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Research Article

Doing More with Less: A District Hospital's Early Experience with a Trauma System Implementation

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Abstract

Introduction: Segamat Hospital (SH) faces challenges in providing optimal trauma care due to multiple factors. Information on Malaysian district hospital trauma outcomes is limited. This study aimed to ascertain our trauma outcomes as well as to determine if a trauma system is a feasible means to reduce trauma mortality in the context of a resource-limited setting.

Method: SH began implementing an organized trauma system as well as a massive transfusion protocol (MTP) on 1st January 2025. This cross-sectional retrospective study included trauma cases requiring general surgical intervention from January 2021 to December 2025, whilst patients with isolated traumatic brain injuries, isolated long bone injuries, isolated burn injuries, and pediatric patients were excluded. Data on demographics, mechanism of injury, severity of injury, and outcomes were collected and analyzed. Comparison of patient outcomes pre- and post-trauma system implementation was performed.

Result: A total of 112 patients (mean age 34.5 years; 76.8% male) were included. Blunt trauma from motor vehicle accidents accounted for most of the injuries. Overall mortality and complication rates were 14.3% and 38.4%, respectively. The most common complication was acute kidney injury. Irreversible hemorrhagic shock and severe brain injuries accounted for the majority of the mortalities. Pre- and post-implementation of trauma system cohorts were similar in injury characteristics. Time to the operating room was significantly shorter after trauma system implementation (p=0.001). Although overall mortality rate remained above 10% post trauma system implementation, no deaths were attributed to massive hemorrhage, suggesting that hemorrhage-related mortality may have been reduced.

Conclusion: Our early findings suggest that an organized trauma system is not only feasible despite resource limitations, but that a context-specific trauma system may prevent deaths from massive hemorrhage without contributing to futile care. Further research is necessary to confirm our preliminary findings and explore the scalability and cost equity of trauma systems in district hospitals.

Keywords: Trauma surgery, Emergency general surgery, Surgical Trauma Care, Rural Health Services.

Introduction

According to the World Health Organization (WHO), 4.4 million people die annually due to trauma, typically affecting the working population [1]. The leading cause of death in this productive age group (15-40 years old) in Malaysia in 2023 is road traffic accidents (RTA), as reported by the Department of Statistics Malaysia (DOSM) [2]. The tenets of the 11th edition of Advanced Trauma Life Support (ATLS) strongly recommend a locally tailored trauma system that is capable of providing an organized, coordinated effort that delivers the full range of care to all injured patients with the primary goal of having the right patient get the right care at the right time [3]. Mature trauma systems have been universally found to reduce mortality rates attributed to reduced prehospital time, reduced length of stay, as well as an overall increment in quality of life, as demonstrated in higher-income countries [4]. In contrast, trauma patients in rural areas face delays in receiving

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treatment for their injuries due to delays in prehospital time as well as definitive care [5]. Due to geographical, infrastructural, and socioeconomic factors, trauma systems are highly variable both at the global and national level. In Malaysia, trauma centers are concentrated in urban areas such as state hospitals. The district of Segamat is rural in the northwest of the southern state of Johor, Malaysia, with a population of over 197,000 people [2]. Local statistics reveal that Segamat has the highest RTA mortality rate in the state of Johor – just over 5% – and the highest number of RTA fatalities when compared with any other Malaysian districts of similar population density [2]. Segamat Hospital (SH) is a unique district hospital as compared to many other Malaysian public hospitals as it serves not only the district of Segamat, but also the southern parts of the state of Pahang (i.e. Muadzam Shah) and Negeri Sembilan (i.e. Gemas). Therefore, SH services all trauma cases in a geographically large area. Although SH does not have a dedicated trauma team, it does have its own in-house general surgeons, emergency physicians (EP), orthopedic surgeons, anesthetists, radiologists, as well as blood bank services, which tend to work in-silo rather than in synchrony when handling trauma patients. Being a small district hospital, SH does not have its own trauma surgeon, neurosurgeon, vascular surgeon, or intensivist. The closest level 1 trauma center is in Johor Bahru, the capital city of the state, which is 200km away, with a rough travel time of 2.5hours by road, which reports a mortality rate of 10.8% [6].

Recognizing the high prevalence of RTAs as well as high RTA mortality rates within the district of Segamat, SH introduced a trauma system in 2025. To date, there is no published record of an organized trauma system within the district hospital setting in Malaysia. Therefore, the trauma system used in SH was tailored to cater to the limited-resource setting SH faces as a district hospital. Like other hospitals' systems, SH's trauma system is essentially a multi-team effort. The trauma alert or activation is initiated by the attending EP. Once a severely injured patient arrives at SH Emergency Department (ED), an assessment will be made as to whether the patient fulfills the criteria for a trauma alert. Our trauma system is illustrated in Figure 1. In general, the injured patient needs to fulfill one mechanism criterion and one physiological or anatomical criterion before the trauma activation cascade is initiated; however, the threshold to activate the trauma alert is at the prerogative of the EP, even if these criteria are not fulfilled. Once a trauma alert has been made, a cascade of rapid response occurs, and the patient will be quickly attended by other EPs, the General Surgical team, the anesthetic team and, on occasion, the orthopedics team. In addition, the alert also ensures that an empty Operating Room (OR) is prepared and the radiology team is alerted to the possibility of an urgent CT. SH's trauma system does not apply to the pediatric group (age <18) and patients with isolated burn injuries. In addition, it is noteworthy that our trauma system does not include poor GCS scores in its activation criteria, as practiced by many trauma centers. The main reason for this is due to the cluster system of neurosurgical services of our public health system, in which neurosurgeons, due to their limited numbers, are mainly serving in bigger tertiary centers. Most district hospitals in Malaysia do not have neurosurgeons, and most TBI cases are either transferred to tertiary centers for urgent intervention or are consulted via teleconsultation and given monitoring and update plans. Our hospital acknowledges the burden of TBI at our center; however, due to the infancy of our trauma system, the integration of neurosurgery services is an ongoing dialogue. Massive transfusion protocol (MTP) was also introduced in 2025 with the same goal of preventing the lethal triad. SH's MTP is illustrated in Figure 2. MTP can be activated by any specialist attending to the patient; however, it is generally activated by the attending surgeon and coordinated by the surgical medical officers. MTP can be triggered even when a trauma alert is not triggered. Although there is a fixed ratio of blood products given by the blood bank, the contents of each box can be tailored according to patients' needs as per the surgeon's request. Both MTP and our trauma alert system were implemented all at once after a few simulated runs. For quality improvement efforts, SH recorded the time it took for each department to review patients or carry out specific roles such as performing bedside chest and pelvic X-rays, as well as whether there were any challenges faced during each trauma call. In addition, SH recorded the indication and criteria used for each trauma activation instance and whether there was any deviation from these preset criteria. Although this trauma system is in its incipient stage, this study was conducted to determine

trauma outcomes at SH as well as to identify strategies for improving trauma outcomes at SH, especially with respect to the newly introduced trauma system in SH.

Methods

We performed a cross-sectional retrospective study of all trauma patients who needed general surgical trauma intervention from 1st January 2021 to 31st December 2025 in SH. Data on all patients who were managed surgically by the General Surgical Department during this study period were extracted from our medical record system. Cases of trauma were identified manually from our census databases, following which the authors screened for inclusion into our data pool. Only patients requiring general surgical intervention (including thoracic and vascular interventions) were included. Because all eligible patients over the five years were included (universal sampling), no sample size calculation was performed. Demographics, mechanisms and injury characteristics, type of surgical intervention, as well as outcomes data (length of stay, complication rates, and mortality) were collected. Duration from trauma to arrival at our center, as well as the duration it took to get a patient to the OR, was also recorded. Duration to the operating room was defined as the time it took for a patient to be brought to the operating room from the time of decision to operate/time of booking. Meanwhile, complications were defined as per the Clavien-Dindo classification, i.e., any deviation from the normal anticipated postoperative course. Overall complication rates as well as the rates of each major complication were documented. As a patient could have more than one complication, the overall complication rate refers to patients with at least one complication, and the rates of individual complications are not additive. Patients with isolated long bone skeletal fractures and isolated traumatic brain injury (TBI) were excluded from the study as these cases were managed by other departments, transferred out to other centers, or had teleconsultation with tertiary centers. In addition, patients with isolated burn injuries and pediatric patients were excluded from this study. All trauma patients included in the study were scored with the Injury Severity Score (ISS) and New Injury Severity Score (NISS) trauma scoring systems [6,7]. Two separate investigators collected data from case medical records to ensure inter-observer reliability. For cases in which there were differences in data entry, the case was referred to the senior-most author for adjudication.

Analysis was performed using SPSS with continuous variables as means or medians and categorical variables as frequencies and percentages. To assess injury severity, the ISS and NISS Scores were stratified into specific clinical categories. A score of 1-15 was defined as non-major trauma, and a score of >15 was utilized as a threshold for major trauma due to its established correlation with a significant increase in mortality risk [8]. To further delineate the patient population, the scores were subcategorized into 16-24 and >24, representing "severe" and "critical" trauma, respectively [9]. Additionally, the Trauma and Injury Severity Score (TRISS) was calculated, with a probability of survival (Ps) of <0.91 utilized as the threshold for severe trauma to identify patients with high-risk clinical outcomes [10,11]. Missing data were excluded from statistical analysis; meanwhile, patients with extensive missing medical records were removed from the study. Comparison for categorical variables was done using the Chi-square test. Fisher's exact test was used where expected cell counts were small. Binary logistic regression for univariate analysis, as well as Cox regression analysis, was used to ascertain factors associated with outcomes. A p-value < 0.05 was considered statistically significant, with hazard ratios reported using a confidence interval (CI) of 95%. Comparative analysis was also made to determine if the trauma system introduced in SH in 2025 had any effect on outcomes at SH. Compliance with the trauma alert system in 2025 was assessed by reviewing the attendance and plan logs of all trauma activations, as well as non-activated cases that fulfilled the alert criteria. To determine if ISS and NISS were reliable in predicting mortality in SH, area under the curve (AUC) analysis was done with receiver operating characteristic (ROC) analysis and the Youden index to determine the optimal cutoff point. The analysis of the reliability of ISS and NISS using AUC and ROC methods in our cohort was aimed at assisting the researchers in determining whether the use of these scores was relevant in our cohort in terms of reporting severity of injuries sustained, prediction of outcomes, as well as a benchmarking method against our tertiary state reference hospital, Hospital Sultanah Aminah Johor Bahru (HSAJB). This was a cross-sectional study in

which there was no direct contact with patients, nor was any personal identifying information collected, stored, or reported. Consent is therefore waived. There are no conflicts of interest to declare. This study is registered with the Malaysian National Medical Research Registry (NMRR) (NMRR ID-26-00464-AXW) and received ethical approval from the Medical Research and Ethics Committee (MREC) of Malaysia in accordance with the Declaration of Helsinki.

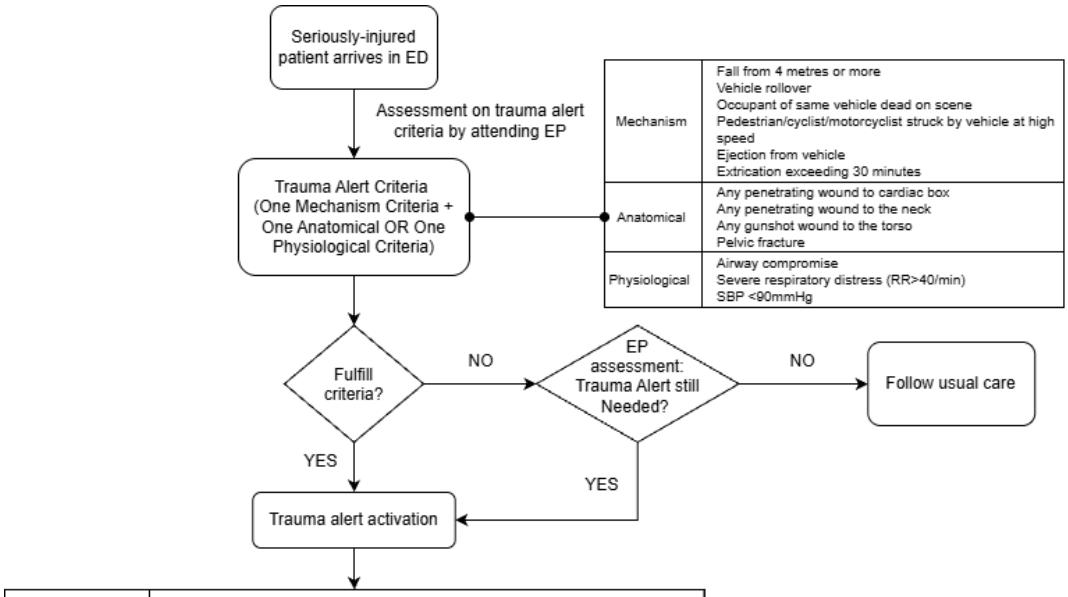
Results

Screening a total of 122 patients, 112 patients were included in the study, which was composed mainly of males in the younger age group. The 2025 cohort, i.e., post-system implementation, was completed through the end of 2025. The remainder were excluded due to significant missing data. Table 1 shows the patient characteristics. The majority of the cases resulted from blunt injury, i.e., RTA, with motorcycles and cars being the greatest number of vehicles involved. Only 62% of those involved in these RTAs used safety restraints. The most common mode of transportation to the SH post-trauma is via ambulance services. More than half of the patients arrived at SH > 60 minutes' post-trauma. About a third of patients sustained critical trauma (ISS >24 in 33.9% and NISS >24 in 37.5%).

Outcomes are as described in Table 2, with the main causes of mortality being severe brain injury. More than a third of patients (38.4%) had at least one documented complication, with the highest number of patients suffering from acute kidney Injury (AKI), followed by Hospital Acquired Pneumonia / Ventilator Associated pneumonia (HAP/VAP). About half of all patients required ICU admission. Initial univariate analysis demonstrated that among all patient factors, suffering from CKD or ESRD was associated with both mortality and complications using Fisher's exact test. However, due to the small number of patients suffering from CKD/ESRD, hazard ratios were not calculable. Multivariate analysis of the study population revealed that only the time from trauma to arrival at the ED was marginally associated with higher rates of complications (HR 1.02, CI 95% 1.003-1.038, p=0.023) after controlling for sex, age, comorbidities, mechanism of injury, GCS on arrival, duration to surgery, number of surgeries, as well as ISS and NISS scores. Although patients with complications had higher mortality (HR 9.53, CI 95% 2.52-35.96, p=0.001), Cox regression analysis did not identify any other factors associated with mortality (controlling for sex, age, comorbidities, mechanism of injury, GCS on arrival, duration to arrival and surgery, as well as number of surgeries). However, caution should be used when interpreting our multivariate analysis, as the number of events was small and therefore overfitting of our Cox models is possible given the number of events per variable.

Table 3 describes the patient characteristics and outcome differences before (2021-2024) and after the trauma system and MTP were introduced (2025). Characteristically, the patients were similar in both groups in terms of comorbidities and mechanism of injury. The proportion of patients with a GCS of 13-15 on arrival was lower after implementation, although this was not statistically significant (p=0.069); given the small numbers in each GCS category, interpretation is limited. The severity of injury sustained is similar between the cohorts, demonstrating some degree of homogeneity. As anticipated, the duration it takes for trauma patients to arrive at our ED showed no changes, as our trauma system does not integrate prehospital alerts or emergency responders such as the fire and rescue services into our trauma system. However, after the trauma system was introduced, the duration from booking to arrival in the OR was significantly shorter (p=0.001), with more patients arriving at the OR in less than 60 minutes. After the introduction of the trauma alert system in 2025, around a quarter of the patients who required surgical intervention had trauma alert activation. The investigators reviewed the attendance and plan logs of all 9 cases in which the trauma alert was activated. There were no instances where the attending EP activated the cascade outside of the alert criteria. For the remaining 27 cases of 2025 that did not utilize the trauma activation, there were 6 cases (22.2%) that fulfilled the criteria for a trauma alert although the alert was not initiated. Among the nine activations, compliance with the team response cascade was 100%, as all respective teams attended and carried out their specific roles within the stipulated time of 30 minutes. There were no deviations from the MTP where it was utilized. Despite trauma patients reaching the OR faster, the overall mortality and complication rates pre- and post-trauma systems showed no significant difference.

Nonetheless, no deaths were attributed to massive hemorrhage after the implementation of a trauma system (0/36 versus 5/76 before implementation; Fisher's exact p=0.17). When individual cases were carefully reviewed, the main reasons for the lack of improvement in the mortality rates were attributed to patients who had succumbed to severe brain injury. With regards to how well the ISS and NISS scores performed in predicting mortality in SH, Figure 3 demonstrates the ROC curve for ISS and NISS, while Table 4 demonstrates the optimal cutoff values for these scoring systems. Both scores discriminated mortality well. For ISS, the optimal cutoff is >26, marginally higher than the conventional cutoff, whilst NISS score >24 was the optimal cutoff, conforming to the conventional definition. At the conventional cutoff of >24, both scores identified 15 of 16 deaths (sensitivity 93.8%). The differences in Youden index between neighboring cutoffs were small.



Team	Action to be taken (within 30 minutes of alert)
Surgery	Urgent review by on call surgeon and team. Urgent decision making: i.e. need for urgent surgery, urgent CT imaging, MTP activation
Anaesthesiology	An empty OR is prepared. Urgent review by on call intensive care and anaesthesiologist team.
Radiology	CT suite is emptied for anticipation of urgent CT imaging Radiographer on call attends patient in ED for urgent chest and pelvic X-Rays
Blood Bank	Stand-by for possible MTP activation.
Orthopaedics	Stand-by for certain cases, i.e. massively bleeding limb injuries or pelvic injuries.

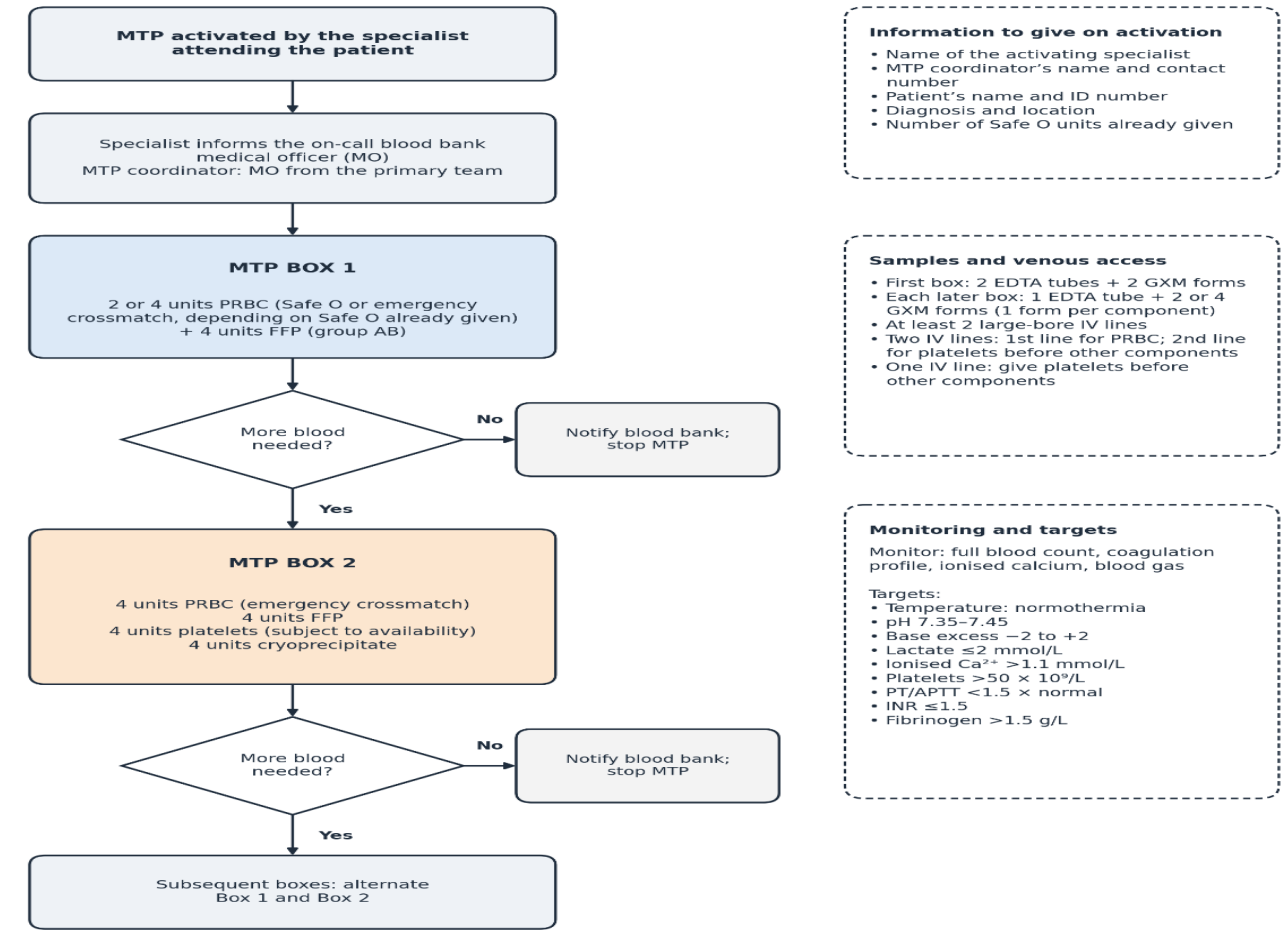
Figure 1 shows the general flow of the trauma system introduced.

Table 1. Patient Characteristics

VARIABLE	n=112 (%)
AGE in mean (SD)	34.51 (20.518)
SEX	
Male	86 (76.8%)
Female	26 (23.2%)
ETHNICITY	
Malay	74 (66.1%)
Chinese	18 (16.1%)
Indians	11 (9.8%)
Sabahans/Sarawakians	1 (0.9%)
Foreigners	8 (7.1%)
COMORBIDITIES	
Hypertension	17 (15.2%)
Diabetes	6 (5.4%)
COAD/Asthma	8 (7.1%)
CKD/ESRD	4 (3.6%)
IHD	2 (1.8%)
Cancer	2 (1.8%)
MECHANISM OF INJURY	
Blunt	99 (88.4%)
Penetrating	11(9.8%)
Blast	1 (0.9%)
Others	1 (0.9%)
LOCATION OF INJURY	
Road	83 (74.1%)
Workplace	9 (8.0%)
Home	8 (7.1%)
Recreation	1 (0.9%)
RTA CHARACTERISTICS (n=86)	
Restraint used	54 (62.8%)
Car driver/passengers	30 (34.9%)
Motorcycle rider/passengers	47 (54.7%)
Bicycle	1 (1.2%)
Heavy vehicles driver/passenger	4 (4.7%)
Pedestrian	4 (4.7%)
TRANSPORT TO SH	
Ambulance	84 (75%)
Private vehicle	27 (24.1%)
Public transport	1 (0.9%)
INTERHOSPITAL TRANSFER TO SH, n (%)	3 (2.7%)
DURATION FROM TRAUMA TO ARRIVAL AT SH (n=103) median in minutes (range)	69 (3-5760)
<60mins	46 (44.7%)
60-120mins	29 (28.2%)
>120mins	28 (27.2%)
GCS ON ARRIVAL	
3-8	9 (8%)
9-12	7 (6.3%)
13-15	96 (85.7%)
DURATION OF BOOKING TO ARRIVAL IN OR (n=65) in minutes, median (range)	60 (6-1210)
<60mins	34 (52.3%)
60-120mins	21 (32.3%)
>120mins	10 (15.4%)
ISS Score median (range)	17 (1-75)
1-15	50 (44.6%)
16-24	24 (21.4%)
>24	38 (33.9%)
NISS Score median (range)	20 (1-75)
1-5	46 (41.1%)
16-24	24 (21.4%)
>24	42 (37.5%)
TRISS median (range)	0.983 (0.04-1)
<0.91	23 (20.5%)
≥0.91	89 (79.5%)

Table 2. Overall Trauma Outcomes in SH

OUTCOMES	n=112 (%)
OVERALL MORTALITY	16 (14.3%)
LENGTH OF STAY, median in days (range)	6 (1 - 107)
ICU ADMISSION	54 (48.2%)
LENGTH OF ICU STAY, median in days (range)	6 (1 - 41)
MAIN CAUSES OF MORTALITY	(n=16)
Cardiac Events	2 (12.5%)
Irreversible Hypovolemic Shock	5 (31.3%)
Severe Brain Injury	5 (31.3%)
Sepsis	4 (25%)
OVERALL COMPLICATION RATES	43 (38.4%)
POSTOPERATIVE COMPLICATIONS RATES *(patients may have more than 1 complication)*	
HAP/VAP	21 (18.8%)
ARDS	16 (14.3%)
Surgical Site Infection	5 (4.5%)
Abdominal Compartment Syndrome	0 (0%)
Sepsis	10 (8.9%)
Cardiac events	3 (2.67%)
Limb Loss (both physical and functional)	1 (0.9%)
Thromboembolism	5 (4.5%)
CVA	2 (1.8%)
AKI	25 (22.3%)



EDTA, ethylenediaminetetraacetic acid; FFP, fresh frozen plasma; GXM, group and crossmatch; INR, international normalised ratio; MO, medical officer; MTP, massive transfusion protocol; PRBC, packed red blood cells; PT/APTT, prothrombin time/activated partial thromboplastin time.

Figure 2 shows the massive transfusion protocol (MTP) introduced in Segamat Hospital.

Table 3. Comparison of demographics and outcomes between the pre- and post-trauma system introduction

VARIABLE	PRE-TRAUMA SYSTEM (2021-2024) (n=76)	POST-TRAUMA SYSTEM (2025) (n=36)	p-value
AGE mean in years (SD)	34.8 (19.8)	33.8 (22.2)	0.321
SEX			0.037
Male	54 (71.1%)	32 (88.9)	
Female	22 (28.9%)	4 (11.1%)	
COMORBIDITIES			
Hypertension	9 (11.8%)	8 (22.2%)	0.153
Diabetes	4 (5.3%)	2 (5.6%)	0.631
COAD/Asthma	3 (3.9%)	5 (13.9%)	0.069
CKD/ESRD	3 (3.9%)	1 (2.8%)	0.614
IHD	1 (1.3%)	1 (2.8%)	0.542
Cancer	1 (1.3%)	1 (2.8%)	0.542
MECHANISM OF INJURY			0.251
Blunt	64 (84.2%)	35 (97.2%)	
Penetrating	10 (13.2%)	1 (2.8%)	
Blast	1 (1.3%)	0 (0)	
Others	1 (1.3%)	0 (0)	
INTERHOSPITAL TRANSFER TO SH, n (%)	1 (1.3%)	2 (5.6%)	0.241
DURATION FROM TRAUMA TO ARRIVAL AT SH	n=71	n=32	
Median in minutes (range)	78 (4-704)	62 (3-5760)	0.542
< 60 mins	28 (39.4%)	18 (56.3%)	0.23
60-120mins	23 (32.4%)	6 (18.8%)	
> 120 mins	20 (28.2%)	8 (25.0%)	
GCS ON ARRIVAL			0.069
3-8	6 (7.9%)	3 (8.3%)	
9-12	2 (2.6%)	5 (13.9%)	
13-15	68 (89.5%)	28 (77.8%)	
MTP ACTIVATION (n,%)	-	15 (41.7%)	-
TRAUMA ACTIVATION (n,%)	-	9 (25%)	-
DURATION OF BOOKING TO ARRIVAL IN OR	n=42	n=23	
Median in minutes (range)	67 (24-1210)	38 (6-240)	0.001
<60mins	17 (40.5%)	17 (73.9%)	0.03
60-120mins	17 (40.5%)	4 (17.4%)	
>120mins	8 (19.0%)	2 (8.7)	
ISS Score median (range)	17 (1-75)	15.5 (1-48)	
1-15	32 (42.1%)	18 (50%)	0.635
16-24	18 (23.7%)	6 (16.7%)	
>24	26 (34.2%)	12 (33.3%)	
NISS Score median (range)	20 (1-75)	20 (1-49)	
1-15	30 (39.5%)	16 (44.4%)	0.873
16-24	17 (22.4%)	7 (19.4%)	
>24	29 (38.2%)	13 (36.1%)	
TRISS median (range)	0.985 (0.04-1.0)	0.975 (0.31-0.998)	
<0.91	15 (19.7%)	8 (22.2%)	0.787
≥0.91	61 (80.3%)	28 (77.8%)	
OVERALL MORTALITY RATE	11 (14.5%)	5 (13.9%)	0.934
OVERALL COMPLICATIONS RATE	27 (35.5%)	16 (44.4%)	0.365
LENGTH OF STAY median in days (range)	6 (1-39)	8.5 (1-107)	0.159
ICU ADMISSION	36 (47.4%)	18 (50%)	0.795
LENGTH OF ICU STAY, in days (median, range)	5 (1-33)	7.5 days (1-41)	0.09
MAIN CAUSES OF MORTALITY	n=11	n=5	0.33
Cardiac Events	1 (9.1%)	1 (20.0%)	
Irreversible Hypovolemic Shock	5 (45.5%)	0 (0%)	
Severe Brain Injury	3 (27.3%)	2 (40.0%)	
Sepsis	2 (18.2%)	2 (40.0%)	

Table 4. Areas under the receiver operating characteristics (ROC) curve, Youden-optimal cutoff values and corresponding sensitivity, specificity and Youden index (J) of ISS & NISS in predicting mortality in SH

Score	AUC	95% CI	Cutoff Value	Sensitivity (%)	Specificity (%)	Youden Index (J)
ISS	0.908	0.844-0.971	>24 (conventional)	93.8	75	0.688
			>26 (optimal)	87.5	82.3	0.698
			>27	81.3	84.4	0.656
NISS	0.882	0.809-0.955	>24 (optimal)	93.8	71.9	0.656
			>26	87.5	76	0.635
			>27	81.3	79.2	0.604

Note: J = Youden index (sensitivity + specificity − 1). Cutoffs are expressed as scores greater than the stated value; the optimal cutoff is the value with the highest J. Sensitivity and specificity are based on 16 deaths and 96 survivors.

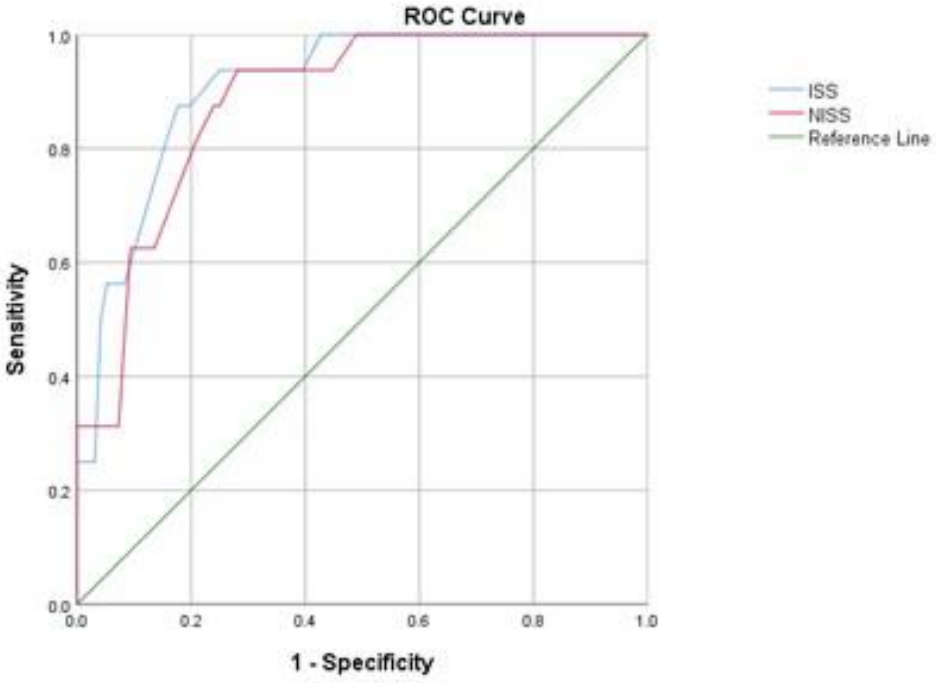


Figure 3 shows the receiver operating characteristics (ROC) curves of NISS and ISS in predicting trauma mortality. Areas under the curve were 0.908 for ISS and 0.882 for NISS; the diagonal reference line represents no discrimination (AUC 0.5).

Discussion

According to data collected by the ED of SH, the total number of trauma cases receiving care at the ED of SH in 5 years is 11,027, with an average of 2200 cases annually, predominantly involving RTAs. This is a staggering number considering the size and resources of SH. Therefore, some emphasis should be placed on preventing these RTAs in the first place. Segamat district is home to a number of hazardous roads, and data-driven road safety policies are currently being implemented, with particular emphasis on improving safety awareness — an area our cohort clearly identified as lacking [12,13]. While we remain cautiously optimistic about ongoing improvements in road safety, it is important to recognize that such changes take time; as such, this trauma system is likely to remain necessary for the foreseeable future. The burden of trauma care is therefore not to be understated, particularly in discussions surrounding cost and resource allocation. In our cohort, trauma activation was recorded in a quarter of cases, while MTP activation occurred in more than a third. Such coordinated efforts carry substantial costs — financially, in terms of blood product utilization, and in human resources — not to mention the demand placed on intensive care bed capacity. Acknowledging socioeconomic and geographical challenges, as well as resources, trauma systems are tailored around these challenges with the goal of providing definitive care within the golden hour, the delay of which harms a patient's chances of survival and is often a result of prehospital delays [14-16]. Prehospital delay is particularly pronounced in our cohort, where more than half arrive beyond the golden hour. This is likely due to the large catchment areas, limited access to rural areas, and reliance on land-based transport as the sole means of reaching patients. Therefore, if improvement is hoped for, steps to overcome the "distance penalty" need to be undertaken, which have been reported to be successful in Canada and Australia [17]. Of course, this is only one of the many systemic issues when discussing prehospital care in Malaysia, which, in general, has a long way to go in terms of reaching first-world prehospital care. Although many simple adjuncts are routinely used at the scene of the trauma, such as the cervical collar, intravenous line insertion, and pelvic binder application, there is a significant potential for the implementation of other early interventions, such as at-the-scene tranexamic acid (TXA), which has been found to improve mortality [18,19]. Additional prehospital improvements should also include transitioning paramedics from a more passive to an active role, enabling the trauma alert cascade to begin at the scene of injury, alongside fostering greater collaboration between agencies — such as the police, fire and rescue departments, and emergency departments — rather than the current paradigm in which each agency operates in isolation. Aside from prehospital trauma care, another aspect that needs further examination is the integration of neurosurgery care for TBI cases. SH's trauma system, although tailored to our center's capabilities, does not give due respect to TBI cases, which correspond to a large proportion of all our trauma cases and morbidity and mortality among severely injured patients. Due to systemic issues within Malaysia's public healthcare, our system only caters to the bleeding patient. In its current form, our system is therefore best described as a hemorrhage-focused, surgically-led trauma system rather than a comprehensive trauma system with integrated neurotrauma care. Moving forward, a pragmatic approach is not only to ensure continued dialogue and integration efforts of neurosurgery services in district healthcare, but also to consider empowering general surgeons to provide emergent neurosurgical intervention within the confines of TBI cases, especially when there are no neurosurgeons servicing a district center. From a broader standpoint, despite these shortcomings and resource limitations, our trauma alert and MTP compliance rate demonstrate that this system is feasible.

District hospitals in Malaysia do not have an established trauma system. Hence, no previous studies have been published regarding trauma systems and outcomes in district hospitals. There is a significant knowledge gap that exists on the utility of a trauma system not only within the Malaysian context but also at the international level. With a wide mortality range between studies looking into district trauma care – somewhere between 3% and 15% – as well as heterogeneity in district hospitals' management of trauma cases in terms

of population differences, definitions of a district hospital, and trauma systems, it is challenging to compare outcomes objectively [20-23]. The authors, therefore, acknowledge that a benchmark on standard of care is necessary to identify strategies for improvement. Because HSAJB serves as the tertiary trauma center for the southern region, this center was considered the reference for the standard of care. Two main measures were used to benchmark against HSAJB. Firstly, we compared the reliability of NISS and ISS scores at our center and HSAJB, and secondly, we compared outcomes. ISS and NISS scores of >24 have conventionally been used to indicate severe trauma. In our cohort, both scores discriminated mortality well, and the optimal cutoffs based on the Youden index were >26 for ISS and >24 for NISS. Our NISS findings closely align with those of HSAJB, where the NISS AUC was 0.878, and the optimal cutoff was >24 [6]. HSAJB did not report ISS, so no direct ISS benchmark is available. The optimal ISS cutoff was >26 in our cohort, which is only marginally higher than the conventional >24, with a similar Youden index (0.698 versus 0.688). The small difference in our cutoffs suggests that the ROC curve is flat in this region and that the precise position of the optimum should not be over-interpreted. Because of the small sample size and small number of events occurring, the curve generated in our analysis was step-like and therefore the confidence intervals around our AUCs were wide too. With only 16 deaths, each death represents 6.3 percentage points of sensitivity, so the reclassification of a single patient can shift the optimal cutoff. The small difference in the Youden indices for scores of 24 to 27 indicates that they are statistically difficult to distinguish in such a small sample size. Therefore, ISS cutoff >26 should be regarded as specific to this cohort rather than evidence that the conventional threshold will not hold well in our population. From a clinical outcome point of view, the conventional cutoff of >24 for both ISS and NISS offered the highest sensitivity and appears to be most appropriate for SH, especially when one considers that missing a death is costlier than over-triaging. However, when discussing resource allocation, a higher threshold may be more appropriate as specificity matters more in that context. When comparing HSAJB's mortality rate of 10.8% with our own, our higher mortality rate (14.3%) suggests room for improvement. However, the two cohorts differ in inclusion criteria, case-mix, and study period (2011–2014 for HSAJB), and the comparison should be interpreted with caution [6]. The difference in outcomes is multifactorial, i.e., resources, organized care, and the availability of a neurosurgeon, which are inherent in district care. Therefore, context-specific protocols along with structured, continuous, and formalized quality improvement (QI) efforts are needed in SH if trauma mortality is to be overcome [24-26].

Several limitations have been identified that may confound our study. First and foremost, this is a cross-sectional retrospective study; therefore, a few confounders may be present, for example, the level of experience of the in-house general surgeons and whether these surgeons may have had formal advanced operative trauma skills training is not considered (such as the Definitive Trauma Surgery Care (DSTC) Course). In addition, not all patients' information may be available in retrospect, which emphasizes the importance of appropriate documentation of patients' care, data collection, and upkeep. Secondly, there are no follow-up records for our reference to ascertain how our patients fared post-discharge. It would be valuable to determine how the index trauma, as well as post-admission complications, affected the quality of life of our patients. Thirdly, due to exclusion criteria, such as trauma patients who sustained only orthopedic or neurosurgical injuries or burn injuries, this study is not a reflection of the true burden and outcomes of all SH's trauma cases but rather a scrutiny of the more seriously injured patients handled. In addition, the number of events is relatively small for our multivariate analysis to be robust enough to draw formal associations between factors and outcomes. Likewise, the ISS and NISS cutoffs were derived and assessed in the same sample of 16 deaths without internal or external validation and should be regarded as exploratory. Finally, these data only reflect the first year of the newly minted trauma system; therefore, our findings of a reduced hemorrhage-related death post trauma system implementation may only be considered an inference, rather than a true association. Indeed, the difference in hemorrhage-related deaths (0/36 versus 5/76) was not statistically significant (Fisher's exact p=0.17), and the study was not powered to detect it—furthermore, the concurrent introduction of the trauma system and MTP complicated efforts to isolate their independent associations. Temporal trends, changes in referral

patterns, and ongoing QI initiatives are potential confounders, as the implementation of the trauma system and routine auditing may have enhanced care quality and thereby inflated apparent outcomes relative to expectations. Although marred by limitations, this research acts as a pioneer. By documenting the trauma system at SH, which manages these severely injured patients through an organized specialist-led resuscitation, this study provides the first record of how a district hospital, despite its scarce resources, can provide critical tertiary-level stabilization that allows the severely injured patients to survive. Our early results that death from massive hemorrhage, a preventable cause of death, may be reduced even in a resource-scarce setting should signal that a context-specific trauma system, although resource-intensive, is not to be considered futile, and further studies confirming the efficacy of such a system as well as the equity of cost should be undertaken alongside other prehospital strategies in trauma care.

Conclusion

Our investigation is an early account that a trauma system in a resource constrained setting was associated with a shorter time to the operating room for patients requiring surgery and may reduce haemorrhage-related mortality. This documentation of the Segamat district trauma model serves as a pioneer record, suggesting that a multidiscipline and an organised specialist-led resuscitation and structured auditing is feasible and may help overcome geographic barriers and resource constraints in district trauma care. Larger scale research to confirm our preliminary findings, explore scalability and cost equity on trauma systems in district hospitals.

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Conflict of Interest Disclosures

The authors have no competing interests to declare and have no financial interests in any material discussed in this article.

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Authors' Contributions

All authors contributed to the study conception and design and have read and approved the final manuscript.
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Ethical Statement

This study was conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki. This study was registered with the Malaysian National Medical Research Registry (NMRR) and was ethically approved by the Medical Research Ethics Committee (MREC). Registration ID: NMRR ID-26-00464-AXW.

Declaration of Generative AI and AI-assisted technologies

The authors did not use any generative AI or AI-assisted technologies in the preparation of work.

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