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FULL PAPER

The technical aspects of a feasible new technique for ipsilateral percutaneous transhepatic portal vein embolization

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Objective: To devise a simple new technique wherein absolute ethanol is injected via a sheath under proximal balloon occlusion of the right portal vein using a single-balloon catheter and to examine its feasibility and safety for ipsilateral portal vein embolization (PVE).

Methods: Between 2010 and 2016, PVE was performed in 19 patients prior to undergoing extended right hepatectomy. PVE was performed via a percutaneous transhepatic ipsilateral approach, the right portal branch was embolized under ultrasound guidance, and a balloon catheter was placed in the proximal site of the main right portal branch. Absolute ethanol was injected through a sheath under proximal balloon occlusion of the right portal vein using a double-lumen catheter. We evaluated its technical success and complications following

PVE and changes in liver enzyme levels. Furthermore, we calculated changes in future liver remnant (FLR) and FLR/total functional liver volume (TFLV) ratio and assessed complications following hepatic resection.

Results: PVE was successfully performed in all patients. Mean FLR and FLR/TFLV significantly increased following PVE ($p < 0.01$). The change in the FLR and FLR/TFLV ratio was $39.6 \pm 16.2\%$. One patient (6.5%) developed procedure-related complications following PVE (perihepatic hematoma).

Conclusion: The new technique for ipsilateral right PVE is safe, effective, and convenient.

Advances in knowledge: This is the first study to investigate the efficacy of injecting ethanol via a sheath under proximal balloon occlusion of the right portal vein using a single-balloon catheter.

INTRODUCTION

Percutaneous transhepatic portal vein embolization (PVE) is a standard procedure that is performed prior to extended hepatic resection in patients with a small residual liver volume. The aim of PVE is to increase the volume and function of future liver remnant (FLR) and thus decrease postoperative complications and morbidity and mortality risk.^{1,2} A recent meta-analysis has confirmed the safety and efficacy of PVE.³ The PVE technique varies depending on the institution and the various embolic materials used, including gelatin sponges (Gelfoam), fibrin glue, coils, thrombin, polyvinyl alcohol (PVA) particles, and absolute ethanol. Combinations of these materials have also been used in PVE.⁴⁻¹² Here, we performed standard PVE procedures using percutaneous transhepatic, ipsilateral, and balloon-occluding approaches. However, no consensus regarding which embolic material is the most suitable has been established.

We evaluated a new technique wherein absolute ethanol is injected via a sheath under proximal balloon occlusion of the right portal vein using a single-balloon catheter and examined its safety and feasibility for performing ipsilateral PVE.

METHODS AND MATERIALS

Study population

This study was approved by the institutional review board, and the need for written informed consent was waived owing to the study's retrospective design. Between April 2010 and December 2016, to increase the volume of an insufficiently small left FLR before surgery were enrolled at a single institution. In total, we included 25 patients (18 males and 7 females) who underwent the new PVE technique or the conventional balloon technique (age range: 45–86 years; mean age: 69.5 ± 3.0 years). Finally, 19 patients (14 males and 5 females) between ages 45 and 86 years

Figure 1. Patient inclusion chart. PVE,portal vein embolization. MPR,multi-planar reconstruction. 3DVR, three-dimensional volume rendering.

(mean age: 69.5 ± 4.0 years) underwent the new PVE technique. The remaining six patients underwent the conventional balloon technique of ipsilateral PVE that has been previously reported¹³ due to right portal vein anomalies, including four cases of trifurcated branching and two cases of solitary posterior branching from the portal trunk (Figure 1).

All patients with advanced hepatobiliary malignancy who underwent preoperative right PVE had tumors limited to the right hepatic lobe with small FLRs and none had extrahepatic disease.

PVE technique

All procedures were performed under local anesthesia by an interventional radiologist with 21 years of experience or by a physician under his supervision. Example of these procedures is shown in Figure 2. Size of the balloon was chosen by measurement of large axis of the portal vein on portal phase image of pre-procedural dynamic CT. We used the ipsilateral approach for all PVE procedures. The right portal vein was punctured or entered (instead of embolized) using ultrasound guidance. After a 6-Fr sheath was placed in the right portal branch, a 5-Fr Cobra catheter was inserted in the main portal trunk over a 0.035 inch guidewire, and digital subtraction portography was performed to visualize the portal vein anatomy. The balloon catheter (Selecon MP catheter, Terumo, Tokyo; shaft diameter of 5.5 Fr., balloon inflation diameter of 10 mm) was guided into the proximal portion (first branch) of the right portal vein using a 0.035-inch guidewire. This guidewire usually left into the central lumen of balloon catheter until acquiring sufficient

portal embolization because of keeping the central lumen of balloon catheter patent.

After inflating the balloon, we performed portography via the balloon catheter, carefully confirming the precise location of the orifice of the left portal branch in order to prevent the inadvertent

Figure 2. Diagram illustrates new technique for ipsilateral right PVE with absolute ethanol. A single-lumen balloon catheter is obstructing the right main portal branch; all ethanol, which is injected through the slit between catheter and sheath, returns to distal branches of right portal vein. Arrows indicate the direction of the flow of the injected ethanol.

administration of absolute ethanol. Some cases needed to avoid incomplete occlusion with over inflation of the balloon reaching 12 mm in diameter. The tip of the sheath was brought close to the balloon, contrast imaging was performed through the sheath, and the image was reviewed again to ensure sufficient visibility of the occluded branch of the portal vein (the area near the right branch). Digital subtraction angiography was performed, and the amount of absolute ethanol that was injected was determined according to the amount of contrast medium used. After gradually injecting the planned amount of absolute ethanol through the sheath, we allowed it to remain stationary for 8–10 min.

After confirming occlusion of the portal vein branch, we used 2–3 ml of contrast medium to verify the successful removal of absolute ethanol through the sheath. If the embolism was insufficient, 2–5 ml of absolute ethanol was reintroduced and left stationary for another 8–10 min according to previous methods (using absolute ethanol).^{10,13,14} Once the portal vein embolism was confirmed, the balloon was deflated and contrast imaging was performed through the tip of the balloon catheter. Digital subtraction portography was used to confirm complete embolization of the right portal branches and the presence of complications including inadvertent embolization (Figure 2). Contrarily, the conventional balloon technique of ipsilateral PVE was performed using a reverse-curved 5 Fr balloon catheter with a tip hole (Selecon balloon catheter; Terumo Clinical Supply Co., Ltd., Gifu, Japan). Absolute ethanol was bolus-injected into both the right anterior and right posterior branch following selective right anterior and posterior portography with balloon occlusion using the reversed catheter technique. Finally, the sheath and balloon catheter were slowly removed, and strips of gelatin sponge that were mixed with contrast medium were used to close the tract of the sheath.

Liver volume and laboratory data

Contrast-enhanced CT was performed prior to PVE and shortly before hepatic resection. Transverse CT images were obtained using 64-row multidetector helical CT. Following intravenous contrast injection, portal phase images with 5 mm section thickness were obtained of the dome to the inferior part of the liver. Images of the operator-defined, handheld regions of the total liver volume (TLV), liver tumor volume (TV), and FLR volume (Segments II–IV) were measured at a workstation (SYNAPSE VINCENT; Fuji Photo Film Co., Ltd. Tokyo, Japan) by an interventional radiologist and the referring surgeon, and total functional liver volume (TFLV) was calculated using TLV and TV. The FLR/TFLV ratio was calculated before and after PVE.

Statistical analysis

We assessed the technical outcome of PVE, defining technical success as the achievement of complete portal occlusion of the targeted segments. Changes in liver enzyme serum levels were assessed during and after PVE and graded according to the National Cancer Institute Common Terminology Criteria for Adverse Events, v. 4.0. FLR and FLR/TFLV ratios before and after PVE were compared using the Wilcoxon signed rank test. A p -value <0.050 was considered statistically significant for all tests.

Statistical analyses were performed using SPSS for Windows, v. 12.0 (SPSS Inc., Chicago, IL) software.

RESULTS

Overall, 19 patients underwent the new PVE technique. The primary cancers included hilar cholangiocarcinoma in nine patients, colorectal liver metastases in eight, gallbladder cancer in one, and hepatocellular carcinoma in one. The new technique for PVE of the liver segments was performed successfully, and all patients achieved complete occlusion of the targeted portal venous branches (Figure 3). Mean volume of absolute ethanol was 12.8 ± 3.5 ml (range: 9–18 ml). Incomplete obstruction and recanalization were not observed. Perihepatic hematoma was the only complication related to the PVE procedure, occurring in 1 (6.5%) of 19 patients; however, there were no major procedure-related complications. No complication prevented hepatic resection, and no patient developed liver insufficiency following PVE or liver resection. There were no severe adverse events associated with serum enzyme levels, but there were postprocedural elevations of aspartate aminotransferase and alanine aminotransferase levels. Severe adverse events (grade >3) due to serum enzyme levels occurred in 5 of 19 patients (26%); however, these elevations were transient, and all of the patients returned to normal prior to surgery.

Patient characteristics and liver volume data before and after PVE are summarized in Table 1. CT was performed between 15 and 28 days (median: 21 days; mean: 20.0 ± 4.0 days) after PVE and confirmed occlusion in all embolized portal branches. Mean TFLVs before and after PVE were 1164 ± 160 ml (range: 860–1450 ml) and 1178 ± 148 ml (range: 885–1480 ml) ($p = 0.23$). The volume of the left liver lobe's FLR was 401 ± 128 ml (range: 261–554 ml) prior to PVE and significantly increased to 566 ± 185 ml (range: 401–730 ml) after PVE ($p < 0.01$). Mean FLR/TFLV ratio also significantly increased from $34.4 \pm 5.3\%$ to $48.3 \pm 3.6\%$ ($p < 0.01$). The change in FLR induced by PVE was $39.6 \pm 10.2\%$ (range: 18.4–48.8%), and the change in the FLR/TFLV ratio was $13.8 \pm 2.5\%$ (range: 9.2–21.8%).

DISCUSSION

Percutaneous transhepatic PVE was first reported by Kimura and Makuuchi et al.^{1,2} to improve the safety of extensive liver resections performed to retain liver function. Each medical facility has its own method of performing PVE; however, the general procedure involves puncturing the portal vein either on the contralateral side of the portion of the liver that is targeted for resection (embolism side: contralateral approach) or on the affected side (ipsilateral approach). At our institution (Kindai University Hospital), we have adopted the percutaneous ipsilateral approach, its advantages including direct access to the portal branches and minimal risk of portal vein thrombosis and inadvertent vascular injury to the FLR. Therefore, we believe that ipsilateral PVE is a more preferable approach.^{6,7}

When performing ipsilateral PVE, normal embolic material may be used alone or in combination with a balloon catheter with an inverted tip or a custom-made triple-lumen balloon catheter to prevent the flow of embolic material into

Figure 3. Images in a 68-year-old male with colorectal hepatic metastases. (a) Anteroposterior portogram obtained before embolization of the right portal venous branches through a 5-Fr angiographic catheter in the main portal trunk. (b) Anteroposterior portogram obtained after right portal vein embolization shows a complete occlusion of the right portal venous branches. (c) Transverse contrast-enhanced CT image before portal vein embolization shows patent portal venous branches. The calculated FLR for segment I–IV is 345 cm³ and the FLR/TFLV ratio is 31.7%. (d) Transverse contrast-enhanced CT image 18 days after portal vein embolization demonstrates thrombotic occlusion of the branches and hypertrophy of the left liver lobe. Significant FLR hypertrophy is evident with FLR as 443 cm³ and the FLR/TFLV ratio as 47.0% (% changes in FLR and FLR/TFLV ratio are 37.5 and 13.4%, respectively). FLR, future liver remnant; TFLV total functional liver volume.

the unresected side of the portal vein. Balloon catheters use sheaths that are slightly larger than normal catheters because the balloon is large at the tip. However, once the balloon has passed the tip of the sheath, there is enough space for liquid to pass between the balloon catheter's shaft and the inner lumen of the sheath, and our technique takes advantage of this fact. Few studies have evaluated PVE techniques that involve injecting

liquid embolic material through the sheath while the balloon is inflated. A previous study reported on a "balloon technique" for performing ipsilateral PVE using a custom-shaped balloon catheter; however, it was a complicated technique and required special procedures that were time consuming.¹³ Further, the method used in this study allows the same PVE technique to be performed with several types of balloon catheters apart

Table 1. Changes in liver volume before and after portal vein embolization^a

Variable	Before PVE	After PVE	% Change	<i>p</i> -value ^a
TFLV	1164 ± 160 cm ³ (860–1450)	1178 ± 148 cm ³ (885–1480)	1.2 ± 2.2% (–10.2–11.8)	0.23
FLR	401 ± 128 cm ³ (261–554)	566 ± 185 cm ³ (372.6–930.8)	39.6 ± 10.2% (18.4–48.8)	<0.01
FLR/TFLV ratio	34.4 ± 5.3% (26.6–43.0)	48.3 ± 3.6% (40.2–59.4)	13.8 ± 2.5% (9.2–21.8)	<0.01

FLR, future liver remnant; PVE, portal vein embolization; TFLV, total functional liver volume;

Data are summarized as mean ± standard deviation and data in parenthesis are range.

^a*p*-values were calculated to compare values between before and after PVE by using the Wilcoxon signed rank test.

from the original catheter; this flexibility makes the technique highly useful.

There is still debate over which embolic material to use; cyanoacrylate and PVA are not used frequently in our country, and there have been reports of problems with reopening due to the use of a gelatin sponge and fibrin glue. In contrast, absolute ethanol, which has a powerful coagulant effect, is commonly used in interventional radiology techniques, including surgical procedures, which eliminate renal function. Absolute ethanol causes tissue fixation, sludged blood cells, and protein denaturation and coagulation. Here, PVE was successful in all patients, and recanalization of the embolized portal branches was not detected following the procedure. Absolute ethanol can embolize both distal outflow and proximal inflow of the portal branches because it diffuses quickly owing to its low density and viscosity.^{12,13,15,16} We believe that using pure absolute ethanol caused quickly and strictly embolization of the portal vein rather than ethanol mixed with contrast medium because it caused time extension. Previously, absolute ethanol was infused during balloon occlusion via the ipsilateral approach using reverse-curved catheters.¹³ This prevents reflux of embolic material into the portal branches of the FLR,^{10,13–17} and the ipsilateral approach thus helps avoid injury to the FLR.^{17,18} With the new technique, it is easy to infuse

absolute ethanol into the right portal branches via the ipsilateral approach. Nevertheless, in our technique, only absolute ethanol is used to inject embolic material between the catheter shaft and outer jacket of the sheath, because other embolic materials, such as gelatin sponges, fibrin glue, coils, thrombin, and PVA particles, are not suitable for this purpose.

This study has several limitations. First, it was a retrospective pilot study conducted at a single institution. Second, the length of hospital stay after PVE, intensive care stay, and overall duration of hospital stay were not evaluated. Third, FLR volume is not the only necessary factor involved in avoiding postoperative complications. Finally, our method used absolute ethanol as the embolic material. Absolute ethanol is mainly used by physicians in our country,^{10,13–17} whereas investigators of studies in other countries have primarily used spherical particles with proximal coils or n-Butyl cyanoacrylate mixed with iodized oil.¹⁹

CONCLUSION

In conclusion, we reported the initial results from our ipsilateral PVE technique wherein anhydrous ethanol is injected through a sheath to occlude the portal vein using a single-balloon catheter. This technique is relatively simple and allows PVE to be performed safely and feasibly.

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