

TRAUMA DECREASES MONOCYTE INFLAMMATORY ACTIVITY DESPITE PERIPHERAL EXPANSION

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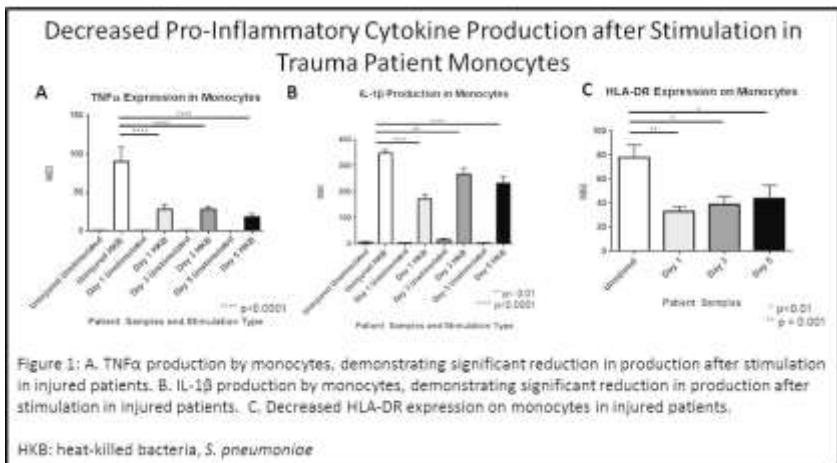
Invited Discussant: Peter Rhee, MD, MPH

Introduction: Trauma induces a complex immune response that requires a systems biology research approach. Here, we use a novel technology, cytometry by time-of-flight mass spectrometry (CyTOF), to characterize the multi-cellular response to severe trauma.

Methods: Peripheral blood mononuclear cells (PBMCs) from trauma patients with injury severity score > 20 (n=10) were collected at day 1, 3, and 5 after injury, as well as from age- and gender-matched controls. Samples were stained with a 38-marker lymphoid-cell phenotyping CyTOF staining panel. Separately, matched cell samples were stimulated with heat-killed *S. pneumoniae* and stained with a 38-marker cytokine CyTOF staining panel.

Results: CyTOF staining profiles showed that monocytes significantly increased as a percentage of total circulating cells and in their expression of the proliferation marker Ki-67. However, when stimulated with bacteria, diminished relative pro-inflammatory cytokine production was seen. Specifically, TNF α and IL-1 β production was significantly less robust in trauma patient monocytes at all time points studied (Figure 1A and 1B). Furthermore, HLA-DR surface expression on monocytes was significantly decreased in trauma samples at all time points (Figure 1C), indicating decreased ability to present antigens for cell-mediated immune function.

Conclusion: These results are part of the first comprehensive evaluation of changes in peripheral blood immune cell populations over time after injury, demonstrating specific trauma-induced cellular phenotypic changes. We found significant changes in trauma patients' monocyte pro-inflammatory cytokine production when stimulated, as well as decreased HLA-DR expression on monocytes. Together, this data shows that while peripheral monocyte populations may expand after injury, these cells show significant loss of pro-inflammatory function that could increase susceptibility to infection after trauma.



THE ALVARADO SCORE SHOULD BE USED TO REDUCE EMERGENCY DEPARTMENT LENGTH OF STAY AND RADIATION EXPOSURE IN SELECT PATIENTS WITH ABDOMINAL PAIN

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Invited Discussant: Elizabeth Benjamin, MD

Introduction: Abdominal pain is one of the most common reasons patients seek treatment in emergency departments (ED), and computed tomography (CT) is frequently used to aid in a diagnosis; however, length of stay in the ED and risks of radiation remain a concern. The hypothesis in this study was that the use of the Alvarado Score (AS) could diagnose and rule out acute appendicitis (AA) in a certain proportion of patients, thereby reducing the overall number of unnecessary CT scans and decreasing emergency department (ED) length of stay.

Methods: A retrospective review of patients who underwent CT to rule out AA from January 1st, 2015, to December 31st, 2015, was performed. Data collected from the electronic medical record included patient demographics, past medical history, ED documentation, operative interventions, complications, and length of stay. The AS was then calculated for each patient from the electronic medical record. Time to CT completion and length of stay in the ED were calculated utilizing the time the patient was seen by ED staff, time of CT order, and time of CT findings reported by radiology.

Results: 492 patients (68.1% female, median age 33) underwent CT to rule out AA during the study period. The majority of CT scans (70%) did not have findings consistent with AA. The median AS for patients diagnosed with AA on CT scan was 7, and was significantly higher than those without (AS=3). 100% of female patients with an AS of 10 and male patients with an AS of 9 or 10 had AA confirmed by surgical pathology. Conversely, $\leq 5\%$ of female patients with an AS ≤ 2 and 0% of male patients with an AS ≤ 1 were diagnosed with AA. There were 106 patients (21.5%) found to have AS within these ranges. Collectively, these 106 patients spent 10,239 minutes in the ED from the time a CT scan was ordered until the radiologist's report.

Conclusion: Males with an AS of ≥ 9 and Females with AS of 10 should be considered candidates for treatment of AA without further studies. Males with AS of 1 or less and females with AS of 2 or less can be safely discharged with close follow-up if symptoms change. Increased time for observation or CT could help aid diagnosis of AA in males with AS of 2-8 and in females with AS of 3-9. By using AS, a significant proportion of patients can avoid the radiation risk, the increased cost, and increased length of stay in the ED associated with CT.

Alvarado Score Calculation	
RLQ tenderness	2 points
Rebound tenderness	1 point
Temp > 37.3° C	1 point
Migration of pain to RLQ	1 point
Nausea or vomiting	1 point
Anorexia	1 point
WBC > 10,000	2 points
WBC left shift	1 point
Total	10 points

“NO ZONE” APPROACH IN PENETRATING NECK TRAUMA REDUCES UNNECESSARY COMPUTED TOMOGRAPHY ANGIOGRAPHY AND NEGATIVE EXPLORATIONS

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Invited Discussant: John Bini, MD

Introduction: Neck zones have been used to guide therapeutic management of penetrating neck trauma (PNT). The most recent management guidelines advocate computed tomography angiography (CTA) for any suspected vascular or aero-digestive injuries in all zones and give zone II injuries special consideration where operative intervention should be considered for symptomatic patients. We hypothesized that physical examination can safely guide CTA use in a “no-zone” approach.

Methods: 8-year retrospective analysis of adult patients with PNT at our Level I trauma center was performed. We included all patients in whom the platysma was violated. Patients were classified into three groups; hard signs, soft signs, and asymptomatic. CTA use and positive CTA (contrast extravasation, dissection, or intimal flap) and missed injuries were reported. Our outcomes were need for operative intervention and therapeutic neck exploration (defined by repair of major vascular or aero-digestive injuries).

Results: A total of 337 patients with PNT met the inclusion criteria of platysma violation. 82 patients had hard signs, 156 had soft signs, and 99 were asymptomatic. The vast majority of patients (80/82) with hard signs went to the OR. In patients with soft signs (n=156), CTA was performed in 84% (131/156); 20% (11/131) had a positive CTA and 0.8 % (1/131) had therapeutic neck exploration. A total of 26% (40/156) patients with soft signs went to the OR for full neck exploration and 35% (14/40) had therapeutic neck exploration. Only 8.4% of patients with soft signs in zone II required therapeutic neck exploration. The rate of therapeutic neck exploration was not significantly different (p=0.59) among the 3 neck zones. In the asymptomatic group (n=99), 80% (79/99) of patients had CTA and none required therapeutic neck exploration. Regardless of the zone of injury, in asymptomatic patients there was no therapeutic neck exploration even with a positive CTA (**Table**). There were higher rates of negative exploration (65%) and unnecessary CTA (80%) in the soft signs and asymptomatic groups, respectively. There were no missed or delayed injuries identified.

Conclusion: Physical examination, not the zone of injury, should be the primary guide to CTA use in patients with penetrating neck trauma. Asymptomatic patients do not require CTA and should be managed with observation regardless of the zone of injury. Zone-based algorithms result in unnecessary negative explorations in patients with soft signs and may need revisions.

Patients without hard signs (soft and asymptomatic)	Variable (n)	Therapeutic neck exploration % (n)
Zone 1 (n=49)	Soft signs (27)	14.8% (4)
	Asymptomatic (22)	0%
	Positive CTA (1/63)*	0%
Zone 2 (n=140)	Soft signs (85)	8.4% (7)
	Asymptomatic (57)	0%
	Positive CTA (9/105)*	0%
Zone 3 (n=55)	Soft signs (36)	8.3% (3)
	Asymptomatic (19)	0%
	Positive CTA (3/51)*	20.0% (1)

* Positive CTA to total CTA

The Cardiovascular Effects of Rapid Sequence Intubation: Reconsidering the A, B, Cs of Trauma Resuscitation

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Invited Discussant: Herbert Phelan, III, MD

Background: Evidence supporting the traditional Airway, Breathing, Circulation (ABC) approach to trauma care is based on expert consensus, with little data to support the order of the factors. Furthermore, this sequence has been challenged in the management of medical cardiac arrest, advocating instead for circulation first. The objective of this study is to retrospectively evaluate the cardiovascular effects of Rapid Sequence Intubation (RSI) while obtaining the airway during the ABC sequence in hypotensive trauma patients.

Methods: Institutional Review Board approval was obtained to retrospectively evaluate the charts of patients that arrived to a level one trauma center, not intubated in route, and with hypotension on arrival defined by systolic blood pressure (SBP) of 90mmHg or less. The study period was January 1 of 2014 to December 31 of 2015. Variables examined included SBP before and after RSI, ISS, blood transfusion timing in relation to RSI and mortality.

Results: During the study period 229 patients were deemed hypotensive upon arrival to our center. Of those 133 were not intubated in the trauma bay, 22 patients arrived with no measurable blood pressure and 8 patients did not have a second SBP measurement immediately after RSI. 66 hypotensive patients underwent intubation and had SBP measured immediately prior and after RSI. The majority of the patients were male (76%), the mechanism of injury was penetrating trauma in 36%. RSI resulted in major cardiovascular effects with 75% of the already hypotensive patients dropping the SBP further (Mean: -18 mmHg, Median: -15 mmHg). Within this group, 35 (53%) were non-survivors (D) and 31 (45%) survived (A). The non-survivors had a significantly higher ISS compared with survivors (D-ISS: Median 30, Mean 33.8 vs A-ISS: Median 17, Mean 22.5, $p < 0.05$). Both groups had a drop in SBP during RSI which was not statistically different, though higher in the non-survivors (D-SBP drop: Mean 21.8 mmHg vs A-SBP drop: Mean 13.1 mmHg, $p = 0.25$). Strikingly, patients who underwent RSI prior to blood transfusion had a significantly higher mortality rate than those who had blood transfusion initiated first (50% vs 78% $p < 0.05$).

Conclusions: In this retrospective review RSI resulted in a further drop in SBP in hypotensive trauma patients. Mortality rate was higher when RSI was performed before blood transfusion was initiated. Further studies are required to consider the initiation of blood transfusion first in hypotensive patients who are maintaining the airway.

PROSPECTIVE EVALUATION OF ADMISSION CORTISOL IN TRAUMA

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Invited Discussant: Luke Leenen, MD, PhD

Introduction:

Adrenal insufficiency (AI) has been shown to occur soon after trauma and is associated with increased mortality. Prior studies involving patients in the immediate post-trauma period have been essentially limited to patients with hemorrhagic shock. The purpose of this study was to investigate the impact of acute adrenal insufficiency in all critically ill trauma patients. We hypothesized that critically ill trauma patients with severe adrenal insufficiency would be at higher risk for requiring vasopressors, have a greater need for blood product administration, and have a higher mortality rate.

Methods:

A blinded, prospective, observational study was performed at an ACS verified Level I trauma center including all patients with highest level trauma team activations, from 12/1/14-1/31/16, who were admitted to the ICU. Exclusion criteria were age <18, transfer from another hospital, previous steroid use, etomidate administration, brain death or comfort care within 24 hours of admission, or insufficient quantity of blood available for testing. Serum cortisol levels were measured from the initial blood draw in the trauma bay. Patients were categorized according to cortisol ≤ 15 $\mu\text{g/dL}$ (severe), 15.01-25 $\mu\text{g/dL}$ (moderate), or > 25 $\mu\text{g/dL}$ (normal) and compared on demographics, injury severity score (ISS), initial vital signs, blood products usage, pressor requirements, steroids given for AI, and mortality. Groups were compared with Chi square and Mann Whitney U tests with significance attributed to a p value < 0.05 .

Results:

During the study period, 340 patients with highest level trauma activations were admitted to the ICU; 187 were excluded and 153 patients were included in analysis. Patients were activated for hypotension (n=42), decreased GCS (n=82), mechanism (n= 16), and other (n=13). Patients were severely injured with a mean ISS of 24; overall mortality was 14%. Mechanism of injury was blunt in 126 patients (82%) and penetrating in 27 patients (18%). Demographics were similar among the groups. Mean admission cortisol level was 24 ± 10 $\mu\text{g/dL}$.

Initial cortisol	N	ISS	Blood products (1 st 24h)	Pressor (24h)	Pressor (24-72h)	Mortality
≤ 15 $\mu\text{g/dL}$	18	28 [22-37]	8 [1-28]	8 (42%)	9 (47%)	7 (39%)
15.01-25 $\mu\text{g/dL}$	67	25 [21-33]	3 [0-6]	6 (9%)*	17 (25%)	11 (16%)*
> 25 $\mu\text{g/dL}$	68	22[14-27]*	0 [0-3]	5 (7%)*	8 (11%)*	4 (6%)*

*p < 0.05 compared to cortisol ≤ 15 $\mu\text{g/dL}$.

Conclusion:

Patients with moderate to severe adrenal insufficiency on admission required more blood products, were more likely to require pressors within 24 hours of arrival, and had a higher mortality rate than patients with normal admission cortisol levels. We recommend obtaining an admission cortisol level as part of the trauma panel in order to help identify these high risk patients.

NONOPERATIVELY MANAGED BLUNT SPLENIC TRAUMA IS ASSOCIATED WITH HIGHER INCIDENCE OF VENOUS THROMBOEMBOLISM

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Invited Discussant: Jordan Weinberg, MD

Introduction: Previous studies have linked hypercoagulability and increased risk of venous thromboembolism (VTE) to thrombocytosis after splenectomy. Despite increases in nonoperative management, there are no data investigating the influence of various solid organ injuries on VTE incidence in this group. We hypothesize that nonoperatively managed blunt injury to the spleen, compared to the liver, will have higher rates of VTE.

Methods: A retrospective review of 1016 adult patients with blunt trauma and abdominal solid organ injury admitted to the intensive care unit (ICU) from 01/2010-01/2016 was performed. Patients with isolated liver injury were compared to those with isolated spleen injury, with a subgroup analysis in patients managed nonoperatively. Parametric data is presented as mean \pm standard deviation and nonparametric as median (interquartile range). Significance was considered at $p \leq 0.05$.

Results: Patients with isolated liver injury ($n=101$) had a VTE rate of 7.9%, while those with isolated spleen injury ($n=88$) had a significantly higher VTE rate of 17.0% ($p=0.045$). Groups were similar in age, gender, heart rate, systolic blood pressure, Glasgow Coma Scale score, base deficit, hematocrit, platelet counts, injury severity score, Greenfield Risk Assessment Profile score, hospital length of stay (LOS), ICU LOS, and delayed prophylaxis ($>48h$) (all $p > 0.05$). Additionally, no difference was found in transfusion requirements, pelvic or leg fractures, or OR time (all $p > 0.2$). When assessing nonoperatively managed patients with isolated liver ($n=86$) vs. isolated spleen injury ($n=71$), groups remained similar in all categories (all $p > 0.8$), however, VTE incidence was significantly higher in isolated spleen injury (9.9% vs. 2.3%, $p=0.043$). (Table 1) Additionally, all pulmonary emboli ($n=5$) occurred in patients with isolated spleen injury ($p=0.012$).

Conclusion: Differences in VTE incidence in blunt trauma patients, both overall and when nonoperatively managed, may be associated with the organ of injury. Isolated splenic trauma, managed operatively or nonoperatively, appears to be prothrombotic compared to liver trauma.

Table 1. Nonoperatively Managed Solid Organ Injury

	Isolated Liver Injury $n=86$	Isolated Spleen Injury $n=71$	p-value
Age, years	40 \pm 18	40 \pm 18	0.828
Male gender, % (n)	59.3% (51)	71.8% (51)	0.101
Heart Rate, bpm	95 \pm 20	94 \pm 27	0.745
Systolic Blood Pressure, mmHg	129 \pm 28	134 \pm 25	0.294
Glasgow Coma Scale Score	13 \pm 4	13 \pm 4	0.945
Base Deficit	-2 \pm 3	-2 \pm 4	0.257
Hematocrit	39 \pm 6	40 \pm 7	0.966
Platelet Count, Admission	267 \pm 81	264 \pm 101	0.826
Platelet Count, Lowest	144 \pm 60	155 \pm 63	0.383
Platelet Count, Highest	457 \pm 227	434 \pm 244	0.554
Injury Severity Score	26 \pm 11	23 \pm 10	0.089
Greenfield Risk Assessment Profile Score	8 \pm 4	8 \pm 4	0.654
Length of Stay, days	12 (6-19)	9 (6-21)	0.765
ICU Length of Stay, days	4 (2-11)	4 (3-7)	0.827
Delayed Prophylaxis ($>48h$), % (n)	20.0% (11)	14.3% (7)	0.442
Venous Thromboembolism, % (n)	2.3% (2)	9.9% (7)	0.043*
Deep Venous Thrombosis, % (n)	2.3% (2)	2.8% (2)	0.845
Pulmonary Embolism, % (n)	0% (0)	7.0% (5)	0.012*

ANGIOEMBOLIZATION IN THE MANAGEMENT OF ISOLATED SPLENIC INJURIES: IS THERE REALLY A RELATIONSHIP BETWEEN EMBOLIZATION AND SPLENIC SALVAGE?

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Invited Discussant: Indermeet Bhullar, MD

Introduction: There is variability in the use of angioembolization (AE) for splenic injuries at U.S. trauma centers. Recent data suggest improved splenic salvage rates when AE is employed for high-grade injuries; however, protocols and salvage rates vary among centers. Our center has a low rate of AE with an observed high rate of splenic salvage. We hypothesized that splenectomy rates will not be significantly different between institutions that frequently employ AE versus institutions that do not.

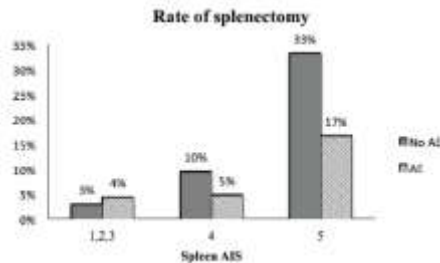
Methods: Data for this study was obtained using the National Trauma Data Bank (NTDB, 2014). Patients were included if they had ICD-9-CM codes for splenic injury and were ≥ 18 yrs old. Patients were excluded if they died in the ED and if they went from the ED to the OR for splenectomy. Only patients with isolated splenic injuries were analyzed. Descriptive measures including age, gender, race, ISS, splenic AIS score, hospital teaching status, and trauma center designation (I-V) were included. Trauma centers were grouped into quartiles based on frequency of AE in isolated splenic injuries. Unadjusted analyses and logistical regression analyses were performed. Models were created controlling for center effect and using the quartile of AE as an independent variable.

Results: There were a total of 2,762 isolated splenic injuries in adult trauma patients in 2014. After exclusion criteria, there were 1,895 patients at 358 centers. Of these patients, 313 (16.5%) underwent AE and 124 (6.5%) had a splenectomy. Overall, splenectomy rates were not different for AE (19/294, 6%) vs. no AE (105/1477, 7%, p NS).

However, splenectomy rates were lower for high-grade injuries when AE was used vs. not (AE vs. no AE - AIS 4: 5%

vs. 10%; AIS 5: 17% vs. 33%; Figure). Quartiles for AE use were created to analyze the association between centers' AE practices and splenectomy rates. Mean center AE rates in the lowest vs. highest quartiles were 1.9% and 31.7%, respectively. Splenectomy rates were lower in centers with high AE use vs. those with low AE use (4.4% vs. 8.5% in the highest vs. lowest quartiles, $p=0.004$). The impact of quartiles of AE rate remained significant in regression analysis when controlling for age, gender, race, spleen AIS, mechanism of injury, and type of center (OR 0.77, $p = 0.001$). Findings were robust in all regression models employed.

Conclusion: Contrary to our hypothesis, AE use was associated with reduced splenectomy rates in isolated splenic injuries. Our analysis is agnostic to the rationale for AE, suggesting that overall aggressive use of AE is associated with reduced splenectomy rates regardless of any specific protocol. These findings suggest that AE may increase the rate of splenic salvage in isolated splenic injuries. Future investigation should be directed towards identifying the correct patient population for which the rate of AE use as a means to improve splenic salvage is sufficiently high enough to outweigh any added cost and risk of the procedure.



THE MANGLED EXTREMITY SCORE AND AMPUTATION: TIME FOR A REVISION

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Invited Discussant: Jon Perlstein, MD

Background: The Mangled Extremity Severity Score (MESS) was developed 25 years ago in an attempt to utilize the extent of skeletal and soft tissue injury, limb ischemia, shock, and age to predict the need for amputation after extremity injury. Subsequently, there have been mixed reviews as to the utility of this score, especially when considering the technological advances in diagnostic and treatment modalities that have occurred over the past two decades. We hypothesized that the MESS, when applied to a data set collected prospectively in modern times, would not correlate with the need for amputation.

Methods: We applied the MESS score to patient data collected in the American Association for the Surgery of Trauma PROspective Vascular Injury Treatment (PROOVIT) registry. This registry contains demographic, diagnostic, treatment, and outcome data on patients admitted to one of 14 Level 1 trauma centers, collected prospectively.

Results: Between February 2013 and August 2015, 230 patients with lower extremity arterial injuries were entered into the PROOVIT registry. The majority were male with a mean age of 34 years (range 4-92) and a blunt mechanism of injury at a rate of 47.3%. Isolated femoral injuries were found in 44.3% of cases, popliteal in 26%, with the remaining occurring in below-knee arteries or multiple locations. 9.1% required immediate amputation for damage control. A MESS of 8 or greater was associated with higher transfusion rates (9.2 units vs 6.4, $p=0.03$) and a longer stay in the ICU (10.5 days vs 5.5, $p=0.005$). 81.3% of limbs were ultimately salvaged (mean MESS 4.29) and 17.7% required primary or secondary amputation (mean MESS 6.58, $p<0.001$). However, after controlling for confounding variables including mechanism of injury, degree of arterial injury, and concomitant venous and orthopedic injuries, the MESS between salvaged and amputated limbs was no longer significantly different (TABLE). Importantly, a MESS of 8 predicted amputation in only 32.7% of patients.

Conclusion: Therapeutic advances in the treatment of vascular, orthopedic, neurologic and soft tissue injuries have reduced the diagnostic accuracy of the MESS in predicting the need for amputation. There remains a significant need to examine additional predictors of amputation following severe extremity injury.

Table:

MESS Elements	Amputations Mean score (n = 43)	Not amputated Mean score (n = 187)	p-value unadjusted	p-value adjusted*
Skeletal/soft tissue score	2.58	1.71	<0.0001	0.5439
Limb ischemia	1.93	1.16	<0.0001	0.5560
Shock	0.51	0.32	0.20	0.5150
Age score	0.86	0.66	0.22	0.2272
Total MESS	6.58	4.29	<0.0001	0.2643

*Adjusted for significant confounders including mechanism, arterial transection, concomitant nerve and orthopedic injuries

BEYOND THE PROPPR RATIO: TRANSFUSING YOUNG BLOOD IMPROVES CLINICAL OUTCOMES IN SEVERELY INJURED TRAUMA PATIENTS

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Invited Discussant: Louis Magnotti, MD

Introduction: Outcomes following the transfusion of older blood in severely injured trauma patients are not well described. Standardized methods to analyze the age of blood and the influence of multiple transfusions are lacking. The purpose of this study was to determine the impact of young versus old red blood cell (RBC) transfusions in severely injured trauma patients. We hypothesized that transfusing RBCs < 14 days old would improve clinical outcomes in severely injured trauma patients.

Methods: Prospectively collected data from the Pragmatic Randomized Optimal Platelet and Plasma Ratio (PROPPR) trial were analyzed. We compared patients receiving young RBCs (mean age <14 days) to patients receiving old RBCs (mean age ≥14 days). To evaluate the potential harm of receiving even a single unit of old RBCs, we compared patients receiving ≥ 3 units of exclusively young RBCs (age of each individual transfused unit <14 days) to patients receiving ≥3 units of exclusively old RBCs (age of each individual transfused unit ≥14 days). Linear and logistic regression models were generated for all study outcomes and accounted for age, injury severity score, and number of units transfused. To evaluate for survival bias, a subgroup analysis was completed on patients surviving the first 24 hours.

Results: 10,700 units of RBCs were transfused during the study period; 2,294 units were young RBCs (mean age 11 days) and 8,406 units were old RBCs (mean age 23 days). 465 units of exclusively young RBCs (mean age 9 days) and 2,455 units of exclusively old RBCs (mean age 27 days) were transfused. In the subgroup analysis, 1,862 units of young RBCs (mean age of 11 days) and 6,866 units of old RBCs (mean age 23 days) were transfused. 396 units of exclusively young RBCs (mean age 9 days) and 2,262 units of exclusively old RBCs (mean age 27 days) were transfused. The age of RBCs between PROPPR study groups (1:1:1 vs 1:1:2) was not statistically different. Patients transfused old RBCs had an increased risk of acute kidney injury (AKI) and all infectious complications excluding ventilator associated pneumonia and had fewer hospital-free days compared to patients transfused young RBCs (Table 1).

Conclusion: Transfusion of young RBCs in severely injured trauma patients is associated with increased hospital-free days and a reduced risk of both AKI and infectious complications. The associated risk reduction for AKI and infectious complications is stronger if patients receive exclusively young RBCs rather than a mean age of young RBCs.

Table 1: All patients		n	AKI OR [95% CI]*	P	Infection OR [95% CI]*	P	Hospital free days β coef** [95% CI]	P
Young RBCs	170	Reference	2.2 [1.3-3.6]	0.002	Reference	0.038	-2.3 [(-) 3.6-1.0]	0.001
Old RBCs	508	2.2 [1.3-3.6]			1.5 [1.0-2.3]			
Exclusively young RBCs	46	Reference	5.1 [1.4-18.2]	0.012	Reference	0.041		
Exclusively old RBCs	188	5.1 [1.4-18.2]			2.7 [1.0-6.9]			
Subgroup Analysis			AKI OR [95% CI]*	P	Infection OR [95% CI]*	P	Hospital free days β coef** [95% CI]	P
Young RBCs	146	Reference	2.1 [1.3-3.6]	0.005	Reference	0.036	-2.2 [(-) 3.6-0.8]	0.002
Old RBCs	432	2.1 [1.3-3.6]			1.6 [1.0-2.4]			
Exclusively young RBCs	40	Reference	4.9 [1.3-17.8]	0.016	Reference	0.042		
Exclusively old RBCs	167	4.9 [1.3-17.8]			2.7 [1.0-7.2]			

*Odds ratios calculated with logistic regression. AKI: acute kidney injury. OR: Odds ratio, CI: confidence interval.

**β coefficient calculated with linear regression

Acute vascular interventional radiology techniques in acute care medicine and surgery performed by trained acute care physicians.

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Invited Discussant: A. Peter Ekeh, MD

Introduction: Comprehensive treatment of a patient in the field of acute-care medicine and surgery (AMS) includes surgical techniques as well as several other treatment modalities. Since acute vascular interventional radiology techniques (AVIRT) have become increasingly popular, adequately training in-house physicians in this field can further improve the quality of on-site care delivered.

Methods: After obtaining approval from the institutional ethics committee, a retrospective study of daily referrals and AVIRT procedures performed over a period of 1 year by acute care physicians trained in AMS, including those conducted out of hours, was carried out. The trained physicians with Japanese Association of Acute Medicine's Board certification had completed at least 1 year of training as a member of the endovascular team in the radiology department of another university hospital. This study was designed in such a way that at any given time, at least one of the physicians was available to come to the hospital within 1 h and perform AVIRT. Femoral sheath insertion was performed by the resident physicians under the guidance of the trained physicians.

Results: This study comprised 77 endovascular procedures for therapeutic AVIRT (trauma, n = 29; non-trauma, n = 48) conducted over the past 1 year. (Table) AVIRT was performed in 62 patients with a mean age of 64 years (range: 9–88 years), of which 55% were male. Furthermore, 47% of the procedures performed were out-of-hours referrals (trauma = 52%, non-trauma = 44%). Three patients underwent resuscitative endovascular balloon occlusion of the aorta in the emergency room. AVIRT procedures were performed using 8-9 Fr. guiding catheters with 8-9 Fr. femoral artery sheath in stroke patients and 5 Fr. catheters with 5 Fr. sheath in patients with pelvic injuries. In other cases, 4 Fr. guiding sheath catheters, or 6 Fr. catheters with 6 Fr. femoral artery sheath were used. Treatment materials included detachable microcoils, gelfoam, polyvinyl alcohol particles, and N-butyl-2-cyanoacrylate. No major device-related complications were encountered. The overall mortality rate within 60 days was 8%, and the causes of death included exsanguination (n = 2), pneumonia (n = 2), sepsis (n = 1), and brain death (n = 1).

Conclusion: AVIRT performed by trained acute care physicians appears to be significantly advantageous for acute on-site care because it has a good technical success. Therefore, a standard training program for acute care physicians or trauma surgeons should be established to make these techniques a part of the universally accepted regimen.

Trauma (n = 29)	Non-trauma (n = 48)
Embolization (coil, gelfoam, or NBCA)	Embolization (coil, gelfoam, PVA, or NBCA)
Aortic aneurysm	Glomerular and bleeding 11
Blunt injury	Hemiparesis 4
Spinal injury	Retropneumothorax/hemothorax 3
Septic injury	Hemifacial (lower facial artery aneurysm) 2
Pelvic injury	Hemiparesis 2
Pelvic injury	Paralysis of lower limb 1
Cholel	Hepatic cell carcinoma 2
Striated artery laceration	Pelvic aneurysm 1
Post-operative bleeding	Mechanical lower limb 1
Retropneumothorax/hemothorax (vascular injury)	Stroke/pneumothorax/hemothorax 3
Delayed bleeding	Mechanical cerebral revascularization
Stroke / Spinal	Stroke (cortical infarction) 11
Head trauma	Others (angiopathy or drug ingestion)
Spinal laceration	Radial artery catheter 1
Striated artery laceration	Superior mesenteric artery occlusion 1
Cerebral aneurysm/infarct	Isolated iliac artery pseudoaneurysm 1
Cerebral subdural hematoma	Flap artery aneurysm 1

NBCA, N-butyl-2-cyanoacrylate; PVA, polyvinyl alcohol particles.

EARLY FLUID OVERRESUSCITATION PATTERNS IN SEVERE PEDIATRIC BURN INJURIES AND INFLUENCE ON OUTCOMES

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Invited Discussant: Tina Palmieri, MD

Introduction:

Overresuscitation after severe burn is thought to predispose to complications such as extremity compartment syndrome and pulmonary edema. Formulas predicting resuscitation volume are variably useful depending on individual application. We investigated the rate of overresuscitation in a cohort of burn patients and the association between overresuscitation and late surgical and overall complications.

Methods:

Institutional IRB approval was obtained. A retrospective review was performed (2009 - 2015) of a single-institution prospectively-maintained burn registry. Patients less than 18 years of age admitted with total body surface area (TBSA) thermal injury greater than 15% were included. Exclusion criteria included age > 18 years, death within 72 hours of admission, completion of first 8 hours after injury at an outside institution, and concomitant non-burn traumatic injuries. Total fluid resuscitation in the first 8 hours after burn was determined and compared to optimal resuscitation as predicted by the modified Parkland formula. Outcomes were compared based on percent deviation from predicted Parkland needs stratified by receipt of < 25%, 25 - 50%, 50 - 100%, 100 - 200%, and > 200% predicted fluid needs. All parametric data were examined using Student's t-test and non-parametric data were analyzed using Chi-squared testing. Multivariate analysis based on a priori hypotheses was performed for all outcomes in question.

Results:

Fifty patients met inclusion criteria. Median age was 4 years (IQR 2.0 - 11.5 years), and 75% were male. Median TBSA was 21.2% (IQR 16 - 32.5%). 60% of patients received initial care at outside institutions, and patients received a median of 12.8% of their initial resuscitation volume prior to referral center arrival (IQR 0 - 41.1%). Patients received on average 110% higher fluid volume (SD 120%) than the need predicted by the modified Parkland formula in the first 8 hours after injury. 19 (38%) patients underwent escharotomy or late intubation, defined as intubation after the initial ED presentation. 13 (26%) required escharotomy and 10 (20%) required late intubation. In multivariate analysis adjusting for TBSA, patient weight, and ED disposition (ICU versus routine ward), overresuscitation did not increase risk of escharotomy and was not an independent predictor of length of stay or duration of mechanical ventilation. However, overresuscitation was an independent predictor of longer ICU stay ($p = 0.03$), and was associated with a higher risk of unplanned reintubation after initial emergency room evaluation (OR 2.0, CI 0.93 - 4.2, $p = 0.08$).

Conclusions:

In a single institution experience, burn patients were consistently overresuscitated in the first eight hours after injury. Overresuscitation is associated with risk of late intubation and is an independent predictor of duration of ICU admission. Careful attention to very early fluid resuscitation, although difficult due to the interplay between prehospital personnel, referring hospitals, and burn centers, is critical to appropriate early fluid administration in severely burned patients.

IMPROVED PREDICTION OF HIT IN THE SICU USING A SIMPLIFIED MODEL OF THE WARKENTIN 4-T SYSTEM: 3-T

Matthew B. Bloom* MD, Oksana Volod MD, Jeffery Johnson MD, Terris White MD, Eric J. Ley* MD, Rodrigo F. Alban* MD, Daniel R. Margulies* MD, Cedars-Sinai Medical Center

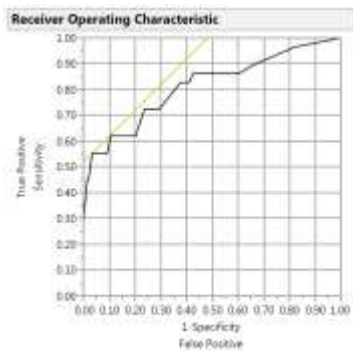
Invited Discussant: Steven Johnson, MD

Introduction: The Warkentin 4-T scoring system for determining the pre-test probability of heparin-induced thrombocytopenia (HIT) has been shown not to be accurate in the ICU, and does not take into account body mass index (BMI), previously described as an associated factor. Our objective was to create an improved scoring system with the inclusion of BMI and platelet factors most relevant to ICU patients.

Methods: Prospectively collected data on patients in the surgical and cardiac ICU between January 2007 and February 2016 presumed to have HIT by clinical suspicion were reviewed. Patients were categorized into 3 BMI groups as normal weight (18.5-24.9), overweight (25-29.9), obese (≥ 30). Demographic and clinical data including Warkentin 4-T scores and its sub-scores, Serotonin Release Assay (SRA), and thromboembolic diseases were recorded. HIT positive patients were defined as having SRA $>20\%$. 2-sided Cochran-Armitage Trend Test was used to confirm an ordered association between heavier BMI groups and increasing incidence of HIT. Multivariate analyses were used to identify independent predictors of HIT. Increasingly large BMI groups were awarded 0, 1 or 2 points, similar to the Warkentin scoring system. Receiver operating characteristic (ROC) curves were analyzed to compare accuracy of multiple predictive models.

Results: A total of 523 patients met inclusion criteria. Mean age was 60.2 ± 15.8 years, 59% were male, and mean BMI was 27 ± 6.2 kg/m². 49 (9%) patients were positive for HIT. Incidence of HIT increased progressively with BMI [6.6%, 7.8%, 15.3%; $P = 0.0081$]. On univariate analysis, only BMI, 4T(Timing) $P < 0.001$; 4T(oTher) $P < 0.001$; and the total 4T score $P < 0.001$ were associated with HIT. In multivariate analysis, BMI [aOR = 4.19, 95% CI = 1.48-12.9, $P = 0.025$]; 4T(Timing) [aOR = 2.37, 95% CI = 1.26-4.53, $P = 0.007$]; and 4T(oTher) [aOR = 3.96, 95% CI = 1.09-8.90, $P < 0.001$], were independently associated with HIT. ROC curves were compared between 4-T model (AUC = 0.768) and models with BMI and components of the 4-T model. A model with BMI, 4T(Timing), and 4T(oTher) had significantly improved receiver characteristics (AUC = 0.841), and was better than a model which included the entire 4-T scoring system with BMI (AUC = 0.791).

Conclusion: Including patient 'T'hickness into a pre-test probability model along with platelet 'T'iming and the exclusion of o'T'her causes of thrombocytopenia yields a simplified '3-T' scoring system that has increased predictive accuracy in the ICU. Additional biochemical work is indicated to further decipher the role of obesity in this immune-mediated condition.



HIGH RATIO PLASMA RESUSCITATION DOES NOT IMPROVE SURVIVAL IN PEDIATRIC TRAUMA PATIENTS

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Michael A. Johnson MD, Lucas P. Neff MD, University of Pennsylvania

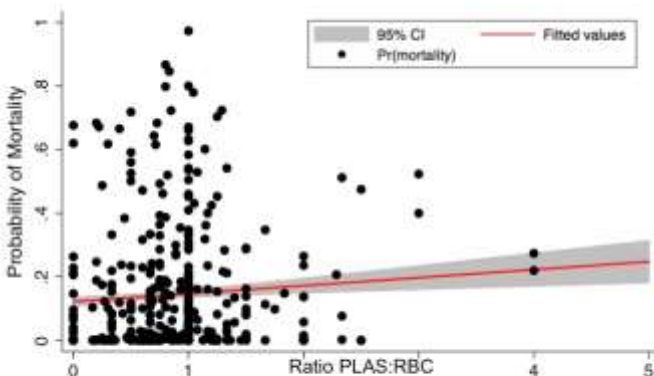
Invited Discussant: David Notrica, MD

Introduction: Damage control resuscitation including balanced resuscitation with high ratios of plasma (PLAS) and platelets (PLT) to red blood cells (RBC) improves survival in adult patients. We hypothesize that a high ratio PLAS to RBC resuscitation strategy similarly improves mortality in severely injured pediatric patients.

Methods: The Department of Defense Trauma Registry (DoDTR) was queried from 2001-2013 for pediatric trauma patients (<18 years). Burns, drowning, isolated head trauma, and missing injury severity score (ISS) were excluded. Of the remaining patients, those receiving a massive transfusion (MT) were evaluated. MT patients were defined as receiving ≥ 40 mL/kg total blood products in 24 hours. Mortality at 24 hours and in-hospital was evaluated for increasing PLAS to RBC ratios. Secondary outcomes included blood product utilization over 24 hours, ventilator days, and ICU and hospital length of stay (LOS).

Results: The DoDTR yielded 4,990 combat-injured pediatric trauma patients of whom 435 met inclusion criteria. Analysis of PLAS to RBC ratios across the entire spectrum of possible ratios in these patients demonstrated no clear inflection point where mortality was improved (Figure). Using a division between high (HI) and low (LO) ratio PLAS:RBC of 1:2, there was no difference in all-cause mortality at 24 hours (HI 6.1% vs. LO 2.7%, $p=0.26$) and hospital mortality (HI 14.9% vs. LO 15.1%, $p=0.97$). Cox regression analysis also demonstrated no mortality benefit to a HI ratio strategy (OR 1.17, 95% CI, 0.53-2.58, $p=0.69$). HI ratio patients received less RBC but more PLAS and PLT and more total blood products. Those in the HI ratio group also had more ventilator days (HI 4.1 vs. LO 2.3, $p<0.01$) and a longer ICU LOS (HI 6.1 vs. LO 4.0, $p=0.02$).

Conclusion: In combat-injured children undergoing a MT, a high ratio of PLAS to RBC does not appear to improve survival. Further prospective studies should be performed to determine the optimal resuscitation strategy in critically injured pediatric patients.



**ADMISSION N-TERMINAL PRO-BRAIN NATRIURETIC PEPTIDE
CONCENTRATIONS PREDICT DEVELOPMENT OF ATRIAL FIBRILLATION
IN GENERAL SURGICAL INTENSIVE CARE UNIT PATIENTS**

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Lee-Lewandrowski MPH, Ph.D., Haytham Kaafrani MD, MPH, Peter Fagenholz MD,
David R. King* MD, Marc Demoya* MD, Kathryn Butler MD, Jarone Lee MD, MPH,
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Invited Discussant: Kevin Schuster, MD, MPH

Introduction: New onset atrial fibrillation (AF) in critically ill patients is associated with significant morbidity, prolonged hospitalization, and increased mortality. N-terminal pro-B type natriuretic peptide (NT-proBNP) is released by the cardiomyocytes in response to stress and may predict development of AF after cardiac, vascular, and thoracic surgery. We hypothesized that NT-proBNP level at the time of admission to the surgical ICU would help predict the development of AF in a general surgical and trauma population.

Methods: From July to October 2015, NT-proBNP concentrations were measured at the time of ICU admission. Abnormal NT-proBNP concentrations were based on currently accepted age-adjusted cut-offs. We examined the relationship between the development of AF and demographic (age, gender) and clinical variables (reason for admission, APACHE II score, Charlson Comorbidity Index, history of AF, coronary artery disease, coronary artery bypass graft surgery, valve surgery, thoracic surgery, medications, and fluid balance) using univariate analysis and a multivariable logistic regression model.

Results: 387 subjects were included in the cohort, none of whom were in AF at ICU admission. The mean age was 62 (± 16) years and 40.3% were female. The risk of developing AF was higher for abnormal vs. normal NT-proBNP, 22% vs. 4%, respectively. Using optimal derived cutoffs (regardless of age), the risk of developing AF was 2% for NT-proBNP < 600 ng/L, 15% for NT-proBNP 600-2,000 ng/L, and 27% for NT-proBNP > 2,000 ng/L. Multiple logistic regression analysis identified three predictors for new-onset AF: Age ≥ 70 (OR 3.7, 95% CI 1.5-9.3), history of AF (OR 25.3, 95% CI 9.6-67.0), and NT-proBNP ≥ 600 (OR 4.3, 95% CI 1.3-14.2). When none or only one predictor was present, AF incidence was <1%. When all three predictors were present, AF incidence was 66%.

Conclusion: NT-proBNP level at the time of admission to a general surgical ICU is predictive of the development of AF in the first 3 ICU days in patients in sinus rhythm at the time of ICU admission. Addition of NT-proBNP level to known risk factors can improve predictive power and identify patients who might potentially benefit from evidence-based prophylactic treatment for AF.

EARLY TRANEXAMIC ACID ADMINISTRATION AMELIORATES THE ENDOTHELIOPATHY OF TRAUMA AND SHOCK

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Invited Discussant: Grant O'Keefe, MD, MPH

Introduction: Systemic vascular endothelial injury is a consequence of trauma-hemorrhagic shock (T/HS) which results in disturbances of coagulation, inflammation and endothelial barrier integrity. Administration of tranexamic acid (TXA) in trauma patients is associated with a survival benefit and fewer complications if given early after injury. Mechanisms for this protective effect include the anti-fibrinolytic and anti-inflammatory effects of TXA. We hypothesized that "early" administration of TXA would abrogate vascular endothelial cell activation and injury following T/HS. This was studied *in vitro*.

Methods: Confluent human umbilical vein endothelial cells (HUVEC) were exposed to hydrogen peroxide (H₂O₂, 100μM) and/or epinephrine (epi, 10-3μM) to simulate post T/HS oxidant exposure and/or sympathoadrenal activation. TXA (150μM) was added 15, 60 or 120 minutes after H₂O₂ challenge. Markers of endothelial cell activation and/or injury studied included cell monolayer permeability, ICAM expression, syndecan release, tissue type plasminogen activator (tPA), plasmin activator inhibitor-1 (PAI-1) and angiopoietin 2 to angiopoietin 1 ratio (APO-2/APO-1). These biomarkers were measured 30 and 60 minutes after "early" TXA administration (15 minutes after H₂O₂/epi treatment) or "delayed" (at 60 or 120 minutes after H₂O₂/epi treatment).

Results: (mean ± SD; N = 4 for each group)

	Perm. (nmol/cm ² /hr)	Syndecan (ng/ml)	tPA (pg/ml)	PAI-1 (pg/ml)	APO2/APO1 (pg/ml)	ICAM (MFI)
HUVEC alone	0.29±0.02	23.6±1.2	1515±34.1	5750±51.6	0.3±8.2	8.9±1.4
HUVEC + H ₂ O ₂ (15min)	0.60±0.05*	42.6±2.8*	3172±36.6*	5075±59.2*	2.0±6.68*	25.5±2.2*
HUVEC + epi	0.54±0.04*	41.8±2.2*	1600±43.2	5765±76.2	1.5±5.8*	24.2±2.6*
HUVEC + H ₂ O ₂ + epi	0.78±0.06*	74.5±5.6*	2860±55.2*	5150±38.9*	2.5±4.8*	36.0±3.4*
HUVEC + H ₂ O ₂ + epi +TXA(30)	0.34±0.03	28.9±1.4*	1605±50.1	5460±55.4*	0.3±7.9	9.9±1.8
HUVEC + H ₂ O ₂ + epi +TXA(60)	0.35±0.03	29.6±1.2*	1570±41.8	5500±81.6*	0.4±5.6	10.2±3.1
HUVEC + H ₂ O ₂ +epi +TXA (1hr delay)	0.71±0.05*#	70.2±4.9*#	3550±74.1*#	5325±79.9*	2.0±7.3*#	34.8±2.4*#
HUVEC + H ₂ O ₂ +epi+TXA (2hr delay)	0.77±0.07*#	72.2±5.1*#	3280±66.5*#	5250±58.7*	2.3±6.2*#	35.7±3.9*#

*p<0.001 vs. HUVEC control, #p<0.001 vs. TXA (T=30 and 60)

Conclusion: Anti-fibrinolytic and other protective effects of TXA administration on endothelial activation/injury are time dependant. This study supports the concept that the clinical efficacy of TXA administration requires "early administration".

ASPIRIN CHEMOPROPHYLAXIS DECREASES VENOUS THROMBOEMBOLISM IN 13,221 TRAUMA PATIENTS

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Invited Discussant: Raminder Nirula, MD, PhD

Introduction: Survivors of injury exhibit a multifactorial hypercoagulable state and have increased risk of venous thromboembolism (VTE). Despite ever earlier and aggressive chemoprophylaxis (CP) with various heparin compounds ("standard" CP; sCP), VTE rates have remained essentially unchanged. In high quality studies, aspirin has been shown to decrease VTE in postoperative patients. We hypothesized that inhibiting platelet function with aspirin as an adjunct to sCP would reduce the incidence of VTE in trauma patients.

Methods: Administrative and registry databases were queried to identify all adult patients admitted to a Level I Trauma center from January 2012 to June 2015. Patients that did not receive sCP or had a VTE present on admission (POA) were excluded. Exclusion criteria was not mutually exclusive. Continuous variables are presented as median (IQR); categorical variables are presented as proportions. Univariate analysis was conducted to compare demographic and injury data between patients receiving sCP or sCP plus aspirin (sCP+A). Cox proportional hazard models evaluated the potential aspirin benefit on symptomatic VTE incidence. The model included: dose of heparin or enoxaparin (prophylactic or therapeutic), major venous repair, central venous catheter, the Trauma Embolic Scoring System (TESS, includes age, ISS, obesity, lower-extremity fracture, ventilation > 3 days) and aspirin (81 or 325 mg/day). TESS is a previously validated score for assessing risk of VTE in trauma patients. Adjunctive use and dose of aspirin was at the discretion of the treating physician. Screening for VTE was not conducted.

Results: 13,221 patients were included in the study. 2,689 were excluded as they either had a VTE POA (40), or were discharged (2346) or died very early (316) prior to receiving sCP [discharge/death length of stay 1 (1, 2) days]. Median date of sCP initiation was day 1 (0.8, 2). 1886 patients received sCP+A by hospital day 3 (1, 6). 353 patients (3.4%) had a new symptomatic VTE on hospital day 5 (3, 10). While there was no difference in mechanism (89% blunt, $p=0.4$) between patients on sPA or sCP+A, patients on sCP+A had a higher TESS [4 (2, 5) vs. 4 (2, 6), $p<0.001$]. The Cox regression model revealed that aspirin administration was independently associated with a decreased relative hazard of VTE (hazard ratio, 0.75; 95% confidence interval 0.60-0.95; $p=0.02$). Absolute risk reduction was 1.8% and number needed to treat was 55 at 60 days post-injury. There were no increased bleeding or wound complications associated with sCP+A (point estimate 1.23, 95% CI 0.68-2.2, $p=0.50$).

Conclusion: In this large trauma cohort, adjunctive aspirin was independently associated with a significant reduction in VTE. There was no increase in bleeding complications associated with combining aspirin and standard chemoprophylaxis early after injury.

DEVELOPMENT OF A NOVEL COOLING TOURNIQUET TO MINIMIZE ISCHEMIC INJURY IN EXTREMITY TRAUMA

Shahram Aarabi MD, MPH, Xu Wang Ph.D., Alexander St. John MD, Esther Lim BS, Mark Trupiano BS, Ashley Emery Ph.D., Kaj Johansen MD, Ph.D., Niten Singh MD, Susan Stern MD, Nathan White MD, MS, Eileen Bulger* MD, Grant O'Keefe* MD, MPH, University of Washington

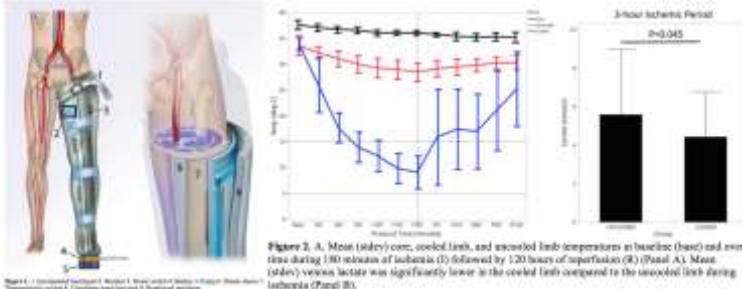
Invited Discussant: Warren Dorlac, MD

Introduction: Tourniquets are widely used in the care of extremity trauma. Therapeutic cooling is known to reduce ischemic injury in various tissues. We have (1) investigated the benefits of early cooling in an animal model of acute limb ischemia and, (2) used our data to build a device that cools injured extremities to minimize ischemic damage.

Methods: Acute hind limb ischemia was induced in swine (n=10) via aortic occlusion. One limb was externally cooled to 5-15°C and the uncooled contralateral limb served as a matched control. Serial limb venous blood gas measurements were obtained during 3 hours of ischemia followed by 2 hours of reperfusion. Continuous core body and limb temperatures were measured. Based on these data, we used COMSOL 4.4 computer heat transfer modeling of a human lower limb to determine the external cooling required to achieve core limb temperatures of 5-15°C. We then developed a cooling tourniquet device using Peltier solid-state cooling modules (TECs) and a counter-current circulating water system (**Figure 1**). Finally, we tested the ability of our prototype to achieve our cooling goals in an metal cast model of a human lower limb.

Results: During ischemia, mean (SD) limb temperature was 15.9 (7.5)°C in the cooled limb versus 30.1 (2.1)°C in the control limb (ANOVA, $p < 0.001$). Goal limb temperature was reached within 60 minutes of cooling (**Figure 2A**). There were trends in mean venous pH, 7.30 (0.1) vs. 7.20 (0.1) (T-test $p = 0.09$), and potassium, 4.8 (0.8) vs. 5.1 (1.1) mEq (T-test $p = 0.09$), between cooled and uncooled limbs. Venous lactate was significantly decreased during ischemia in the cooled limb, 4.4 (2.3) mmol/L, compared to the uncooled limb, 5.6 (3.4) mmol/L (T-test $p = 0.045$) (**Figure 2B**). COMSOL simulations demonstrated that heat removal of 150 watts is required to cool a human lower limb to 5-15°C within 30 minutes and that this could be achieved with our configuration of TECs and heat sink. Lastly, experiments on our model human lower limb showed that our prototype was able to achieve cooling to 5-15°C within 30 minutes.

Conclusion: Our data show that cooling to 5-15°C favorably affects limb metabolism during acute limb ischemia. We have used these data and computer heat transfer models to build a novel tourniquet device that can provide the same cooling to human lower limbs. We are now conducting animal experiments with our prototype device to evaluate the benefit of this approach in extremity trauma.



DAMAGE CONTROL SURGERY IN WEIGHTLESSNESS: A COMPARATIVE STUDY OF TORSO HEMORRHAGE CONTROL COMPARING TERRESTRIAL AND WEIGHTLESS CONDITIONS

Andrew W. Kirkpatrick* MD, Jessica L. McKee MSc, Homer Tien MD, Anthony LaPorta MD, Kit Lavell DFC, David R. King* MD, McBeth B. Paul MD, Susan Brien MD, Tim Leslie MSc, Derek Roberts MD, Reginald Franciose MD, Vivian McAlister MD, Jonathan Wong BSc, Danielle Bouchard Chad G. Ball* MD, University Of Calgary

Invited Discussant: Christine Gaarder, MD

Introduction: Torso bleeding remains the most preventable cause of post-traumatic death worldwide. Remote Damage Control Resuscitation (RDCR) endeavours to rescue the most catastrophically injured, but has not focused on pre-hospital surgical torso haemorrhage control. We examined the comparative logistics and metrics of intra-peritoneal packing in weightlessness in Parabolic flight (0g) compared terrestrial gravity (1g) as an extreme example of surgical RDCR.

Methods: A customized surgical phantom ("Cut-Suit" – CS) was constructed with high-fidelity intra-peritoneal anatomy, including a simulated vasculature system including a hydraulic "blood" pumping system with flow-meter. A standardized HC task was to explore the CS and identify major "bleeding" (coloured, thickened water - 5 cp) from a stellate liver injury flowing at a constant pressure of 80 mmHg. Ten volunteer surgeons performed RDCR laparotomies on the CS onboard a research aircraft (Falcon 20 – F20), first in 1g followed by 0g. The standardized RDCR laparotomy was sectioned into 20 second windows to enable conduct in Parabolic flight and thereafter comparison between 1g and 0g, "Blood" was pumped only during these time segments. These segments comprised incision, retraction, direction, exploration, hemorrhage-control, and abbreviated closure, with up to 12 windows only permitted to complete the laparotomy. Hemostasis was attempted through standard guaze packing of the liver injury which the surgeons were previously unaware of prior to RDCRL.

Results: All 10 surgeons successfully performed hemorrhage control on the CS in both 1 and 0g. Overall, there was no difference in blood loss between 1 and 0g ($p=0.23$) or in the observation period following packing of the liver injury ($p=0.687$). Compared to RDCRL in 1g, only the identification of bleeding phase in 0g induced more "blood" loss ($p=0.032$). Only the "incision" phase of the RDCRL took longer ($p=0.02$) in 0 versus 1g. Overall surgeons rated their personal physiologic performance and the relative difficulty of DCRL surgery in 0g as "harder" than 1g (median Likert both 2/5). However, surgical instrument control, and conducting all phases of laparotomy and hepatic packing for hemorrhage control were rated equivalent between 1 and 0g (median Likert all 3/5), except for skin closure (Median 1/5).

Conclusion: Performing RDCR laparotomies with packing of a simulated torso exsanguination in a high-fidelity surgical phantom was feasible onboard a research aircraft in both normal and weightless conditions. Despite being subjectively "harder" most phases of operative intervention were rated equivalently, and there was no statistical difference in "blood" loss in weightlessness. Direct Operative control of torso hemorrhage is theoretically possible in extreme environments if logistics are provided for.

THE IMPACT OF ACUTE CARE SURGERY SERVICE ON TIMELINESS OF CARE FOR PATIENTS WHO REQUIRE EMERGENT EXPLORATORY LAPAROTOMY FOR ACUTE ABDOMEN.

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Invited Discussant: Jason Lees, MD

Introduction: Timely surgical intervention is vital to improve postoperative outcomes for patients who undergo emergent exploratory laparotomy (EEL) for acute abdomen (AA). Acute Care Surgery (ACS) is a concept emerged since 2006 which dedicating care for patients who need emergent surgery, trauma, and surgical critical care. Our department developed ACS service since 2013. We conducted this study to assess the impact of ACS service on timeliness of care for patients require EEL for AA and perioperative outcomes.

Methods: Patients who underwent EEL for AA (1/2007 – 1/2014) at our institution were reviewed. EELs for trauma were excluded. Patients' demographics, comorbidities, diagnoses, type of surgery, the estimated mortality rate calculated by the American College of Surgeons National Surgical Quality Improvement Program Surgical Risk Calculator (ACS NSQIP SRC), hours between admission to surgical consultation, hours between admission to operating room, postoperative length of stay (LOS) and in-hospital mortality were recorded. These variables were compared between two groups: Patients who were operated during 1/2007 - 12/2012 (Pre-ACS group) vs Patients who were operated during 1/2013 – 1/2014 (Post-ACS group). Chi square test was used for non-parametric variables. Student's t-test was used for parametric variables.

Results: Five hundred and forty two patients who met inclusion criteria were identified. There were 254 males (47%). The median age was 62 years (range 17 – 98). Types of surgery were as following: upper gastrointestinal tract 23% (n=60), Small bowel 50% (n=271), large bowel 37% (n=202), and others 2% (n=9). The overall in-hospital mortality rate was 15% (n=81). There were 424 patients in the pre-ACS group and 118 patients in the post-ACS group. There were no differences between two groups in demographics, comorbidities, diagnoses, type of surgery, and the estimated mortality rate by ACS NSQIP SRC. Hours between admission to surgical consultation and hours between admission to operating room were shorter in Post-ACS group than Pre-ACS group (7.8 ± 5.4 hours vs 17.1 ± 45.9 hours, $p=0.002$. 8.6 ± 7.1 hours vs 39.6 ± 58.6 hours, $p<0.001$, respectively). Compared to Pre-ACS group, Post-ACS group had shorter postoperative LOS (8.7 ± 7.1 days vs 11.4 ± 17.9 days, $p=0.039$). The in-hospital mortality rate was similar between two groups (15% [63/424] vs 15% [18/118], $p=0.915$).

Conclusion: The development of ACS service improved the timeliness of surgical consultation and operation and eventually associated with shorter postoperative LOS.

NONOPERATIVE MANAGEMENT RATHER THAN ENDOVASCULAR REPAIR MAY BE SAFE FOR GRADE II TRAUMATIC AORTIC INJURIES: A TEN YEAR RETROSPECTIVE ANALYSIS

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Invited Discussant: J. Wayne Meredith, MD

Introduction: Chest X-rays have a high false negative rate for blunt thoracic aortic injuries (BTAs). The resulting increased use of chest CT scans combined with significant improvements in the quality of CT scanners has identified an increasing group of patients with minimal aortic injury (MAI) (grade I-II). Although the Society of Vascular Surgery (SVS) guidelines recommend thoracic endovascular aortic repair (TEVAR) for grade II-IV BTAs and nonoperative management (NOM) only for grade I, there is limited but increasing evidence that grade II may also be observed safely without TEVAR. The purpose of this study was to compare the outcomes of (TEVAR vs. NOM) for grade I-IV BTAs and determine if grade II can also be safely observed with NOM.

Methods: The records of patients with BTAs over an 11 year period from 2004 to 2015 at a Level I trauma center were retrospectively reviewed. Images were reviewed by a board certified radiologist and graded according to Society of Vascular Surgery (SVS) guideline (Grade I-IV). Failure of NOM was defined as aortic rupture after admission. Demographics, injury severity score and outcomes were recorded. The failure rate for grade I-IV injuries was compared for the two treatment groups (TEVAR vs. NOM). Statistical analysis was performed with ANOVA test of variance, Fisher's exact test, and χ^2 test.

Results: A total of 105 adult (age>15) patients with BTAs were identified over the 11 year period. Of these 34 (32%) patients were excluded, 17 (16%) that died soon after arrival due to other injuries prior to addressing aortic injury and 17 (16%) for undergoing operative repair (2004-2007). Of the remaining 71 patients, 48 (68%) had TEVAR and 23 (32%) had NOM. The distribution in each treatment arm by grade was as follows: TEVAR grade I 8 (17%), II 6 (13%), III 16 (33%) and IV 18 (38%); NOM grade I 8 (35%), grade II 8 (35%), and grade III 7 (30%). The failure rate after TEVAR and NOM was 0% for each grade (I-IV). Although MAI (grade I-II) patients that had a TEVAR had a hospital length of stay nearly twice as long as the NOM group, this did not reach significance (TEVAR vs. NOM, 32 vs. 17, $p=0.2$). There was a significant difference between the times from admission till TEVAR for grade I-II vs. grade III-IV (60 hrs vs. 9 hrs, $p=0.04$). Two patients (one grade I and one grade II) had their TEVAR procedures delayed for 11 and 18 days respectively, till significant infections could be cleared, questioning the need for the TEVAR at all. Eight patients with grade I had an unnecessary TEVAR and should have been observed based on SVS guidelines with NOM. Seven patients with grade III injuries that could not undergo TEVAR due to anatomy or medical conditions also had a 0% failure rate with NOM. Follow up CT scans for the 23 NOM patients showed progression in 2 patients (one from grade I to II, and one from grade II to III), no change in 18, and resolution in 3 grade I injuries.

Conclusions: Although the Society of Vascular Surgery (SVS) guidelines recommend thoracic endovascular aortic repair (TEVAR) for grade II-IV blunt thoracic aortic injuries and NOM only for grade I injuries, grade II injuries may also be safe for NOM. Given the small patient population, future multicenter studies with long term follow up will be needed to evaluate which grades can be safely observed with NOM.

IMPROVED PREDICTION OF MOF BY NON-INVASIVE ASSESSMENT OF MICROCIRCULATORY CHANGES AFTER SEVERE SHOCK AND RESUSCITATION IN TRAUMA

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Invited Discussant: Gregory Victorino, MD

Introduction: Blood product resuscitation following severe hemorrhage is associated with impaired microcirculation and have been associated to multiorgan dysfunction during inflammatory conditions such as severe sepsis and septic shock. The relationship between commonly used parameters of hypo-perfusion such as lactic acid and accurate quantitative measurements of impaired micro-circulation remains elusive. In this investigation, we assessed microcirculation in vivo and compared it with markers of hypo-perfusion measured on admission, in order to better predict the occurrence of MOF after hemorrhage.

Methods: Adult trauma patients, admitted to the ICU after interventions for hemorrhage control were prospectively included. Microcirculation was examined with side-stream dark field imaging. MOF was defined as two or more SOFA organ scores ≥ 3 during hospitalization. Associations were evaluated with simple and multiple logistic regressions (MLR) and discriminative ability with AU-ROC.

Results: Forty-three patients were included, 41 males, mean age 29.2, (SD ± 8.8). Penetrating trauma occurred in 88.7%. Median RTS was 6.9 (IQR 5.9–7.8), median ISS was 25 (IRQ 16–29). The most common bleeding sources were lung in 34.9%, liver/spleen in 32.2% and abdominal vessels in 25.6%. Mean of blood loss was 2242.2 ± 1296.9 ml. PRBC were transfused in 81.4% of the patients. Massive transfusion criteria were met in 44.7%. MOF occurred in 7 subjects (16.3%). Microcirculatory findings immediately upon arrival to ICU, were significantly lower in MOF patients. Lactic acid (LA) and base deficit were significantly higher in this subset of patients. (Table)

Table. Comparison of perfusion variables between MOF and no-MOF patients

Variable	No MOF	MOF	P	AU-ROC
Lactic acid	3.2	8.3	<0.001	0.84
Base deficit	6.8	14.3	0.002	0.79
% Perfused small vessels*	94.5%	84.9%	0.002	0.79
Micro-vascular flow index*	2.8	2.3	0.027	0.71
Functional capillary density*	8.2	6.3	<0.001	0.82
Total capillary density*	11.7	10.4	0.024	0.72

* Side-stream dark field imaging

Of the microcirculation parameters, functional capillary density (FCD) discriminated best the risk of MOF (AUROC 0.82, CI-95% 0.69-0.95). The best MLR model identified independent contribution of LA (OR 1.66, CI-95% 1.08-2.56, $p=0.022$) and FCD (OR 0.13, CI-95% 0.02-0.98, $p=0.049$) to the MOF risk, (AUROC 0.94, CI-95% 0.87-1.00).

Conclusion: Microcirculatory alterations (MA) measured here independently and significantly predicted MOF after trauma. Our ability to predict MOF was significantly improved when bedside measurements of MA were combined with LA. The hysteresis of these findings deserves further investigation.

FROM SKIN TO WITHIN – A COMPARISON OF THREE TISSUE PERFUSION MEASUREMENT TECHNIQUES AND IDENTIFICATION OF SURVIVAL THRESHOLDS

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Richard Severino MS, Mihae Yu* MD, The Queen's Medical Center

Invited Discussant: Gail Tominaga, MD

Introduction: Measuring tissue perfusion may identify states of occult shock leading to earlier treatment and shock reversal. Several non-invasive techniques provide quantitative measurements of tissue perfusion. Transcutaneous pO₂(PtcO₂) changes with PaO₂ and FiO₂ in non-shock states, but during shock, PtcO₂ approximates cardiac output with minimum response to increasing PaO₂ and PaO₂ due to vasoconstriction of the skin. This response is called the Oxygen Challenge test (OCT) and has been shown to predict organ failure, mortality, and used as an endpoint of resuscitation. An OCT value of ≥ 25 mmHg implies adequate perfusion and < 25 mmHg implies shock (1). The perfusion index (PI), based on pulse co-oximetry measurements at multiple wavelengths (Masimo, Irvine CA) provides an alternative measurement of skin and fingernail bed tissue perfusion. Near-infrared spectroscopy measurements of tissue hemoglobin oxygen saturation (StO₂, Hutchinson Technologies, Hutchinson MN) can also provide a composite measurement of skin to thenar muscle tissue oxygenation. Despite the differences between these perfusion measurements, lower values are associated with severity of illness and/or increased mortality.

Methods: Measurements of OCT, PI, and StO₂, were obtained in 79 critically-ill adults with pulmonary artery catheters during resuscitation and throughout the ICU stay. Perfusion measurements obtained near the 24-hr point of resuscitation were used in this analysis. The area under the receiver operating characteristic curve (AUROC) for survival was used to compare the three methods. Survival thresholds were selected from positive and negative predictive (PPV & NPV) curves generated for each method. Chi-squared tests were then performed at the selected thresholds.

Results: Demographics of the 79 patients were: 67 \pm 16 years of age, 49 males: 30 females, APACHE II 25.9 \pm 7.8, 49 septic shock/severe sepsis, 21 hemorrhagic shock, 19 cardiac failure, and 60 respiratory failure patients (several patients had more than one diagnosis). Fifty-five of the 79 subjects survived to discharge or transfer to other acute care facilities. The OCT demonstrated an optimal range from 15-30 mmHg and was superior to PI or StO₂ (AUROC=0.71 vs 0.67 vs 0.56, respectively.) An OCT threshold of 25 mmHg yielded a PPV=84% and NPV=67% ($p<0.001$). A PI threshold value of 2.4 yielded a PPV=82% and NPV=46% ($p=0.02$). There was no clear threshold value for StO₂ at 24hrs.

Conclusion: Noninvasive tissue perfusion measurements can provide useful information during resuscitation. In this mixed cohort of critically-ill patients, the OCT with a threshold value of 25 mmHg at 24h was most closely associated with survival. A PI of 2.4 or greater at 24h was also associated with survival. However, StO₂ at 24h was unable to demonstrate a relationship to survival in this investigation. Further investigation is needed to determine the relation of these perfusion measurements in the treatment of shock.

1) Yu M et al, Shock 2007;27:615.

COMPENSATORY RESERVE INDEX: PERFORMANCE OF A NOVEL MONITORING TECHNOLOGY TO IDENTIFY THE BLEEDING TRAUMA PATIENT

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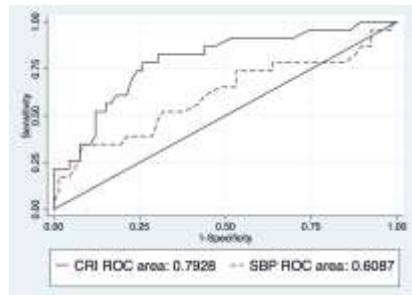
Invited Discussant: Raymond Fang, MD

Introduction: Hemorrhage is the most substantial cause of death after injury. Standard measures of systolic blood pressure (SBP) and heart rate (HR) have been demonstrated to be poor surrogate indicators of physiologic compromise until normal compensatory mechanisms have been overwhelmed. Compensatory Reserve Index (CRI) is a novel noninvasive monitoring technology that has the ability to continuously assess physiologic reserve with feature extraction of real time arterial pulse waveforms. We hypothesized that CRI would be a better predictor of physiologic compromise secondary to hemorrhage than traditional vital signs.

Methods: A prospective observational study of 89 subjects that met trauma center activation criteria at a single level I trauma center was conducted between October 2015-February 2016. The CRI finger probe device was placed on injured patients upon arrival to the trauma resuscitation unit and remained in place until admission. CRI was represented by values between 0 (no reserve) and 1 (full reserve). Data collected included patient demographics, systolic blood pressure (SBP), heart rate (HR), shock index (SI) and requirement for hemorrhage-associated Life Saving Intervention (LSI) (operation or angiography for hemorrhage, compression or tourniquet control of external bleeding, transfusion > 2 u PRBC). Using admission physiologic monitoring values, receiver-operator characteristic (ROC) curves were formulated and appropriate thresholds were calculated for prediction modeling.

Results: Using a threshold values of $SBP < 110$, $SI < 0.9$, and $CRI < 0.70$, prediction analyses were obtained. For predicting hemorrhage, CRI demonstrated a sensitivity of 83% and a negative predictive value (NPV) of 91% as compared to SBP and SI where the sensitivity to detect hemorrhage were 26% ($p < 0.05$) and 39% ($p < 0.05$) respectively. Comparing the NPV of the traditional vital signs to CRI, SBP had an associated NPV of 78% while SI had a NPV of 81%. ROC curves generated from admission CRI and SBP measures demonstrated values of 0.793 and 0.609 respectively (See Figure). CRI identified significant hemorrhage requiring therapy more reliably than SBP or SI ($p < 0.05$).

Conclusion: The CRI device outperformed standard vital signs in the acute resuscitation phase after injury. This novel monitoring technology offers promise for potential applications to triage and resuscitation of injured patients, in the field and in the hospital.



UNDERTRIAGE OF SEVERELY INJURED ADULTS IN THE UNITED STATES: WHO IS NOT GETTING TO THE RIGHT PLACE AT THE RIGHT TIME?

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Rochester

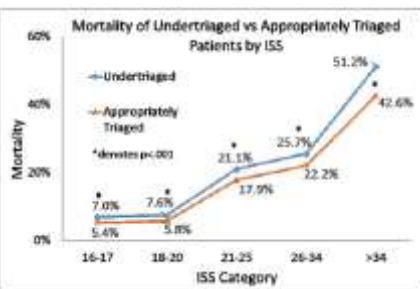
Invited Discussant: Jeffrey Salomone, MD

Introduction: Severely injured patients should receive care at high acuity trauma centers to avoid preventable mortality according to the ACS Committee on Trauma. Undertriage (UT) is said to occur when these patients are cared for at lower acuity centers. The purpose of this study was to determine if the goal UT rate of <5% was met in recent years and if characteristics of UT patients can be identified in a national cohort.

Methods: Severely injured (ISS ≥ 16) adults aged 16 years or greater were identified from the 2010-2012 National Trauma Data Bank. UT was defined as those who received definitive care or died (i.e. not transferred) at hospitals without state or ACS level I or II verification. Mortality by ISS was compared between UT and appropriately triaged patients. Multivariable logistic regression was used to determine independent risk factors for UT and the impact of UT on mortality. Covariates included patient demographics, mechanism, injury severity, and comorbidity.

Results: Of 355,510 severely injured patients, 17,433 were UT (4.9%). Younger, less severely injured, and certain minority patients were most likely to be UT (Table). After risk adjustment, older age, greater ISS, black race, and comorbidity were protective against UT while younger patients and other minorities were at increased risk of UT (all $p < .05$). Mortality was greater in UT patients regardless of ISS (Figure). This was confirmed by multivariable analysis which found greater odds of death in UT patients (OR=1.14, $p < .001$).

Covariate	Undertriaged	Appropriately Triaged	p value
Age (years)			
<18	575 (8.9%)	9994 (31.1%)	<.001
18-40	5541 (4.3%)	123563 (35.7%)	
41-64	5429 (4.5%)	116953 (35.5%)	
≥65	5493 (5.8%)	89667 (34.2%)	
Sex			
Female	3440 (5.1%)	101288 (34.9%)	<.001
Male	11993 (4.8%)	235791 (35.2%)	
Race			
White	11494 (4.3%)	242596 (35.3%)	<.001
Black	1403 (3.1%)	43350 (36.8%)	
Other minority	4536 (8.0%)	32131 (32.0%)	
ISS			
16-17	7025 (5.6%)	118470 (34.4%)	<.001
18-20	2255 (5.5%)	38688 (34.5%)	
21-25	4058 (4.7%)	81465 (35.3%)	
26-34	2751 (3.9%)	67129 (36.1%)	
≥35	1344 (4.0%)	32325 (36.0%)	



Conclusion: The UT goal of <5% was met in this study; however, a substantial number of severely injured patients received definitive care at lower acuity centers. Since this was associated with increased mortality, triage systems and trauma center capacity can be further refined to better care for these patients in the future. Patients with risk factors for UT identified in this study should be specifically targeted for improved triage.

THE LUNG RESCUE UNIT (LRU) - DOES A DEDICATED INTENSIVE CARE UNIT FOR VENO-VENOUS EXTRA-CORPOREAL MEMBRANE OXYGENATION (VV ECMO) IMPROVE SURVIVAL TO DISCHARGE?

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Invited Discussant: Lena Napolitano, MD, MPH

Introduction: The use of veno-venous extra corporeal membrane oxygenation (VV ECMO) for acute respiratory failure/distress syndrome (ARF/ARDS) has increased since 2009. Despite this, data from the international ELSO registry has not shown a statistical increase in survival to discharge. Specialized units for patients requiring VV ECMO are not standard and patients are often cohorted with other critically ill patients. The purpose of this study was to compare the survival rates to discharge from a unique, newly created, dedicated multi-disciplinary intensive care unit, with standardized care for adult patients requiring VV EVMO for ARF/ARDS, to national and international rates.

Methods: We retrospectively collected data on all adult patients admitted to the LRU between January 1st, 2015 and December 31st, 2015. All patients that were on VV ECMO for the indication of respiratory failure were enrolled. Demographics, past medical history, pre-ECMO data, indication for VV ECMO as well as duration of ECMO and survival to decannulation and discharge were recorded. Means (+ standard deviation) and medians (interquartile range [IQR]) were reported when appropriate. Pearson's chi-square statistic was used to compare survival rates. A p-value below 0.05 was considered statistically significant.

Results: 49 patients were treated with VV ECMO during the study period. Mean age was 46 years (± 16). 35 (71%) were male. Median PaO₂/FiO₂ ratio prior to cannulation was 66 (IQR 53-86). Median ventilator days prior to cannulation was 2 (IQR=1-4). Median time on VV ECMO for all patients was 311 hours (IQR=203-461). Overall, 38 (78%) patients were successfully decannulated with 35 (71%) patients surviving to hospital discharge. When compared to an international cohort from the ELSO database with survival to discharge rates of 54% for a similar VV ECMO patient population, we demonstrated a relative increase in survival to discharge of 31% (p=0.02). When compared to a similar cohort of VV ECMO patients in the United States alone, we demonstrated a 39% relative increase in survival to discharge (71% vs 51%, p=0.008).

Conclusion: The use of VV ECMO for ARF/ARDS is increasing. We have demonstrated that a dedicated multi-disciplinary intensive care unit for the purpose of providing standardized care with specialized trained providers can significantly improve survival to discharge for patients that require VV ECMO for ARF/ARDS.

PROGNOSTIC VALUE OF PRE-OPERATIVE IMAGING AND OPERATIVE FINDINGS IN YOUNG MEN WITH ACUTE APPENDICITIS

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Invited Discussant: Carlos Brown, MD

Introduction: Pre-operative imaging in suspected appendicitis is ubiquitous. Although useful in women of child-bearing age, we question its use in young men with clinical findings suggestive of appendicitis. Identifying perforated appendicitis is often cited as the indication for imaging. We sought to determine the utility of pre-operative imaging in both management strategy and effects on morbidity in young men with suspected appendicitis.

Methods: At our high-volume, public hospital we conducted a retrospective review of men 18 to 35 years of age who underwent appendectomy from December 2010 – December 2013. Appendicitis was suspected if abdominal pain was localized to the right lower quadrant. Demographics, pre-operative history and exam findings, imaging results, operative reports, and outcomes were collected. The cohort was divided based on whether they were imaged prior to operation. The primary outcome was intraoperative diagnosis of complicated appendicitis. Secondary outcomes included major morbidity (Clavien-Dindo score ≥ 2) and negative appendectomy.

Results: A total of 1164 patients underwent an appendectomy; 418 were young men and only 131 (31.3%) had no pre-operative imaging. Anorexia (45.0% vs. 33.4%, $p = 0.02$) and pain exclusively in the right lower quadrant (97.7% vs. 84.3%, $p < 0.001$) were more common among those not imaged. Time to antibiotic administration (3.1 hours vs. 6.1 hours, $p < 0.001$) and time to appendectomy (7.1 hours vs. 10.7 hours, $p < 0.001$) were greater in the imaged group. There was no difference in rates of complicated appendicitis (15.3% vs. 17.1%), negative appendectomy (3.8% vs. 2.8%) or morbidity (10.7% vs. 6.6%) between groups ($p > 0.05$). Imaging was not accurate in identifying patients with intra-operative diagnosis of complicated appendicitis (sensitivity (SEN) 28.6%, positive predictive value (PPV) 87.5%). Pre-operative imaging suggesting perforation/abscess was not associated with post-operative morbidity (SEN 5.3%, PPV 6.3%). Intra-operative findings of complicated vs. non-complicated appendicitis were more predictive of major morbidity than imaging (SEN 42.1%, specificity 84.7%, negative predictive value 95.4%). On multivariate analysis, the operative diagnosis of complicated appendicitis was the only factor associated with major morbidity (OR = 2.56, $p = 0.01$).

Conclusion: In young men with a high clinical suspicion of acute appendicitis, pre-operative CT scan does not add prognostic value over operative findings. This population should proceed directly to surgery to avoid delays to definitive care.