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Risk factors of 180-day rebleeding after management of blunt splenic injury without surgery and embolization: a national database study

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Abstract

Purpose This study aimed to identify risk factors for rebleeding within 180 days post-discharge in blunt splenic injury patients managed without splenectomy or embolization.

Materials and methods A retrospective analysis was conducted using Taiwan's National Health Insurance Research Database. Adult patients aged ≥ 18 years with blunt splenic injury (ICD-9-CM codes 865.01–865.09) from 2000 to 2012 were included. Patients who died, underwent splenectomy (ICD-9-OP codes 41.5, 41.42,41.43, and 41.95) or transcatheter arterial embolization (TAE) (ICD-9-OP codes 39.79 and 99.29) on the first admission were excluded. The primary endpoint was rebleeding, which was identified if patients underwent splenectomy or TAE at 180 days after discharge. Multivariate logistic regression was used to identify risk factors, which were validated in a separate cohort.

Results Of 6,140 patients, 80 (1.302%) experienced rebleeding within 180 days. Five significant risk factors were identified: age < 54 years (aOR 3.129, $p = 0.014$), male sex (aOR 2.691, $p = 0.010$), non-traffic accident-induced injury (aOR 2.459, $p = 0.006$), ISS ≥ 16 (aOR 2.130, $p = 0.021$), and congestive heart failure (aOR 6.014, $p = 0.006$). We generate Delayed Splenic Bleeding System (DSBS). Patients with > 2 points had significantly higher rebleeding rates (risk-identifying cohort: 2.2% vs. 0.6%, OR 3.790, $p < 0.001$; validation cohort: 2.6% vs. 0.8%, OR 3.129, $p = 0.022$).

Conclusions Age < 54 years, male, non-traffic accident-induced injury, ISS ≥ 16, and congestive heart failure are risk factors of rebleeding within 180 days after discharge from treating blunt splenic injury without splenectomy or embolization. Despite limitations, this study underscores large-scale data's role in identifying risks which can aid clinicians in prioritizing additional interventions during NOM.

Keywords Blunt splenic injury, Rebleeding risk prediction, Non-operative management, Transcatheter arterial embolization, Splenectomy

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Introduction

Expert panels have suggested various protocols and guidelines for the management of splenic injuries to ensure optimal patient outcomes. Over the past two decades, non-operative management (NOM) has been recommended as the primary treatment of choice for hemodynamically stable patients to preserve their splenic function [1–3] and prevent the overwhelming post-splenectomy infection syndrome, with reported mortality rates of up to 70% [4, 5]. According to the WSES, splenic injury grade higher than IV is a potent risk factor necessitating operative management both upon patient arrival and as definitive treatment, whereas splenic injury grade higher than III is as a risk factor for angioembolization [6]. Requarth et al. observed that the estimated management failure rate without splenic artery embolization increased from 4.7 to 83.1% in patients with splenic injury grades I–V [7]. In cases of milder splenic injury, clinicians may choose NOM instead of splenectomy or arterial embolization. Peitzman et al. reported a substantial difference in mortality rates between successful and failed NOM cases, with mortality rates of less than 4% in successful cases and 16.5% in failed cases [8]. The timing of NOM failure ranges from hours to weeks after injury, with reported NOM failure rates of 16.7–25.0% [7, 9] and even up to 33% in a previous small series [10]. In Taiwan, the NOM rate of splenic injury in tertiary centers has increased from 56 to 73% [2, 11], and the success rate of NOM has reached 90% [2, 3, 7].

Delayed bleeding represents a major complication associated with NOM. Rebleeding from blunt splenic injury is indeed a scarcely documented phenomenon in literature and a rarity when juxtaposed with findings from other studies. It was first described in 1902 by Baudet [12], who noted its occurrence at 48 h after trauma. Potential mechanisms include the expansion of a subcapsular hematoma, clot disruption, or rupture of a pseudoaneurysm or splenic pseudocyst. Its incidence ranges from approximately 0.4–2% [13–15] and tends to occur between 4 and 8 days after injury [15]. It may occur within 10 days in up to 90% of cases [16], with the vast majority occurring within 14 days from the initial injury [17]. Using the North Carolina Trauma Registry, Kratzke et al. showed that among 1419 (84%) patients who were initially managed non-operatively, 2% underwent delayed splenectomy [14].

Though relatively rare, delayed splenic bleeding is associated with a significantly higher mortality rate, ranging from 5 to 15%, compared to just 1% for acute injuries [18]. Identifying patients at increased risk of delayed splenic bleeding is essential to prevent potentially fatal outcomes. However, the definition of delayed bleeding remains contentious. However, the definition of delayed bleeding remains controversial [14], often overlapping with cases of NOM failure. Previous studies have identified factors such as an Injury Severity Score (ISS) > 24, splenic injury grade > II, age > 40 years, and higher initial injury grades as predictors of NOM failure [1, 19–21], observing only the higher injury grades may elevate the risk of delayed splenic rupture, thereby augmenting the rates of failed NOM outcomes [7, 9]. To date, no clear risk factors or predictive systems have been established to identify delayed splenic bleeding in patients initially deemed not to require splenectomy or embolization [14, 22].

This study aimed to identify risk factors for rebleeding within 180 days after discharge following treatment for blunt splenic injury without splenectomy or embolization. Identifying high-risk patients could enable clinicians to easily recognize those requiring closer monitoring and prioritize additional examinations or interventions during the NOM of relatively low-grade splenic injuries initially deemed unlikely to require splenectomy or embolization.

Methods

Database

The dataset used for this study was from Taiwan's National Health Insurance Research Database (NHIRD) (registration number: NHIRD-103-246), provided by the NHI Administration and the Ministry of Health and Welfare. Data were extracted from inpatient expenditures by admission (DD file) and from the registry of beneficiaries and the Registry of Catastrophic Illness Patient Database (RCIPD) entered into the NHIRD between January 1, 1996, and December 31, 2013. The study protocol was reviewed and approved by the Institutional Review Board (approval no. EMRP-106-063). The acquisition of informed consent from patients was not required owing to the nature of the study. The STROBE guideline was used to ensure proper reporting of methods, results, and discussion.

Inclusion and exclusion criteria

Adult patients aged more than 18 years with blunt splenic injury from 2000 to 2012 were included. Blunt splenic injury was defined based on the following International Classification of Diseases-Ninth Revision (ICD-9) diagnostic codes: 865.01 (hematoma of spleen without laceration) [14], 865.02 (laceration without major disruption), 865.03 (laceration extending into the parenchyma), 865.04 (massive splenic parenchymal disruption), and 865.09 (unspecified splenic injury) [23, 24]. Patients who died on the first admission and underwent total splenectomy, partial splenectomy (ICD-9-OP codes 41.5, 41.42, 41.43 [14], and 41.95 [23, 24]) or transcatheter arterial embolization (TAE) (ICD-9-OP codes 39.79 and 99.29)

were excluded. Patients whose sex was not determined were also excluded.

Endpoint

The primary endpoint was rebleeding, which was identified if patients underwent splenectomy or TAE at 180 days after discharge. The secondary endpoints were the duration between two admissions, length of hospital stay, and mortality on the second admission. All included patients were followed up until death or removal from the NHI program, performance of rebleeding, or the end of the study on December 31, 2013, whichever came first.

Covariate assessment

The basic characteristics of the included patients, such as age, sex, and major coexisting diseases, as assessed using the Charlson Comorbidity Index score [25], were analyzed. Additionally, other comorbidities recorded in the RCIPD of the NHIRD, including dialysis, dementia, rheumatoid disease, malignancy, and severe liver disease (defined as cirrhosis with intractable ascites, hepatic encephalopathy, or esophageal variceal bleeding), were extracted. Similarly, hypertension (ICD-9: 401–405), hyperlipidemia (571.2, 571.4–6, 572.2–8, and 456.0–456.21), gout (582, 583, 585, 586, and 588), and obesity (278.0x and 278.1x) [26–29] were included as covariates.

The severity of injury was evaluated as follows: (i) patients with ISS ≥ 16 points were recorded in the RCIPD with ICD-9 diagnostic code 959.99, and (ii) intracranial hemorrhage (ICD-9 codes 852.0, 852.2, 852.4, and 853.0), hemothorax (ICD-9 codes 860.2 and 860.4), renal injury (ICD-9 code 866.xx, not 866.1), pelvic fracture (ICD-9 code 808.x) and femoral fracture (ICD-9 codes 820 and 821) [23, 24] were analyzed as covariates to evaluate the risk of rebleeding in patients.

Statistical analysis

Data extraction and randomization were conducted using MySQL software. Data analysis was performed using SPSS software version 22 (IBM Corp., Armonk, NY, USA), and descriptive statistics and contingency tables were generated. Continuous variables, such as age and duration of hospital stay, were analyzed using the Kolmogorov-Smirnov test. Non-normally distributed data were compared using the Wilcoxon rank-sum test and presented as medians (interquartile ranges), whereas normally distributed data were examined using Student's t-test and expressed as means (standard deviations). Differences in categorical variables between the risk-identifying and validation cohorts in our model were investigated using either the chi-squared test or Fisher's exact test. Patients were randomly divided into the risk-identifying cohort (80%) and the validation cohort [30–33]. Figure 1 presents the schematic for this study.

In the risk-identifying cohort, all covariates predicting rebleeding within 180 days after management without splenectomy or transcatheter arterial embolization (TAE) were analyzed using a univariate logistic regression model. Continuous variables, such as age and the number of risk factors, were converted into categorical variables based on receiver operating characteristic (ROC) curves. Factors with a p-value < 0.2 in the univariate analysis were included in a multivariable backward stepwise logistic regression model to calculate the odds ratio (OR) and regression coefficient for rebleeding within 180 days after discharge. The regression coefficient of variables significantly related to recurrence ($p < 0.05$) was multiplied by numbers and rounded to the nearest integer to create a score on an additive scale [34–37]; this score was then incorporated into the model's derivation group. The efficacy of the prediction model was evaluated in terms of discrimination, as measured using the area under the ROC curve (AUC), and calibration, as assessed using the Hosmer-Lemeshow goodness-of-fit test. Subsequently, the scoring system was used in the validation group to assess the effectiveness of the model. Statistical significance was defined as a two-sided p-value of < 0.05.

Results

A total of 12,442 adult patients with blunt splenic bleeding were identified from 2000 to 2012. After excluding 6,302 patients based on the exclusion criteria (Figs. 1), 6,140 patients were enrolled in the final analysis and then divided into the risk-identifying cohort ($n = 4,916$) and validation cohort ($n = 1,224$).

Basic characteristics

Table 1 summarizes the basic clinical characteristics of the risk-identifying cohort and validation cohort. No significant differences were observed between the two groups with respect to age, sex, severity of trauma, accompanying bleeding, and comorbidities, except for hyperlipidemia (3.66% in the risk-identifying cohort vs. 2.21% in the validation cohort; $p = 0.043$).

80 (1.302%) enrolled patients suffered from rebleeding that required splenectomy or TAE within 180 days after discharge with median duration 6 days (Range 0-180 days) from discharge. 43 patients (53.75%) suffered rebleeding within 7 days, 17.5% within 8–14 days, and 8.75% within 15–30 days after discharge from initial injury (Fig. 2). No in-hospital mortality was reported in either group. The proportion of patients who underwent splenectomy and TAE was similar between the two groups. Moreover, the length of hospital stays on the second admission, duration between the first and second admissions, and duration between the first discharge and second admission were similar between the two groups (Table 1).

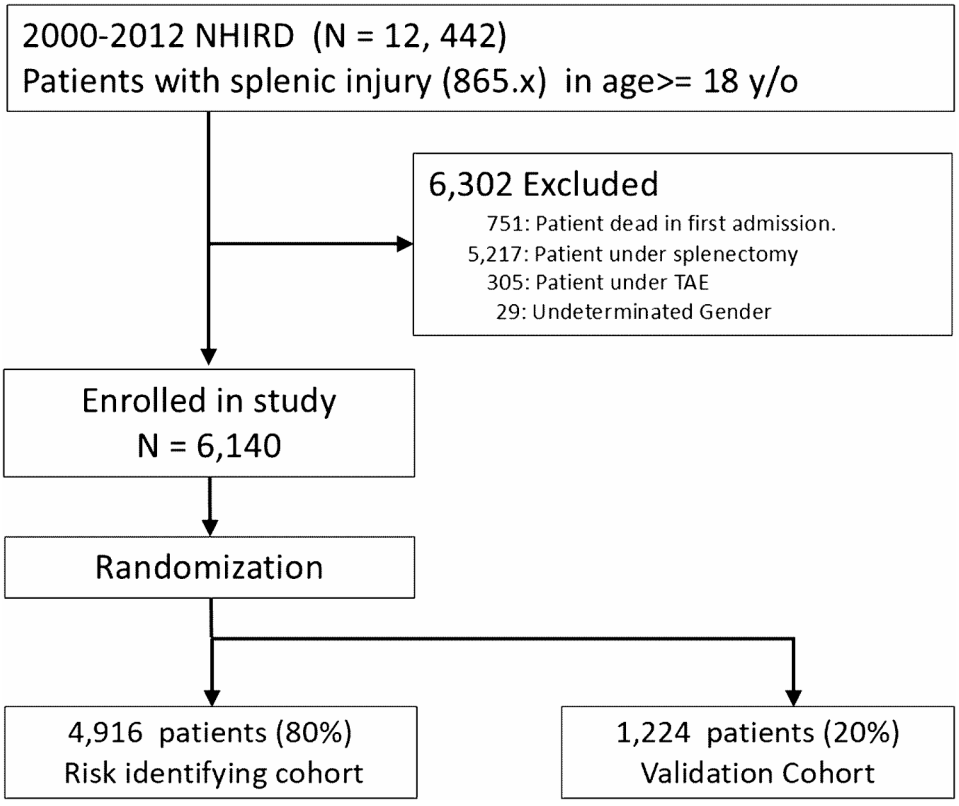

Fig. 1 Study algorithms

Identification of risk factors for 180-Day rebleeding

Multivariate analysis conducted on the risk-identifying cohort (Table 2) revealed five significant risk factors for rebleeding within 180 days following NOM of blunt splenic injury including age < 54 years (adjust Odds Ratio(aOR) 3.129, 95%CI = 1.255-7.800, $p = 0.014$), male sex (aOR 2.691, 95%CI = 1.271–5.698, $p = 0.010$), non-traffic accident-induced injury (aOR 2.459, 95%CI = 1.302–4.646, $p = 0.006$), ISS ≥ 16 (aOR 2.130, 95%CI = 1.121–4.049, $p = 0.021$), and history of congestive heart failure (aOR 6.014, 95%CI = 1.656–21.844, $p = 0.006$).

Generation of the scoring system for the prediction of delayed splenic bleeding

We tested several scoring systems to obtain the scoring system with the highest reliability and calibration. As a result, the Delayed Splenic Bleeding System (DSBS) (Table 3) was generated for these patients based on the following factors: age < 54 years (1 point), male sex (1 point), non-traffic accident-induced injury (1 point), ISS ≥ 16 (1 point), and history of congestive heart failure (2 points). Table 4 presents the distribution of included patients based on the number of risk factors present. In the risk-identifying cohort, the rebleeding rate within 180 days after discharge increased progressively with the number of risk factors: 0% in patients without risk factors, 0.4% in those with 1 point, 0.7% in those with 2 points, 2.0% in those with 3 points, and 3.3% in patients with 4 points, 8.3% in patients with 5 points, and 100% in patients with 6 points.

Using a receiver operating characteristic (ROC) curve, we evaluated the relationship between the risk scores a patient has and the likelihood of rebleeding episodes. The area under the curve (AUC) was 0.686 (95% CI: 0.623–0.749, $p < 0.001$) with good calibration (Hosmer-Lemeshow $\chi 2 = 0.257$, $p = 0.879$) and a cut-off value of > 2 points. Patients were divided into groups based on whether they had more than two points (Table 5).

Having more than two risk factors significantly increases the risk of rebleeding

In the risk-identifying cohort, patients with more than two points demonstrated a higher rebleeding rate (2.2% vs. 0.6% for those with ≤ 2 points; OR: 3.790, 95% CI: 2.159–6.653, $p < 0.001$) and an increased likelihood of requiring splenectomy (OR: 3.176, $p < 0.001$) for rebleeding episodes. However, there was no significant difference in time to recurrence from discharge (Median 5.5 days for patients with > 2 points vs. 7 days for those with ≤ 2 points; $p = 0.961$).

Similarly, in the validation cohort, the AUC was 0.650 ($p = 0.025$) with good calibration (Hosmer-Lemeshow $\chi 2 = 1.485$, $p = 0.476$) using ROC curve. Patients with

Table 1 Clinical characteristics

	Risk identifying Cohort		Validation Cohort		
	***N*=**	**4916**	***N*=**	**1224**	***p***
Age, median (IQR) y	35.46	(27.50)	38.00	(27.81)	0.324
Sex					
Female	1503	30.57%	367	29.98%	0.703
Male	3413	69.43%	857	70.02%	
Trauma severity					
Traffic accident	1882	38.28%	466	38.07%	0.895
Spleen laceration severity					0.455
Hematoma of spleen without laceration	669	13.61%	180	14.71%	
Capsular tears without parenchymal injury	289	5.88%	82	6.70%	
Laceration into parenchyma	429	8.73%	99	8.09%	
Massive parenchymal disruption	1062	21.60%	275	22.47%	
Unspecified splenic injury	2467	50.18%	588	48.04%	
ISS ≥ 16	512	10.41%	151	12.34%	0.057
Accompanying damage					
Intracranial hemorrhage	238	4.84%	55	4.49%	0.653
Hemothorax	787	16.01%	203	16.58%	0.633
Blunt hepatic injury	600	12.21%	153	12.50%	0.770
Blunt renal injury	600	12.21%	153	12.50%	0.770
Pelvic fracture	212	4.31%	46	3.76%	4.260
Femoral fracture	182	3.70%	44	3.59%	0.932
Length of hospitalization, median (IQR)	8	(8)	8	(7)	0.355
Major coexisting disease					
Myocardial infarction	18	0.37%	7	0.57%	0.316
Congestive heart failure	84	1.71%	13	1.06%	0.123
Vascular disease	23	0.47%	7	0.57%	0.647
Cerebrovascular disease	137	2.79%	35	2.86%	0.923
Dementia	7	0.14%	4	0.33%	0.246
Chronic pulmonary disease	166	3.38%	43	3.51%	0.792
Rheumatic disease	22	0.45%	5	0.41%	1.000
Peptic ulcer disease	330	6.71%	81	6.62%	0.949
Severe liver disease	58	1.18%	16	1.31%	0.663
Diabetes mellitus	311	6.33%	73	5.96%	0.692
Hemiplegia	38	0.77%	6	0.49%	0.348
On dialysis	19	0.39%	2	0.16%	0.408
Malignancy	138	2.81%	36	2.94%	0.773
HTN	434	8.83%	112	9.15%	0.736
Hyperlipidemia	165	3.36%	27	2.21%	**0.043***
Gout	126	2.56%	31	2.53%	1.000
Obesity	7	0.14%	2	0.16%	0.697
Rebleeding requiring interventions	**61**	**1.24%**	**19**	**1.55%**	0.398
Splenectomy	54	88.52%	17	89.47%	1.000
Transcatheter arterial embolization	7	11.48%	2	10.53%	1.000
Length of hospitalization, median (IQR)	9	(8)	10	(6)	0.919
In-hospital mortality	0	0.00%	0	0.00%	
Duration from discharge	7	(19)	5	(12)	0.667
Duration from the first admission	18	(24)	12	(16)	0.553

* $p < 0.05$

more than two risk factors demonstrated a higher rebleeding rate (2.6% vs. 0.8% for those with ≤ 2 points; OR: 3.129, 95% CI: 1.181–8.289, $p = 0.022$). However, the risk of splenectomy was not significantly different between the groups (OR: 2.637, $p = 0.058$). The time to recurrence from discharge also remained comparable (Median 8 days for patients with > 2 points vs. 5 days for those with ≤ 2 points; $p = 0.476$).

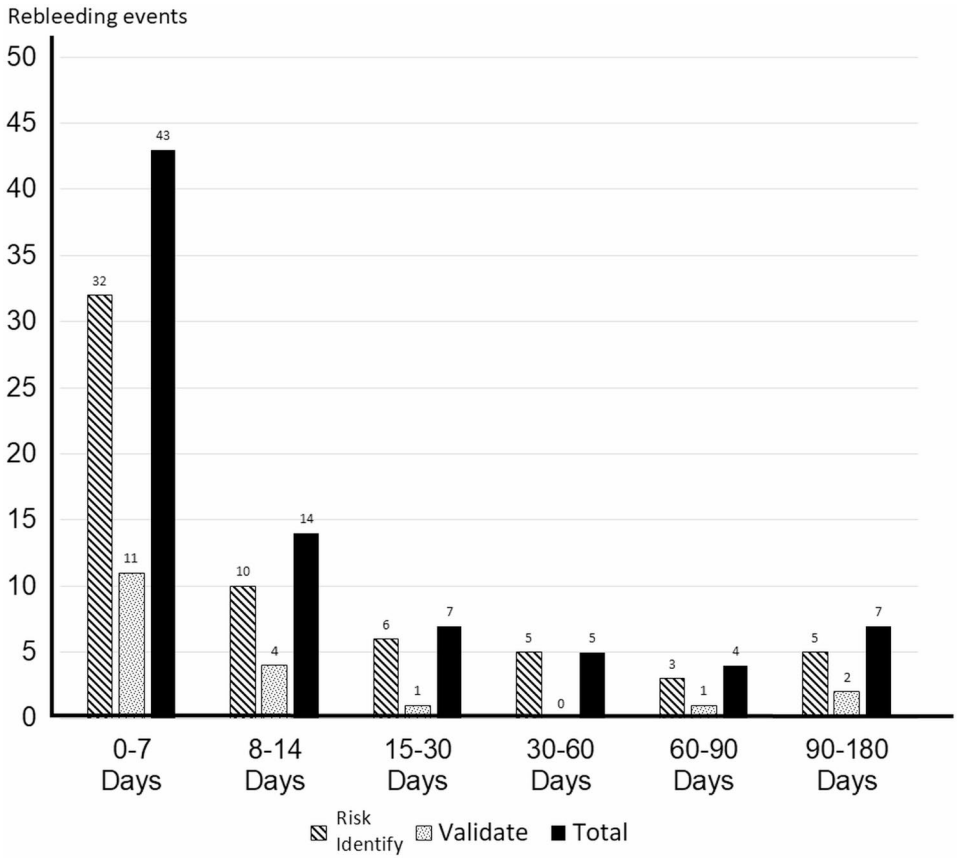

Fig. 2 Days from discharge to Delayed Splenic Bleeding events

Discussion

This study analyzed data from Taiwan's National Health Insurance Research Database to identify risk factors for delayed rebleeding following non-operative management (NOM) of blunt splenic injuries. Among 6,140 patients, 80 (1.302%) experienced rebleeding within 180 days after discharge. Five significant risk factors were identified: Age < 54 years (aOR 3.129, $p = 0.014$), male sex (aOR 2.691, $p = 0.010$), non-traffic accident-induced injury (aOR 2.459, $p = 0.006$), ISS ≥ 16 (aOR 2.130, $p = 0.021$), and congestive heart failure (aOR 6.014, $p = 0.006$). As the rebleeding risk evaluation scoring system, DSBS, patients with more than two points demonstrated a substantially higher rebleeding risk (OR 3.790, $p < 0.001$) in the risk-identifying cohort, with similar results confirmed through internal validation (OR 3.129, $p = 0.022$). These findings provide a foundation for risk stratification tools to help clinicians identify high-risk patients and implement timely examinations or interventions during NOM to reduce rebleeding rates.

Our study further demonstrated that age < 54 years, male sex, ISS scores ≥ 16, and non-traffic accident-induced injuries, and history of congestive heart failure are associated with a higher rebleeding risk. Our research identifies age < 54 years as a significant risk factor for delayed splenic bleeding. Previously, Kratzke et al. [14] reported that older age (≥ 30 years) was correlated with an increased likelihood of requiring delayed splenectomy, which aligns with our findings. Earlier studies on blunt splenic trauma also indicate that patients over 55 years have higher rates of non-operative management (NOM) failure (11% vs. 7% for those under 55) and increased mortality rates. Furthermore, age has been identified as an independent predictor of mortality in high-grade injuries (Abbreviated Injury Scale ≥ 3), with elderly patients facing higher risks in both operative and non-operative settings [38]. However, these studies predominantly focused on in-hospital outcomes, whereas our research examines the incidence of rebleeding following successful discharge. Evidence also suggests that patients aged 20 to 50 years account for 85.59% of all blunt splenic injury hospitalizations [39]. While younger adults may sustain injuries more frequently, patients aged 30–54 years exhibit higher NOM success rates [38]. Nonetheless, this age group experiences the highest injury rates, which may contribute to a greater risk of delayed splenic bleeding after discharge, potentially due to factors such as recurrent trauma. This correlation explains why age < 54 years is identified as a significant risk factor in our study.

Table 2 Logistic regression analysis of parameters and risk factors

	Univariant Analysis		Multivariate Analysis						
	OR	***p***	**adjust OR**		**95% CI**				***p***
Age < 54	2.526	0.032	3.129	(	1.255	-	7.800	)	**0.014***
Male	2.948	0.005	2.691	(	1.271	-	5.698	)	**0.010***
Trauma severity									
Non-Traffic accident	2.558	0.004	2.459	(	1.302	-	4.646	)	**0.006***
Lower Splenic injury severity#	1.468	0.210							
ISS > = 16	2.133	0.020	2.130	(	1.121	-	4.049	)	**0.021***
Accompanied Bleeding									
ICH	1.017	0.978							
Hemothorax	0.790	0.536							
Blunt Hepatic injury	0.932	0.861							
Blunt Kidney Injury	0.932	0.861							
Pelvic fracture	0.000	0.995							
Femoral fracture	0.000	0.995							
Major coexisting disease									
Myocardial infarction	0.000	0.999							
Congestive heart failure	3.049	0.064	6.014	(	1.656	-	21.844	)	**0.006***
Vascular Disease	0.000	0.998							
Cerebraovascular disease	0.000	0.996							
Dementia	0.000	0.999							
Chronic pulmonary disease	0.474	0.460							
Rheumatic disease	3.837	0.193	3.054	(	0.314	-	29.732	)	0.336
Peptic ulcer disease	0.975	0.961							
Severe Liver disease	2.905	0.145	2.455	(	0.561	-	10.732	)	0.233
DM	0.499	0.335							
Hemiplegia	0.000	0.998							
Under Dialysis	4.479	0.148	5.881	(	0.652	-	53.022	)	0.114
Malignancy	1.808	0.322							
HTN	1.569	0.239							
Hyperlipidemia	0.477	0.464							
Gout	1.293	0.723							
Obesity	0.000	0.999							

 # Lower Splenic laceration severity includes patients with hematoma of spleen without laceration (856.01) and laceration without major disruption (856.02)

* $p < 0.05$

Table 3 Delayed splenic bleeding system (DSBS)

Age	Score
Age < 54 years	1
Male sex	1
Non-traffic accident-induced injury	1
ISS ≥ 16	1
Congestive heart failure	2

Similar to our findings, which indicated the male and high ISS score as risk factors of rebleeding, Harmon et al. reported 32 instances (0.4%) of delayed splenic hemorrhage in a cohort of 6867 patients with splenic injuries, identifying male sex, severe injuries (ISS 9–57), and concurrent injuries as primary risk factors, with cases observed up to 16 days after admission [13]. Moreover, lower left rib fractures have been identified as an "alarm bell" for delayed splenic rupture [40], while a higher initial injury grade has been recognized as a potential risk factor for unsuccessful NOM outcomes [7].

Notably, our study identified a significant relationship between injury mechanisms and rebleeding risk, a topic rarely discussed in the literature. Non-traffic accidents, which typically involve lower impact forces, may initially reduce the need for surgery or TAE. However, complications such as subcapsular hematoma, pseudoaneurysm, or splenic pseudocyst can significantly elevate the risk of delayed rebleeding. This may suggest that the severity of splenic injuries is often underestimated in low-energy trauma cases. Moreover, congestive heart failure was identified as a risk factor for rebleeding. While no direct relationship between congestive heart failure and splenic injury has been established [41], potential mechanisms may include coagulation abnormalities, increased venous pressure, or fluid retention leading to elevated

Table 4 Distribution of patients according to the risk factors in different groups

Number of risk factors	Risk identifying Cohort			Validation Cohort			Total Cohort		
	Total number	180-day delay splenic rebleeding	180-days rebleeding rate	Total number	180-day delay splenic rebleeding	180-days rebleeding rate	Total number	180-day delay splenic rebleeding	180-day re-bleeding rate
0	128	0	0%	23	0	0%	151	0	0%
1	839	3	0.4%	203	0	0%	1042	3	0.3%
2	1935	14	0.7%	486	6	1.2%	2427	20	0.8%
3	1791	35	2.0%	433	13	2.9%	2237	48	2.1%
4	210	7	3.3%	58	0	0%	268	7	2.6%
5	12	1	8.3%	2	0	0%	13	1	7.1%
6	1	1	100%	N.A.	N.A.	N.A.	1	1	100%

Table 5 The DSB, mortality, and operative events within 180 days between different score groups

Risk-identifying cohort						
Endpoint	**Score ≦ 2 (ref.)**		**Score > 2**		**OR**	*p*
	N=	**2902**	*N*=	**2014**		
Delayed splenic bleeding	17	(0.6%)	44	(2.2%)	3.790 (2.159–6.653)	**< 0.001***
Mortality event	0		0		N.A.	
Operative events	17	(0.6%)	37	(1.8%)	3.176 (1.783–5.656)	**< 0.001***
Time to Recur Median (IQR)Days	7 (16)		5.5(28)			0.961
Derivation group Performance:						
ROC: AUC = 0.686,95%CI = 0.623–0.749, $p < 0.001$, Calibration (Hosmer-Lemeshow goodness-of-fit test) $\chi 2 = 0.257$ ($p = 0.879$)						
Validation group						
Endpoint	**Score ≦ 2 (ref.)**		**Score > 2**		**OR**	*P*
	N=	**718**	*N*=	**506**		
Delayed splenic bleeding	6	(0.8%)	13	(2.6%)	3.129 (1.181–8.289)	**0.022***
Mortality event	0		0		N.A.	
Operative events	6	(0.8%)	11	(2.2%)	2.637 (0.969–7.178)	0.058
Time to Recur Median (IQR)Days	5(3)		8(52)			0.831
Validation group performance						
ROC: AUC = 0.650, 95%CI = 0.555–0.745, $p = 0.025$, Calibration (Hosmer-Lemeshow goodness-of-fit test) $\chi 2 = 1.485$ ($p = 0.476$)						

intra-abdominal pressure. In summary, these findings underscore the importance of comprehensive risk assessments and potential interventions before discharge, even for patients suffering from low-energy trauma, to decrease rebleeding risks.

Existing guidelines recommend hospital stays of one day for low-grade injuries and up to three days for high-grade injuries, with monitoring in specialized settings. Early mobility is advised for low-grade injuries (WSES class I, AAST grades I–II) after 24 h, while high-grade injuries (WSES classes II–III, AAST grades III–V) require stable hemoglobin levels, which means three successive hemoglobin readings taken at 8 h apart after the first reading are within a 10% range of each other, over 24 h before mobilization and if there are no other contraindications for early mobilization [42]. Despite these guidelines, 2–10% of patients may still experience significant bleeding more than 24 h after the initial trauma [16, 43]. Our findings align with prior studies, showing rebleeding typically occurs within 5–7 days post-discharge, or 12–18 days from the initial injury (Table 1), with a 0% mortality rate in our cohort. However, the reported mortality of DSB ranges from 5 to 15%, compared with 1% mortality for acute injuries [18]. Thus, we believe that identifying precise risk factors is essential for guiding further diagnostic and therapeutic interventions to reduce the risk of delayed splenic bleeding (DSB) and associated mortality.

Our study highlights that assessing the risk of delayed splenic bleeding before discharge is crucial for identifying high-risk patients. Specifically, patients with more than two risk factors may benefit from additional interventions. Supporting this, Requarth et al. [7]reported a significantly higher failure rate of observational management without TAE compared to cases where TAE was integrated, particularly in splenic injury grades IV–V. Their study revealed stark differences in failure rates: 43.7% (95% CI: 25.5–63.8) versus 17.3% (95% CI: 7.8–34.1) ($p = 0.035$) and an alarming 83.1% (95% CI: 45.2–96.7) versus 25.0% (95% CI: 8.7–53.8) ($p = 0.016$ [7]. Guidelines recommend considering angiography and

possible TAE for all hemodynamically stable adults with WSES class III injuries (AAST grades IV–V), especially when surgeries requiring positional changes are planned, even in the absence of a CT brush. For patients with WSES class II injuries (AAST grade III) or higher under NOM, follow-up imaging with contrast-enhanced ultrasound or CT scan at 48–72 h after admission is considered the best approach to detect vascular complications [42].

Although our study did not include precise splenic injury grades, the findings suggest that patients with more than two risk factors would benefit from additional imaging, such as contrast-enhanced ultrasound or CT scan, and potentially angiography. Performing angiography and potential TAE could reduce the risk of rebleeding, ultimately enhancing patient safety after discharge and improving outcomes following successful NOM. Future prospective, multicenter studies are needed to validate these findings in more diverse patient populations. Such studies should focus on refining parameter weightings, identifying additional risk factors, and evaluating the real-world applicability of these risk assessments to guide decision-making. These efforts will be crucial for optimizing management strategies and improving outcomes across various healthcare settings.

Limitations

This study has some limitations. First, the retrospective nature of the dataset owned potential selection bias, which may limit the comprehensiveness of the analysis. Key variables such as the AAST grade, WSES class, demographic details, and socioeconomic indicators were not available in our dataset. Additionally, critical clinical data, including vital signs and laboratory results, which could be significant for predicting short-term outcomes, were absent. The diversity of coding practices among surgeons also raises the possibility of incorrect coding. Moreover, the analysis relied solely on inpatient expenditure and admission data, potentially underestimating the prevalence of comorbidities.

Second, the study's findings are based on Taiwan's National Health Insurance Research Database, which covers nearly 99% of the Taiwanese population [44]. While this comprehensive dataset provides valuable insights, it is still region-specific, and the generalizability of the results to populations in other parts of the world with different healthcare systems and clinical practices remains uncertain. It is essential to account for these contextual differences when applying the findings to broader or international populations.

Third, the reliance on hospital readmission data may introduce observation bias. Patients who experienced fatal complications outside of hospital settings or in emergency care may not have been captured in the dataset. This could result in an underestimation of the true incidence of rebleeding and its associated outcomes.

Furthermore, the diversity of coding practices among surgeons introduces a potential risk of incorrect coding. However, a significant portion of the ICD-9 codes was meticulously assigned by expert coders using hospital admission logs, with cross-references to the NHI payment system codes. The data utilized for analysis, including age, sex, and admission specifics, were trustworthy, and the use of the RCIPD ensured a fair degree of accuracy in diagnosing comorbidities, thereby constraining the likelihood of procedural miscoding, thereby minimizing the likelihood of procedural miscoding.

Conclusions

In this comprehensive study, we identified five significant risk factors for rebleeding within 180 days following discharge after non-operative management of blunt splenic injuries including age < 54 years, male sex, non-traffic accident-induced injury, ISS ≥ 16, and a history of congestive heart failure. Internal validation confirmed that patients with more than two points of Delayed Splenic Bleeding System (DSBS) exhibited a significantly increased risk of rebleeding. Despite lacking detailed splenic injury grading and being limited by database constraints, this study highlights the value of large-scale data in identifying risk factors for rare events. These findings suggest that patients with low-grade splenic injuries, but multiple risk factors may benefit from additional follow-up to prevent complications. Clinicians can use this risk assessment tool to improve decision-making, reduce possible rebleeding, and enhance patient safety.

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Author contributions

Conceptualization: JHC, YKH, CYC, PWH, PCYMethodology: JHC, PCY, HYL, CYCSoftware: JHCValidation: JHC, PCY; Formal analysis: JHC, YKH, HYL, CYC; Resources: JHC, PCY; Data curation: JHC; Writing (original draft): CYC, PWHWriting (Revision draft): CYC, HYL.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The Institutional Review Board of E-da Hospital approved the study protocol **(EMRP-106-063)** and was conducted in accordance with the ethical principles of the Helsinki declaration. The acquisition of informed consent from patients was not required due to the retrospective nature of the study.

Consent for publication

Not applicable.

Competing interests
The authors declare no competing interests.

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