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Original Research

Use of vital signs in predicting surgical intervention in a South African population: A cross-sectional study

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ABSTRACT

Background: While vital signs are widely obtained for trauma patients around the world, the association of these signs with surgical intervention has yet to be defined. Early detection of trauma patients requiring surgery is essential to timely intervention and reduction of morbidity and mortality.

Objective: The aim of this study was to determine the association of vital signs with surgical intervention in a South African patient population.

Methods: This retrospective cohort included 7857 trauma patients admitted at Grey's Hospital in Pietermaritzburg, South Africa over a five-year period December 2012–April 2018. Exclusion criteria included missing key data points. Variables for analysis included sex, mechanism of injury, admission Glasgow Coma Scale (GCS), systolic blood pressure, diastolic blood pressure, temperature, heart rate, and respiratory rate. Surgical intervention was defined by the need for treatment requiring time in the operating room. Data were analyzed using a univariate and multivariate logistic regression to determine an association between admission vital signs and surgical intervention and was compared to the association of the Revised Trauma Score to surgical intervention.

Results: Of the 8722 trauma patient records available, exclusion of patients with incomplete data resulted in 7857 patient records available for analysis. Two thousand two hundred and ninety-six (29.2%) patients required surgical intervention in the operating room. Multivariate analysis revealed that male sex [odds ratio (OR) 1.25, 95% confidence interval (CI) 1.06–1.48], stab wound (OR 3.42, CI 2.99–3.09), gunshot wound (OR 4.27, CI 3.58–5.09), systolic hypotension (OR 1.81, CI 1.32–2.48), hypothermia (OR 1.77, CI 1.34–2.34), tachycardia (OR 1.84, CI 1.61–2.10), and tachypnea (OR 1.26, CI 1.08–1.45) were associated with an increased likelihood of surgical intervention.

Conclusions: In this cohort of patients, the need for surgical intervention was best predicted by penetrating mechanisms of injury, tachycardia, and systolic hypotension. These data show that rapid and focused patient assessments should be used to triage patients for emergency surgery to avoid delays.

1. Background

Trauma is a leading cause of mortality and morbidity worldwide. More than 90% of trauma-related injury occurs in low- and middle-income countries [1,2]. South Africa's burden of injury is significant and, according to the National Injury Mortality Surveillance System, most often related to violence, traffic injuries, and suicide [3]. A significant proportion of trauma patients arriving at hospital emergency departments may require a surgical intervention. Trauma patients requiring surgical intervention are already at high risk of an adverse outcome [4]. There are many contributing risk factors to these adverse outcomes, but clinical characteristics and surgical indication are generally the most important [5,6]. At a systems-level, delays in emergency surgical care have also been associated with increased mortality, longer length of stay, and higher costs [7]. Thus, appropriate and rapid triage of these trauma patients is crucial [8].

Prior studies have influenced protocols that utilize admission vital signs to predict mortality and inform trauma team activation and

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management [9,10]. While the data is variable, some studies have emphasized the importance of the Glasgow Coma Score and the presence/quality of radial pulse for life-saving interventions [11], while others have analyzed shock index or sex of patient as predictors of the need for massive transfusions or surgical airways [12]. Algorithms have also been constructed to guide decision-making processes for various mechanisms of injury, but since the creation of these guidelines, very few studies have analyzed the characteristics and admission data of these patients requiring surgical interventions [9]. The aim of this study was to determine the association of vital signs and mechanism of injury with the need for surgical intervention. The objectives were to establish trends of relevant vital signs to improve triage by identifying patients who must be expedited to the operating room.

2. Methods

2.1. Study design and population

We conducted a retrospective review of over 8000 trauma patients admitted to the Pietermaritzburg Metropolitan Trauma Service (PMTS) at Grey's Hospital in Pietermaritzburg, Kwa-Zulu Natal Province (KZN), South Africa over a five-year period, from December 2012–April 2018. The records were retrieved from the regional trauma registry, known as the Hybrid Electronic Medical Record (HEMR) system. PMTS is one of the largest academic trauma centers in the western part of the province and a definitive trauma referral center for 19 rural hospitals with a total catchment population of over 3 million. The HEMR is a relational database that captures admission data, operative data, adverse events, and discharge data in realtime. For each new trauma patient, the initial encounter form serves as the patient's medical record for the entirety of their admission. This work has been reported in line with the STROCSS criteria [13]. Ethics approval was granted by the Biomedical Research Ethics Committee (BCA221/13 and BE 053/16) of this study's primary institution.

2.2. Inclusion criteria

From December 2012–April 2018, 8722 patients were admitted to the Pietermaritzburg Metropolitan Trauma Service. All patients of all ages were eligible for inclusion in the study. However, of the 8722 patient records, 865 were excluded due to missing data such as explicit triage information regarding the receipt of surgical care. Thus, 7857 patient records were included in the study.

2.3. Measurements

Vital signs were taken upon arrival to the ED. The following variables were included in the study: age, sex, mechanism of injury, systolic blood pressure (SBP, mmHg), diastolic blood pressure (DBP, mmHg), temperature (°C), pulse rate (beats per minute), respiratory rate (breaths per minute), and the Glasgow Coma Score which measures eye response [1–4], verbal response [1–5], and motor response [1–6]. Information regarding the patient's receipt of an operative intervention was also analyzed along with free text with a brief description of the intervention performed. Operative intervention was defined as any procedure requiring operating room time at any point in the trauma patient's admission. Among trauma operations, laparotomies/laparoscopies made up a third of the procedures (33.3%) followed by surgical debridement (11.5%), orthopedic procedures (7.2%), and other procedures (48.0%). The Revised Trauma Score (RTS) was also calculated for these patients to compare odds associated with surgical intervention [14]. The RTS is calculated as 0.9368(Glasgow Coma Score) + 0.7326(systolic blood pressure) + 0.2908(respiratory rate).

2.4. Analysis

All data were analyzed using R 3.6.1. Descriptive statistics, the χ^2 test, Student *t*-test, and logistic multivariate regression were used to examine factors associated with the receipt of surgical intervention. The crude models included one covariate and the outcome. We entered selected variables i.e. age, sex, and vital signs into the adjusted models using a Bonferroni correction and performed a complete case analysis. P-values < 0.05 were used to establish statistical significance.

3. Results

After excluding those missing data, 7857 patient records were available for analysis. Among these, 2296 (29.2%) required surgical intervention. The mean age of all patients was 29.4 with a standard deviation of 14.3, and this was the similar for the surgical and no surgical intervention subgroups. There were 6278 (79.9%) males, 1278 (16.3%) females, and 301 (3.8%) unknown. For the total study population, there were 4453 (56.7%) who sustained blunt trauma, 2219 (28.2%) with stab wounds, and 866 (11.0%) with gunshot wounds upon presentation. The majority (81.5%, n = 6408) of patients had a Glasgow Coma Score (GCS) upon admission between 13 and 15. Average RTS was 7.50 (SD 0.87) for the entire cohort and did differ significantly between those who did and did not receive surgical intervention ($p = 0.039$). Univariate analysis demonstrated several statistically significant differences between the surgical and non-surgical cohort for all covariates with the exception of age ($p = 0.06$). (Table 1).

Unadjusted logistic regression of these variables demonstrated that male sex, stab wound and gunshot wound mechanisms of injury, an admission Glasgow Coma Scale of 13–15, systolic hypotension, diastolic hypotension, hypothermia, fever, tachycardia, and tachypnea were all associated with the receipt of surgical intervention (Table 2). Diastolic hypertension and bradycardia were negatively associated with the receipt of surgical intervention in the univariate logistic regression.

Multivariate logistic regression demonstrated that patients who presented with a stab wound [odds ratio (OR) 3.42, 95% confidence interval (CI) 2.99–3.09, $p < 0.001$], gunshot wound (OR 4.27, CI 3.58–5.09, $p < 0.001$), or were male (OR 1.25, CI 1.06–1.48, $p = 0.008$) were more likely to require surgical intervention. Among vital sign covariates, those with tachycardia (> 100 beats per minute) (OR 1.84, CI 1.61–2.10, $p < 0.001$), systolic hypotension (< 90 mmHg) (OR 1.81, CI 1.32–2.48, $p < 0.001$), hypothermia (< 35.0 °C) (OR 1.77, CI 1.34–2.34, $p < 0.001$), or tachypnea (> 20 breaths per minute) (OR 1.26, CI 1.08–1.45, $p = 0.002$) were also more likely to require surgical intervention. Patients who were bradycardic on admission (< 60 beats per minute) were less likely to require surgical intervention (OR 0.53, CI 0.39–0.71, $p < 0.001$) (Table 3). Furthermore, a GCS of 9–12, systolic hypertension (> 130 mmHg), diastolic hypotension (< 60 mmHg) and hypertension (> 80 mmHg), bradypnea (< 12 breaths per minute), and fever (> 38.0 °C) were not significantly associated with surgical interventions. We compared our findings against the use of RTS and found that individual vital signs were more strongly associated with surgical intervention than an RTS < 6 (OR 1.23, CI 1.00–1.51, $p = 0.050$) in a multivariate model (Table 4). A subgroup analysis of laparoscopy/laparotomy demonstrated an even stronger association between the specific surgical intervention and sex (OR 1.59, CI 1.20–2.14, $p = 0.002$), stab wounds (OR 5.00, CI 4.03–6.24, $p < 0.001$), gunshot wounds (OR 7.24, CI 5.63–9.32, $p < 0.001$), tachycardia (OR 2.19, CI 1.81–2.66, $p < 0.001$), and tachypnea (OR 1.44, CI 1.16–1.78, $p < 0.001$) (Supplementary Table A). Other types of surgical intervention were not powered to conduct subgroup analyses.

4. Discussion

This study sought to identify factors associated with operative

Table 1
Demographic and clinical characteristics of patient population.

	Total (N = 7857)	Surgical Intervention (N = 2296)	No Surgical Intervention (N = 5561)	
	Mean (SD)/N (%)	Mean (SD)/N (%)	Mean (SD)/N (%)	*p-value*
Age	29.4 (14.3)	29.9 (12.6)	29.3 (15.0)	0.063
Sex				< 0.001
Female	1278 (16.3)	300 (13.1)	978 (17.6)	
Male	6278 (79.9)	1895 (82.5)	4383 (78.8)	
Missing	301 (3.8)	101 (4.4)	200 (3.6)	
Mechanism of Injury				< 0.001
Blunt	4453 (56.7)	829 (36.1)	3624 (65.2)	
Stab wound	2219 (28.2)	971 (42.3)	1248 (22.4)	
Gunshot wound	866 (11.0)	427 (18.6)	439 (7.9)	
Unknown/Other	319 (4.1)	69 (3.0)	250 (4.5)	
Revised Trauma Score	7.50 (0.87)	7.53 (0.81)	7.49 (0.89)	0.039
Admission Glasgow Coma Score				< 0.001
< 8	694 (8.8)	174 (7.6)	520 (9.4)	
9–12	552 (6.6)	122 (5.3)	430 (7.7)	
13–15	6408 (81.5)	1913 (83.3)	4495 (80.8)	
Missing	203 (2.6)	87 (3.8)	116 (2.1)	
Systolic Blood Pressure				< 0.001
Hypotensive < 90	294 (3.7)	147 (6.4)	147 (2.6)	
Normal 90-130	5053 (64.3)	1456 (63.4)	3597 (64.7)	
Hypertensive > 130	2353 (30.0)	655 (28.5)	1698 (30.5)	
Missing	156 (2.0)	38 (1.7)	118 (2.1)	
Diastolic Blood Pressure				0.001
Hypotensive < 60	1582 (20.1)	484 (21.1)	1067 (19.2)	
Normal 60-80	3869 (49.2)	1136 (49.5)	2733 (49.2)	
Hypertensive > 80	2244 (28.6)	605 (26.4)	1639 (29.5)	
Missing	161 (2.0)	40 (1.7)	121 (2.2)	
Temperature				< 0.001
Hypothermic < 35.0	319 (4.1)	139 (6.1)	180 (3.2)	
Normal 35.0-38.0	6887 (87.7)	1918 (83.5)	4969 (89.4)	
Febrile > 38.0	179 (2.3)	65 (2.8)	114 (2.1)	
Missing	471 (6.0)	174 (7.6)	297 (5.3)	
Heart Rate				< 0.001
Bradycardia < 60	474 (6.0)	77 (3.4)	397 (7.1)	
Normal 60-100	5081 (64.7)	1353 (58.9)	3728 (67.1)	
Tachycardia > 100	2238 (28.5)	844 (36.8)	1394 (25.1)	
Missing	63 (0.8)	22 (1.0)	41 (0.7)	
Respiratory Rate				< 0.001
Bradypnea < 12	219 (2.8)	67 (2.9)	152 (2.7)	
Normal 12-20	5604 (71.3)	1527 (66.5)	4077 (73.3)	
Tachypnea > 20	1581 (20.1)	559 (24.3)	1022 (18.4)	
Missing	452 (5.8)	143 (6.2)	309 (5.6)	

intervention in trauma patients in South Africa. It offers one of the largest reviews of admission data for this purpose from the Pietermaritzburg Metropolitan Trauma Service. While prior studies have suggested that certain aspects of GCS and the presence and quality of a patient's radial pulse can predict the need for life-saving interventions, few have directly analyzed the impact of vital signs on prediction of surgical intervention [11,15]. Since delays to operating room access for emergency operations have been shown to increase risk of in-hospital mortality, longer length of stay, and total hospital costs, it is critically important to triage patients most in need of an operative intervention as quickly as possible [7].

The first striking result from this study is the high rate of penetrating trauma (40.6%) versus blunt trauma (56.7%). Hospitals in high-income countries tend to see blunt trauma more commonly; in Europe, the rate of penetrating trauma is much lower, at around 4%. Penetrating trauma in the United States is somewhat higher, closer to 9% and likely related to easier access to firearms [16–18]. Both rates are significantly lower than was observed in this South African cohort. Because blunt trauma less commonly requires surgical intervention than penetrating trauma, a greater proportion of trauma is managed nonoperatively in the US and Europe than in South Africa. The high ratio of penetrating trauma in this study, and in South Africa in general, translates to a higher rate of operative intervention. While algorithms exist regarding indications for transport to the operating room when patients present with penetrating trauma (hemodynamic instability, peritonitis, impalement, evisceration, or frank blood from the nasogastric tube or upon rectal examination), few studies have demonstrated which elements of the objective data on admission are most predictive. In this study, we found that penetrating trauma was highly associated with the need for surgical intervention.

One notable finding is that being male was independently associated with the need for surgical intervention. Recently, greater attention has been paid to the importance of sex and gender-specific research in trauma and emergency medicine. Despite the fact that men more frequently present as trauma patients due to high-risk behavior and have higher mortality, it is not clear why being male is associated with a higher rate of operations on multivariate analysis [19–21]. Our results lend support to previous findings that females are less likely to be directed to trauma centers, given the disproportionately low number of female patients in this cohort, or receive surgical intervention when needed[22–24]. This may be related to differences in injury severity predominantly related to less high-risk behavior or gender bias within the healthcare system. Future research should be conducted to identify and intervene upon trauma specific to women.

Our results demonstrated that systolic hypotension, tachycardia, hypothermia, and tachypnea are all significantly associated with an increased need for surgical intervention, particularly in laparotomy/laparoscopy cases, whereas bradycardia was associated with a lower

Table 2
Crude (Unadjusted) odds ratio of selected factors influencing need for surgical intervention.

	Odds Ratio (95% CI)	*p-value*
Age	1.00 (1.00–1.01)	0.084
Sex		
Female	*Reference*	
Male	1.41 (1.23–1.62)	< 0.001
Mechanism of Injury		
Blunt	*Reference*	
Stab wound	3.40 (3.04–3.81)	< 0.001
Gunshot wound	4.25 (3.64–4.96)	< 0.001
Admission Glasgow Coma Score		
13-15	*Reference*	
9–12	0.67 (0.54–0.82)	0.001
< 8	0.79 (0.66–0.94)	0.009
Systolic Blood Pressure		
Normal 90–130	*Reference*	
Hypotensive < 90	2.47 (1.95–3.13)	< 0.001
Hypertensive > 130	0.95 (0.85–1.06)	0.388
Diastolic Blood Pressure		
Normal 60–80	*Reference*	
Hypotensive < 60	1.16 (1.02–1.32)	0.021
Hypertensive > 80	0.89 (0.79–1.00)	0.045
Temperature		
Normal 35.0-38.0	*Reference*	
Hypothermic < 35.0	2.00 (1.59–2.51)	< 0.001
Febrile > 38.0	1.48 (1.08–2.01)	0.013
Heart Rate		
Normal 60–100	*Reference*	
Bradycardia < 60	0.53 (0.41–0.68)	< 0.001
Tachycardia > 100	1.67 (1.50–1.85)	< 0.001
Respiratory Rate		
Normal 12–20	*Reference*	
Bradypnea < 12	1.18 (0.87–1.57)	0.277
Tachypnea > 20	1.46 (1.30–1.64)	< 0.001

Table 3
Logistic regression of selected factors influencing need for surgical intervention.

	Odds Ratio (95% CI)	*p-value*
Sex		
Female	*Reference*	
Male	1.25 (1.06–1.48)	0.008
Mechanism of Injury		
Blunt	*Reference*	
Stab wound	3.42 (2.99–3.09)	< 0.001
Gunshot wound	4.27 (3.58–5.09)	< 0.001
Admission Glasgow Coma Score		
13-15	*Reference*	
9–12	0.81 (0.63–1.04)	0.114
< 8	0.83 (0.65–1.04)	0.104
Systolic Blood Pressure		
Normal 90–130	*Reference*	
Hypotensive < 90	1.81 (1.32–2.48)	< 0.001
Hypertensive > 130	0.99 (0.86–1.15)	0.941
Diastolic Blood Pressure		
Normal 60–80	*Reference*	
Hypotensive < 60	1.00 (0.85–1.17)	0.963
Hypertensive > 80	0.86 (0.74–1.01)	0.072
Temperature		
Normal 35.0-38.0	*Reference*	
Hypothermia < 35.0	1.77 (1.34–2.34)	< 0.001
Febrile > 38.0	1.25 (0.86–1.79)	0.234
Heart Rate		
Normal 60–100	*Reference*	
Bradycardia < 60	0.53 (0.39–0.71)	< 0.001
Tachycardia > 100	1.84 (1.61–2.10)	< 0.001
Respiratory Rate		
Normal 12–20	*Reference*	
Bradypnea < 12	1.02 (0.72–1.43)	0.897
Tachypnea > 20	1.26 (1.08–1.45)	0.002

Table 4
Adjusted odds ratio of RTS influencing need for surgical intervention.

	Odds Ratio (95% CI)	*p-value*
RTS		
≥ 6	*Reference*	
< 6	1.23 (1.00–1.51)	0.050
Sex		
Female	*Reference*	
Male	1.07 (0.92–1.26)	0.366
Mechanism of Injury		
Blunt	*Reference*	
Stab wound	3.41 (3.01–3.86)	< 0.001
Gunshot wound	4.23 (3.58–5.00)	< 0.001

likelihood of requiring an operation. These findings are echoed by prior studies analyzing the predictive power of vital signs for clinical deterioration [25]. The literature on the utility of vital signs during trauma team activation and resuscitation is conflicting and the outcomes most commonly studied relate to overall mortality, rather than need for operative intervention [9,26]. While emergency physicians and trauma surgeons acknowledge the collection of vital signs, they are most commonly regarded as status assessment and rarely integrated into decision-making [27]. Our data demonstrate not only the use of traditional vital signs, but also the specific utility of mechanism of injury, in helping prehospital systems triage specific patients. This information should be used to determine the urgency of need for an available trauma surgery team upon patient arrival to a hospital. For example, trauma hospitals often distinguish “major traumas” that require a surgeon's presence within 15 minutes versus “minor traumas” that require a surgeon's presence within a less urgent timeframe. However, the criteria used to determine such parameters should be based on clinical evidence. Our data indicates that hypotension, tachycardia, hypothermia, and tachypnea can be used as parameters to evaluate these trauma patients, whereas data points such as GCS may not be as relevant. This triage system could then expedite transfer of the relevant patients from the trauma bay to definitive treatment in the operating room.

Although every effort was made to minimize bias in this study, there are inherent limitations to our data and subsequent analyses. This data set contains admission records spanning several years, but only contains information from patients admitted to the trauma service. Therefore, interpretation of these analyses is not applicable to non-trauma related emergency room admission potentially requiring surgical intervention. It is also possible that the omission of patients with missing data could lead to a sampling bias that may underrepresent females, but only 10% of patients were omitted from the analysis and the gender disparity we observed would still be present if all missing patients were female. Another limitation is that this data does not include information on patient comorbidities from the HEMR. However, considering that the large majority of our study population is young men, it is likely that a low rate of confounding comorbidities are present that would affect our results. Finally, this data is specifically taken from Grey's Hospital in Pietermaritzburg, Kwa-Zulu Natal Province, South Africa and prior analysis has indicated that the pattern of trauma may differ from that in high-income countries or even the Western Cape of South Africa in terms of mechanism of injury; therefore, these results should be validated in other contexts [28].

5. Conclusions

Our data suggests that mechanism of injury should be of highest priority when assessing a patient for transport to the operating room. Delays in clinical intervention can result in higher mortality, higher morbidity, and increased cost to both the patient and hospital system in the long-term. Taking special note of gender, mechanism of injury, and vital signs may contribute to more rapid triage of patients. Prehospital identification of such patients may enable hospitals to mobilize resources sooner in order to facilitate transport to operating rooms. Further study is required to establish how these factors and others outside the scope of this study can determine the likelihood of surgical intervention in other contexts.

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Ethical statement

The use of protected patient health information adhered to the ethical principles outlined in the Declaration of Helsinki as amended in 2013. Ethics approval was granted by the Biomedical Research Ethics Committee (BCA221/13 and BE 053/16) of the University of Kwa Zulu-Natal and from the Research Unit of the Department of Health, in KZN.

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CRediT authorship contribution statement

Amee D. Azad: Data curation, Writing - original draft, Software, Validation, Writing - review & editing. **Victor Y. Kong:** Conceptualization, Methodology, Supervision, Writing - review & editing. **Damian L. Clarke:** Conceptualization, Methodology, Supervision, Writing - review & editing. **Grant L. Laing:** Conceptualization, Methodology, Data curation, Writing - original draft, Supervision, Writing - review & editing. **Tiffany E. Chao:** Conceptualization, Methodology, Data curation, Writing - original draft, Supervision, Writing - review & editing.

Declaration of competing interest

The authors declare no financial disclosures or competing interests.

Appendix A. Supplementary data

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