Impact of time to surgery on mortality in hypotensive patients with noncompressible torso hemorrhage: An AAST multicenter, prospective study

CONTINUING MEDICAL EDUCATION CREDIT INFORMATION

Accreditation

This activity has been planned and implemented in accordance with the accreditation requirements and policies of the Accreditation Council for Continuing Medical Education (ACCME) through the joint providership of the American College of Surgeons and American Association for the Surgery of Trauma. The American College of 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 activity for a maximum of 1.00 *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 1.00 credit meets the requirements for self-assessment.

AMERICAN COLLEGE OF SURGEONS *Inspiring Quality: Highest Standards, Better Outcomes* 100+years

ACCME ACCREDITED WITH COMMENDATION

AMERICAN COLLEGE OF SURGEONS DIVISION OF EDUCATION

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.

Disclosure Information

In accordance with the ACCME Accreditation Criteria, the American College of Surgeons must ensure that anyone in a position to control the content of the educational activity (planners and speakers/authors/discussants/moderators) has disclosed all financial relationships with any commercial interest (termed by the ACCME as "ineligible companies", defined below) held in the last 24 months (see below for definitions). Please note that first authors were required to collect and submit disclosure information on behalf all other authors/contributors, if applicable.

Ineligible Company: The ACCME defines an "ineligible company" as any entity producing, marketing, re-selling, or distributing health care goods or services used on or consumed by patients. Providers of clinical services directly to patients are NOT included in this definition.

Financial Relationships: Relationships in which the individual benefits by receiving a salary, royalty, intellectual property rights, consulting fee, honoraria, ownership interest (e.g., stocks, stock options or other ownership interest, excluding diversified mutual funds), or other financial benefit. Financial benefits are usually associated with roles such as employment, management position, independent contractor (including contracted research), consulting, speaking and teaching, membership on advisory committees or review panels, board membership, and other activities from which remuneration is received, or expected. ACCME considers relationships of the person involved in the CME activity to include financial relationships of a spouse or partner.

Conflict of Interest: Circumstances create a conflict of interest when an individual has an opportunity to affect CME content about products or services of a commercial interest with which he/she has a financial relationship.

The ACCME also requires that ACS manage any reported conflict and eliminate the potential for bias during the session. Any conflicts noted below have been managed to our satisfaction. The disclosure information is intended to identify any commercial relationships and allow learners to form their own judgments. However, if you perceive a bias during the educational activity, please report it on the evaluation.

AUTHORS/CONTRIBUTORS

Juan Duchesne, Kevin Slaughter, Ivan Puente, John D. Berne, Brian Yorkgitis, Jennifer Mull, Jason Sperry, Matthew Tessmer, Todd Costantini, Allison E. Berndtson, Taylor Kai, Giannina Rokvic, Scott Norwood, Katelyn Meadows, Grace Chang, Brittney M. Lemon, Tomas Jacome, Lauren Van Sant, Jasmeet Paul, Zoe Maher, Amy J. Goldberg, Robert M. Madayag, Greg Pinson, Mark J. Lieser, James Haan, Gary Marshall, Matthew Carrick, and Danielle Tatum have nothing to disclose.

EDITORIAL BOARD MEMBERS

First Name	Last Name	Disclosure?	Name of Commercial Interest	What was Received?	What was the Role?
Michael	Nance	Yes	Endo Pharmaceuticals	Consulting fee	Consultant
Heena	Santry	Yes	NBBJ	Salary	Employee
Jose	Diaz	Yes	Acumed/Acute Innovations	Consulting fee	Consultant
Lena	Napolitano	Yes	Merck Global Negative Advisory Board/Abbvie Critical Care Working Group	Consulting fee	Advisor/ Consultant

Roxie Albrecht, Walter Biffl, Karen Brasel, Clay Cothren Burlew, Raul Coimbra, Todd Costantini, Rochelle Dicker, Tabitha Garwe, Kenji Inaba, Rosemary Kozar, David Livingston, Ali Salim, Deborah Stein, Alex Valadka, Robert Winchell, Bishoy L. Zakhary, and Ben Zarzau have no disclosures or conflicts of interest to report. The Editorial Office staff has no disclosures to report.

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.

Credits can only be claimed online

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.

Questions

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

Juan Duchesne, MD, FACS, FCCP, FCCM, Kevin Slaughter, MD, Ivan Puente, MD, FACS, John D. Berne, MD, MPH, FACS, Brian Yorkgitis, DO, Jennifer Mull, MSN, RN, Jason Sperry, MD, MPH, Matthew Tessmer, BS, Todd Costantini, MD, Allison E. Berndtson, MD, Taylor Kai, MD, Giannina Rokvic, BS, Scott Norwood, MD, FACS, FCCM, Katelyn Meadows, RN, Grace Chang, DO, Brittney M. Lemon, DO, Tomas Jacome, MD, FACS, Lauren Van Sant, DO, Jasmeet Paul, MD, FACS, Zoe Maher, MD, Amy J. Goldberg, MD, FACS, Robert M. Madayag, MD, FACS, Greg Pinson, MD, Mark J. Lieser, MD, James Haan, MD, FACS, Gary Marshall, MD, FACS, Matthew Carrick, MD, *and* **Danielle Tatum, PhD**,
New Orleans, Louisiana

BACKGROUND: Death from noncompressible torso hemorrhage (NCTH) may be preventable with improved prehospital care and shorter in-hospital times to hemorrhage control. We hypothesized that shorter times to surgical intervention for hemorrhage control would decrease mortality in hypotensive patients with NCTH.

METHODS: This was an AAST-sponsored multicenter, prospective analysis of hypotensive patients aged 15+ years who presented with NCTH from May 2018 to December 2020. Hypotension was defined as an initial systolic blood pressure (SBP) ≤ 90 mm Hg. Primary outcomes of interest were time to surgical intervention and in-hospital mortality.

RESULTS: There were 242 hypotensive patients, of which 48 died (19.8%). Nonsurvivors had higher mean age (47.3 vs. 38.8; $p = 0.02$), higher mean New Injury Severity Score (38 vs. 29; $p < 0.001$), lower admit systolic blood pressure (68 vs. 79 mm Hg; $p < 0.01$), higher incidence of vascular injury (41.7% vs. 21.1%; $p = 0.02$), and shorter median (interquartile range, 25–75) time from injury to operating room start (74 minutes [48–98 minutes] vs. 88 minutes [61–128 minutes]; $p = 0.03$) than did survivors. Multivariable Cox regression showed shorter time from emergency department arrival to operating room start was not associated with improved survival ($p = 0.04$).

CONCLUSION: Patients who died arrived to a trauma center in a similar time frame as did survivors but presented in greater physiological distress and had significantly shorter times to surgical hemorrhage intervention than did survivors. This suggests that even expediting a critically ill patient through the current trauma system is not sufficient time to save lives from NCTH. Civilian prehospital advance resuscitative care starting from the patient first contact needs special consideration. (*J Trauma Acute Care Surg.* 2022;92: 801–811.

LEVEL OF EVIDENCE: Prognostic/Epidemiologic, Level III
KEY WORDS: Noncompressible torso hemorrhage; time to hemorrhage control; damage-control resuscitation; definitive control; advanced resuscitative care.

Noncompressible torso hemorrhage (NCTH) is the leading cause of potentially preventable death in both military and civilian populations, accounting for 30% to 40% of trauma-related mortality.[1–3] Time is critical in hemorrhage control, as many deaths occur within the first few minutes following injury. In patients with severe truncal hemorrhage, expedited and effective hemostatic resuscitation and hemorrhage control is needed to restore end organ perfusion and improve outcomes.

Submitted: August 26, 2021, Revised: October 29, 2021, Accepted: November 19, 2021, Published online: January 18, 2022.

From the Tulane University School of Medicine (J.D., K.S., D.T.), New Orleans, Louisiana; Broward Health Medical Center (I.P., J.D.B.), Fort Lauderdale; University of Florida-Jacksonville (B.Y., J.M.), Jacksonville, Florida; University of Pittsburgh (J.S., M.T.), Pittsburgh, Pennsylvania; UC San Diego Medical Center (T.C., A.E.B.), San Diego, California; University of Kentucky Chandler Medical Center (T.K., G.R.), Lexington, Kentucky; University of Texas Health Tyler (S.N., K.M.), Tyler, Texas; Mount Sinai Hospital (G.C., B.M.L.), Chicago, Illinois; Our Lady of the Lake Regional Medical Center (T.J.), Baton Rouge, Louisiana; University of New Mexico Hospital (L.V.S., J.P.), Albuquerque, New Mexico; Temple University Hospital (Z.M., A.J.G.), Philadelphia, Pennsylvania; St. Anthony Hospital (R.M.M., G.P.), Lakewood, Colorado; Research Medical Center (M.J.L.), Kansas City, Missouri; Ascension Via Christi Hospital St. Francis (J.H.), Wichita, Kansas; and Medical City Plano (G.M., M.C.), Plano, Texas.

This study will be presented as a podium presentation at the 80th Annual Meeting of the American Association for the Surgery of Trauma (AAST) to be held September 29 to October 2, 2021 in Atlanta, Georgia.

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: Juan Duchesne, MD, FACS, FCCP, FCCM, Department of Surgery, Tulane University School of Medicine, 1412 Tulane Ave, New Orleans, LA 70112; email: jduchesn@tulane.edu.

DOI: 10.1097/TA.0000000000003544

Traditionally in the United States (US), a "scoop and run" approach is deployed by emergency medical services (EMS), with heavy emphasis on expedited transport time to a trauma center. The current structural logistics for most US trauma centers upon arrival of a hemodynamically unstable patient is to first stop in the emergency department (ED) for initial assessment and management. In hypotensive NCTH patients, a focused assessment with sonography for trauma (FAST) ultrasound can demonstrate the need for surgical intervention; however, in the presence of a negative FAST, there is still a need for better diagnostic examinations. This group of patients are then often routed from the ED to the radiology suit for further imaging and then to either the operating room (OR) or interventional radiology suite for definitive hemorrhage control. This protracted course can be a time-consuming and life-threatening journey for a hemorrhaging patient with severe truncal injury.

Many hemorrhage-related deaths may be preventable with improved prehospital care and shorter times to definitive surgical care. Decreasing the time to definitive surgical care via OR resuscitation has been shown to improve outcomes, especially in penetrating trauma patients.[4] Clarke et al.[5] reported that the extent of hypotension and length of time (up to 90 minutes) in the ED in hypotensive patients with isolated intra-abdominal injuries increased the probability of death by 1% for each additional 3 minutes in the ED. In a recent retrospective analysis of a large sample from an urban Level I trauma center, Meizoso et al.[6] found that taking more than 10 minutes to get to the OR was independently associated with mortality. This was the first study to examine and quantify how long is too long to spend in the trauma bay with a patient requiring an immediate

operation. The present study sought to expand on previous studies by prospectively observing time to surgery and mortality among NCTH patients, including those injured by blunt, as well as penetrating mechanisms.[6] We hypothesized that shorter times to surgical intervention for hemorrhage control would decrease mortality in hypotensive patients with NCTH.

PATIENTS AND METHODS

Study Population

This was a multicenter, prospective, observational study of injured patients with NCTH presenting to 15 participating trauma centers from May 2018 to December 2020. Of these centers, 13 are American College of Surgeons (ACS) and/or state designated as Level I and two are designated as Level II. Patients were included if they were 15 years or older with penetrating traumatic injury to torso (chest, abdomen or pelvis) with systolic blood pressure (SBP) of 90 mm Hg or lower at time of presentation to the ED or blunt traumatic injury to the torso with SBP of 90 mm Hg or lower. Exclusion criteria included patients younger than 15 years, transferred from an outside facility, penetrating gunshot wound to the head, extremity vascular injuries, had CPR performed prior to or upon arrival, received resuscitative thoracotomy in ED, had time to the OR longer than 12 hours, or with missing outcome data. This study was conducted following approval from the appropriate institutional review board at each collaborating center.

Study Variables

Data collected included patient demographics, Injury Severity Scores, injury location (chest, abdomen, pelvis), prehospital time, length of stay in the ED, admission vital signs, resuscitation therapy required in first 24 hours, admission laboratory workup, ED interventions, imaging studies, intraoperative injury findings, OR preparation time, time to wound vacuum-assisted closure placement or wound closure, in hospital mortality, and hospital length of stay. Prehospital time was defined as the total time from activation of EMS to ED arrival in minutes. Length of stay in the ED was defined as the time in minutes from ED presentation to OR arrival. Operating room preparation time was defined as time in minutes from arrival in OR to time of skin incision. Time to hemorrhage control was defined as time from ED presentation to wound vacuum-assisted closure placement or time to wound closure. Hypotension was defined as an initial ED SBP ≤ 90 mm Hg. The ED interventions examined included endotracheal intubation, chest tube thoracostomy, pelvic stabilization, tourniquet placement, resuscitative balloon occlusion of the aorta (REBOA), and resuscitation (Supplemental Digital Content, http://links.lww.com/TA/C307).

Components of damage-control resuscitation (DCR) were examined for incidence of compliance.[7] The components examined included use of prehospital blood, balanced massive transfusion protocol (MTP), use of tranexamic acid (TXA), use of thromboelastography, and use of REBOA. Balanced MTP was defined as a 1:1 to 1:2 plasma to PRBC ratio. The primary outcome of interest was all cause in-hospital mortality and time to surgery.

Statistical Analysis

Analysis was conducted using SPSS v27 (IBM; Armonk, NY). Values were reported as number, frequency, ranges, mean, standard deviation, median, and interquartile ranges (IQRs) where appropriate. χ^2 Analysis, Fisher exact test, Student *t* test, and the Mann-Whitney *U* test were used to compare groups where appropriate. Survival analysis was performed using multivariable Cox regression to assess the impact of time to surgery on mortality. These results were reported as adjusted hazard ratios along with corresponding 95% confidence intervals. The level of significance was set at $p < 0.05$.

RESULTS

A total of 264 patients with SBP of 90 mm Hg or lower were entered into the database by the end of the study period. Of these, 22 (8.3%) were excluded due to missing outcome data (Fig. 1). Overall mortality was 19.8% (n = 48), with no difference in mortality rates between blunt and penetrating cohorts (19.0% vs. 21.3%, respectively; $p = 0.65$). Most of the deaths (n = 27, 56.3%) occurred within the first 24 hours of arrival with 20 (41.7%) mortality during the early phase of resuscitation (Table 1). There was no difference between surviving and deceased patients regarding incidence of chest injury, abdomen injury, or pelvic injury; however, nonsurvivors were significantly more likely to present with vascular injury ($p = 0.02$). Half of the cohort had injury to a single region (n = 122, 50.4%). Patients who died were significantly older than those that survived ($p = 0.02$), had higher mean New Injury Severity Score (NISS) ($p < 0.001$), lower ED SBP ($p < 0.01$), and had higher ED shock index ($p = 0.03$). The deceased cohort was more coagulopathic upon presentation as evidenced by significantly higher mean initial laboratory values for prothrombin time, partial thromboplastin time, and international normalized ratio ($p < 0.01$ for all).

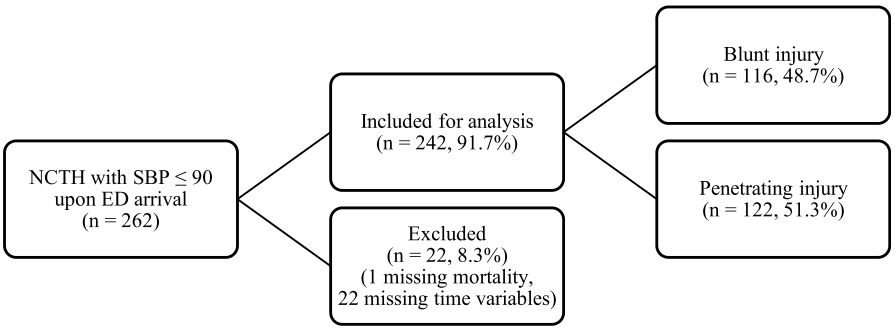

Figure 1. Flowchart of patient inclusion.

TABLE 1. Demographic, Prehospital, and Clinical Presentation of Study Population

Parameters	Total (N = 242)	Survivors (n = 194, 80.1%)	Nonsurvivors (n = 48, 19.8%)	*P*
Age, y*	40.5 (17.5)	38.8 (15.7)	47.3 (22.6)	0.02
Male, n (%)	181 (74.8)	143 (73.7)	38 (79.2)	0.44
Injury type, n (%)				
Blunt	116 (48.7)	94 (49.5)	22 (45.8)	0.65
Penetrating	122 (51.3)	96 (50.5)	26 (54.2)	
NISS*	31 (15)	29 (14)	38 (18)	<0.001
Chest injury, n (%)	133 (55.0)	102 (52.6)	31 (64.6)	0.13
Chest AIS score*	2.4 (1.7)	2.2 (1.7)	3.0 (1.6)	<0.01
Abdomen injury, n (%)	179 (74.0)	144 (74.2)	35 (72.9)	0.85
Abdomen AIS score*	2.9 (1.7)	2.8 (1.6)	3.1 (1.9)	0.32
Pelvis injury, n (%)	55 (22.7)	43 (22.2)	12 (25.0)	0.68
Pelvis AIS score*	1 (1.5)	0.9 (1.4)	1.1 (1.8)	0.28
Vascular injury, n (%)	61 (25.2)	41 (21.1)	20 (41.7)	0.02
PH PRBC, n (%)	20 (24.4)	14 (22.6)	6 (30.0)	0.50
PH plasma, n (%)	7 (8.5)	4 (6.5)	3 (15.0)	0.23
PH crystalloids, n (%)	87 (36.0)	64 (33.0)	23 (47.9)	0.05
Clinical presentation				
Admit vitals*				
Heart rate	109 (28)	110 (25)	105 (37)	0.39
SBP	77 (16)	79 (12)	68 (24)	<0.01
Shock Index	1.4 (0.5)	1.4 (0.5)	1.6 (0.5)	0.03
Respiratory rate	22 (9)	22 (9)	21 (12)	0.67
Glasgow Coma Scale scores	11 (5)	12 (4)	9 (5)	<0.001
TBI, n (%)	26 (11.0)	21 (11.2)	5 (10.4)	0.88
Admission laboratory values*				
Hemoglobin	11.7 (2.1)	11.9 (2.0)	10.9 (2.4)	<0.01
Hematocrit	35.9 (6.0)	36.4 (5.5)	33.5 (7.3)	0.02
Platelet count	217.6 (99.3)	230.8 (97.4)	156.8 (85.4)	<0.001
Lactate	6.4 (4.3)	6.2 (4.3)	7.2 (4.4)	0.28
Fibrinogen	24.2 (95.5)	239.9 (90.9)	209.8 (112.9)	0.22
PT	15.5 (5.1)	14.6 (2.7)	19.5 (9.5)	<0.01
PTT	34.2 (25.2)	30.6 (19.4)	51.6 (39.5)	<0.01
INR	1.3 (0.5)	1.2 (0.2)	1.8 (1.1)	<0.01
pH	7.21 (0.22)	7.23 (0.23)	7.10 (0.18)	<0.001
Base deficit	−1.5 (9.9)	−0.9 (8.9)	−3.8 (13.3)	0.25
ED procedures, n (%)				
Intubation	92 (38.8)	61 (32.3)	31 (64.6)	<0.001
Chest tube	84 (35.4)	59 (31.2)	25 (52.1)	<0.01
Pelvic stabilization	16 (6.8)	12 (6.3)	4 (8.3)	0.63
REBOA	9 (3.8)	7 (3.7)	2 (4.2)	0.88
TXA given	18 (7.4)	14 (7.2)	4 (8.3)	0.54
PRBC, units*	2.3 (2.2)	2.2 (2.3)	2.6 (1.9)	0.33
Plasma*	1.3 (2.0)	1.3 (1.9)	1.3 (2.0)	0.97
Platelets, units*	0.3 (0.7)	0.3 (0.7)	0.2 (0.7)	0.58
Crystalloids, mL*	725 (903)	720 (851)	743 (1100)	0.89

Continuous values are denoted by * and reported as mean (SD). All categorical values are frequencies reported as n (%).
AIS, Abbreviated Injury Scale; PH, prehospital; TBI, traumatic brain injury; PT, prothrombin time; PTT, partial thromboplastin time; INR, international normalized ratio.

ED Interventions

There was no difference in frequency of ED resuscitation (83.5% survivors vs. 89.6% nonsurvivors, $p = 0.54$), and mean number of blood products utilized in ED were similar between survivors and nonsurvivors. Nonsurvivors were more likely to undergo endotracheal intubation and chest tube thoracostomy in the ED compared with survivors ($p < 0.01$ for both). Subgroup analysis by injury type revealed similar findings.

Preoperative Imaging and Operative Characteristics

Preoperative imaging studies and operative descriptors are detailed in Table 2. There was no difference between cohorts in

TABLE 2. Preoperative Imaging Studies and Operative Descriptors of Study Cohort

Imaging Studies Prior to OR	Total (N = 242)	Survivors (n = 194, 80.1%)	Nonsurvivors (n = 48, 19.8%)	*P*
Imaging studies done	218 (92.0)	176 (93.1)	42 (87.5)	0.20
Chest x-ray	181 (74.8)	148 (76.3)	33 (68.8)	0.28
Pelvis x-ray	101 (41.7)	80 (41.2)	21 (43.8)	0.75
Head CT	51 (21.1)	46 (23.7)	5 (10.4)	0.04
Chest CT	83 (34.3)	78 (40.2)	5 (10.4)	<0.001
Abdomen/pelvis CT	90 (37.2)	83 (42.8)	7 (14.6)	<0.001
FAST	147 (60.7)	119 (61.3)	28 (58.3)	0.70
Positive FAST	101 (68.7)	80 (67.2)	21 (75.0)	0.43
OR variables				
Type of OR				
Hybrid	29 (12.2)	25 (13.2)	4 (8.3)	0.36
Regular	208 (87.8)	164 (86.8)	44 (91.7)	
Fluid resuscitation	227 (95.8)	180 (95.2)	47 (97.9)	0.41
PRBC, units*	4.9 (12.3)	4.9 (6.2)	12.3 (12.5)	<0.001
Plasma, units*	4.2 (9.5)	4.2 (6.4)	9.5 (10.0)	<0.001
Platelets, packs*	0.9 (2.1)	0.9 (1.5)	2.1 (2.8)	<0.01
Crystalloids, mL*	2221 (2125)	2222 (1825)	2125 (2068)	0.76
TXA given	37 (15.3)	25 (12.9)	12 (25.0)	0.04
Highest HR reading*	121 (23)	118 (21)	133 (26)	<0.001
Lowest SBP*	79 (26)	83 (22)	61 (31)	<0.001
Lowest end tidal volume*	227 (196)	238 (196)	187 (194)	0.21
Damage-control thoracotomy	51 (21.5)	32 (16.9)	19 (39.6)	<0.01
Damage-control laparotomy	153 (64.6)	120 (63.5)	33 (68.8)	0.50

All values are frequencies reported as n (%) unless denoted by * which indicates mean (SD).
CT, computed tomography; PRBC, packed red blood cells; HR, heart rate.

frequency of chest or pelvis x-ray imaging studies performed prior to arriving in an OR. However, significantly more survivors underwent computed tomography studies of the head, chest, and/or abdomen and pelvis prior to the OR.

An examination of intraoperative variables showed no difference in frequency of resuscitation; however, survivors received significantly less blood products than did nonsurvivors ($p < 0.01$). Frequency of intraoperative TXA utilization was higher in the nonsurviving group than in survivors (25.0% vs. 12.9%, respectively; $p = 0.04$). Highest heart rate and lowest SBP during surgery were then examined. The deceased group had significantly higher peak heart rates (133 vs. 118 beats per minute, $p < 0.001$) and lower lowest SBP (61 mm Hg vs. 83; $p < 0.001$) compared with the surviving cohort. Significantly more patients in the deceased group underwent damage-control thoracotomy (39.6% vs. 16.9%, $p < 0.01$), but there was no difference between the groups in rates of damage-control laparotomy.

Phases of Care Timeline Analysis

Time variables for each portion of patient care are detailed in Figure 2.

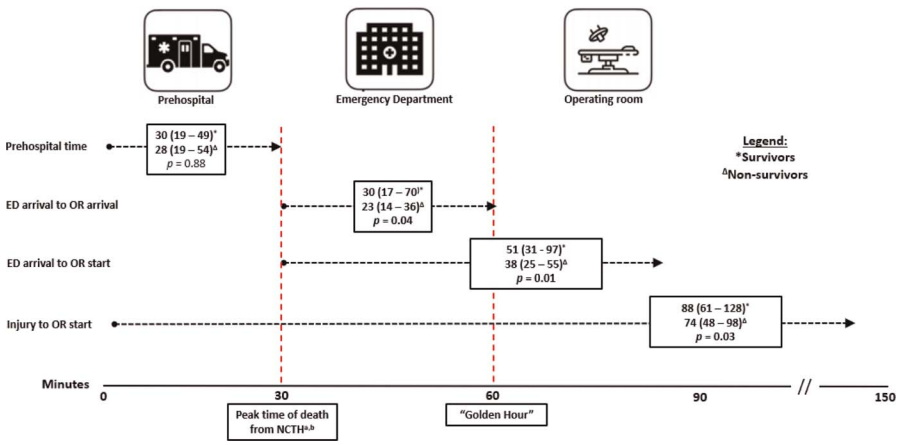

Figure 2. Time variables (in minutes) for phases of care in hypotensive, NCTH patients.

TABLE 3. Cox Regression Analysis of Factors Associated With Mortality

Parameters	Hazard Ratio	95% CI	*P* Value
Age, y	1.03	1.01–1.05	<0.01
New Injury Severity Score	1.02	1.01–1.04	0.02
Initial shock index	1.15	1.07–1.24	<0.001
Chest injury	1.23	0.59–2.56	0.59
Vascular injury	2.00	0.98–4.20	0.06
Prehospital time, min	0.99	0.98–1.01	0.48
ED arrival to surgery start, min	0.98	0.97–0.99	0.04

95% CI, 95% confidence interval.

There was no difference between survivors and nonsurvivors regarding median (IQR) prehospital time 30 minutes (19–51 minutes). However, both median (IQR) ED time (27 minutes [16–63 minutes]) and median (IQR) time from ED to OR start (48 minutes [30–85 minutes]) were significantly shorter in the nonsurviving group ($p \leq 0.04$ for both). There was no difference in median (IQR) OR preparation time between groups (15 [10–22] survivors vs. 13 [8–19] nonsurvivors; $p = 0.09$). When analyzing the continuum of care from time of injury to OR start (84 [58–117 minutes]), the deceased group had significantly shorter time ($p = 0.03$).

Predictors of Mortality

Multivariable Cox regression controlled for known predictors of mortality and examined impact of time to OR start on survival (Table 3). Confounders of age, NISS, and initial ED shock index were all significantly associated with mortality, while chest and vascular injury were not. Shorter time from ED arrival to surgery start was a predictor of mortality ($p = 0.04$).

Use of DCR Components

Frequency of use of DCR components was examined in survivors and nonsurvivors (Table 4). Prehospital blood was administered to 20 (8.3%) patients total with no difference between survivors and nonsurvivors ($p = 0.23$). Prehospital plasma use was of low frequency (n = 7, 2.9%). A total of 55 (24.2%) patients received TXA in either the ED or intraoperatively and did not differ between cohorts. A total of 225 patients had data for intraoperative blood product use recorded. Of these, 44 (19.6%) received crystalloid only and no blood products, 24 (10.7%) received either 1 or 2 units of only PRBC or plasma (not both). The remaining 157 (69.8%) received both PRBC and plasma products. Within that subgroup, balanced ratio component therapy for resuscitation was used in 87.9% and did not differ between groups.

DISCUSSION

Time is a critical and irrecoverable factor in severe hemorrhage. The long-entrenched dogma of the golden hour has long maintained that critically injured patients who reach definitive care within an hour of injury have better outcomes than those who arrive outside of that first hour.[8] Here, we question this dogma and demonstrate that, in patients with NCTH who present with severe hypotension, expedited time to damage-control surgery is not sufficient to reverse deranged physiology that is too far gone. Nonsurvivors arrived in greater physiological distress, which prompted significantly faster time to operative intervention, compared with survivors, and yet still suffered worse outcomes. In addition, compliance was low with many aspects of DCR with only a small fraction used in the patient population. This suggests that there is room for improvement in our current trauma system to adequately mitigate potentially preventable deaths due to hemorrhage.

The foundation of the current trauma system emphasizes rapid transport of the injured patient and early intervention to control hemorrhage. This is of paramount importance in NCTH, where the peak time to death has been demonstrated to be within 30 minutes of severe truncal injury.[9,10] Median prehospital times reported here (30 minutes overall, 38 minutes for blunt, and 23 minutes for penetrating) were align closely to those of a recent National Trauma Data Bank (NTDB) analysis of more than 2.5 million NCTH patients. This highlights that patients are arriving near or after the peak time to mortality for this injury cohort. Importantly, there was no difference in prehospital time between survivors and nonsurvivors in the present study, but there was a significant difference in physiology upon arrival. Nonsurvivors arrived in a higher degree of shock, were more coagulopathic, and required significantly more blood intraoperatively. This indicates that the volume loss and associated physiological deterioration that occurred in nonsurvivors were largely insurmountable

TABLE 4. Frequency of DCR Component Use

DCR Component	Total (N = 242)	Survivors (n = 194)	Nonsurvivors (n = 48)	*P*
Volume replacement			n = 48	
PH PRBC	20 (8.3)	14 (7.2)	22 (12.5)	0.23
PH plasma	7 (2.9)	4 (2.1)	3 (6.3)	0.12
Balanced ratio resuscitation in OR	138/157 (87.9)	102/116 (87.9)	36/41 (87.8)	0.88
TEG	70 (28.9)	59 (30.4)	11 (22.9)	0.24
Volume retention				
REBOA	9 (3.8)	7 (3.7)	2 (4.2)	0.88
ED or intraoperative TXA	55 (24.2)	39 (21.7)	16 (34.0)	0.08

Note: 157 patients (116 survivors and 41 nonsurvivors) received both PRBC and plasma intraoperatively, so those samples sizes were used as the denominator in assessment of balanced resuscitation in the OR.
TEG, thromboelastography

by the time these patients arrived at an ED, and suggests that "scoop and run" should be modified to a "scoop and control" approach.

Further, our findings of an overall mortality rate of 19.8%, with a median time spent in the ED of 27 minutes, and median ED arrival to surgical start of 47.5 minutes are nearly identical to those in a similar patient population from admit years 2012 to 2013.[11] The similarity in mortality rates over a decade underscores the known stagnation of mortality rates in this population, while the similar time frames of care phases suggest that reduced ED times and times to OR start have plateaued. However, it may not be feasible in many centers to make further reductions in in-hospital processes to expedite time to the OR. If in-hospital processes are nearly as efficient as they can be within the current system and if the peak time of death is occurring within the median time from injury to ED arrival, then the opportunity for meaningful change must lie outside of the hospital. Resuscitative and hemorrhage control adjuncts should be brought closer to the point of injury while maintaining rapid transport.[9,10,12,13]

The military has recognized NCTH as a leading cause of potentially preventable deaths and has responded by implementing advanced resuscitative care (ARC) on the battlefield, which includes whole blood resuscitation and REBOA.[14] Military experience has demonstrated that resuscitation with blood products improves outcomes, especially when started early in the prehospital phase.[15,16] During the military conflicts in Afghanistan and Iraq in the early 2000s, use of whole blood resurfaced and has since become the cornerstone of battlefield resuscitation.[17] A review of more than 6000 units of warm fresh whole blood transfused by the military to patients with severe hemorrhage who required massive transfusion revealed decreased 48-hour and 30-day mortalities.[18]

These interventions are not current practice in the prehospital phase of civilian trauma care in the United States; however, as military successes in trauma care often cross into civilian care, use of whole blood or modified (leukoreduced) whole blood is experiencing renewed interest.[19–23] Prehospital administration of plasma, packed red blood cells, and whole blood have each been examined to varying degrees in the civilian sector and have been associated with survival benefit.[23–25] However, implementation in many areas has been slow, and the practices have yet to become widely adopted. Of the 15 large, urban trauma centers included in this study, only six recorded use of prehospital PRBC in a total of 20 patients and a lone center reported use of prehospital plasma in seven patients. Similarly, REBOA remains vastly underutilized by trauma surgeons in many trauma centers, perhaps due to mixed results regarding survival benefit or the lack of clear guidelines or consensus.[26–31] Here, REBOA was used in only 9 (3.7%) patients.

Numerous previous studies have examined potentially preventable prehospital and early in-hospital deaths in attempts to determine who might benefit from advanced resuscitative techniques.[32] A retrospective cohort study reviewed 198 autopsy reports for NCTH patients who presented to a large Level I trauma center with cardiac arrest and found that more than 10% could have benefitted from prehospital REBOA.[33] Another recent retrospective review of 316 prehospital and early in-hospital deaths identified 12% as potentially preventable and that might have been amenable to ARC interventions.[13] Kalkwarf et al.[34] examined more than 1800 trauma deaths categorized as preventable or potentially preventable and concluded that 34.5% of deaths were potentially preventable. To realize this potential benefit and to reduce what have become stagnant mortality rates in this patient population despite numerous in-hospital advancements, evidence-based improvements in prehospital care driven by the military must find their way into the civilian arena.[12,21]

Lastly, trauma care has long emphasized the ABCs—sequential priorities of Airway, Breathing, and Circulation—as standard of care in treatment of the critically injured patient. However, the order of this sequence has recently been called into question, particularly for patients who are in hypovolemic shock with ventilation perfusion mismatch.[35,36] Ferrada et al.[36] demonstrated via a multicenter review that reordering of the sequence to CAB—resuscitation with blood product first followed by endotracheal intubation—in patients with presumptive hypovolemic shock was not associated with increased mortality. Numerous studies have demonstrated that prioritizing perfusion over airway improves outcomes in nontrauma patients, and reduced time to initiation of in-hospital MTP is known to yield better clinical outcomes in hypotensive patients.[37–42] Importantly, intravenous and intraosseous access have been shown to not increase EMS scene times.[35] Therefore, extension of the CAB model into prehospital ARC may improve survival and warrants further investigation.

Operationalizing ARC into civilian care will be rich with challenges, many of which have been previously discussed.[9,13,32] For example, execution of REBOA requires arterial access, which is outside of the scope of practice of paramedics and could potentially require an overhaul of the current prehospital system by dispatching physicians to the scene of injury. In addition, it is important in a discussion of prehospital procedures to remember that there is no one-size-fits-all approach, but rather the solutions must be tailored appropriately, depending on factors, such as injury type, proximity to the nearest trauma center, and availability of resources.[35] For example, there is a significant and growing body of evidence demonstrating the harm that can result from prehospital procedures in cases of penetrating torso trauma in urban locations.[43–46] Conversely, major limb trauma from both blunt and penetrating mechanisms has been shown to benefit from prehospital tourniquet application, even in rural locations.[47–49] Importantly, these interventions should not delay scene or transport times and should be applied to the appropriate patient subset.

Study Limitations

There are several study limitations that require mention. First, prehospital times reported here represent time from EMS dispatch to ED arrival and do not account for the time elapsed between injury and call to emergency services, and thus, likely are an underestimation of true time from injury to presentation. This further emphasizes that the opportunity for lifesaving intervention has often passed before a patient reaches definitive care. Second, prehospital procedures outside of fluid resuscitation were not captured. Therefore, any potential effect(s) of volume preserving measures such as pressure dressings and tourniquets cannot be known in the present dataset. Third, there may be a subset of patients who were initially hypotensive who hemodynamically improved in response to resuscitation. However, only initial ED vitals were captured so this potential subset of patients cannot be examined in the present dataset. Further, longer time to surgery may reflect a survivor bias whereby more physiologically

stable patients undergo urgent, but not emergent surgery. However, there were no differences observed in Injury Severity Score, admit shock index, or admit Glasgow Coma Scale between those who reached surgical intervention within or beyond 60 minutes of ED arrival. Low overall use of many components of DCR across institutions may have potentially contributed to some deaths, but there was no difference in frequency between survivors and nonsurvivors so is likely not a primary explanatory factor. Finally, there may be additional confounders that are unaccounted for in this study, which may have influenced outcomes.

Conclusion

In conclusion, many patients with NCTH die before they can realistically reach an ED or operating suite and long before the fabled "Golden Hour." This suggests that the current US trauma system is not sufficient to reduce mortality from NCTH. Faster is better for this critically injured population, and hemorrhage control and blood product resuscitation should be moved closer to the point of injury as part of ARC while maintaining rapid transport if potentially preventable deaths are to be prevented.

AUTHORSHIP

J.D., D.T., J.S., T.C. participated in the study conception and design. K.S., I.P., J.D.B., B.Y., J.M., J.S., M.T., T.C., A.E.B., T.K., G.R., S.N., K.M., G.C., B.M.L., T.J., L.V.S., J.P., Z.M., A.J.G., R.M.M., G.P., M.J.L., J.H., G.M., M.C., D.T. participated in the acquisition of data. J.D., D.T., A.E.B. participated in the analysis and interpretation of article. D.T., J.D. participated in the drafting of article. J.D., D.T., A.E.B. participated in the critical review/revision.

ACKNOWLEDGMENTS

The following deserve recognition and acknowledgment for their contributions to this collaborative effort:
Yohan Diaz Zuniga, CCRC—University of Florida-Jacksonville, Jacksonville, Florida; Dalier Rodriguez-Mederos, MD, CCRP—Broward Health Medical Center, Fort Lauderdale, Florida; Terry Curry, RN—UC San Diego Medical Center, San Diego, California; Andrew Bernard, MD—University of Kentucky Chandler Medical Center, Lexington, Kentucky; Gerald Wang, DO—Mount Sinai Hospital, Chicago, Illinois; Jennifer Pekarek, BSN, RN, CCRP, TCRN—St. Anthony Hospital, Lakewood, Colorado; Hillary Lippke, BSN, RN—St. Anthony Hospital, Lakewood, Colorado; Kathy Rodkey—Medical Center Plano, Plano, Texas.

DISCLOSURE

The authors declare no conflicts of interest.

REFERENCES

1. Stannard A, Morrison JJ, Scott DJ, Ivatury RA, Ross JD, Rasmussen TE. The epidemiology of noncompressible torso hemorrhage in the wars in Iraq and Afghanistan. *J Trauma Acute Care Surg*. 2013;74(3):830–834.
2. Morrison JJ, Stannard A, Rasmussen TE, Jansen JO, Tai NR, Midwinter MJ. Injury pattern and mortality of noncompressible torso hemorrhage in UK combat casualties. *J Trauma Acute Care Surg*. 2013;75(2 Suppl 2):S263–S268.
3. Morrison JJ. Noncompressible torso hemorrhage. *Crit Care Clin*. 2017; 33(1):37–54.
4. Asensio JA, Arroyo H Jr., Veloz W, Forno W, Gambaro E, Roldan GA, Murray J, Velmahos G, Demetriades D. Penetrating thoracoabdominal injuries: ongoing dilemma—which cavity and when? *World J Surg*. 2002; 26(5):539–543.
5. 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.
6. Meizoso JP, Ray JJ, Karcutskie CA 4th, Allen CJ, Zakrison TL, Pust GD, Koru-Sengul T, Ginzburg E, Pizano LR, Schulman CI, 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.
7. Cannon JW, Khan MA, Raja AS, Cohen M, Como JJ, Cotton BA, Dubose JJ, Fox EE, Inaba K, Rodriguez CJ, et al. Damage control resuscitation in patients with severe traumatic hemorrhage: a practice management guideline from the eastern Association for the Surgery of trauma. *J Trauma Acute Care Surg*. 2017;82(3):605–617.
8. Lerner EB, Moscati RM. The golden hour: scientific fact or medical "urban legend"? *Acad Emerg Med*. 2001;8(7):758–760.
9. Holcomb JB. Transport time and preoperating room hemostatic interventions are important: improving outcomes after severe truncal injury. *Crit Care Med*. 2018;46(3):447–453.
10. Alarhayem AQ, Myers JG, Dent D, Liao L, Muir M, Mueller D, Nicholson S, Cestero R, Johnson MC, Stewart R, 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.
11. Harvin JA, Maxim T, Inaba K, Martinez-Aguilar MA, King DR, Choudhry AJ, Zielinksi MD, Akinyeye S, Todd SR, Griffin RL, et al. Mortality after emergent trauma laparotomy: a multicenter, retrospective study. *J Trauma Acute Care Surg*. 2017;83(3):464–468.
12. Duchesne J, Taghavi S, Houghton A, Khan M, Perreira B, Cotton B, Tatum D, Brenner M, Ferrada P, Hörer T, et al. Prehospital mortality due to hemorrhagic shock remains high and unchanged: a summary of current civilian EMS practices and new military changes. *Shock*. 2020.epub ahead of print. doi:10.1097/SHK.0000000000001522.
13. Carroll SL, Dye DW, Smedley WA, Stephens SW, Reiff DA, Kerby JD, Holcomb JB, Jansen JO. Early and prehospital trauma deaths: who might benefit from advanced resuscitative care? *J Trauma Acute Care Surg*. 2020;88(6):776–782.
14. Butler FK Jr., Holcomb JB, Shackelford S, Barbabella S, Bailey JA, Baker JB, Cap AP, Conklin CC, Cunningham CW, Davis M, et al. Advanced resuscitative care in Tactical Combat Casualty Care: TCCC guidelines change 18-01:14 October 2018. *J Spec Oper Med*. 2018;18(4):37–55.
15. Shackelford SA, Del Junco DJ, Powell-Dunford N, Mazuchowski EL, Howard JT, Kotwal RS, Gurney J, Butler FK Jr., Gross K, Stockinger ZT. Association of prehospital blood product transfusion during medical evacuation of combat casualties in Afghanistan with acute and 30-day survival. *JAMA*. 2017;318(16):1581–1591.
16. O'Reilly DJ, Morrison JJ, Jansen JO, Apodaca AN, Rasmussen TE, Midwinter MJ. Prehospital blood transfusion in the en route management of severe combat trauma: a matched cohort study. *J Trauma Acute Care Surg*. 2014;77(3 Suppl 2):S114–S120.
17. Pivalizza EG, Stephens CT, Sridhar S, Gumbert SD, Rossmann S, Bertholf MF, Bai Y, Cotton BA. Whole blood for resuscitation in adult civilian trauma in 2017: a narrative review. *Anesth Analg*. 2018;127(1):157–162.
18. Spinella PC. Warm fresh whole blood transfusion for severe hemorrhage: U.S. Military and potential civilian applications. *Crit Care Med*. 2008;36-(Suppl 7):S340–S345.
19. Cotton BA, Podbielski J, Camp E, Welch T, del Junco D, Bai Y, Hobbs R, Scroggins J, Hartwell B, Kozar R, et al. A randomized controlled pilot trial of modified whole blood versus component therapy in severely injured patients requiring large volume transfusions. *Ann Surg*. 2013;258(4):527–532.
20. Hanna K, Bible L, Chehab M, Asmar S, Douglas M, Ditillo M, Castanon L, Tang A, Joseph B. Nationwide analysis of whole blood hemostatic resuscitation in civilian trauma. *J Trauma Acute Care Surg*. 2020;89(2):329–335.
21. Duchesne J, Taghavi S, Ninokawa S, Harris C, Schroll R, McGrew P, McGinness C, Reily R, Guidry C, Tatum D. After 800 MTP Events, mortality due to hemorrhagic shock remains high and unchanged despite several In-Hospital Hemorrhage Control Advancements. *Shock*. 2021;56(1S):70–78. epub ahead of print.
22. Naumann DN, Boulton AJ, Sandhu A, Campbell K, Charlton W, Gurney JM, Martin MJ, Scorer T, Doughty H. Fresh whole blood from walking blood banks for patients with traumatic hemorrhagic shock: a systematic review and meta-analysis. *J Trauma Acute Care Surg*. 2020;89(4):792–800.
23. Williams J, Merutka N, Meyer D, Bai Y, Prater S, Cabrera R, Holcomb JB, Wade CE, Love JD, Cotton BA. Safety profile and impact of low-titer group O whole blood for emergency use in trauma. *J Trauma Acute Care Surg*. 2020;88(1):87–93.
24. Sperry JL, Guyette FX, Brown JB, Yazer MH, Triulzi DJ, Early-Young BJ, Adams PW, Daley BJ, Miller RS, Harbrecht BG, et al. Prehospital plasma during air medical transport in trauma patients at risk for hemorrhagic shock. *N Engl J Med*. 2018;379(4):315–326.

25. Moore HB, Moore EE, Chapman MP, McVaney K, Bryskiewicz G, Blechar R, Chin T, Burley CC, Pieracci F, West FB, et al. Plasma-first resuscitation to treat haemorrhagic shock during emergency ground transportation in an urban area: a randomised trial. *Lancet*. 2018;392(10144): 283–291.
26. Bekdache O, Paradis T, Shen YBH, Elbahrawy A, Grushka J, Deckelbaum D, Khwaja K, Fata P, Razek T, Beckett A. Resuscitative endovascular balloon occlusion of the aorta (REBOA): indications: advantages and challenges of implementation in traumatic non-compressible torso hemorrhage. *Trauma Surg Acute Care Open*. 2019;4(1):e000262.
27. Joseph B, Zeeshan M, Sakran JV, Hamidi M, Kulvatunyou N, Khan M, O'Keeffe T, Rhee P. Nationwide analysis of resuscitative endovascular balloon occlusion of the aorta in civilian trauma. *JAMA Surg*. 2019;154(6): 500–508.
28. Brenner M, Inaba K, Aiolfi A, DuBose J, Fabian T, Bee T, Holcomb JB, Moore L, Skarupa D, Scalea T, et al. Resuscitative endovascular balloon occlusion of the aorta and resuscitative thoracotomy in select patients with hemorrhagic shock: early results from the American Association for the Surgery of Trauma's aortic occlusion in resuscitation for trauma and acute care surgery registry. *J Am Coll Surg*. 2018;226(5):730–740.
29. Harfouche M, Inaba K, Cannon J, Seamon M, Moore E, Scalea T, DuBose J. Patterns and outcomes of zone 3 REBOA use in the management of severe pelvic fractures: results from the AAST aortic occlusion for resuscitation in trauma and acute care surgery database. *J Trauma Acute Care Surg*. 2021; 90(4):659–665.
30. Duchesne J, Costantini TW, Khan M, Taub E, Rhee P, Morse B, Namias N, Schwarz Z, Graves J, Kim DY, et al. The effect of hemorrhage control adjuncts on outcome in severe pelvic fracture: a multi-institutional study. *J Trauma Acute Care Surg*. 2019;87(1):117–124.
31. Jarvis S, Kelly M, Mains C, Corrigan C, Patel N, Carrick M, Lieser M, Banton K, Bar-Or D. A descriptive survey on the use of resuscitative endovascular balloon occlusion of the aorta (REBOA) for pelvic fractures at US level I trauma centers. *Patient Saf Surg*. 2019;13:43.
32. Qasim Z, Butler FK, Holcomb JB, Kotora J, Eastridge B, Brohi K, Scalea T, Schwab CW, Drew B, Gurney J, et al. Selective prehospital advanced resuscitative care—developing a strategy to prevent prehospital deaths from noncompressible torso hemorrhage. *Shock*. 2022;57(1):7–14. epub ahead of print.
33. Henry R, Matsushima K, Henry RN, Wong V, Warriner Z, Strumwasser A, Foran CP, Inaba K, Rasmussen TE, Demetriades D. Who would have benefited from the prehospital use of resuscitative endovascular balloon occlusion of the aorta (REBOA)? An autopsy study. *J Am Coll Surg*. 2019; 229(4):383–388.e1.
34. Kalkwarf KJ, Drake SA, Yang Y, Thetford C, Myers L, Brock M, Wolf DA, Persse D, Wade CE, Holcomb JB. Bleeding to death in a big city: an analysis of all trauma deaths from hemorrhage in a metropolitan area during 1 year. *J Trauma Acute Care Surg*. 2020;89(4):716–722.
35. Ninokawa S, Friedman J, Tatum D, Smith A, Taghavi S, McGrew P, Duchesne J. Patient contact time and prehospital interventions in hypotensive trauma patients: should we reconsider the "ABC" algorithm when time is of the essence? *Am Surg*. 2020;86(8):937–943.
36. Ferrada P, Callcut RA, Skarupa DJ, Duane TM, Garcia A, Inaba K, Khor D, Anto V, Sperry J, Turay D, et al. Circulation first—the time has come to question the sequencing of care in the ABCs of trauma; an American Association for the Surgery of Trauma multicenter trial. *World J Emerg Surg*. 2018;13:8.
37. Ong ME, Ng FS, Anushia P, Tham LP, Leong BS, Ong VY, Tiah L, Lim SH, Anantharaman V. Comparison of chest compression only and standard cardiopulmonary resuscitation for out-of-hospital cardiac arrest in Singapore. *Resuscitation*. 2008;78(2):119–126.
38. Zhan L, Yang LJ, Huang Y, He Q, Liu GJ. Continuous chest compression versus interrupted chest compression for cardiopulmonary resuscitation of non-asphyxial out-of-hospital cardiac arrest. *Cochrane Database Syst Rev*. 2017;3(3):CD010134.
39. Hüpfl M, Selig HF, Nagele P. Chest-compression-only versus standard cardiopulmonary resuscitation: a meta-analysis. *Lancet*. 2010;376(9752): 1552–1557.
40. Meyer DE, Vincent LE, Fox EE, O'Keeffe T, Inaba K, Bulger E, Holcomb JB, Cotton BA. Every minute counts: time to delivery of initial massive transfusion cooler and its impact on mortality. *J Trauma Acute Care Surg*. 2017;83(1): 19–24.
41. Beattie G, Cohan CM, Ng VL, Victorino GP. Liquid plasma: a solution to optimizing early and balanced plasma resuscitation in massive transfusion. *J Trauma Acute Care Surg*. 2020;89(3):488–495.
42. Radwan ZA, Bai Y, Matijevic N, del Junco DJ, McCarthy JJ, Wade CE, Holcomb JB, Cotton BA. An emergency department thawed plasma protocol for severely injured patients. *JAMA Surg*. 2013;148(2):170–175.
43. Taghavi S, Maher Z, Goldberg AJ, Chang G, Mendiola M, Anderson C, Ninokawa S, Tatebe LC, Maluso P, et al. An Eastern Association for the Surgery of Trauma multicenter trial examining prehospital procedures in penetrating trauma patients. *J Trauma Acute Care Surg*. 2021;91(1): 130–140.
44. Winter E, Hynes AM, Shultz K, Holena DN, Malhotra NR, Cannon JW. Association of Police Transport with Survival among Patients with Penetrating Trauma in Philadelphia, Pennsylvania. *JAMA Netw Open*. 2021; 4(1):e2034868.
45. Seamon MJ, Doane SM, Gaughan JP, Kulp H, D'Andrea AP, Pathak AS, Santora TA, Goldberg AJ, Wydro GC. Prehospital interventions for penetrating trauma victims: a prospective comparison between advanced life support and basic life support. *Injury*. 2013;44(5):634–638.
46. Haut ER, Kalish BT, Efron DT, Haider AH, Stevens KA, Kieninger AN, Cornwell EE 3rd, Chang DC. Spine immobilization in penetrating trauma: more harm than good? *J Trauma*. 2010;68(1):115–120.
47. Smith AA, Ochoa JE, Wong S, Beatty S, Elder J, Guidry C, McGrew P, McGinness C, Duchesne J, Schroll R. Prehospital tourniquet use in penetrating extremity trauma: decreased blood transfusions and limb complications. *J Trauma Acute Care Surg*. 2019;86(1):43–51.
48. Scerbo MH, Mumm JP, Gates K, Love JD, Wade CE, Holcomb JB, Cotton BA. Safety and appropriateness of tourniquets in 105 civilians. *Prehosp Emerg Care*. 2016;20(6):712–722.
49. Bedri H, Ayoub H, Engelbart JM, Lilienthal M, Galet C, Skeete DA. Tourniquet application for bleeding control in a rural trauma system: outcomes and implications for prehospital providers. *Prehosp Emerg Care*. 2021;1–9.

DISCUSSION

LAWRENCE LOTTENBERG, M.D. (Jupiter, Florida): Good morning. Thank you so much for the honor and the opportunity of the podium to discuss this highly-poignant study from our own multicenter group here at the AAST.

This is a study authored by Dr. Duchesne and a whole host of other investigators, many of whom I have had the pleasure of knowing, mentoring, and working with over the years. They bring a wealth of knowledge.

Trauma care has evolved so much over my 40-year career, we've seen so many improvements in prehospital and in-hospital care. We've learned so much from our violent crime cities, mass shootings and extraordinary military experience.

We are now left with the conundrum of a relatively small group of patients with non-compressible torso hemorrhage.

The study group hypothesized that shorter times to surgical intervention would decrease mortality in hypotensive patients with non-compressible torso hemorrhage, just like you and I would have assumed.

The group was diverse, all over the U.S., all types of patients, both blunt and penetrating, all hypotensive as defined by the group as a systolic of less than 90, all arriving at major trauma centers, all getting timely resuscitative care, all getting to the OR in a timely fashion.

Despite everything all of us know we can throw at these patients in extremis, there was still almost a 20 percent mortality.

Additionally, the sicker patients got to the OR quicker and had hemorrhage control quicker, but still this did not make a difference that we all thought it would. So, even expediating a critically-ill patient through the current system is not enough.

It seems that the group concludes that the difference maker may, in fact, be at the time and place of injury and not specifically in the trauma recess room or in the OR.

So what else can we do in the next 40 years? I have the following questions.

You mentioned TXA but what about other pharmacology? Did you look at PCC use? Did you look at concentrated fibrinogen in the field?

What about point-of-care testing in the field? Would this give you a better idea of what is going on and an earlier diagnosis of trauma-induced coagulopathy?

What percentage of the non-compressible torso patients were intubated in the field? And how did that subgroup compare to the non-intubated patients arriving with a systolic of less than 90?

Did you look at patients who were awake with a systolic of less than 80? A systolic of less than 70?

Did they get circulation airway breathing first or airway breathing circulation first?

Next question, how do you think we can use REBOA in the field in the U.S., outside of the military?

For the subset of gunshot wounds, were you able to use the Shot Spotter technology to give you a head start on the injured patients?

And the follow-up to that was, do you think that law enforcement transportation, scoop-and-run, will make a difference over EMS transportation?

Which of the patients had junctional injuries? And are you considering these junctional injuries also non-compressible torso? And if so, has any technology such as Extat or any of the foams going to play a role in the future?

And what about the use of so-called junctional tourniquets or aortic compression-type tourniquets?

Finally, did any of these patients in this group go to trauma centers that bypasses the trauma resuscitation room and go directly to the operating room? Would this few minutes of change, would this few minutes of care truly make a difference?

This is not the first study that did not fulfill the original hypothesis, nor the first study that yields more questions than answers. But it certainly leaves all of us with a new group of patients to look at for the next frontier.

I thank all of you very much for allowing me the privilege of discussing this paper.

SAMIR M. FAKHRY, M.D. (Nashville, Tennessee): Hi, Juan, congratulations on another great piece of work on a very difficult subject. I have to commend you. It's been great fun following your work.

You made me think and the question that I am trying to answer is, is it actually possible to save these people?

I don't know if you have enough information to look and see what the injuries were exactly and was it reasonable to expect that they could be saved?

I'd be curious to see what you think.

Congratulations, once again, on really great work.

MARC A. de MOYA, M.D. (Milwaukee, Wisconsin): Juan, great to see you.

Wanted to ask you about the power analysis in this particular study because I'm a bit concerned of a Type 2 error here because of the effect size is fairly small, potentially, and so even though you have a good number of patients overall, I'm not sure that it actually was, you know, good enough to actually answer that question in terms of that time issue.

You know, as Dr. Holcomb has brought up in the past, actually, I think that this time point to definitive hemorrhage control and revascularization is a key outcome measure for these trauma patients.

And so that's my first question is regarding the sample size, Number 1, and Type 2 error.

The second question is related to prehospital care. I think that we still, to this day, do too many things in the field that actually hurt our patients, as Dr. Goldberg has pointed out, in work in Philadelphia.

And so I'd like to actually just ask you about that because it seems as though there was a lot of this – catch as catch can – you know, in terms of the prehospital resuscitation strategies and limiting that resuscitation in the field and just getting them to the hospital.

Thank you.

ZACHARY J. COLES, M.D. (Englewood, New Jersey):

It seems that prehospital care and timing is a big aspect of your study so I just wanted to know if you are planning to present this at the EMS conference coming up in the next couple of days.

Thank you.

JUAN C. DUCHESNE, M.D. (New Orleans, Louisiana): I'll do my best, sir. So we're going to start, first of all, thank you, Dr. Lottenberg, for the very good questions.

Regarding tranexamic acid, point-of-care and other pharmacology use, we did not collect that information in the prehospital setting but it is definitely something that we will start collecting since this AAST study is now going to be, hopefully, a new registry through the AAST Multi-Institutional Trials.

Regarding prehospital intubation, that is a very good question and actually we noted that patients that, non-survivors, they had more need of intubation and that put into question the ABC versus the CAB. I think once we gather more patient information we're going to have more clarity on this item.

I am not advocating for REBOA in the field. I am advocating for something that will potentially help in the field without staying and play. So that's something that we need better analysis on what would be the best intervention, if it's going to be foam expanders or any other kind of intervention/REBOA. It's all up for question out there.

Junctional was not collected but we demonstrated in previous analyses that junctional hemorrhaged patient's mortality was very similar to non-compressible torso hemorrhage, being that this is a new field of study.

Regarding the Spot Shooter and the law enforcement, our group demonstrated that law enforcement for penetrating injury and severe hypotension patients can make a difference so that's something that definitely needs more validation prospectively.

Bypass of the emergency department and going directly to the OR, we have data on 29 patients that actually underwent directly to the OR. And it was interesting that out of that 29, 25 patients survived, 4 died.

But, like Dr. de Moya mentioned, there might be a power analysis issue in our numbers and, obviously, through COVID that our numbers actually didn't actually suffer a little bit and that's why we want to keep this as an open analyses, registry, so we can keep collecting data.

Dr. Fakhry, thank you for your questions. Most of these injuries actually in the non-survivors were chest and vascular injuries. And I'm not sure if with new interventions there might be a hope to get them alive to our trauma center but it's something that is open for more studies.

And I already talked about Dr. de Moya's issue with the power analysis and prehospital care.

We are not advocating for stay-and-play. We are advocating for scoop-and-control. And Dr. Coles, thank you so much, we will be looking forward for EMS conference. Thank you.

