

## Brief Communication (Original)

# Increasing the remnant liver volume using portal vein embolization

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**Background:** Portal vein embolization (PVE) is a common procedure to induce hypertrophy of the remnant liver (RL) before major hepatectomy.

**Objective:** Evaluate increased RL volume after PVE based on CT volumetric measurement.

**Methods:** Multi-detector computed tomography (MDCT) was used to measure hepatic volumetric measurement, including total liver volume and RL volumes of pre- and post-PVE. Complications were recorded from PVE and from three-month after post-extended hepatectomy liver dysfunction.

**Result and conclusion:** There was a 10% increase in RL volume. Mean days between CT and PVE were 20 days. No major complications from PVE were observed.

**Keywords:** Portal vein embolization, volume of remnant liver, extended hepatectomy, multidetector CT, CT volumetric measurement

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Major hepatectomy is a common surgical procedure. The remaining liver parenchyma is an important predictor of operative results. One method for the retaining viable liver is pre-operative portal vein embolization (PVE).

The remnant liver (RL) is the rest of normal liver parenchyma after excluding the tumor, portal vein, inferior vena cava, interlobar fissure, and resected hepatic lobe. The RL volume is also known as future liver remnant (FLR) and remnant liver volume (RLV).

Portal vein embolization (PVE) is a standard procedure to induce adequate hypertrophy of the remnant liver (RL) before major hepatectomy [1, 2]. The PVE can be considered for patients whose RL is less than 20% of liver volume [1-3]. Biliary complications or mortality usually occurs within three months of the extended hepatectomy [4].

Advanced imaging is a valuable method for pre-operative and post-operative evaluation and follow-up. Computed tomography (CT) volumetric measurement is a technique to help making treatment

decision. When an adequate RL volume is available, one can hope for less complication. The CT volumetric measurement is an accurate non-invasive procedure for evaluating responses to PVE and predicting the outcome of extended liver resections [4].

Portal vein embolization (PVE) has been performed at King Chulalongkorn Memorial Hospital (KCMH) since 2001. In previous studies [5, 6], we reported our experience with 10 pre-operative PVE patients with hepatobiliary malignancy. We demonstrated that PVE was a useful and safe optional procedure to increase RL volume, and the mean increased RL volume was 13.7%. In this study, we evaluated the liver volume using CT volumetric measurement after four-week PVE.

## Materials and methods

We studied all patients who underwent portal vein embolization (PVE) before major hepatectomy at KCMH between September 2003 and August 2008. We excluded patients who underwent left hepatectomy where Picture Archiving Computed System (PACS) was not available.

PVE was performed using the percutaneous transhepatic technique. The right portal vein was evaluated by contrast media and selection of

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tributaries for embolization. Tissue adhesive material (Histoacryl, N-butyl-2-cyanoacrylate mixed with Lipiodol) was injected to occlude the right main portal vein and selecting tributaries.

Outcome measurements were hepatic volumetry using multi-detector computed tomography (MDCT) hepatic scanning according to the KCMH protocol [10]. We determined the total liver volume and RL volume before undergoing PVE and total liver volume and RL volume four-week after portal vein embolization.

The volumes were calculated at the workstations (Wizard, SIEMENS, Germany). In the calculation, slice volumes were summed using volume program (*syngo* Volume Evaluation version B10/2004A, SIEMENS Medical, Germany), and giving volume in cubic centimeter, as shown in **Fig. 1** [10]. Volume was individually measured by one observer. Random samples of patients were measured twice by the observer and advisor.

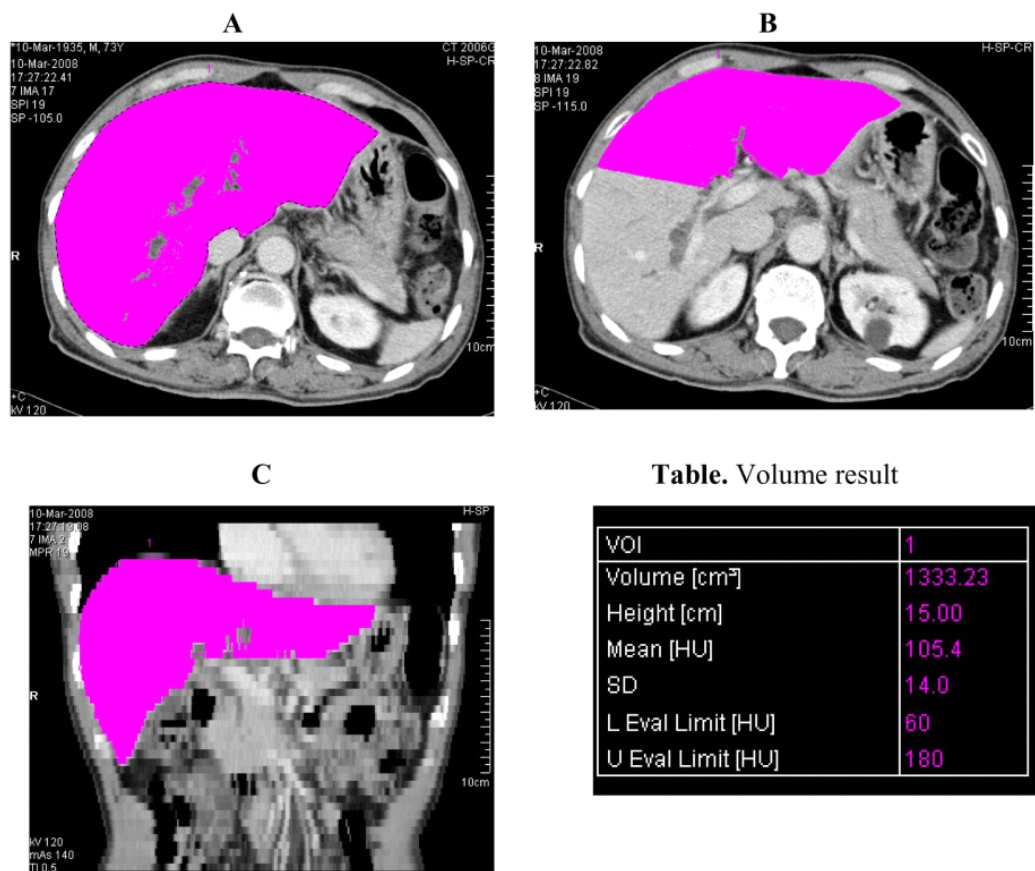
The patient's were reviewed on discharge for 1) basic information such as underlying disease, age, and

sex, 2) complications from PVE procedure [12], and 3) three-month post-operative (extended hepatectomy) liver dysfunction [4], defined by increasing total bilirubin, and/or prothrombin time over the pre-operative values.

Quantitative data of total liver volume and RL volume, pre- and post-PVE were continuous variables. Data was expressed as mean and percent of increased RL volume, ratio to total liver volume, and ratio to body weight.

Rate of complications of the PVE procedure and rate of three-month post-operative (extended hepatectomy) liver dysfunction were analyzed as descriptive statistics.

Correlation between increased RL volume and post- operative (extended hepatectomy) liver dysfunction were analyzed by Pearson's Correlation Coefficient (*r*) (SPSS analysis software version 15; statistical package for Social Sciences, Chicago, USA). The Pearson's Correlation Coefficient (*r*) close to 1.0 was considered significant correlation.



**Fig. 1** Examples of region of interest (ROI) which calculating to volume in cubic centimeter unit (A), axial view of total liver volume (B), and axial view of future remnant liver volume (C). The volume result in Table is calculated automatically.

## Results

Forty-three cases, 35 males, 8 females) were included. Mean age was 55.7 years, range 40-75 years. Underlying liver diseases were 14 hepatocellular carcinomas, 14 cholangiocarcinomas, 14 liver metastases, and one hepatic angiosarcoma.

Means of total liver and RL volumes before PVE were 1,488 mL and 545 mL, respectively. After PVE, the total liver and RL volumes were 1,341 mL and 612 mL, respectively (**Table 1**).

The calculated percent of RL volume to total liver volume on pre- and post-PVE were 37% and 47%. Thus, the increase in RL volume was 10% (**Table 2**). The mean CT post-PVE days was 20 days (range: 12-60 days).

Minor complications from PVE were recorded in two cases. They were reflux of small pieces of glue to main portal and left portal veins.

Post extended hepatectomy laboratory data were recorded for total bilirubin in 15 cases, and for prothrombin time in six cases. In eleven out of 15 cases, total bilirubin increased after the operation. Six cases with recorded prothrombin time were too small for statistical analysis.

Pearson's correlation coefficient (r) between increased RL volume and liver dysfunction (increased TB) was 0.02 (calculated from 11 cases).

## Discussion

In the present study, an adequate RL volume was one important factor for successful extended hepatectomy. Increased RL volume could be induced by the PVE procedure. PVE was a safe procedure with a small incidence of complications.

The volume of the liver is measured by MDCT software, which was of proven accuracy for actual liver volume [10, 11].

In the 43 cases, the demographic data was comparable with the prevalence of their underlying diseases. These are 14 cases each for hepatocellular carcinoma, cholangiocarcinoma, liver metastasis, and one case of hepatic angiosarcoma.

Sirichindakul et al. [5] found 11% increased RL volume in 29 post PVE patients. There was no significant change in our study, showing a 10% increase in RL volume; from 37% to 47%.

Adequate RL volume found by Uhl et al. [2] was more than 20% post-operative liver volume and 40% in cirrhotic patients. Nearly 33% of our populations were hepatocellular carcinomas with some degree of cirrhosis. Thus, RL volume post-PVE was 47%, showing an adequate volume for success.

However, multiple factors have an influence on hepatic regeneration post-portal vein embolization and partial hepatectomy, as described by Yokoyama et al. [13]. These factors include biliary obstruction, diabetes, histories of ethanol abuse, nutrition, gender, aging, and infection. In our study, the majority of cases had viral hepatitis, which is an inhibiting factor for hepatic regeneration. Cholangiocarcinoma causes biliary obstruction resulting in elevation of bilirubin level and decreases hepatic regeneration capability. Moreover, male patients show lesser hepatic regeneration than female [13].

If RL volume was less than 25% of the total liver, there was also an association with post-operative hepatic dysfunction (defined by an increased bilirubin and prothrombin time), as described by Shoup et al.

**Table 1.** Volume of liver.

Mean volume	Before PVE	After PVE
RL volume (mL)	545	612
Total liver volume (mL)	1,488	1,341

**Table 2.** Volume of liver in term of percent and ratio.

	RL (%)	Ratio of RL
Before PVE	37	0.37
After PVE	47	0.47

Mean days: CT after PVE = 20 days (12-60 days).

[7]. In our study, Pearson's correlation coefficient ( $r$ ) between increased RL volume and liver dysfunction (increased TB) was 0.02. All of increased TB cases had an RL volume of more than 34%. Seven out of 11 increased TB cases were hepatocellular carcinomas. Moreover, the serum total bilirubin level had many confounding factors such as underlying liver disease or post-chemo-embolization.

There were two minor cases of complications from PVE without any serious sequelae. This corresponds with studies by Giraudo [3] and Kodama et al. [12] who documented the safety of the PVE.

The present study has some limitations. Firstly, there were no data of complete record at laboratory. Second, there were different intervals for CT after PVE. A prospective design using the same protocol needs to be used in future studies.

In conclusion, PVE could increase RL volume by about 10% of the total liver volume before major hepatectomy. There were no significant complications from PVE.

The authors have no conflict of interest to report.

## References

1. Nagino M, Kamiya J, Nishio H, Ebata T, Arai T, Nimura Y. Two hundred forty consecutive portal vein embolizations before extended hepatectomy for biliary cancer: surgical outcome and long-term follow-up. *Ann Surg.* 2006; 243:364-72.
2. Uhl M, Euringer W, Makowiec F, Adam U, Schneider A, Langer M. [Portal vein embolization preparation for major hepatic resection: a new standard in liver surgery.](#) *Rofo.* 2007; 179:31-7.
3. Giraudo G, Greget M, Oussoultzoglou E, Rosso E, Bachellier P, Jaeck D. [Preoperative contralateral portal vein embolization before major hepatic resection is a safe and efficient procedure: a large single institution experience.](#) *Surgery.* 2008; 143:476-82.
4. Vauthey JN, Chaoui A, Do KA, Bilimoria MM, Fenstermacher MJ, Charnsangavej C, et al. Standardized measurement of the future liver remnant prior to extended liver resection: methodology and clinical associations. *Surgery.* 2000; 127:512-9.
5. Sirichindakul B, Nonthasoot B, Taesombat W, Supaphol J, Nivatvongs S, Janchai A, et al. Role of portal vein embolization in hepatobiliary malignancy. *Hepatogastroenterology.* 2007; 54:2297-300.
6. Sirichindakul B, Nonthasoot B, Thienpaitoon P, Nivatvongs S, Janchai A. Preoperative portal vein embolization in hepatobiliary tract malignancy: an experience at King Chulalongkorn Memorial Hospital. *J Med Assoc Thai.* 2005; 88:1115-9.
7. Shoup M, Gonen M, D'Angelica M, Jarnagin WR, DeMatteo RP, Schwartz LH, et al. Volumetric analysis predicts hepatic dysfunction in patients undergoing major liver resection. *J Gastrointest Surg.* 2003; 7: 325-30.
8. Truant S, Oberlin O, Sergent G, Lebuffe G, Gambiez L, Ernst O, et al. Remnant liver volume to body weight ratio  $\geq$  or  $\leq$  0.5%: a new cut-off to estimate postoperative risks after extended resection in noncirrhotic liver. *J Am Coll Surg.* 2007; 204:22-33.
9. Abdalla EK, Denys A, Chevalier P, Nemr RA, Vauthey JN. Total and segmental liver volume variations: implications for liver surgery. *Surgery.* 2004; 135: 404-10.
10. Tanpowpong N, Vajragupta L, Sirichindakul B, Nonthasoot B. Accuracy of liver volume measurement using Multidetector Computed Tomography (MDCT) in King Chulalongkorn Memorial Hospital (KCMH). *Asian Biomed.* 2007; 1:415.
11. Zacharia TT. Assessment of future remnant liver regeneration after portal vein embolization using three-dimensional CT and MR volumetric analyses. *Australas Radiol.* 2006; 50:543-8.
12. Kodama Y, Shimizu T, Endo H, Miyamoto N, Miyasaka K. [Complications of percutaneous transhepatic portal vein embolization.](#) *J Vasc Interv Radiol.* 2002; 13: 1233-7.
13. Yokoyama Y, Nagino M, Nimura Y. Mechanisms of hepatic regeneration following portal vein embolization and partial hepatectomy: a review. *World J Surg.* 2007; 31:367-374.