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Retrospective Value Assessment of a Dedicated, Trauma Hybrid Operating Room

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Abstract

Background: In traumatic hemorrhage, hybrid operating rooms (OR) offer near simultaneous performance of endovascular and open techniques, with correlations to earlier hemorrhage control, fewer transfusions, and possible decreased mortality. However, hybrid ORs are resource intensive. This study quantifies and describes a single-center experience with the complications, cost-utility, and value of a dedicated trauma hybrid operating room.

Methods: This retrospective cohort study evaluated 292 consecutive adult trauma patients who underwent immediate (< 4 hours) operative intervention at a Level 1 Trauma Center. 106 patients treated prior to the construction of a hybrid OR served as historical controls to the 186 patients treated thereafter. Demographics, hemorrhage control procedures, financial data, as well as postoperative complications and outcomes were collected via electronic medical records. Value and incremental cost-utility ratio were calculated.

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Contribution Statement

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Conflict of Interest Statement:
The authors report no conflict of interest.

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Results: Demographics and severity of illness were similar between cohorts. Resuscitative Endovascular Occlusion of the Aorta (REBOA) was more frequently used in the hybrid OR. Hemorrhage control occurred faster (60 vs 49 min, $p = 0.005$) and, in the 4–24-hour post-admission period, required less red blood cell (mean 1.0 vs 0 units, $p = 0.001$) and plasma (mean 1.0 vs 0 units, $p < 0.001$) transfusions. Complications were similar except for a significant decrease in pneumonia (7% vs 4%, $p = 0.008$). Severe complications (Clavien-Dindo Classification ≥3) were similar. Across the patient admission, costs were not significantly different ($50,023 vs $54,740, $p = 0.637$). There was no change in overall value (1.00 vs 1.07, $p = 0.778$).

Conclusions: The conversion of our standard trauma operating room to an endovascular hybrid operating room provided measurable improvements in hemorrhage control, red blood cell and plasma transfusions, and postoperative pneumonia without significant increase in cost. Value was unchanged.

Study Type: Economic/value-based evaluations

Level of Evidence: III

Social Media Statement:

Adoption of a dedicated, trauma hybrid operating room resulted less transfusions and fewer complications but with overall similar value to a standard trauma OR #trauma #surgery #value

Keywords

trauma; value; operating room; hybrid

Background

Traumatic injury accounts for approximately 9% of all deaths worldwide and more years of potential life lost prior to age 70 than any other cause (1, 2). Exsanguinating hemorrhage causes more than one third of all trauma deaths and is the leading cause of potentially preventable injury-related death (3–6). To facilitate effective operative management of life-threatening hemorrhage from traumatic injury, several regulatory agencies mandate the immediate availability of an operating room that is dedicated for trauma patients (7). There are significant concerns regarding the adoption of hybrid operating rooms for trauma in the United States (8).

To obtain early, effective hemorrhage control, it may be advantageous to perform endovascular techniques (9–15). It can be cumbersome to perform these procedures in a standard operating room with a drivable C-arm, and dangerous to transfer an unstable, bleeding trauma patient to and from an Interventional Radiology suite. Therefore, some trauma centers have built dedicated trauma hybrid operating rooms furnished with angiographic equipment, such as ceiling-mounted C-arms, carbon fiber fluoroscopy-compatible tables, and fluoroscopy control rooms behind lead-lined glass windows for radiation shielding (16–19). This approach has been associated with earlier hemorrhage control, fewer blood product transfusions, and in some studies, decreased mortality among patients with exsanguination or hemorrhagic shock (9, 10, 13, 17). A single Japanese center demonstrated that hybrid operating rooms placed within the trauma bays met willingness-to-pay thresholds, indicating cost-effectiveness (20). However, there are challenges regarding the implementation of such a system in the United States, with concerns over upfront costs, returns on investment, and reimbursement schemes and at least one study has detailed the increase in costs for hybrid rooms over standard counterparts (8, 21).

The purpose of this study is to quantify and describe the cost-utility and value (i.e., clinical outcomes relative to resource use) of a dedicated, trauma hybrid operating room. Value is defined from the health-system perspective, in which that both low costs and low complications are desirable. This retrospective cohort study compares clinical outcomes, charges, and costs before and after implementation of a dedicated, trauma hybrid operating room at a Level I trauma center. We chose an expenditure-based costing methods for professional charges, intensive care unit charges, and total admission charges and costs through the entire patient admission based on availability of data. This data may inform institutional stakeholders when considering the implementation of a hybrid operating room.

Methods

Study population

This study was performed as a secondary analysis of a previously published, retrospective cohort of 292 consecutive adult trauma patients who underwent immediate operation (i.e., within four hours of arrival) at a Level I trauma center (18). The control group included 106 patients who were managed in a standard trauma operating room in the 42-month period between March 2012 and September 2016. 186 patients were managed in the following 42-month period, October 2016 to April 2020. Derivation of the study population is illustrated in Supplemental Figure 1. Patients were excluded for age less than 18 years, initial operation for hemorrhage control at referring facility (n=18), emergency department or pre-hospital blunt traumatic arrest (n=20), and immediate surgery for purposes other than hemorrhage control (e.g., diagnostic laparoscopy, isolated airway procedure, neurosurgery for isolated brain injury, or wound exploration and closure, n=41). Immediate surgery was defined as occurring within four hours of arrival. This was consistent with published literature and chosen to also capture patients who failed a brief trial of observation (22). The Institutional Review Board approved this study (#202001256).

Trauma hybrid operating room specifications, costs, training, and protocols

The trauma hybrid operating room was built in a repurposed angiography suite, immediately adjacent to other operating rooms, and one floor above an emergency department with six trauma resuscitation bays. Angiography equipment in the hybrid operating room included a ceiling-mounted C-arm, a carbon fiber fluoroscopy-compatible table, and a fluoroscopy control room behind lead-lined glass windows (Philips AlluraClarity). The initial cost of repurposing the angiographic suite to the trauma hybrid room was approximately $1.6 million. One of the authors trained trauma surgeons and senior residents in REBOA concepts and techniques using a combination of 90-minute slide presentations and hands-on simulation sessions. Several 30-minute REBOA training sessions were offered to operating room, emergency department, and ancillary staff.

The annual utilization-rate of a dedicated trauma operating room remained at approximately 3% during the duration the study. No previous literature has reported the utilization rate a dedicated trauma operating room, though with reports of direct-to-operating room rates of 5% for all trauma activations, this is likely consistent with other hospitals (23). REBOA was placed in the operating room in the majority of cases (94.7%), reflecting our practice of direct-to-operating room resuscitation for severely injured trauma patients (24).

Data collection

Data regarding patient characteristics, hemorrhage control procedures, resuscitation parameters, and clinical outcomes were collected from a prospectively maintained, institutional trauma registry and supplemented by manual review of electronic health records, including operative reports and intraoperative anesthesia records that contain hemodynamic trends along with the timing of blood product and vasopressor administration. Data representing patient characteristics included demographics, mechanism of injury, Injury Severity and Glasgow Coma Scale scores, vital signs, laboratory values, and extended focused assessment with sonography for trauma (E-FAST) exam findings. Data representing hemorrhage control procedures included anatomic region of exploration with associated operative maneuvers as well as the performance of angiographic procedures within 12 hours of arrival, including anatomic sites and therapeutic interventions. Endovascular interventions were performed by a trauma surgeon, interventional radiologist, or vascular surgeon.

Anesthesia data flowsheets were used to identify the time of hemorrhage control, defined as achieving a sustained systolic blood pressure 100 mmHg or greater without ongoing vasopressor or blood product transfusion requirements or subsequent episodes of hypotension with systolic blood pressure less than 90 mmHg, consistent with principles of damage control resuscitation (24).

Data representing resuscitation included the administration of red cell and plasma transfusions within four hours of arrival and 4–24 hours after arrival as well as administration of tranexamic acid within four hours of arrival, consistent with the four-hour cutoff for immediate surgery (22). Component product resuscitation was practiced through much of this study, as our whole blood resuscitation protocol was not started until 2020. Data representing clinical outcomes included postoperative complications classified as infectious or non-infectious and according to the Clavien-Dindo Classification (CDC) system that was adapted for trauma patients by Naumann et al. (25). Other clinical outcomes included lengths of stay in the hospital and in the ICU, days on mechanical ventilation, and discharge disposition.

Financial data included expenditure-based charges billed by providers, for ICU care, and for the entire hospital admission as well as costs incurred for the entire hospital admission. These values were reported in United States Dollars and adjusted using the Consumer-Price Index HealthCare Index to May 2021 dollars, given that healthcare prices typically outpace overall inflation.

Statistical analysis

The primary statistical objective was to assess the impact of a dedicated, trauma hybrid operating room on value of care (i.e., clinical outcomes relative to resource use). Raw clinical outcomes and financial data were compared before and after implementation of a dedicated, trauma hybrid operating room. In addition, the incremental cost-utility ratio was calculated by subtracting the median cost for a standard admission from that of a hybrid operating room admission, yielding incremental costs, subtracting the health outcomes for a standard admission from that of a hybrid operating room admission, yielding incremental utility, and dividing incremental costs by incremental utility (see equation 1)(26).

$$Incremental\ Cost - Incremental\ Utility = \frac{Median\ Cost\ Hybrid\ Admission - Median\ Cost\ Standard\ Admission}{Health\ Outcomes\ Hybrid - Health\ Outcomes\ Standard}$$

Given available data, value was calculated by the inverse of the percentage of serious adverse events divided by the median cost times a constant to bring the value of the control to 1.0 for comparison. The inverse was taken to assign low value to adverse events and high cost (see equation 2).

$$Value = \frac{{}^{1}\!/_{Adverse\ Events\ (\%)}}{Median\ Total\ Cost} \times constant$$

Binary variables were compared by Fisher's Exact test and reported as raw numbers with percentages. Continuous variables were compared by the Kruskal-Wallis test and reported as median values with interquartile ranges. Statistical analysis was performed using the open-source Python (version 3.7.6) programming language with the Spyder (version 4.0.1) environment and SPSS (version 23, IBM, Armonk, NY) with significance set at α=0.05.

Guidelines

Our study adhered to the CHEERS guidelines as data permitted and the checklist can be found in the supplementary materials.

Results

Patient characteristics are demonstrated in Table 1. There were no significant differences between the control and hybrid operating room cases, with two exceptions: a lower hemoglobin on initial iSTAT in the hybrid operating room and a higher rate of normal TEG. There was no difference in blunt or penetrating trauma, Glasgow Coma Scale, systolic blood pressure, FAST, or lactic acid between the two consecutive study populations who underwent immediate operative intervention. There were no differences in insurance coverage between the groups. Consistent with other trauma populations, most patients in both groups were either un-insured (44.3% and 41.9%, for control and hybrid operating room, respectively) or insured by Medicare (26.4% and 30.1%).

Marginal differences appeared in resuscitation between the two study populations. Table 2 shows how REBOA became a more frequent intervention during the latter study period.

Rates of open operative techniques did not differ, with similar rates of sternotomy, laparotomy, pelvic packing, neck exploration, and vascular management. While both study populations obtained effective hemorrhage control for most patients, when compared to the control, those in the dedicated hybrid operating room obtained it faster in terms of both time from admission to hemorrhage control (135 vs 104 minutes, p = 0.005) and time from operating start to hemorrhage control (60 min vs 49 min, p = 0.005) and required less overall median red blood cell (1.0 vs 0, p = 0.001) and plasma (1.0 vs 0, p <0.001) transfusions in the 4–24-hour period following stabilization. Time from admission to operating room did not differ, nor did transfusion rates in the first 4 hours of hospital admission.

Outcomes were largely similar between to the two groups, as shown in Table 3. Infectious complications were lower in the hybrid operating room group, largely driven by a significant decrease in post-operative pneumonia. Hospital and ICU length of stay were similar, as were locations of disposition. Nearly half of both patient groups were discharged home, with the second half being largely covered by the “non-home discharge” category in which the medical records failed to specify location. Mortality was similar between the two groups. This held true in a subgroup analysis of those patients who required angiographic intervention. Costs and charges are shown in Table 4. After adjusting for health care specific inflation, ICU, professional, and total charges did not differ significantly, nor did total costs. Incremental costs for a hybrid operating room hospital admission were $4,717 ($54,740 minus $50,773),. Incremental utility in median grade of overall complications was −2.0 (0.0 minus 2.00). Therefore, it cost approximately $2,358 per patient for an associated decrease in complication grade by one point per patient. Value was calculated in Table 5. We defined serious complications as CDC ≥3, as these complications required intervention or resulted in mortality. Value was set at 1.0 for the control and found to be 1.07 for the hybrid operating room.

A subgroup analysis was performed on patients requiring angiography both before and after introduction of the hybrid operating room. Time to hemorrhage control was not significantly different between the two (169 vs 161 min, p = 0.7). Costs were nearly identical between the two groups.

Discussion

This single-center, retrospective cohort study examined the value and incremental cost-utility of care in trauma patients requiring operative intervention within 4 hours of arrival at a Level 1 trauma center prior to and following the creation of a dedicated, hybrid operating room. We found no significant difference in value as defined by the inverse of the percentage of serious adverse events divided by the median cost.

This study expands on work previously published (18). We found earlier hemorrhage control, decreased transfusion requirement, decreased infectious complications, and fewer days on mechanical ventilation, with non-significant increase in the total costs of care and similar overall value. Our work complements one previous study of the hybrid operating room for trauma patients, which found an incremental cost-utility ratio of $32,522 per QALY gained (20).

Trauma centers are costly(27–29). In addition to staff, equipment, and space, there is also the opportunity cost of these factors of production while trauma resources sit idle. While a dedicated trauma operating room is a requirement of trauma centers, opportunity cost of revoking accreditation and using the room for an alternative service will vary widely. At our institution, the opportunity cost of leaving the room as an independent interventional radiology suite was $1.0 million in net profits annually, though freeing up a standard operating room (as opposed to a dedicated trauma room) for general surgery procedures in this tower can be estimated to add around $1.9–2.0 million annually based on average caseloads (30). Trauma centers, in addition, have been shown to provide value and profit. Using Medicare and Medicaid claims data combined with patient data from the National Study on Costs and Outcomes in Trauma, MacKenzie et al. found that the incremental cost of one life-year saved at trauma center compared to a non-trauma center was $36,319 (31). This is well below the $50,000–100,000 cost-effectiveness threshold in the literature (32, 33). Annual profit for a Level I trauma center is estimated at $1.5 million, with the bulk of profits generated from those with length of stay less than eleven days (34). With upfront costs of $1.6 million for construction of our hybrid operating room, we estimate costs can be recuperated within a reasonable period.

Approximately one fifth of our patients underwent angiography, a proportion that did not change between the groups. As this represents the primary advantage of a hybrid operating room, we preformed a subgroup analysis comparing time to hemorrhage control and costs of those who required an angiographic intervention. Neither had significant changes, suggesting other confounders contributed to the decrease in time to hemorrhage control. General hybrid rooms are, however, associated with higher costs. Patel et al found that hybrid rooms cost on average $12.33 more per minute that standard operating rooms, related largely to inventory, construction, and total personnel costs (21). These costs decreased with increasing utilization, however, this would likely not be applicable for dedicated trauma rooms, as our utilization rate was less than 4%.

Our hybrid operating room resulted in $2,358 more costs per patient for an associated decrease in complication grade by one point on the CDC. Several studies have related cost to complications. In a review article assessing the economic burden of complications across multiple surgeries, an excess costs ranged from $1,698 for a surgical site infection to $94,830 for a pancreatic fistula, with serious complications CDCIII-IV at $57,614 (35). In a similar study looking in general at patients undergoing major surgery, those with uneventful postoperative course had mean costs per case of $27,946 with cost rising to $159,345 in those who experiencing grade IV complication (36). Minor complications are also costly. Our study demonstrated a decrease in complications driven largely by decreased infections, pneumonia, and days requiring mechanical ventilation though without significant changes in ICU charges. This may be secondary to transfusion-related immunodulation as previously reported (37, 38). In a study by Rello et al, development of ventilator associated pneumonia was associated with a mean increase of hospital charges per patient of approximately $40,000 (39). However, given that the incidence of post-operative pneumonia ranges from 8–50% in the published literature, detecting a true a significant difference is elusive and our study may not be adequately powered to detect these differences. Avoidance of minor and severe complications can result in clear cost-savings. To our knowledge, there are no validated studies associating CDC and utility outcomes, such as Health Related Quality of Life outcomes or QALYs. However, Cuthbertson et al have noted that cumulative QALYs in intensive care patients are far below those of the general population, even up to 5 years after their stay (40).

Our study has several limitations. As a single-institutional study, our outcomes, costs, and patient population may not be reflective of other hospitals. There are also limitations in both costing measurement and quality outcomes. At the time of writing, two of three articles in series on value in acute care surgery have been published (41, 42). The first reviewed costing methods and studies that employed them while the second did the same for quality outcomes. Ideally, we would be able to perform micro costing or time-driven activity-based costing methods to determine precisely how costs changed over the study period. We chose an expenditure-based costing model on the availability of charge/cost data and to provide a global assessment of costs of care. We also do not have access to the specific fixed and variable costs associated with each use. More detailed study would be difficult to interpret, as each patient presented with various complexities of injury, with varying operative times and resources, and need for operative and post-operative interventions. Similarly, effective measurement of quality is difficult in this heterogenous population and objective measures may not reflect patient or family values (43). Given the length of the study period, there is concern for data drift and change in practice. REBOA was introduced to our system coincidentally just before the construction of our hybrid operating room. However, as REBOA was performed in a minority of total cases (6.5%) this likely did not impact median costs. There were no other identifiable changes in practice patterns during the study period. Our available data does not capture QALY, functional outcomes, return to work, or other health related quality of life outcomes and therefore our analysis is limited by expense reports and complications. We see future opportunities for studying specific injury patterns in the context of value within our level one trauma center.

Conclusions

Our study demonstrated no significant difference in total cost, and significant decreases in time to hemorrhage control, red cell transfusions, and postoperative pneumonia following the introduction of a dedicated trauma hybrid operating room. Overall value was similar before and after constructing the hybrid operating room. Given the many limitations and hospital-specific factors that affect cost-utility, this data should be cautiously interpreted by trauma departments and hospital administrations when considering the introduction of a dedicated trauma hybrid operating room. However, acknowledging these limitation, level 1 trauma-systems with low utilization rates of their dedicated trauma operating room may not gain value by constructing a hybrid room.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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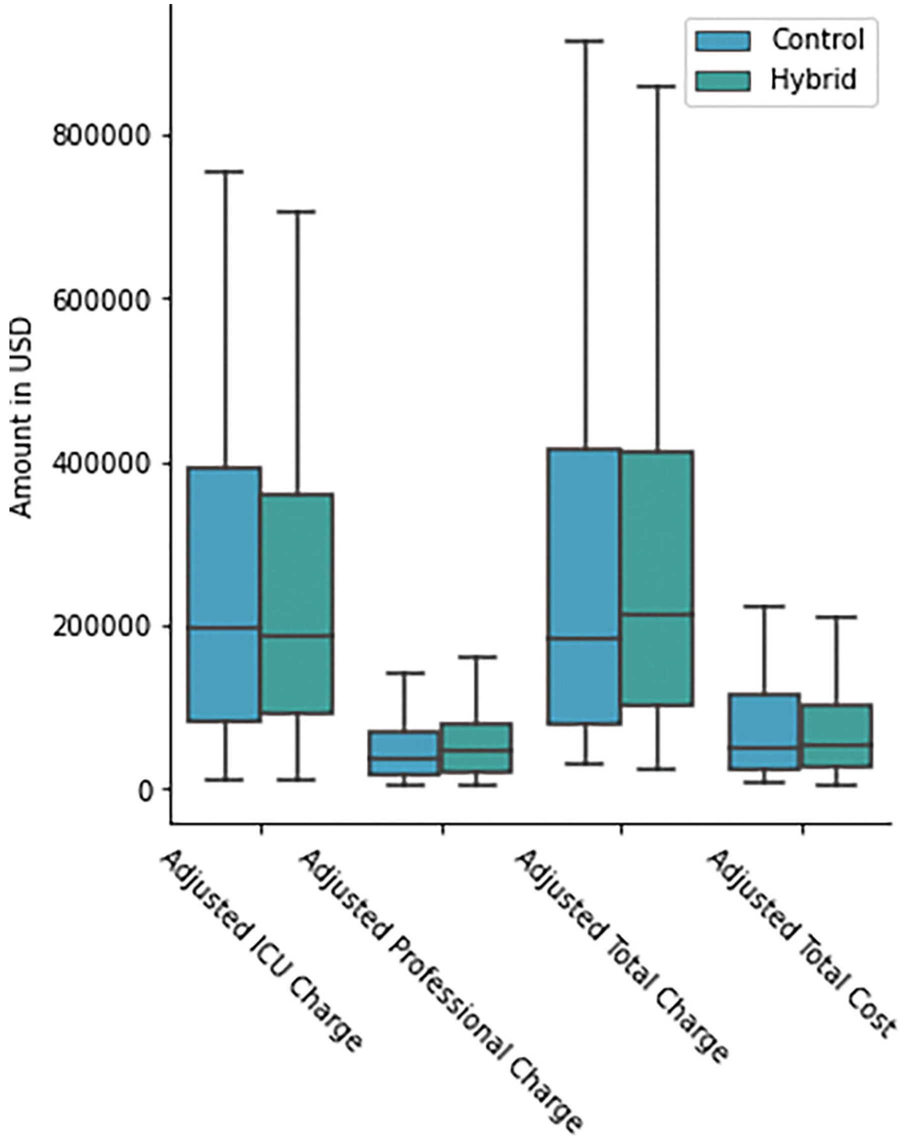

Figure 1.

Boxplot comparing total dollar amounts for profession charges, ICU charges, total charges, and total costs. Differences were non-significant. ICU: Intensive Care Unit

Table 1:

Characteristics of patients undergoing immediate surgery for hemorrhage control before and after implementation of a dedicated, trauma hybrid operating room (OR).

Patient characteristics	Control cases (n=106)	Hybrid OR cases (n=186)	*p*
Age	40 [26–52]	41 [27–61]	0.176
Female	22 (21%)	52 (28%)	0.208
Injury Severity Score	18 [13–27]	22 [13–29]	0.187
Blunt injury	63 (59%)	119 (64%)	0.454
Penetrating injury	43 (41%)	67 (36%)	0.454
Traumatic arrest in field or ED[a]	1 (1%)	7 (4%)	0.266
Intubated in field or ED	37 (35%)	66 (35%)	>0.999
Glasgow Coma Scale	15 [3–15]	15 [7–15]	0.662
Best eye opening response	4 [1–4]	4 [1–4]	0.230
Best verbal response	5 [1–5]	5 [1–5]	0.689
Best motor response	6 [1–6]	6 [4–6]	0.474
Heart rate	107 [90–124]	110 [93–128]	0.464
Respiratory Rate	18 [15–22]	20 [17–24]	0.008
Systolic blood pressure (mmHg)	95 [84–111]	95 [86–109]	0.886
Mean arterial pressure (mmHg)	70 [61–82]	71 [61–83]	0.990
FAST performed	80 (75%)	154 (83%)	0.169
FAST negative	40 (38%)	73 (39%)	0.804
FAST equivocal	5 (5%)	10 (5%)	>0.999
FAST positive	35 (33%)	71 (38%)	0.448
Temperature (Celsius)	36.3 [35.3–36.8]	36.3 [35.7–36.7]	0.513
pH	7.29 [7.21–7.35]	7.28 [7.19–7.34]	0.230
Lactic acid (mmol/L)	3.1 [2.0–4.7]	3.4 [1.9–5.4]	0.666
Hemoglobin (g/dL)	11.1 [10.0–13.0]	10.2 [9.0–11.7]	0.001
International Normalized Ratio	1.3 [1.1–1.4]	1.2 [1.1–1.3]	0.087
Normal TEG	56 (53%)	128 (69%)	0.008
Insurance			
Medicaid	8 (7.5)	14 (7.5)	>0.999
Medicare	28 (26.4)	56 (30.1)	0.591
Non-CMS Government	7 (6.6)	6 (3.2)	0.238
Private	16 (15.1)	32 (17.2)	0.743
None	47 (44.3)	78 (41.9)	0.713

[a]These cases are traumatic arrests following penetrating trauma, as blunt traumatic arrests were excluded. ED: emergency department, FAST: focused assessment with sonography for trauma, TEG: thromboelastography. Data are presented as n (%) or median [interquartile range].

Table 2:

Hemorrhage control procedures and resuscitation parameters before and after implementation of a dedicated, trauma hybrid operating room (OR).

Hemorrhage control and resuscitation	Control cases (n=106)	Hybrid OR cases (n=186)	*p*
Transferred from ED directly to OR	59 (56%)	119 (64%)	0.172
Underwent REBOA	1 (1%)	18 (8%)	0.013
Underwent sternotomy or thoracotomy	7 (7%)	24 (13%)	0.115
Aortic cross clamp placed	4 (4%)	13 (7%)	0.309
Pericardiotomy	5 (5%)	19 (10%)	0.123
Cardiac laceration repair	1 (1%)	6 (3%)	0.428
Pulmonary resection or tractotomy	1 (1%)	3 (2%)	>0.999
Underwent laparotomy	81 (76%)	144 (77%)	0.885
Solid organ resection	29 (27%)	47 (25%)	0.782
Solid organ repair	15 (14%)	40 (22%)	0.161
Hollow viscus resection	25 (24%)	30 (16%)	0.123
Diaphragm repair	10 (9%)	16 (9%)	0.833
Underwent preperitoneal pelvic packing	9 (8%)	23 (12%)	0.338
Underwent neck exploration	9 (8%)	13 (7%)	0.650
Operative management of a named vessel	28 (26%)	58 (31%)	0.425
Bypass, interposition graft, or patch repair	7 (7%)	11 (6%)	0.805
Endovascular stent or balloon angioplasty	2 (2%)	2 (1%)	0.623
Primary repair	5 (5%)	20 (11%)	0.085
Ligation	15 (14%)	22 (12%)	0.586
CT or Vascular Surgery consultation	14 (13%)	23 (12%)	0.856
Underwent angiography	19 (18%)	39 (21%)	0.647
Angiography performed in IR suite	16 (15%)	0 (0%)	<0.001
Central/aortogram	5 (5%)	8 (4%)	>0.999
Peripheral/extremity angiography	3 (3%)	5 (3%)	>0.999
Visceral angiography	6 (6%)	9 (5%)	0.787
Pelvic angiography	7 (7%)	22 (12%)	0.221
Therapeutic angiography[a]	13 (12%)	24 (13%)	>0.999
Obtained hemorrhage control[b]	102 (96%)	176 (95%)	0.777
Interval: admit to OR start	54 [25–114]	46 [26–81]	0.22
Interval: OR start to hemorrhage control (min)	60 [42–84]	49 [34–69]	0.005
Interval: arrival to hemorrhage control time	135 [83–190]	104 [75–154]	0.005
Total OR plus angiography time (min)	133 [92–243]	135 [91–188]	0.971
TXA administered 0–4 h after arrival	20 (19%)	33 (18%)	0.875
RBC transfusions 0–4 h after arrival	3.0 [0.0–5.0]	2.5 [1.0–5.0]	0.730
Plasma transfusions 0–4 h after arrival	2.0 [0.0–4.0]	1.5 [0.0–4.0]	0.742
RBC transfusions 4–24 h after arrival	1.0 [0.0–3.0]	0.0 [0.0–2.0]	0.001
Plasma transfusions 4–24 h after arrival	1.0 [0.0–3.0]	0.0 [0.0–1.0]	<0.001

[a]Endovascular stent placement, balloon angioplasty, coil placement, or embolization.

[b]Systolic blood pressure 100 mmHg or greater without ongoing vasopressor or blood product transfusion requirements. ED: emergency department, REBOA: resuscitative endovascular balloon occlusion of the aorta, CT: presented as n (%) or median [interquartile range]. Cardiothoracic, IR: Interventional Radiology, TXA: tranexamic acid, RBC: red blood cell. Data are presented as n (%) or median [interquartile range].

Table 3:

Clinical outcomes before and after implementation of a dedicated, trauma hybrid operating room (OR).

Clinical outcomes	Control cases (n=106)	Hybrid OR cases (n=186)	*p*
Postoperative complications			
Any complication	58 (55%)	90 (48%)	0.331
Any infectious complication	29 (27%)	27 (15%)	0.009
Pneumonia	13 (12%)	7 (4%)	0.008
Bloodstream infection	9 (9%)	8 (4%)	0.163
Surgical site infection	6 (6%)	9 (5%)	0.787
Urinary tract infection	5 (5%)	4 (2%)	0.293
Clostridium difficile infection	0 (0%)	1 (1%)	>0.999
Graft infection	0 (0%)	1 (1%)	>0.999
Clavien-Dindo classifications[a]			
Overall, median	2.0 [0.0–4.0]	0.0 [0.0–4.0]	0.364
Grade 1, n (%)	3 (3%)	6 (3%)	0.331
Grade 2, n (%)	13 (12%)	19 (10%)	0.697
Grade 3a, n (%)	4 (4%)	7 (4%)	>0.999
Grade 3b, n (%)	5 (5%)	9 (5%)	>0.999
Grade 4a, n (%)	7 (7%)	12 (6%)	>0.999
Grade 4b, n (%)	15 (14%)	12 (6%)	0.036
Grade 5a, n (%)	7 (7%)	9 (5%)	0.596
Grade 5b, n (%)	4 (4%)	16 (9%)	0.150
Hospital length of stay (d)	9.5 [5.0–23.3]	9.0 [5.8–19.0]	0.791
ICU length of stay (d)	6.0 [2.0–17.0]	5.0 [2.0–13.0]	0.636
ICU-free hospital days	4.0 [2.0–6.0]	4.0 [1.0–7.3]	0.615
Days on mechanical ventilation	3.0 [1.0–8.0]	2.0 [1.0–5.3]	0.011
Ventilator-free ICU days	2.0 [0.0–6.3]	3.0 [1.0–7.0]	0.144
Discharge disposition			
Home	52 (49%)	104 (56%)	0.274
Prison	6 (6%)	5 (3%)	0.215
Another hospital	5 (5%)	7 (4%)	0.762
Subacute/inpatient rehabilitation	17 (16%)	20 (11%)	0.204
Long-term acute care	13 (12%)	22 (12%)	>0.999
Custodial care/nursing home	2 (2%)	1 (1%)	0.299
Hospice	0 (0%)	2 (1%)	0.536
In-hospital mortality	11 (10%)	25 (13%)	0.579
Non-home discharge	54 (51%)	82 (44%)	0.274

[a]Adapted for trauma by Naumann et al.(25) ICU: intensive care unit. Data are presented as n (%) or median [interquartile range].

Table 4:

Cost and charge data before and after implementation of a dedicated, trauma hybrid operating room (OR).

Costs and charges	Control cases (n=106)	Hybrid OR cases (n=186)	*p*
ICU charges	198,029 [82,720–383,029]	187,790 [93,480–359,451]	0.814
Professional charges	37,098 [18,230–68,541]	47,681 [22,178–78,319]	0.736
Total charges	181,227 [80,053–402,440]	214,121 [103,211–413,123]	0.189
Total costs	50,023 [22,325 – 110,874]	54,740 [27,793 – 101,918]	0.637
Total costs - Angiography Subgroup	103,428 [70,778–141,316]	103,230 [60,748–176,603]	0.778

Medians are reported in US dollars with interquartile range and adjusted using the HealthCare Index with May 2021 as reference date. ICU: intensive care unit.

Table 5:

Value calculation comparing adverse events to median costs adjusted to base value of one for the control. Adverse events were defined as Clavien-Dindo (CD) classification ≥3.

Component variables	**Control (n = 106)**	**Hybrid OR (n = 186)**	**p**
Adverse Events (CD ≥ 3)	42 (41%)	60 (35%)	0.331
Total cost per patient, median $	$ 50,023	$ 54,740	0.778
Value (Health System)	1.00	1.07	