SOUTHERN SURGICAL ASSOCIATION ARTICLE

Critical Care Resuscitation Unit: An Innovative Solution to Expedite Transfer of Patients with Time-Sensitive Critical Illness

Thomas M Scalea, MD, FACS, MCCM, Lewis Rubinson, MD, PhD, Quincy Tran, MD, PhD, Kevin M Jones, MD, Jeffrey H Rea, MD, Deborah M Stein, MD, MPH, FACS, FCCM, Stephen T Bartlett, MD, FACS, James V O'Connor, MD, FACS, FCCP

BACKGROUND: Time-sensitive, critical surgical illnesses require care at specialized centers. Trauma systems facilitate patient transport to designated trauma centers, but formal systems for nontraumatic critical illness do not exist. We created the critical care resuscitation unit to expedite transfers of adult critically ill patients with time-sensitive conditions to a quaternary academic medical center, hypothesizing that this would decrease time to transfer, increase transfer volume, and improve outcomes.

STUDY DESIGN: Critical care transfers to the University of Maryland Medical Center during the first year of the critical care resuscitation unit (July 2013 to June 2014) were compared with a previous year (July 2011 to June 2012). Times from transfer request to arrival and operating room and hospital mortality were compared.

RESULTS: There was a 64.5% increase in transfers with a 93.6% increase in critically ill surgical patients. For patients requiring operation, median time to arrival and operating room (118 vs 223 minutes and 1,113 vs 3,424 minutes, respectively; $p < 0.001$ for both) and median hospital length of stay (13 vs 17 days; $p < 0.001$) were reduced significantly. There was a nonsignificant trend toward lower mortality (14.6% vs 16.5%; $p = 0.27$).

CONCLUSIONS: The critical care resuscitation unit dramatically increased the volume of critically ill surgical patients. It decreased transfer times, increased volume, and, for those who required urgent operation, decreased time from initial referral to operating room. This benefit seems to be most marked in patients needing urgent operation. This might be a paradigm shift expediting the transfer of patients with time-sensitive critical illness to an appropriately resourced specialty center. (J Am Coll Surg 2016;■:1−8. © 2016 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

Critically ill patients require specialized care available in an ICU, and might also need subspecialty expertise. In some conditions, such as aortic emergencies, stroke, hemorrhage, abdominal catastrophes, sepsis, refractory respiratory failure, and acute vascular compromise, time to definitive care is especially important. Outcomes for some of these patients might also be better at high-volume centers.[1-6] However, some patients might initially present to a local facility that cannot provide the comprehensive care needed and must then be transferred to a referral center.[7,8] Among the nearly 5,000 acute care hospitals in the United States, 27% provide only one specialized service among the following important time-sensitive conditions: stroke, ST-segment elevation MI, and trauma.[9] Despite the frequency of transfer of patients with these life-threatening conditions, formal systems to insure timely transfer to the referral centers rarely exist.

Since the 1966 landmark white paper that catalyzed the formation of trauma systems, care for the injured has been organized within regionalized systems, which

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From the Department of Surgery (Scalea, Stein, Bartlett, O'Connor), Department of Medicine (Rubinson), and Department of Emergency Medicine (Tran, Jones, Rea), R Adams Cowley Shock Trauma Center, University of Maryland Medical Center, Baltimore, MD.

Correspondence address: Thomas M Scalea, MD, FACS, MCCM, Department of Surgery, R Adams Cowley Shock Trauma Center, University of Maryland School of Medicine, 22 S Greene St, Baltimore, MD 21201. email: tscalea@umm.edu

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Abbreviations and Acronyms

ACES = acute care emergency service
CCRU = critical care resuscitation unit
CS = cardiac surgery service
MEC = Maryland Express Care
STC = shock trauma center
UMMC = University of Maryland Medical Center

has demonstrated improved survival.[10-12] The ability to rapidly transport seriously injured patients to designated centers from either the scene or an emergency department is an integral part of these systems. A similar formal integrated system for critically ill, nontrauma patients does not exist in the United States.[13-15]

To optimize outcomes, high-volume referral centers should have a suitable location to receive, resuscitate and, facilitate prompt subspecialty consultation. For surgical patients, rapid operative care might be needed. Direct transfers to an ICU seem logical, but the lack of an immediately available bed, especially at large referral centers, is an impediment to inter-hospital transfers.[14,16] This can have profound clinical implications.[17,18] In addition, most ICUs are designed to provide high-level care over a period of time, but might not be ideally suited to perform rapid evaluation of a new patient.

The University of Maryland Medical Center (UMMC) is an 801-bed quaternary care hospital and the flagship institution for a 12-hospital system. Co-located on the campus is the R Adams Cowley Shock Trauma Center (STC), which is the only free-standing trauma center in the United States. The UMMC/STC has the following high-volume specialty services: cardiothoracic surgery, vascular surgery, emergency general surgery, trauma, neurosurgery, transplant surgery, neurology, and oncology. Critically ill patients at UMMC receive care in 1 of 7 adult specialized ICUs with a total of 155 beds.

To increase UMMC/STC capability of providing immediate ICU access to accommodate interhospital transfers with time-sensitive surgical critical illness, we opened the critical care resuscitation unit (CCRU) in July 2013, a 6-bed ICU located in the STC, to increase adult critical care transfers, decrease referral requests that were not transferred (lost admissions), and improve outcomes for nontrauma critical care transfers. The CCRU is staffed 24 hours a day, 7 days a week by an attending intensivist who actively triages and manages CCRU patients, allocates bed resources, and facilities throughput. The CCRU staff and subspecialty consultants collaborate to rapidly assess patients, perform complex critical care interventions, and transfer patients to the appropriate unit or operating room for definitive management.

METHODS

Nontrauma interhospital transfer process

Other facilities refer patients to UMMC via our in-house referral center, Maryland ExpressCare (MEC). Maryland ExpressCare coordinates communication between the referring and accepting physicians, arranges full-service critical care ground transport, and organizes aeromedical transportation when appropriate. Maryland ExpressCare records information on all referrals, even those patients ultimately not transported to UMMC.

Before opening the CCRU, a patient was accepted for transfer by a fellow or attending physician from the relevant subspecialty service. Transport was not initiated until a bed in the appropriate ICU was available. After the opening of the CCRU, the transfer process was expedited. Patients were still referred through MEC and all patients underwent a specialty consultation to determine whether transfer to UMMC was appropriate. However, rather than requiring bed availability in the appropriate ICU, patients were transferred to the CCRU. The CCRU attending provided critical care guidance to the referring clinician and medical oversight for the MEC transfer teams. Similar to STC's trauma processes, the CCRU procedures were developed and optimized for rapid evaluation, resuscitation, and intervention. Patients requiring emergent operation went to the operating room; others were transferred to the appropriate ICU when a bed was available. We had a CCRU length of stay goal of 6 hours to permit continuous CCRU bed availability. The study was approved by the IRB of the University of Maryland School of Medicine.

Nontrauma interhospital transfer volume

Adult critically ill, inter-hospital transfers admitted to a UMMC ICU or CCRU were identified from the MEC database. We compared 2 similar calendar periods for which complete transfer data existed: July 2011 to June 2012 (pre-CCRU) and July 2013 to June 2014 (post-CCRU). We excluded July 2012 to June 2013 because we did not have complete transfer data and to allow the CCRU to mature. In the post-CCRU group, critical care transfers included all transfers admitted to the CCRU or another UMMC ICU. For both time periods, patients transferred for injury management and pediatric transfers were excluded from the analyses. Each MEC record was manually matched to the appropriate inpatient record; records that could not be verified were excluded. Time of referral was recorded in the MEC database and

time of arrival was recorded in the inpatient record from census tracking data. If, at the time of arrival, referral could not be validated, these patients were also excluded (Fig. 1). Lost admissions, defined as those patients referred to UMMC but not transferred, were compared for the same periods.

Pre-critical care resuscitation unit vs post-critical care resuscitation unit

Times from initiating MEC referral to arrival, operative intervention within the first 12 hours of arrival, or operation at any time during their hospitalization; hospital length of stay; and mortality were compared between the pre-CCRU and post-CCRU groups. Because the primary mission of the CCRU is to expedite time-sensitive surgical critical care transfers, patients transferred to the acute care emergency service (ACES) and cardiac surgery service (CS), who often require emergent surgical care, were compared pre-CCRU and post-CCRU. Additionally, subsets of these patients who went to the operating rooms within 12 hours of arrival, which we defined as an urgent operation, were compared between the 2 time periods.

Statistical analysis

Frequency data were analyzed using chi-square tests with Yates correction when appropriate. Time to events was reported as median and interquartile ranges and analyzed using Wilcoxon rank-sum test. All p values were 2-sided and p values <0.05 were considered to be statistically significant. Statistical tests were performed with Sigma Plot, version 13 (Systat Software).

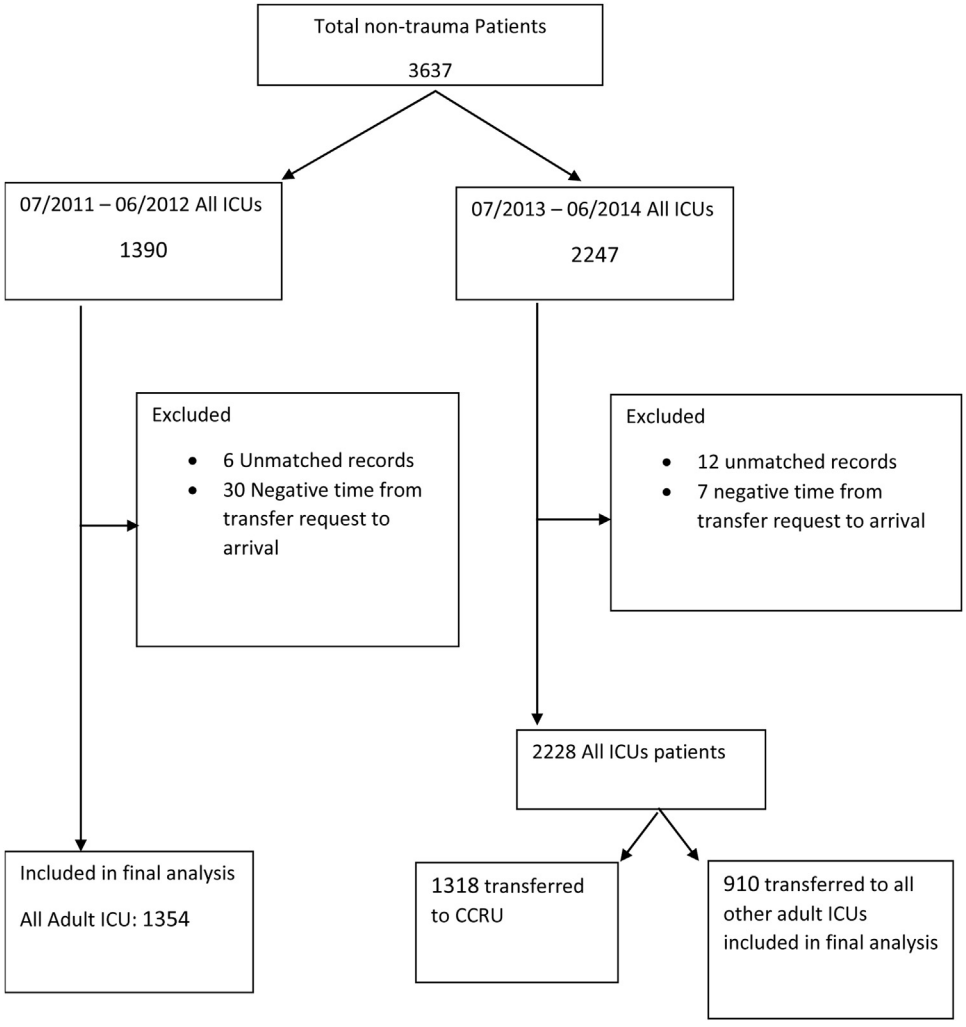

Figure 1. Critical care resuscitation unit (CCRU) flow diagram.

RESULTS

During the post-CCRU period, 2,228 critical care transfers were admitted to UMMC compared with 1,354 in the pre-CCRU era. This represents a 64.5% increase in total critical care transfers and a 93.6% increase in critically ill surgical transfers. Of the 2,228 patients, 1,318 (59.2%) were transferred to the CCRU; the remaining 910 patients were transferred directly to a UMMC ICU (Fig. 1 and Table 1). In the pre-CCRU era, there were 469 lost admissions (25.7% of transfer requests) and post-CCRU, there were 363 lost admissions (14% of transfer requests). Although the transfer volume increased, lost admissions and the percentage of lost admissions to total referrals were reduced significantly (Table 1). In the post-CCRU era, there were still lost admissions, however, most were either not considered appropriate CCRU transfers as they were not critically ill, or, rarely, the 6-bed unit was at capacity.

Patients transferred to the CCRU arrived significantly faster (median time from consultation to arrival was 129 vs 234 minutes; $p < 0.001$) (Table 2). Likewise, significantly more CCRU patients required an operation during their hospital course (46% vs 31.1%; $p < 0.0001$) and a significantly higher percentage had an operation within 12 hours of arrival (41% vs 21.4%; $p < 0.0001$). For all surgical patients, time from consult to arrival and time from arrival to incision were significantly shorter in the post-CCRU era (118 vs 223 minutes and 1,133 vs 3,424 minutes respectively; $p < 0.001$ for both).

In the post-CCRU era, overall length of stay was significantly longer (9 vs 8 days; $p = 0.01$), however, it was significantly shorter for those requiring an operation (13 vs 17 days; $p < 0.001$). There was a trend toward lower mortality for all CCRU patients compared with the pre-CCRU period, as well as for the subset that required an operation, but neither comparison was statistically significant (Table 2).

Acute care emergency service and cardiac surgery patients

The combined number of ACES and CS patients transferred to the CCRU increased by 66.8% when compared with the earlier period (Table 3). Comparing the pre and post-CCRU periods, there was no difference in hospital length of stay or percentage of patients requiring surgery, however, significantly more CCRU patients required an urgent operation (31.1% vs 50%; $p < 0.001$). For all operative patients, time from consult to arrival and time from arrival to incision were significantly shorter post-CCRU (120 vs 202 minutes and 779 vs 1,393 minutes, respectively; $p < 0.001$ for both). Post-CCRU, 114 patients had an urgent operation (32% of all ACES and CS patients and 50% of those requiring an operation). This is a significant increase compared with the pre-CCRU period, when 41 patients had urgent surgery (19.2% of all ACES and CS patients and 31.1% requiring

Table 1. Nontrauma, Adult Critical Care Transfers and Lost Admissions to the University of Maryland Medical Center

Variables	2011–2012 ICUs	2013–2014 ICU/CCRU	2013–2014 CCRU	p Value
Total critical care transfers, n	1,354	2,228	1,318	
Mortality, n (%)	224 (16.5)	365 (16.4)	193 (14.6)	0.31
Length of stay, d (excludes in-hospital mortality), median (interquartile range)	8 (4–15)	8 (4–15)	9 (5–16)	0.059
Lost admissions, n	469	363		
Lost admissions/total critical care referrals, %	25.7	14		<0.001
Clinical service, n				
Acute care emergency service	57	161	155	
Cardiac surgery	157	225	202	
Neurosurgery	219	375	222	
Orthopaedics	2	10	10	
Surgical ear, nose, throat	6	4	4	
Surgical oncology	1	13	13	
Thoracic surgery	23	14	12	
Transplant surgery	14	52	47	
Vascular surgery	40	143	140	
Urology	0	8	8	
Other*	835	1,223	505	

*Numerous clinical services, including cardiology, medicine, neurology, and pulmonary critical care.
CCRU, critical care resuscitation unit.

Table 2. Timing and Outcomes of Critical Care Transfers to the University of Maryland Medical Center: Pre vs Post-Critical Care Resuscitation Unit

Variables	2011–2012 Transfers to adult ICU	2013–2014 Transfers to CCRU	p Value
n	1,354	1,318	
Deaths, n (%)	224 (16.5)	193 (14.6)	0.27
Time from consult to arrival, min, median (IQR)	234 (142–418)	129 (85–236)	<0.001
Hospital LOS, d (excluding deaths), median (IQR)	8 (4–15)	9 (6–16)	0.01
CCRU LOS, h, median (IQR)	NA	9 (4–20)	
Patients operated during hospitalization, n (%)	421 (31.1)	605 (46)	<0.0001
Deaths, n (%)	65 (15.4)	77 (12.7)	0.25
Time from consult to arrival, min, median (IQR)	223 (146–406)	118 (76–200)	<0.001
Time from arrival to incision, min, median (IQR)	3,424 (927–9,752)	1,133 (323–5,195)	<0.001
Hospital LOS, d (excluding deaths), median (IQR)	17 (10–28)	13 (8–23)	<0.001
Patients operated within 12 h of arrival, n (% of operations)	90 (21.4)	248 (41)	<0.0001
Deaths, n (%)	13 (14.4)	31 (12.5)	0.78
Time from consult to arrival, min, median (IQR)	166 (118–258)	106 (67–155)	<0.001
Time from arrival to incision, min, median (IQR)	318 (192–489)	262 (177–446)	0.105
Hospital LOS, d (excluding deaths), median (IQR)	13 (7–26)	13 (7–21)	0.32

CCRU, critical care resuscitation unit; IQR, interquartile range; LOS, length of stay; NA, not applicable.

operation). During the CCRU period, these patients arrived in less time, with a median arrival time of 107 vs 162 minutes, but were not transferred to the operating room any faster and did not have a significantly faster time to incision (Table 3). For the first 7 months of the CCRU there was a statistically significant reduction in mortality. This did not persist for 12 months of data. In the post-CCRU period, there was a trend toward lower morality for all ACES and CS patients, including those having an urgent operation, but this did not achieve statistical significance (Table 3).

DISCUSSION

Regionalized care makes sense for a multitude of conditions. There are good data to support concentrating volume of complex surgical illness in a few centers, and there is a survival advantage for conditions such as pancreatic cancer, esophageal cancer, and aortic aneurysms.[19] This is a relatively simple process when patients can be evaluated as outpatients and then electively scheduled for their complex surgical procedures. Those patients might well need ICU care postoperatively, but this can be anticipated and plans made accordingly.

Table 3. Critical Care Transfers to University of Maryland Medical Center's Acute Care Emergency Surgery and Cardiac Surgery Services: Pre- vs Post-Critical Care Resuscitation Unit

Variables	2011–2012 ACES+CS	2013–2014 ACES+CS	p Value
n	214	357	
Deaths, n (%)	31 (14.5)	45 (12.6)	0.60
Time from consult to arrival, min, median (IQR)	199 (138–368)	131 (77–254)	<0.001
Hospital LOS, d (excluding deaths), median (IQR)	9 (6–19)	10 (5–18)	1.00
Patients operated during hospitalization, n (%)	132 (61.7)	228 (63.9)	0.70
Deaths, n (%)	17 (12.9)	27 (11.8)	0.92
Time from consult to arrival, min, median (IQR)	202 (138–409)	120 (74–220)	<0.001
Time from arrival to incision, min, median (IQR)	1393 (462–5102)	779 (219–4,133)	<0.001
Hospital LOS, d (excluding deaths), median (IQR)	12 (7–25)	12 (7–22)	0.5
Procedure in operating room within 12 h of arrival, n (% of operations)	41 (31.1)	114 (50)	<0.001
Deaths, n (%)	7 (17.1)	12 (10.5)	0.4
Time from consult to arrival, min, median (IQR)	162 (113–225)	107 (68–169)	<0.001
Time from arrival to incision, min, median (IQR)	254 (164–447)	224 (156–408)	0.49
Hospital LOS, d (excluding deaths), median (IQR)	8 (6–20)	11 (7–19)	0.65

ACES, acute care emergency surgery; CS, cardiac surgery services; IQR, interquartile range; LOS, length of stay.

In 1966, the Institute of Medicine defined injury as an epidemic in the United States. That report called for better organization around injury care.[10] Several subsequent reports from West and colleagues[20,21] followed, each one found that organized trauma care saved lives. More recently, we have realized that organizing care for other time-sensitive conditions likely matters. Centers that streamline care for conditions such as acute MI and stroke have now become common. We measure quality as the time it takes to deliver care once the patient reaches that center. Measures like "door to balloon time" are used to assess quality of care in these centers; however, we do not measure the time it takes to get the patient to that center.

In addition, community hospitals have recently become much less enamored with providing complex care. The finances of medical care now make it much less attractive for many community hospitals to provide comprehensive care for complex problems, particularly if they are only caring for a few of those patients per year. The volume of critically ill patients transferred from community hospitals to academic medical centers has increased. Several years ago, the most common reason for a lost admission at UMMC was the lack of an available ICU bed. Accepting the patient in transfer was not a problem, but identifying an immediately available bed became increasingly problematic. By the time the ICU bed was available, patients had often been transferred elsewhere. Therefore, we envisioned and created the CCRU.

The CCRU had the following goals: increase the transfer volume of critically ill patients, decrease lost admissions, minimize transfer times, and improve outcomes. The CCRU was conceived as a short-stay, fully capable ICU designed to rapidly admit, evaluate, and resuscitate critically ill, interhospital transfer patients, and coordinate care with multiple subspecialty services. In essence, we brought the model that we use for trauma in the STC to UMMC to care for other surgical patients. We believed this would increase bed availability and more fully align critical care with the various subspecialty services.

In the first year after opening the CCRU, there was a 64.5% increase in all critical care transfers, a 22.6% reduction in lost admissions, and a statistically significant reduction in time from transfer referral to patient arrival. Remarkably, this 6-bed ICU, which represents an increase of only 3.9% in total adult critical care bed capacity, admitted almost as many patients as were admitted to 1 of the 7 specialized ICUs before its opening. The impact of 6 additional ICU beds cannot solely explain this volume increase. With a median CCRU length of stay of 9 hours, improved throughput with patients promptly transferred to the appropriate specialty unit or the operating room, might have enhanced overall system efficiency. Because the unit was designed to accept admissions, the workflow is dramatically different than a traditional ICU, which focuses on longitudinal care.

A delay in admission to an ICU is associated with increased mortality.[17,22] The appropriate consulting UMMC specialty attending and the CCRU attending both participate on the referral phone conversation. Once the patient is accepted, the CCRU attending sets priorities for pending admissions and recommends mode of transport based on the patient's clinical status and the time sensitivity of the condition. In the post-CCRU period, this process reduced median time to arrival and therefore access to specialty expertise by more than 100 minutes. Faster time to intervention can improve outcomes because time to definitive treatment improves survival in some time-sensitive conditions.[5,6,11,12,23]

It has also been demonstrated that patients admitted to high-volume centers have improved survival, and this relationship is particularly evident in subsets of high-risk, critically ill, septic, and mechanically ventilated patients.[1-4] Clearly, this benefit is obviated by limited bed availability because refusal of an ICU admission results in higher mortality.[18] There are also negative consequences to admitting patients to a strained, near-capacity unit—less time is spent on rounds and, more importantly, a small increase in mortality was noted.[24,25]

Despite improved time to ICU admission, we did not see a statistically significant reduction in mortality. Although the entire CCRU cohort, and the subset requiring surgery, trended toward lower mortality, convincing evidence for improved outcomes was not found. The comparison groups might have had different conditions and severity of illness, but currently available data did not allow for physiologic risk adjustment. Among the CCRU patients, a higher percentage required an operation during their hospital stay and an urgent operation within 12 hours of arrival, suggesting higher acuity. It seems reasonable to conclude that these were the patients who previously were lost admissions. The referring hospital recognized that patient's required emergent care and, when we were not able to accept them immediately, they were transferred a center with an available bed.

The CCRU admits critically ill patients with a spectrum of underlying conditions. We currently do not have the physiologic data to allow risk adjustments. The pre-CCRU dataset was not the 12 months before the opening, as the complete transfer dataset was July 2011 to June 2012. However, there were no organizational or referral pattern changes in the year just before the CCRU opening. Future evaluations to assess the potential

effectiveness of the CCRU will concentrate on high-risk conditions, using severity of illness adjustment and developing a larger, more robust dataset.

There are several crucial factors that influence interhospital transfers of critically ill patients, specifically, increasing demand for critical care services, ICU bed capacity, severity of illness, and an available referral center.[9,14,16,26,27] Several reports have advocated an organized, integrated interhospital transfer system based on the trauma model.[7,8,14]

To our knowledge, the CCRU is the first of its kind in the United States. This unique concept might be a paradigm shift expediting the transfer of patients with time-sensitive critical illness.

The CCRU functions as an ICU, but it has many differences from a traditional surgical ICU. Even busy ICUs have peak periods of admission. For instance, most postoperative patients arrive in the mid-afternoon, as the elective operative volume is completed. In addition, in most academic medical centers, ICUs are often specialized. Examples include a cardiac surgery ICU, neurology ICU, or trauma ICU. The CCRU, however, must be able to provide critical care services at any time across a wide spectrum of diseases. Therefore, we staffed it to deliver high-volume care 24 hours per day. The CCRU is more like an emergency department ICU, including performing high-end procedural tasks. We commonly cannulate patients for extracorporeal membrane oxygenation, insert intra-aortic balloon pumps or intracranial pressure monitoring devices, and have performed bedside decompressive laparotomy in the CCRU.

We recruited a specialized group of physicians to staff the CCRU. Given its unique mission, we believed that physicians with broad and diverse experience would be ideal. We recruited a medical director (LR) who is an internist and a pulmonary critical care physician with extensive experience in disaster management. We also recruited a number of emergency medicine physicians who are formally trained in critical care. At STC, we have been training emergency physicians in critical care since 1997. A number of our recruits were our former trainees; others trained elsewhere. One additional physician was a family medicine physician who completed our surgical critical care fellowship. All of these physicians have expertise in the extensive disease states seen in the CCRU, as well as broad-based critical care training, and all are technically adept. Although we often use subspecialty expertise for upper-end procedures, such as extracorporeal membrane oxygenation cannulation, our intensivists can perform all standard critical care procedures.

We created a specialized modular nursing orientation for the CCRU that included didactics and clinical orientation in the trauma resuscitation unit and the cardiac surgery ICU. Virtually all of the CCRU nursing staff were recruited from various shock trauma ICUs or the cardiac surgery ICU. For them to accrue the expanded set of skills needed to care for the myriad of diseases seen in the CCRU, we used the expertise in a number of subspecialty ICUs to craft that orientation package.

The final question might be why departments of surgery should be interested in a project such as the CCRU. Certainly the expanded clinical volume driven through divisions such as acute care emergency surgery, cardiac surgery, and vascular surgery seems to support the CCRU. However, there was a cost to the CCRU, both operational and in terms of physician recruitment. Even with robust critical care billing, affording full-time salaries to staff the CCRU was challenging. We created a partnership with the medical center to be able to defer some of those costs. The additional medical center revenue from the increased volume allowed both the medical center and our practice plan to be profitable from this venture.

Academic medical centers are becoming increasingly geared toward the care of critically ill patients. Although many of these patients are not purely surgical, many of them have surgical facets to their diseases. Owning projects like the CCRU allows departments of surgery to remain important contributors to the future of academic medical centers. In our opinion, many departments of medicine do not see this as their problem. The department of surgery can and should fill this void. The relationship between surgical critical care and emergency medicine is natural and allows departments to continue to build bridges with our colleagues.

CONCLUSIONS

The CCRU has been an important advance in the care of critically ill patients at our institution. The exceptional structures at the University of Maryland, where trauma and surgical critical care exist in partnership with the department of surgery, but not within it, make us unique. Emergency surgery, trauma, and critical care exist as a program in the school of medicine with its own practice plan. We have wonderful relationships with the chair of surgery and the rest of our surgical colleagues. In fact, the CCRU was the joint vision of the chair of surgery (STB) and the director of the program in trauma (TMS). This tight link has allowed us to create the CCRU without substantial political or administrative problems. Although our system might not be exportable everywhere, the principles articulated here seem to be universal, and we offer them as a partial blueprint for other institutions.

Author Contributions

Study conception and design: Scalea, Rubinson, Stein, Bartlett, O'Connor

Acquisition of data: Rubinson, Jones, Rea, O'Connor

Analysis and interpretation of data: Scalea, Rubinson, Tran, Jones, Rea, O'Connor

Drafting of manuscript: Scalea, Rubinson, Tran, Rea, Stein, O'Connor

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