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Intensive Care Unit Bed Availability and Outcomes for Hospitalized Patients With Sudden Clinical Deterioration

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Background: Intensive care unit (ICU) beds, a scarce resource, may require prioritization of admissions when demand exceeds supply. We evaluated the effect of ICU bed availability on processes and outcomes of care for hospitalized patients with sudden clinical deterioration.

Methods: We identified consecutive hospitalized adults in Calgary, Alberta, Canada, with sudden clinical deterioration triggering medical emergency team activation between January 1, 2007, and December 31, 2009. We compared ICU admission rates (within 2 hours of medical emergency team activation), patient goals of care (resuscitative, medical, and comfort), and hospital mortality according to the number of ICU beds available (0, 1, 2, or >2), adjusting for patient, physician, and hospital characteristics (using data from clinical and administrative databases).

Results: The cohort consisted of 3494 patients. Reduced ICU bed availability was associated with a decreased likelihood of patient admission within 2 hours of medical emergency team activation ($P=.03$) and with an increased likelihood of change in patient goals of care ($P<.01$). Patients with sudden clinical deterioration when zero ICU beds were available were 33.0% (95% CI, −5.1% to 57.3%) less likely to be admitted to the ICU and 89.6% (95% CI, 24.9% to 188.0%) more likely to have their goals of care changed compared with when more than 2 ICU beds were available. Hospital mortality did not vary significantly by ICU bed availability ($P=.82$).

Conclusion: Among hospitalized patients with sudden clinical deterioration, we noted a significant association between the number of ICU beds available and ICU admission and patient goals of care but not hospital mortality.

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THE INSTITUTE OF MEDICINE's report *To Err Is Human*[1] raised awareness about the high risk of medical errors, adverse events, and preventable death among hospitalized vulnerable populations with sudden clinical deterioration. In response, strategies to identify, evaluate, and quickly treat these patients using rapid response systems have been prioritized by prominent health care organizations.[2,3]

See Invited Commentary at end of article

Intensive care unit (ICU) beds are an integral structural component of rapid response systems and provide life-saving support for critically ill patients.[4] However, ICU beds are a scarce resource for which demand periodically exceeds supply.[5] Aging populations are expected to steadily increase demand for critical care services,[6,7] raising concerns about mechanisms for resource allocation when demand exceeds supply.[5]

Physicians routinely make decisions in the setting of resource constraints, despite limited training in resource allocation.[5,8] Available evidence suggests that notions of equity often guide physician care[9,10] and that patients who are perceived to be unlikely to benefit from critical care are more often declined ICU admission.[5] Although the tenets of biomedical ethics and international law indicate that protocols should be used to guide resource allocation when demand for ICU resources exceeds supply,[11,12] formal triage protocols are not routinely part of rapid response systems or decision making surrounding patient ICU admission.[8] For these reasons, we undertook a study to examine the association between ICU bed availability (0, 1, 2, or >2 beds) and the processes and outcomes of care for a population-based cohort of hospitalized patients with sudden clinical deterioration.

METHODS

STUDY COHORT

We identified consecutive hospitalized adults (excluding cardiac surgery and coronary care units) in Calgary, Alberta, Canada (with a 1.5-million catchment population) having sudden clinical deterioration identified by the rapid response system and triggering medical emergency team (MET) activation between January 1, 2007, and December 31, 2009. A rapid response system is a hospital-based capability to detect patients with sudden clinical deterioration and mechanism to quickly respond to patients' needs, while a MET is a group of clinicians activated by the rapid response system.[4] Alberta Health Services manages all METs (each composed of 1 ICU physician, nurse, and respiratory therapist 24 h/d and 7 d/wk) and medical-surgical (general system) ICUs (53 funded beds) in Calgary (3 hospitals, with a total of 2040 beds, each with a MET and an ICU). The ICUs are closed units staffed by fully trained intensivists. To trigger MET activation, the Alberta Health Services rapid response system used the following physiologically based criteria[13]: (1) respiratory (threatened airway, respiratory rate of <8 or >30 breaths/min, or acute change in oxygen saturation of <90%, despite oxygen >5 L/min), (2) heart rate (pulse rate of <40 or >140 beats/min), (3) blood pressure (systolic blood pressure of <90 mm Hg), (4) neurological (sudden decrease in Glasgow Coma Scale score of ≥2 points or prolonged or repeated seizures), and (5) worried ("any patient that you are seriously worried about"). Decisions to admit patients to the ICU are made by the attending physician on a case-by-case basis, without a triage protocol or decision-making support. Hospital wards activating the MET are not generally aware of ICU bed availability.

DATA SOURCES

We used data from Alberta Health Services clinical and administrative databases. The MET database captures reason for assessment, vital signs, diagnostic and therapeutic interventions, and patient disposition, with data acquired at the time of patient assessment. The ICU database is an electronic patient information system that captures demographic, clinical, and outcome data for all patients admitted to the ICU (excluding coronary care units). Alberta Health Services administrative databases capture data on all hospitalized patients, including vital status at discharge, dates of admission and discharge, up to 25 *Canadian Enhancement of International Statistical Classification of Diseases, 10th Revision*, diagnostic codes, and up to 20 *Canadian Classification of Health Interventions* procedure codes. Hospital electronic medical records are used by the study hospitals and contain detailed patient information, including physician orders and patient goals of care. These 4 databases are used for clinical care and administrative data capture and have been used for program evaluation and research.[14]

PATIENT, PHYSICIAN, AND HOSPITAL FACTORS

We identified factors that may affect the likelihood of ICU admission after a MET activation. Hospital factors included the number of ICU beds available (0, 1, 2, or >2) and the day of the week (weekday [Monday 8 AM to Friday 5 PM] vs weekend) and time of day (daytime [8 AM to 5 PM] vs nighttime) of the MET activation.[15] Available ICU beds were defined as the number of beds (funded to be operational) without an assigned patient at the time of MET activation. Physician factors included the type of physician attending the MET activation (ICU attending physician, ICU fellow, resident, or ICU physician extender [defined as a licensed nonintensivist physician providing in-hospital support to the ICU attending physician]). Patient factors included demographic variables, socioeconomic status, race/ethnicity, comorbidities, reason for hospital admission (medical, surgical, or neurological), and baseline patient goals of care (resuscitative [life-sustaining care that includes ICU admission], medical [life-sustaining care that does not include ICU admission], and comfort [care focused on symptom control]). Socioeconomic status was defined using the median neighborhood household income quintile.[16] The presence of comorbidities was derived using the Deyo classification of Charlson comorbidities and validated *Canadian Enhancement of International Statistical Classification of Diseases, 10th Revision*, coding algorithms (summarized as a single comorbidity score for multivariable analyses).[17] First Nations populations were defined using the registry file from Alberta Health Services administrative databases.[18] Chinese race/ethnicity was determined using the Chinese surname list algorithm,[19] and South Asian race/ethnicity was defined using the Nam Pehchan classification program.[20]

PROCESS AND OUTCOME MEASURES

The primary outcome was ICU admission within 2 hours of MET activation,[21] identified using the MET and ICU databases. We chose ICU admission within 2 hours because local policy is to decide on patient disposition within 30 minutes of MET arrival. An additional 90 minutes was provided to enable ICU transfer. We examined the following 4 secondary outcome measures: (1) change in patient goals of care (resuscitative, medical, or comfort) within 24 hours of MET activation; (2) hospital mortality; (3) health care resource use, evaluated by investigations and interventions performed during the initial MET activation or a new MET activation (including the use of cardiopulmonary resuscitation); and (4) ICU admission during the remainder of the hospitalization (ie, >2 hours following the initial MET activation).

STATISTICAL ANALYSIS

The primary analysis tested associations between the number of ICU beds available (0, 1, 2, or >2) and ICU admission within 2 hours of MET activation using a generalized estimating equations model. The unit of analysis was the initial MET activation during the hospitalization (subsequent MET activations were evaluated as an outcome). We selected a generalized estimating equations model because it is an extension of standard logistic regression analysis that adjusts for correlation among observations (ie, patients with >1 hospitalization having a MET activation during the study period or patients clustered within hospitals)[22,23] and provides population average effect (average response for observations sharing the same covariates), which has familiar interpretation and is more useful when estimating effects at a population level.[24,25] We adjusted for patient, physician, and hospital covariates (all baseline variables measured) when analyzing outcome measures. Health care resource use was tested across the 4 defined levels of ICU bed availability using Pearson product moment correlation χ^2 test for differences in proportions and Kruskal-Wallis test for differences in medians. Sensitivity analyses were performed to explore the effect on the primary outcome of study hospital, time of MET activation, physician attending MET activation, and patient goals of care. Statistical analyses were performed using commercially available software (SAS version 9.2; SAS Institute, Inc), and 2-sided $P < .05$ was considered significant. The Conjoint Health Research Ethics Board at the University of Calgary approved this study and waived the need for informed consent from patients and physicians.

Table 1. Patient, Physician, and Hospital Characteristics at the Time of Medical Emergency Team (MET) Activation

	ICU Beds Available, No.			
Characteristic	0 (n = 249)	1 (n = 470)	2 (n = 718)	>2 (n = 2057)
Patient				
Age, median (IQR), y	75 (62-84)	75 (61-82)	72 (57-81)	71 (56-81)
Female sex, No. (%)	128 (51.4)	216 (46.0)	366 (51.0)	928 (45.1)
Race/ethnicity, No. (%)				
First Nations	4 (1.6)	7 (1.5)	13 (1.8)	39 (1.9)
Chinese	6 (2.4)	10 (2.1)	19 (2.6)	42 (2.0)
South Asian	5 (2.0)	23 (4.9)	26 (3.6)	89 (4.3)
Other	234 (94.0)	430 (91.5)	660 (91.9)	1887 (91.7)
Social program beneficiary, No. (%)	12 (4.8)	29 (6.2)	46 (6.4)	147 (7.1)
Household income quintile, No. (%)[a]	(n = 244)	(n = 467)	(n = 710)	(n = 2047)
1, Lowest	55 (22.5)	113 (24.2)	171 (24.1)	533 (26.0)
2	60 (25.0)	99 (21.2)	162 (22.8)	447 (21.8)
3	50 (20.5)	104 (22.3)	146 (20.6)	405 (19.8)
4	46 (18.9)	73 (15.6)	128 (18.0)	331 (16.2)
5, Highest	33 (13.5)	78 (16.7)	103 (14.5)	331 (16.2)
Comorbidity, No. (%)				
Congestive heart failure	33 (13.3)	75 (16.0)	100 (13.9)	321 (15.6)
Coronary artery disease	14 (5.6)	29 (6.2)	65 (9.1)	153 (7.4)
Chronic lung disease	32 (12.9)	71 (15.1)	94 (13.1)	289 (14.0)
Diabetes mellitus	34 (13.7)	64 (13.6)	117 (16.3)	329 (16.0)
Liver disease	6 (2.4)	21 (4.5)	34 (4.7)	99 (4.8)
History of malignant neoplasm	29 (11.6)	58 (12.3)	87 (12.1)	267 (13.0)
Human immunodeficiency virus	0	0	3 (0.4)	6 (0.3)
Neurological disease	21 (8.4)	37 (7.9)	65 (9.1)	163 (7.9)
Renal insufficiency	21 (8.4)	41 (8.7)	64 (8.9)	217 (10.5)
Any comorbidity	103 (41.4)	207 (44.0)	338 (47.1)	965 (46.9)
Charlson score, median (IQR)[b]	3 (2-6)	3 (2-5)	2 (1-3)	2 (1-3)
Baseline patient goals of care, No. (%)				
Resuscitative	157 (63.1)	319 (67.9)	485 (67.5)	1424 (69.2)
Medical	91 (36.5)	147 (31.3)	228 (31.8)	627 (30.5)
Comfort	1 (0.4)	4 (0.9)	5 (0.7)	6 (0.3)
Length of hospital stay before MET activation, median (IQR), d	4 (1-13)	4 (2-14)	5 (2-14)	5 (2-15)
Reason for hospital admission, No. (%)[a]				
Medical	150 (60.2)	279 (59.4)	419 (58.4)	1232 (60.0)
Surgical	90 (36.1)	168 (35.7)	250 (34.8)	671 (32.6)
Neurological	9 (3.6)	23 (4.9)	49 (6.8)	153 (7.4)
Prior ICU admission during hospital stay	19 (7.6)	35 (7.4)	68 (9.5)	239 (11.6)
Reason for MET activation, No. (%)[c]				
Respiratory	114 (45.8)	221 (47.0)	371 (51.7)	1150 (55.9)
Heart rate	47 (18.9)	69 (14.7)	129 (18.0)	330 (16.0)
Systolic blood pressure <90 mm Hg	66 (26.5)	130 (27.7)	192 (26.7)	514 (25.0)
Neurological	117 (47.0)	257 (54.7)	361 (50.3)	1047 (50.9)
Worried	51 (20.5)	102 (21.7)	160 (22.3)	445 (21.6)
Physician				
Type of physician attending MET activation, No. (%)	(n = 249)	(n = 469)	(n = 717)	(n = 2051)
ICU physician extender	72 (28.9)	144 (30.7)	255 (35.5)	863 (42.0)
Resident	72 (28.9)	102 (21.7)	106 (14.8)	218 (10.6)
ICU fellow	11 (4.4)	37 (7.9)	60 (8.4)	194 (9.5)
ICU attending	94 (37.8)	186 (39.6)	296 (41.2)	776 (37.7)
Hospital				
Time of MET activation, No. (%)				
Weekday	178 (71.5)	367 (78.1)	544 (75.8)	1486 (72.2)
Weekend or statutory holiday	71 (28.5)	104 (22.1)	174 (24.2)	571 (27.8)
Nighttime, 5 PM to 8 AM	126 (50.6)	244 (51.9)	397 (55.3)	1264 (61.4)

Abbreviations: ICU, intensive care unit; IQR, interquartile range.
[a] Due to missing data, totals do not sum to subpopulations.
[b] Calculated for patients with 1 or more comorbidities.
[c] Numbers do not sum to 100% because more than 1 reason for MET activation was observed in some patients.

RESULTS

PATIENT CHARACTERISTICS

The cohort consisted of 3494 patients (3.2 patients per day with sudden clinical deterioration and MET activation). The median age was 72 years (interquartile range [IQR], 57-81 years), 46.8% were female, 46.2% had 1 or more comorbidities, and 10.3% had a prior ICU admission during their hospital stay. Fewer MET activations occurred when zero ICU beds (249 [7.1%]) or 1 ICU bed (470 [13.5%]) was available. Patient characteristics by ICU bed availability were similar, with a few notable exceptions (**Table 1**). MET activations at night and for respiratory reasons were more common when more ICU beds were available. Residents were more likely to be the

Table 2. Medical Emergency Team (MET) Processes of Care

Process	ICU Beds Available, No. 0 (n = 249)	1 (n = 470)	2 (n = 718)	>2 (n = 2057)	*P* Value[a]
Duration of MET activation, median (IQR), min	53 (34-85)	54 (35-84)	51 (31-76)	53 (33-80)	.13[b]
Investigation, No. (%)					
Arterial blood gas	104 (41.8)	219 (46.6)	366 (51.0)	1156 (56.2)	<.01
Electrocardiogram	157 (63.1)	265 (56.4)	395 (55.0)	1165 (56.6)	.18
Radiograph of chest or abdomen	108 (43.4)	185 (39.4)	318 (44.3)	994 (48.3)	<.01
Computed tomography	17 (6.8)	26 (5.5)	52 (7.2)	137 (6.7)	.71
Intervention, No. (%)					
Airway suctioned	15 (6.0)	50 (10.6)	93 (13.0)	341 (16.6)	<.01
Oxygen	181 (72.7)	334 (71.1)	531 (74.0)	1570 (76.3)	.08
Nebulized medications	23 (9.2)	53 (11.3)	92 (12.8)	298 (14.5)	.05
Intubation and mechanical ventilation	11 (4.4)	30 (6.4)	53 (7.4)	207 (10.1)	<.01
Peripheral intravenous line	73 (29.3)	151 (32.1)	214 (29.8)	666 (32.4)	.51
Central intravenous line	5 (2.0)	8 (1.7)	23 (3.2)	54 (2.6)	.41
Fluid bolus	86 (34.5)	169 (36.0)	249 (34.7)	747 (36.3)	.85
Vasoactive medication	7 (2.8)	21 (4.5)	36 (5.0)	112 (5.4)	.31
Foley catheter inserted	27 (10.8)	51 (10.9)	62 (8.6)	232 (11.3)	.27
Nasogastric tube inserted	7 (2.8)	12 (2.6)	30 (4.2)	105 (5.1)	.05

Abbreviation: IQR, interquartile range.
[a] Pearson product moment correlation χ^2 test for differences in proportions unless otherwise indicated.
[b] Kruskal-Wallis test for differences in medians.

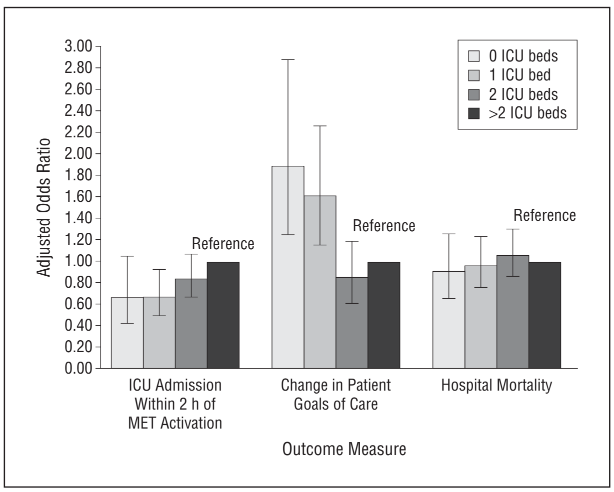

Figure. Adjusted odds ratios for intensive care unit (ICU) admission within 2 hours of medical emergency team (MET) activation, change in patient goals of care, and hospital mortality according to ICU bed availability. Vertical lines indicate 95% CIs.

physician attending MET activation when fewer ICU beds were available.

PROCESS OF CARE

We examined MET processes of care according to the number of ICU beds available (**Table 2**). Although the duration of MET activations was similar across groups (median, 53 minutes; IQR, 33-80 minutes), there were significant positive associations between the number of ICU beds available and the use of investigations and interventions. Patients were more likely to have arterial blood gases measured and radiographs obtained of the chest or abdomen when more ICU beds were available ($P < .01$ for both). Noninvasive airway interventions, including airway suctioning ($P < .01$), oxygen ($P = .08$), and nebulized medications ($P = .05$), were more frequently provided when more ICU beds were available. In total during MET activations, 4.4% of patients were intubated and mechanically ventilated when zero ICU beds were available and 10.1% of patients when more than 2 ICU beds were available ($P < .01$).

OUTCOMES

Multivariable-adjusted analyses of patient outcomes of care are summarized in the **Figure**, **Table 3**, and **Table 4**. Hospitalized patients with sudden clinical deterioration were significantly more likely to be admitted to the ICU within 2 hours of MET activation when more ICU beds were available ($P = .03$) (Table 3). In total, 11.6% of patients evaluated by the MET when zero ICU beds were available and 21.4% of patients when more than 2 ICU beds were available were admitted to the ICU within 2 hours of MET activation. Among patients not admitted to the ICU within 2 hours of MET activation, subsequent ICU admissions were infrequent in all 4 groups (eTable; available at http://www.archinternmed.com). Few patients in all 4 groups (411 [11.8%]) experienced cardiac arrest or new MET activation following the initial patient MET activation. Length of ICU stay for patients admitted to the ICU within 2 hours of MET activation (median, 4 days; IQR, 2-8 days) and length of hospital stay after MET activation for patients discharged alive (median, 15 days; IQR, 7-35 days) were similar across the groups. More patients had their goals of care changed from resuscitative care to medical or comfort care when zero ICU beds were available (37 [14.9%]) compared with when 2 or more ICU beds were available (174 [8.5%]) ($P < .01$). Hospital mortality was similar across the 4 patients groups ($P = .82$), ranging from 32.1% to 34.7%.

Table 3. Medical Emergency Team (MET) Outcomes of Care

Outcome	ICU Beds Available, No. 0 (n = 249)	1 (n = 470)	2 (n = 718)	>2 (n = 2057)	*P* Value[a]
ICU admission within 2 h of MET activation, No. (%)	29 (11.6)	68 (14.5)	127 (17.7)	440 (21.4)	.03
Time from MET activation to ICU admission, median (IQR), min[b]	65 (43-105)	55 (31-84)	50 (36-71)	57 (37-83)	.05
Subsequent ICU admission, No. (%)[c]	26 (10.4)	31 (6.6)	62 (8.6)	203 (10.0)	.20
Change in patient goals of care, No. (%)[d]	37 (14.9)	62 (13.2)	56 (7.8)	174 (8.5)	<.01
Cardiac arrest or new MET activation, No. (%)[e]	28 (11.2)	57 (12.1)	79 (11.0)	247 (12.0)	.92
Length of ICU stay, median (IQR), d[b]	5 (2-9)	3 (1-6)	4 (1-9)	4 (2-8)	.72
Length of hospital stay after MET activation, median (IQR), d[f]	13 (6-37)	13 (6-34)	15 (6-36)	15 (7-35)	.36
Hospital mortality, No. (%)	80 (32.1)	153 (32.6)	249 (34.7)	704 (34.2)	.82
Hospital disposition for patients discharged alive, No. (%)[g]	(n = 169)	(n = 317)	(n = 469)	(n = 1351)	
Home without support services	89 (52.7)	168 (53.0)	242 (51.6)	690 (51.1)	
Home with support services	34 (20.1)	51 (16.1)	65 (13.9)	214 (15.8)	.17
Another hospital or facility	46 (27.2)	98 (30.9)	162 (34.5)	447 (33.1)	

Abbreviations: ICU, intensive care unit; IQR, interquartile range.
[a]Using a generalized estimating equations model, *P* values were adjusted for age, sex, race/ethnicity, socioeconomic status, comorbidities, baseline patient goals of care, reason for hospital admission, ICU admission before MET activation, length of hospital stay before MET activation, reason for MET activation, time of MET activation, and type of physician attending MET activation.
[b]Among patients admitted to the ICU within 2 hours of MET activation.
[c]Patients not admitted to an ICU within 2 hours of MET activation but admitted to an ICU during the remainder of the hospital stay.
[d]Change in patient goals of care (resuscitative care, medical care, or comfort care) within 24 hours of MET activation.
[e]Cardiac arrest in the hospital or a new MET activation after the initial MET activation.
[f]Among patients discharged alive (includes ICU stay if relevant).
[g]Due to missing data, totals do not sum to subpopulations.

The number of ICU beds available was associated with the likelihood of ICU admission within 2 hours of MET activation and with change in patient goals of care (Table 4 and Figure). Compared with when more than 2 ICU beds were available, ICU admission was 33.0% (95% CI, −5.1% to 57.3%) less likely when zero ICU beds were available and 32.4% (95% CI, 7.3% to 50.7%) less likely when 1 ICU bed was available. Conversely, change in patient goals of care from resuscitative care to medical or comfort care was 89.6% (95% CI, 24.9%-188.0%) more likely when zero ICU beds were available and 61.8% (95% CI, 15.5%-126.6%) more likely when 1 ICU bed was available. The adjusted odds ratios for hospital mortality were not significantly different across the 4 groups, although the 95% CI when zero ICU beds were available included a 25.6% increase in hospital mortality. Results were similar when analyses were stratified according to study hospital, time of MET activation, and physician attending MET activation or when restricted to patients with resuscitative goals of care at the time of MET activation.

COMMENT

In this population-based cohort study, we found a strong association between the number of ICU beds available and processes of care for hospitalized patients with sudden clinical deterioration. We noted a lower probability of patient ICU admission and a higher probability of change in patient goals of care from resuscitative care to medical or comfort care as the number of ICU beds available decreased. Hospital mortality was similar for patients regardless of the number of ICU beds available. This suggests that, for hospitalized patients with sudden clinical deterioration, the number of ICU beds available at the time of their deterioration affects processes of care but may not influence hospital mortality.

Our study provides important information on how ICU bed availability can affect processes of care for hospitalized patients with sudden clinical deterioration. Results of previous studies[5,26-30] have demonstrated that as hospitals close ICU beds, patients admitted to the ICU are sicker, are less likely to be admitted for monitoring, and have shorter stays but with no adverse effects. Patient age, illness severity, and medical diagnosis were noted to be associated with decisions not to admit patients to the ICU.[5,31-35] Our study adds to the literature in several ways. First, we demonstrate that the decision to admit a hospitalized patient with sudden clinical deterioration to the ICU is influenced by the number of ICU beds available. Second, rationing of ICU beds is a routine occurrence. We found that during a 3-year period, there was no ICU bed available at the time of MET activation for 7.1% of patients with sudden clinical deterioration. This is equivalent to 1 or 2 patients per week experiencing sudden clinical deterioration at a time when no ICU beds are available. Third, the decision to admit a hospitalized patient with sudden clinical deterioration to the ICU is complex and is influenced by patient, physician, and hospital factors. For example, our results suggest that ICU admission may be influenced by the type of physician attending MET activation (ICU attending, trainee, or ICU physician extender), despite ICU attending medical oversight of the rapid response system. Fourth, with limited training in resource allocation, it is unclear how effective physicians are at identifying patients who are most likely to benefit from ICU admission. In our study, there was no difference in hospital mortality among patients with MET activation according to the availability of ICU beds. Furthermore, among those patients who were not admitted to ICU, the risk of new MET activation and subsequent ICU admission was similar. These results sug-

Table 4. Adjusted Odds Ratios for Outcome Measures[a]

Variable	Adjusted Odds Ratio (95% CI)	*P* Value
ICU Admission Within 2 h of MET Activation		
ICU beds available, No.		.03
0	0.670 (0.427-1.051)	
1	0.676 (0.493-0.927)	
2	0.845 (0.668-1.068)	
>2	1 [Reference]	
Age, for each additional year	0.995 (0.989-1.000)	.05
Charlson score, for each additional point	1.048 (1.012-1.084)	<.01
Baseline patient goals of care, resuscitative vs medical or comfort	8.245 (5.934-11.457)	<.01
Length of hospital stay before MET activation, for each additional day	0.996 (0.991-1.000)	.02
Prior ICU admission during hospital stay	1.878 (1.431-2.464)	<.01
Reason for MET activation		
Respiratory	3.939 (3.168-4.899)	<.01
Systolic blood pressure <90 mm Hg	1.735 (1.378-2.185)	<.01
Neurological	1.295 (1.068-1.569)	.01
Worried	1.559 (1.252-1.941)	<.01
Time of MET activation		
Nighttime, 5 PM to 8 AM	1.518 (1.201-1.920)	<.01
Weekend	1.390 (1.125-1.717)	<.01
Type of physician attending MET activation		<.01
ICU physician extender	0.653 (0.435-0.978)	
Resident	0.698 (0.507-0.962)	
ICU fellow	1.228 (0.874-1.727)	
ICU attending	1 [Reference]	
Change in Patient Goals of Care[b]		
ICU beds available, No.		<.01
0	1.896 (1.249-2.880)	
1	1.618 (1.155-2.266)	
2	0.853 (0.610-1.193)	
>2	1 [Reference]	
Age, for each additional year	1.032 (1.022-1.043)	<.01
Baseline patient goals of care, resuscitative care vs medical or comfort	0.633 (0.483-0.829)	<.01
Reason for hospital admission		
Medical	1.423 (1.066-1.900)	<.01
Neurological	2.383 (1.509-3.761)	
Surgical	1 [Reference]	
Reason for MET activation		
Respiratory	2.555 (1.946-3.354)	<.01
Neurological	1.744 (1.353-2.248)	<.01
Worried	1.339 (1.015-1.766)	.04
Hospital Mortality		
ICU beds available, No.		
0	0.910 (0.660-1.256)	.82
1	0.965 (0.757-1.230)	
2	1.062 (0.865-1.304)	
>2	1 [Reference]	
Age, for each additional year	1.023 (1.017-1.029)	<.01
Baseline patient goals of care, resuscitative vs medical or comfort	0.320 (0.266-0.385)	<.01
Reason for hospital admission		<.01
Medical	1.555 (1.299-1.861)	
Neurological	1.196 (0.852-1.678)	
Surgical	1 [Reference]	
Reason for MET activation		
Respiratory	2.900 (2.433-3.458)	<.01
Systolic blood pressure <90 mm Hg	2.064 (1.707-2.494)	<.01
Neurological	1.509 (1.281-1.778)	<.01
Worried	1.592 (1.317-1.924)	<.01
Time of MET activation		
Nighttime, 5 PM to 8 AM	1.329 (1.081-1.635)	<.01
Weekend	1.328 (1.109-1.591)	<.01

Abbreviations: ICU, intensive care unit; MET, medical emergency team.

[a]Using a generalized estimating equations model, odds ratios are reported for ICU bed availability and patient, physician, and hospital characteristics with $P \leq .05$ after adjustment for age, sex, race/ethnicity, socioeconomic status, comorbidities, baseline patient goals of care, reason for hospital admission, ICU admission before MET activation, length of hospital stay before MET activation, reason for MET activation, time of MET activation, and type of physician attending MET activation.

[b]Within 24 hours of MET activation.

gest that available resources may have been efficiently allocated to meet patient needs. Conversely, findings from other studies[36-38] have suggested that prognostication for critically ill patients is difficult and that physicians can be overconfident in their ability to identify patients with poor prognoses who are unlikely to benefit from ICU care.

Our study also underscores some important challenges for ensuring optimal allocation of ICU beds. First, results from our study may also suggest that ICU physicians are more likely to admit patients who will not benefit from critical care resources when ICU beds are available. Having different clinical thresholds for patient ICU admission based on physician or health system factors may result in misallocation of patients to hospital units and may compromise the quality and efficiency of health care delivery.[8,39] Intensive care unit admission and discharge guidelines could optimize patient allocation.[40,41] Second, mechanisms are required to increase the flexibility of critical care resources in systems that operate near capacity. METs are one mechanism for providing ICU outreach. Alternative strategies could include creating temporary ICU resources (strategies not now used by the study hospitals) by transferring hospitalized patients with sudden clinical deterioration to other spaces in the hospital that are suitable for advanced resuscitation and monitoring (eg, coronary care unit, postoperative care unit, or emergency department), while securing access to an ICU bed or transferring patients between ICUs. Third, mechanisms are needed to explicitly manage resource allocation when demand exceeds supply. Development and implementation of valid and reliable triage instruments would make evaluation and decision-making processes for critically ill patients transparent.[42]

As a result of the study design, we acknowledge the following limitations. First, the definition of our primary outcome (ICU admission within 2 hours of MET activation) is somewhat subjective because patients may be monitored on the ward and admitted after 2 hours if clinical conditions change. Nevertheless, this measure has been proposed as an indicator of ICU quality,[21] and sensitivity analyses using different time thresholds for ICU admission (within 1, 3, 4, or 5 hours) demonstrated similar findings. Second, even with adjustment, residual confounding is an inherent risk for all observational studies, and it is possible that factors other than the number of ICU beds available might explain differences in ICU admission rates. However, most MET activations are triggered by hospital ward nurses who are unaware of ICU bed availability; as such, we do not anticipate the case mix of patients (specifically, unmeasured characteristics) triggering MET activations to change with the number of ICU beds available. Third, despite a study cohort of more than 3000 patients with detailed hospitalization (but not posthospitalization) data, we are unable to exclude small but clinically important differences in patient outcomes. Fourth, our study was performed in a single publicly funded health region. Allocation of ICU resources and decision-making processes for patient goals of care may vary across health care jurisdictions; therefore, the results may not apply to other institutions. However, the challenges of scarce ICU resources presented herein are likely common in other health organizations.[5]

In summary, for hospitalized patients, the number of ICU beds available at the time of sudden clinical deterioration affects processes of care. As the number of available ICU beds decreases, patients are less likely to be admitted to the ICU and are more likely to have their goals of care changed, although this does not seem to be associated with hospital mortality. This suggests that the development of validated ICU admission and discharge guidelines might improve hospital efficiency, without affecting outcomes.

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INVITED COMMENTARY

ONLINE FIRST

Deferred Admission to the Intensive Care Unit

Rationing Critical Care or Expediting Care Transitions?

There are several reasons to doubt that we can expand the supply of high-quality critical care to meet the expected surge in demand brought on by an aging population. First, critical care expenditures already strain nations' abilities to meet other socially desirable goals.[1] Second, most critically ill patients are cared for by physicians who lack specific training in critical care medicine,[2] a staffing model that