long-term use and reductions in complication rates during insertion.[3,4]

Multiple studies have suggested a strong association between the number of PICC lumens and risk of complications, such as central-line associated bloodstream infection (CLABSI), venous thrombosis, and catheter occlusion.[5-8,9,10-12] These complications may lead to device failure, interrupt therapy, prolonged length of stay, and increased healthcare costs.[13-15] Thus, available guidelines recommend using PICCs with the least clinically necessary number of lumens.[1,16] Quality improvement strategies that have targeted decreasing the number of PICC lumens have reduced complications and healthcare costs.[17-19] However, variability exists in the selection of the number of PICC lumens, and many providers request multilumen devices "just in case" additional lumens are needed.[20,21] Such variation in device selection may stem from the paucity of information that defines the appropriate indications for the use of single- versus multilumen PICCs.

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Therefore, to ensure appropriateness of PICC use, we designed an intervention to improve selection of the number of PICC lumens.

METHODS

We conducted this pre–post quasi-experimental study in accordance with SQUIRE guidelines.[22] Details regarding clinical parameters associated with the decision to place a PICC, patient characteristics, comorbidities, complications, and laboratory values were collected from the medical records of patients. All PICCs were placed by the Vascular Access Service Team (VAST) during the study period.

Intervention

The intervention consisted of three components: first, all hospitalists, pharmacists, and VAST nurses received education in the form of a CME lecture that emphasized use of the Michigan Appropriateness Guide for Intravenous Catheters (MAGIC).[1] These criteria define when use of a PICC is appropriate and emphasize how best to select the most appropriate device characteristics such as lumens and catheter gauge. Next, a multidisciplinary task force that consisted of hospitalists, VAST nurses, and pharmacists developed a list of indications specifying when use of a multilumen PICC was appropriate.[1] Third, the order for a PICC in our electronic medical record (EMR) system was modified to set single-lumen PICCs as default. If a multilumen PICC was requested, text-based justification from the ordering clinician was required.

As an additional safeguard, a VAST nurse reviewed the num-

ber of lumens and clinical scenario for each PICC order prior to insertion. If the number of lumens ordered was considered inappropriate on the basis of the developed list of MAGIC recommendations, the case was referred to a pharmacist for additional review. The pharmacist then reviewed active and anticipated medications, explored options for adjusting the medication delivery plan, and discussed these options with the ordering clinician to determine the most appropriate number of lumens.

Measures and Definitions

In accordance with the criteria set by the Centers for Disease Control National Healthcare Safety Network,[23] CLABSI was defined as a confirmed positive blood culture with a PICC in place for 48 hours or longer without another identified infection source or a positive PICC tip culture in the setting of clinically suspected infection. Venous thrombosis was defined as symptomatic upper extremity deep vein thromboembolism or pulmonary embolism that was radiographically confirmed after the placement of a PICC or within one week of device removal. Catheter occlusion was captured when documented or when tPA was administered for problems related to the PICC. The appropriateness of the number of PICC lumens was independently adjudicated by an attending physician and clinical pharmacist by comparing the indications of the device placed against predefined appropriateness criteria.

Outcomes

The primary outcome of interest was the change in the proportion of single-lumen PICCs placed. Secondary outcomes included (1) the placement of PICCs with an appropriate number of lumens, (2) the occurrence of PICC-related complications (CLABSI, venous thrombosis, and catheter occlusion), and (3) the need for a second procedure to place a multilumen device or additional vascular access.

Statistical Analysis

Descriptive statistics were used to tabulate and summarize patient and PICC characteristics. Differences between pre- and postintervention populations were assessed using χ^2, Fishers exact, *t*-, and Wilcoxon rank sum tests. Differences in complications were assessed using the two-sample tests of proportions. Results were reported as medians (IQR) and percentages with corresponding 95% confidence intervals. All statistical tests were two-sided, with $P < .05$ considered statistically significant. Analyses were conducted with Stata v.14 (stataCorp, College Station, Texas).

Ethical and Regulatory Oversight

This study was approved by the Institutional Review Board at the University of Michigan (IRB#HUM00118168).

RESULTS

Of the 133 PICCs placed preintervention, 64.7% (n = 86) were single lumen, 33.1% (n = 44) were double lumen, and 2.3% (n = 3) were triple lumen. Compared with the preintervention period, the use of single-lumen PICCs significantly increased following the intervention (64.7% to 93.6%; $P < .001$; Figure 1).

Simultaneous administration of multiple incompatible medications

TPN infusion with concurrent need for additional IV medications

Simultaneous use of continuous vesicant or irritant chemotherapy with other medications

Double Lumen: IV tacrolimus, IV fosarnet, IV cytarabine or doxorubicin/vincristine as a combined infusion with simultaneous use of additional IV medications.

Triple Lumen: continuous vesicant or irritant chemotherapy meeting the requirement for a double lumen PICC plus actively receiving blood products.

Need for vasopressors

ie continuous use of phenylephrine, vasopressin, dopamine, norepinephrine, epinephrine, dobutamine, milrinone.

FIG 1. Michigan Multilumen PICC Criteria

Abbreviations: IV, intravenous; PICC, peripherally inserted central catheter; TPN, total parenteral nutrition.

As well, the proportion of PICCs with an inappropriate number of lumens decreased from 25.6% to 2.2% ($P < .001$;Table 1).

Preintervention, 14.3% (95% CI = 8.34-20.23) of the patients with PICCs experienced at least one complication (n = 19). Following the intervention, 15.1% (95% CI = 7.79-22.32) of the 93 patients with PICCs experienced at least one complication (absolute difference = 0.8%, $P = .872$). With respect to individual complications, CLABSI decreased from 5.3% (n = 7; 95% CI = 1.47-9.06) to 2.2% (n = 2; 95% CI = −0.80-5.10; $P = .239$). Similarly, the incidence of catheter occlusion decreased from 8.3% (n = 11; 95% CI = 3.59-12.95) to 6.5% (n = 6; 95% CI = 1.46-11.44; $P = .610$; Table). Notably, only 12.1% (n = 21) of patients with a single-lumen PICC experienced any complication, whereas 20.0% (n = 10) of patients with a double lumen, and 66.7% (n = 2) with a triple lumen experienced a PICC-associated complication ($P = .022$). Patients with triple lumens had a significantly higher incidence of catheter occlusion compared with patients that received double- and single-lumen PICCs (66.7% vs. 12.0% and 5.2%, respectively; $P = .003$).

No patient who received a single-lumen device required a second procedure for the placement of a device with additional lumens. Similarly, no documentation suggesting an insufficient number of PICC lumens or the need for additional vascular access (eg, placement of additional PICCs) was found in medical records of patients postintervention. Pharmacists supporting the interventions and VAST team members reported no disagreements when discussing number of lumens or appropriateness of catheter choice.

DISCUSSION

In this single center, pre–post quasi-experimental study, a multimodal intervention based on the MAGIC criteria significantly reduced the use of multilumen PICCs. Additionally, a trend toward reductions in complications, including CLABSI and catheter occlusion, was also observed. Notably, these changes in ordering practices did not lead to requests for additional devices or replacement with a multilumen PICC when a single-lumen device was inserted. Collectively, our findings suggest that the use of single-lumen devices in a large direct care service can be feasibly

TABLE. **Patient Characteristics and Complications**

Patient Characteristic, n (%)	Preintervention (n = 133)	Postintervention (n = 93)	*P* Value
Age, mean (SD)	60.9 (1.5)	60.3 (1.8)	.802
Female	72 (54.1)	38 (40.9)	.049
Charlson, median (IQR)	4 (2-6)	4 (2-7)	.678
Smoking status			.321
Never	56 (43.4)	37 (40.2)	
Former	54 (41.9)	42 (45.7)	
Current	19 (14.7)	13 (14.1)	
Body mass index, mean (SD)	30.7 (0.9)	29.6 (1.2)	.455
Length of stay, median (IQR)	8 (5-13)	7 (5-13)	.429
Ever ICU stay	5 (3.8)	4 (4.3)	1.00
History of CLABSI and/or VTE	27 (20.3)	16 (17.2)	.559
Lab values, mean (SD)			
White blood cell count	9.4 (1.0)	10.1 (0.7)	.575
Absolute neutrophils	7.3 (0.8)	7.7 (0.5)	.732
Estimated Glomerular Filtration Rate (eGFR)	56.4 (0.9)	59.0 (0.4)	.018
eGFR < 45	118 (88.7)	92 (98.92)	.003
Medications			
Systemic anticoagulant	132 (99.3)	93 (100)	.402
Antiplatelet medication	49 (36.8)	35 (37.6)	.903
PICC Characteristics, n (%)			
Lumens			<.001
Single	86 (64.7)	87 (93.6)	
Double	44 (33.1)	6 (6.5)	
Triple	3 (2.3)	0	
Inappropriate PICC selection	34 (25.6)	2 (2.2)	<.001
Complications, n (%) (95% CI)			
CLABSI	7 (5.26) (1.47-9.06)	2 (2.15) (–0.80-5.10)	.239
VTE	4 (3.01) (0.10-5.91)	7 (7.53) (2.16-12.89)	.120
Catheter occlusion	11 (8.27) (3.59-12.95)	6 (6.45) (1.46-11.44)	.610
Any complication	19 (14.29) (8.34-20.23)	14 (15.1) (7.79-22.32)	.872

Abbreviations: CLABSI, central line-associated bloodstream infection; ICU, intensive care unit; IQR, interquartile range; PICC, peripherally inserted central catheter; SD, standard deviation; VTE, venous thromboembolism.

and safely increased through this approach. Larger scale studies that implement MAGIC to inform placement of multilumen PICCs and reduce PICC-related complications now appear necessary.

The presence of a PICC, even for short periods, significantly increases the risk of CLABSI and is one of the strongest predictors of venous thrombosis risk in the hospital setting.[19,24,25] Although some factors that lead to this increased risk are patient-related and not modifiable (eg, malignancy or intensive care unit status), increased risk linked to the gauge of PICCs and the number of PICC lumens can be modified by improving device selection.[9,18,26] Deliberate use of PICCs with the least numbers of clinically necessary lumens decreases risk of CLABSI, venous thrombosis, and overall cost.[17,19,26] Additionally, greater rates of occlusion with each additional PICC lumen may result in the interruption of intravenous therapy, the administration of costly medications (eg, tissue plasminogen activator) to salvage the PICC, and premature removal of devices should the occlusion prove irreversible.[8]

We observed a trend toward decreased PICC complications following implementation of our criteria, especially for the outcomes of CLABSI and catheter occlusion. Given the pilot nature of this study, we were underpowered to detect a statistically significant change in PICC adverse events. However, we did observe a statistically significant increase in the rate of single-lumen PICC use following our intervention. Notably, this increase occurred in the setting of high rates of single-lumen PICC use at baseline (64%). Therefore, an important takeaway from our findings is that room for improving PICC appropriateness exists even among high performers. In turn, high baseline use of single-lumen PICCs may also explain why a robust reduction in PICC complications was not observed in our study, given that other studies showing reduction in the rates of complications began with considerably

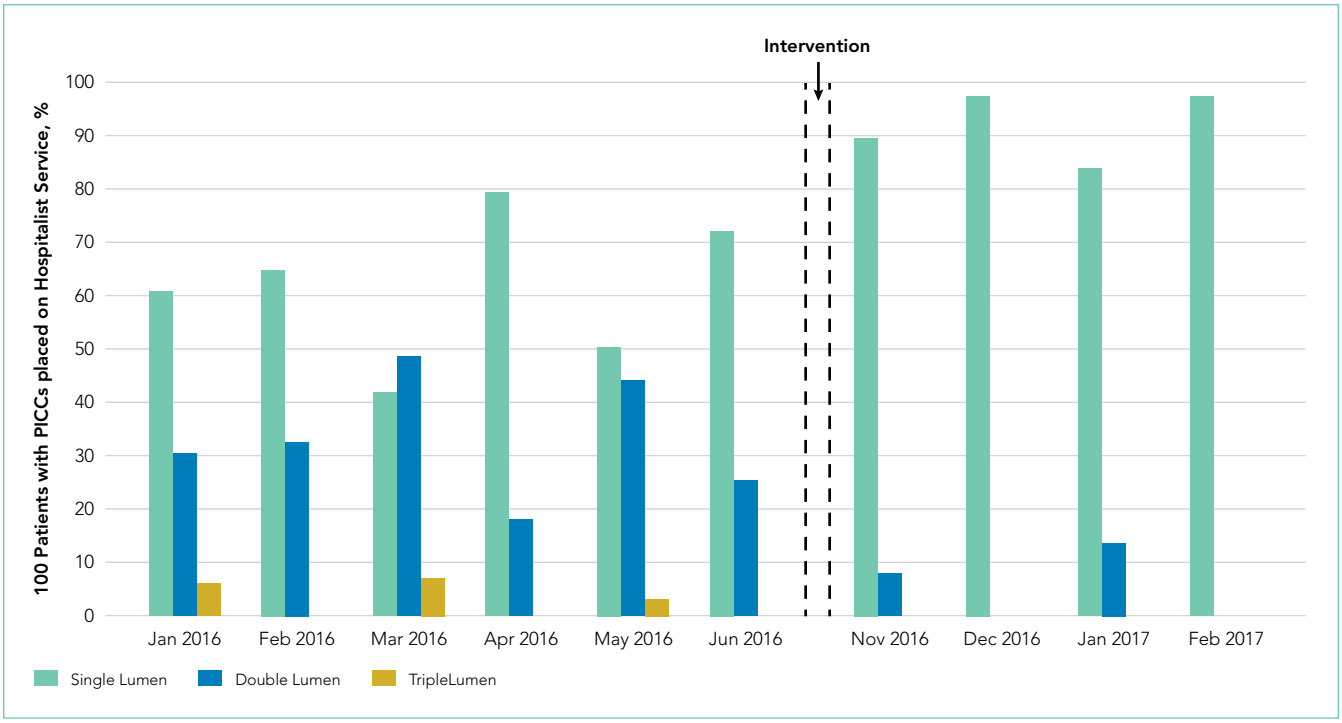

FIG 2. Utilization of PICCs by Number of Lumens, from Pre- to Postintervention.
Abbreviation: PICC, peripherally inserted central catheter

low rates of single-lumen device use.[19] Outcomes may improve, however, if we expand and sustain these changes or expand to larger settings. For example, (based on assumptions from a previously published simulation study and our average hospital medicine daily census of 98 patients) the increased use of single- over multilumen PICCs is expected to decrease CLABSI events and venous thrombosis episodes by 2.4-fold in our hospital medicine service with an associated cost savings of $74,300 each year.[17] Additionally, we would also expect the increase in the proportion of single-lumen PICCs to reduce rates of catheter occlusion. This reduction, in turn, would lessen interruptions in intravenous therapy, the need for medications to treat occlusion, and the need for device replacement all leading to reduced costs.[27] Overall, our intervention (informed by appropriateness criteria) provides substantial benefits to hospital savings and patient safety.

After our intervention, 98% of all PICCs placed were found to comply with appropriate criteria for multilumen PICC use. We unexpectedly found that the most important factor driving our findings was not oversight or order modification by the pharmacy team or VAST nurses, but rather better decisions made by physicians at the outset. Specifically, we did not find a single instance wherein the original PICC order was changed to a device with a different number of lumens after review from the VAST team. We attribute this finding to receptiveness of physicians to change ordering practices following education and the redesign of the default EMR PICC order, both of which provided a scientific rationale for multilumen PICC use. Clarifying the risk and criteria of the use of multilumen devices along with providing an EMR ordering process that supports best practice helped hospitalists "do the right thing." Additionally, setting single-lumen devices as the preselected EMR order and requiring text-based justification for placement of a multilumen PICC helped provide a nudge to physicians, much as it has done with antibiotic choices.[28]

Our study has limitations. First, we were only able to identify complications that were captured by our EMR. Given that over 70% of the patients in our study were discharged with a PICC in place, we do not know whether complications may have developed outside the hospital. Second, our intervention was resource intensive and required partnership with pharmacy, VAST, and hospitalists. Thus, the generalizability of our intervention to other institutions without similar support is unclear. Third, despite an increase in the use of single-lumen PICCs and a decrease in multilumen devices, we did not observe a significant reduction in all types of complications. While our high rate of single-lumen PICC use may account for these findings, larger scale studies are needed to better study the impact of MAGIC and appropriateness criteria on PICC complications. Finally, given our approach, we cannot identify the most effective modality within our bundled intervention. Stepped wedge or single-component studies are needed to further address this question.

In conclusion, we piloted a multimodal intervention to promote the use of single-lumen PICCs while lowering the use of multilumen devices. By using MAGIC to create appropriate indications, the use of multilumen PICCs declined and complications trended downwards. Larger, multicenter studies to validate our findings and examine the sustainability of this intervention would be welcomed.

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Things We Do for No Reason: Intermittent Pneumatic Compression for Medical Ward Patients?

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The "Things We Do for No Reason" series reviews practices that have become common parts of hospital care but 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.

CLINICAL SCENARIO

A 74-year-old man with a history of diabetes and gastrointestinal bleeding two months prior, presents with nausea/vomiting and diarrhea after eating unrefrigerated leftovers. Body mass index is 25. Labs are unremarkable except for a blood urea nitrogen of 37 mg/dL, serum creatinine of 1.6 mg/dL up from 1.3, and white blood cell count of 12 K/μL. He is afebrile with blood pressure of 100/60 mm Hg. He lives alone and is fully ambulatory at baseline. The Emergency Department physician requests observation admission for "dehydration/gastroenteritis." The admitting hospitalist orders intermittent pneumatic compression (IPC) for venous thromboembolism (VTE) prophylaxis.

BACKGROUND

The American Public Health Association has called VTE prophylaxis a "public health crisis" due to the gap between existing evidence and implementation.[1] The incidence of symptomatic deep venous thrombosis (DVT) and pulmonary embolism (PE) in hospitalized medical patients managed without prophylaxis is 0.96% and 1.2%, respectively,[2] whereas that of asymptomatic DVT in hospitalized patients is approximately 1.8%.[2,3] IPC is widely used, and an international registry of 15,156 hospitalized acutely ill medical patients found that 22% of United States patients received IPC for VTE prophylaxis compared with 0.2% of patients in other countries.[4]

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WHY YOU MIGHT THINK IPC IS THE BEST OPTION FOR VTE PROPHYLAXIS IN MEDICAL WARD PATIENTS

The main reason clinicians opt to use IPC for VTE prophylaxis is the wish to avoid the bleeding risk associated with heparin. The American College of Chest Physicians antithrombotic guideline 9th edition (ACCP-AT9) recommends mechanical prophylaxis for patients at increased risk for thrombosis who are either bleeding or at "high risk for major bleeding."[5] The guideline considered patients to have an excessive bleeding risk if they had an active gastroduodenal ulcer, bleeding within the past three months, a platelet count below 50,000/ml, or more than one of the following risk factors: age ≥ 85, hepatic failure with INR >1.5, severe renal failure with GFR <30 mL/min/m^2, ICU/CCU admission, central venous catheter, rheumatic disease, current cancer, or male gender.[5] IPC also avoids the risk of heparin-induced thrombocytopenia, which is a rare but potentially devastating condition.

Prior studies have shown that IPC reduces VTE in high-risk groups such as orthopedic, surgical, trauma, and stroke patients. The largest systematic review on the topic found 70 studies of 16,164 high-risk patients and concluded that IPC reduced the rate of DVT from 16.7% to 7.3% and PE from 2.8% to 1.2%.[6] Since the publication of this systematic review, an additional large randomized trial of immobile patients with acute stroke was published, which found a reduction in the composite endpoint of proximal DVT on screening compression ultrasound or symptomatic proximal DVT from 12.1% to 8.5%.[7] Another systematic review of 12 studies of high-risk ICU patients found that IPC conferred a relative risk of 0.5 (95% CI: 0.20-1.23) for DVT, although this result was not statistically significant.[8] Finally, a Cochrane review of studies that compared IPC combined with pharmacologic prophylaxis with pharmacologic prophylaxis alone in high-risk trauma and surgical patients found reduced PE for the combination.[9]

WHY IPC MIGHT NOT BE AS HELPFUL IN MEDICAL WARD PATIENTS

IPC devices are frequently not worn or turned on. A study at two university-affiliated level one trauma centers found IPC to be functioning properly in only 19% of trauma patients.[10] In another study of gynecologic oncology patients, 52% of IPCs were functioning improperly and 25% of patients experienced some discomfort, inconvenience, or problems with external pneumatic compression.[11] Redness, itching, or discomfort was

TABLE 1. **University of California (UC) San Diego "3 Bucket" Model Updated from the CHEST AT-8 Model**

Low Risk: Observation status with expected LOS < 48 hours. Minor ambulatory surgery unless multiple strong risk factors, Medical patients ambulating in hall and not moderate or high risk. Ambulatory cancer patients admitted for short chemotherapy infusion.	No prophylaxis but ambulate and reassess intermittently
Moderate Risk: Most general, thoracic, open gynecologic or urologic surgery patients. Active cancer or past VTE or known thrombophilia in medical patients with LOS>48 hours. Medical patients with decrease in usual ambulation AND VTE risk factors: myocardial infarction, stroke, congestive heart failure, pneumonia, active inflammation/infection, dehydration, age >65.	Pharmacologic prophylaxis (UFH or LMWH)
High Risk: Hip or knee arthroplasty, hip fracture surgery, multiple major trauma, spinal cord injury or major spinal surgery, abdominal-pelvic surgery for cancer.	IPC and pharmacologic prophylaxis (UFH or LMWH)

cited by 26% of patients, and patients removed IPCs 11% of the time when nurses left the room.[11,12] In another study, skin breakdown occurred in 3% of IPC patients as compared with 1% in the control group.[7]

Concerns about a possible link between IPC and increased fall risk was raised by a 2005 report of 40 falls by the Pennsylvania Patient Safety Reporting System,[13] and IPC accounted for 16 of 3,562 hospital falls according to Boelig and colleagues.[14] Ritsema et al. found that the most important perceived barriers to IPC compliance according to patient surveys were that the devices "prevented walking or getting up" (47%), "were tethering or tangling" (25%), and "woke the patient from sleep" (15%).[15]

IPC devices are not created equally, differing in "anatomical location of the sleeve garment, number and location of air bladders, patterns for compression cycles and duration of inflation time and deflation time."[16] Comparative effectiveness may differ. A study comparing a rapid inflation asymmetrical compression device by Venaflow with a sequential circumferential compression device by Kendall in a high-risk post knee replacement population produced DVT rates of 6.9% versus 15%, respectively (P = .007).[16,17] Furthermore, the type of sleeve and device may affect comfort and compliance as some sleeves are considered "breathable."

Perhaps most importantly, data supporting IPC efficacy in general medical ward patients are virtually nonexistent. Ho's meta-analysis of IPC after excluding surgical patients found a relative risk (RR) of 0.53 (95% CI: 0.35-0.81, P < .01) for DVT in nine trials and a nonstatistically significant RR of 0.64 (95% CI: 0.29-1.42. P = .27) for PE in six trials.[6] However, if high-risk populations such as trauma, critical care, and stroke are excluded, then the only remaining study is a letter to the editor published in 1982 that compared 20 patients with unstable angina treated with IPC with 23 controls and found a nonsignificant reduction in screened VTE.[18] Given the near complete lack of data supporting IPC in medical patients, the ACCP-AT9 guideline rates the strength of evidence recommendation to use IPC only in medical patients who are currently bleeding or at high risk of major bleeding as "2C," which is defined as "weak recommendation" based on "low-quality or very low-quality evidence."[19] Similarly, the latest American College of Physicians guidelines (2011) recommend pharmacologic prophylaxis for medical patients rather than IPC, except when bleeding risk outweighs the likely benefit of pharmacologic prophylaxis. The guidelines specifically recommend against graduated compression stockings given the lack of efficacy and increased risk of skin breakdown.[20]

IPC is expensive. The cost for pneumatic compression boots is quoted in the literature at $120 with a range of $80-$250.[21] Furthermore, patients averaged 2.5 pairs per hospitalization.[22] An online search of retail prices revealed a pair of knee-length Covidien 5329 compression sleeves at $299.19 per pair[23] and knee-length Kendall 7325-2 compression sleeves at $433.76 per pair[24] with pumps costing $7,518.07 for Venodyne 610 Advantage,[25] $6,965.98 for VenaFlow Elite,[26] and $5,750.50 for Covidien 29525 700 series Kendall SCD.[27] However, using these prices would be overestimating costs given that hospitals do not pay retail prices. A prior surgical cost/benefit analysis used a prevalence of 6.9% and a 69% reduction of DVT.[28] However, recent data showed that VTE incidence in 31,219 medical patients was only 0.57% and RR for a large VTE prevention initiative was a nonsignificant 10% reduction.[29] Even if we use a VTE prevalence of 1% for the general medical floor and 0.5% RR reduction, 200 patients would need to be treated to prevent one symptomatic VTE and would cost about $24,000 for IPC sleeves alone (estimating $120 per patient) without factoring in additional costs of pump purchase or rental and six additional episodes of anticipated skin breakdown. In comparison, the cost for VTE treatment ranges from $7,712 to $16,644.[30]

WHAT SHOULD WE DO INSTEAD?

First, one should consider if VTE prophylaxis is needed based on risk assessment. According to the Agency for Healthcare Research and Quality (AHRQ), the most widely used risk stratification model is the University of California San Diego "3 bucket model" (Table 1) derived from tables in ACCP-AT8 guidelines.[31] The Caprini risk assessment model has been validated for surgical patients, but AHRQ offers caveats related to the complexity of the tool, the difficulty many sites have integrating it into order sets, and the negative experience of the Michigan Hospital Medicine Safety Consortium. The consortium enrolled 43 hospitals with the great majority using the Caprini risk assessment model, but it failed to reduce VTE in medical patients.[31] Alternatively, the ACCP-AT9 guidelines recommend the Padua prediction score for risk assessment of medical patients (Table 2). VTE occurs in 0.3% of low-risk patients (Padua score <4) and 11.0% of high-risk patients (Padua score ≥4). If IPC is used in the low-risk populations with a predicted VTE rate of 0.3, then 666 patients would need to be treated to prevent one VTE. Treating 666 patients would cost

TABLE 2. **Padua Prediction Score to Assess Risk Factors for VTE in Hospitalized Medical Patients (score <4 = low risk; score ≥4 = high risk)**

Risk Factor	Points
Active cancer	3
Previous VTE (excluding superficial vein thrombosis)	3
Reduced mobility	3
Thrombophilia	3
Trauma and/or surgery in past month	2
Age ≥ 70	1
Heart or respiratory failure	1
Acute myocardial infarction or stroke	1
Acute infection or rheumatologic disorder	1
Obesity BMI ≥ 30	1
Ongoing hormonal treatment	1

$79,920 for IPC sleeves alone plus $5,500-$7,500 per pump and result in 20 additional episodes of skin breakdown. Therefore, IPC should be reserved for high-risk populations with contraindications to pharmacologic prophylaxis.

RECOMMENDATIONS

- The VTE risk of general medicine ward patients should be assessed, preferably with the "3 bucket" or Padua risk assessment models.
- For low-risk patients, no VTE prophylaxis is indicated. Ambulation ought to be encouraged for low-risk patients.
- If prophylaxis is indicated, then bleeding risk should be assessed to determine a contraindication to pharmacologic prophylaxis. If there is excessive bleeding risk, then treatment with IPC may be considered even though there are only data to support this in high-risk populations such as surgical, stroke, trauma, and critical care patients.
- If using IPC, then strategies that ensure compliance and consider patient comfort based on type and location of sleeves should be implemented.
- Combined IPC and pharmacologic prophylaxis should be used for high-risk trauma or surgical patients.

CONCLUSIONS

No current evidence supports IPC efficacy in general medical ward patients despite its widespread use; thus, prospective trials in this population are needed. Given costs, potential side effects, and uncertain efficacy in general medical ward patients, IPC should be reserved for surgical, trauma, critical care, or stroke patients. It may be considered for moderate to high-risk medical patients with excessive bleeding risk. Our clinical scenario patient bled within the past three months (odds ratio for bleeding 3.64; 95% CI, 2.21-5.99).[32] On the basis of the increased risk, a dutiful hospitalist might be tempted to order IPC. However, given that our patient is ambulatory, is toileting frequently, and has an expected observation stay of less than 48 hours, he is considered low risk for VTE (Table 1). Additionally, his Padua score of two confirms his low risk status (Table 2). No VTE prophylaxis would be indicated.

Do you think this is a low-value practice? Is this truly a "Thing We Do for No Reason?" Share what you do in your practice and join in the conversation online by retweeting it on Twitter (#TWDFNR) and liking it on Facebook. We invite you to propose ideas for other "Things We Do for No Reason" topics by emailingTWDFNR@hospitalmedicine.org.

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The Basement Flight

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 14-year-old girl with a history of asthma presented to the Emergency Department (ED) with three months of persistent, nonproductive cough, and progressive shortness of breath. She reported fatigue, chest tightness, orthopnea, and dyspnea with exertion. She denied fever, rhinorrhea, congestion, hemoptysis, or paroxysmal nocturnal dyspnea.

Her age and past medical history of asthma are incongruent with her new symptoms, as asthma is typified by intermittent exacerbations, not progressive symptoms. Thus, another process, in addition to asthma, is most likely present; it is also important to question the accuracy of previous diagnoses in light of new information. Her symptoms may signify an underlying cardiopulmonary process, such as infiltrative diseases (eg, lymphoma or sarcoidosis), atypical infections, genetic conditions (eg, variant cystic fibrosis), autoimmune conditions, or cardiomyopathy. A detailed symptom history, family history, and careful physical examination will help expand and then refine the differential diagnosis. At this stage, typical infections are less likely.

She had presented two months prior with nonproductive cough and dyspnea. At that presentation, her temperature was 36.3°C, heart rate 110 beats per minute, blood pressure 119/63 mm Hg, respiratory rate 43 breaths per minute, and oxygen saturation 86% while breathing ambient air. A chest CT with contrast demonstrated diffuse patchy multifocal ground-glass opacities in the bilateral lungs as well as a mixture of atelectasis and lobular emphysema in the dependent lobes bilaterally (Figure 1). Her main pulmonary artery was dilated at 3.6 cm (mean of 2.42 cm with SD 0.22). She was diagnosed with atypical pneumonia. She was administered azithromycin, weaned off oxygen, and discharged after a seven-day hospitalization.

Two months prior, she had marked tachypnea, tachycardia, and hypoxemia, and imaging revealed diffuse ground-glass opacities. The differential diagnosis for this constellation of symptoms is extensive and includes many conditions that have an inflammatory component, such as atypical pneumonia caused by *Mycoplasma* or *Chlamydia pneumoniae* or a common respiratory virus such as rhinovirus or human metapneumovirus. However, two findings make an acute pneumonia unlikely to be the sole cause of her symptoms: underlying emphysema and an enlarged pulmonary artery. Emphysema is an uncommon finding in children and can be related to congenital or acquired causes; congenital lobar emphysema most often presents earlier in life and is focal, not diffuse. Alpha-1-anti-trypin deficiency and mutations in connective tissue genes such as

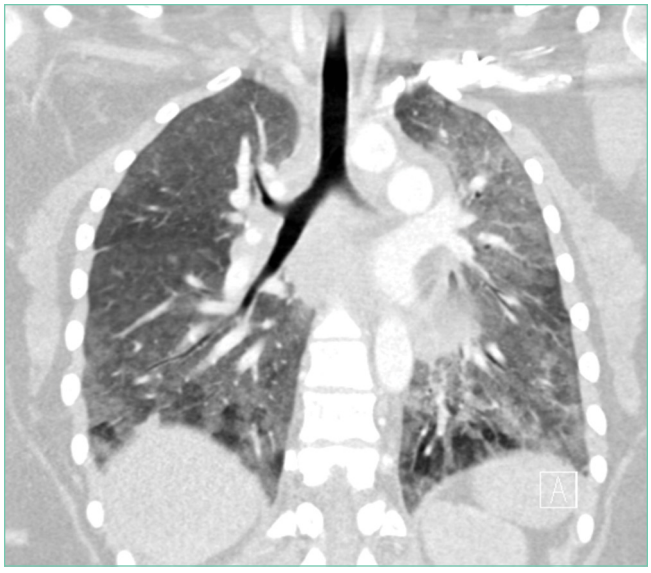

FIG 1. Coronal Chest CT demonstrating diffuse patchy ground-glass opacities in the left lung, particularly the left upper lobe. Multifocal ground-glass opacities are also noted throughout the right lung.

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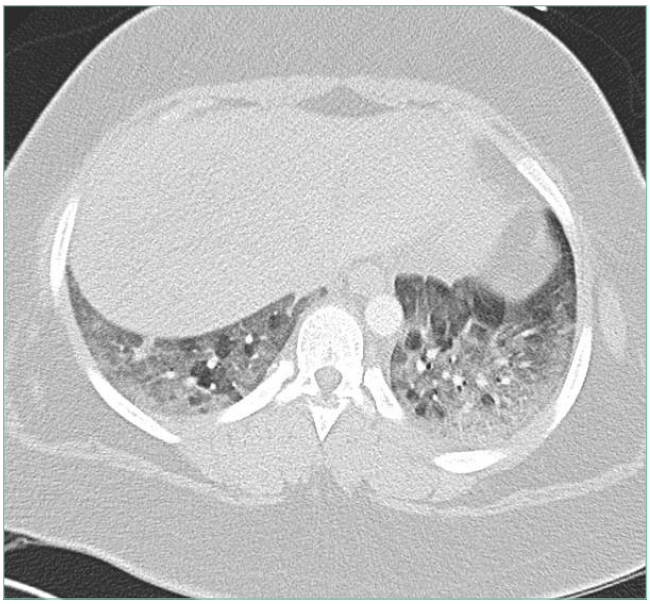

FIG 2. Axial Chest CT demonstrating diffuse centrilobular ground-glass opacities and patchy areas of lobular air-trapping with mosaic attenuation seen most prominently in the bilateral lower lobes.

those encoding for elastin and fibrillin can lead to pulmonary disease. While not diagnostic of pulmonary hypertension, her dilated pulmonary artery, coupled with her history, makes pulmonary hypertension a strong possibility. While her pulmonary hypertension is most likely secondary to chronic lung disease based on the emphysematous changes on the CT, it could still be related to a cardiac etiology.

The patient had a history of seasonal allergies and well-controlled asthma. She was hospitalized at age six for an asthma exacerbation associated with a respiratory infection. She was discharged with an albuterol inhaler, but seldom used it. Her parents denied any regular coughing during the day or night. She was morbidly obese. Her tonsils and adenoids were removed to treat obstructive sleep apnea (OSA) at age seven, and a subsequent polysomnography was normal. Her medications included intranasal fluticasone propionate and oral iron supplementation. She had no known allergies or recent travels. She had never smoked. She had two pet cats and a dog. Her mother had a history of obesity, OSA, and eczema. Her father had diabetes and eczema.

The patient's history prior to the recent few months sheds little light on the cause of her current symptoms. While it is possible that her current symptoms are related to the worsening of a process that had been present for many years which mimicked asthma, this seems implausible given the long period of time between her last asthma exacerbation and her present symptoms. Similarly, while tonsillar and adenoidal hypertrophy can be associated with infiltrative diseases (such as lymphoma), this is less common than the usual (and normal) disproportionate increase in size of the adenoids compared to other airway structures during growth in children.

She was admitted to the hospital. On initial examination, her temperature was 37.4°C, heart rate 125 beats per minute, blood pressure 143/69 mm Hg, respiratory rate 48 breaths per minute, and oxygen saturation 86% breathing ambient air. Her BMI was 58 kg/m2. Her exam demonstrated increased work of breathing with accessory muscle use, and decreased breath sounds at the bases. There were no wheezes or crackles. Cardiovascular, abdominal, and skin exams were normal except for tachycardia. At rest, later in the hospitalization, her oxygen saturation was 97% breathing ambient air and heart rate 110 bpm. After two minutes of walking, her oxygen saturation was 77% and heart rate 132 bpm. Two minutes after resting, her oxygen saturation increased to 91%.

Her white blood cell count was 11.9 x 10^9/L (67% neutrophils, 24.2% lymphocytes, 6% monocytes, and 2% eosinophils), hemoglobin 11.2 g/dL, and platelet count 278,000/mm^3. Her complete metabolic panel was normal. The C-reactive protein (CRP) was 24 mg/L (normal range, < 4.9) and erythrocyte sedimentation rate (ESR) 103 mm/hour (normal range, 0-32). A venous blood gas (VBG) showed a pH of 7.42 and pCO2 39. An EKG demonstrated sinus tachycardia.

The combination of the patient's tachypnea, hypoxemia, respiratory distress, and obesity is striking. Her lack of adventitious lung sounds is surprising given her CT findings, but the sensitivity of chest auscultation may be limited in obese patients. Her laboratory findings help narrow the diagnostic frame: she has mild anemia and leukocytosis along with significant inflammation. The normal CO_2 concentration on VBG is concerning given the degree of her tachypnea and reflects significant alveolar hypoventilation.

This marked inflammation with diffuse lung findings again raises the possibility of an inflammatory or, less likely, infectious disorder. Sjogren's syndrome, systemic lupus erythematosus (SLE), and juvenile dermatomyositis can present in young women with interstitial lung disease. She does have exposure to pets and hypersensitivity pneumonitis can worsen rapidly with continued exposure. Another possibility is that she has an underlying immunodeficiency such as common variable immunodeficiency, although a history of recurrent infections such as pneumonia, bacteremia, or sinusitis is lacking.

An echocardiogram should be performed. In addition, laboratory evaluation for the aforementioned autoimmune causes of interstitial lung disease, immunoglobulin levels, pulmonary function testing (if available as an inpatient), and potentially a bronchoscopy with bronchoalveolar lavage (BAL), and biopsy should be pursued. The BAL and biopsy would be helpful in evaluating for infection and interstitial lung disease in an expeditious manner.

A chest CT without contrast was done and compared to the scan from two months prior. New diffuse, ill-defined centrilobular ground-glass opacities were evident throughout the lung fields; dilation of the main pulmonary artery was unchanged, and previously seen ground-glass opacities had

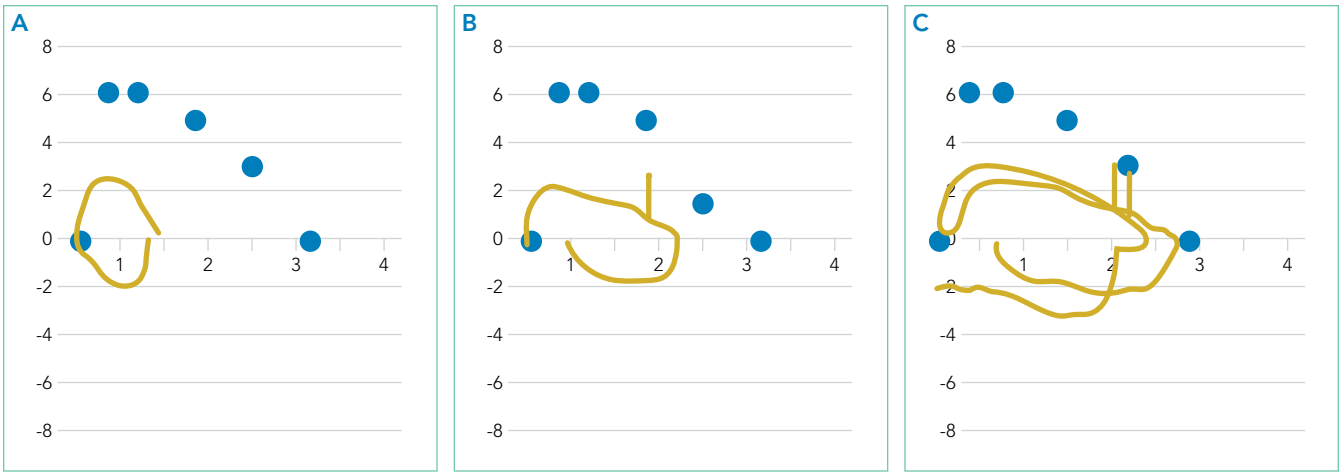

FIG 3. Spirometric Flow Volume Loops Before and After Exposure Removal. (A) At admission: FVC 1.07L (35% predicted); FEV1: 1.07L (39% predicted); FEV1/FVC 100%. (B) two months postremoval: FVC 2.00L (66% predicted); FEV1: 188L (69% predicted); FEV1/FVC: 94%. (C) 6 months postremoval: FVC: 2.74 L (95% predicted); FEV1: 2.03L (78% predicted), FEV1/FVC: 74%.

resolved. There were patchy areas of air-trapping and mosaic attenuation in the lower lobes (Figure 2). Transthoracic echocardiogram demonstrated a right ventricular systolic pressure of 58 mm Hg with flattened intraventricular septum during systole. Left and right ventricular systolic function were normal. The left ventricular diastolic function was normal. Pulmonary function testing demonstrated a FEV1/FVC ratio of 100 (112% predicted), FVC 1.07 L (35% predicted) and FEV1 1.07 L (39% predicted), and total lung capacity was 2.7L (56% predicted) (Figure 3). Single-breath carbon monoxide uptake in the lung was not interpretable based on 2017 European Respiratory Society (ERS)/American Thoracic Society (ATS) technical standards.

This information is helpful in classifying whether this patient's primary condition is cardiac or pulmonary in nature. Her normal left ventricular systolic and diastolic function make a cardiac etiology for her pulmonary hypertension less likely. Further, the combination of pulmonary hypertension, a restrictive pattern on pulmonary function testing, and findings consistent with interstitial lung disease on cross-sectional imaging all suggest a primary pulmonary etiology rather than a cardiac, infectious, or thromboembolic condition. While chronic thromboembolic hypertension can result in nonspecific mosaic attenuation, it typically would not cause centrilobular ground-glass opacities nor restrictive lung disease. Thus, it seems most likely that this patient has a progressive pulmonary process resulting in hypoxia, pulmonary hypertension, centrilobular opacities, and lower-lobe mosaic attenuation. Considerations for this process can be broadly categorized as one of the childhood interstitial lung disease (chILD). While this differential diagnosis is broad, strong consideration should be given to hypersensitivity pneumonitis, chronic aspiration, sarcoidosis, and Sjogren's syndrome. An intriguing possibility is that the patient's "response to azithromycin" two months prior was due to the avoidance of an inhaled antigen while she was in the hospital; a detailed environmental history should be explored. The normal polysomnography after tonsilloadenoidectomy makes it unlikely that OSA is a major contributor to her current presentation. However, since the surgery was seven years ago, and her BMI is presently 58 kg/m^2 she remains at risk for OSA and obesity-hypoventilation syndrome. Polysomnography should be done after her acute symptoms improve.

She was started on 5 mm Hg of continuous positive airway pressure (CPAP) at night after a sleep study on room air demonstrated severe OSA with a respiratory disturbance index of 13 events per hour. Antinuclear antibodies (ANA), anti-neutrophil cytoplasmic antibody (ANCA), anti-Jo-1 antibody, anti-RNP antibody, anti-Smith antibody, anti-Ro/SSA and anti-La/SSB antibody were negative as was the histoplasmin antibody. Serum angiotensin-converting enzyme (ACE) level was normal. Mycoplasma IgM and IgG were negative. IgE was 529 kU/L (normal range, <114).

This evaluation reduces the likelihood the patient has Sjogren's syndrome, SLE, dermatomyositis, or ANCA-associated pulmonary disease. While many patients with dermatomyositis may have negative serologic evaluations, other findings usually present such as rash and myositis are lacking. The negative ANCA evaluation makes granulomatosis with polyangiitis and microscopic polyangiitis very unlikely given the high sensitivity of the ANCA assay for these conditions. ANCA assays are less sensitive for eosinophilic granulomatosis with polyangiitis (EGPA), but the lack of eosinophilia significantly decreases the likelihood of EGPA. ACE levels have relatively poor operating characteristics in the evaluation of sarcoidosis; however, sarcoidosis seems unlikely in this case, especially as patients with sarcoidosis tend to have low or normal IgE levels. Patients with asthma can have elevated IgE levels. However, very elevated IgE levels are more common in other conditions, including allergic bronchopulmonary aspergillosis (ABPA) and the Hyper-IgE syndrome. The latter manifests with recurrent infections and eczema, and is inherited in an autosomal dominant manner.

However, both the Hyper-IgE syndrome and ABPA have much higher IgE levels than seen in this case. Allergen-specific IgE testing (including for antibodies to Aspergillus) should be sent. It seems that an interstitial lung disease is present; the waxing and waning pattern and clinical presentation, along with the lack of other systemic findings, make hypersensitivity pneumonitis most likely.

The family lived in an apartment building. Her symptoms started when the family's neighbor recently moved his outdoor pigeon coop into his basement. The patient often smelled the pigeons and noted feathers coming through the holes in the wall.

One of the key diagnostic features of hypersensitivity pneumonitis (HP) is the history of exposure to a potential offending antigen—in this case likely bird feathers—along with worsening upon reexposure to that antigen. HP is primarily a clinical diagnosis, and testing for serum precipitants has limited value, given the high false negative rate and the frequent lack of clinical symptoms accompanying positive testing. Bronchoalveolar lavage fluid may reveal lymphocytosis and reduced CD4:CD8 ratio. Crackles are commonly heard on examination, but in this case were likely not auscultated due to her obese habitus. The most important treatment is withdrawal of the offending antigen. Limited data suggest that corticosteroid therapy may be helpful in certain HP cases, including subacute, chronic and severe cases as well as patients with hypoxemia, significant imaging findings, and those with significant abnormalities on pulmonary function testing (PFT).

A hypersensitivity pneumonitis precipitins panel was sent with positive antibodies to *M. faeni, T. Vulgaris, A. Fumigatus 1 and 6, A. Flavus*, and *pigeon serum*. Her symptoms gradually improved within five days of oral prednisone (60 mg). She was discharged home without dyspnea and normal oxygen saturation while breathing ambient air. A repeat echocardiogram after nighttime CPAP for one week demonstrated a right ventricular systolic pressure of 17 mm Hg consistent with improved pulmonary hypertension.

Three weeks later, she returned to clinic for follow up. She had re-experienced dyspnea, cough, and wheezing, which improved when she was outdoors. She was afebrile, tachypneic, tachycardic, and her oxygen saturation was 92% on ambient air.

Her steroid-responsive interstitial lung disease and rapid improvement upon avoidance of the offending antigen is consistent with HP. The positive serum precipitins assay lends further credence to the diagnosis of HP, although serologic analysis with such antibody assays is limited by false positives and false negatives; further, individuals exposed to pigeons often have antibodies present without evidence of HP. History taking at this visit should ask specifically about further pigeon exposure: were the pigeons removed from the home completely, were heating-cooling filters changed, carpets cleaned, and bedding laundered? An in-home evaluation may be helpful before conducting further diagnostic testing.

She was admitted for oxygen therapy and a bronchoscopy, which showed mucosal friability and cobblestoning, suggesting inflammation. BAL revealed a normal CD4:CD8 ratio of 3; BAL cultures were sterile. Her shortness of breath significantly improved following a prolonged course of systemic steroids and removal from the triggering environment. PFTs improved with a FEV1/FVC ratio of 94 (105% predicted), FVC of 2.00 L (66% predicted), FEV1 of 1.88L (69% predicted) (Figure 3B). Her presenting symptoms of persistent cough and progressive dyspnea on exertion, characteristic CT, sterile BAL cultures, positive serum precipitants against pigeon serum, and resolution of her symptoms with withdrawal of the offending antigen were diagnostic of hypersensitivity pneumonitis due to pigeon exposure, also known as bird fancier's disease.

COMMENTARY

The patient's original presentation of dyspnea, tachypnea, and hypoxia is commonly associated with pediatric pneumonia and asthma exacerbations.[1] However, an alternative diagnosis was suggested by the lack of wheezing, absence of fever, and recurrent presentations with progressive symptoms.

Hypersensitivity pneumonitis (HP) represents an exaggerated T-cell meditated immune response to inhalation of an offending antigen that results in a restrictive ventilatory defect and interstitial infiltrates.[2] Bird pneumonitis (also known as bird fancier's disease) is a frequent cause of HP, accounting for approximately 65-70% of cases.[3] HP, however, only manifests in a small number of subjects exposed to culprit antigens, suggesting an underlying genetic susceptibility.[4] Prevalence estimates vary depending on bird species, county, climate, and other possible factors.

There are no standard criteria for the diagnosis of HP, though a combination of findings is suggestive. A recent prospective multicenter study created a scoring system for HP based on factors associated with the disease to aid in accurate diagnosis. The most relevant criteria included antigen exposure, recurrent symptoms noted within 4-8 hours after antigen exposure, weight loss, presence of specific IgG antibodies to avian antigens, and inspiratory crackles on exam. Using this rule, the probability that our patient has HP based on clinical characteristics was 93% with an area under the receiver operating curve of 0.93 (96% CI: 0.90-0.95).[5] Chest imaging (high resolution CT) often consists of a mosaic pattern of air trapping, as seen in this patient in combination with ground-glass opacities.[6] Bronchoalveolar lavage (BAL) is sensitive in detecting lung inflammation in a patient with suspected HP. On BAL, a lymphocytic alveolitis can be seen, but absence of this finding does not exclude HP.[5,7,8] Pulmonary function tests (PFTs) may be normal in acute HP. When abnormal, PFTs may reveal a restrictive pattern and reduction in carbon monoxide diffusing capacity.[7] However, BAL and PFT results are neither specific nor diagnostic of HP; it is important

to consider results in the context of the clinical picture.

The respiratory response to inhalation of the avian antigen has traditionally been classified as acute, subacute, or chronic.[9] The acute response occurs within hours of exposure to the offending agent and usually resolves within 24 hours after antigen withdrawal. The subacute presentation involves cough and dyspnea over several days to weeks, and can progress to chronic and permanent lung damage if unrecognized and untreated. In chronic presentations, lung abnormalities may persist despite antigen avoidance and pharmacologic interventions.[4,10] The patient's symptoms occurred over a six-month period which coincided with pigeon exposure and resolved during each hospitalization with steroid treatment and removal from the offending agent. Her presentation was consistent with a subacute time course of HP.

The dilated pulmonary artery, elevated right systolic ventricular pressure, and normal right ventricular function in our patient suggested pulmonary hypertension of chronic duration. Her risk factors for pulmonary hypertension included asthma, sleep apnea, possible obesity-hypoventilation syndrome, and HP-associated interstitial lung disease.[11]

The most important intervention in HP is avoidance of the causative antigen. Medical therapy without removal of antigen is inadequate. Systemic corticosteroids can help ameliorate acute symptoms though dosing and duration remains unclear. For chronic patients unresponsive to steroid therapy, lung transplantation can be considered.[4]

The key to diagnosis of HP in this patient—and to minimizing repeat testing upon the patient's recrudescence of symptoms—was the clinician's consideration that the major impetus for the patient's improvement in the hospital was removal from the offending antigen in her home environment. As in this case, taking time to delve deeply into a patient's environment—even by descending the basement stairs—may lead to the diagnosis.

LEARNING POINTS

- Consider hypersensitivity pneumonitis (HP) in patients with recurrent respiratory distress, offending exposure, and resolution of symptoms with removal of culprit antigen.
- The most important treatment of HP is removal of the offending antigen; systemic and/or inhaled corticosteroids are indicated until the full resolution of respiratory symptoms.
- Prognosis is dependent on early diagnosis and removal of offending exposures.
- Failure to treat HP might result in end-stage lung disease from pulmonary fibrosis secondary to long-term inflammation.

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Random Drug Testing of Physicians: A Complex Issue Framed in 7 Questions

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Should physicians be subject to random drug testing? It's a controversial topic. One in 10 Americans suffer from a drug use disorder at some point in their lives.[1] Although physicians engaging in drug diversion is very rare, we recognize, in the context of rising rates of opiate use, that drug misuse and addiction can involve physicians.[2,3] When it occurs, addiction can drive behaviors that endanger both clinicians and patients. Media reports on drug diversion describe an anesthesiologist who died of overdose from diverted fentanyl and a surgical technician with HIV who used and replaced opioids in the operating room, resulting in thousands of patients needing to be tested for infection.[4] Multiple outbreaks of hepatitis C involving more than a dozen hospitals in eight states were traced to a single healthcare provider diverting narcotics.[5] An investigation of outbreaks at various medical centers in the United States over a 10-year period identified nearly 30,000 patients that were potentially exposed and more than 100 iatrogenic infections.[6]

The profession of medicine holds a special place in the esteem of the public, with healthcare providers being among the most trusted professions. Patients rely on us to keep them safe when they are at their most vulnerable. This trust is predicated on the belief that the profession of medicine will self-regulate. Drug diversion by clinicians is a violation of this trust.

Our hospital utilizes existing structures to address substance use disorder; such structures include regular education on recognizing impairment for the medical staff, an impaired clinician policy for suspicion of impairment, and a state physician health program that provides nonpunitive evaluation and treatment for substance use by clinicians. In response to the imperative to mitigate the potential for drug diversion, our health system undertook a number of additional initiatives. These initiatives, included inventory control and tracking of controlled substances and random testing and trigger-based audits of returned medications to ensure the entire amount had been accounted for. As part of this system-wide initiative, UCHealth began random drug testing of employees in safety-sensitive positions (for whom impairment would represent the potential for harm to others). Medical staff are not employees of the health system and were not initially subject to testing. The key questions at the time included the following:

- Is our organization doing everything possible to prevent drug diversion?
- If nurses and other staff are subject to random drug testing, why would physicians be exempt?

The University of Colorado Hospital (UCH) is the academic medical center within UCHealth. The structure of the relationship between the hospital and its medical staff requires the question of drug testing for physicians to be addressed by the UCH Medical Board (Medical Executive Committee). Medical staff leadership and key opinion leaders were engaged in the process of considering random drug testing of the medical staff. In the process, medical staff leadership raised additional questions about the process of decision making:

- How should this issue be handled in the context of physician autonomy?
- How do we assure the concerns of the medical staff are heard and addressed?

The guiding principles considered by the medical staff leadership in the implementation of random drug testing included the following: (1) as a matter of medical professionalism, for random drug testing to be implemented, the medical staff must elect to submit to mandatory testing; (2) the random drug testing program must be designed to minimize harm; and (3) the process for random drug testing program design needs to engage front-line clinicians. This resulted in a series of communications, meetings, and outreach to groups within the medical staff.

From front-line medical staff members, we heard overwhelming consensus for the moral case to prevent patient harm resulting from drug diversion, our professional duty to address the issue, and the need to maintain public trust in the institution of medicine. At the same time, medical staff members often expressed skepticism regarding the efficacy of random drug testing as a tactic, concerns about operational implementation, and fears regarding the unintended consequences:

- How strong is the evidence that random drug testing prevents drug diversion?
- How can we be confident that false-positive tests will not cause innocent clinicians to be incorrectly accused of drug use?

The efficacy of random drug testing in preventing drug diversion is not settled. The discussion of how to proceed in the absence of well-designed studies on the tactic was robust. One common principle we heard from members of the medical staff was that our response be driven by an authentic organizational desire to reduce patient harm. They expressed

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that the process of testing needs to respect the boundaries between work and home life and to avoid the disruption of clinical responsibilities. Whether targeting testing to "higher risk" groups of clinicians is appropriate and whether or not alcohol and/or marijuana would be tested came up often.

Other concerns expressed also included the intrusion of the institution into the private medical conditions of the medical staff members, breach of confidentiality, or accessibility of the information obtained as a result of the program for unrelated legal proceedings. One of the most prominent fears expressed was the possible impact of false-positive tests on the clinicians' careers.

Following the listening tour by the medical staff and hospital leadership and extensive discussions, the Medical Board voted to approve a policy to implement random drug testing. The deliberative process lasted for approximately eight months. We sought input from other healthcare systems, such as the Veterans Administration and Cleveland Clinic, that conduct random drug tests on employed physicians. A physician from Massachusetts General Hospital who led the 2004 implementation of random drug testing for anesthesiologists was invited to come to Colorado to give grand rounds about the experience in his department and answer questions about the implementation of random drug testing at a Medical Board meeting.[7] The policy went into effect January 2017.

The design of the program sought to explicitly address the issues raised by the front-line clinicians. In the interest of equity, all specialties, including Radiology and Pathology, are subject to testing. Medical staff are selected for testing using a random number generator and retained in the random selection pool at all times, regardless of previous selection for testing. Consistent with the underlying objective of identifying drug diversion, testing is limited to drugs at higher risk for diversion (eg, amphetamine, barbiturate, benzodiazepine, butorphanol, cocaine metabolite, fentanyl, ketamine, meperidine, methadone, nalbuphine, opiates, oxycodone, and tramadol). Although alcohol and marijuana are substances of abuse, they are not substances of healthcare diversion and thus are excluded from random drug testing (although included in testing for impairment). Random drug testing is conducted only for medical staff who are onsite and providing clinical services. The individuals selected for random drug testing are notified by Employee Health, or their clinical supervisor, to present to Employee Health that day to provide a urine sample. The involvement of the clinical supervisor in specific departments and the flexibility in time of presentation was implemented to address the concerns of the medical staff regarding harm from the disruption of acute patient care.

To address the concern regarding false-positive tests, an external medical laboratory that performs testing compliant with Substance Abuse and Mental Health Services and governmental standards is used. Samples are split providing the ability to perform independent testing of two samples. The thresholds are set to minimize false-positive tests. Positive results are sent to an independent medical review officer who confidentially contacts the medical staff member to assess for valid prescriptions to explain the test results. Unexplained positive test results trigger the testing of the second half of the split sample.

To address issues of dignity, privacy, and confidentiality, Employee Health discretely oversees the urine collection. The test results are not part of the individual's medical record. Only the coordinator for random drug testing in Human Resources compliance can access the test results, which are stored in a separate, secure database. The medical review officer shares no information about the medical staff members' medical conditions. A positive drug assay attributable to a valid medical explanation is reported as a negative test.

Positive test results, which would be reported to the President of the Medical Staff, would trigger further investigation, potential Medical Board action consistent with medical staff bylaws, and reporting to licensing bodies as appropriate. We recognize that most addiction is not associated with diversion, and all individuals struggling with substance use need support. The medical staff and hospital leadership committed through this process to connecting medical staff members who are identified by random drug testing to help for substance use disorder, starting with the State Physician Health Program.

The Medical Executive Committees of all hospitals within UCHealth have also approved random drug testing of medical staff. We are not the first healthcare organization to tackle the potential for drug diversion by healthcare workers. To our knowledge, we are the largest health system to have nonemployed medical staff leadership vote for the entire medical staff to be subject to random drug testing. Along the journey, the approach of random drug testing for physicians was vigorously debated. In this regard, we proffer one final question:

- How would you have voted?

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Clinical Operations Research: A New Frontier for Inquiry in Academic Health Systems

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Patient throughput in healthcare systems is increasingly important to policymakers, hospital leaders, clinicians, and patients alike. In 1983, Congress passed legislation instructing the Centers for Medicare and Medicaid Services (CMS) to implement the "prospective payment system," which sets reimbursement for CMS hospitalizations to a fixed rate, regardless of the length of stay (LOS). Policy changes such as this coupled with increased market consolidation (ie, fewer hospitals for more patients) and increased patient acuity have created significant challenges for hospital leaders to manage patient throughput and reduce or maintain LOS.[1] Additionally, emergency department (ED) overcrowding and intensive care unit (ICU) capacity strain studies have demonstrated associations with adverse patient outcomes and quality of care.[2-5] Finally, and perhaps most importantly, the impact of these forces on clinicians and patients has compromised the patient-clinician relationship and patient experience. As patient throughput is important to multiple stakeholders, novel approaches to understanding and mitigating bottlenecks are imperative.

The article by Mishra and colleagues in this month's issue of the *Journal of Hospital Medicine* (JHM) describes one such novel methodology to evaluate patient throughput at a major academic hospital.[6] The authors utilized process mapping, time and motion study, and hospital data to simulate four discrete future states for internal medicine patients that were under consideration for implementation at their institution: (1) localizing housestaff teams and patients to specific wards; (2) adding an additional 26-bed ward; (3) adding an additional hospitalist team; and (4) adding an additional ward and team and allowing for four additional patient admissions per day. Each of these approaches improved certain metrics with the tradeoff of worsening other metrics. Interestingly, geographic localization of housestaff teams and patients alone (Future State 1) resulted in decreased rounding time and patient dispersion but increased LOS and ED boarding time. Adding an additional ward (Future State 2) had the opposite effect (ie, decreased LOS and ED boarding time but increased rounding time and patient dispersion). Adding an additional hospitalist team (Future State 3) did not change LOS or ED boarding time but reduced patient dispersion and team census. Finally, adding both a ward and hospitalist team (Future State 4) reduced LOS and ED boarding time but increased rounding time and patient dispersion. These results provide a compelling case for modeling changes in clinical operations to weigh the risks and benefits of each approach with hospital priorities prior to implementation of one strategy versus another.

This study is an important step forward in bringing a rigorous scientific approach to clinical operations. If every academic center, or potentially every hospital, were to implement the approach described in this study, the potential for improvement in patient outcomes, quality metrics, and cost reduction that have been the intents of policymakers for over 30 years could be dramatic. But even if this approach were implemented (or possibly as a result of implementation), additional aspects of hospital operations might be uncovered given the infancy of this critical field. Indeed, we can think of at least five additional factors and approaches to consider as next steps to move this field forward. First, as the authors noted, multiple additional simulation inputs could be considered, including multidisciplinary workflow (eg, housestaff, hospitalists, nurses, clinical pharmacists, respiratory therapists, social workers, case managers, physical and occupational therapists, speech and language pathologists, etc.) and allowing for patients to transfer wards and teams during their hospitalizations. Second, qualitative investigation regarding clinician burnout, multidisciplinary cohesiveness, and patient satisfaction are crucial to implementation success. Third, repeat time and motion studies would aid in assessing for changes in time spent with patients and for educational purposes under the new care models. Fourth, medicine wards and teams do not operate in isolation within a hospital. It would be important to evaluate the impact of such changes on other wards and services, as all hospital wards and services are interdependent. And finally, determining costs associated with these models is critical for hospital leadership, resource allocation, implementation, and sustainability. For example, Future State 4 would increase admissions by 1,080 per year, but would that offset the cost of opening a new ward and hiring additional clinicians?

In addition, the authors feature the profoundly important concept of "geographic localization." This construct has been investigated primarily among critically ill patients. Geographic

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dispersion has been shown to be associated with adverse clinical outcomes and quality metrics.[7] Although this has begun to be studied among ward patients,[8] the authors take this a step further by modeling future states incorporating geographic localization. Future State 4 resulted in the best overall outcomes but increased rounding time and patient dispersion, although these differences were not statistically significant. This piques our curiosity about the possibility of a fifth future state: adding geographic localization to Future State 4. Adding a new ward and new clinician team might provide a unique opportunity to geographically localize patients and to study the collective impact. Additionally, it is possible that geographic localization only improves outcomes if all teams (ie, house-staff and hospitalist teams) have geographically localized patients rather than exclusively housestaff having geographically localized patients.

Indeed, these results raise much broader and interesting questions surrounding ward capacity strain, that is, when patients' demand for clinical resources exceeds availability.[9] At our institution, we conducted a study to define the construct of ward capacity strain and demonstrated that among patients admitted to wards from EDs and ICUs in three University of Pennsylvania Health System hospitals, selected measures of patient volume, staff workload, and overall acuity were associated with longer ED and ICU boarding times. These same factors accounted for decreased patient throughput to varying, but sometimes large, degrees.[10] We subsequently used this same definition of ward capacity strain to evaluate the association with 30-day hospital readmissions. We demonstrated that ward capacity strain metrics improved prediction of 30-day hospital readmission risk in nearly one out of three hospital wards, with medications administered, hospital discharges, and census being three of the five strongest predictors of 30-day hospital readmissions.[11] These findings from our own institution further underscore the importance of the work by Mishra et al. and suggest future directions that could combine different measures of hospital throughput and patient outcomes into a more data-driven process for optimizing hospital resources, supporting the efforts of clinicians, and providing high-quality patient care.

This study is a breakthrough in the scientific rigor of hospital operations. It will lay the groundwork for a multitude of subsequent questions and studies that will move clinical operations into evidence-based practices. We find this work exciting and inspiring. We look forward to additional work from Mishra et al. and look forward to applying similar approaches to clinical operations at our institution.

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The Interplay between Financial Incentives, Institutional Culture, and Physician Behavior: An Incompletely Understood Relationship Worth Elucidating

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The United States spends approximately 18% of its gross domestic product on healthcare, nearly double the average expenditure by other high-income countries.[1] This increased financial investment does not consistently correlate with better care, as quality outcomes in the US rank well below many developed nations that spend far less on clinical care on a per capita basis.[1,2] These troubling and unsustainable spending trends have compelled national and regional policymakers, health system leaders, and researchers to search for ways to curb healthcare spending and improve healthcare value.

Approximately 32% of overall healthcare spending in the US occurs in hospitals,[3] and there is broad acknowledgment that inpatient care can be delivered more cost effectively.[4] In recent years, numerous policy interventions—including Medicare's hospital readmission reductions program, hospital-acquired condition reductions program, hospital value-based purchasing program, and the Bundled Payment for Care Improvement program—have been implemented in an effort to improve the quality and costs of inpatient care.[4,5]

These policies attempt to increase care value by utilizing innovative reimbursement techniques designed to hold clinical systems financially accountable for outcomes and spending. They are designed to move our system away from the traditional fee-for-service paradigm, which encourages overuse and has been identified as a major driver of bloated healthcare costs in the US.[6,7] The success of certain national payment reform pilots, such as the Comprehensive Care for Joint Replacement Model, indicate that payment models which hold clinicians and systems accountable hold promise for both reducing costs and improving outcomes.[8]

However, to influence clinical outcomes and costs, these national payment reforms must prompt local changes in how care is delivered and financed. Understanding systems- and clinician-level factors that enable the delivery of higher value care is, therefore, paramount for effectively translating national policies into local improvements in care value. Among hospitalists and hospital-based clinicians, institutional and clinical cultures represent an important lever for influencing physician practice patterns and, by extension, the quality and costs of care. Hospital and departmental cultures have been shown to influence physician behaviors profoundly in ways that improve quality and value, primarily via top-down initiatives focused on education and improving awareness. Examples of cultural success stories include efforts to reduce unnecessary utilization of diagnostic testing,[9] improve adoption of hand-washing techniques on wards,[10] and translate education about high-value care into sustained increases in the delivery of high-value clinical services.[11]

In "The Association of Hospitals Productivity Payments and High-Value Care Culture," Gupta et al. present the results of a study examining associations between how hospitals compensate their hospitalists—specifically the provision of performance-based incentives—and the strength of a hospital's high-value care culture.[12] The authors administered the High-Value Care Culture Survey™ (HVCCS), a validated survey instrument designed to assess the degree to which a hospital's culture promotes the delivery of high-value care, to 255 hospitalists across 12 hospitals, including safety-net, community, and university-based hospitals. The hospitals' predominant physician compensation models were grouped into three categories: salary model (no performance-based bonus), salary model with a productivity adjustment (ie, a bonus based on clinical volumes), and a salary model with a quality/value adjustment (ie, a bonus for delivering higher value care). The authors found that hospitalists who were salaried but also received productivity adjustments reported significantly lower mean HVCCS scores than salaried hospitalists who did not receive bonuses or adjustments. Compared with salaried hospitalists, hospitalists receiving compensation via salary plus value-based adjustments were nonsignificantly more likely to have higher HVCCS scores.

How are we to interpret these results? While we must be exceedingly careful about presuming causal mechanisms underlying these associations, they are nonetheless intriguing and should prompt further discussion about the relationship between payment incentives, provider behavior, and organizational culture. One potential explanation for these findings is that hospitals that rely on high clinical volumes to drive their financial performance may use productivity bonuses as a way to align hospitalists' incentives with those of their institution, thereby promoting volume at the expense of value.

Behavioral economics theory provides an alternative lens through which to interpret the work of Gupta et al. The relationship between incentives and nonfinancial sources of per-

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sonal motivation remain an important consideration in financial incentive design.[13] A basic concept in behavioral economics is that there are two fundamental types of motivation of human behavior: extrinsic motivation, where people are motivated to act by the prospect of material rewards or punishments, and intrinsic motivation, a source of motivation that leads people to behave in ways that do not produce an obvious personal or material reward.[13] Substantial evidence indicates that external rewards can have counterproductive effects on an individual's intrinsic motivation, leading to a "crowding-out" effect that decreases the individual's internal drive. When the "crowding-out" effect occurs, behaviors may be motivated by a desire to follow the rules, rather than true intrinsic drive. This change in the underlying forces motivating behavior can have a negative impact on self-esteem and result in a perceived loss of professional autonomy.[13,14] Perhaps more than any other professional group, healthcare professionals are fueled by intrinsic motivation and a yearning for professional autonomy. It is therefore plausible that doctors are particularly sensitive to, and disturbed by, the feeling that external rewards are "crowding out" this internal drive. Thus, the inverse association between productivity payments —volume-based rewards—and HVCCS scores may reflect this tension between intrinsic and extrinsic drives.

Of course, we need to interpret the authors' findings cautiously in light of the cross-sectional study design and the potential for residual confounding. Indeed, the presence of an association between how hospitalists are compensated and their perceptions of the degree to which their institution's culture promotes the delivery of high-value care does not prove that these two things are causally linked. Additionally, the small sample size limits the generalizability of these findings and efforts to draw robust conclusions from this work regarding the interplay between how a hospital pays its physicians, hospital culture, and the value of care delivered in this institution. Moreover, a more rigorous characterization of the nature of productivity payments compared with value-based performance payments and pure salaried wages would have been extremely useful to help interpret the likelihood that these payment models influenced the behavior of clinicians and perceptions of culture. In particular, how payment models define "productivity" and "quality" thresholds for achieving performance-based payments and the degree of control that physicians have on achieving them are critical determinants of the power of these incentives to influence clinician behavior and of clinicians' perceptions of the degree to which their institution cultivates a high-value culture.[14]

Despite these limitations, this study raises a number of interesting hypotheses regarding the relationship between clinician payment models, incentive design, and clinical culture that warrant further investigation. For example, how do financial incentives designed to improve the value of inpatient care actually influence the practice patterns of hospitalists? Surprisingly little is known about this topic. Does the physician payment model design generally and implementation of targeted financial incentives for delivering higher value care in particular directly influence clinical culture? If so, how? Also, does the cultural effect actually undermine the goals of the financial incentive?

More broadly, systematic efforts to evaluate how clinical and hospital cultures impact the ability of financial incentives to motivate desired changes in clinicians' behaviors will help healthcare leaders use financial incentives more effectively to motivate the delivery of higher quality, more cost-effective care. Increasing use and evaluation of different alternative payment models across hospitals nationwide represents an opportunity to characterize associations between different payment models and the delivery of high-quality, cost-effective care.[15] Parallel efforts to characterize the clinical culture of these hospitals could help to better understand if and how hospital culture mediates this relationship. Moreover, because inpatient care is increasing and, in many hospitals, primarily provided by multidisciplinary teams, additional research is needed to understand how different payment models influence inpatient clinical team performance.

The connection between culture, financial incentives, and value-based care remains difficult to determine, but essential to clarify. Gupta et al. demonstrated that how a clinical system pays its physicians appears to be associated with physicians' perceptions of how strongly the hospital's culture emphasizes the delivery of high-value care. Work culture is a profound determinant of employee happiness, satisfaction, and productivity. The consistent delivery of high-value care is undoubtedly harder in clinical cultures that do not prize and support this end. Health system leaders focused on improving care value would be wise to pay close attention to their employees' perceptions of their culture – and use these perceptions as one of several measures of their progress toward enabling their organization to deliver higher value care consistently.

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Discharge by Noon: The Time Has Come for More Times to be the Right Time

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Hospitalists have become well versed in campaigns championing safe, efficient, and timely discharges, as well as in the pragmatic challenges of achieving them. Successfully discharging a patient from the hospital requires synchronizing several elements; as a result, improvement efforts focus on promoting shared mental models and team identification of early discharges. The urgency for timely discharges, much like (and unlike[1]) hotel check-out times, becomes increasingly relevant when hospitals are functioning at or beyond full capacity. As inpatient medical care grows increasingly more specialized, promoting high-quality discharges theoretically allows for not only more beds, but also that the right bed is available for the right patient at the right time. In addition, financial realities in terms of reimbursement and the high cost of adding capacity imply that hospitals need to maximize throughput from the beds they already have. For these reasons, hospital administrators and operational leaders have focused on early discharges as a goal—and have often used discharge before noon (DCBN) as the metric to measure performance.

In this issue of the *Journal of Hospital Medicine*, Destino et al. reported that it is possible to achieve a higher percentage of early discharges, which allowed for decompression of post-anesthesia care and emergency areas without a measurable negative impact on patient or family satisfaction or length of stay (LOS).[2] The improvement they report is remarkable. However, it will be important for them to report back, as quality improvement projects often revert to prior state unless the processes are reinforced and embedded in hospital culture. In addition, what goes unreported in Destino et al. are the unmeasured and unanticipated outcomes related to focusing on a single, laudable goal. This study and others have yet to confirm that systems have enough resiliency to improve discharge timeliness without diverting resources from other aspects of care.[3] In other words, can inpatient teams do everything at the same time without sacrificing quality; ie, improve discharge timeliness, accept and admit new patients faster, respond to deteriorating patients, spend enough time with patients and families to meet their needs (and validated survey expectations), and in educational settings, meet the learning needs of trainees?[4] This may prove to be true if implementation techniques are individualized to hospitals, services, and units and are incorporated into existing workflows, minimizing extraneous "asks" on already overtaxed providers. Evidence to support this would go a long way in engaging stakeholders to prioritize quality discharges.

In this issue, too, James, et al. ask the question "if DCBN is a good indicator of shorter LOS or is DCBN an arbitrary indicator."[5] The answer may be yes, no, both, maybe, and it depends. Certainly, no pathophysiological reasons exist for a certain time of day to be the "right" time for discharge. The key question for hospitalists and health systems leaders is whether setting time goals leads clinicians to delay discharges of medically and logistically ready patients in the afternoon or evening, particularly if the metric is linked to monetary performance incentives. This is also likely a matter of degrees, ie, set the DCBN goal at 80%-100% and gaming is much more likely; set the goal at 20%-30% and this might reflect a realistic range and be less likely to incentivize gaming. Notably, the hospital in the James study did *not* have a DCBN goal. It would be interesting to see what would happen in that hospital or another hospital before and after implementing a DCBN goal—and further assess a dose-response curve. Another approach would be to perform qualitative analysis of readiness for discharge via chart reviews and determine if patients could have left in the afternoon or evening but might have been delayed to buff up the performance on the DCBN metric.

James et al. additionally demonstrate differences for medical and surgical patients, underscoring that a DCBN goal is unlikely to yield the same results in different patient cohorts or settings. The authors note several workflow reasons for this variation, but other considerations are regularity of timelines for recovery being different for surgical patients, role of elective admissions scheduled in advance, and the potential use of conditional orders (ie, orders entered before dawn that nurses can activate as patients meet criteria).

What both studies highlight is that although morning discharges can help with patient flow, hospitalists and hospital leaders need to be mindful and seek more information before implementing DCBN programs. One strategy that can promote efficient discharge regardless of the position of the sun in the sky, account for variation in patient populations and individual patients, and mitigate the potential for gaming the system is to strive toward measuring time from medical readiness to the time of discharge. Although some institutions have had success with this work,[6] it remains challenging to implement this across all patient populations. Criteria for medical readiness need to be agreed upon and validated, and then a real-time way of identifying when criteria are met needs to be developed. In this regard, hospitals may have to invest individually or collectively to build such systems, but the benefit would be to enable and promote performance of timely dis-

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charge for all patients at all times of day.

Much as we have adopted cultural changes over the years to raise awareness regarding patient safety such as nosocomial infections and hand hygiene, an emphasis on high-quality discharges too needs to become integral to hospital practices to sustain performance and any associated metrics. As to what to measure? A validated "medical readiness to discharge" may be the gold standard but may be difficult to attain. Until then, carefully constructed approaches to prioritizing early discharges through proactive planning, shared mental models, interdisciplinary teamwork, and appropriate incentives to those who do it well could yield the results we want as hospitalists, as patients, and as families.

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Nudging Providers to Improve Sleep for Hospitalized Patients

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It is 5:45 AM. Thousands of diligent interns are roaming inpatient wards, quietly entering hospital rooms, and gently nudging their patients awake. Little do they know that their rounding is part of a system that unintentionally degrades the quantity and quality of patient sleep and may leave patients worse off than the illness that originally brought them to the hospital.[1] A multitude of adverse outcomes has been associated with sleep deprivation, including aberrant glucose metabolism, impaired wound healing, impaired physical function and coordination, and altered cognition.[2] To put it simply, sleep is vital.[3] Restoring normal sleep patterns in hospitalized patients may decrease hospital length of stay, reduce hospital readmissions, and, as such, should be a new priority for quality improvement.[4]

In this edition of the *Journal of Hospital Medicine*, Arora et al. present a single-center, pre–post analysis of an intervention designed to improve sleep for hospitalized patients.[5] The SIESTA (Sleep for Inpatients: Empowering Staff to Act) intervention was composed of the following three components: provider education on patient sleep, Electronic Health Record (EHR) promotion of sleep-friendly order entry, and empowerment of nurses to actively protect patient sleep. Education and changes to order entry were implemented in two hospital units, but only one received the additional nurse-empowerment intervention. Results were compared for six months pre- and post-intervention. Although the authors found increases in sleep-friendly orders in both units, nighttime room entries and patient-reported sleep disturbance decreased only in the nurse-empowerment unit.

Previous studies assessing both pharmacologic sleep aids as well as bundled nonpharmacologic interventions have demonstrated mixed results and focused primarily on ICU populations.[6,7] What sets this study apart from prior interventions aimed at improving patient sleep is the novelty and implications of their successful intervention. In this study, the authors used the EHR and nursing huddles to "nudge" providers to protect their patients' sleep. The "nudge" concept, first studied in behavioral economics and more recently applied to healthcare, represents ways to present choices that positively influence behavior without restricting options.[8] This study incorporates two distinct nudges, one that utilized the EMR to adjust the default timing of orders for vital sign procurement and delivery of VTE-prophylaxis, and another that made sleep part of the default checklist for nursing huddles. This study suggests that nudges altered both physician and nurse behavior and encouraged improvements in process measures, if not clinical outcomes, around patient sleep.

A key insight and strength of this study was to engage and empower nurses to promote better sleep for patients. In particular, nurses in the sleep-enhanced unit suggested—during the course of the intervention—that sleep protection be added as a default item in daily huddles. As illustrated in the Figure, the timing of this suggestion corresponded with an inflection point in reducing patient room disruptions at night. This simple, low-cost nudge sustained sleep improvement while the effect of the initial higher-cost intervention using pocket cards and posters had begun to fade. This is not a randomized clinical trial, but rather a pragmatic assessment of a rigorous quality improvement initiative. Although more follow-up time, particularly after the nurse-empowerment intervention was adjusted, would be helpful to assess the durability of their intervention, we applaud the authors for demonstrating adaptability and efforts for ongoing engagement, as is needed in real-world quality improvement initiatives.

There are additional factors that disrupt patient sleep that were not targeted in this study but could very well respond to nudges. Recently, Wesselius et al. showed that patient-reported nocturnal awakenings were frequently due to toilet visits and awakening by hospital staff.[9] Perhaps nudges could be implemented to reduce unnecessary overnight intravenous fluids, prevent late dosing of diuretics, and delay the default timing of standard morning phlebotomy orders.

Although this study by Arora et al. makes a very meaningful contribution to the literature on sleep and hospitalization, it also raises unanswered questions.[5] First and foremost, while the pragmatic nature of this study should inspire other hospitals to attempt similar sleep promotion interventions, the use of a pre–post design (rather than a randomized, control design) leaves room for future studies to explore causality more rigorously. Second, although this study has demonstrated significant uptake in standardized order sets to improve sleep (and a corresponding decrease in patient-reported disruptions), future studies should also explore more distal and more chal-

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lenging outcomes of care. These could include length of stay, incidence of delirium (especially in older adults), and frequency of readmission after discharge. Finally, more longitudinal data to explore the sustainability of order set usage and reported or observed interruptions would be useful to guide hospitals that would like to follow the example set by the SIESTA study.

Notwithstanding these limitations, there is an incredible opportunity for nudges and technology to combine to change the paradigms of clinical care. One of the outcomes of this study was to reduce nocturnal room entry for clinical tasks such as obtaining vital signs. It is worth considering whether providers even need to enter patient rooms to obtain vital signs. The technology now exists to measure vitals passively and continuously via low-impact wearable devices. Milani et al. employed the use of such devices, as well as other techniques, including red-enriched light and sensors that warned staff in clinical areas when noises exceeded acceptable thresholds for sleep, and demonstrated decreases in hospital length of stay and readmission rates.[4]

Arora et al. present a compelling study of utilizing nudges to influence physician and nurse behavior.[5] They show that rigorous quality improvement initiatives can be studied and disseminated in a compelling manner. Their study calls appropriate attention to the need for improving patient sleep and provides us with additional tools that can be used in these efforts. Future research is needed to determine whether the changes observed in process measures will translate into meaningful effects on clinical outcomes and to continue to identify ways to curb some of the toxicities of hospital care.

Disclosures: The authors have nothing to disclose.

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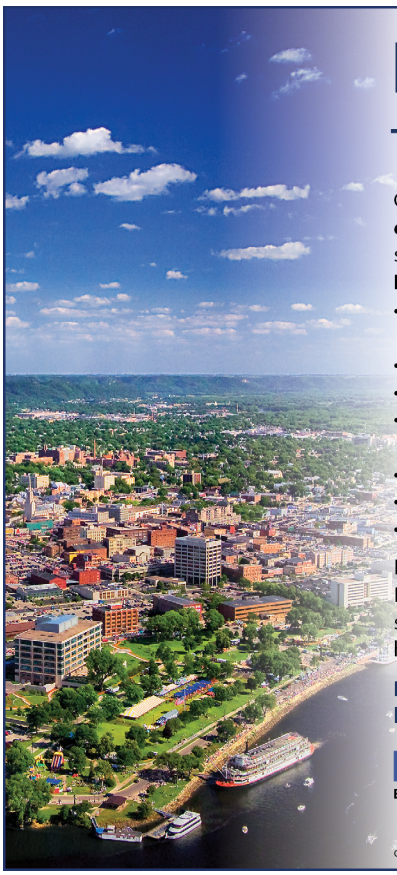

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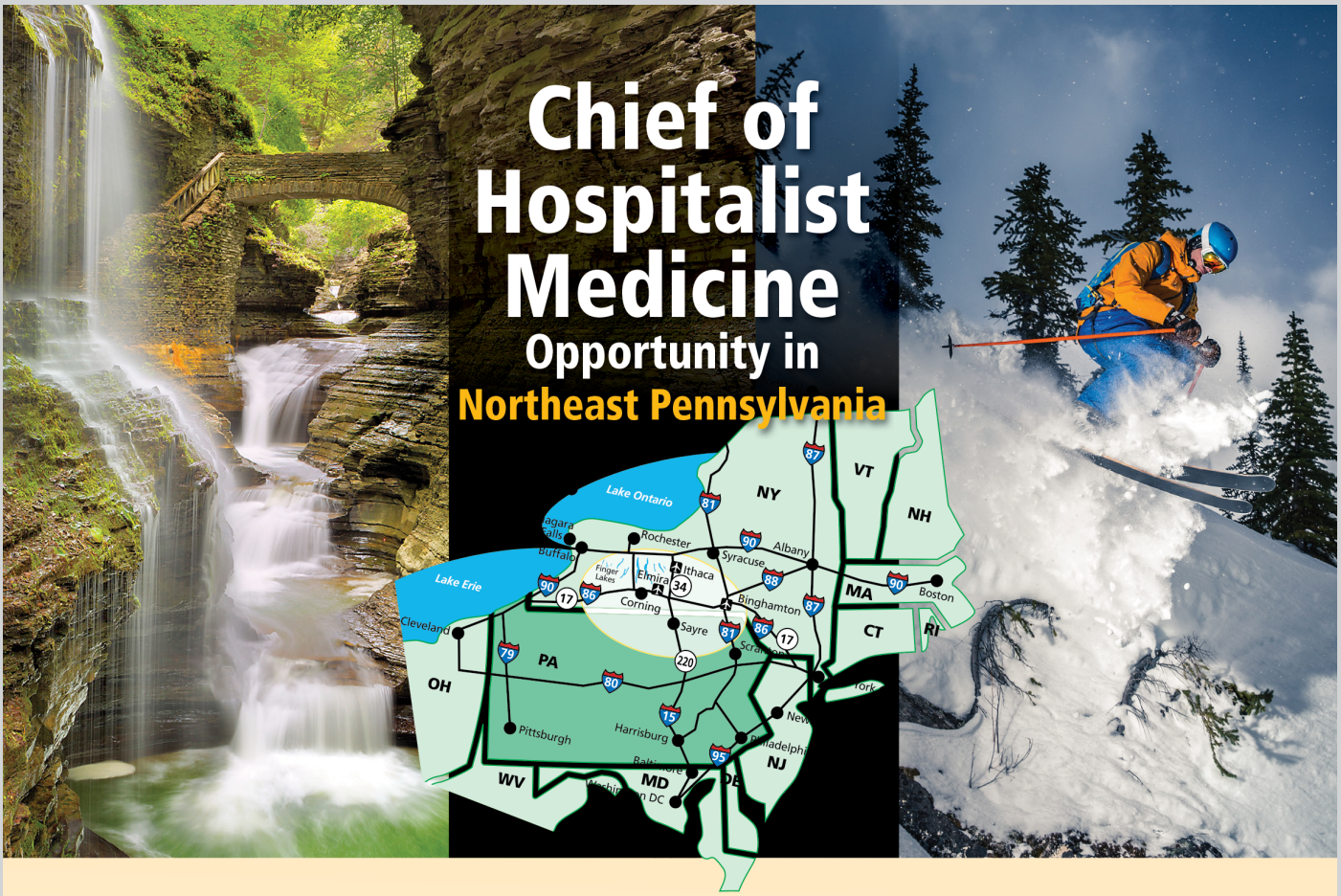

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