

Serial Changes of the Splenic Volume after Traumatic Intraperitoneal Hemorrhage¹

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Purpose: We wanted to evaluate the serial changes of the splenic volume in patients with traumatic intraperitoneal hemorrhage.

Materials and Methods: 20 consecutive patients with traumatic intraperitoneal hemorrhage and who underwent initial CT, early follow-up CT within 30 days and late follow-up CT examinations thereafter were included in this study. The volume of the spleen on each CT examination was measured and the relative splenic volume (RSV) on the initial and early follow-up CT examinations was calculated on the basis of the splenic volume on the late follow-up CT. The hemoperitoneum score was calculated on the basis of the size of the intraperitoneal hemorrhage.

Results: The average RSVs of the initial and early follow-up CT were 62.0% and 133.3%, respectively, and all the patients showed an increase of the splenic and relative splenic volumes on the early follow-up CT, as compared with those on the initial CT. Initial splenic contraction was seen in 18 patients (90.0%) and early splenomegaly was seen in 14 patients (70.0%). Patients with initial splenic contraction and early splenomegaly were the most common (12 patient, 60.0%).

Conclusion: Initial physiologic splenic contraction was seen in most of the patients with hemoperitoneum, and thereafter early splenomegaly was commonly seen before normalization of the splenic volume.

Index words : Spleen
Hemoperitoneum
Abdominal Injuries

Hemoperitoneum is an emergency life-threatening condition that is caused by blunt abdominal trauma, and the spleen and liver seem to be the most frequently injured organs (1-3). Splenic enlargement is often observed on follow-up computed tomography (CT) exami-

nation after traumatic hemoperitoneum, but this splenic enlargement is known to return to normal size after physiologic contraction of the spleen rather than being true splenic enlargement (4, 5). The spleen serves as a reservoir for formed blood elements and it is known that red blood cells are released into the circulation by splenic contraction in the face of bleeding (5-7).

Goodman and Aprahamian (4) described an average 25% increase of splenic volume on follow-up CT examination after blunt abdominal trauma, which they interpreted as being initial physiologic splenic contraction

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with an eventual return to normal size. They emphasized that this enlargement of the spleen on follow-up CT should not be considered an indicator of a deteriorating condition. Although they considered the volume of the spleen on follow-up CT examination as normal, it is difficult to know the normal volume of the individual spleen in the absence of performing a CT examination before the traumatic event.

We recently found that the splenic volume was decreased on long-term follow-up CT examination, as compared with that seen on the previous follow-up CT, in a patient with a history of traumatic hemoperitoneum. This experience alerted us that the spleen might enlarge rather than return to normal size. We retrospectively studied the serial changes of splenic volume in patients with traumatic hemoperitoneum and who underwent long-term follow-up CT examination. We presumed that the splenic volume on the long-term follow-up CT examination might be close to the pre-traumatic splenic volume. To the best of our knowledge, no study has yet focused on the long-term follow-up study of the splenic volume changes in patients with hemoperitoneum.

The purpose of this study is to evaluate the initial and early changes of splenic volume in patients with traumatic hemoperitoneum, based on the estimated normal splenic volume obtained on the long-term follow-up CT examination.

Materials and Methods

Study Group

All the consecutive patients who underwent abdominal CT examinations for traumatic intraperitoneal hemorrhage after blunt abdominal trauma at our institution between the years 2004 to 2008 were retrospectively reviewed to determine their eligibility for this study. Patients were included in this study if they had undergone an initial CT within one day after trauma, at least one follow-up CT within 30 days and at least one additional follow-up CT obtained 30 days after trauma. Patients with splenic injury, infectious disease, chronic liver disease, hematologic disorders or other underlying disease that cause splenomegaly were excluded. The study group consisted of 20 patients (18 men and two women, age range: 9–68 years, average age: 42.0 years). A review of the medical records was conducted to calculate the total amount of blood transfusion. Approval from our institutional review board was obtained for

this retrospective study.

CT Examination

CT examinations were performed on a single-detector helical CT (HighSpeed, GE Healthcare), a 4-multidetector CT (MDCT) (LightSpeed plus, GE Healthcare) or a 64-MDCT scanner (LightSpeed VCT, GE Healthcare) for generating axial images with contiguous 5-mm-thick sections.

A total of 101 CT examinations were performed for the 20 patients. The average was 5.1 CT examinations per patient (range: 3–11). The CT examinations were divided into three groups according to time interval: for the initial CT, CT examinations performed within 24 hours after trauma; for the early follow-up CT (early CT), CT examinations were performed within 30 days after trauma; for the late follow-up CT (late CT), CT examinations were performed 30 days after trauma. The number of initial CT examinations was 20, the number of early CT examinations was 43 (average: 2.2, range: 1–4) and the number of late CT examinations was 38 (average: 1.9, range: 1–8).

Image Analysis

Two radiologists retrospectively reviewed all the CT images on a PACS workstation (Radpia, Hyundai Information Technology). They evaluated the presence of intraperitoneal hemorrhage and visceral organ injuries by working in consensus. One radiologist used an area-measuring tool and the summation-of-areas technique on the CT scans to measure the volumes of the

Table 1. Hemoperitoneum Scores

Hemoperitoneum Score	Patients
1 ~ 5	8
6 ~ 10	4
11 ~ 15	4
16 ~ 20	1
21 ~ 25	1
26 ~ 30	1
31 ~ 35	1
Total	20

Table 2. Visceral Injuries

Injured Visceral Organ	Patients
Liver	12
Bowel or mesentery	7
Pancreas	2
Adrenal gland	2
Kidney	1

spleen at the maximal magnification of a PACS monitor. The cross-sectional area of each image of the spleen was determined on the monitor by tracking the margin of the spleen with a built-in cursor controlled by a mouse. The section volumes were then calculated by multiplying each cross-sectional area by the section thickness and these were added to determine the total splenic volume. The validity and reproducibility of this method have been previously reported (8-10). If two or more early CT examinations were performed, then the largest splenic volume was recorded, and if two or more late CT examinations were obtained, the splenic volume of the last CT examination was then recorded. The average time interval between the traumatic event and the last CT examination was 243.9 days (range: 31-980 days).

On the presumption that the volume of the spleen on the last CT was close to the normal volume, the relative splenic volume on the initial CT (initial RSV) was calculated as follows: [(volume on the initial CT) \times 100]/volume on the last CT]. The relative splenic volume on the early CT (the early RSV) was also calculated as follows: [(volume on the early CT) \times 100]/volume on the last CT]. The relative splenic volume with less than a 10% increase or decrease was considered to have no significant change.

According to the initial RSV, the patients were divided into two groups: the splenic contraction group (less than 90% of the initial RSV) and the normal group. According to the early RSV, the patients were also divided into two other groups: the splenomegaly group (more than 110% of the early RSV) and the normal group. We further divided the patients into four groups based on the combination of the initial and early RSV for analyzing the pattern of serial changes of the splenic volume: group A

(initial splenic contraction and early splenomegaly), group B (initial splenic contraction and a normal early RSV), group C (a normal initial RSV and early splenomegaly) and group D (normal initial and early RSV).

For a more meaningful estimate of the amount of intraperitoneal fluid, we used a hemoperitoneum score for the initial CT examination. The collections of intraperitoneal fluid were categorized into six sites: 1) the perihepatic space, 2) the perisplenic space, 3) the right paracolic gutter with including the hepatorenal fossa, 4) the left paracolic gutter, 5) the mesentery and 6) the pelvis including the pouch of Douglas. Two radiologists working in consensus selected the one representative image of the largest amount of intraperitoneal hemorrhage for each of the six sites. The dimension of the intraperitoneal fluid on each representative image was determined at maximal magnification on a PACS monitor by one radiologist using an area-measuring tool. The total size of the intraperitoneal fluid in a patient was calculated as the sum of the size of the intraperitoneal fluid seen on each image. To complete the hemoperitoneum score, one point was given for a 1,000 mm² total size of the intraperitoneal fluid.

Statistical Analysis

Statistical analysis was performed using SPSS version 14.0 for Windows. A paired t-test was performed to evaluate the statistical differences on comparing the splenic volumes of the initial and early follow-up CT examinations. We also determined the correlations between the initial RSV and the hemoperitoneum score and between the early RSV and the volume of blood transfusion by using Pearson correlation coefficients. *P*

Table 3. Volume Change of the Spleen

Group	Patients	Initial CT		Early CT		Late CT	H Score	Transfusion	
		SV (cc) (Range)	RSV (%) (Range)	SV (cc) (Range)	RSV (%) (Range)	SV (cc) (Range)	(Range)	RBC (l) (Range)	FFP (l) (Range)
A	12	91.8 \pm 33.2 (47.5~159.7)	52.2 \pm 15.2 (32.8~88.3)	259.2 \pm 81.4 (92.2~366.4)	142.4 \pm 13.3 (119.2~168.4)	108.8 \pm 53.0 (77.4~239.9)	11.2 \pm 8.9 (3~31)	2.3 \pm 1.8 (0.0~6.2)	45.2 \pm 91.5 (0.0~329.4)
B	6	122.7 \pm 42.7 (78.3~180.2)	69.9 \pm 13.6 (48.1~83.9)	178.3 \pm 43.4 (118.5~228.9)	102.4 \pm 4.8 (96.1~109.3)	173.6 \pm 39.7 (118.9~225.0)	7.8 \pm 9.2 (1~26)	1.1 \pm 1.2 (0.0~3.2)	20.6 \pm 21.1 (0.0~56.9)
C	2	153.6 \pm 109.8 (75.9~231.3)	97.9 \pm 2.8 (95.9~99.8)	231.8 \pm 92.9 (166.1~297.5)	170.9 \pm 67.3 (123.4~218.5)	158.6 \pm 116.7 (76.0~241.1)	8.0 \pm 4.2 (5~11)	0.8 \pm 0.2 (0.7~1.0)	15.4 \pm 17.6 (2.9~27.8)
D	0								
Total	20	107.3 \pm 46.9 (47.5~231.3)	62.0 \pm 20.0 (32.8~99.8)	232.2 \pm 78.5 (99.2~366.4)	133.3 \pm 29.2 (96.1~218.5)	176.4 \pm 53.0 (76.0~241.1)	9.9 \pm 8.5 (1~31)	1.8 \pm 1.6 (0.0~6.2)	34.9 \pm 71.8 (0.0~329.4)

Note.— SV = splenic volume, RSV = relative splenic volume, H Score = hemoperitoneum score, RBC = packed red blood cells, FFP = fresh frozen plasma

values <0.05 were deemed significant.

Results

The average hemoperitoneum score of all the patients was 9.9 (range: 1–39) and a relatively large amount of hemoperitoneum (hemoperitoneum score > 10) was seen in 8 patients (40.0%) (Table 1). Visceral injuries were seen in all the patients and the liver was the most frequently injured organ (12 patients, 60%) (Table 2). Transfusions were necessary for 18 patients (90%), and four patients (20.0%) required surgical procedures.

The average RSVs of the initial and early CT were 62.0% and 133.3%, respectively, and all the patients showed an increase of the splenic and relative splenic volumes on the early CT as compared with that of the initial CT ($p=0.000$) (Table 3). Initial splenic contraction (groups A and B) was seen in 18 patients (90.0%) and the average initial RSV of the splenic contraction group was 58.1%. There was no significant correlation between the

initial RSV and the hemoperitoneum score ($p=0.529$).

Early splenomegaly (groups A and C) was seen in 14 patients (70.0%) and the average early RSV of the splenomegaly group was 146.5%. The change in the early RSV peaked 13.8 days after trauma. There was no significant correlation between the early RSV and the amount of transfusion ($p=0.514$). Patients with initial splenic contraction and early splenomegaly (group A) were most common (12 patient, 60.0%) (Fig. 1).

Discussion

The spleen is the largest lymphoid organ in the human body and it serves numerous functions such as formation of antibodies, production of lymphocytes and monocytes, filtration, phagocytosis and destruction of red blood cells (5, 6). It also serves as a storage site for formed blood elements (5, 6). Although the spleen contains a small volume of red blood cells, this small number of red cells can be effectively infused into the circu-

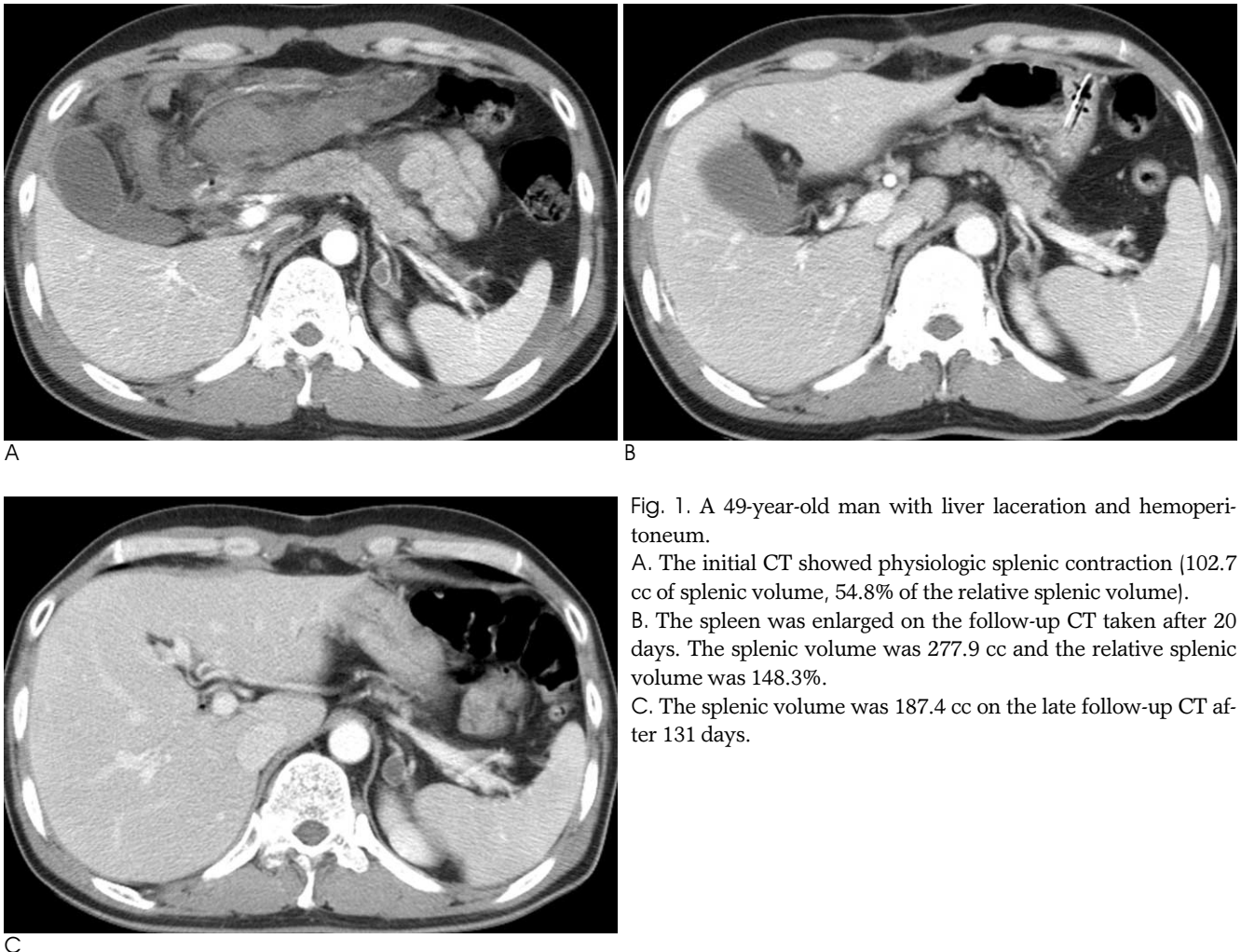


Fig. 1. A 49-year-old man with liver laceration and hemoperitoneum.

A. The initial CT showed physiologic splenic contraction (102.7 cc of splenic volume, 54.8% of the relative splenic volume).

B. The spleen was enlarged on the follow-up CT taken after 20 days. The splenic volume was 277.9 cc and the relative splenic volume was 148.3%.

C. The splenic volume was 187.4 cc on the late follow-up CT after 131 days.

lation by splenic contraction in the face of acute physiological stress, including hemorrhage, exercise, diving, breath holding and drowning (5-7). This splenic contraction is controlled by the actions of postganglionic fibers on the capsule and trabeculae (5). Our study revealed no significant correlation between the initial RSV and the hemoperitoneum score. This means initial splenic contraction is related to the systemic effect of trauma rather than to only the effect of bleeding. The effect of the total severity of trauma was not included in our study.

Goodman and Aprahamian (4) reported that the average splenic volume increased 25% between the initial and follow-up CT examinations in the patients with blunt abdominal trauma and 57% of their patients had an average increase in splenic volume of 56%. This splenic enlargement was believed to represent a return to normal size after physiologic contraction. But in their study, the time interval between the initial and follow-up CT examinations was less than 7 days and there was no long-term follow-up study. Our study also revealed a significant increase of the splenic volume between the initial and early follow-CT examinations, but the early RSV was significantly increased in 14 patients (70%), with the average early RSV being 146.5%. This result means there was early splenomegaly rather than a return to normal size after the initial splenic contraction. Initial physiologic splenic contraction with a return to the normal early RSV was seen in 6 patients (30%). Our study revealed that the most common pattern of the serial changes of splenic volume was initial splenic contraction, early splenomegaly and a late return to normal size (group A), which was all seen in 12 of the patients (60%). The early RSV peaked 13.8 days after trauma in our study. But Goodman and Aprahamian (4) reported that the changes in splenic volume peaked 6 days after trauma, and this difference is thought to be related to the relatively short follow-up interval of their study.

The causes of diffuse splenomegaly are diverse and they can be categorized on the basis of pathogenesis: 1) congestive splenomegaly that includes portal hypertension and infectious or inflammatory diseases, 2) hyperplastic splenomegaly that includes hemolytic anemia, 3) infiltrative splenomegaly and 4) splenic neoplasm (5, 11). The physiology of early splenomegaly after intraperitoneal hemorrhage may be multifactorial. Transfusion can be considered as one cause of splenomegaly (4). The spleen is composed of two functionally and morphologically distinct compartments, the red pulp and the white pulp, and the red pulp is a blood

filter that removes foreign material and damaged erythrocytes (12, 13). Hyperplastic splenomegaly is caused by hypertrophy resulting from the removal of circulating abnormal blood cells (4). Yet we did not find significant correlation between early RSV and the amount of blood transfusion. The second pertinent fact is that the circulating blood volume can influence the volume of the spleen (4, 13, 14). With aggressive fluid replacement, the spleen may enlarge in response to the increased circulatory volume. In our study, it was difficult to calculate the total volume of a patient's fluid replacement and intake. Last, the spleen also may enlarge due to increased portal vein resistance in patient with liver injury.

Early splenomegaly after hemoperitoneum has not been previously reported and its clinical significance is not yet established. Goodman and Aprahamian (4) reported that splenic enlargement after blunt abdominal trauma was not an indicator of clinical deterioration and this represented a return to normal size rather than true enlargement. But our study revealed that true splenic enlargement after hemoperitoneum commonly occurred. This splenic enlargement was not necessarily a sign of clinical deterioration, but rather, it was a sign of circulating volume overload.

Several limitations of our study should be mentioned. First, the time interval of the early and late follow-up CT examinations was heterogeneous. Second, many patients suffered from multiple injuries, including extraabdominal damage. Our study did not include the effect of the total severity of traumatic injury. Last, our study was not designed to consider the influence of other factors such as age, gender, operation and the total volume replacement. An operation for hemoperitoneum may be another factor of physiologic stress. We could not compare the degree of the splenic volume changes between the group that received an operation or conservative treatment due to the small case numbers.

In conclusion, physiologic splenic contraction was seen in most of the patients who had hemoperitoneum, and thereafter early splenomegaly was commonly seen before a return to normal size. Early splenomegaly may be related to blood transfusion, a circulating volume overload or increased portal vein resistance with liver injury.

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외상성 복강 내 출혈 후 비장 부피의 순차적 변화¹

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목적: 외상성 복강 내 출혈 환자에서 비장 부피의 순차적인 변화에 대하여 알아보고자 하였다.

대상과 방법: 외상 후 복강 내 출혈이 있었던 환자 중 초기 CT, 30일 이내의 조기 추적 CT, 그리고 30일 이후의 후기 추적 CT를 시행한 20명을 대상으로 하였다. 각각의 CT에서 비장의 부피를 측정하였고, 후기 추적 CT의 비장 부피를 기준으로 초기 및 조기 추적 CT에서의 상대적 비장 부피를 계산하였다. 복강 내 출혈의 면적을 기준으로 복강 내 출혈 점수를 산출하였다.

결과: 초기 CT 및 조기 추적 CT에서의 상대적 비장 부피의 평균은 각각 62.0% 및 133.3% 이었고, 모든 환자에서 초기 CT보다 조기 추적 CT에서 상대적 비장 부피가 증가하였다. 초기 비장 수축이 18명(90.0%)에서 있었고, 초기 비장 비대는 14명(70.0%)에서 보였다. 초기 비장 수축과 조기 비장 비대를 보인 환자가 가장 많았다(12명, 60.0%).

결론: 생리적 비장 수축은 복강 내 출혈 환자의 대부분에서 보였고, 이후 비장의 부피가 정상으로 되기 전에 조기 비장 비대가 흔하게 나타났다.