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ORIGINAL RESEARCH

Mortality risk in stable patients with penetrating abdominal trauma: critical timing considerations

Heng-Fu Lin[1,2], Shih-Ching Kang[3], Yu-Chi-Kuo[3], Yau-Ren Chang[1], Chih-Yuan Fu[3,4,5,*], Faran Bokhari[4,5]

[1]Division of Trauma, Department of Surgery, Far Eastern Memorial Hospital, 22000 New Taipei City, Taiwan
[2]Graduate Institute of Medicine, Yuan Ze University, 32000 Taoyuan, Taiwan
[3]Department of Trauma and Emergency Surgery, Chang Gung Memorial Hospital, Chang Gung University, 333 Taoyuan, Taiwan
[4]Department of Trauma and Burn, John H. Stroger Jr. Hospital of Cook County, Chicago, IL 60612, USA
[5]Department of Surgery, Trauma Services, OSF Healthcare St Francis Medical Center, Peoria, IL 61637, USA

***Correspondence**
fucy@cgmh.org.tw
(Chih-Yuan Fu)

Abstract

Background: The management of penetrating abdominal trauma (PAT) remains controversial, particularly for patients with stable hemodynamics. This study evaluates the influence of timing—transportation, resuscitation, and time to abdominal surgery—on the outcomes of PAT patients with stable hemodynamics. Additionally, it investigates mortality-associated factors among non-survivors in this cohort. **Methods**: A retrospective analysis of the National Trauma Data Bank (2007–2015) identified PAT patients with stable hemodynamics (systolic blood pressure $\geq$90 mmHg) who underwent abdominal operations. Patients with unstable hemodynamics or delayed surgeries (>120 hours post-admission) were excluded. Demographics, emergency medical service (EMS) response time, emergency department (ED) duration, abbreviated injury scale (AIS) of abdomen, injury severity scores (ISS), and hollow viscus injury (HVI) presence were analyzed. Multivariate logistic regression determined mortality-associated factors. **Results**: Among the 31,662 PAT patients who underwent abdominal operations, 5900 patients (18.6%) had stable hemodynamics and underwent surgery more than 2 hours after ED arrival, which was the focus of this study. Among these patients, non-survivors were older, had prolonged EMS + ED times, higher abdominal AIS and ISS scores, and an increased presence of HVI. Time to surgery was not significantly associated with mortality ($p = 0.450$). Patients with HVI demonstrated a higher risk of mortality. Subset analyses revealed that non-survivors with HVI experienced significantly longer surgical delays compared to survivors. In contrast, no significant difference in time to abdominal surgery was observed between survivors and non-survivors among patients without HVI. **Conclusions**: For stable PAT patients, delayed surgery did not correlate with increased mortality. However, prolonged preoperative delays (EMS + ED) and the presence of HVI were significant risk factors for mortality. Optimizing EMS and ED workflows and prioritizing timely interventions for HVI are critical for improving outcomes.

Keywords

Penetrating abdominal trauma; Mortality; Time to surgery

1. Introduction

The management of penetrating abdominal trauma (PAT) has been a topic of debate for decades [1]. Most patients with surgical indications, including those presenting with hemodynamic instability, evisceration or peritonitis, require an exploratory laparotomy. Delayed surgical intervention for PAT patients with clear indications leads to increased morbidity and mortality [1–4]. In cases of hemodynamic instability, immediate surgery is typically necessary, often without further evaluation or resuscitation.

However, for patients with stable hemodynamics, physicians face a dilemma between proceeding with immediate surgery, ensuring adequate resuscitation and conducting comprehensive studies. The purpose of this study was to evaluate the role of timing in various procedures such as transportation time, resuscitation time in the emergency department (ED), and time to abdominal surgery for PAT patients with stable hemodynamics.

Our hypothesis is that, in addition to the time to definitive treatment, which has been extensively studied, the condition of patients upon arrival may play a more critical role in the survival of PAT patients with stable hemodynamics. Furthermore, the characteristics of non-survivors among PAT patients with stable hemodynamics were also evaluated.

2. Materials and methods

2.1 Study design and setting

An analysis of the National Trauma Data Bank (NTDB) was conducted to identify patients with penetrating trauma,

characterized by International Classification of Disease (ICD)-9 codes 863.0–869.9 (intra-abdominal injuries), who exhibited stable hemodynamics (systolic blood pressure (SBP) >90 mmHg upon ED arrival) and underwent abdominal operations between 2007 and 2015 [5]. The original files included RDS_DCODE, RDS_ECODE and RDS_PCODE. Patients were excluded if they had non-penetrating trauma, unstable hemodynamics necessitating immediate abdominal surgery, missing key data, transfers from other hospitals or abdominal operations performed more than 120 hours post-admission. (Abdominal operations after 120 hours were excluded as these may have resulted from inaccurate records or reasons unrelated to intra-abdominal injury.) For ethical approval and consent to participate, this retrospective study was exempted by the Institutional Review Board of the Cook County Health & Hospitals System (CCHHS IRB).

General demographics (age and gender), ED conditions (SBP, respiratory rate (RR), pulse rate and Glasgow Coma Scale (GCS)), emergency medical services (EMS) response time, ED duration, time to abdominal surgery, abbreviated injury scale (AIS) of abdomen and injury severity score (ISS) were evaluated. Hemodynamic instability was defined as an SBP of less than 90 mmHg. Additionally, the presence of hollow viscus injury (HVI) was recorded as a variable. Comparisons were made between survivors and non-survivors, and independent factors associated with mortality were identified using multivariate logistic regression (MLR) analysis [6]. Subset analyses were also performed for patients with and without HVI.

2.2 Statistical analysis

We merged and analyzed all original NTDB files with R (V3.3.1) (https://cran.csie.ntu.edu.tw/). Percentages compared nominal data using the Chi-square test, and means with standard deviations compared numerical data using Student's *t*-test, considering $p < 0.05$ as statistically significant. Significant univariate factors were included in MLR analysis to assess mortality-related factors. Data entry and figure generation were done with Microsoft Excel (V16.13.1, Microsoft Corporation, Redmond, WA, USA).

3. Results

During the 9-year study period, 31,662 PAT patients who underwent abdominal operations were included in the NTDB. The median age was 32.2 years, with 28,211 males (89.1%) and 3451 females (10.9%). The mortality rate was 7.0% (2214 patients). The mean AIS for the abdomen and ISS were 2.8 and 14.8, respectively. The mean time from the ED to the operating room was 3.6 hours.

Among the 31,662 PAT patients who underwent abdominal operations, 25,268 (79.8%) received surgery within 2 hours of ED arrival (Fig. 1). Although most patients underwent surgery within this timeframe, 6394 patients (20.2%) had operations more than 2 hours after ED arrival. The patient distribution is shown in Fig. 2. A comparison between survivors and non-survivors among patients with stable hemodynamics who underwent surgery more than 2 hours after ED arrival is presented in Table 1 (a total of 5900 patients), excluding 494 patients with unstable hemodynamics. Non-survivors were significantly older (40.8 *vs.* 32.1 years, $p < 0.001$) and had longer EMS + ED times (447.5 *vs.* 337.0 minutes, $p < 0.001$), longer times to abdominal surgery (20.3 *vs.* 13.0 hours, $p < 0.001$), higher AIS of the abdomen (4.1 *vs.* 2.0, $p < 0.001$), higher ISS (26.3 *vs.* 13.5, $p < 0.001$) and a higher incidence of HVI (54.6% *vs.* 44.2%, $p = 0.014$). However, MLR analysis revealed that only increased age, EMS + ED time, AIS of the abdomen, ISS and the presence of HVI were significantly associated with non-survival. No significant association was observed between time to abdominal surgery and mortality ($p = 0.450$). The presence of HVI was associated with a 53.2% increase in non-survival compared to non-HVI patients ($p = 0.037$) (Table 2).

Two subset analyses were performed for patients with and without HVI (Tables 3 and 4). In both groups, non-survivors had significantly longer EMS + ED times (patients with HVI: 412.2 *vs.* 358.3 minutes, $p = 0.009$; patients without HVI: 369.2 *vs.* 320.3 minutes, $p < 0.001$), higher AIS of the abdomen (patients with HVI: 4.3 *vs.* 2.9, $p = 0.016$; patients without HVI: 3.8 *vs.* 2.5, $p = 0.024$) and higher ISS (patients with HVI: 23.7 *vs.* 14.3, $p < 0.001$; patients without HVI: 29.3 *vs.* 12.9, $p < 0.001$) compared to survivors. Among patients with HVI, non-survivors had a significantly longer time to abdominal surgery than survivors (23.7 *vs.* 14.1 hours, $p < 0.001$). In contrast, no significant difference in time to abdominal surgery was observed between survivors and non-survivors in patients without HVI (15.1 *vs.* 12.2 hours, $p = 0.256$).

4. Discussion

The diagnosis of PAT is often straightforward and demands prompt surgical intervention. Especially for unstable patients, surgery is typically performed without the need for extensive diagnostic evaluations, as stabilizing the patient takes precedence [1–4]. Similarly, for patients presenting with overt peritonitis or evisceration, the surgical approach is expedited [7, 8]. However, it is interesting to evaluate whether there is room for additional resuscitation and assessment in the treatment of PAT patients with stable hemodynamics.

In this study, it was observed that over 20% of the cases with stable hemodynamics who underwent surgery more than two hours after their initial presentation. This finding is notable and warrants a deeper investigation into the factors influencing this delayed surgical intervention. Were these delays a result of diagnostic uncertainty, resource availability or specific patient characteristics? Additionally, it raises the question of whether these delays had any impact on clinical outcomes, such as postoperative complications or mortality. It is reasonable that stable patients without immediate signs of hemodynamic instability or peritoneal signs may allow for further diagnostic imaging, such as focused assessment with sonography for trauma or computed tomography, to refine the surgical indication [9, 10]. Therefore, this observation appears to align with the current medical situation.

Though there was no significant difference in the time to abdominal surgery between survivors and non-survivors. Com-

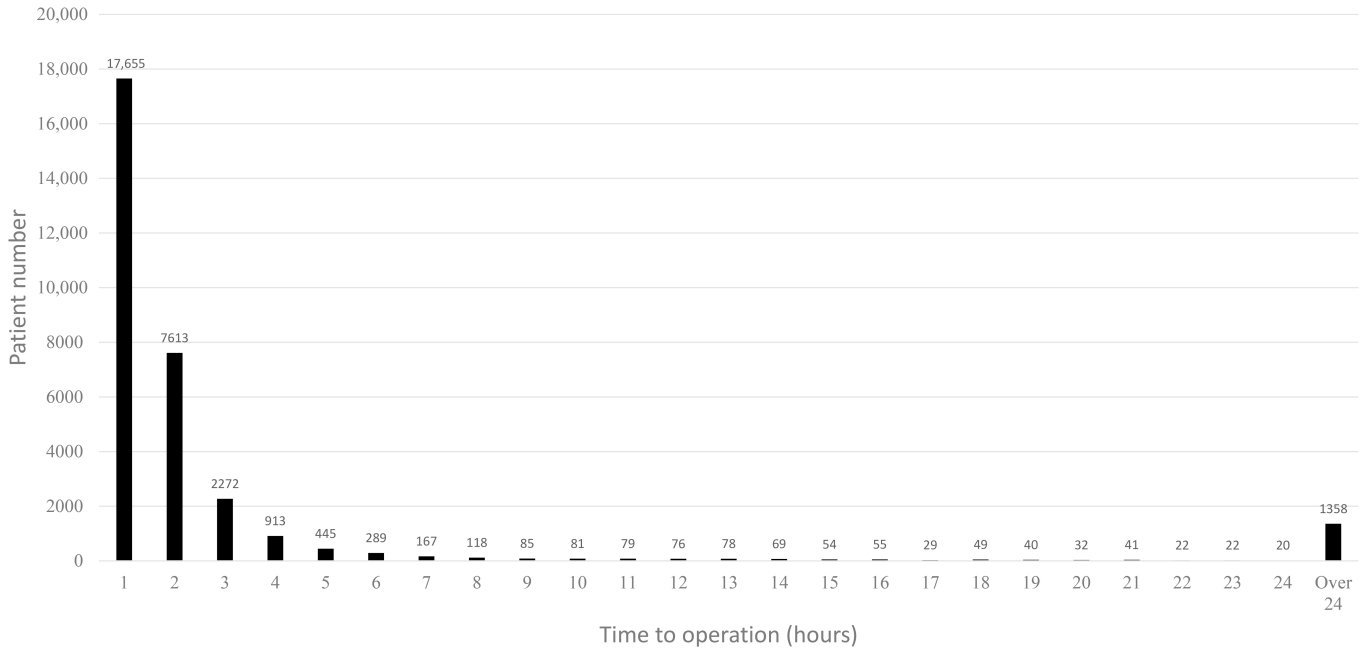

FIGURE 1. Number of patients who received abdominal operation in each hour.

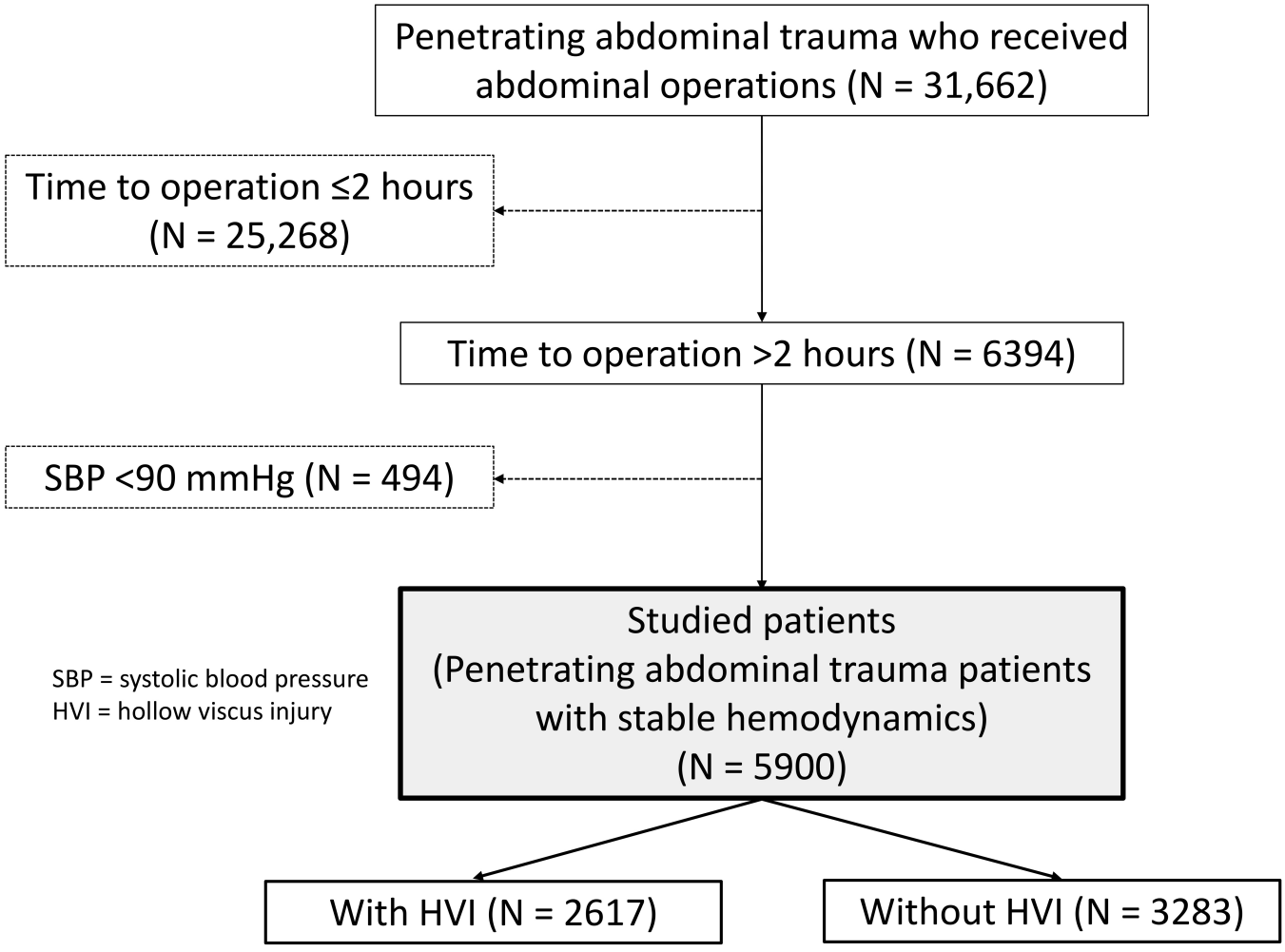

FIGURE 2. Patient distribution of the current study.

TABLE 1. Comparisons between survivors and non-survivors among PAT patients with stable hemodynamics (SBP ≥90 mmHg) (N = 5900).

PAT patients with stable hemodynamics	Non-survivors (N = 108)	Survivors (N = 5792)	*p*-value
Age (yr)	40.8 ± 18.7	32.1 ± 12.9	<0.001[$]
Male (N, %)	94 (87.0%)	5092 (87.9%)	0.887[#]
SBP in the ED (mmHg)	130.0 ± 24.7	133.0 ± 22.4	0.094[$]
Pulse in the ED (min)	96.1 ± 22.3	93.4 ± 34.5	0.181[$]
RR in the ED (min)	14.4 ± 8.0	14.7 ± 7.1	0.533[$]
GCS in ED	11.0 ± 6.1	11.8 ± 6.3	0.158[$]
EMS + ED time (min)	447.5 ± 1718.3	337.0 ± 822.5	<0.001[$]
Time to abdominal operation (h)	20.3 ± 23.2	13.0 ± 19.1	<0.001[$]
AIS of abdomen	4.1 ± 2.4	2.0 ± 0.9	<0.001[$]
ISS	26.3 ± 14.3	13.5 ± 9.7	<0.001[$]
HVI (N, %)	59 (54.6%)	2558 (44.2%)	0.014[#]

Variables are Mean ± SD.
PAT: penetrating abdominal trauma; SBP: systolic blood pressure; ED: emergency department; RR: respiratory rate; GCS: Glasgow coma scale; EMS: emergency medical service; AIS: abbreviated injury scale; ISS: injury severity score; HVI: hollow viscus injury; SD: standard deviation.
[$]*Student t test;* [#]*Chi-square test.*

TABLE 2. Multivariate logistic regression analysis of the independent risk factors for mortality among PAT patients with stable hemodynamics (SBP ≥90 mmHg) (N = 5900).

Variables	Odds of mortality	95% CI		*p*-value*
		Lower	Upper	
Age (yr)	1.044	1.022	1.068	<0.001
EMS + ED time (min)	1.008	1.003	1.015	0.011
Time to abdominal operation (h)	-	-	-	0.45
AIS of abdomen	2.411	2.096	2.638	<0.001
ISS	1.076	1.055	1.100	<0.001
HVI (N, %)	1.532	1.318	1.709	0.037

PAT: penetrating abdominal trauma; SBP: systolic blood pressure; ED: emergency department; EMS: emergency medical service; AIS: abbreviated injury scale; ISS: injury severity score; HVI: hollow viscus injury; CI: confidence interval.
**Multivariate logistic regression.*

pared with survivors, however, non-survivors had significantly longer EMS + ED time. The ability to safely delay surgery in stable patients provides an opportunity for more precise surgical planning and potentially reduces unnecessary procedures [11]. It still highlights the importance of clinical judgment and the potential risks of underestimating subtle signs of deterioration [12, 13].

For initially stable patients, the urgency to expedite treatment is theoretically lower compared to unstable patients, as their condition allows more time for thorough evaluation in the ED. However, despite this theoretical advantage, the overall transportation time and ED time—including resuscitation and diagnostic survey—should still be minimized to ensure optimal outcomes. Prolonged delays in the ED can increase the risk of complications, particularly in cases where subtle signs of deterioration may go unnoticed. In the management of PAT, the immediate need for medical intervention is often easily identified at the scene of the trauma. As a result, unnecessary examinations in the ED can and should be avoided, focusing instead on rapid decision-making and prioritizing essential interventions. This approach not only saves valuable time but also aligns with the principle of prompt and efficient trauma care.

In addition to the issue of timing, the presence of HVI has emerged as an independent risk factor for mortality in PAT patients with stable hemodynamics. Unlike solid organs, which have a more robust blood supply and tend to bleed significantly—making hemodynamic instability more apparent and prompting quicker surgical decisions—the risk of hemorrhagic shock in PAT patients with HVI is relatively lower [14]. This hemodynamic stability may partially explain why surgery is not typically performed within the first two

TABLE 3. Comparisons between survivors and non-survivors among PAT patients with stable hemodynamics (SBP ≥ 90 mmHg) and HVI (N = 2617).

PAT patients with stable hemodynamics and HVI	Non-survivor (N = 59)	Survivors (N = 2558)	*p*-value
Age (yr)	44.0 ± 19.8	32.0 ± 13.1	<0.001[$]
Male (N, %)	52 (88.1%)	2259 (88.3%)	0.862[#]
SBP in ED (mmHg)	129.5 ± 24.7	132.7 ± 22.7	0.287[$]
Pulse in the ED (min)	95.2 ± 33.4	83.2 ± 41.6	0.544[$]
RR in the ED (min)	16.2 ± 5.3	15.9 ± 4.3	0.718[$]
GCS in ED (min)	12.5 ± 4.4	14.4 ± 2.1	0.002[$]
EMS + ED time (min)	412.2 ± 388.7	358.3 ± 301.6	0.009[$]
Time to abdominal operation (h)	23.7 ± 12.0	14.1 ± 20.2	<0.001[$]
AIS of abdomen	4.3 ± 3.0	2.9 ± 1.5	0.016[$]
ISS	23.7 ± 12.0	14.3 ± 9.0	<0.001[$]

Variables are Mean ± SD.
PAT: penetrating abdominal trauma; SBP: systolic blood pressure; ED: emergency department; RR: respiratory rate; GCS: Glasgow coma scale; EMS: emergency medical service; AIS: abbreviated injury scale; ISS: injury severity score; HVI: hollow viscus injury; SD: standard deviation.
[$]*Student t test;* [#]*Chi-square test.*

TABLE 4. Comparisons between survivors and non-survivors among PAT patients with stable hemodynamics (SBP ≥90 mmHg) but without HVI (N = 3283).

PAT patients with stable hemodynamics but without HVI	Non-survivors (N = 49)	Survivors (N = 3234)	*p*-value
Age (yr)	36.9 ± 16.5	32.2 ± 12.8	0.011[$]
Male (N, %)	42 (85.7%)	2833 (87.6%)	0.862[#]
SBP in ED (mmHg)	128.4 ± 24.8	133.3 ± 22.1	0.124[$]
Pulse in the ED (min)	90.7 ± 45.9	86.1 ± 32.8	0.813[$]
RR in the ED (min)	16.0 ± 5.7	16.0 ± 5.5	1.000[$]
GCS in ED	9.1 ± 7.3	9.7 ± 7.6	0.548[$]
EMS + ED time (min)	369.2 ± 711.6	320.3 ± 414.2	<0.001[$]
Time to abdominal operation (h)	15.1 ± 17.7	12.2 ± 18.1	0.256[$]
AIS of abdomen	3.8 ± 3.2	2.5 ± 2.0	0.024[$]
ISS	29.3 ± 16.4	12.9 ± 10.2	<0.001[$]

Variables are Mean ± SD.
PAT: penetrating abdominal trauma; SBP: systolic blood pressure; ED: emergency department; RR: respiratory rate; GCS: Glasgow coma scale; EMS: emergency medical service; AIS: abbreviated injury scale; ISS: injury severity score; HVI: hollow viscus injury; SD: standard deviation.
[$]*Student t test;* [#]*Chi-square test.*

hours after ED arrival in over 20% of these cases [15–17]. The absence of overt signs of instability, however, can create a false sense of security, potentially delaying critical interventions.

Nevertheless, the clinical risk profile associated with HVI underscores the need for heightened vigilance and timely intervention. The spillage of gastrointestinal contents into the peritoneal cavity is a serious complication, as it introduces a high bacterial load and digestive enzymes, which rapidly provoke severe inflammatory responses [18]. If left untreated, this contamination can lead to diffuse peritonitis and sepsis, significantly increasing morbidity and mortality rates [19].

Further complicating the scenario, the delayed recognition of HVI can exacerbate secondary complications, such as acute kidney injury and multi-organ failure, due to the systemic inflammatory response syndrome triggered by sepsis [20–22]. These complications not only worsen patient outcomes but also pose considerable challenges for post-operative care. Studies suggest that even a slight delay in identifying and treating HVI can substantially affect survival rates, highlighting the critical need for rapid diagnostic evaluation and decision-making in stable patients with suspected HVI [11, 23].

5. Limitations

Several limitations should be considered when interpreting the results of this study. First, although our study includes a nationwide sample from the NTDB, the data may be incomplete and contain inaccuracies. Second, potential inaccuracies in the procedure codes for abdominal operations may also limit the interpretation of the results. Third, while we acknowledge that incorporating updated data would strengthen the research, the NTDB/Trauma Quality Improvement Program (TQIP) data licensing for this study covers only the years 2007–2015, and data from other years were unavailable. Despite this limitation, there have been no revolutionary changes in recent years regarding the management of penetrating abdominal trauma in stable patients. Clinical practices for these patients have remained largely consistent. Therefore, we believe the 2007–2015 data retains significant relevance to the topic under investigation. Finally, the outcomes of survivors were not thoroughly evaluated due to variability in the definitions of complications. Further studies with a prospective design and long-term follow-up are warranted to better define the impact of time to surgery on PAT patient outcomes.

6. Conclusions

For PAT patients with stable hemodynamics, no association was observed between a longer time to operation and mortality. However, shorter EMS and ED times are recommended. The presence of HVI, as well as higher abdominal AIS and ISS scores, negatively impacted patient outcomes.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

HFL and CYF—designed the research study; wrote the manuscript. SCK—performed the research. YCK, FB and YRC—analyzed the data. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

For ethical approval and consent to participate, this retrospective study was exempted by the Institutional Review Board of the Cook County Health & Hospitals System (CCHHS IRB).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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