ORIGINAL ARTICLE

Complications and recovery patterns after blunt splenic injury: Recommended duration and follow-up methods

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ABSTRACT

BACKGROUND: Splenic artery embolization (SAE) is commonly employed as a non-operative management technique for splenic injury. Nonetheless, information on follow-up duration and methods, and the natural course of splenic infarction after SAE is limited. Thus, this study is aimed to analyze the patterns of complications and recovery of splenic infarction after SAE and to determine the appropriate follow-up duration and method.

METHODS: Medical records of 314 patients with blunt splenic injury admitted at the Pusan National University Hospital, Level I Trauma Centre were analyzed to identify patients who underwent SAE between January 2014 and November 2018. Computed tomography (CT) scans that were obtained after SAE in patients who were followed up were compared with all their previous CT scans to identify any changes in the spleen and the occurrence of complications such as sustained bleeding, pseudoaneurysm, splenic infarctions, or abscess formation.

RESULTS: Of the 314 patients, 132 who underwent SAE were included in the study. In total, 30 complications were noted among the 132 patients; of these, 7 (5.30%) required repeat embolization and 9 (6.82%) required splenectomy. Splenic infarction of <50% occurred in 76 patients and that of ≥50% including total and near-total infarctions occurred in 40 patients. Among patients with splenic infarction of ≥50%, 3 (2.27%) patients had abscesses between 16 and 21 days after SAE, and the range of infarctions increased as the AAAST-OIS grade increased. After SAE, repeat abdominal CT scans for >14 days were obtained in 75 patients; among these, 67 presented with recovery of splenic infarction. The median period of recovery was 43 days after SAE.

CONCLUSION: The present findings suggest that patients with ≥50% infarction may need 3 weeks of closed observation, with or without a follow-up CT scan, to rule out infection after SAE, follow-up CT follow-up at 6 weeks after SAE may be necessary to confirm the recovery of the spleen.

Keywords: Blunt injury; embolization; follow-up study; splenic infarction.

INTRODUCTION

Non-operative management (NOM) is a widely accepted method for managing hemodynamically stable patients with blunt splenic injury.[1–3] NOM can minimize the risk of emergency laparotomy and preserve the immunoprotective function of the spleen.[4,5] Splenic artery embolization (SAE) was developed by Sclafani et al.[6,7] as a technique for the treatment of splenic injury in the 1980s. Since then, SAE has been widely used in the treatment of blunt splenic injury.[8,9] Although SAE is undertaken for hemodynamically stable low-grade splenic injuries, some institutions have expanded the application of SAE to Grades IV and V injuries according to the American Association for the Surgery of Trauma Organ Injury Scale (AAST-OIS) (Table 1).[9,10] Given the broad acceptance of SAE, this intervention has been considered a safe and

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Table 1. Spleen injury scale (2018 revision)

AAST grade	Imaging criteria (CT findings)
I	- Subcapsular hematoma < 10% surface area - Parenchymal laceration < 1cm depth - Capsular tear
II	- Subcapsular hematoma 10-50% surface area; intraparenchymal hematoma <5 cm - Parenchymal laceration 1-3 cm
III	- Subcpsular hematoma >50% surface area; ruptured subcapsular or intraparenchymal hematoma ≥5 cm - Parenchymal laceration >3cm depth
IV	- Any injury in the presence of a splenic vascular injury or active bleeding confined within splenic capsule - Parenchymal laceration involving segmental or hilar vessels producing >25% devascularization
V	- Any injury in the presence of a splenic vascular injury with active bleeding extended beyond the spleen into the peritoneum - Shattered spleen

Vascular injury is defined as a pseudoaneurysm or arteriovenous fistula and appears as a focal collection of vascular contrast that decreases in attenuation with delayed imaging. Active bleeding from a vascular injury presents as vascular contrast, focal or diffuse, that increases in size or attenuation in the delayed phase. Vascular thrombosis can lead to organ infarction.
AAST: American Association for the Surgery of Trauma.

effective option for the NOM of splenic injury. Furthermore, NOM is considered the standard treatment for blunt splenic injury, rather than as an alternative to surgery.[11–15]

It is well known that complications may occur after SAE. However, only few studies have investigated the natural course of recovery of splenic infarction after SAE.[11,15] Therefore, information on the follow-up duration and modality of post-SAE observations, which currently depends on the clinician's preference, is limited.

Accordingly, the present study was conducted to evaluate the complications and recovery patterns in the spleen after SAE and to suggest the duration and method of post-SAE follow-up.

MATERIALS AND METHODS

We retrospectively reviewed the medical records of 314 patients with blunt splenic injury who were admitted to the Pusan National University Hospital, Level I Trauma Centre between January 2014 and November 2018. Computed tomography (CT) scan was carried out in patients with blunt abdominal trauma who were hemodynamically stable or promptly recovered after fluid resuscitation. Patients with extravasation, blush, or pseudoaneurysms after blunt splenic injuries were eligible to undergo arteriography regardless of the AAST-OIS grade. Contrast extravasation was defined as an irregular collection through intra- or extra-parenchymal enhancement with attenuation, which was either similar to or greater than that of the aorta or a major artery.[16] Initial CT scans that were obtained on admission were retrospectively reviewed and classified according to the AAST-OIS grading system.[17] Splenic arteriography and SAE were carried out by physicians from the department of radiology.

Proximal embolization was defined as the placement of embolization material in the main trunk of the splenic artery, and distal embolization was defined as embolization involving >1 branch of the splenic artery.[15] Gelfoam (Mascia brunelli®, Milano, Italy), coil (COOK®, Bloomington, IN, USA), or n-butyl cyanoacrylate (NBCA) (Alteco®, Osaka, Japan) glue were used as the embolic materials based on the status of individual patients after discussion between the radiologist and the attending trauma doctor. Embolization was considered successful if there was disappearance of the irregular collection or blush of contrast in the final splenic arteriography.

Unless otherwise specifically indicated, CT scans were conducted on days 3 and 7 after SAE, as well as during the follow-up at the outpatient clinic. Because it is difficult to measure splenic volume in trauma patients using routine examinations, such as splenic scintigraphy, the range of splenic infarction was classified as ≥50% and <50%. This was distinguishable on CT scans, and the results were confirmed by two researchers. An infarction of more than 90% was defined as a near-total infarction and a 100% infarction was defined as a total infarction; these infarction types were included in the more than 50% infarction group and were sometimes classified separately. The study population was grouped according to splenic infarction of <50% or ≥50%, including near-total and total infarction. All follow-up CT scans were compared, and the recovery progress from infarction was observed.

Recovery from infarction was only analyzed in patients whose follow-up CT scans were conducted at >2 weeks. Recovery

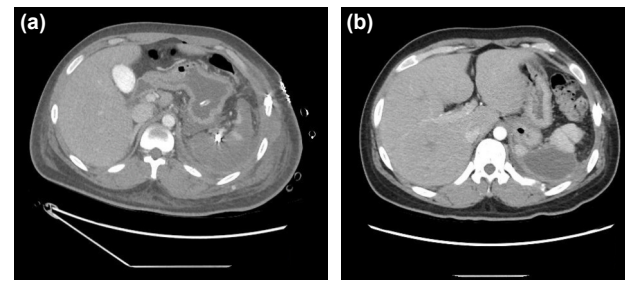

Figure 1. (a) Follow-up abdominal CT scans revealing near-total infarctions except the collateral circulation 7 days after splenic artery embolization. **(b)** CT showed the reduction of splenic infarction 35 days after splenic artery embolization. We defined this as recovery of the spleen.

of the spleen was determined by comparing the initial and follow-up CT scans, and the time of recovery was determined as the time when an apparent reduction in infarction size was observed. This was confirmed by two researchers (Fig. 1).

Statistical Analysis

Statistical analyses were conducted using IBM SPSS ver. 21.0 (IBM C., Armonk, NY, USA). Complications were analyzed according to the size of infarction, difference in infarction scope (which was defined based on the ASAST-OIS grading system), and embolic material using the Fisher's exact test. Gas formation based on the range of infarction was analyzed using the Chi-square test. P<0.05 were considered statistically significant.

This study was approved by the Institutional Review Board of Pusan National University Hospital, Busan, Korea, and was performed in accordance with the ethical standards set forth in the 1964 Declaration of Helsinki and its later amendments (IRB No.: H-1902-008-076). The need for informed consent was waived due to the retrospective nature of the study.

RESULTS

We analyzed data from the medical records of 314 patients with blunt splenic injury. Of these, 85 and 86 patients underwent emergency laparotomy and NOM, respectively, and 143 patients underwent splenic arteriography. Among the 143 patients with splenic arteriography, 132 underwent SAE and 11 underwent diagnostic arteriography. Of the 132 patients who underwent SAE, 116 were selected to observe the course of infarction. Seventy-six patients developed splenic infarction of <50%, while 40 patients developed splenic infarction of ≥50%, including total and near-total infarction (Fig. 2).

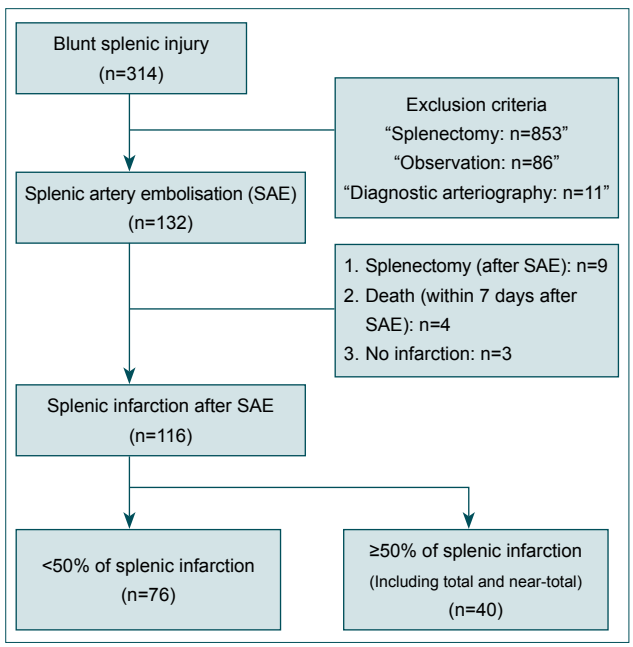

Figure 2. Diagram of patient selection for observing the natural course of splenic infarction after splenic artery embolization (SAE).

Table 2. Recovery of splenic infarction based on follow-up CT findings in patients with follow-up CT scans for >2 weeks after splenic artery embolisation

Recovery of splenic infarction	Duration of follow-up (day, median)
Total patients (n=75)	14–191 (42)
Not observed recovery (n=8)	14–63 (18.5)
Observed recovery (n=67)	14–191 (43)

CT: Computed tomography.

Among the 116 patients (age, 44.85±20.35 years) with splenic infarction, 92 were male and 24 were female. The average AAST-OIS grade was 2.49±0.87. Only one patient underwent proximal embolization with a coil, the remaining patients underwent distal embolization. With regard to the type of embolization material, coil (n=3), NBCA glue (n=36), Gelfoam (n=58), and both Gelfoam and coil (n=19) were used in this study population. The range of infarction was not significantly different according to the type of embolic material used (p=0.068).

CT scans were obtained in 76 of 116 patients with >2 weeks of follow-up either during their hospitalization or following discharge post SAE. Of these 76 patients, 67 (89.33%) showed improvements of the splenic infarction, whereas eight showed no improvement. The median follow-up period of CT scans in patients with no improvement was 18.5 days, whereas the median follow-up period in those with improvement was 43 days (Table 2).

Post-SAE complications were defined as sustained bleeding, pseudoaneurysms, splenic infarctions (includes only near-total or total infarction), or abscesses, which were considered major complications after SAE and were also factors that influenced patient recovery and hospitalization duration. Follow-up CT scans were compared with all previous CT scans to evaluate any changes, including sustained bleeding, formation of pseudoaneurysms, progress of the splenic infarctions, or development of the abscesses after the SAE. In addition all follow-up CT scans were compared with initial CT scans to determine the post-SAE change patterns. In the 132 patients who underwent SAE, 30 complications were reported (Table 3).

Intra-splenic gas formation was significantly different between the ≥50% infarction group and the <50% infarction group (15 patients [37.5%] vs. 1 patient [1.3%], p<0.05). Notably, all cases of abscesses occurred in the ≥50% infarction group (p=0.010; compared with the <50% infarction group; Table 4).

The range of infarctions after SAE increased with the increase in the AAAST-OIS grade (Table 5).

Table 3. Complications after SAE† (n=132 patients)

Complication (n=30)	Number (%)	Days after SAE† until complication was diagnosed (day, median)
Bleeding or pseudoaneurysms (repeat SAE)	7 (5.30)	2–56 (5)
Bleeding (splenectomy)	9 (6.82)	0–4 (0.5)
Infarctions (Near-total and total)	11 (8.33)	1–9 (3), confirmed by CT
Abscesses	3 (2.27)	16–21 (18), Confirmed by CT and percutaneous drainage was preformed

CT: Computed tomography; SAE: Splenic artery embolisation.

Table 4. Development of abscesses according to the range of splenic infarctions and gas formation within splenic parenchyma after splenic artery embolisation

Range of infarction	n=116	Gas within spleen (%)	p-value	Abscess (%)	p-value
≥50% (including near-total and total infarctions)	n=40	15 (37.5)	<0.05	3 (7.5)	0.010
<50%	n=76	1 (0.3)		0 (0)	

Table 5. Range of splenic infarction after splenic artery embolisation according to the AAST-OIS grade

Grade	n=116	<50% (%)	50–90% (%)	≥90% (%) (near-total and total)	p-value
I	n=11	9 (81.8)	2 (18.2)	0 (0.0)	0.002
II	n=55	43 (78.2)	10 (18.2)	2 (0.0)	
III	n=33	16 (48.5)	13 39.4)	4 (12.1)	
IV	n=16	8 (50.0)	4 (25.0)	4 (25.0)	
V	n=1	0 (0.0)	0 (0.0)	1 (100.0)	

AAST-OIS: American Association for the Surgery of Trauma – Organ Injury Scale.

DISCUSSION

There are only few reports on post-SAE follow-up. One study showed the recovery of splenic infarction with follow-up ultrasonography, whereas another study argued the necessity of follow-up CT scan to eliminate the risk of infection in cases where the intra-splenic gas formation was observed within the infarction.[15,18] However, these studies have not suggested a specific follow-up duration. In this study, we observed the natural course of spleen recovery after SAE using CT scans. Based on the development patterns of complications and the timing of spleen recovery, we suggest that the duration and method of follow-up, which varied according to each attending doctor and patient, should be further systemized.

Most studies have reported post-procedural bleeding, near-total infarction, and abscess as major complications, and fever, pleural effusion, coil migration, and partial splenic infarction as minor complications. Notably, a multicenter study by Hann et al.[14] has reported 20% major and 23% minor complications, and another study has reported 27% major and 53% minor complications.[15] In our study, major complications were observed in 20.9% of the patients, the finding is similar to that in the studies mentioned above.

Overall, three patients developed abscesses, and all of them were in the ≥50% infarction group, implying that the range of infarction was associated with the development of abscesses (p=0.01). Moreover, in the ≥50% infarction group, 15 patients (37.5%) developed intra-splenic gas, and of the 15 patients, two developed abscess. According to a previous report, it is difficult to distinguish intra-parenchymal gas from abscesses on follow-up CT scans after SAE.[18] In that study, among the included 63 patients, seven developed splenic gas after SAE; of the seven patients, four showed resolved, two developed abscesses (for which percutaneous pus drainage was performed), and one underwent splenectomy. Notably, in the present study, only one (1.3%) of the 76 patients in the <50% infarction group developed splenic gas based on follow-up CT scans, implying an association between the range of infarction and the development of gas (p<0.05). In addition, abscess was diagnosed in a median of 18 days after SAE, suggesting that 3 weeks of observation were needed after SAE.

Post-procedural bleeding, including pseudoaneurysms, can be identified within a short follow-up duration. Not all patients require repeated CT scans for long-term evaluation. However, this study found a higher likelihood of infections in patients

with ≥50% infarction. Patients with a high AAST-OIS grade were associated with large infarctions, which might be associated with the development of intrasplenic gas and abscesses after SAE.

To date, the clinical implication of splenic infarctions developed after SAE is not yet clear. Killeen et al.[18] reported the development of splenic infarction in 63% and 100% of cases with proximal embolization and distal embolization, respectively, but most of them recovered without specific complications. Because the spleen has abundant collateral blood vessels, most clinicians do not pay careful attention to splenic infarctions.[19] However, the splenic infarctions can be the cause of fever or the source of infections post SAE.[20,21] Moreover, in case of large infarctions, percutaneous cultures are needed to identify any infections, and if there are any accompanying symptoms, such as fever and abdominal pain, surgical treatment may be needed.[14]

Among the 116 patients who showed splenic infarction, no patient required surgical treatment. The spleen was preserved in the remaining 115 patients except in one patient who developed total infarction. On day 21, an abscess was detected and percutaneous abscess drainage was performed, after which the spleen was liquefied.

Of the 116 patients with splenic infarction, 41 were lost to follow-up and 75 were examined for recovery from splenic infarction. The average time to confirmation of recovery was 43 days in the 75 patients, and was 37 days in the ≥50% infarction group. Overall, 67 patients underwent follow-up CT scans 3 times, and the time from SAE to follow-up CT scan differed slightly according to the patients' status and their attending doctor.

Vaccinations for *Streptococcus pneumonia*, *Neisseria meningitides* and *Haemophilus influenza* type B were administered

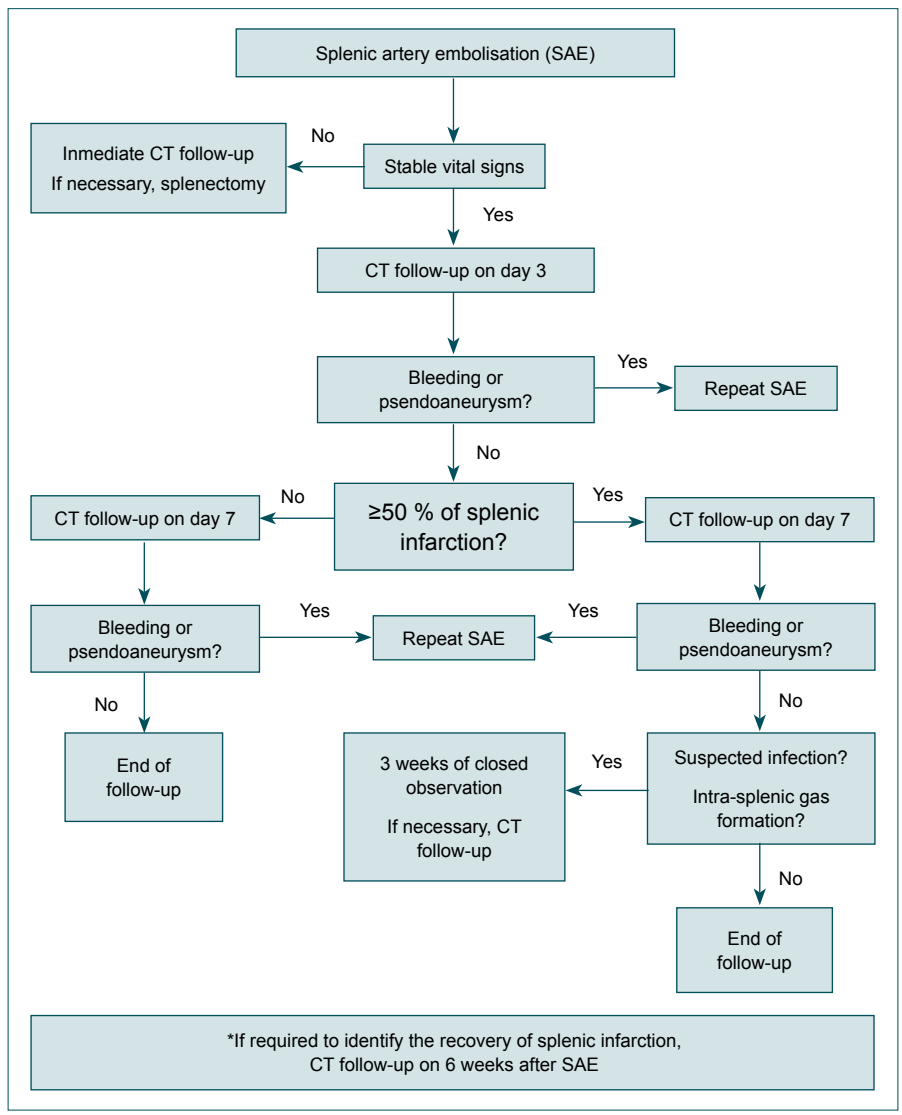

Figure 3. Algorithm to propose the duration and method of follow-up according to the range of splenic infarctions after splenic artery embolization. CT: Computed tomography; OIS: Organ injury scale.

to only one patient whose splenic parenchyma completely disappeared after abscess. There are no standardized parameters for accurately measuring the immunologic function of the spleen, and several studies have reported that the immunologic function of the spleen is well preserved in patients undergoing NOM after splenic injury.[22] Therefore, clinicians do not routinely administer vaccinations during NOM. In the present study, vaccination was not undertaken unless there was a complete disappearance/absence of the spleen.

This study has some limitations. First, the duration of the follow-up CT scan was inconsistent due to the retrospective nature of the study. Whether follow-up CT was performed depended on the attending doctors' discretion and the patients' conditions. Moreover, the follow-up periods and frequencies differed among patients. If the duration of CT follow-up was consistent, which would be possible in prospective studies, the duration of follow-up for recovery from infarction could be reduced. Second, we could not rule out the effects of antibiotics in the development of abscess. Most patients with blunt splenic injury were multi-trauma patients. Of the 314 patients, 29 were treated for the splenic injury alone and did not receive antibiotics. However, all three patients who developed abscess had received antibiotics due to multiple traumas. Therefore, it is unclear whether the use of antibiotics might have affected complications such as abscess.

Conclusion

We developed a standard algorithm to suggest the appropriate post-SAE follow-up duration and method (Fig. 3). Our findings recommend that patients who undergo SAE require a 3-week closed observation to rule out infections, with or without follow-up CT scans, and a follow-up CT at 6 weeks may be required to confirm recovery.

Ethics Committee Approval: This study was approved by the Institutional Review Board of Pusan National University Hospital, Busan, Korea (Date: 26.02.2019, Decision No: H-1902-008-076).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: J.H.K., C.W.K.; Design: J.H.K., C.W.K.; Supervision: J.H.K., C.W.K.; Resource: S.B.L.; Data: C.I.P.; Analysis: C.I.P., S.J.P.; Literature search: C.I.P., S.J.P.; Writing: S.B.L.; Critical revision: S.B.L.

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Künt splenik yaralanma sonrası komplikasyonlar ve iyileşme paternleri: Önerilen süre ve takip yöntemleri

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AMAÇ: Splenik arter embolizasyonu (SAE), dalak yaralanmasının ameliyatsız yönetimi olan bir teknik olarak yaygın kullanılmaktadır. Bununla birlikte, SAE sonrası takip süresi ve yöntemleri ile dalak enfarktüsünün doğal seyri hakkındaki bilgiler sınırlıdır. Bu çalışmada, SAE sonrası dalak enfarktüsünün komplikasyonları ve iyileşme paternlerini analiz etmek ve uygun takip süresi ve yöntemini belirlemek amaçlanmıştır.

GEREÇ VE YÖNTEM: Ocak 2014 ile Kasım 2018 arasında Pusan Ulusal Üniversite Hastanesi, Birinci Basamak Travma Merkezi'ne başvuran künt dalak yaralanması olan 314 hastanın tıbbi kayıtları, SAE uygulanan hastaları belirlemek üzere analiz edildi. Takip edilen hastalarda SAE sonrası elde edilen bilgisayarlı tomografi (BT) görüntüleri, dalakta herhangi bir değişiklik olup olmadığını ve devam eden kanama, psödoanevrizma, dalak enfarktüsü veya apse oluşumu gibi komplikasyonların oluşumunu belirlemek için önceki tüm BT taramaları ile karşılaştırıldı.

BULGULAR: Üç yüz on dört hastadan SAE yapılan 132'si çalışmaya dahil edildi. Toplamda, 132 hasta arasında 30 komplikasyon kaydedildi; bunların 7'si (%5,30) embolizasyon tekrarı ve 9'u (%6.82) splenektomi gerektirmişti. Yetmiş altı hastada %50'nin altında dalak enfarktüsü ve 40 hastada total ve totale yakın enfarktüsler dahil ≥%50 dalak enfarktüsü kaydedildi. Dalak enfarktüsü ≥%50 olan hastalar arasında, 3 (%2.27) hastada SAE'den 16 ila 21 gün sonra apse varlığı kaydedildi ve AAST-OIS derecesi arttıkça enfarktüs genişliğinin arttığı saptandı. Splenik arter embolizasyonunu takiben, 75 hastada >14 gün boyunca tekrarlanan abdominal BT taramaları elde edildi; bunlardan 67'sinde dalak enfarktüsünün iyileştiği görüldü. Splenik arter embolizasyonundan sonra medyan iyileşme süresi 43 gündü.

TARTIŞMA: Mevcut bulgular, ≥%50 enfarktüslü hastaların SAE sonrası enfeksiyonu ekarte etmek için takip BT taraması olsun veya olmasın 3 haftalık kapalı gözleme ihtiyaç duyabileceğini düşündürmektedir; dalakta iyileşmeyi doğrulamak için SAE'den 6 hafta sonra BT takibi gerekli olabilir.

Anahtar sözcükler: Dalak enfarktüsü; embolizasyon; künt yaralanma; takip çalışması.

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