discrimination of the SSS is somewhat lower than current versions of APACHE, MPM, and SAPS, likely because age and comorbidities were not available for consideration. Investigational drug studies, however, would typically track these additional variables. External validation would be welcome, especially with simultaneous comparison to existing models, and with specific attention to calibration, which should be superior in a disease-specific model. As the authors have noted, societal demands for transparency create a pressing need to confidently know how we are doing. The SSS is a welcome addition to a rapidly expanding toolbox.

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Who Decides Who Should Benefit? Allocating Critical Care in the Context of "Futile Treatment"*

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Critical care medicine is a finite resource. Although the degree of scarcity is highly variable among different social contexts, national guidelines regarding the fair allocation of this resource are limited. Critical care physicians often allocate resources at the bedside, using a first-come, first-serve approach while attempting to prioritize care for those who potentially benefit to the greatest degree. In most circumstances, these physician-guided decisions are not explicit; rather, they are made implicitly within the context of cultural norms and local standards of care, without considering the impact on society (1–3).

In this issue of *Critical Care Medicine*, Huynh et al (4) attempt to empirically study the impact of providing "futile" medical care on the allocation of critical care resources. By demonstrating an association between the provision of "futile" treatment and the opportunity cost of delayed access to critical care services by patients who would potentially render greater benefit, they attempt to provide justification for forgoing "futile" medical care. While these authors should be commended for their attempt to study this challenging question empirically, the implications of this study need to be interpreted cautiously for two major reasons.

First, the definition of "futile" treatment used by these authors requires closer scrutiny (5, 6). The medical literature of past 3 decades contains an intense debate addressing the concept of futility, and ultimately there is no consensus regarding an objective definition (7). In their study, Huynh et al (4) categorize "futile treatment" based on the *perception* of one physician for a single patient on a single day. Therefore, whether or not a patient is receiving futile treatment depends on the value system and viewpoint of the treating physician. Within this context, a patient may receive "futile treatment" one day, but not the next, even if the patient is receiving the

*See also p. 1977.

Key Words: access to care; allocation; futile treatment; futility; triage

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same treatment. The implications for using this definition are disconcerting, as the values and beliefs of the treating physician have been shown to influence whether comfort care is provided as an option, influencing life and death decisions (8).

The Society of Critical Care Medicine states that "treatments should be defined as futile only when they will not accomplish their intended goal" (9). Because the intended goals of treatment may differ among stakeholders, defining futile treatment requires the incorporation of viewpoints from multiple perspectives (6). In this study, it is unclear whether other stakeholders (i.e., nurses, ancillary staff, families of patients, and patients) would also perceive the treatment as futile. Some family members may prioritize extending biological life as long as possible, even at the cost of suffering (10). Stonington (11) describes the cultural perception of continuing life-sustaining interventions as a "debt of life," even though others may perceive the same interventions as futile. Other external factors, including the census in the ICU, have also been shown to influence the intended goals of care for patients, further demonstrating how the perception of futile treatment depends on a complex array of multiple internal and external factors (12).

Depending solely on the perception of physicians to define futile treatment requires that physicians are accurate prognosticators. In reality, however, there is often great uncertainty in outcome for critically ill patients; physicians are known to lack the ability to prognosticate accurately. In this study, two of the reasons physicians used to define futility included "death is imminent" and "[patient will] not survive outside of the ICU" (5). Yet, a remarkable 32% of the patients perceived as receiving futile treatment survived to discharge from the hospital, and 15% of the survivors lived longer than 6 months (4).

The second reason to interpret this study cautiously is that even if the categorization of "futile treatment" is accepted, the results demonstrate only a *potential* association between the provision of "futile treatment" and suboptimal access to critical care services for others. Granted, delayed access to critical care leads to poorer outcomes; however, triaging patients into ICUs is complex and influenced by a number of different factors. In this study, when the ICU was defined as "full" and there was at least one patient receiving "futile treatment," 81 patients were admitted to the ICU from the emergency department. More than half of these patients were admitted within 4 hours despite a "full" census, demonstrating that a "full" ICU and the provision of "futile treatment" did not necessarily preclude a patient from being admitted to the ICU. Similarly, for patients who were transferred from a referring facility, 22 patients had to wait greater than 1 day before transfer, yet only nine of these patients waited when the ICU was "full" and there was a patient receiving "futile treatment." Thirty-seven additional patients waited but were never transferred. Of these, 15 patients waited when the ICU was "full," and there was a patient receiving "futile treatment." However, only six of these patients were *potentially* negatively affected by the delay; nine patients improved, received care at another facility, or were transferred to a skilled nursing facility (4). These data do not necessarily show a direct association between the provision of "futile treatment" and delayed access to critical care. Understanding the factors that influence how patients are triaged into the ICU, particularly when there is a "full" census, in addition to the outcomes for patients who receive delayed care, is necessary to make a definitive association.

Overall, Huynh et al (4) address a very important question that warrants further investigation with empirical studies. However, caution should be used in interpreting the results of this particular study. While critical care services are limited, allocation is complex and influenced by a myriad of factors. The decision to provide access to critical care services to one patient while denying critical care for another patient requires an explicit national approach based on guidelines that incorporate the viewpoints of multiple stakeholders rather than implicit judgments made by individual physicians. This national approach should focus on waste reduction rather than on the redistribution of resources from a patient who is perceived as "futile" to one who is "worthy" of receiving critical care (13, 14).

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The Opportunity Cost of Futile Treatment in the ICU*

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Objective: When used to prolong life without achieving a benefit meaningful to the patient, critical care is often considered "futile." Although futile treatment is acknowledged as a misuse of resources by many, no study has evaluated its opportunity cost, that is, how it affects care for others. Our objective was to evaluate delays in care when futile treatment is provided.

Design: For 3 months, we surveyed critical care physicians in five ICUs to identify patients that clinicians identified as receiving futile treatment. We identified days when an ICU was full and contained at least one patient who was receiving futile treatment. For those days, we evaluated the number of patients waiting for ICU admission more than 4 hours in the emergency department or more than 1 day at an outside hospital.

Setting: One health system that included a quaternary care medical center and an affiliated community hospital.

Patients: Critically ill patients.

Interventions: None.

Measurements and Main Results: Boarding time in the emergency department and waiting time on the transfer list. Thirty-six critical care specialists made 6,916 assessments on 1,136 patients of whom 123 were assessed to receive futile treatment. A full ICU was less likely to contain a patient receiving futile treatment compared with an ICU with available beds (38% vs 68%, $p < 0.001$). On 72 (16%) days, an ICU was full and contained at least one patient receiving futile treatment. During these days, 33 patients boarded in the emergency department for more than 4 hours after admitted to the ICU team, nine patients waited more than 1 day to be transferred from an outside hospital, and 15 patients canceled the transfer request after waiting more than 1 day. Two patients died while waiting to be transferred.

Conclusions: Futile critical care was associated with delays in care to other patients. (*Crit Care Med* 2014; 42:1977–1982)

Key Words: critical care; futile; opportunity cost

***See also p. 2127.**

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Drs. Huynh, Kleerup, and Wenger contributed to study concept and design. Drs. Huynh and Raj contributed to data collection. Drs. Huynh, Kleerup, Raj, and Wenger contributed to analysis and interpretation of data. Drs. Huynh and Wenger contributed to statistical analysis. Drs. Huynh and Wenger contributed to drafting of the article. Drs. Huynh, Kleerup, Raj, and Wenger contributed to critical revision of the article. Drs. Huynh and Wenger had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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The ICU provides specialized, high-level care to the sickest patients. In an academic medical center, the ICU accepts critically ill patients from the emergency department (ED), the hospital ward where they may have decompensated, and from other hospitals when those patients need a higher level of care (1). The outcome of a critically ill patient depends on timely access to ICU interventions, and a delay in transfer to an ICU is associated with adverse effects (2–5). Cardoso et al (2) reported that critically ill patients who had to wait for admission to the ICU due to bed unavailability had higher mortality; each hour of waiting in the ED or the general hospital ward was associated with a 1.5% increased risk of ICU death. Chalfin et al (3) reported that critically ill patients boarding longer in the ED had increased hospital length of stay and higher ICU and hospital mortality. These studies show that when critical care demand exceeds supply, patient care can be compromised. Thus, critical care is a limited, high-intensity resource that requires careful allocation.

The demand for ICU level care has increased dramatically in recent years, and a shortage is anticipated in the near future (6, 7). Nevertheless, critical care is sometimes provided to patients who cannot benefit from it (8). While provision of hospice care has increased for dying patients over the past decade in the United States, so has provision of intensive care in close proximity to death (9), suggesting that allocation of ICU care to patients who can derive benefit is imperfect. Clinicians commonly consider aggressive treatments that prolong life without achieving an effect that the patient can meaningfully appreciate to be futile treatment. Although there is no objective, widely accepted definition of futile treatment and patients and families may not agree with the assessment, studies find physician assessments of futile treatment to be common across critical care settings (8, 10–12).

Because the supply of critical care is limited, futile critical care may compromise the care received by other patients. Futile treatment may present an *opportunity cost*, defined as the loss of potential gain from other alternatives when one alternative is chosen, if critical care is unavailable for another patient for whom it is indicated. We evaluated the opportunity cost of futile treatment as perceived by the physician by measuring delays in admission to the ICU from the ED and in ICU transfer from an outside hospital. We hypothesized that providing futile treatment denies critical care access to other patients in need.

METHODS

This study evaluates whether there was an opportunity cost associated with the provision of physician-perceived futile treatment that was quantitated in a comprehensive evaluation of critical care at one healthcare system over a 3-month period. Details of the definition of futile treatment and the core data collection are described in detail elsewhere (11) and summarized here. This study was approved by the UCLA institutional review board (IRB#11-002942-AM-00006).

Setting

This study was performed at a 466-bed quaternary care academic medical center and an academically affiliated 266-bed community hospital. There are five adult ICUs in the quaternary care medical center: a Medical ICU (MICU), a Neurocritical Care Unit (Neuro-ICU), a Cardiac Care Unit (CCU), a Cardiothoracic ICU (CT-ICU), and a Liver Transplant ICU (which declined to participate in the study). The academic community hospital has one mixed-use ICU (whose capacity decreased from 22 to 18 when its location moved during the study period). The ED at the quaternary care medical center is a certified level 1 trauma center for the greater Los Angeles area and, on average, sees 130 patients per day, of which 30% are admitted to the hospital and 11% of adult admissions are admitted to the ICU. Due to high occupancy, this ED was in diversion for 731 hours (34%) during our 3-month study period. At the academic community hospital, there are approximately 115 ED visits per day, of which 24% are admitted to the hospital and 6.8% of adult admissions are admitted to the ICU. The studied health system serves as a major referral center for higher level of care in the region.

Assessment of Futile Critical Care

Thirteen clinicians who provide care for critically ill patients were convened for a focus group to discuss whether and to whom they provide futile treatment. During the open-ended discussion, participants were asked to describe patients for whom they provided ICU treatment that they judged to be futile. Audiotapes were transcribed, and categories of futile treatment were identified for which there was consensus.

Based on the focus group discussion, a questionnaire was developed to identify patients perceived as receiving futile critical care. For each ICU patient under the physician's care, the attending physician completed a brief paper-and-pencil questionnaire asking whether they perceived the patient was receiving futile treatment, receiving probably futile treatment, or not receiving futile treatment. The definition of "probably futile treatment" was left to the clinician's judgment. Every day from December 15, 2011, through March 15, 2012, research assistants administered the questionnaire to each attending critical care specialist providing treatment in five ICUs in the health system: MICU, Neuro-ICU, CCU, CT-ICU, and academic community hospital mixed-use ICU. All clinicians provided informed consent. Hospital and 6-month outcomes were obtained for all patients, and proportions in each futility category were compared using a chi-square test.

Opportunity Cost Evaluation

Midnight and noon census data were obtained for the five ICUs for the 3-month study period. An ICU was considered "full" and unavailable for new admissions on days when the averaged midnight and noon census of that unit showed less than two available beds (one bed is always reserved as a "code bed"). Census data were merged with daily futility assessments to identify whether there was at least one patient assessed as receiving futile treatment on days when the unit was full. Only actual days of an assessment of futile treatment were included (and not subsequent days if the assessment changed), and assessments of "probably futile treatment" were not considered in the analysis of opportunity cost. The relationship between whether the ICU was full and whether there was a patient in it perceived as receiving futile treatment was evaluated using a chi-square test.

ED Boarding Time. All ICU admissions from the ED at both hospitals were recorded during the study period. "Boarding time" in the ED was defined as the time between when the ED physician noted the decision to admit the patient (bed control had called the admitting team) and the time of the patient's departure from the ED. Although some ED literature suggests that a 2-hour delay has negative clinical implications (13), based on critical care clinical experience, boarding time was dichotomized at 4 hours. For each ICU admission from the ED, we computed whether the ED boarding time exceeded 4 hours. For such patients, we evaluated whether the delayed ICU admission occurred on a day that the ICU was full and whether there was a patient receiving futile treatment in the ICU that day.

Requests for ICU Transfer. The number of outside hospital transfer requests, reason for transfer, and ICU requested were collected from the health system transfer center for the 3-month study period. We also collected the number of days between request and transfer, cancellations after transfer request and, when available, the reason why transfer was canceled. Patients not transferred to the ICU within 1 day of the transfer request were considered "waiting on the transfer list." For each day that a patient waited on the transfer list for ICU admission from an outside hospital, we assessed whether the requested ICU was full and whether there was a patient assessed as receiving futile treatment in that ICU on that day.

RESULTS

During the 3-month study period, 36 critical care clinicians in five ICUs provided care to 1,193 patients. After excluding boarders in the ICUs and missed and invalid assessments, 6,916 assessments were made on 1,136 patients. Of these 1,136 patients, 904 patients (80%) never received futile treatment, 98 patients (8.6%) received probably futile treatment, and 123 patients (11%) received futile treatment (11 patients were dropped because they were assessed as receiving futile treatment on the day they were transitioned to comfort care). These 123 patients received 464 days of futile treatment. Futile treatment assessments accounted for 6.7% of all assessments during the study.

The mortality of patients who were perceived to receive futile treatment was significantly higher than those of patients who were not. For patients who never received futile treatment, the in-hospital mortality was 4.6% and the 6-month mortality was 7.3%. On the contrary, 68% of the patients who were perceived to receive futile ICU treatment died before hospital discharge, 85% died within 6 months, and survivors remained in severely compromised health states (11).

ICU Capacity and Whether the ICU Contained a Patient Receiving Futile Treatment

Over the 92-day study period, there was at least one patient perceived as receiving futile treatment in the ICU on 255 of the 460 (55%) cumulative ICU days. This ranged from 88 of 92 days in the MICU to 15 of 92 days in the CCU. The ICUs were full on 191 of 460 days (42%), ranging from 18 days (20%) at the Community hospital ICU to 55 days (60%) at the CT-ICU. Overall, ICUs were full and contained a patient receiving futile treatment on 72 of 191 (38%) full days, ranging from 19 of 22 full days (86%) in the MICU to six of 52 full days (11%) in the CCU. ICUs were significantly more likely to contain a patient receiving futile treatment on days when they were not full compared with days when they were full (68% vs 38%, $p < 0.001$) (**Table 1**).

Delayed ICU Admission From the ED

During the study period, patients admitted from the ED to the ICU were more likely to wait 4 or more hours in the ED if the target ICU was full compared to not full (61% vs 35%, $p = 0.05$). Median time waiting for ICU admission among the group waiting 4 or more hours was 339 minutes (interquartile range, 284–495 min). Eighty-one patients were admitted from the ED to the ICU on days when the unit was at capacity and there was a patient receiving futile treatment in that unit (**Table 2**). Thirty-three of these patients boarded in the ED for over 4 hours after they were officially admitted to the ICU.

Delay of ICU Transfer From Outside Hospitals

There were 163 transfer requests to the five study ICUs from outside hospitals during the study period. Of these, 104 patients were transferred within 1 day of the request, 22 patients were transferred after waiting for more than 1 day, and 37 requests were canceled (**Table 3**). Of the 22 patients who had to wait for more than 1 day, nine patients spent 16 days waiting to be transferred when the ICU was full and at least one patient was receiving futile treatment in the unit. Of the 37 patients who never transferred, 15 patients waited (for a total of 30 d) when the ICU was full and at least one patient was receiving futile treatment in the unit. Of these 15 patients who canceled the transfer request after waiting at least 1 day when the intended ICU was full and contained at least one patient receiving futile treatment, five patients were transferred to other hospitals, three patients improved and did not

TABLE 1. Characterization of ICU Days During 3-Month Study Period by Whether the ICU is Full and Whether There Is a Patient Receiving Futile Treatment in That ICU on That Day

	Overall		ICU Not Full		ICU Full	
ICU	Total Days	Days With Futile Patient in Unit (%)	Days	Days Unit Not Full + Futile Patient in Unit (%)	Days	Days Unit Full + Futile Patient in Unit (%)
Medical ICU	92	88 (96)	70	69 (99)	22	19 (86)
Neurocritical Care Unit	92	33 (36)	48	17 (35)	44	16 (36)
Cardiothoracic ICU	92	51 (55)	37	27 (73)	55	24 (44)
Cardiac Care Unit	92	15 (16)	40	9 (23)	52	6 (12)
Academic Community Hospital ICU	92	68 (74)	74	61 (82)	18	7 (39)
Total	460	255 (55)	269	183 (68)	191	72 (38)

Futile patient = patient receiving treatment in the ICU that is perceived to be futile by the critical care attending.
ICU is considered full when there are 0 or 1 bed available for new admissions.

TABLE 2. Emergency Department Admissions

ICU	ICU Beds	No. of Admissions From ED	No. of Admissions When ICU Full + Futile Patient in ICU	No. of Admissions Boarding ≥ 4 Hr in ED When ICU Full + Futile Patient in ICU
Medical ICU	24	130	32	19
Neurocritical Care Unit	24	121	26	7
Cardiothoracic ICU	24	12	3	0
Cardiac Care Unit	12	60	3	0
Academic Community Hospital ICU	22, 18[a]	140	17	7
Total	106, 102[a]	463	81	33

ED = emergency department, futile patient = patient receiving treatment in the ICU that is perceived to be futile by the critical care attending.
[a]Academic Community Hospital ICU contained 22 beds (study days, 1–25) and 18 beds (study days, 26–92).
Emergency department patients with delayed admission to the ICU when the ICU was full and a patient was receiving futile treatment in that ICU on that day.

TABLE 3. ICU Transfer Requests From Outside Hospitals

	Transferred After Waiting > 1 D			Transfer Requests Canceled After Waiting > 1 D		
ICU	Patients Transferred After > 1 D	Days Waited When Unit Full (Patients)	Days Waited When Unit Full + Futile Patient in Unit (Patients)	Transfer Requests Canceled	Days Waited When Unit Full (Patients)	Days Waited When Unit Full + Futile Patient in Unit (Patients)
Medical ICU	9	4 (3)	4 (3)	12	20 (7)	16 (7)
Neurocritical Care Unit	5	18 (5)	9 (4)	16	15 (12)	6 (6)
Cardiothoracic ICU	2	4 (2)	2 (1)	6	9 (3)	8 (2)
Cardiac Care Unit	6	16 (6)	1 (1)	2	2 (2)	0 (0)
Academic Community Hospital ICU	0	0 (0)	0 (0)	1	0 (0)	0 (0)
Total	22	42 (16)	16 (9)	37	46 (24)	30 (15)

Futile patient = patient receiving treatment in the ICU that is perceived to be futile by the critical care attending.
For patients who waited more than 1 day to be transferred or before canceling the transfer request, this table shows the number of days spent waiting on the transfer list when the ICU was full and contained a patient receiving futile treatment.

require ICU transfer, four patients were lost to follow-up, one patient was discharged to a skilled nursing facility, and two patients died while awaiting transfer.

DISCUSSION

Physicians are beholden to provide the best possible care for their patients and also to use the tools of medicine for their intended purposes. While the principle of justice is fundamental to the practice of medicine (14), it was recognized more than a quarter century ago that in the fragmented U.S. healthcare system resources saved from one patient will not necessarily justly benefit another (15). Although the number of patients affected was small, this study demonstrates an association between patients receiving nonbeneficial critical care and delays in ICU admission for patients in the ED and delayed or failed interhospital ICU transfers. One cannot know whether the two patients who died waiting for an ICU bed would have survived if they had been transferred in a timely fashion or if harm came to the patients with delayed admission from the ED and other facilities. However, these potentially adverse events can be traced to bed unavailability due to critical care units providing treatment that was perceived by the treating physician to be futile. Patients receiving these futile treatments either died or remained in severely adverse health states that the critical care physicians deemed to be inappropriate for critical care (11). Furthermore, futile ICU treatment carried opportunity costs that possibly harmed other patients.

While futile ICU treatment violates the "physician's professional responsibility for appropriate allocation of resources" (14) and inappropriately uses precious healthcare resources, in a healthcare system functioning at capacity it is not clear that providing futile treatment is less expensive than providing nonfutile treatment. Futile treatment days in the ICU are less expensive than routine ICU treatment (estimated costs are \$4004 vs \$4732), at least at the studied healthcare system (11), and patients that would fill these beds are commonly transferred with end-stage organ failure for consideration of expensive procedures such as organ transplants. However, whether less expensive or not, futile critical care is an inappropriate application of specialized treatment for patients who cannot benefit from it.

Our study found that there were more patients receiving futile treatment when the ICU had empty beds. There are several possible explanations for this. Perhaps on busy days, the perception of futile treatment is different than on days when clinicians have more time to view the "full picture." More likely, a busy ICU forces clinicians to have difficult discussions with patients and families regarding prognosis to shift goals of care. The fact that fewer patients received futile treatment when the ICU was full suggests that physicians strive harder to minimize nonefficacious treatments when their ICU is full and patients are waiting. This finding is consistent with a study showing that goals of care were more frequently addressed and changed when ICU beds were unavailable (16).

Several studies have shown that critically ill patients have the best chance of survival when care is delivered expeditiously by well-trained intensivists (17–19). Most EDs are not designed or staffed to provide extended critical care, and critically ill patients who board in the ED potentially miss a window of opportunity in which the ICU might offer a survival advantage (4). The volume of critically ill patients initially evaluated in the ED is increasing (20), and delays in medical attention can be especially detrimental. Patients who "board" in the ED not only have higher mortality but also have longer lengths of stay and higher resource utilization (3). Downstream effects include ED crowding and compromised capability to provide quality and timely care to other patients (13, 21).

One of the responsibilities of an academic medical center is to provide equitable access to transfer requests from other hospitals, acting as a regional safety net providing specialized advanced healthcare services (1). Patients who transfer to a tertiary care ICU generally have higher mortality than directly admitted patients, but this difference dissipates after adjusting for severity of illness (22). In a 3-month period, we recorded two deaths and a total of 46 days when patients waited to be transferred from a hospital incapable of providing the necessary level of care.

This study is limited because it was performed at a single health system recognized for resource-intensive treatment (23); it is unclear whether these results can be generalized to other hospitals. Future multicenter studies will be necessary. One of the ICUs declined to participate, suggesting that the measured futile treatment and perhaps the opportunity costs may be an underestimate (24, 25). Additionally, missing futility assessments (4.8%) likely occurred when the ICU was busy, making the opportunity cost estimate conservative. Also, "probably futile treatment" (accounting for another 98 patients) was excluded from this analysis. Finally, midnight and noon census snapshots of bed availability may not reflect bed availability at other times of the day.

There is no recognized objective method of prospectively defining futile treatment. The assessments by critical care physicians studied here inherently include the clinicians' subjective judgments. Furthermore, clinician prognostication is never 100% accurate and for some patients the chance, no matter how miniscule, of improvement or continued existence with poor quality of life is acceptable to the family (or rarely, to the patient). Because futile treatment was defined by the critical care physician, it is likely that many patients' families would not agree with the assessment. Lastly, patients delayed while waiting on the transfer list may not have benefited from transfer to the academic ICU since they may have been too ill to benefit from critical care or perhaps another waiting patient may have filled the slot vacated by the patient receiving futile treatment.

CONCLUSIONS

It is unjust when a patient is unable to access intensive care because ICU beds are occupied by patients who cannot benefit from such care. Our findings are particularly relevant in the United States but are also instructive elsewhere given universal concerns regarding providing treatments that are nonbeneficial. The ethic of "first come, first served" is not only inefficient and wasteful but it is also contrary to Medicine's responsibility to apply healthcare resources to best serve society. In the context of healthcare reform, which aims to more justly distribute medical care to the nation, opportunity cost is one more reason that futile treatment should be minimized.

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Relationship Between ICU Bed Availability, ICU Readmission, and Cardiac Arrest in the General Wards

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Objective: The decision to admit a patient to the ICU is complex, reflecting patient factors and available resources. Previous work has shown that ICU census does not impact mortality of patients admitted to the ICU. However, the effect of ICU bed availability on patients outside the ICU is unknown. We sought to determine the association between ICU bed availability, ICU readmissions, and ward cardiac arrests.

Design: In this observational study using data collected between 2009 and 2011, rates of ICU readmission and ward cardiac arrest were determined per 12-hour shift. The relationship between these rates and the number of available ICU beds at the start of each shift (accounting for census and nursing capacity) was investigated. Grouped logistic regression was used to adjust for potential confounders.

Setting: Five specialized adult ICUs comprising 63 adult ICU beds in an academic medical center.

Patients: Any patient admitted to a non-ICU inpatient unit was counted in the ward census and considered at risk for ward cardiac arrest. Patients discharged from an ICU were considered at risk for ICU readmission.

Interventions: None.

Measurements and Main Results: Data were available for 2,086 of 2,190 shifts. The odds of ICU readmission increased with each decrease in the overall number of available ICU beds (odds ratio = 1.06; 95% CI, 1.00–1.12; $p = 0.03$), with a similar but not statistically significant association demonstrated in ward cardiac arrest rate (odds ratio = 1.06; 95% CI, 0.98–1.14; $p = 0.16$). In subgroup analysis, the odds of ward cardiac arrest increased with each decrease in the number of medical ICU beds available (odds ratio = 1.26; 95% CI, 1.06–1.49; $p = 0.01$).

Conclusions: Reduced ICU bed availability is associated with increased rates of ICU readmission and ward cardiac arrest. This suggests that systemic factors are associated with patient outcomes, and flexible critical care resources may be needed when demand is high. (*Crit Care Med* 2014; 42:2037–2041)

Key Words: in-hospital cardiac arrest; intensive care unit; patient readmission

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Dr. Edelson obtained the data and supervised the study. Dr. Huber, Dr. Town, and Mr. Yuen obtained and transcribed the raw data. Statistical analysis was performed by Dr. Churpek and Mr. Yuen. All authors contributed to the study design and article preparation.

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An analysis of trends in critical care use from 2000 to 2005 in the United States reported that the number of ICU beds, days, and occupancy rates have all increased over time (1). Importantly, demand for critical care resources increased at a greater rate than the ICU bed supply (1), with further increases in demand expected due to an aging population with increased comorbidities (2). As demand for ICU beds outpaces the supply, the number of available ICU beds will become increasingly limited, potentially resulting in sicker patients being left in the wards.

Reports on the association between limited ICU bed availability and adverse effects in ICU patient populations have been mixed. A large study of the Acute Physiology and Chronic Health Evaluation database demonstrated no association between bed availability and ICU mortality (3). However, decreased ICU bed availability has been shown to be associated with increased severity of illness in patients admitted to the ICU (4–6), suggesting that bed availability plays a role in triage decisions. Some studies have demonstrated a shorter ICU length of stay associated with limited bed availability, which may indicate increased pressure to discharge patients when beds are limited (3, 5, 6). Finally, one study of a neurological ICU demonstrated an association between increased patient flow rates and increased rates of readmission to the ICU (7).

Meanwhile, studies of the effects of the ICU bed availability on patients *outside* the ICU have only examined high-risk ward patients who are evaluated for transfer to the ICU (8–13). In these populations, decreased ICU bed availability has been associated with decreased rates of transfer into the ICU (8, 9, 12, 14), and an increase in mortality among patients refused transfer to the ICU (8, 13, 14). However, the effects of ICU bed availability on ward patients may extend beyond those patients directly evaluated for transfer to the ICU.

Determining the impact of limited ICU bed availability on outcomes both in the wards and in the ICU has important implications for the health and safety of hospitalized patients. The aims of this study were to examine the effects of ICU bed availability on both the general ward and ICU patient populations. We hypothesized that decreased ICU bed availability would be associated with an increase in readmission to the ICU within 24 hours. Additionally, we hypothesized that decreased ICU bed availability would be associated with an increase in the rate of cardiac arrest in the general wards.

MATERIALS AND METHODS

Study Population and Setting

We conducted an observational cohort study between January 1, 2009, and December 31, 2011, at a tertiary care academic medical center with 63 total adult ICU beds, including specialized medical, cardiac, surgical, and neurological ICUs, and 272 adult general inpatient ward beds. Our hospital has had a rapid response team (RRT) in place since 2008 composed of a critical care nurse, with the availability of a respiratory therapist and hospital medicine or critical care attending as previously described (15). RRT trigger criteria are general, such as "tachypnea" and "staff worry," and are not tied to specific vital signs. This study was approved by the Institutional Review Board at the University of Chicago. A waiver of informed consent was granted on the basis of minimal risk and general impracticability. Collection of patient information was designed to comply with the HIPAA regulations.

Data Collection

ICU bed availability was collected in a handwritten institutional log. At the start of each 7 AM and 7 PM shift, the ICU manager or charge nurse recorded the census and capacity of each ICU. The "census" refers to the number of patients within the ICU at the start of the shift. The "capacity" refers to the total number of beds available to accommodate patients with the available nurses for the shift. Therefore, if there were 10 physical beds, but only enough nurses to care for eight patients, then the capacity would have been logged as eight. Bed availability represents the capacity minus the census. Data from each log were entered into a spreadsheet (Microsoft Excel 2010, Microsoft, Redmond, WA) independently by two authors (M.H., J.T.). Shifts with missing or incomplete data were excluded. When there was a difference in data entry between M.H. and J.T. (representing a transcription error by one or both of the authors), author T.Y. examined the handwritten log and resolved the difference by entering the correct data point in the final dataset. All data were entered, checked, and finalized prior to being merged with the outcomes data. As such, all authors were blinded to outcomes at the point of data entry. Once merged with outcomes, no changes were made to the data. Demographic data and hospital ward occupancy at the start of each shift were obtained from electronic administrative databases.

ICU readmission was defined, a priori, as an ICU readmission or a ward cardiac arrest within 24 hours of discharge from an ICU to a ward. The ICU readmission rate was calculated per shift using the total number of discharges as the denominator and the number of those patients who had an ICU readmission as the numerator. ICU readmission rate was analyzed as a proportion rather than as a whole number to account for variation in transfer rates out of the ICU. ICU readmission data were obtained from the Admission-Discharge-Transfer administrative database. Cardiac arrest was defined as the loss of palpable pulse with attempted resuscitation on any general inpatient ward (medical or surgical). The cardiac arrest rate was calculated per shift using the number of patients in the general wards as the denominator and the number of arrests as the numerator. The cardiac arrest rate was reported as arrests per 10,000 ward patients per shift for simplicity. Cardiac arrests were identified using a prospectively collected and verified quality improvement database previously described (16). Comfort care deaths (e.g., deaths in patients with a do-not-attempt resuscitation order) were excluded from analysis.

Statistical Analysis

Analyses were performed using a statistical software application (Stata version 11.0, Statacorp, College Station, TX). Descriptive statistics were compared using Student *t* test, chi-square test, or Wilcoxon rank sum test as appropriate. The associations between ICU bed availability and ICU readmission rate or cardiac arrest rate in the general inpatient wards were analyzed using grouped logistic regression. The final models were adjusted for potential confounders by adding the variables of calendar year (2008, 2009, etc.), season (Summer, Spring, etc.), day of week (Monday, Tuesday, etc.), and time of day (day vs night). A subgroup analysis was conducted by separately analyzing the data using medical ICU (MICU) and non-MICU bed availability. All tests of statistical significance used a two-sided p value less than 0.05.

RESULTS

Over the study period, there were 60,355 admissions over 2,190 consecutive shifts, of which 2,086 (95.3%) had complete data. Shifts with missing data were evenly distributed by year, season, day of week, and day versus night. The mean age of all admitted patients was 54 ± 18 years, 43% were men, and 24% were surgical admissions. The median length of hospital stay was 3 days (interquartile range, 2–6 d). There were 8,238 discharges from the ICU, with 245 (3%) readmitted within 24 hours. There were 117 ward cardiac arrests, resulting in a ward cardiac arrest rate of 2.63 per 10,000 patient-shifts. Descriptive statistics of bed availability are shown in **Table 1**.

ICU readmission rates by ICU bed availability in quartiles are illustrated in **Figure 1**. The odds of readmission to the ICU significantly increased with each unit decrease in total ICU bed availability after adjusting for potential confounders (odds ratio [OR] = 1.06; 95% CI, 1.00–1.12; $p = 0.03$) (**Fig. 2**).

Figure 3 shows the ward cardiac rates by ICU bed availability in quartiles. The association between the number of available ICU beds and ward cardiac arrest rates was similar to that of ICU readmissions but was not statistically significant (OR, 1.06; 95% CI, 0.98–1.14; $p = 0.16$). In unadjusted analysis of the MICU bed availability, the rate of cardiac arrest in the general wards nearly doubled when comparing zero versus one or more available MICU beds (3.89 vs 2.11 per 10,000 patients-shifts, $p = 0.01$) (**Fig. 4**). After adjusting for potential confounders, MICU bed availability was significantly associated with ward cardiac arrest rates (OR = 1.25; 95% CI, 1.06–1.49; $p = 0.01$). Non-MICU bed availability was not associated with ward cardiac arrest rates (OR, 1.01; 95% CI, 0.92–1.10; $p = 0.86$).

DISCUSSION

In this study, we found that the ICU readmission rate increased significantly as ICU bed availability decreased. In addition, the cardiac arrest rate among all ward patients increased with decreasing MICU bed availability. This is the first study to demonstrate this association, which was most pronounced when the MICU was full as compared to when one or more MICU beds were available, as the unadjusted rates of cardiac arrest nearly doubled when the MICU was full. This study demonstrates that limited ICU bed availability is associated with adverse effects in the hospital population at large, including both ward and ICU patients.

Associations between the outcomes of ICU patients (including readmission) and various indicators of ICU activity such as ICU census (3), admission volume and occupancy (17, 18), workload (19), and patient turnover (7) have previously been reported. Our study is unique in that it analyzes multiple specialized ICUs within our institution over an extended period of ICU traffic from a system-level perspective. Lack of ICU bed vacancy was a significant risk factor for ICU readmission in one study (20); however, the authors defined readmission using a longer window of 7 days from ICU discharge and did not specifically account for nursing staffing in their ICU bed availability data.

The increased rate of cardiac arrest in the wards with reduced ICU bed availability is consistent with previous studies showing increased mortality in patients refused transfer to the ICU (6, 8, 9, 14) or who experience delays in critical care (21, 22) at times of limited ICU bed availability. Robert et al (13) furthered this and showed an association between refusal of ICU transfer due to a full ICU and increased patient mortality. Despite the previous work on outcomes of patients evaluated for ICU admission in the face of ICU bed limitations, we are not aware of any other studies examining the effects of ICU bed limitations on the hospital population as a whole.

In subgroup analysis, the increased rate of cardiac arrest with limited ICU bed availability was driven by the availability of MICU beds, which is a unique finding. Over the data collection period, 72% of ward cardiac arrests occurred in patients on a medical service (data not shown). In our hospital, had clinical deterioration been identified in these patients before

TABLE 1. Descriptive Statistics of Bed Availability

Total shifts, *n*	2,190
Shifts with complete data, *n* (%)	2,086 (98.5)
Ward occupancy, median (IQR)	218 (201–231)
Combined ICU beds, median (IQR)	61 (58–63)
MICU	16 (15–16)
Non-MICU	42 (38–44)
Combined ICU bed availability, median (IQR)	5 (3–7)
MICU bed availability	1 (0–2)
Non-MICU bed availability	3 (2–5)
Shifts with zero available ICU beds, *n* (%)	
Any ICU bed	6 (0.3)
MICU bed	557 (2.7)
Non-MICU bed	65 (3.1)
Total ICU to ward discharges, *n*	8,238
ICU discharges per shift, median (IQR)	4 (3–6)
Total ICU readmissions, *n*	245
ICU readmission per 100 discharges	2.63
Total cardiac arrests, *n*	117
Cardiac arrest rate per 10,000 ward patient-shifts	2.63

IQR = interquartile range, MICU = medical ICU.

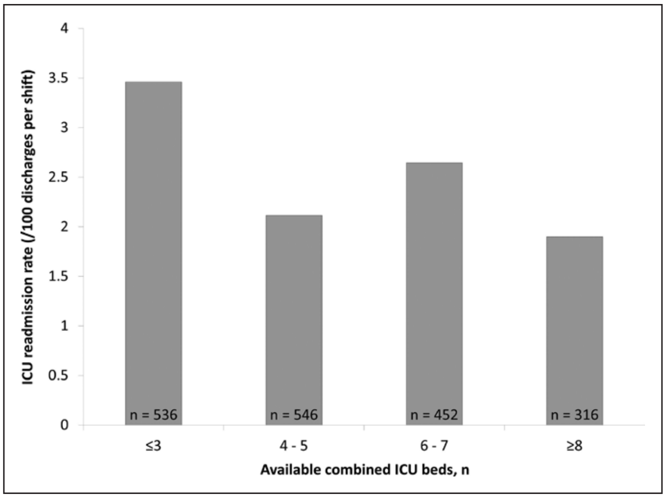

Figure 1. Adjusted ICU readmission rate by combined ICU bed availability, n = number of 12-hour shifts, $p = 0.03$.

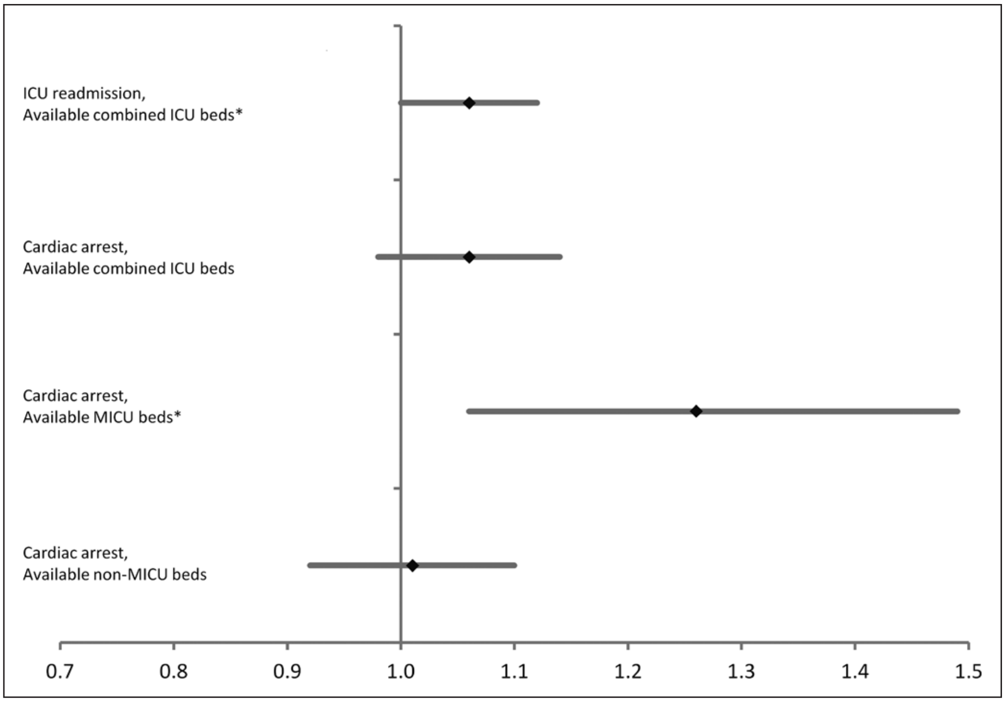

Figure 2. Odds ratios and 95% CIs for ICU readmission and ward cardiac arrest per unit decrease in ICU bed availability using grouped logistic regression and adjusted for academic year, season, time of day, and day of week. The odds ratio for ward cardiac arrest was also calculated for subgroups of available medical ICU (MICU) and non-MICU beds. *$p < 0.05$.

of increased critical care strain, a flexible, system-wide process may help to meet unpredictable surges in critical care demand (25–28). In addition, the implementation of previously described quality improvement practices to reduce ICU length of stay may increase the number of available beds (29–31).

There are several important strengths of our study. First, we used prospectively collected data in a large population of both medical and surgical patients. In addition, we accounted for both physical beds and staffing resources in the determination of bed availability, which was not specifically accounted for in earlier studies (23). Finally, our study included all patients at risk in the general wards rather than just those evaluated by the ICU team.

cardiac arrest, they most likely would have been referred for transfer to the MICU rather than another ICU. Our findings may indicate unintended effects of a higher barrier to ICU admission as sicker patients may remain in the wards where they are at risk for deterioration.

Our study has several implications. The first is the demonstrated need for improved triage of ward patients into the ICU when ICU beds are scarce. Although numerous decision-making tools for ICU admission exist, none has proven to improve outcomes (23, 24). Our findings also suggest the need to respond acutely to perturbations in ICU bed availability, particularly accounting for MICU bed availability. During times

This study has several limitations. First, this was a single-center study at an academic hospital. Institutional factors, including policies for admission to individual ICUs, may make the findings less generalizable. We conducted our analysis at the shift level, and therefore, patient-specific data were not available. We, therefore, did not determine whether the ward patients who suffered cardiac arrest were evaluated for transfer to the ICU prior to their arrest. In addition, we defined our subgroups of MICUs and non-MICUs by the physical bed location rather than admitting service. However, the vast majority of patients in the MICU are on the MICU service. We acknowledge that this is an observational study of a complex system and cannot

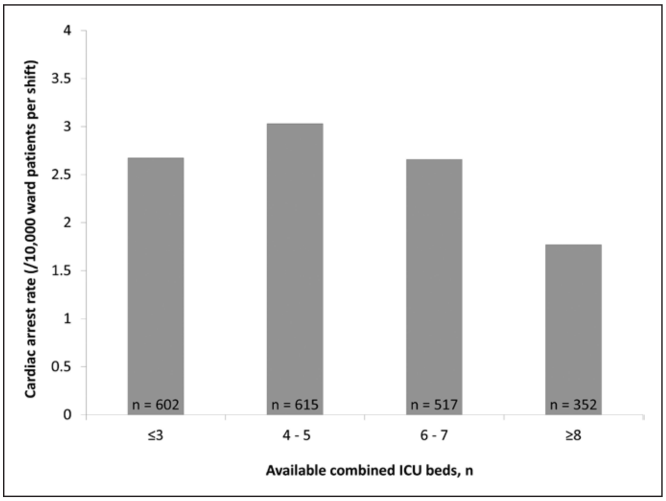

Figure 3. Ward cardiac arrest rate by combined ICU bed availability, n = number of 12-hour shifts, $p = 0.16$.

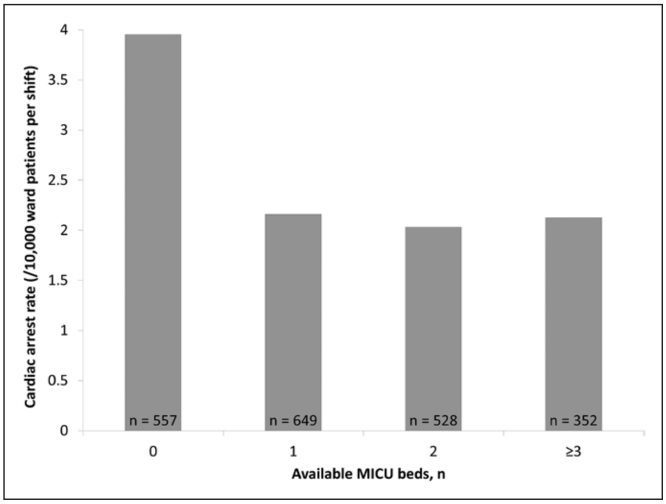

Figure 4. Ward cardiac arrest rate by medical ICU (MICU) bed availability, n = number of 12-hour shifts, $p = 0.01$.

establish causality between the ICU readmission rate and ICU bed availability. Finally, we examined bed availability per shift rather than ICU turnover or bed availability in real time.

In conclusion, we demonstrated an association between decreased total ICU bed availability and increased rates of unplanned ICU readmissions within 24 hours. We also demonstrated an association between decreased total ICU bed availability and increased rates of cardiac arrest in the wards, driven by MICU bed availability. These findings suggest suboptimal triage of patients into the ICU and premature discharge of patients from the ICU when ICU beds are scarce. Additional research is needed to establish optimal triage practices and hospital-wide bed allocation to maximize ICU bed availability for high-risk patients.

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