Hiroshima J. Med. Sci.
Vol. 68, No. 2·3, 43~47, September, 2019
HIMJ 68–7

Accelerated Splenic Enlargement after Splenic Trauma: Influence of Splenic Arterial Embolization

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ABSTRACT

Splenic injury is common in blunt trauma. As post-injury splenic volume changes are unclear, the aim of this study was to elucidate such changes. This retrospective study included 18 patients (14 males, median age 24.5 years) with a splenic injury treated between January 2009 and December 2016. All underwent computed tomography (CT) during admission to our hospital and at the last follow-up visit. The splenic volumes on the first and last enhanced delayed-phase CT scans were compared. The fluid response, transfusion, injury severity score, trauma grade, and extent of splenic artery embolization (SAE) were obtained from medical records. The volume change was assessed with a Mann-Whitney U-test. The volume change in patients treated conservatively was also evaluated to study the natural course after injury. On the first and last scans, the median splenic volume was 105.8 (interquartile range [IQR] 65.4–139.7) and 123.6 (IQR 102.0–225.0) cm^3, respectively. The volume increased by 67 (-0.4 ± 120.0) %. SAE was the only factor significantly related to the volume change ($p < 0.05$). The median follow-up period was 13 (IQR 6–20) days. In conservatively treated patients, the splenic volume change was correlated with the interval between the first and last CT studies. Our findings suggest that the volume of the injured spleen increases in the natural course after trauma. SAE resulted in a decrease in the splenic volume.

Key words: *Splenic volume*, *Transarterial embolization*, *Injured spleen*

INTRODUCTION

Splenic injury is one of the most common injuries in blunt trauma[2]. Multidetector-row computed tomography (CT) has become indispensable for diagnosing trauma patients[4]. Contrast-enhanced CT findings, such as the trauma grade, contrast blush, degree of hemorrhage, and injury to other organs, help determine the treatment strategy[10].

Splenic artery embolization (SAE), rather than splenectomy, is now used to treat hemodynamically stable patients with splenic injury. The requirement for SAE is indicated when contrast-enhanced CT demonstrates contrast medium extravasation (EV) or moderate to severe splenic injury[2]. The extent of splenic embolization and the size of the residual splenic parenchyma affect splenic function, but few studies have addressed changes in the splenic volume after blunt splenic injury. It is important for physicians to determine the splenic volume change to anticipate the residual function of the injured spleen after trauma and SAE[8,9]. Sequential changes in the spleen size occur after trauma, and a decrease in the spleen size has been observed after abdominal trauma without splenic injury[3]. However, the effect of splenic injury on the spleen size remains unknown.

We aimed to elucidate the sequential changes in the splenic volume after blunt splenic injury.

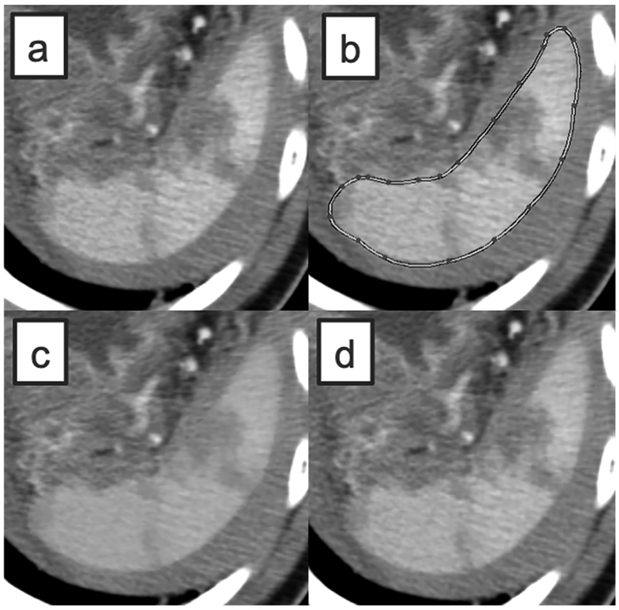

Figure 1 A 21-year-old man with blunt splenic injury. a. Delayed-phase contrast-enhanced computed tomography scan. b. The connected points outline the spleen (point-control method). c. The area inside the line was masked. d. The non-contrast area (hematoma) was deleted.

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Table 1 Patient Data.

	n = 18
Male, n (%)	14 (77.8)
Age, years*	24.5 (19.8–41.8)
ISS*	28 (13–34)
Transient- or non-responder, n (%)	7 (38.9)
AAST grade, n (%)	
I	2 (11.1)
II	2 (11.1)
III	11 (61.1)
IV	3 (16.7)
V	0 (0)
SAE, n (%)	10 (55.6)
Distal embolization	9
Proximal embolization	1
Hb, g/dl*	12.1 (10.9–13.4)
Initial platelet count (× 10^3/μl)	213 (167–266)
Days between first and last CT scans (range)	13 (6–20)

ISS: injury severity score; AAST: American Association for the Surgery of Trauma; SAE: splenic arterial embolization; Hb: hemoglobin; CT: computed tomography
*median (interquartile range)

MATERIALS AND METHODS

This study was approved by our institutional ethics committee.

Patients

This was a retrospective observational single-center study of Japanese trauma patients who arrived at our tertiary care hospital.

The search for splenic injury diagnoses in our radiology information system revealed 27 patients who were seen between January 2009 and December 2016. Of these, 21 had undergone contrast-enhanced CT at the time of admission and at follow-up; and 3 patients were excluded because they underwent splenectomy (n = 2) or SAE at another facility (n = 1). Consequently, 18 patients were included in this study.

Table 2 Volume change of conservative treatment and SAE group.

	All n = 18	Conservative treatment n = 8	SAE n = 10	p-value
First CT, cm³	105.8 (65.4–139.7)	103.1 (60.8–145)	106.0 (76.1–135.9)	0.573
Last CT, cm³	123.6 (102.0–225)	218.3 (157.7–279.0)	109.8 (89.2–130.5)	0.016
Change rate, %	+ 67 (– 0.4–120.0)	+ 101.5 (62.9–140.1)	+ 5.6 (– 39.4–50.6)	0.004

SAE: splenic arterial embolization

The delayed phases of contrast-enhanced CT images obtained at arrival and follow-up were selected. The splenic volume in these images was calculated using AZE VirtualPlace (AZE, Ltd., Tokyo, Japan). We first plotted points on the contrast-enhanced CT images and drew an outline of the spleen. After masking the area inside the line, we deleted the non-contrast area reflecting hematoma (Figure 1). We performed this process at 5-mm intervals on each slice. The splenic volume was calculated by integrating all masks.

The splenic volume on the first and last CT studies of each patient was recorded, and changes in the volume were calculated with the formula:

volume change = [(last volume) – (first volume])/(first volume)] × 100

We evaluated factors thought to impact splenic volume, including gender, age, response to fluid resuscita-

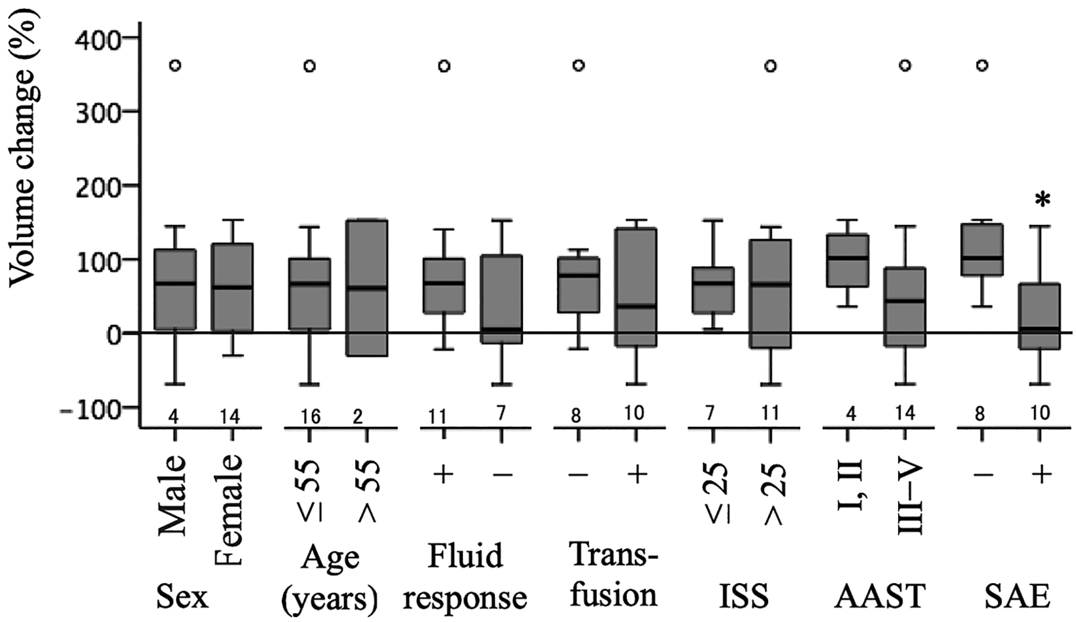


Figure 2 Splenic artery embolization (SAE) was the only the factor related to splenic volume change. SAE significantly decreased the splenic volume (*p < 0.05). ISS, Injury Severity score; AAST, the American Association for the Surgery of Trauma, SAE; splenic arterial embolization

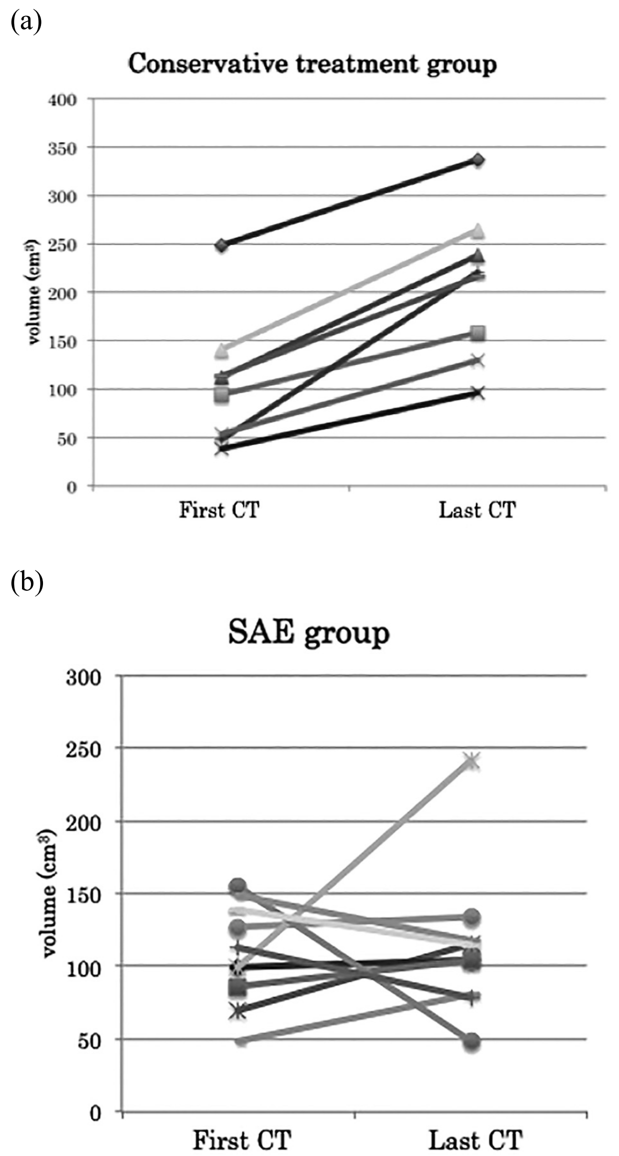


Figure 3 Splenic volume changes by different treatment regimens. a. Splenic volume at the first and last computed tomography (CT) scan of conservatively treated patients. The splenic volume was larger in all 8 patients who had undergone conservative treatment. b. Splenic volume at the first and last CT scan of splenic artery embolization-treated patients (SAE). The splenic volume was decreased in 4 of 10 patients treated by SAE.

tion, transfusion, trauma grade [based on the American Association for the Surgery of Trauma (AAST)], injury severity score (ISS), interval between the first and last CT studies, hemoglobin level, platelet count, and the extent of SAE.

Analysis

Categorical variables were reported as frequency counts and percentages and continuous variables as a median with IQR. Mann-Whitney U-tests were used for continuous variables. Correlations were analyzed with the Spearman correlation coefficient. Analysis was carried out using SPSS Statistics version 21.0 (IBM, Armonk, NY). All p-values < 0.05 were considered statistically significant.

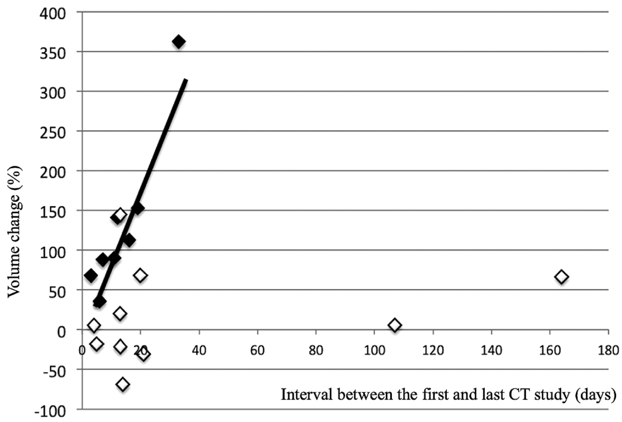


Figure 4 Correlation between splenic volume changes and the interval between computed tomography (CT) studies. In the 8 conservatively treated patients (solid squares), there was a correlation between the splenic volume change and the interval between the first and last CT studies (r = 0.952, p = 0.05). White: SAE, black: conservative treatment.

RESULTS

Of the 18 patients, 14 (77.8%) were males and the median of age of all patients was 24.5 years (Table 1). The median interval from the first to last CT study was 13 (IQR, 6–20) days. The median splenic volume in the first CT images was 105.8 cm^3; it was 123.6 cm^3 in the last CT scan. The median volume change was 67% (Table 2).

In univariate analysis, SAE was the only factor significantly related with splenic volume changes (Figure 2). Of the 18 patients, 8 were treated conservatively; their splenic volume increased by a median of 101.5% between the first and last scans (Figure 3a and Table 2). There was a positive correlation between the volume change and the interval between the first and last CT scans (Figure 4).

The median splenic volume increased from 106.0 cm^3 to 109.8 cm^3 on the first and last scans, respectively, in patients treated by SAE (n = 10); the median volume change was 5.6% (Table 2). The splenic volume decreased in 4 patients (Figure 3b).

In our study population, there was no correlation between the platelet count at last follow-up and the splenic volume change (Figure 5). In one patient, a 41-year-old male, the platelet count exceeded $1 \times 10^6/\mu l$ on the 17^{th} day after trauma; the splenic volume on the last scan was 48.6 cm^3, approximately 70% lower than on the first CT image (Figure 6). As he manifested a high degree of extravasation, a gelatin sponge was injected from the proximal rather than distal splenic artery.

DISCUSSION

Our study showed that SAE resulted in a lower subsequent increase in the splenic volume than conservative treatment (median: 5.6% vs 101.5%, p = 0.004). Preece et al.[7] also reported that SAE at a distal site on the splenic artery impacted the splenic volume.

In the natural course after trauma, the splenic volume

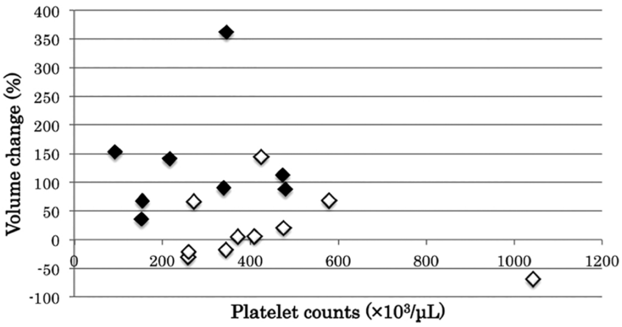


Figure 5 Correlation between splenic volume changes and the interval between computed tomography (CT) studies. There was no correlation between splenic volume change and platelet count at last follow-up. White: SAE, black: conservative treatment.

of conservatively treated patients increased with the passage of time, a finding also reported by Preece et al.[7]. In patients with hypovolemic shock or blunt abdominal trauma without splenic injury, a reduction in the splenic volume has been reported[3,5]. As pooling blood cells accumulate in the red pulp, the splenic volume observed on CT scans performed shortly after the injury is indicative of hypovolemia. The platelet concentration in the injured organ increases, and platelet-derived growth factor (GF), which promotes vascularization and an increase in fibroblasts and myofibroblasts, is released[1]. This phenomenon may account for the splenic volume increase after splenic injury.

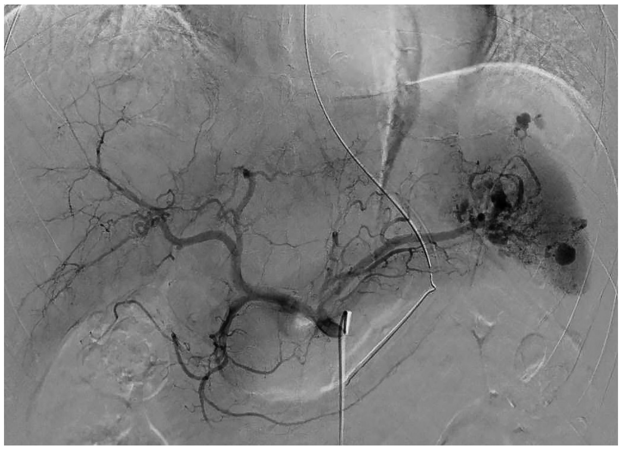
The 70% splenic volume loss we observed in the patient treated by SAE was indicative of a splenic functional disorder. According to Ou et al.[6], there is a weak correlation between the change in splenic volume and platelet count. We found no such correlation as, other than SAE, several factors affected the platelet count. However, we suggest that platelet counts should be monitored in patients with a large splenic embolization range.

Our study has some limitations. The patients' pre-injury splenic volume and splenic function were unknown. We used the platelet count to assess splenic function although this method may be inadequate. As this study was retrospective, the interval between the first and last CT scans differed among patients. Large prospective studies are needed to assess splenic volume changes in trauma patients with splenic injury.

Our findings indicate that the splenic volume increases in the natural course after trauma, irrespective of the early ISS grade and AAST score, and that SAE leads to a transient decrease in splenic volume.

(Received May 29, 2019)
(Accepted August 8, 2019)

(a)



(b)

(c)

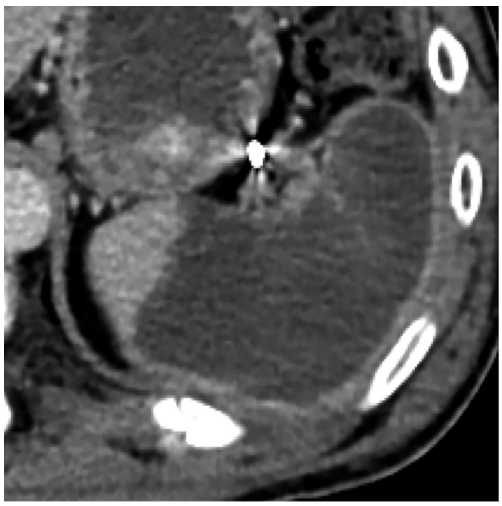


Figure 6 A 41-year-old man with traumatic splenic. The ISS was 34, and platelet count exceeded $1 \times 10^6/\mu l$ after the trauma. a. Celiac arteriogram showing contrast medium extravasation. b. Small pieces of gelatin sponge were injected from the proximal splenic artery. c. SAE resulted in an approximately 70% volume reduction.

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