Delayed Traumatic Splenic Rupture as a Life-threatening Clinical Manifestation Treatable with Splenectomy: A Study of Twelve Cases and Literature Review

Ann. Ital. Chir., 2025 96, 3: 296–308
https://doi.org/10.62713/aic.3767

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AIM: While most splenic ruptures manifest as immediate hemorrhage, a minority of patients experience delayed rupture, which occurs days to weeks after the initial trauma. Although there have been reports of delayed splenic rupture following trauma, the exact pathophysiology of this condition and the appropriate treatment remain contentious. This article aims to further discuss and summarize the diagnosis and treatment protocols for delayed traumatic rupture of the spleen through the collection and analysis of existing clinical data, combined with previous literature.

CASE PRESENTATION: From 2012 to 2023, we identified 12 adults admitted to a trauma center with delayed traumatic rupture of the spleen (DRS). After excluding unrelated cases, we focused on patients with a definitive DRS diagnosis. The majority were male, aged 46–90 years, with some having pre-existing conditions like cirrhosis or cancer. Most injuries were from falls or car accidents, occurring 2–7 days before admission. Five patients had additional traumatic injuries. All experienced left-side abdominal pain and were diagnosed using imaging. They received medical intervention to stabilize their condition, with initial hemoglobin levels slightly low.

RESULTS: Clinical data of 12 splenic rupture cases presenting with symptoms between 2 and 7 days after splenic trauma but without any pre-existing splenic pathology were collected from November 2012 to August 2023. Among these cases, 8 patients underwent splenectomy immediately following the diagnosis of delayed splenic rupture. For the remaining 4 patients, conservative treatment was initially attempted, but due to inadequate control of their condition, the treatment plan was subsequently altered to surgical intervention, yielding favorable clinical outcomes.

CONCLUSIONS: Delayed splenic rupture is a disease caused by multiple factors. The atypical clinical manifestations of delayed rupture pose challenges to timely and accurate diagnosis, making computed tomography (CT) the preferred diagnostic method for delayed splenic rupture. Emergency surgical treatment is the optimal surgical approach for managing delayed splenic rupture.

Keywords: spleen; trauma; surgery; case report

Introduction

The spleen is one of the most commonly injured organs following abdominal trauma, with the incidence of splenic injury being as high as 40% to 50% among all types of abdominal trauma. Delayed traumatic rupture of the spleen (DRS), defined as the delayed rupture of the spleen following abdominal trauma, is a rare yet critical splenic injury [1]. While the overall mortality rate of acute splenic injury is approximately 1%, the mortality rate of DRS is disproportionately higher, ranging from 5% to 15%. This elevated mortality can be attributed to missed diagnoses or misdiagnoses, often due to detection performed during the clinically asymptomatic period [1–5]. Consequently, it is imperative to maintain a high level of suspicion and awareness regarding the potential existence of DRS when precursor symptoms manifest. Thus, prompt diagnosis and surgical intervention are crucial in mitigating the morbidity and mortality associated with splenic hemorrhage [1,5]. Additionally, spleen rupture accounts for approximately 10% of the open abdominal injury cases [1,6–18]. However, compared to immediate splenic hemorrhage, delayed splenic hemorrhage is relatively rare, accounting for only about 15% of the cases [1,3,19].

The pathological mechanisms of DRS are subject to diverse interpretations [1,2,15,20–23], and the literature on the di-

Submitted: 24 September 2024 Revised: 23 November 2024 Accepted: 26 November 2024 Published: 10 March 2025
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Table 1. Pre-admission conditions of ten patients with delayed rupture of the spleen.

Case	Age (years)	Sex	Type of injury	Associated injuries	Duration of pre-hospital (days)	Symptoms during pre-hospital
1	53	M	Falling down while walking	Nil	5	Abdominal pain (details unknown)
2	48	M	Falling off motorbikes	Nil	7	Abdominal pain of left upper quadrant
3	67	F	Falling down while sitting	Nil	6	Abdominal pain of left upper quadrant
4	59	M	Car accident	Right 80% pneumothorax compressed lung	2	Pectoralgia
5	46	M	Falling off motorbikes	Nil	7	Abdominal pain of left upper quadrant
6	48	F	Falling down in the bathroom	Left renal capsule hematoma and left multiple rib fractures	4	Abdominal pain of left upper quadrant
7	57	F	Falling down from a tree	Right multiple rib fractures	5	Abdominal pain of left upper quadrant
8	51	M	Car accident	Nil	3	Abdominal pain of left upper quadrant
9	51	M	Falling down while walking	Nil	5	Abdominal pain of left upper quadrant
10	90	F	Falling down while walking	Nil	7	Abdominal pain (details unknown)
11	67	M	Falling off a ladder	Left 10th rib fracture	7	Abdominal pain (details unknown)
12	76	F	Fall down	Left pleural effusion, left 10th rib fracture	5	Pectoralgia and abdominal pain of left upper quadrant

M, male; F, female.

agnosis and treatment of DRS is relatively scarce. Therefore, this study was designed to approach analysis of clinical data of DRS, coupled with a literature review of the past studies, in order to shed light on the best possible clinical treatment for DRS, as well as the pathomechanisms underlying the disease. This article presents a review of the clinical data pertaining to 12 cases diagnosed with DRS and admitted to our institution. All of these 12 patients had fully recovered with favorable clinical outcomes.

This case has been reported in line with the case report guidelines: Case Report (CARE) Guidelines to ensure the accuracy and completeness of the report (**supplementary material**).

Case Presentation

We performed a medical record search from November 2012 to August 2023, which led to an identification of 12 adults (18 years of age or older) with DRS admitted to the Department of Emergency Trauma Center at Hangzhou First People's Hospital and Zhejiang Hospital. We first conducted a comprehensive assessment of the patients' current medical condition, auxiliary examination results, and past medical history. Cases where there was immediate splenic rupture and hemorrhage following trauma, as well as those where the rupture and hemorrhage were unrelated to trauma, were excluded. Consequently, only patients with a definitive diagnosis of DRS were included. The included patients were labeled as cases 1 to 12, and their general information are presented in Table 1. Fifty-eight percent of the patients (7 cases) were men, and patients had an age range from 46 to 90 years, with an average age of 59.4 years. A total of 7 patients (58%) had no comorbidities. Some noteworthy conditions of the remaining cases warrant our attention: (i) Case 5 suffered from liver cirrhosis; (ii) Case 7 suffered from stable hypertension and had undergone radical resection of left breast cancer 5 years ago; (iii) With a history of cirrhosis for 3 years and left patellar fracture for 20 years, case 10 underwent laparoscopic radical resection of rectal cancer and cirrhotic liver 3 years ago; (iv) Case 11 had a 5-year history of hypertension, with diabetes and coronary heart disease for 8 and 10 years, respectively; (v) Case 12 had a history of hypertension is more than 4 years, with unknown period of coronary heart disease, and had received closure treatment of patent ductus arteriosus 4 years ago.

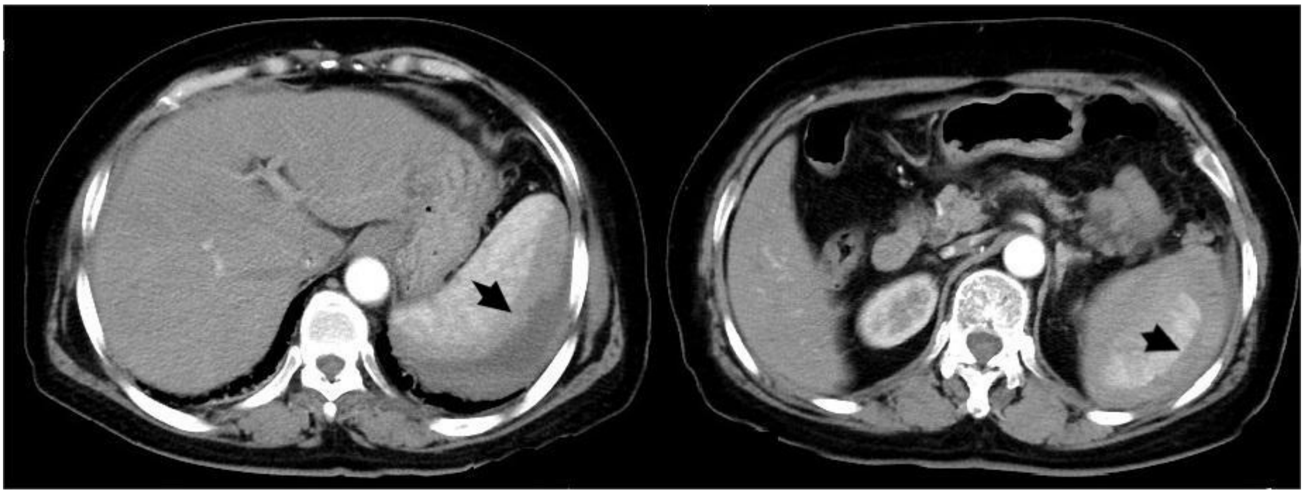

Fig. 1. Enhanced contrast CT showing delayed splenic rupture, with features of heterogeneous density of spleen, splenic subcapsular hemorrhage, effusion and hematocele in abdominal and pelvic cavity and hepatic multiple cysts. Location of the rupture is indicated by the arrow. CT, computed tomography.

Regarding the causes of injury, 8 cases suffered injury due to careless fall, while the rest of the cases were injured due to car accident. The time from trauma occurrence to hospital admission was 2 to 7 days, with an average of 5.25 days. Five cases from this sample present various types of traumatic injuries, including pleural effusion (case 12), pneumothorax (case 4), renal capsule hematoma (case 6), and rib fractures (cases 6, 7, 11 and 12). Eleven of the 12 cases suffered left waist or left upper abdominal pain, which was tolerable, and one of these cases did not manifest obvious abdominal pain.

All the patients were diagnosed with DRS using color ultrasound or abdominal computed tomography (CT) (Fig. 1; Table 2). Rescue measures, including hemostatic drugs and infusion, were given during intensive care to keep heart rate in the range of 60–104 bpm and blood pressures in the range of 86–156 mmHg and 49–89 mmHg for systolic and diastolic blood pressure, respectively. The first recorded level of hemoglobin was in the range of 77–139 g/L (normal range: 115–150 g/L), averaging 110.1 g/L (Table 3).

Results

For patients who have been definitively diagnosed with DRS, our first consideration is emergency surgical intervention, particularly for those exhibiting unstable vital signs, wherein emergency surgery would be contemplated alongside active shock correction measures. For patients with more urgent traumatic complications (such as pneumothorax, case 4), we opted for deferred surgery after managing the urgent condition. In some cases, where patients and their families have a strong preference for conservative treatment, we would adopt conservative treatment for a fixed period of time if our assessment of their vital signs reveals no immediate life-threatening situation. However, ultimately, due to ineffective treatment (auxiliary examinations indicating no improvement or progression of bleeding), surgical intervention is still required. In this case study, 8 cases had an emergency open or laparoscopic splenectomy within 24 hours after admission. Cases 3, 4, 8 and 12 had splenectomy 7 days, 7 days, 3 days and 2 days after admission, respectively. These patients had pneumothorax and other diseases, which should be prioritized over spleen rupture, or their families insisted on using conservative treatment. However, after implementing conservative treatment, all of these patients chose elective surgery. A blood clot of 200 to 2500 mL was found in the abdominal cavity with splenic subcapsular ruptured hematoma in all patients. Lacerations were found to at the upper pole (2 cases), lower pole (5 cases), multiple poles (1 case), and be undetermined (2 cases), respectively. The remaining 2 cases had a crushed spleen (Table 2).

In these patients, the hemoglobin level ranged from 66 to 123 g/L with an average of 95.7 g/L on first or second postoperative days and from 81 to 139 g/L with an average of 102.4 g/L on the fourth or fifth postoperative days. The postoperative hospitalization length was 8 to 22 days with an average of 15.75 days, and their platelet level ranged from 415 to 834 $\times$ 10^9/L (normal range: 125–350 $\times$ 10^9/L) with an average of 538.25 $\times$ 10^9/L on the day of discharge. No pathological abnormality of the spleen was detected (Table 4).

All patients, during the outpatient follow-up one month after discharge, showed no surgery-related complications. Their vital signs were stable, the auxiliary examination results were normal, and their quality of life was not significantly affected due to the splenic rupture.

Table 2. Radiographic findings and intraoperative manifestations of patients with delayed rupture of the spleen.

Case	B-ultrasound findings	CT findings	Surgical modality	Bleeding (mL)	Specimen
1	Moderate echo under the splenic capsule accompanied by inhomogeneous changes in the spleen, with possibility of splenic rupture, and moderate amount of fluid in the abdominal cavity.	-	Emergency laparotomy	800	The rupture on the surface of the upper pole of the spleen is star-shaped.
2	With a thickness of 8.6 cm and a length of approximately 10.4 cm, there is an inhomogeneous, slightly hyperechoic area measuring 8.497 cm inside, with unclear boundaries.	Abdominal cavity effusion, uneven increase in splenic density, uneven enhancement after enhancement, lateral trumpet-like changes, high-density shadow around the spleen.	Emergency laparotomy	1800	Comminuted rupture.
3	-	Accumulation of fluid and blood in the abdominal and pelvic cavities, uneven splenic density, and uneven enhancement after contrast enhancement.	Elective laparotomy after 7 days	200	Comminuted rupture.
4	Inhomogeneous echoic area at the lower pole of the spleen (approximately 4.4 × 3 × 2.7 cm in size), with blood accumulation in the colon, bladder, and pelvic cavity on both sides.	-	Elective laparoscopy after 7 days	800	A 4 cm rupture at the lower pole of the spleen.
5	Moderate amount of fluid in the abdominal cavity, sonographic findings suggestive of splenic rupture.	-	Emergency laparotomy	2500	A 1 cm rupture at the lower pole of the spleen.
6	-	Subcapsular hemorrhage of the spleen	Emergency laparotomy	1500	Three ruptures were observed on the dorsal side of the spleen, each measuring approximately 2 cm in length and 0.5 cm in depth. On the superior abdominal side, near the splenic hilum, there was a longitudinal rupture which was approximately 3 cm in length and 1 cm in depth. On the inferior abdominal side, near the splenic hilum, there was another longitudinal rupture which was approximately 2 cm in length and 1 cm in depth. Additionally, a rupture of approximately 0.3 cm was observed on the blood vessel at the inferior pole of the splenic hilum.
7	-	Splenic rupture accompanied by subcapsular hemorrhage, with blood accumulation in the pelvic cavity.	Emergency laparoscopy	Great quantity	Upper pole of the spleen.

Table 2. Continued.

Case	B-ultrasound findings	CT findings	Surgical modality	Bleeding (mL)	Specimen
8	-	Enlarged spleen with mixed density shadows.	Elective laparoscopy after 3 days	Small quantity	-
9	-	Splenic rupture accompanied by blood accumulation around the spleen, in the abdominal cavity and in the pelvic cavity.	Emergency laparotomy	1000	-
10	-	Patchy mixed high-density shadows under the splenic capsule, possibly indicating subacute splenic hemorrhage. Fluid accumulation was observed around the liver, in the abdominal cavity, and in the pelvic cavity.	Emergency laparotomy	Great quantity	Rupture at the lower pole.
11	-	Splenic rupture accompanied by subcapsular hemorrhage.	Emergency laparotomy	800	A 4 cm rupture at the lower pole of the spleen.
12	A small amount of fluid-filled dark area was visible in the abdominal cavity, with hematoma under the splenic capsule.	Contusion and laceration at the lower pole of the spleen accompanied by blood accumulation around the spleen, and fluid and blood accumulation in the abdominal and pelvic cavities.	Elective laparotomy after 2 days	1000	A 2 cm rupture at the lower pole of the spleen.

CT, computed tomography.

Discussion

The Etiology of DRS and the Diverse Pathological Theories

The occurrence of most DRS cases is secondary to trauma [5,12,24]. Minor or trivial trauma such as mild hurt, nausea, vomiting, cough, suddenly sitting up, slowly slipping to the floor [25], colonoscopic procedure [19] or a low energy trauma [12,26] are common causes of DRS [1,3,15,22,24,27–29], but this condition very rarely occurs in those using implantable left ventricular assist device [10]. Fifty percent of our cases had a low-energy trauma. Mockford and Brown [24] reported one case who woke up from nightmares 2 months ago. The patient felt pain on the left upper abdomen while trying to sit up, but the pain subsided later. Two months later, the patient experienced the left upper abdominal pain again. Following a diagnosis of splenic rupture, an exploratory laparotomy was performed on this patient. Splenic hematoma and rupture hemorrhage were found during surgery. After splenectomy, subsequent pathological examination verified the coexistence of old and new subcapsular hematomas. In this study, 6 cases had experienced car accident, motorcycle accident or falling down. The causes of minor DRS may include splenomegaly [1], underlying malignancy or infective process such as mononucleosis and lymphoma [5,22,24,25], and conditions such as pregnancy, parturition or defecation [9].

The exact mechanism of this serious and possible life-threatening complication is still not entirely clear [1], but several theories have been proposed to explain its pathophysiological and clinical manifestations [20,27]. The first theory [1,2,15,20–23] is delayed rupture of splenic subcapsular hematoma (Fig. 2). Trauma results in splenic parenchymal injury without laceration of spleen capsule. With the persistent intrasplenic bleeding, subcapsular hematoma would form eventually. Progressive increase of intrasplenic pressure may lead to capsule burst and the rupture of subcapsular hematoma, resulting in intra-abdominal hemorrhage several days or more following the initial injury. This is the most widely accepted theory. The splenic pathology of the 12 cases in this study all presented as delayed rupture of the splenic capsule with no pathological abnormality of spleen. The second theory is that clot lysis will result in continuous rise of the intrasplenic colloid osmotic pressure. With the increase of subcapsular pressure, the capsule burst and the subcapsular hematoma ruptures [4,27]. According to the third theory, perisplenic hematoma ruptures into peritoneal cavity at a later time due to tamponade and compression by the surrounding organs [2,4,15,20,21]. The fourth theory concerns about the adherence of the greater omentum to the splenic capsule in response to inflammation, resulting in maceration of the capsule and uncontrolled bleeding [2,28]. The fifth theory [7,22,30] stipulates that a direct action of the rib fracture

Table 3. Clinical summary of patients with delayed rupture of the spleen.

Case	Temperature (°C)	Pulse (/min)	Respiratory rate (/min)	Systolic blood pressure (mmHg)	Diastolic blood pressure (mmHg)	WBC count ($\times 10^9$/L)	Hemoglobin (g/L)	Paracentesis drainage
1	37.5	90	-	120	75	12.9	113	Blood that does not coagulate
2	36.6	89	-	133	88	21.84	139	Blood that does not coagulate
3	36.9	70	-	102	62	15.79	132	-
4	36.7	69	20	136	79	4.6	91	Blood that does not coagulate
5	36.7	60	19	86	49	-	-	-
6	37	76	20	101	62	-	-	-
7	37.4	104	20	156	89	-	-	-
8	36.3	74	18	114	81	2.8	104	Blood that does not coagulate
9	37.3	86	19	138	78	-	-	-
10	37	70	18	153	59	10.1	105	-
11	37	98	19	138	87	6.5	120	-
12	36.5	90	19	134	73	9.2	77	-

WBC, white blood cell.

Table 4. Results of post-surgical auxiliary examinations conducted at different time points.

Case	1–2 days after surgery				4–5 days after the surgery				At discharge	
	WBC ($\times 10^9$/L)	Hb (g/L)	PLT ($\times 10^9$/L)	CRP (mg/L)	WBC ($\times 10^9$/L)	Hb (g/L)	PLT ($\times 10^9$/L)	CRP (mg/L)	Post-surgical hospitalization duration (days)	PLT ($\times 10^9$/L)
1	15.53	81	162	32.32	7.9	85	468	23.64	18	834
2	20.15	116	228	85.52	7.64	111	452	8.17	18	535
3	21.18	96	347	109.44	8.46	81	818	81.34	22	457
4	10	103	225	40	7.8	119	636	6	15	636
5	18.4	66	168	150	17.5	82	391	142	18	565
6	16.4	73	121	16	15.5	84	253	62	19	536
7	14.6	114	153	6	11.3	115	514	7	19	519
8	10.7	123	203	-	6.7	139	298	-	8	433
9	13.1	101	236	30	7	108	373	-	10	470
10	24	93	126	233	11.2	117	291	-	14	547
11	14	80	147	30	-	-	-	-	8	415
12	12.9	102	324	40	16.5	85	394	128.5	20	512

Hb, hemoglobin; PLT, platelet; CRP, C-reactive protein.

edges, which are present in 40% of blunt splenic injury on the splenic capsule and parenchyma, due to patient mobilization may produce delayed rupture [9]. The last theory is that rupture from a pseudoaneurysm [1,4,20,25] of intraparenchymal splenic artery branches or rupture from a asymptomatic splenic pseudocyst [1,4,20,28] may occur after the formation of an intrasplenic hematoma. The last two theories are regarded as the potential mechanisms contributing to the occurrence of DRS.

Diagnosis of DRS and Challenges Facing the Clinicians

The interval between injury and rupture of the spleen in our cases was 2 to 7 days with an average of 5.25 days. Eleven of the 12 cases exhibited obvious features of DRS, specifically left upper quadrant abdominal pain, during their first visit. Interestingly, the vital signs and hemoglobin levels of most patients did not indicate the presence of hemorrhagic shock or hemorrhagic anemia. This may be attributed to the fact that the splenic capsule of most patients was not completely ruptured, which is consistent with the subsequent CT results and intraoperative specimen findings that will be elaborated upon. The prolonged absence of overt symptoms after trauma can lead patients and doctors to dismiss atypical abdominal pain as unrelated to the injury. Additionally, atypical pain in the left hypochondrium region can also be associated with musculoskeletal injuries, liver dam-

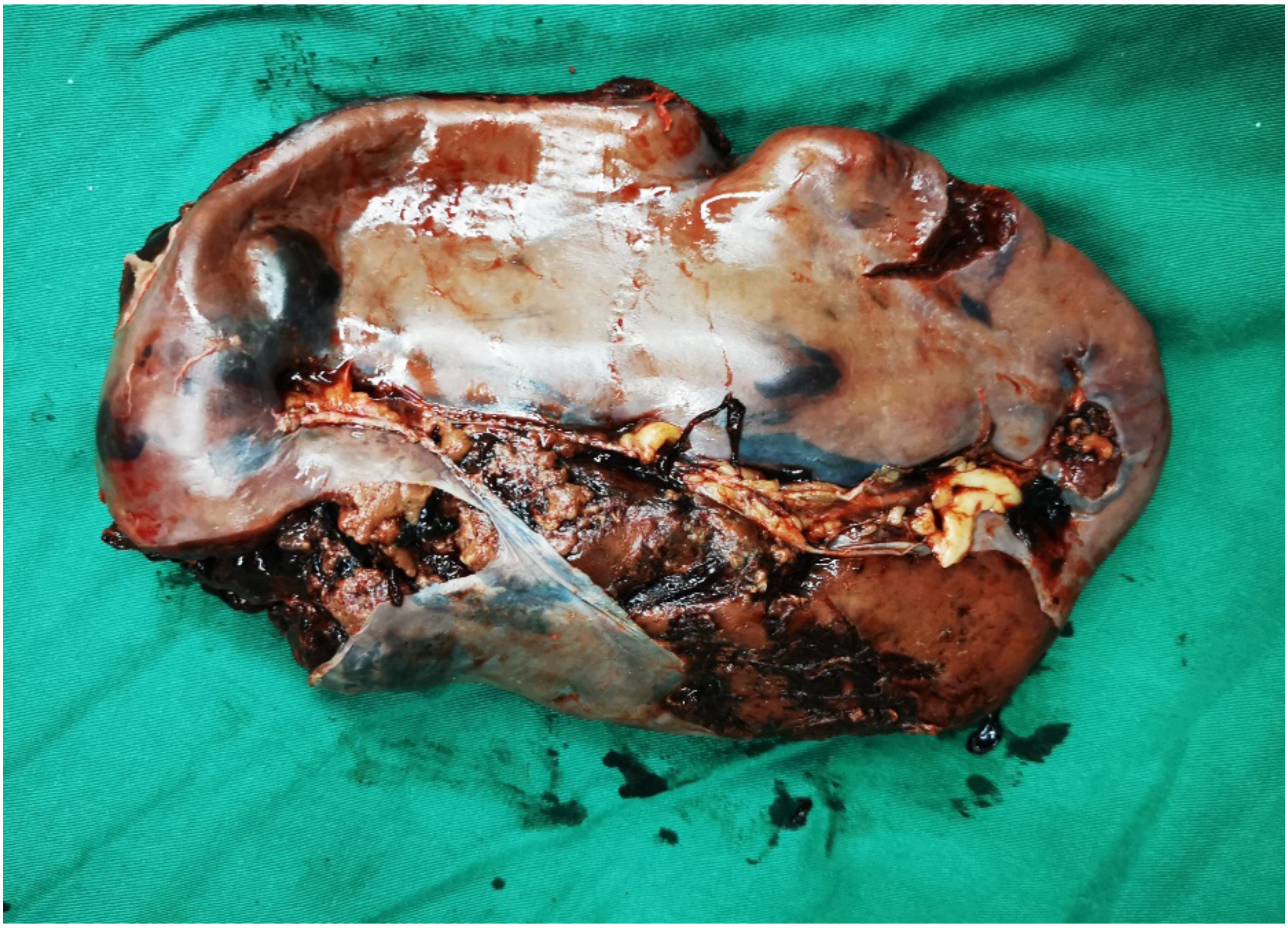

Fig. 2. Ruptured splenic capsule and subcapsular hematoma.

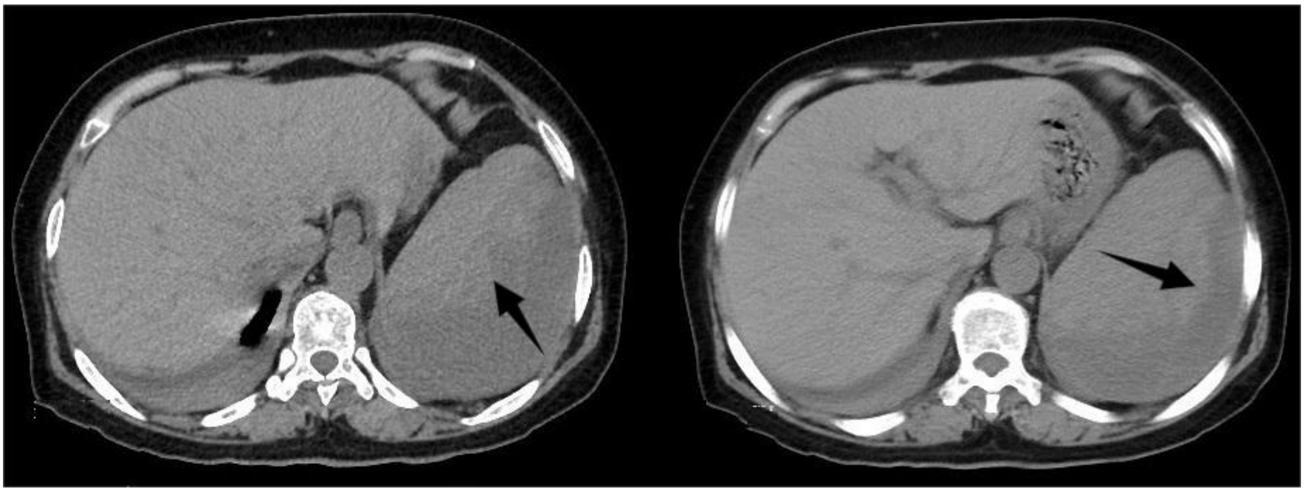

Fig. 3. Rechecked CT revealing a significant increase in the subcapsular hemorrhage days after hospitalization. Location of the delayed splenic rupture is indicated by the arrow.

age, or respiratory and circulatory system injuries, further obscuring splenic injury. These scenarios can contribute to delayed medical attention or conservative treatment without radiological assessment, potentially worsening the condition. In this study, 11 cases presented with atypical right upper abdominal pain, upon their first visit. Given the patients' multiple injuries post-trauma and the unclear diagnoses, we conducted both ultrasound and CT scans for all patients, which yielded positive results. This approach helped to prevent misdiagnosis and missed diagnoses, ensuring timely and accurate identification of splenic injury.

However, upon analyzing the past medical histories of these cases, we identified two patients with well-controlled cirrhosis (cases 5 and 10). One of them exhibited mild hypotension upon admission, which may be related to abnormalities in the portal venous system, whereas the other showed no significant abnormalities. Previous diseases unrelated to the hepatopancreatobiliary and spleen systems had no notable impact on the occurrence and progression of DRS. Rupture of the normal spleen, the organ commonly vulnerable to injuries [1,6–18] after abdominal trauma, may either present with immediate hemorrhage or delayed hemorrhage in up to 15% of the cases [1,3,19]. First described by Baudet in 1902 [1,19,20,25], DRS occurs in patients sustaining blunt trauma who experience no hemodynamic instability or other clinical symptoms for more than 48 hours after the initial injury [2,4,9,15,25,31]. It is characterized by initial clinical quiescence and subsequent splenic rupture. This asymptomatic window period is now referred to as the “latent period of Baudet” [2]. DRS tends to occur in 4 weeks after trauma in 90% of these patients [19,28] and 75%–80% of DRS cases occur in the first 2 weeks after injury [19,21,27], frequently happening in 4 to 8 days after trauma [4]. The DRS of all 12 cases in this study occurred 1 week after trauma. In some cases, the delay could be very much extended. For example, Deva and Thompson [28] reported a case with DRS 5.5 years after conservative management of traumatic splenic injury. Upon the diagnosis of DRS, a splenectomy was performed for this patient. During surgery, 3 L of free intraperitoneal blood was evacuated. Fresh blood and hematoma were found beneath the splenic capsule, which had been stripped off the parenchyma. Subsequent pathological examination also verified fresh subcapsular blood with normal splenic parenchyma. The possibility of DRS should be speculated when patients develop symptoms of abdominal pain, especially when accompanied by a history of abdominal trauma. Death cases due to rare DRS have also been reported in literature [1,20]. This underscores the importance to improve awareness and alertness to DRS and to implement early diagnosis and treatment for DRS so as to reduce complication and mortality rates.

The main clinical signs and symptoms of splenic rupture are abdominal hemorrhage including splenic laceration and peritoneal irritation [5,8,25], abdominal pain, rebound tenderness and/or tenderness or hypotension [1,4,5]. However, patients with DRS usually present with dull abdominal pain without typical clinical presentations. The diagnosis of DRS poses a major challenge to even the most astute clinician, as it may resemble to other medical emergencies [5]. The main manifestations of DRS are so atypical that they need to be differentiated from a wide range of diseases affecting the chest, abdomen, and musculoskeletal system [3–5,19,25,31]. The clinical symptoms of left upper abdominal tenderness [5,22], rebound tenderness, Kehr’s sign (left shoulder pain secondary to diaphragmatic irritation by the hemoperitoneum) [1,3,9,15,21,29] and Ballance’s sign (dullness around the splenic area signifying hematoma formation, combined with shifting dullness in the right flank from free blood) [5,21] are often considered the characteristics of DRS. However, in the absence of reliable predictors of DRS, the risks of DRS should always be meticulously evaluated when selecting nonsurgical treatments for these patients [4].

Computed Tomography-assisted Clinical Diagnosis of DRS

All patients in this study underwent preoperative ultrasound or abdominal CT scans, which revealed positive detection of DRS. Specifically, 5 cases underwent ultrasound examinations, while 9 patients underwent CT scans. Among them, 6 cases (cases 6, 7, 8, 10, 11 and 12, representing 50%) exhibited high-density shadows around the spleen on CT, indicating subcapsular hematomas with incompletely ruptured capsules. This was also confirmed by examination on the surgical specimens. The CT scans of the other 3 cases (cases 3, 4 and 9, representing 25%) showed unevenly increased spleen density or uneven enhancement after contrast enhancement. These patients were found to have splenic fragmentation and rupture during subsequent surgeries. Interestingly, the degrees of damage to the spleen in these two cases did not result in variations in the patients’ vital signs with statistical significance. Hemorrhagic shock is not very common among patients with DRS, due to several factors: (i) The rupture may initially be subcapsular, with bleeding confined under the splenic capsule, slowing the hemorrhage. (ii) In some cases, due to local coagulation and adhesion with surrounding organs, a hematoma may form. This hematoma may be temporarily stable, but it may continue to bleed after the patient being subjected to further impact or participating in vigorous exercise. (iii) The rupture site may be small, resulting in slow and minimal bleeding. Patients often have a latent period with minimal or no symptoms, allowing the body’s coagulation mechanisms to respond. The slow bleeding rate and the latent period contribute to less acute blood loss, reducing the risk of hemorrhagic shock [32]. However, despite the lower immediate risk, prompt treatment is crucial to prevent delayed splenic rupture from deterioration.

Both B-ultrasound and CT can aid in the diagnosis of DRS, and each of them features distinctive advantages. The greatest advantage of B-ultrasound lies in its convenience and speed, enabling timely assessment of the patient’s condition, and it can be performed beside the patient’s bed, with a lower risk of causing secondary harm to the patient. Compared to B-ultrasound, CT can provide more information about the patient. The comprehensive CT scans performed in cases 3, 4, 6, 7, 8, 9, 10, 11 and 12 had accurately identified the extent of splenic rupture (whether the splenic capsule was intact). As a common and mature clinical diagnostic tool, CT can effectively aid in the diagnosis of DRS compared to B-ultrasound, especially in situations where patient transport is difficult and after excluding CT-related contraindications; therefore, this diagnostic method should be prioritized for use.

Although the use of serial CT scans as an adjunct to the nonoperative management of splenic injury is deemed controversial in literature [25,26], the value of CT scans in the diagnosis of splenic injury has been well established [7,16,23,33,34]. With a 100% sensitivity in detection [2], CT is the preferred imaging examination, supplanting angiography and ultrasound, for the diagnosis of DRS [3–5,7,14]. Authors [1,5,7,19,21,35] found that the sensitivity, specificity and accuracy of CT scan in the diagnosis of blunt abdominal injury were as high as 85%, 100% and 97%, respectively. CT findings substantiate the diagnostic accuracy and are proved to be useful for successful reduction of unnecessary exploratory laparotomy in splenic injury [11]. CT scan can help with clearly displaying the anatomy and internal architecture of the spleen, and it is usually proved valuable in the diagnostic arena by virtue of its ability to show increased density at the site of recent hemorrhage [11,13], which can often be regarded as a defect due to hematoma in an ultrasound and radioisotope scan [1,7,16]. The CT findings are also useful for grading blunt splenic injury (BSI) and identification or quantification of hemoperitoneum [11]. CT scan can also well provide information on the degree of splenic parenchymal injury, the extent of splenic laceration and hematoma, and the volume of hemoperitoneum [1,16,33], which can frequently increase the diagnostic confidence of surgeons and play an important role in decreasing the frequency of unnecessary exploratory laparotomy [33]. It has been shown that CT is an accurate, noninvasive method or rapidly diagnosing splenic trauma [6], and Leeper *et al*. [14] suggested a repeated CT scan at 48 hours rather than 7 days in response to a sentinel DRS event as repeated CT could demonstrate a 10% rate of progression/worsening of splenic injury. Kodikara [1] considered that despite the comparatively low reliability of CT in predicting DRS, this imaging approach can discover the expansion of splenic hematoma to predict an imminent splenic rupture. As in cases 3, 4 and 8 reported herein, the rechecked CT scan found that the splenic subcapsular hematoma had grown in size (Fig. 3); therefore, splenectomy was adopted immediately to prevent hemorrhagic shock caused by subcapsular hematoma rupture. For the patients with unexplained abdominal pain without a history of trauma or with negative ultrasound examination result, even if their hemodynamics is stable, abdominal CT examination is of great value in the establishing diagnosis [1,3,6]. CT scan also can identify some splenic post-traumatic lesions that are related to the failure of conservative treatment, like parenchymal pseudoaneurysms, subcapsular hematomas, and splenic psedocysts [7]. In addition, CT scan can well display the features of DRS such as splenic abscess formation and post-traumatic splenic artery pseudoaneurysm. In addition, knowing that CT may fail to detect splenic injury if the scan is performed before the subcapsular hematoma formation, or before it grows to a visible size, we should be cautious in interpreting the CT scan results as a normal appearance of the spleen on the initial scan could be a false reassurance [4]. Therefore, regularly rechecked CT scan during the latency period of the high-risk patients with abdominal injury is conducive to early detection of DRS [4,5,19,27,30]. The non-invasive bedside Focused Assessment with Sonography for Trauma (FAST) has been regarded as the modality of choice on the grounds of the ease in determining the presence of intraperitoneal hemorrhage and facilitating the decision-making on performing urgent exploratory laparotomy for hemodynamically unstable patients [11]. However, one-fourth of splenic injuries could be missed by ultrasonography, indicating that a negative ultrasound was not accurate to rule out splenic injuries [11,19] or DRS [20]. While FAST can only be used to detect the presence of free fluid in the abdomen, a systematic exploration of the abdomen is required to confirm the diagnosis of DRS [15]. Scholars found that diagnostic peritoneal lavage should be adopted in the diagnostic process of DRS, but 0.9%–2.5% of the cases would have a false-positive result especially in the patients comorbid with pelvic fractures and retroperitoneal hematoma [30]. In addition, negative result of diagnostic peritoneal lavage cannot completely rule out the existence of DRS [2,30], so diagnostic peritoneal lavage is not particularly advantageous in the diagnosis process of DRS [5,29].

Treatment of DRS

In this study, all patients ultimately underwent surgical intervention. Among them, 8 cases (Cases 1, 2, 5, 6, 7, 9, 10, 11; 66.6%) underwent emergency surgery within 24 hours of admission. However, Case 4 required urgent attention for a pneumothorax (right-sided, with approximately 80% compression of the right lung), and thus underwent surgery after the pneumothorax had resolved. The remaining 3 cases (Cases 3, 8, 12) initially received conservative treatment for various reasons, including strong requests from patients and their families. After 2–7 days of conservative management, repeat CT scans and blood tests revealed no significant improvement or even further deterioration, which prompts surgical intervention as rescue treatment. Ultimately, all patients were discharged in good health with favorable outcomes. Based on these findings, we believe that surgical treatment for patients with DRS is of high treatment value. Conservative management for DRS, which primarily focuses on maintaining vital signs and pain relief, is usually indicated if an incompletely ruptured splenic capsule has a compressive effect on hemostasis. Given the limited self-regenerative capacity of the injured spleen, conservative management often fails to achieve satisfactory outcomes (as seen in Cases 3, 8 and 12). Furthermore, considering that splenic functions can be compensated by other tissues and organs following splenectomy, with minimal impact on patients' daily lives, we conclude that surgery is the preferred treatment option for DRS.

By referencing the consensus of experts in China and various clinical guidelines, as well as our own clinical experiences, we synthesized the following indications for performing emergency surgery on patients with DRS: (i) The patient's hemodynamics are unstable and even prone to shock, or significant improvement in vital signs is limited after systemic rehydration and other symptomatic treatment. (ii) Imaging examination strategies such as ultrasound and CT indicate severe damage of the spleen, accompanied by other organ damage. (iii) Imaging examination indicates persistent bleeding in abdominal cavity. (iv) There is splenic center rupture, splenic hilar laceration or massive tissue inactivation. (v) The symptoms with unknown reasons, such as increasingly abdominal pain, show signs of exacerbation, necessitating immediate laparotomy. (vi) Individuals with previous spleen disease. Among the reported patients, Case 4 urgently needed treatment due to pneumothorax. Case 8 and his families opted for conservative treatment even after the physician advised them on the possibility of conducting. However, after the initial conservative treatment, a subsequent CT scan revealed a further increase in intra-abdominal hemorrhage, warranting surgical intervention for controlling the pathological condition. In Case 12, the patient suffered from severe cholangitis due to gallstone, so the doctor prioritized gallbladder drainage for controlling infection. After the more urgent symptoms had been addressed or the patients exhibited no obvious improvements after receiving the conservative treatment, surgical treatment was prescribed. In summary, given our understanding of DRS, the principal principles surrounding the treatment should lie in life sustenance, followed by instant surgical intervention, *i.e.*, splenectomy.

A growing line of evidence [5,7,30] has demonstrated that nonoperative management (NOM) for splenic injury holds promise in safeguarding hematological and immune functions [6,15,22] of the spleen, owing to the advances in imaging techniques [18] and the increased awareness of the overwhelming post-splenectomy infections [15,18,28,36]. For example, splenic arterial embolization (SAE) rather than surgery for hemodynamically stable patients have successfully performed in some medical centers [4,5,25,34]. In the past 30 years, increasing number of physicians have adopted NOM for blunt splenic injury in patients with stable hemodynamics [4,8,11,14,26,34]; however, the NOM protocol across the practicing institutions lacks standardization and there is a lack of agreement on protocol by trauma surgeons of the same institution [14]. So far, NOM for blunt splenic injury has been widely used and is considered the gold-standard procedure [7,14,25]. However, Clancy *et al.* [26] found that the mortality rate associated with a failed NOM was 4% as higher overall severity of injuries which need a greater RBC and fluid amongst. The decision of conducting NOM depends largely on the initial imaging results and other clinical factors including the patient's age [34], the presence of concurrent injuries, the degree of splenic injury that is gauged with the Splenic Injury Scale proposed by the American Association for the Surgery of Trauma (AAST), and the reliability of clinical assessments [4,5,8]. However, unjustified implementation of SAE may precipitate the occurrence of side effects [34] such as DRS, splenic abscess, septicemia, splenic vein thrombosis that leads to post-embolization segmental splenic infarction in 63%–100% of patients [13,18,26], pleural effusions, paralytic ileus, pancreatitis, atypical vascular access, and contrast-induced renal insufficiency. Bourgeois and Fey [15] concluded that splenorrhaphy, which is more frequently and successfully conducted in children who have a much more elastic capsule than adults, has a decreasing role because most injuries now operated upon are severe splenic trauma. Actually, the occurrence of post-splenectomy infections is less than 0.5% [27], indicating that an expeditious splenectomy is in the best interest of these patients. Authors [11,13,14,25,26,31] considered that DRS was one of the rare but serious complications of NOM. The implementation of conservative and operative managements can be really subjective [5], and conservative therapy or splenoplasty may put the patients at risk of persistent bleeding, infection and DRS [5,7,8,11,28,36,37]. Mahon and Sutton [37] analyzed 11 patients with splenic injury initially receiving NOM and revealed that 73% of these cases subsequently required surgery for delayed hemorrhage. It has been reported that the need for operation was obviated only in 30% of patients with nonoperative splenic trauma and the average length of hospital stay for patients managed through observation was longer than those who had splenectomy, which incurs no excess risk for early infectious complications [36]. A case report showed that a patient with DRS, who had endured unsuccessful splenic embolization, successfully recovered after splenectomy [10]. Pucci *et al.* [17] reported the first case of a totally laparoscopic splenectomy for DRS after embolization in 2007. Moreover, the failure rate for NOM was reported to be approximately 10% [7] or 12% [18] in patients with grade III (19%) and grade IV injuries (100%), who had significant morbidity and mortality compared to those receiving immediate surgical treatment and faced worsening severity of splenic injury; these findings underline the need to prudently utilize nonsurgical treatment in adults with DRS. An overall failure rate of 33% for using NOM in DRS has also been reported [27]. Ward and Gillatt [30] found that delayed splenic rupture in adults may necessitate urgent laparotomy and splenectomy in up to 73% of splenic injuries. A death case owing to the delayed rupture of healthy spleen following blunt trauma, even though splenectomy had been performed, has been reported [1]. Splenectomy is required in patients with ongoing intra-abdominal bleeding, evidence of multiple injuries, abnormal laboratory parameters, and the requirement for blood transfusion [5]. All the 12 cases in this report had undergone splenectomy, and three total laparoscopic splenectomy procedures we performed ended up with good clinical results. It is worth noting that all of the conditions of 12 patients did not improve and even worsened further during the NOM process, requiring splenectomy to achieve good clinical outcomes without post-procedure infection. Case 3 developed persistent low fever (less than 38.5 °C) from the third day after NOM, but the symptoms of fever and chills resolve without medication on the second day post-splenectomy, indicating the possible attribution of fever to subcapsular hematoma caused by splenic rupture.

The Impact of Splenectomy

The spleen is a crucial lymphatic organ that stores blood, participates in hematopoiesis, clears senescent red blood cells, initiates immune responses, synthesizes biologically active substances, and filters blood. The effects of splenectomy are summarized in the following:

I. Decline in Immune Function. After splenectomy, the body's resistance to certain bacteria and viruses decreases, especially in children, whose immune defense can be affected to a greater extent [38]. Although other immune organs such as lymph nodes and the liver can partially compensate for the spleen's declining immune functions, this would still result in partial alteration to the overall immune function to some degree. With such altered immune state, patients may become more vulnerable to infectious diseases such as respiratory infections and intestinal infections.

II. Alterations in the Blood System. The spleen stores platelets in the blood system. After splenectomy, this may lead to an increase in platelet count, thereby exacerbating blood coagulation and increasing the risk of thrombosis [39]. The spleen also participates in the destruction of aged or abnormal red blood cells. After splenectomy, this function is weakened, possibly leading to hemolytic anemia or polycythemia.

III. Impact on Digestive System. Splenectomy may affect the function of the digestive system because the spleen is located adjacent to the digestive system [40]. Patients may experience symptoms such as appetite loss, dyspepsia, bloating, gastroesophageal reflux, constipation, or diarrhea. These effects are usually temporary, but some patients may be affected for a longer period. In the early postoperative period, patients need to pay attention to dietary adjustments and avoid oily, spicy, or other irritating foods.

Conclusions

In clinical practice, we should pay more attention to DRS even in cases with atypical history, atypical trauma mechanism, and no history of splenic pathology. Combined with the literature and our clinical experiences, we believe that DRS is a valid clinical entity consistently matching Baudet's description of delayed splenic rupture. Despite the relatively low incidence of DRS, the mortality rate of DRS can be as high as 5%–15% compared with 1% mortality rate of acute spleen injury. Thus, more sensitive tests should be performed to confirm DRS from among the cases of abdominal injury and/or blunt chest trauma with varying clinical manifestations. Patients should be reminded, prior to discharge following the admission for blunt abdominal trauma, to seek immediate medical help in case of unexplained abdominal pain. CT is the preferred auxiliary tool for the diagnosis of DRS. Surgery should be timely performed once DRS is diagnosed. Splenectomy should be performed especially in DRS patients who have failed conservative therapy over time, because splenoplasty is often very difficult under this premise. Laparoscopy is a potentially useful adjunct for DRS, but its exact role has not been delineated. Complications such as infection and abnormalities in blood components after splenectomy warrant further attention during subsequent outpatient follow-ups.

Availability of Data and Materials

The data analyzed was available at the request of the corresponding author.

Author Contributions

JCZ designed the research and made the first draft. JCZ and GFZ performed the research. LL provided help for manuscript preparation and advice on the research, and helped analyze the data. SBX and CKJ analyzed the data. All authors have been involved in revising it critically for important intellectual content. All authors gave final approval of the version to be published. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

In this study, all participants voluntarily signed an informed consent form after fully understanding the research objectives, procedures, potential risks, and measures for protecting personal privacy. All the contents conducted in this article adhered to the Declaration of Helsinki. This procedure ensured the ethical nature of the research and was in compliance with the laws and regulations of China as well as the guiding principles of Ethics Committee of Hangzhou First People's Hospital. All research activities were conducted after obtaining approval from the Ethics Committee of Hangzhou First People's Hospital (Ethics Approval Number: ZN-2024314-01).

Acknowledgment

Not applicable.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.62713/aic.3767.

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