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Contents

Monthly Volume 16 Number 10 October 27, 2024

EDITORIAL

ORIGINAL ARTICLE

Case Control Study

Retrospective Cohort Study

Contents

World Journal of Gastrointestinal Surgery

Monthly Volume 16 Number 10 October 27, 2024

Retrospective Study

Observational Study

World Journal of Gastrointestinal Surgery

Monthly Volume 16 Number 10 October 27, 2024

Contents

LETTER TO THE EDITOR

World Journal of Gastrointestinal Surgery

Monthly Volume 16 Number 10 October 27, 2024

Contents

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ORIGINAL ARTICLE

Retrospective Study

Follow-up strategy for early detection of delayed pseudoaneurysms in patients with blunt traumatic spleen injury: A single-center retrospective study

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Abstract

BACKGROUND

The spleen is the most commonly injured solid organ in blunt abdominal trauma, and splenic pseudoaneurysm rupture is associated with a high risk of mortality. Nonoperative management has become the standard treatment for hemodynamically stable patients with splenic injuries. On the other hand, delayed splenic pseudoaneurysms can develop in any patient, and at present, there are no known risk factors that may reliably predict their occurrence. Furthermore, there is a lack of consensus regarding the most appropriate strategies for monitoring and managing splenic injuries, especially lower-grade (I-III).

AIM

To determine the predictors of pseudo-aneurysm formation following splenic injury and develop follow-up strategies for early detection of pseudoaneurysms.

METHODS

We retrospectively analyzed patients who visited the Level I Trauma Center between January 2013 and December 2022 and were diagnosed with spleen injuries after blunt abdominal trauma.

RESULTS

Using the American Association for the Surgery of Trauma spleen injury scale, the splenic injuries were categorized into the following order based on severity: Grade I (n = 57, 17.6%), grade II (n = 114, 35.3%), grade III (n = 89, 27.6%), grade IV (n = 50, 15.5%), and grade V (n = 13, 4.0%). Of a total of 323 patients, 35 underwent splenectomy and 126 underwent angioembolization. 19 underwent delayed angioembolization, and 5 under-went both initial and delayed angioem-

bolization. In 14 patients who had undergone delayed angioembolization, no extravasation or pseudoaneurysm was observed on the initial computed tomography scan. There are no particular patient-related risk factors for the formation of a delayed splenic pseudoaneurysm, which can occur even in a grade I spleen injury or even 21 days after the injury. The mean detection time for a delayed pseudoaneurysm was 6.26 ± 5.4 (1-21, median: 6, interquartile range: 2-9) days.

CONCLUSION
We recommend regular follow-up computed tomography scans, including an arterial and portal venous phase, at least 1 week and 1 month after injury in any grade of blunt traumatic spleen injury for the timely detection of delayed pseudoaneurysms.

Key Words: Blunt trauma; Spleen injury; Delayed pseudoaneurysm; Angioembolization; Nonoperative management

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Core Tip: Nonoperative management has become the standard treatment for hemodynamically stable patients with splenic injuries. On the other hand, delayed splenic pseudoaneurysms can develop in any patient, and at present, there are no known risk factors that may reliably predict their occurrence. There were also no statistically significant risk factors for delayed pseudoaneurysm formation in our study. We recommend regular follow-up computed tomography scans at least 1 week and 1 month after injury in any grade of blunt traumatic spleen injury.

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INTRODUCTION

The spleen is the most commonly injured solid organ in blunt abdominal trauma[1,2]. In addition, it is an organ with high vascularity, and splenic pseudoaneurysm rupture is associated with a high mortality rate[3]. With technological advancements in interventional radiology, most cases of contrast blushing or splenic pseudoaneurysms found on contrast-enhanced computed tomography (CT) scans can now be treated with angioembolization. Lately, nonoperative management (NOM), which includes close observation and radiologic intervention, has become the standard treatment for hemodynamically stable patients with splenic injuries[1,4].

The World Society of Emergency Surgery recommends splenic artery angioembolization to be performed as the first-line intervention for patients who have sustained splenic trauma and were treated with NOM, are hemodynamically stable, and have a CT scan showing arterial blush[1]. Moreover, World Society of Emergency Surgery recommends selective imaging follow-up at 1-, 3-, and 6-month post angioembolization for patients at risk for long-term complications, but it does not recommend routine imaging follow-up for low-grade splenic injuries.

Notably, delayed splenic pseudoaneurysms can develop in any patient, and at present, there are no known risk factors that may reliably predict their occurrence. Furthermore, there is a lack of consensus regarding the most appropriate strategies for monitoring and managing splenic injuries, especially lower-grade. Therefore, this study aimed to determine the predictors of pseudoaneurysm formation following splenic injury and develop follow-up strategies for early detection of pseudoaneurysms.

MATERIALS AND METHODS

Study design

We retrospectively analyzed patients who visited the Level I Trauma Center between January 2013 and December 2022 and were diagnosed with spleen injuries after blunt abdominal trauma. All enrolled patients were diagnosed with splenic injury based on contrast-enhanced CT scan performed on the day of the hospital visit. The splenic injury grade was classified according to the American Association for the Surgery of Trauma (AAST) spleen injury scale, which is currently the most widely used grading system for splenic trauma[5].

The selected patients were divided into a splenectomy group and an NOM group according to the treatment used. The NOM group was further divided into a close observation group and an angioembolization group based on the immediate treatment used. In the NOM group, some patients underwent delayed splenectomy or angioembolization. The flowchart for the group classification of enrolled patients is shown in Figure 1. Data regarding the following characteristics for all patients were obtained from the hospital's electronic medical records: Age, sex, injury severity score (ISS), AAST spleen

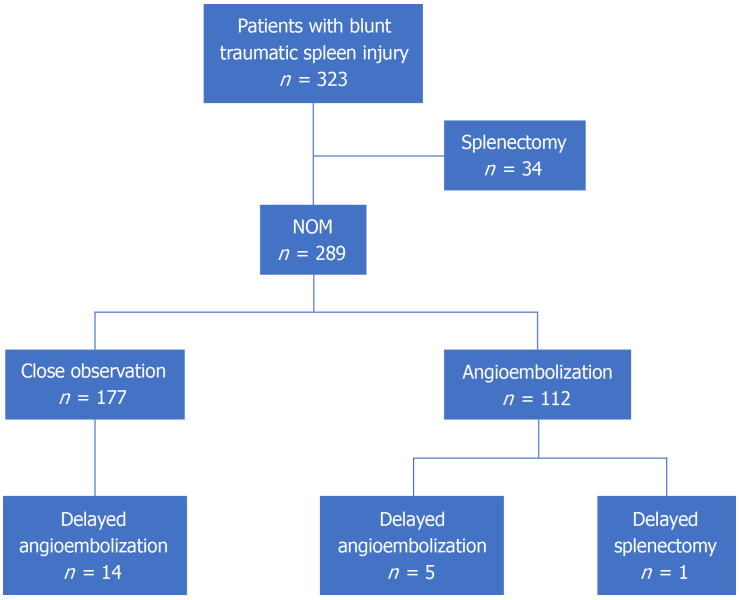

Figure 1 Flowchart of enrolled patients. NOM: Nonoperative management.

injury scale, and the number of follow-up days to the CT scan. The study was reviewed and approved by the Institutional Review Board of the Kyungpook National University Hospital (Approval No. 2023-12-016).

Treatment and follow-up protocol

Angioembolization was performed immediately when vascular lesions, such as blushing or pseudoaneurysms, were identified on the initial CT scan. If the patient's hemodynamic status impeded angioembolization or surgery was warranted for other intraabdominal injuries, splenectomy was performed depending on the patient's condition. Patients were closely monitored when they were hemodynamically stable and did not require angioembolization or surgery.

Patients were admitted to the trauma intensive care unit or general ward depending on their condition. Follow-up CT scans were routinely performed 1 week and 1 month later; occasionally, additional scans were performed at the physician's discretion. Angioembolization was performed when a follow-up CT scan showed blushing or pseudoaneurysms. Once an intrasplenic or perisplenic hematoma was confirmed, we performed a follow-up CT scan every 3 months until the hematoma was completely resolved.

Definitions

Initial blushing and initial pseudoaneurysm were defined as blood extravasation and pseudoaneurysm formation within the spleen on the first CT scan at admission. Initial angioembolization was defined as a procedure that was performed immediately after diagnosis. A delayed pseudoaneurysm was defined as a pseudoaneurysm that was not observed on the first CT scan but became visible on a CT scan performed after the first 24 hours. Similarly, angioembolization performed after 24 hours was defined as delayed angioembolization.

Statistical analysis

Categorical variables (sex and the AAST spleen injury scale) were presented as frequencies and percentages and compared using χ^2 and Fisher exact tests to identify risk factors for the occurrence of delayed pseudoaneurysm. In contrast, continuous variables (age and ISS) were presented as mean and standard deviation and compared using Student's *t*-test. A P value of < 0.05 was considered statistically significant. In addition, we analyzed the shortest and longest periods of delayed pseudoaneurysm occurrence to establish a follow-up strategy. All analyses were performed using the Predictive Analytics SoftWare (PASW) (version 18; IBM, Armonk, NY, United States).

RESULTS

Between January 2013 and December 2022, 323 patients, including 247 (76.5%) male and 76 (23.5%) female patients, were diagnosed with blunt traumatic spleen injuries. The mean age of these patients was 46.69 ± 21.16 (2-93) years. The most common causes of trauma were falls, motorcycle crash and motor vehicle crash (Table 1). Using the AAST spleen injury scale, the splenic injuries were categorized into the following order based on severity: Grade I (n = 57, 17.6%), grade II (n = 114, 35.3%), grade III (n = 89, 27.6%), grade IV (n = 50, 15.5%), and grade V (n = 13, 4.0%). As the AAST spleen injury scale increased, the ISS and the rates of angioembolization and splenectomy also increased gradually. However, in grade V patients, the rate of angioembolization and splenectomy was rather low. Out of 323 patients, angioembolization was performed in 126 (39%) patients and splenectomy was performed in 35 (10.8%) patients. The splenectomy group included

Table 1 Causes of trauma in 323 patients

Cause of trauma	Number of patients, *n*
Fall	69
Motorcycle crash	69
MVC	63
Pedestrian accident	40
Passenger injury	32
Bicycle crash	18
ETC	32

MVC: Motor vehicle crash; ETC: Et cetera.

patients in whom splenectomy was performed concomitantly with surgery because of other abdominal injuries (Table 2).

Of the 126 patients who underwent angioembolization, 112 patients were performed as an initial angioembolization because they showed contrast blushing or pseudoaneurysm on their initial CT scan. Delayed angioembolization was performed in 19 patients. Among them, two patients had grade I injury, 6 had grade II, 8 had grade III, and 3 had grade IV injury. 14 of these patients had delayed pseudoaneurysm formation, although their first CT scans showed no contrast blushing, pseudoaneurysms, or arteriovenous fistulas. In addition, new bleeding lesions, which were identified during follow-up and required delayed angioembolization, were observed in five patients who had previously undergone initial angioembolization. Table 3 presents the characteristics of the 19 patients who developed delayed pseudoaneurysm.

Statistical analysis was performed on 288 patients to determine the risk factors associated with the development of delayed pseudoaneurysms; 35 patients who had undergone an initial and delayed splenectomy were excluded. There was no statistically significant correlation between sex, the AAST spleen injury scale, and delayed pseudoaneurysm occurrence. Age and ISS also showed no statistically significant difference between those without and with delayed pseudoaneurysm (Table 4). The mean detection time for a delayed pseudoaneurysm was 6.26 ± 5.4 (1-21, median: 6, interquartile range: 2-9) days.

DISCUSSION

The spleen is the most commonly injured solid organ in blunt abdominal trauma[1,2]. Over the past few decades, substantial research has been performed regarding the management of splenic trauma. NOM, which ranges from observation and monitoring alone to angioembolization, is considered the first-line treatment for splenic injuries due to blunt trauma primarily because it allows preserving the spleen and its function in hemodynamically stable patients[1,4,6]. At present, NOM is applied in 60%-80% of patients with spleen injuries, with a success rate of 85%-94%[2].

Contrast blushing is an important indication of angioembolization. However, even if contrast blushing is not noted on the first CT scan of a high-grade splenic injury, surgeons must not exclude the possibility of current bleeding[6]. Therefore, in cases of high-grade splenic injury, careful monitoring is necessary even in the absence of contrast blushing. On the other hand, vascular lesions, such as contrast blushing, pseudoaneurysms, and arteriovenous fistulas, which require angioembolization, can occur even in low-grade spleen injuries[7]. Depending on the patient's condition, further treatment (angioembolization or surgery) may be required if contrast blushing is detected on a CT scan.

The pathophysiology of delayed splenic pseudoaneurysm formation is unclear; however, it is believed that since the spleen is a hyper-vascular organ, the weakening of a vessel wall within the spleen caused by blunt trauma causes aneurysmal changes as time passes. Pseudoaneurysms, which do not have a complete vascular wall structure, expand over time and become more fragile under the constant pressure of blood flow, which may cause them to rupture suddenly or bleed excessively. Furthermore, a splenic pseudoaneurysm can cause delayed splenic bleeding days or months after the initial incident; therefore, according to the general course of arterial pseudoaneurysms, they should always be treated independently of their associated symptoms or diameter[3,8]. Indeed, rupturing is the most concerning complication of pseudoaneurysms, and the subsequent bleeding is associated with a significant risk of death. Early diagnosis and treatment are the only ways to improve survival rates[3,9-12].

Currently, contrast-enhanced CT scan is the gold standard for diagnosing splenic pseudoaneurysms because of its sensitivity and widespread usage[3,4,9]. In particular, delayed-phase CT scan helps in differentiating patients with active bleeding from those with confined vascular injuries[6,13]. However, there is still a lack of comprehensive knowledge on the incidence and timing of pseudoaneurysm formation as well as the most optimum time to perform a follow-up CT scan[3,4,6,9,13-15]. Some reports recommend that a follow-up CT scan is not necessary in patients with low-grade splenic injuries[4,9]. Fata *et al*[16] reported that 85% of surgeons do not routinely perform follow-up CT scans on outpatients with spleen injuries. In contrast, some surgeons advocate that selective imaging follow-up must be practiced after discharge for patients with blunt splenic injuries treated with NOM only in the presence of risk factors for long-term complications and depending on the level of activity[1,4]. Although CT provides high-quality diagnostic information, many surgeons

Table 2 Characteristics of patients classified by the American Association for the Surgery of Trauma spleen injury grade and treatment methods

AAST grade	Number of patients, *n*	ISS, mean ± SD	NOM		Splenectomy, *n* (%)
			Close observation, *n* (%)	Angioembolization, *n* (%)	
I	57	18.39 ± 9.96	47 (82.5)	5 (8.8)	5 (8.8)
II	114	18.80 ± 10.7	84 (73.7)	23 (20.2)	7 (6.1)
III	89	17.80 ± 10.22	25 (28.1)	59 (66.3)	5 (5.62)
IV	50	21.60 ± 8.01	4 (8)	36 (72)	11 (22)
V	13	27.23 ± 5.53	3 (23.1)	3 (23.1)	7 (53.85)

AAST: American Association for the Surgery of Trauma; ISS: Injury severity score; NOM: Nonoperative management.

Table 3 Characteristics of the 19 patients with delayed pseudoaneurysm

Age	Sex	AAST grade	ISS	Trauma cause	DPA, detection time, day
33	Female	I	33	Passenger injury	16
42	Male	I	24	Motorcycle crash	8
34	Female	II	14	MVC	10
55	Male	II	22	MVC	5
55	Female	II	4	Assault	1
58	Female	II	6	MVC	3
64	Male	II	18	Fall	2
74	Female	II	22	Passenger injury	21
13	Male	III	13	Pedestrian accident	10
18	Male	III	5	Passenger accident	6
24	Male	III	14	MVC	2
37	Male	III	4	Bicycle crash	9
46	Female	III	25	Passenger injury	1
52	Male	III	8	Motorcycle crash	1
64	Female	III	22	MVC	6
66	Male	III	9	Fall	8
27	Male	IV	43	Bicycle crash	3
46	Male	IV	29	Motorcycle crash	6
66	Male	IV	27	Pedestrian accident	1

AAST: American Association for the Surgery of Trauma; ISS: Injury severity score; DPA: Delayed pseudoaneurysm; MVC: Motor vehicle crash.

oppose routine CT repetition because it can be expensive, depending on the country's environment, and involves exposure to radiation[4].

On the other hand, Savage *et al*[2] recommended that follow-up imaging should be performed even in patients with mild splenic injuries because some patients who did not undergo imaging follow-up had required a splenectomy. Moreover, Norotsky *et al*[17] strongly recommended performing a follow-up CT scan until the splenic injury was completely resolved to prevent delayed rupture of the splenic artery pseudoaneurysm, which is a major potential consequence. Pseudoaneurysm has no specific symptoms; it can rupture days or even months after injury. Therefore, if a pseudoaneurysm ruptures without adequate imaging follow-up after discharge, it may result in catastrophic outcomes[2,8,11].

In our study, the splenic injury grade and delayed pseudoaneurysm occurrence showed no correlation. Therefore, we concur that imaging follow-up must be performed until the splenic injury is completely resolved, even in cases of low-grade spleen injuries. Muroya *et al*[9] published a retrospective review of patients with blunt injuries of the spleen treated with NOM between 2003 and 2010 at five trauma and critical care centers in Japan. Their study revealed the occurrence of

Table 4 The results of the statistical analysis

		Delayed pseudoaneurysm		*P* value
		None	Occurrence	
Sex, *n* (%)	Male	207 (94.5)	12 (5.5)	0.173
	Female	62 (89.9)	7 (10.1)	
AAST grade, *n* (%)	I	50 (96.2)	2 (3.8)	0.649
	II	101 (94.4)	6 (5.6)	
	III	76 (90.5)	8 (9.5)	
	IV	36 (92.3)	3 (7.7)	
	V	6 (100)	0 (0)	
Age, years (mean ± SD)		46.86 ± 21.51	46.00 ± 17.8	0.865
ISS (mean ± SD)		18.62 ± 10.09	18.00 ± 10.87	0.798

AAST: American Association for the Surgery of Trauma; ISS: Injury severity score.

delayed pseudoaneurysm in 16 out of 104 patients (15%); of these 16 patients, 7 had grade II splenic injury and 9 had grade III injury. The authors recommended that follow-up CT scan must be performed approximately 1 week after injury (the pseudoaneurysm was detected within a week in 15 out of 16 patients) and even in low-grade splenic injury (all delayed pseudoaneurysms were found in patients with a splenic injury grade of II or III)[9]. In our study, the higher the splenic injury grade, the higher the rate of initial angioembolization or splenectomy. Because almost all patients in grades IV and V either underwent angioembolization/splenectomy or were deceased, most delayed pseudoaneurysms were detected in splenic injury grades II and III. Weinberg *et al*[18] reported an incidence of 7.1% for delayed pseudoaneurysm formation after NOM in patients with splenic injuries, while Davis *et al*[19] reported this incidence to be 7.7%; in our study, this incidence was 6.6%.

Furthermore, Crawford *et al*[20] reported a case of delayed rupture of the spleen in a 22-year-old man 22 days after injury. Davies *et al*[21] also reported the case of a 15-year-old boy who died due to delayed splenic bleeding 18 days after being discharged because a pseudoaneurysm was not detected initially. In our study, 12 of the 19 patients were diagnosed with delayed pseudoaneurysm within a week, while the remaining 7 patients were diagnosed after a week; the latest case was detected on the 21st day, and the lowest splenic injury was grade I. And no other patient-related factor was statistically different between patients with and without delayed pseudoaneurysm formation. Therefore, we recommend performing routine follow-up CT scans at a minimum of 1 week and 1 month after injury for all patients who undergo NOM for blunt splenic injuries, followed by regular follow-ups if necessary.

Limitations

First, this study used a retrospective study design to analyze patients with blunt traumatic splenic injury from a single trauma center. Second, we did not analyze the causality between injured spleen pathophysiology and delayed pseudoaneurysm formation. Third, the length of time to detect a delayed pseudoaneurysm does not exactly represent the timing of its formation. In addition, follow-up CT scans were not performed at the same time and for all patients. Lastly, angioembolization was performed in all delayed pseudoaneurysm cases considering that pseudoaneurysm would grow in size over time and the vessel wall would weaken, thereby increasing the possibility of rupture. Consequently, the prognosis of NOM for delayed pseudoaneurysm remains uncertain.

CONCLUSION

We recommend regular follow-up CT scans, including an arterial and portal venous phase, at least 1 week and 1 month after injury in any grade of blunt traumatic spleen injury for the timely detection of delayed pseudoaneurysms.

FOOTNOTES

Author contributions: Kim GW and Hwang S did the acquisition and analysis of the data; Cho SH performed data collection and statistical analysis and was a major contributor to writing the manuscript; Lim KH contributed to the conception and design of the work and revised manuscript. All authors read and approved the final manuscript.

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