

# Cone beam versus conventional computed tomography angiography volume measurement in partial splenic embolization

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## Abstract

When performing partial splenic arterial embolization (PSE), it can be difficult to determine the embolization ratio based on 2-dimensional digital subtraction angiography (DSA) image diagnosis alone. Therefore, at our department, we conduct computed tomography (CT) imaging intraoperatively and postoperatively to determine whether the planned embolization has been achieved. In recent years, developments in interventional radiology devices have enabled diagnostic imaging using cone beam CT. Here, we investigated whether the embolization ratio could be predicted from volume measurement with cone beam CT in PSE.

We investigated correlations between volume measurement with conventional CT angiography (CTA) and volume measurement with cone beam CTA in 11 cases that underwent PSE with cone beam CT guidance (Allura Clarity FD20; Phillips, Amsterdam, The Netherlands) between December 2013 and May 2018.

The mean subject age was  $65.0 \pm 5.8$  years (6 men, 5 women). The subjects had underlying liver disorders of hepatitis C virus infection (4 cases), nonalcoholic steatohepatitis (4 cases), and alcohol-related disease (3 cases). A positive correlation was noted between conventional CTA and cone beam CTA, with infarction rates of  $61.28 \pm 9.31\%$  and  $64.04 \pm 9.24\%$ , respectively. The correlation coefficient between the 2 variables was .772.

Because blood washout occurs rapidly in the spleen, contrast medium had to be continuously injected during imaging to enable dual-phase imaging with cone beam CT. However, we successfully performed imaging up to the second phase and volume measurement for the embolization ratio by inserting a catheter into the splenic artery and confirming the cone beam CT arrival time from the DSA images. The results were almost identical to those obtained from volume measurement with conventional CT based on CTA imaging. Thus, our results suggest that the splenic embolization ratio measurement obtained via cone beam CTA can be used to assess PSE treatment endpoints.

**Abbreviations:** CT = computed tomography, CTA = CT angiography, DSA = digital subtraction angiography, IVR = interventional radiology, PSE = partial splenic arterial embolization.

**Keywords:** angiography, computed tomography, partial splenic artery embolization, volume measurement

## 1. Introduction

In liver cirrhosis, the progression of liver fibrosis causes hypersplenism (enlarged spleen), resulting in reduced blood platelet count. In recent years, splenectomy and partial splenic arterial embolization (PSE) have garnered attention as treatment methods for thrombocytopenia caused by hypersplenism.

PSE was first reported in 1973 by Maddison<sup>[1]</sup> as a treatment technique for hypersplenism. At first, it was only indicated for

cases involving severe complications such as splenic abscess, pneumonia, or septicemia. However, after Spigos et al<sup>[2]</sup> reported in 1979 on PSE with limited infarction range, its safety improved and the procedure came to be widely used clinically. Similar to splenectomy, PSE can increase blood platelet count and improve liver function, hypersplenism, portal hypertension, and gastric and esophageal varices; however, detailed diagnostic imaging is required to determine the embolism range. Digital subtraction angiography (DSA) alone is 2-dimensional; it cannot calculate 3-dimensional volume. An intraoperative computed tomography (CT) diagnosis must be performed in addition to conventional DSA imaging, but this can be clinically complex. In recent years, the development of cone beam CT has made it possible to perform diagnostic imaging in the same manner as conventional CT. Cone-beam CT may be a valuable intra-procedural alternative to conventional CT in the evaluation of interventional radiology (IVR) procedures. We investigated whether volume measurement obtained via cone beam CT angiography (CTA) for PSE could be used to predict the embolization ratio.

## 2. Methods

The subjects included 11 liver cirrhosis patients who underwent CTA and cone beam CTA during PSE between December 2013 and May 2018.

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The authors have no conflicts of interest to disclose.

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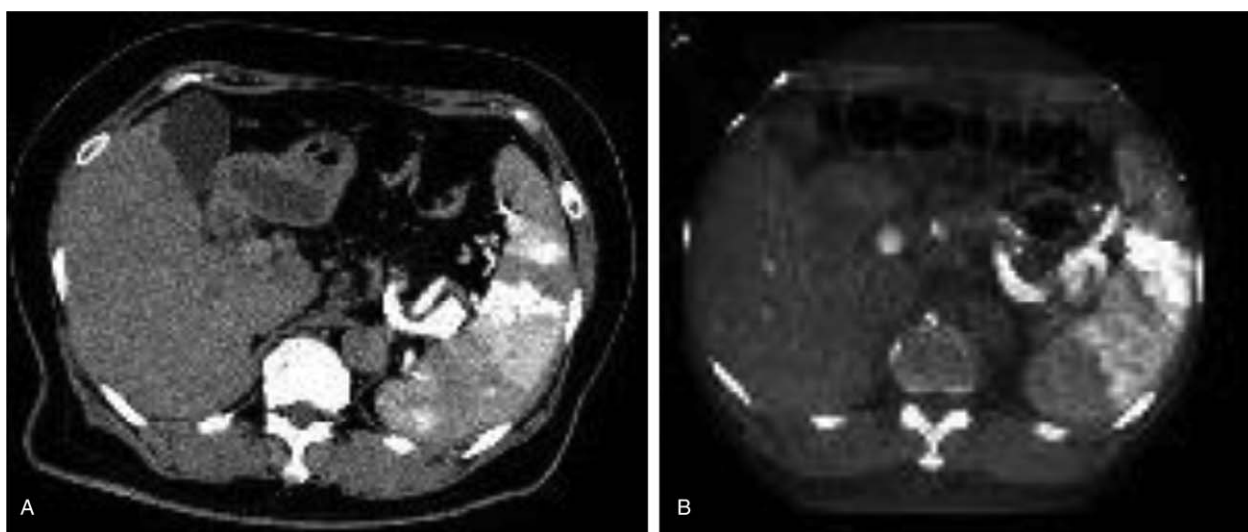
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**Figure 1.** Representative case. (A) Conventional CTA (scan parameter: 120 kVp, 1366 mAs; total scan time: 2.8 seconds; slice thickness: 0.98 mm) (B) cone beam CTA (scan parameter: 119 kVp, 165 mA; total sweep time: 5.2 s; slice thickness: 0.68 mm). CTA=CT angiography.

The abdominal angiography device used was the Allura FD 20 (Phillips, Amsterdam, Netherlands), and the injector used was the Press Duo (Nemoto, Tokyo, Japan). The contrast medium was Omnipaque 140 (Daiichi Sankyo Company, Tokyo, Japan).

The contrast-enhanced CT testing was performed using a 16-row scanner (Aquilion; Toshiba Medical Systems, Tochigi Prefecture, Japan). The cone beam CT equipment was Allura Xper FD 20 (Philips, Amsterdam, Netherlands). All imaging procedures were performed using the same machine. The protocol imaging conditions were as follows: 120 kv, 192 mA, 5 seconds, frame rate, 60 frames per second (fps); inch size, 19; cube size, 100%; FID, 120 cm; rotation area, 240; and reconslice, 600.

Protocol for cone beam CT dual-phase imaging involved confirming cone beam CT arrival time from DSA images after inserting a catheter into the splenic artery. Because contrast medium washout occurs rapidly in the spleen, it was continuously injected during imaging to enable dual-phase imaging. Both cone beam CT and conventional CT images were transferred to the PACS as DICOM data (Fig. 1). Using the EV Insite net software, regions of interest were placed on both cone beam CT and conventional CT DICOM images, adjusted to a 1-mm-slice thickness and situated in the same position. Each scan was retrospectively evaluated by 3 hepatologists.

### 2.1. Ethics statement

Data are available from the Saiseikai Niigata Daini Hospital Data Access/Ethics Committee for researchers who meet the criteria for access to confidential data.

This study was approved by the Institutional Review Board of Saiseikai Niigata Daini Hospital and was conducted in accordance with the principles of the Declaration of Helsinki. All patients provided written informed consent.

### 3. Statistical analysis

Before this study, all demographic and clinicopathological data had been prospectively collected in a computer database. Statistical processing was performed using StatView version

5.0 software (SAS Institute, Cary, NC). The correlation was analyzed using Pearson's correlation coefficient, with  $P < .05$  considered significant.

### 4. Results

The mean subject age was  $65.0 \pm 5.8$  years (6 men, 5 women). The subjects had underlying liver disorders of hepatitis C virus (4 cases), nonalcoholic steatohepatitis (4 cases), and alcohol-related diseases (3 cases) (Table 1). Spleen volume according to conventional CT ( $482.6 \pm 196.1$  mL) was correlated with spleen volume according to cone beam CT ( $491.9 \pm 230.6$  mL) (Fig. 2). The infarct volume with PSE was  $296.8 \pm 136.2$  mL according to conventional CT and  $314.2 \pm 155.9$  mL according to cone beam CT (Fig. 3).

A positive correlation was observed between the infarction rate according to conventional CTA ( $61.28 \pm 9.31\%$ ) and the infarction rate according to cone beam CTA ( $64.04 \pm 9.24\%$ ); the correlation coefficient between the 2 variables was .772 (Fig. 4).

### 5. Discussion

PSE is indicated for hypersplenism, and its aims include improving thrombocytopenia, gastric and esophageal varices caused by portal hypertension, and portal hypertensive gastropathy. It has also

**Table 1**  
Clinical background characteristics of patients performed partial splenic arterial embolization.

Demographic variable	Mean $\pm$ SD	Range
Age, yr	$65.0 \pm 5.8$	55–72
Sex, Male:Female	6:5	NA
Etiology, HCV/NASH/Alcohol	4/4/3	NA
Conventional CT Spleen Volume, mL	$482.6 \pm 196.1$	156.6–762.0
Cone-beam CT spleen volume, mL	$491.9 \pm 230.6$	140.9–800.1
Conventional CT infarction rate, %	$61.3 \pm 9.3$	48.3–76.8
Cone beam CT infarction rate, %	$64.0 \pm 9.2$	45.7–77.7

CT=computed tomography, HCV=hepatitis C virus, NASH=nonalcoholic steatohepatitis.

### Correlation between CB-CTA and CTA

Overall;  $CB-CTA = -58.492 + 1.141X CTA$

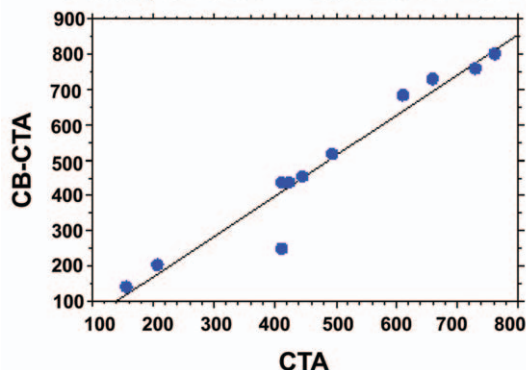


Figure 2. Correlation of overall spleen volume between cone-beam CTA and conventional CTA. CTA=CT angiography.

### Correlation between CB-CTA and CTA

Infarction Ratio;  $CB-CTA = 17.044 + 0.767X CTA$

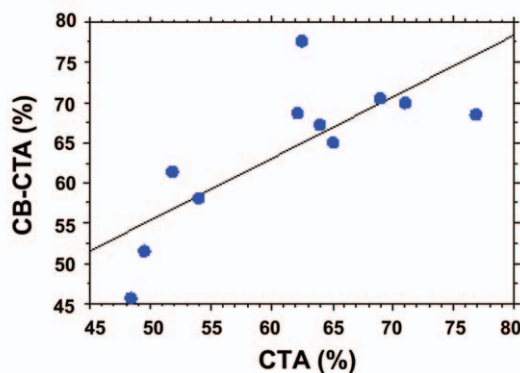


Figure 4. Correlation of infarction ratio between cone-beam CTA and conventional CTA. CTA=CT angiography.

been reported to improve liver function by enhancing liver blood flow.<sup>[3]</sup>

Although reports have indicated that PSE could be used as an alternative to surgery because of its relatively low level of invasiveness and apparent efficacy, it requires skill to secure the intended infarction rate.

Reports have indicated that recurrence is common if the infarction rate is <50%, and the complication onset rate increases when it is >50%<sup>[4]</sup>; therefore, determining the infarction rate is extremely important. Most reports set it at 60% to 80%.<sup>[5]</sup> However, it was previously necessary to repeatedly perform detailed CT imaging in addition to DSA imaging to determine the infarction rate.

Although 3-dimensional angiography, which reconstructs 3-dimensional images from data obtained by rotography with an angiographic device using a conventional imaging intensifier, is appropriate for rendering sites with significant contrast differences such as imaging blood vessels and bone tissue, it can only offer limited visualization of areas of low contrast, such as soft tissue. However, multiplanar reconstruction similar to CT has been made possible with recently developed C-arm multipurpose

angiographic equipment fitted with a flat panel detector.<sup>[6]</sup> The utility of liver diagnostic imaging and IVR using this C-arm CT technology has been reported.<sup>[7-9]</sup> However, no reports have investigated utility during PSE.

Here, we investigated the correlations between volume measurement with conventional CTA images and volume measurement with cone beam CTA in 11 patients who underwent PSE with cone beam CTA after the technology was introduced. A positive correlation was observed between the infarction rate according to conventional CTA ( $61.28 \pm 9.31\%$ ) and the infarction rate according to cone beam CTA ( $64.04 \pm 9.24\%$ ); the correlation coefficient between the 2 variables was .772.

Because blood washout occurs rapidly in the spleen, contrast medium had to be continuously injected during imaging to enable dual-phase imaging with cone beam CT. However, we successfully performed imaging up to the second phase and volume measurement for the embolization ratio by inserting a catheter into the splenic artery and confirming cone beam CT arrival time from DSA images. The results were almost identical to the volume measurement results obtained with conventional CT based on CTA imaging. However, some limitations still exist in our present study. First, as a retrospective study, selection bias was difficult to avoid though both inclusion and exclusion criteria were strictly conducted. Second, the total number of patients enrolled in this study was relatively small, and all cases were from one single center. Third, we follow up carefully patients of radiation exposure because both conventional CTA and cone beam CTA were performed. Lastly, a lack of validation cohorts limited the further confirmation of the PSE therapy for portal hypertension.

Thus, our results suggest that splenic infarction rate measured with cone beam CTA can be used to assess PSE treatment endpoints. Cone beam CTA provides a quantitative means of monitoring during PSE and enables the optimization of PSE both intra- and post-procedurally by predicting the efficacy of infarction rates.

### Correlation between CB-CTA and CTA

Infarction Volume;  $CB-CTA = -10.499 + 1.094X CTA$

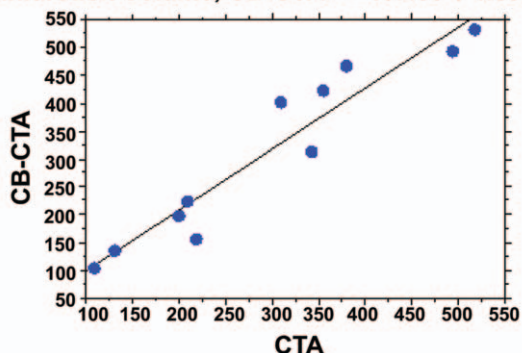


Figure 3. Correlation of infarction spleen volume between cone-beam CTA and conventional CTA. CTA=CT angiography.

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## Author contributions

TI designed the study; extracted and analyzed the data; and drafted the article.

TI, MI, MO, KT, YK, RH, YN, TS, AI, TH, and TY participated in the study and reviewed the article for critical content.

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**Data curation:** Toru Ishikawa, Michitaka Imai.

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**Visualization:** Toru Ishikawa.

**Writing – original draft:** Toru Ishikawa.

**Writing – review & editing:** Toru Ishikawa.

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