Opportunities for improvement in the care of adult trauma patients arriving in shock

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Contents

1 Abstract

1.1 Background

1.2 Methods

1.3 Results

1.4 Conclusion

2 Introduction

3 Introduction

3.1 Epidemiology

Trauma is a major global public health concern. It causes over four million deaths, among those younger populations are the most affected (1). Beyond the high mortality rate, trauma also imposes a substantial socio-economic burden, due to long-term disabilities and rehabilitation needs (1). Hemorrhagic shock, the second most common cause of death following trauma, is the leading preventable cause of death within the first 24 hours post-injury (2–4).

3.2 Shock classifications

Out of the clinical needs to assess the severity of trauma shock, patients can be categorized by stratifying symptoms and physiological parameters into degrees. Many different scoring systems have been developed, such as ATLS classification for hemorrhagic shock (See Table 1 (5)), Trauma Associated Severe Hemorrhage (TASH) and Assessment of Blood Consumption (ABC) scores for predicting massive transfusion (6). While none of these systems comprehensively classifies shock severity across all types of trauma shock, each aid in assessing severity through core physiological indicators. Ultimately, these classifications rely on vital signs and clinical indicators, highlighting the importance of physiological metrics in evaluating shock severity across clinical settings.

Table 1: ATLS classification for haemorrhagic shock, adapted from (5).

Parameter	**Class I**	**Class II** (Mild)	**Class III** (Moderate)	**Class IV** (Severe)
Approximate blood loss	<15%	15–30%	31–40%	>40%
Heart rate		/↑	↑	↑/↑↑
Blood pressure			/↓	↓
Pulse pressure		↓	↓	↓
Respiratory rate			/↑	↑
Urine output			↓	↓↓
Glasgow Coma Scale score			↓	↓
Base deficit	0 to –2 mEq/L	–2 to –6 mEq/L	–6 to –10 mEq/L	–10 mEq/L or less
Need for blood products	Monitor	Possible	Yes	Massive Transfusion Protocol

3.3 Trauma quality improvement and opportunities for improvement

The initial management of trauma patients is highly time-sensitive and prone to error (4,7,8). Quality Improvement (QI) initiatives address these challenges by systematically evaluating care processes and outcomes, aiming to reduce morbidity and mortality (9). Through structured quality measures and collaborative reviews, QI has strengthened trauma care and improved outcomes globally (10,11). Identifying Opportunities for Improvement (OFI) offers a broader perspective than traditional mortality reviews by also including non-fatal outcomes (9). Structured multidisciplinary morbidity and mortality (M&M) reviews are commonly used to identify OFIs. One systemic and comprehensive way to identify OFI is using the Donabedian framework, which asses the quality of care by the three categories of: structure, process, and outcome (9,12).

3.4 Shock and OFI

As mentioned before hemorrhagic shock is the leading cause of preventable death within the first 24 hours of injury (3). Patients in shock have a higher mortality rate than those not (13), with a median time to death of just 2 hours (14). Despite this, the relationship between shock, its severity, and Opportunities for Improvement (OFI) remains largely unexamined. This knowledge would help clinicians better identify and avoid preventable mistakes in shock patients who need urgent care.

3.5 Aims

This study aims to describe the types of opportunities for improvement for adult trauma patients arriving in shock, and to assess how the degree of shock is associated with opportunities for improvement.

4 Methods

4.1 Study design

We conducted a registry based retrospective cohort study, using data from the trauma registry and trauma care quality database at the Karolinska University Hospital in Solna.

4.2 Setting

The trauma registry includes patients treated at Karolinska University Hospital in Solna, which treats all major trauma in the greater metropolitan area of Stockholm. We included patients registered between 2014 and 2023. The trauma care quality database is a subset of the trauma registry and includes patients selected for review.

4.3 Participants

Inclusion in the trauma registry requires either admission through trauma team activation or presenting with an Injury Severity Score (ISS) greater than nine after admission to the Karolinska University Hopsital. Each trauma patient is then included in a morbidity and mortality review process, which involves both individual case evaluations by specialized nurses and audit filters. Patients identified with a high potential for OFIs are discussed at multidisciplinary conferences. The identified OFIs are then categorized into broad and detailed categories. The presence or absence of OFIs is determined by consensus among all participants and is documented in the trauma care quality database.

We included all patients in the trauma registry and Trauma care quality database. We excluded patients younger than 15 and/or were dead on arrival.

4.4 Variables and data sources/measurements

The outcome was defined as the presence of at least one OFI, determined by the multidisciplinary M&M conference in the trauma care quality registry. An OFI can be various types of preventable events, and can be categorized as: clinical judgment error, inadequate resources, delay in treatment, missed injury, inadequate protocols, preventable death and other errors.

The patients will be classified to different degrees of shock in parallel and separately, once with systolic blood pressure (SBP) and once with base excess (BE), regardless of their cause of shock. Based on these two parameters, the patients will be classified into four classes roughly based on the ATLS trauma shock classifications.

We included five other metrics to be adjusted for, due to potential for confounding. Pre-injury ASA and gender were categorical, meanwhile age, ISS and INR were kept continuous.

4.5 Bias

4.6 Study size

All available data in trauma registry and trauma care quality database will be included.

4.7 Quantitative variables

Table 2 shows how we defined shock according to BE and SBP. The BE parameter was divided into four classes with these cutoffs: Class I (above -2), Class II (-2 to -6), Class III (-6 to -10), and Class IV (below -10). Similarly, SBP was divided into four classes: Class I (above 110 mmHg), Class II (109-100 mmHg), Class III (99-90 mmHg), and Class IV (below 90 mmHg). This classification follows the tenth edition ATLS hemorrhage classification (5), which does not specify exact values for any parameter other than BE. To solve this, we assigned numerical SBP values to each class based on findings from Eastridge et al. and Oyetunji et al., who redefined hypotension as 110 mmHg respective 90 mmHg dependent on age(15,16). Therefore, we used 110 mmHg as the lower limit for (Class I: no shock) - (ATLS: normal SBP) and below 90 mmHg for (Class IV: clear shock) - (ATLS: clear hypotension), class 2 and 3 divided equally in between. This also aligns with the classification done by Mutschler et al.(17).

Table 2: ATLS tenth edition - Systolic blood pressure and Base excess (BD).

Parameter - original ATLS 10th edition	**Class I**	**Class II** (Mild)	**Class III** (Moderate)	**Class IV** (Severe)
Base deficit	0 to –2 mEq/L	–2 to –6 mEq/L	–6 to –10 mEq/L	–10 mEq/L or less
Systolic Blood pressure			/↓	↓
Parameter - numerical approximated SBP				
Systolic Blood pressure	>110 mmhg	109-100 mmhg	99-90 mmhg	<90 mmhg

Please note that ATLS classification defines class I for the BE parameter as (0 to -2) however, we choose to follow its original source(18), which defines class I as base deficit (Inverted BE) 2, with no lower limit (i.e. an upper limit for BE).

4.8 Statistical methods

The statistical analysis will be performed using R, a programming language and environment for statistical computing. We will present the types of OFI as percentage distributions and then visualize them in a bar chart. Unadjusted logistic regression will be used to determine the association between the OFI, and degree of shock defined separately by classifying BE and SBP roughly according to ATLS classification of hemorrhagic shock. Adjusted logistic regression will then incorporate other patient factors such as age, sex, preinjury ASA, INR, and ISS. It will be presented as odds ratios (OR) between the presence of OFI, and shock classes. The OR will be determined with 95% confidence intervals, and a significance level of 5% will be used. All statistical analysis will first be done on synthetic data and later implemented on the data collected from the trauma registry and the trauma care quality database to ensure objectivity. Missing data will be addressed by listwise deletion.

5 Results

5.1 Participants

There were a total of 14022 patients in the trauma registry. After excluding the patients younger than 15 and/or were dead on arrival, there were 12153 patients left. Out of those, 7152 patients had been reviewed for the presence of OFI. A total of 2233 patients were excluded due to missing data, resulting in 4919 patients for the final analysis.

The variable with most missing data is BE which lack the data for 1721 patients.

Table 3 - Sample characteristics showing missing data.

5.2 Descriptive data

Table 3 describes the characteristics of the study population. The study demographics median age is 39 (25, 56) and the most common gender is male, 3,506 (71%). Clinically, the median ISS is 5 which is considered minor injuries, median INR is 1,00, and the most common Preinjury ASA class is 1, at 62%.

5.3 Outcome data

Out of the 4919 patients reviewed without missing data, 281 (5.7%) patients had at least one positive OFI.

The most common broad sub-ofi category was clinical judgement error, at 103 (37%). The other three major broad sub-ofis are: inadequate resources 61 (22%), delay in treatment 49 (17%) and missed diagnosis 48 (17%). The smallest one, is other errors, at 5 (1,8%).

When classified, the most common broad sub-ofi in class 1 (no shock) is clinical judgement error both in the BE and SBP groups, while the other sub-ofi also follow a similar distribution between the groups. The largest sub-ofi continuous to be clinical judgment error for BE group in class 2, 3 and 4, at 34,6%; 31,2%; and 42,9% in this order. On other hand, the largest sub-ofi in SBP class 2 is delay in treatment at 50%. The SBP class 3 is evenly distributed between clinical judgement error and missed diagnosis at 40% each. Lastly, class 4 SBP's most common sub-ofi is clinical judgment error 46,7%.

Overall 3989 (81%) of the patients were classified as having no shock (class 1) according to the BE classification, the sum of the remaining classes accounted for 930 (19%) patients. The distribution of the classes were decreasing in numbers with increased severity, with class 2: 644 (13%), class 3: 170 (3,5%), and class 4: 116 (2,4%).

The SBP classification system sorted 4455 (91%) patients as having no shock (class 1), while the remaining classes with patients in shock accounted for 464 (9%) of all the patients. Among the classes defined with shock, class 2 was the biggest at 239 (4,9%), followed by class 4 at 127 (2,6%), and lastly class 3 with 99 (2,0%).

Table 5 - Sub-OFI, classified according to BE

Table 6 - Sub-OFI, classified according to SBP

5.4 Main results

The adjusted analyses showed only statistical significance when comparing BE class 4 to class 1, which had 63% lower odds for OFI (OR 0,37; 95% CI 0,14-0,83; p-value 0.026).

The un-adjusted analysis showed when comparing to class 1 in BE group, class 2 (OR 1,61; 95% CI 1,17-2,20; p-value 0.003) and 3 (OR 1,91; 95% CI 1,08-3,16; p-value 0.018) were significant in increased risk for OFI. For the SBP group, comparison between class 1 and class 4 showed significant increased risk (OR 2,28; 95% CI 1,26-3,85; p-value 0.004).

Table 7 and 8 adjusted log

Characteristic	**Overall** N = 7,152[1]	**No** N = 6,716[1]	**Yes** N = 436[1]	**p-value**
Age (Years)	40 (26, 56)	40 (26, 56)	45 (28, 61)	
Gender (M/F)				
Female	2,159 (30%)	2,041 (30%)	118 (27%)	
Male	4,993 (70%)	4,675 (70%)	318 (73%)	
Pre-injury ASA				
1	4,362 (61%)	4,121 (61%)	241 (55%)	
2	1,803 (25%)	1,684 (25%)	119 (27%)	
3	949 (13%)	874 (13%)	75 (17%)	
4	29 (0.4%)	28 (0.4%)	1 (0.2%)	
Unknown	9	9	0	
Systolic blood pressure (mmhg)	135 (121, 150)	135 (121, 150)	135 (120, 150)	
Unknown	123	114	9	
Injury Severity Score	9 (1, 16)	8 (1, 14)	17 (10, 24)	
Unknown	2	2	0	
OFI categories broad				
Clinical judgement error	157 (36%)	0 (NA%)	157 (36%)	
Delay in treatment	67 (15%)	0 (NA%)	67 (15%)	
Documentation Issues	14 (3.2%)	0 (NA%)	14 (3.2%)	
Inadequate protocols	21 (4.8%)	0 (NA%)	21 (4.8%)	
Inadequate resources	104 (24%)	0 (NA%)	104 (24%)	
Missed diagnosis	67 (15%)	0 (NA%)	67 (15%)	
Other errors	5 (1.1%)	0 (NA%)	5 (1.1%)	
Possibly preventable deaths	1 (0.2%)	0 (NA%)	1 (0.2%)	
Unknown	6,716	6,716	0	
Base Excess (BE)	0.8 (-1.3, 2.1)	0.9 (-1.2, 2.2)	0.0 (-2.4, 1.5)	
Unknown	1,721	1,597	124	
INR	1.00 (1.00, 1.10)	1.00 (1.00, 1.10)	1.00 (1.00, 1.10)	
Unknown	1,620	1,517	103	
Shock classification - BE				
Class 1	4,391 (81%)	4,162 (81%)	229 (73%)	
Class 2	719 (13%)	664 (13%)	55 (18%)	
Class 3	191 (3.5%)	172 (3.4%)	19 (6.1%)	
Class 4	130 (2.4%)	121 (2.4%)	9 (2.9%)	
Unknown	1,721	1,597	124	
Shock classification - SBP				
Class 1	6,356 (90%)	5,983 (91%)	373 (87%)	
Class 2	355 (5.1%)	331 (5.0%)	24 (5.6%)	
Class 3	147 (2.1%)	138 (2.1%)	9 (2.1%)	
Class 4	171 (2.4%)	150 (2.3%)	21 (4.9%)	
Unknown	123	114	9	

[1]Median (Q1, Q3); n (%)

Table 3: Sample characteristics used in regression.

Characteristic	**Overall** N = 4,919[1]	**No** N = 4,638[1]	**Yes** N = 281[1]	**p-value**
Age (Years)	39 (25, 56)	39 (25, 55)	44 (26, 60)	
Gender (M/F)				
Female	1,413 (29%)	1,341 (29%)	72 (26%)	
Male	3,506 (71%)	3,297 (71%)	209 (74%)	
Pre-injury ASA				
1	3,032 (62%)	2,874 (62%)	158 (56%)	
2	1,240 (25%)	1,163 (25%)	77 (27%)	
3	626 (13%)	580 (13%)	46 (16%)	
4	21 (0.4%)	21 (0.5%)	0 (0%)	
Systolic blood pressure (mmhg)	136 (122, 150)	136 (122, 150)	136 (120, 150)	
Injury Severity Score	5 (1, 14)	5 (1, 13)	17 (9, 22)	
OFI categories broad				
Clinical judgement error	103 (37%)	0 (NA%)	103 (37%)	
Delay in treatment	49 (17%)	0 (NA%)	49 (17%)	
Documentation Issues	9 (3.2%)	0 (NA%)	9 (3.2%)	
Inadequate protocols	6 (2.1%)	0 (NA%)	6 (2.1%)	
Inadequate resources	61 (22%)	0 (NA%)	61 (22%)	
Missed diagnosis	48 (17%)	0 (NA%)	48 (17%)	
Other errors	5 (1.8%)	0 (NA%)	5 (1.8%)	
Unknown	4,638	4,638	0	
Base Excess (BE)	0.9 (-1.2, 2.2)	0.9 (-1.1, 2.3)	0.0 (-2.4, 1.4)	
INR	1.00 (1.00, 1.10)	1.00 (1.00, 1.10)	1.00 (1.00, 1.10)	
Shock classification - BE				
Class 1	3,989 (81%)	3,783 (82%)	206 (73%)	
Class 2	644 (13%)	592 (13%)	52 (19%)	
Class 3	170 (3.5%)	154 (3.3%)	16 (5.7%)	
Class 4	116 (2.4%)	109 (2.4%)	7 (2.5%)	
Shock classification - SBP				
Class 1	4,455 (91%)	4,208 (91%)	247 (88%)	
Class 2	239 (4.9%)	225 (4.9%)	14 (5.0%)	
Class 3	98 (2.0%)	93 (2.0%)	5 (1.8%)	
Class 4	127 (2.6%)	112 (2.4%)	15 (5.3%)	

[1]Median (Q1, Q3); n (%)

6 Discussion

7 Conclusion

8 References

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Characteristic	**Class 1** N = 206[1]	**Class 2** N = 52[1]	**Class 3** N = 16[1]	**Class 4** N = 7
OFI categories broad				
Clinical judgement error	77 (37%)	18 (35%)	5 (31%)	3 (43%)
Delay in treatment	32 (16%)	12 (23%)	4 (25%)	1 (14%)
Documentation Issues	6 (2.9%)	2 (3.8%)	1 (6.3%)	0 (0%)
Inadequate protocols	5 (2.4%)	1 (1.9%)	0 (0%)	0 (0%)
Inadequate resources	46 (22%)	9 (17%)	4 (25%)	2 (29%)
Missed diagnosis	39 (19%)	8 (15%)	1 (6.3%)	0 (0%)
Other errors	1 (0.5%)	2 (3.8%)	1 (6.3%)	1 (14%)

[1]n (%)

Characteristic	**Class 1** N = 247[1]	**Class 2** N = 14[1]	**Class 3** N = 5[1]	**Class 4** N = 15
OFI categories broad				
Clinical judgement error	91 (37%)	3 (21%)	2 (40%)	7 (47%)
Delay in treatment	39 (16%)	7 (50%)	1 (20%)	2 (13%)
Documentation Issues	8 (3.2%)	1 (7.1%)	0 (0%)	0 (0%)
Inadequate protocols	4 (1.6%)	1 (7.1%)	0 (0%)	1 (6.7%)
Inadequate resources	57 (23%)	1 (7.1%)	0 (0%)	3 (20%)
Missed diagnosis	44 (18%)	1 (7.1%)	2 (40%)	1 (6.7%)
Other errors	4 (1.6%)	0 (0%)	0 (0%)	1 (6.7%)

[1]n (%)

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Characteristic	Adjusted Model				Unadjusted Model		
	Event Risk	OR[1]	95% CI[1]	p-value	OR[1]	95% CI[1]	p-value
Shock classification - BE							
Class 1	206 / 3,989 (5.2%)	—	—		—	—	
Class 2	52 / 644 (8.1%)	1.12	0.79, 1.55	0.5	1.61	1.17, 2.20	**0.003**
Class 3	16 / 170 (9.4%)	0.93	0.50, 1.62	0.8	1.91	1.08, 3.16	**0.018**
Class 4	7 / 116 (6.0%)	0.37	0.14, 0.83	**0.026**	1.18	0.49, 2.39	0.7
Age (Years)	281 / 4,919 (5.7%)	1.01	1.00, 1.01	0.10			
Gender (M/F)							
Female	72 / 1,413 (5.1%)	—	—				
Male	209 / 3,506 (6.0%)	1.10	0.84, 1.48	0.5			
Pre-injury ASA							
1	158 / 3,032 (5.2%)	—	—				
2	77 / 1,240 (6.2%)	1.05	0.77, 1.41	0.8			
3	46 / 626 (7.3%)	1.19	0.79, 1.76	0.4			
4	0 / 21 (0.00%)	0.00		>0.9			
INR	281 / 4,919 (5.7%)	1.15	0.78, 1.52	0.4			
Injury Severity Score	281 / 4,919 (5.7%)	1.06	1.05, 1.07	**<0.001**			

[1]OR = Odds Ratio, CI = Confidence Interval

Characteristic	Adjusted Model				Unadjusted Model		
	Event Risk	OR[1]	95% CI[1]	p-value	OR[1]	95% CI[1]	p-value
Shock classification - SBP							
Class 1	247 / 4,455 (5.5%)	—	—		—	—	
Class 2	14 / 239 (5.9%)	0.96	0.52, 1.64	0.9	1.06	0.58, 1.78	0.8
Class 3	5 / 98 (5.1%)	0.47	0.16, 1.13	0.13	0.92	0.32, 2.05	0.8
Class 4	15 / 127 (12%)	0.73	0.37, 1.35	0.3	2.28	1.26, 3.85	**0.004**
Age (Years)	281 / 4,919 (5.7%)	1.01	1.00, 1.01	0.076			
Gender (M/F)							
Female	72 / 1,413 (5.1%)	—	—				
Male	209 / 3,506 (6.0%)	1.13	0.85, 1.51	0.4			
Pre-injury ASA							
1	158 / 3,032 (5.2%)	—	—				
2	77 / 1,240 (6.2%)	1.03	0.76, 1.39	0.9			
3	46 / 626 (7.3%)	1.17	0.77, 1.73	0.5			
4	0 / 21 (0.00%)	0.00		>0.9			
INR	281 / 4,919 (5.7%)	1.14	0.76, 1.52	0.4			
Injury Severity Score	281 / 4,919 (5.7%)	1.06	1.05, 1.07	**<0.001**			

[1]OR = Odds Ratio, CI = Confidence Interval

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