Direct to operating room trauma resuscitation: Optimizing patient selection and time-critical outcomes when minutes count

Amelia Johnson, PA-C, Michael Rott, PA-C, Andrea Kuchler, PA-C, Emma Williams, PA-C, Fredrick Cole, MD, Ameen Ramzy, MD, Ronald Barbosa, MD, William Long, MD, *and* **Matthew J. Martin, MD***, Portland, Oregon*

AAST Continuing Medical Education Article

Accreditation Statement

This activity has been planned and implemented in accordance with the Essential Areas and Policies of the Accreditation Council for Continuing Medical Education through the joint providership of the American College of Surgeons and the American Association for the Surgery of Trauma. The American College Surgeons is accredited by the ACCME to provide continuing medical education for physicians.

AMA PRA Category 1 Credits™

The American College of Surgeons designates this journal-based CME activity for a maximum of 1 AMA PRA Category 1 Credit™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Of the AMA PRA Category 1 Credit™ listed above, a maximum of 1 credit meets the requirements for self-assessment.

Credits can only be claimed online

American College of Surgeons

Inspiring Quality:
Highest Standards, Better Outcomes

100+*years*

Objectives

After reading the featured articles published in the *Journal of Trauma and Acute Care Surgery*, participants should be able to demonstrate increased understanding of the material specific to the article. Objectives for each article are featured at the beginning of each article and online. Test questions are at the end of the article, with a critique and specific location in the article referencing the question topic.

Claiming Credit

To claim credit, please visit the AAST website at http://www.aast.org/ and click on the "e-Learning/MOC" tab. You must read the article, successfully complete the post-test and evaluation. Your CME certificate will be available immediately upon receiving a passing score of 75% or higher on the post-test. Post-tests receiving a score of below 75% will require a retake of the test to receive credit.

Disclosure Information

In accordance with the ACCME Accreditation Criteria, the American College of Surgeons, as the accredited provider of this journal activity, must ensure that anyone in a position to control the content of J Trauma Acute Care Surg articles selected for CME credit has disclosed all relevant financial relationships with any commercial interest. Disclosure forms are completed by the editorial staff, associate editors, reviewers, and all authors. The ACCME defines a `commercial interest' as "any entity producing, marketing, re-selling, or distributing health care goods or services consumed by, or used on, patients." "Relevant" financial relationships are those (in any amount) that may create a conflict of interest and occur within the 12'months preceding and during the time that the individual is engaged in writing the article. All reported conflicts are thoroughly managed in order to ensure any potential bias within the content is eliminated. However, if you'perceive a bias within the article, please report the circumstances on the evaluation form.

Please note we have advised the authors that it is their responsibility to disclose within the article if they are describing the use of a device, product, or drug that is not FDA approved or the off-label use of an approved device, product, or drug or unapproved usage.

Disclosures of Significant Relationships with Relevant Commercial Companies/Organizations by the Editorial Staff

Ernest E. Moore, Editor: PI, research support and shared U.S. patents Haemonetics; PI, research support, Instrumentation Laboratory, Inc.; Co-founder, Thrombo Therapeutics. Associate Editors David Hoyt, Ronald V. Maier and Steven Shackford have nothing to disclose. Editorial staff and Angela Sauaia have nothing to disclose.

Author Disclosures

William Long; J&J, Synthes DePuy, Sam Corporation; Royalties, Royalites, Royalties; Patents.

Reviewer Disclosures

The reviewers have nothing to disclose.

Cost

For AAST members and Journal of Trauma and Acute Care Surgery subscribers there is no charge to participate in this activity. For those who are not a member or subscriber, the cost for each credit is $25.

System Requirements

The system requirements are as follows: Adobe® Reader 7.0 or above installed; Internet Explorer® 7 and above; Firefox® 3.0 and above, Chrome® 8.0 and above, or Safari™ 4.0 and above.

Questions

If you have any questions, please contact AAST at 800-789-4006. Paper test and evaluations will not be accepted.

BACKGROUND: Although several trauma centers have developed direct to operating room (DOR) trauma resuscitation programs, there is little published data on optimal patient selection, practices, and outcomes. We sought to analyze triage criteria and interventions associated with optimal DOR outcomes and resource utilization.

METHODS: Retrospective review of all adult DOR resuscitations for a 6-year period was performed. Triage criteria were analyzed individually and grouped into categories: mechanism, physiology, anatomy/injury, or other. The best univariate and multivariate predictors of requiring lifesaving interventions (LSIs) or emergent surgery (ES) were analyzed. Actual and predicted mortality were compared for all patients and for predefined time-sensitive subgroups.

RESULTS: There were 628 DOR patients (5% of all admissions) identified; the majority were male (79%), penetrating mechanism (70%), severely injured (40% ISS >15), and 17% died. Half of patients required LSI and 23% required ES, with significantly greater need for ES and lower need for LSI after penetrating versus blunt injury (p < 0.01). Although injury mechanism criteria triggered most DOR cases and best predicted need for ES, the physiology and anatomy/injury criteria were associated with greater need for LSI and mortality. Observed mortality was significantly lower than predicted mortality with DOR for several key subgroups. Triage schemes for both ES and LSI could be simplified to four to six independent predictors by regression analysis.

CONCLUSION: The DOR program identified severely injured trauma patients at increased risk for requiring LSI and/or ES. Different triage variable categories drive the need for ES versus LSI and could be simplified or optimized based on local needs or preferences. Direct to operating room was associated with better than expected survival among specific time-sensitive subgroups. (*J Trauma Acute Care Surg.* 2020;89: 160–166. Copyright © 2020 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic/Care Management, Level IV.

KEY WORDS: Direct to operating room; resuscitation; trauma; emergency surgery; lifesaving interventions.

Direct to operating room (DOR) trauma resuscitation is a unique approach to the trauma patient with the primary goal of providing immediate procedural and surgical management. In addition, being in the operating room (OR) allows multiple surgical teams to be working simultaneously, a benefit that is uniquely needed in the polytrauma setting.[1] In a DOR scenario, the patient bypasses the emergency department (ED) completely and presents directly to a specified OR that acts as the initial evaluation and resuscitation area. This includes performance of the primary and secondary surveys and ongoing resuscitation with the ability to convert to immediate surgical or other invasive procedural interventions if warranted. Direct to OR was developed from the understanding that shorter times to surgical management are associated with better outcomes in select trauma cohorts.[2–5]

Death from traumatic injuries continues to evolve, and it has been proposed that the temporal distribution has started to shift. Overall, with the advances in medical technology, the widespread acceptance of damage-control surgery and the growth of trauma systems we have seen increased survival.[6] The result of more efficient trauma systems has led to quicker arrival to definitive care centers, including the arrival of patients who previously may have died in the field because of hemorrhage or other rapidly fatal injuries. The need for rapid transport to an area capable of immediate surgical interventions has been increasingly recognized in both civilian and military settings, but in many cases, the standard ED-based resuscitation approach continues to result in preventable delays. Despite this, there remain only a few select trauma centers that have implemented DOR protocols, and there is a paucity of reported experience and analysis in the trauma literature. There is still little current research that refines patient selection, procedures performed, and compares outcomes. As a result, there are major knowledge gaps in areas such as optimal triage and patient selection criteria, execution of DOR resuscitation, and any associated benefits or harms of these programs. In particular, patient selection criteria need to continue to evolve to better predict and select which patients will benefit from bypassing the standard approach and proceed with DOR resuscitation.

Prior limited analyses of DOR have demonstrated potential areas of benefit of DOR on survival and overall faster times

TABLE 1. Demographics and Key Triage Criteria in the DOR Cohort

Penetrating injury, n (%)	440 (70)
Male, n (%)	495 (79)
Age, mean ± SD	38 ± 16
ISS, mean ± SD	14 ± 14
ISS >15, n (%)	246 (39)
Field SBP, mean ± SD	124 ± 33
Arrival SBP, mean ± SD	125 ± 36
SBP <90 field, n (%)	61 (10)
SBP <90 arrival, n (%)	75 (12)
GCS score <9 field, n (%)	133 (24)
GCS score <9 arrival, n (%)	182 (29)
Massive transfusion, n (%)	55 (9)
Base deficit, mean ± SD	7.02 ± 6.9
Base deficit ≥5	187 (30)

Submitted: December 1, 2019, Revised: January 31, 2020, Accepted: March 2, 2020, Published online: March 25, 2020.
From the Trauma and Emergency Surgery Service (A.J., M.R., A.K., E.W., F.C., A.R., R.B., W.L., M.M.), Legacy Emanuel Medical Center, Portland, Oregon; and Trauma Research Program (M.M.), Scripps Mercy Hospital, San Diego, California.
This study was presented at the 33rd Annual Scientific Assembly of the Eastern Association for the Surgery of Trauma, January 14–18, 2020, in Orlando, Florida.
Supplemental digital content is available for this article. Direct URL citations appear in the printed text, and links to the digital files are provided in the HTML text of this article on the journal's Web site (www.jtrauma.com).
Address for reprints: Matthew J. Martin, MD, Trauma Research Program, Scripps Mercy Hospital, 4077 5th Ave, San Diego, CA 92103; email: martin.matthew@scrippshealth.org.

DOI: 10.1097/TA.0000000000002703

TABLE 2. Legacy Emanuel Medical Center DOR Triage Criteria

Criteria	n (%)
Cardiopulmonary arrest	43 (7)
Unstable or surgical airway	14 (2)
Rigid, distended abdomen	11 (2)
Major crush injury to torso	3 (0.5)
Evisceration of abdominal contents	7 (1)
Penetrating/impalement injury trunk or proximal extremity	400 (64)
Amputation proximal to elbow or knee	11 (2)
Crushed, mangled, degloved or pulseless extremity	13 (2)
Profound shock (adults, SBP <80; pediatric, SBP <60)	74 (12)
Reported massive blood loss PTA	5 (1)
Hypothermia (<31°C)	0 (0)
EMS or flight provider request	10 (2)
ED on divert for capacity/resource limitation	2 (0.3)
Other	35 (6)

PTA, prior to arrival.

to intervention.[1,7–10] However, there has been little current research dedicated to further examining the criteria used to activate a DOR protocol and the associated outcomes among specific subgroups. There has also been a paucity of data describing what early surgical procedures were performed or what type of lifesaving interventions (LSIs) were required.[1,7,8] The primary objectives of this study included detailed analysis of DOR triage criteria, the correlation of these criteria with the need for emergent surgery (ES) or LSIs, and delineation of which specific ES and LSI were required in a large cohort of DOR trauma activations.

PATIENTS AND METHODS

This study was performed at Legacy Emanuel Medical Center, a tertiary care referral center and one of two level 1 trauma centers serving the state of Oregon. Institutional review board approval was obtained before the start of the study. All DOR trauma activations were identified in a retrospective review for a 6-year period (2012–2017). Initial data were obtained from review of the trauma registry, which includes prospective identification of which patients received a DOR initial trauma and the primary triage criteria that triggered the DOR activation (see Supplemental Digital Content 1, http://links.lww.com/TA/B638, for the complete institutional DOR protocol and triage criteria). Further detailed data were then obtained from individual chart review, including focused review of the initial trauma resuscitation logs and anesthesia operative logs documenting exact times for all procedural and surgical interventions. Additional data collected included patient demographics, triage criteria used to enter DOR, Injury Severity Score (ISS), Abbreviated Injury Scale by body region, prehospital vital signs and DOR activation triggers, initial hospital vital signs, disposition following the initial DOR resuscitation, hospital and ICU lengths of stay, and complications. The complications were identified and coded using the standardized Trauma Quality Improvement Project definitions and included venous thromboembolic events, myocardial infarction, stroke, pneumonia, surgical site infection, sepsis, anastomotic leak/fistula, unplanned return to the OR, and missed injuries.

Potential LSIs were defined as any of the following procedures if performed during the initial evaluation and resuscitation while in the OR: needle decompression, endotracheal intubation, surgical airway, tourniquet placement, tube thoracostomy placement, massive transfusion, and administration of advanced

TABLE 3. Life Saving Interventions Among DOR Cohort

Procedure	n (%)	Median Start Time From Arrival, min
Any LSI performed	311 (50)	19
Needle decompression	7 (1)	11
Intubation	203 (32)	14
Surgical airway	3 (0.5)	14
Tourniquet placement	1 (0.2)	28
Chest tube placement	132 (21)	23
Massive transfusion	55 (9)	7
ACLS drugs	47 (8)	8

ACLS, advanced cardiac life support.

TABLE 4. Emergent Surgical Interventions Among the DOR Cohort and Median Start Times

Procedure	n (%)	Median Start Time From Arrival, min
Any ES performed within first hour	143 (23)	n/a
Laparotomy	155 (25)	23
Damage control	76 (12)	13
Thoracotomy	18 (3)	51
Sternotomy	27 (4)	18
Neck exploration	21 (3)	38
Pericardial window	9 (1)	49
Vascular control/extremity repair	25 (4)	56
Craniotomy/craniectomy	24 (4)	34

n/a, Not applicable.

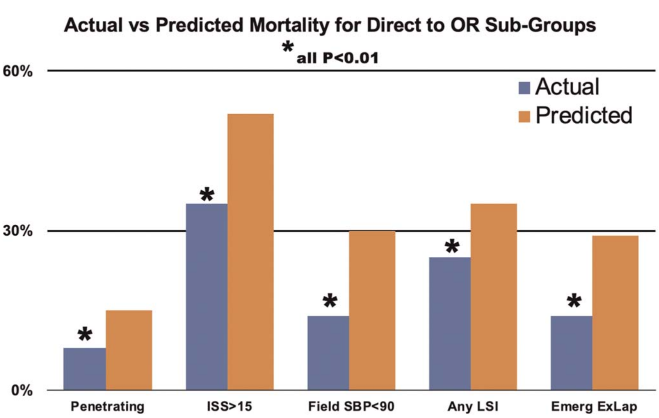

Figure 1. Bar graph showing a comparison of aM (black) versus pM (gray) based on revised-TRISS methodology for select high-risk DOR patient subgroups (* indicates statistically significant differences, $p < 0.05$).

TABLE 5. Characterization of Need for Emergent Interventions and Mortality by Triage Category Grouping

Triage Variable Categories:	DOR Cases*	LSI*	ES*	Mortality*
1. Mechanism	64%	42%	24%	7%
2. Physiology/examination	21%	68%	24%	45%
3. Anatomy/injury	7%	67%	27%	16%
4. Other	8%	45%	4%	28%

*All $p < 0.01$ by χ^2.

cardiac life support (ACLS) medications. Field interventions were defined as any of these same LSI performed by emergency medical system personnel before hospital arrival. Emergent surgery was defined as undergoing a laparotomy, thoracotomy, sternotomy, neck exploration, vascular repair, or pericardial window within 60 minutes of presentation. Procedures were only included as ES if they were performed immediately during the initial trauma evaluation and resuscitation progress, and any procedures performed after admission to the trauma ward or ICU were excluded.

The primary outcome evaluated was actual mortality (aM) and predicted mortality (pM), which was compared for all patients and for predefined time-sensitive subgroups of penetrating injury, severe injury (ISS >15), hypotensive patients (field systolic blood pressure [SBP] <90), severely altered mental status (field Glasgow Coma Scale [GCS] score, <9), any LSI performed, and any ES performed. Actual mortality was compared with pM, which was calculated using the revised Trauma Injury Severity Score (TRISS). Although comparison with a similarly injured cohort that did not receive a DOR activation would be optimal, on preliminary analysis, there were very few patients at our center who required emergent interventions/surgery who were not identified by the DOR triage criteria, thus making direct comparison invalid. The triage criteria were analyzed individually and also grouped into the following four categories: injury mechanism, patient physiology, anatomy/injury pattern, or other. Individual triage variables and the triage variable categories were examined for their association with the need for any LSI, any ES, or a composite outcome including any LSI or ES. Data were analyzed using standard univariate comparative statistics including Student's *t* test, Wilcoxon rank-sum test, and χ^2 or Fisher's exact tests. Independent predictors of requiring an LSI and/or ES were identified by entering all selected triage criteria in forward conditional binary logistic regression models after screening for significant covariance. All statistical analyses were performed using SPSS version 26 (IBM Corp, Chicago, IL), with statistical significance set at a *p* value of <0.05.

RESULTS

There were 16,113 trauma admissions over the study period. Among these, 628 DOR patients were identified, representing 4% of all admissions. Of the DOR patients, 79% were male and 70% had a penetrating mechanism, 39% were severely injured with an ISS of greater than 15, and 17% died. The majority (67%) of DOR patients were younger than 45 years, and 5% of the patients were older than 65 years. The number of patients with hypotension was 61 (10%) based on the field SBP and 75 (12%) upon arrival to the OR. The incidence of severely altered mental status (GCS score, <9) in the field was 122 (24%) and 182 (29%) upon arrival to the OR (Table 1).

The most common individual triage criteria prompting a DOR activation was penetrating injury of the torso or head at 64%, followed by hypotension at 12%. The least used triage trigger was for *resource or capacity needs* at two patients (<1%) (Table 2). Table 3 lists the individual LSIs that were performed and the median time from arrival to start of each intervention. At least one LSI was required in 311 (50%) of patients, and 31% of patients required multiple LSIs. The most commonly required LSIs were endotracheal intubation/airway management, chest tube placement, and massive transfusion. Emergent surgery was required in 163 patients representing 26% of DOR cases. Table 4 lists the types of ES procedures that were performed and the median start time from arrival. The median time for exploratory laparotomy was 23 minutes, and for damage control, it was 13 minutes from arrival. Overall, 54% of DOR patients required the composite endpoint intervention (at least one LSI and/or ES). The majority of ES performed was exploratory laparotomies, and 12% of these were damage control. Of note, the rate of negative thoracic or abdominal explorations was less than 2%, and there was a 1% incidence of missed injuries, none of which were found to result in additional morbidity. All emergent resuscitative operations performed for loss of vital signs or impending arrest during this study period were performed in the OR setting, with no patients undergoing ED thoracotomy among patients who were triaged to the ED rather than DOR.

After initial evaluation in the OR, 163 (26%) proceeded immediately to surgical management, and 143 patients (23%) had a start time within the first hour. There were 20 patients who had ES of more than1 hour, and the majority of this discrepancy was attributed to delayed time stamps of the electronic medical record because of the lag between documentation and real-time patient care. Sixty-one percent went to computed tomography (CT) for imaging, 6% went back to the ED, and 2% were admitted directly from the OR. Of the 61% of the patients who initially went to CT, the majority had a penetrating injury. The mean GCS score in the field and on arrival was 12, and the mean systolic blood pressure in the field and arrival was 126. Ultimately, 124 (20%) of these patients returned to the OR after CT imaging was obtained. There were 5% that were pronounced deceased after the initial DOR resuscitation, with the majority of these arriving without vital signs. When looking at complications, there were 39 cases (6%) that had unplanned subsequent return trips to the OR, and there was a missed injury in 5 (1%) of patients. Overall, from all DOR trauma activations, 68% of patients were discharged home, 5% went to a skilled nursing facility, 4% to inpatient rehab, and 6% to other type of facility. Of the patients surviving to discharge, 68% had a good recovery based on the Glasgow Outcome Scale (>3), and 18% of patients had significantly depressed mental status (GCS score, <9) at discharge. There was an overall 17% mortality rate within the DOR patient cohort, which was significantly lower than the 25% revised-TRISS pM ($p < 0.01$). Analysis of the actual versus pM rates for select high-risk patient categories is shown in Figure 1 and demonstrates similar lower aM for these subgroups. There was no significant difference in mortality rates for the corresponding lower-acuity counterparts to each subgroup.

Table 5 shows the rates of emergent interventions and mortality for each category of DOR triage variables. The highest rates of LSI and ES were among those triaged based on physiology or injury/anatomy variables, followed by mechanism. Although penetrating trauma mechanism was among the most common reason for DOR activation, an ES was only required in 24% of these patients. Outcomes varied widely between categories, ranging from the highest mortality (45%) for the physiology category to the lowest (7%) for mechanism ($p < 0.01$). Independent predictors (all $p < 0.05$) for interventions were identified via the multivariate logistic regression models described previously. For LSI, the strongest independent predictors were field hypotension (OR, 2.2; 95% CI, 1.2–4.0), field GCS score of less than 9 (OR, 1.7; 95% CI, 1.1–2.7), and the triage categories of physiology (OR, 2.1; 95% CI, 1.2–3.4) or anatomy (OR, 2.6; 95% CI, 1.3–5.1) variables. For ES, they were penetrating truncal mechanism (OR, 4.2; 95% CI, 1.9–9.0), and the triage categories of physiology (OR, 3.0; 95% CI, 1.4–6.3) or anatomy (OR, 2.9; 95% CI, 1.2–6.7) variables. For the composite endpoint of ES or LSI, they were field hypotension (OR, 2.6; 95% CI, 1.4–4.7), the need for multiple field interventions (OR, 2.5; 95% CI, 1.2–5.1), and the triage categories of physiology (OR, 1.9; 95% CI, 1.1–3.2) or anatomy (OR, 2.5; 95% CI, 1.3–4.7) variables.

DISCUSSION

This study performed a detailed analysis of a large modern cohort of trauma patients managed within a well-developed direct to OR resuscitation program at our level 1 trauma center. The analysis has served to provide important epidemiologic data regarding the exact types and timing of urgent/emergent bedside LSIs and emergent surgical procedures, and their associated outcome profiles. In addition, we have characterized the utility and resultant rates of LSI and ES for both individual triage criteria and a simplified grouping of related variables into four general triage categories. Past studies have consistently reported that predictors for urgent surgery are penetrating mechanism, hypotension, and GCS score of less than 9.[1,3,4,9,10] This study further analyzed the 14 DOR criteria our facility uses and found the best independent predictors for ES or LSI. The best criteria to identify those who would benefit most from DOR were field hypotension with SBP of less than 90, mechanism, and physiology/examination. The majority of DOR patients were activated based on penetrating mechanism (64%). However, LSI was actually only performed 50% of the time and ES within 1 hour occurred 23% of the time, supporting the need to further optimize the DOR patient selection criteria. Looking closer, the need for ES was significantly greater in penetrating than blunt injuries ($p < 0.01$). This is consistent with the findings that the best independent predictors for ES were mechanism and anatomy/injury pattern. For LSI, the independent predictors were field SBP of less than 90, mechanism, physiology/examination, and anatomy/injury pattern. This supports the general concept that those in extremis would trigger at least one of these predictors and would benefit most from timely LSI.[11,12] Currently, we use 14 triage criteria to activate a trauma as a DOR (Table 2). Based on the independent predictors for LSI and ES, the criteria can be simplified to four to six criteria that would predict which patients would benefit most from DOR activation. These four to six criteria are slightly different when predicting who will need LSI versus ES. The criteria for ES are more mechanism and injury pattern based. These include penetrating mechanism, crush injury, amputation, or evisceration. The need for LSI was predicted by penetrating mechanism, crush injury, unstable airway, and significant examination findings such as cardiopulmonary resuscitation (CPR) or profound shock.

There was improved mortality in certain subgroups including those who were identified as independent predictors for ES and LSI. There was significantly improved mortality (versus predicted rates) seen for penetrating truncal mechanism, ISS of greater than 15, and field SBP of less than 90. There was also improved aM in those who had any LSI performed and those who have an emergent damage-control exploratory laparotomy. There remains a very tangible need for the direct to OR setting because of the well-described peak in early deaths associated with life-threatening hemorrhage as the biggest contributing factor.[6,13,14] The approach to the trauma patient is based on the need for fast decisive decisions that start even before the patient has entered the hospital.[15] Therefore, it is important to look at how to best identify patients who would benefit from DOR and bypassing initial evaluation in the ED.[16] Streamlining this process starts at the scene.[15,17] Timely arrival from the scene is important, as those who require critical interventions or procedures have an increased mortality if they arrive to the hospital greater than 60 minutes.[18,19] There was an observed significant increase in mortality after delay to the OR of greater than 10 minutes in a subset of gunshot wounds to the torso with hypotension.[16] In one study, it was found the median length of time spent in the ED before arriving to the OR was 110 minutes and the likelihood of death increased for every 3 minutes spent in the ED.[20] Even after the patient has arrived to the hospital, there still is a significant time difference of operative start time depending where resuscitation occurs.[21] Direct to OR minimizes the time to incision for patients requiring ES. Some literature reports that mean time to incision in DOR patients was 38 minutes compared with mean time for 99 minutes with non-DOR.[8] Our institution previously noted that a median time to incision was 13 minutes. This study again demonstrated that a median time to incision was 13 minutes for a damage-control laparotomy, indicating that a DOR protocol does contribute to a faster time to incision.[7] There continues to be a significant benefit in correctly identifying what criteria should activate DOR. It is imperative that these criteria are also criteria EMS can ascertain within minutes of arrival at the scene. However, it is still a fluid process of clearly identifying who these patients are in the field.[11,18] Additional considerations that must be taken into account by a center initiating or adjusting a DOR policy is how any change will affect the rates of overtriage, undertriage, and the total volume of DOR activations. For high-volume centers that expect frequent DOR activations, the goal may be to streamline the triage criteria to maximize reduction of overtriage or unnecessary activations. For a lower-volume center, the opposite may be desired, namely, to increase the overtriage rate to both minimize the possibility of undertriaging a patient needing LSI or ES and maintain an adequate volume of DOR activations to maintain the center and trauma team proficiency.

Direct to OR literature has reported using hypotension and penetrating trauma as common triage criteria.[1,7–9,22–24] The Boston Med Flight DOR protocol included penetrating trauma with hemodynamic instability, blunt trauma with concerning abdominal examination and hemodynamic instability, pediatric cold-water drowning, interfacility transfers with a known surgical diagnosis, and unstable hemodynamics as triage criteria for DOR.[9] The University of California, San Diego (UCSD) group included cardiac arrest, persistent hypotension with systolic of less than 100 that is not fluid responsive, uncontrolled external hemorrhage, or amputation as criteria for DOR activation.[8] The criteria used at Legacy Emanuel Medical Center include parts of the previous criteria and additionally include EMS, attending surgeon or charge nurse discretion, physical examination findings of crush injury, evisceration, or unstable airway/surgical airway placed (Table 2). In a prior report, our group identified three factors that predicted the need for urgent surgical intervention: penetrating truncal injury, hypotension, and GCS score of less than 9.[7] Steele et al.[8] found that patients with gunshot wounds, hypotension, or interfacility transfers requiring blood transfusion would need an emergent surgical procedure 62% of the time. This is significantly higher than the 26% of cases requiring urgent surgical procedures at our facility. There are several factors explaining this discrepancy. The study done at UCSD was performed between 1985 and 1995 when CT imaging was not a feasible option for a rapid trauma evaluation, and nonoperative management was a much less developed and accepted practice for major solid organ injuries, as well as their patient population demographics were shifted more toward the extremis side with a higher mean ISS and lower systolic blood pressures, overall suggesting that those patients would require surgical management.[8]

Alarhayem et al.[23] found that mortality increased by 5% to 21.5% in patients with hypotension, with the highest mortality in those with SBP of less than 60, suggesting that these patients are the ones who would benefit the most from immediate surgical management. Patients with penetrating injuries, high ISS, and low GCS score derive the greatest benefit from DOR, experiencing an overall 50% decrease in mortality compared with patients not resuscitated in the OR.[1,7,22]

Despite the improved observed mortality in subgroups our DOR patients, DOR is not widely used in the United States. There is an improved observed mortality in certain subgroups of our DOR patients, which is attributed to the unique capabilities of our DOR program.[25] However, DOR resuscitations are not widely used in the United States. Barriers to the use of DOR include resource utilization and the potential for prolonging time to obtaining necessary imaging. Maintaining an open OR available at all times can be a considerable strain on facilities if that OR is required to be used for other urgent or elective procedures.[26] The relative locations of the OR, ED, and CT scanner to one another impact the efficiency of patient evaluation.[27] Bypassing the ED with a patient in extremis to go to the OR if the OR is not located in a readily accessible area in close proximity to the ED and ambulance dock may not be feasible or advantageous.

To provide additional details about the Legacy Emanuel Direct to OR Program, our center maintains an available and open trauma OR room at all times. The OR is located next door to the CT scanner and the ED trauma bays as previously reported.[7] The trauma OR is used for both DOR traumas and for trauma surgical procedures that have been identified in the ED. The trauma activation charges for level 1 DOR and level 1 activations are the same. No OR time or equipment charges are incurred until an operation is started or an instrument tray is opened. There are no additional costs for resuscitation in the OR compared with resuscitation in the ED if no operation is performed.[1] The initial assessment is performed in the same fashion in the OR as in the ED. Screening radiographs are obtained using portable machines. If no immediate intervention is needed, the patient can be quickly transported from the OR to the adjacent CT scanner while still on the OR table, minimizing any delay to necessary imaging.

This study has several important limitations. It is a retrospective analysis of data compiled over the course of 6 years. This study is looking at the triage criteria used to designate a DOR. However, the criteria used at our institution have not changed since our last study in 2012, making comparisons difficult. Looking at our patient population at our facility, there has been an overall trend toward less DOR patients requiring ES. This is suggestive of increasing overtriage for DOR patients. There are multiple contributing factors to the overtriage, and this continues to emphasize the need for optimizing DOR criteria to select those who would benefit the most. Patients who met multiple triage criteria and those with overlap of triage criteria were not considered separately from those meeting only one criterion, although we did control for patients receiving a single versus multiple prehospital interventions. The indications for some of the interventions performed were not explicitly stated but had to be inferred from the chart review. Patients received from the field and interfacility transfers were both included in this study. This was an additional limitation because this included patients who had obtained imaging before transfer, arrived, and then proceeded directly to surgery. This is an important distinction to make when trying to evaluate the criteria that best predict the need for ES before obtaining CT imaging. However, these patients made up a small minority of the sample and did not affect any of the main outcomes when analyses were run with them excluded. Operation start times may appear later than reality in some cases because of the nature of data entry into the electronic trauma flow sheet. Finally, it is important to recognize that there was no direct comparator group of patients who were triaged to standard ED evaluation and who required LSI or ES. Although this would be ideal for examining outcomes and had been initially planned, our initial review found very few patients who truly needed emergent interventions and were not triaged as a DOR activation at our center. Preliminary comparison with this cohort produced highly skewed data that we felt was actually too biased toward the DOR cohort, as the times to intervention or surgery were markedly longer, reflecting the less urgent nature of their injuries as much or even more than the true time benefits of DOR resuscitation.

CONCLUSIONS

This study provides further guidance in optimizing the DOR triage criteria that are most associated with the need for emergent LSIs, major ES, and with associated mortality rates. Based on our results, we conclude that a simplified DOR triage system could be narrowed down to four to six independent predictors that would capture the majority of the desired patient population and potentially reduce overtriage rates, but that this needs to be tailored to each individual center. The best predictors for ES and those who would benefit the most from faster surgical interventions via DOR were penetrating truncal mechanism, significant anatomy or examination findings such as proximal amputations and major physiologic derangements including prehospital CPR or profound shock with SBP of less than 90. The aM of DOR patients was significantly lower than pM, and this may be related to having the ability to provide timely interventions to those at a high risk of preventable death, although this would need to be confirmed by direct comparison to a matched cohort not managed by DOR resuscitation. Further research is needed to continue to improve both outcomes and resource utilization in the use of DOR activations and to fine-tune triage criteria to optimize the selection of patients who may benefit from this approach. We are currently completing a prospective study of DOR resuscitations that includes real-time attending surgeon review and assessment that should provide novel and more granular insights into the benefit and optimal selection criteria for a DOR program.

AUTHORSHIP

A.J., M.M., F.C., R.B., A.R., and W.L. contributed in the study design. A.J., A.K., M.R., and E.W. contributed in the data acquisition. A.J., M.M., and W.L. contributed in the data analysis. A.J., M.M., R.B., F.C., and A.R. contributed in the data interpretation. A.J., A.K., M.R., E.W., M.M., R.B., and F. C. contributed in the drafting the article. A.J., M.M., R.B., F.C., and W.L. contributed in the revision of the article.

DISCLOSURE

The authors declare no conflicts of interest.
The opinions expressed in this work are those of the authors and do not reflect the official opinions or policies of Legacy Emanuel Medical Center, Scripps Mercy Hospital, or any associated organization.

REFERENCES

1. Wieck MM, Cunningham AJ, Behrens B, Ohm ET, Maxwell BG, Hamilton NA, Adams MC, Cole FJ Jr., Jafri MA. Direct to operating room trauma resuscitation decreases mortality among severely injured children. *J Trauma Acute Care Surg*. 2018;85(4):659–664.
2. Simmons JW, White CE, Eastridge BJ, Holcomb JB, Perkins JG, Mace JE, Blackbourne LH. Impact of improved combat casualty care on combat wounded undergoing exploratory laparotomy and massive transfusion. *J Trauma*. 2011;71(Suppl 1):S82–S86.
3. Harvin JA, Maxim T, Inaba K, et al. Mortality after emergent trauma laparotomy: a multicenter, retrospective study. *J Trauma Acute Care Surg*. 2017; 83(3):464–468.
4. Barbosa RR, Rowell SE, Fox EE, et al. Increasing time to operation is associated with decreased survival in patients with a positive FAST examination requiring emergent laparotomy. *J Trauma Acute Care Surg*. 2013;75:S48–S52.
5. Tien HCN, Jung V, Pinto R, Mainprize T, Scales DC, Rizoli SB. Reducing time-to-treatment decreases mortality of trauma patients with acute subdural hematoma. *Ann Surg*. 2011;253(6):1178–1183.
6. Bardes JM, Inaba K, Schellenberg M, Grabo D, Strumwasser A, Matsushima K, Clark D, Brown N, Demetriades D. The contemporary timing of trauma deaths. *J Trauma Acute Care Surg*. 2018;84(6):893–899.
7. Martin M, Izenberg S, Cole F, Bergstrom S, Long W. A decade of experience with a selective policy for direct to operating room trauma resuscitations. *Am J Surg*. 2012;204(2):187–192.
8. Steele JT, Hoyt DB, Simons RK, Winchell RJ, Garcia J, Fortlage D. Is operating room resuscitation a way to save time? *Am J Surg*. 1997;174(6): 683–687.
9. Van der Wilden GM, Janjua S, Wedel SK, et al. Multi-institutional comparison of helicopter transfers directly to the operating room versus the pit stop in the emergency department. *Am Surg*. 2013;79(9):939–943.
10. Deree J, Shenvi E, Fortlage D, Stout P, Potenza B, Hoyt DB, Coimbra R. Patient factors and operating room resuscitation predict mortality in traumatic abdominal aortic injury: a 20-year analysis. *J Vasc Surg*. 2007;45(3): 493–497.
11. Lehmann RK, Arthurs ZM, Cuadrado DG, Casey LE, Beekley AC, Martin MJ. Trauma team activation: simplified criteria safely reduces overtriage. *Am J Surg*. 2007;193(5):630–635.
12. MacLeod JBA, Cohn SM, Johnson EW, McKenney MG. Trauma deaths in the first hour: are they all unsalvageable injuries? *Am J Surg*. 2007;193(2): 195–199.
13. Bansal V, Fortlage D, Lee JG, Costantini T, Potenza B, Coimbra R. Hemorrhage is more prevalent than brain injury in early trauma deaths: the golden six hours. *Eur J Trauma Emerg Surg*. 2009;35(1):26–30.
14. Remick KN, Schwab CW, Smith BP, Monshizadeh A, Kim PK, Reilly PM. Defining the optimal time to the operating room may salvage early trauma deaths. *J Trauma Acute Care Surg*. 2014;76(5):1251–1258.
15. Martin M, Oh J, Currier H, Tai N, Beekley A, Eckert M, Holcomb J. An analysis of in-hospital deaths at a modern combat support hospital. *J Trauma*. 2009;66(Suppl 4):S51–S60; discussion S60-1.
16. Meizoso JP, Ray JJ, Karcutskie CA4th, et al. Effect of time to operation on mortality for hypotensive patients with gunshot wounds to the torso: the golden 10 minutes. *J Trauma Acute Care Surg*. 2016;81(4):685–691.
17. Qazi K, Kempf JA, Christopher NC, Gerson LW. Paramedic judgment of the need for trauma team activation for pediatric patients. *Acad Emerg Med*. 1998;5(10):1002–1007.
18. Newgard CD, Meier EN, Bulger EM, Buick J, Sheehan K, Lin S, Minei JP, Barnes-Mackey RA, Brasel K. Revisiting the "golden hour": an evaluation of out-of-hospital time in shock and traumatic brain injury. *Ann Emerg Med*. 2015;66(1):30–41.e3.
19. Mowery NT, Dougherty SD, Hildreth AN, Holmes JH4th, Chang MC, Martin RS, Hoth JJ, Meredith JW, Miller PR. Emergency department length of stay is an independent predictor of hospital mortality in trauma activation patients. *J Trauma*. 2011;70(6):1317–1325.
20. Clarke JR, Trooskin SZ, Doshi PJ, Greenwald L, Mode CJ. Time to laparotomy for intra-abdominal bleeding from trauma does affect survival for delays up to 90 minutes. *J Trauma*. 2002;52(3):420–425.
21. Fiedler MD, Jones LM, Miller SF, Finley RK. A correlation of response time and results of abdominal gunshot wounds. *Arch Surg*. 1986;121(8):902–904.
22. Steele R, Gill M, Green SM, Parker T, Lam E, Coba V. Do the american college of surgeons' "major resuscitation" trauma triage criteria predict emergency operative management? *Ann Emerg Med*. 2007;50(1):1–6.
23. Alarhayem AQ, Myers JG, Dent D, et al. Time is the enemy: Mortality in trauma patients with hemorrhage from torso injury occurs long before the "golden hour". *Am J Surg*. 2016;212(6):1101–1105.
24. Hoyt DB. The impact of in-house surgeons and operating room resuscitation on outcome of traumatic injuries. *Arch Surg*. 1989;124(8):906.
25. Demetriades D, Martin M, Salim A, Rhee P, Brown C, Chan L. The effect of trauma center designation and trauma volume on outcome in specific severe injuries. *Ann Surg*. 2005;242(4):512–519.
26. Brasel KJ, Akason J, Weigelt JA. Dedicated operating room for trauma: a costly recommendation. *J Trauma*. 1998;44(5):832–836; discussion 836-8.
27. Marcoux J, Bracco D, Saluja RS. Temporal delays in trauma craniotomies. *J Neurosurg*. 2016;125(3):642–647.