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ORIGINAL ARTICLE

Intraoperative ultrasound guided portal venous thrombectomy in living donor liver transplantation recipient surgery

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Summary

Portal vein reconstruction in liver transplantation from live donor grafts has major challenging factors in cases with portal venous thrombosis (PVT). To overcome this critical surgical challenge, we devised a novel technique, intraoperative ultrasonography (IOUS)-guided thrombectomy of the portal vein. IOUS-guided thrombectomy was applied to the 10 patients whose PVT extended to the splenomesenteric junction. In these patients, closed thin scissors were inserted from the stump of the recipient portal vein under ultrasound guidance and the thrombus was dissected from the venous wall. The application of IOUS-guided thrombectomy in patients with moderate to severe PVT led to a 3-year patency rate of 83%, comparable to that of simple thrombectomy applied to partial or minimal (grade I–II) PVT (83%). IOUS-guided thrombectomy is helpful to adequately remove severe thrombi from the deep lumen of the portal vein, provided the procedure was carried out by an experienced surgeon with adequate preparation for unexpected venous injuries.

Introduction

Portal vein thrombosis (PVT) is no longer considered a contraindication for deceased donor liver transplantation [1–5]. In live donor liver transplantation (LDLT), however, the limited length of the graft portal vein from the live donor and the lack of readily available tissue for reconstruction are major challenging factors for portal vein thrombectomy and portal vein reconstruction [6]. Cryopreserved vein grafts have been used for portal vein reconstruction as interposition or jump grafts in such cases with rather unsatisfactory results [7–9].

Intraoperative ultrasound (IOUS) is widely used in the field of hepatic surgery, offering visualization and real-time understanding of crucial intrahepatic vasculature for safe parenchymal transection [10,11]. In this article, we describe the applicability and outcome of our novel technique, IOUS-guided thrombectomy, to overcome the above-described challenge that is often faced in LDLT.

Methods

Patients

An IOUS-guided thrombectomy was first applied in February 2002. Until January 2006, 191 adult patients underwent primary LDLT at our hospital. Of these, 34 patients (18 men, 16 women) had partial PPVT preoperatively (18%) and are the subjects of this study. Patients found with complete PV and entire superior mesenteric vein (SMV) thrombosis during work up were not transplanted. There were no domino transplantation, or auxiliary partial orthotopic liver transplantation cases. Types of grafts retrieved from living donors were determined according to previously described standardized algorithm [12,13].

None of the patients were diagnosed with a hypercoagulable state of protein C, S, antithrombin III deficiencies, factor V/II mutation, lupus anticoagulant, or with anticardiolipin antibodies. History of oral contraceptive intake, or tumorous obstruction of PV were not

presented. Two patients had undergone Hassab's procedure for esophageal varices, but none were found with history of shunt surgery or with Budd Chiari syndrome. In 10 patients with PVT extending beyond the splenomesenteric junction, IOUS-guided thrombectomy was applied (IOUST group). For 13 patients with PPVT located within the cranial side with minimal extension into the splenomesenteric junction, IOUS was not required and a simple thrombectomy, including eversion of the venous wall, was applied (ST/ET group). In the remaining 11 patients, portal vein was reconstructed with interposition vascular conduits (Vein graft group). Among the 11 cases, two procedures were necessitated by injury to the portal vein during thrombectomy. In reconstructing the portal flow by conduits, cryopreseved vein grafts were used in all but one case (auto graft) as described earlier [7]. Types of cryopreseved grafts used were: femoral vein in five, iliac vein in three, portal vein in one, and superior vena cava in one. Grafts were matched for ABO blood type compatibility. The median cryo-storage period was 419 days (range 91–1207 days).

Portal venous thrombosis in recipients undergoing LDLT in the current series was classified according to the classification previously described by Yerdel and colleagues [2]: grade 1, <50% PPVT with or without minimal obstruction of the superior SMV; grade 2, grade 1 but >50% PPVT; grade 3, complete PV and proximal SMV thrombosis; grade 4, complete PV and entire SMV thrombosis. Preoperative evaluation of PVT was routinely performed with Doppler ultrasound and multi-detector row computed tomography with contrast. Three-dimensional image were obtained in selected cases for better understanding of the surgical team. Information obtained by these modalities was sufficient in the majority of cases. Currently, angiography is seldom performed for evaluating the extent of PV thrombus due to its inherent complications.

Empiric anticoagulation therapy was initiated immediately after transplantation in all cases at our institution. The protocol consisted of dalteparin (25 IU/kg/day) by continuous intravenous infusion from postoperative day (POD) 1, with a switch to heparin (5000 U/day) on POD 3. The dose was changed according to the activated clotting time, which was targeted to a range between 130 and 160 s. Prostaglandin E1 (0.01 μg/kg/min) and a protease inhibitor (mesilate gabexate; 1 mg/kg/h) and antithrombin III concentrates (1500 U/day) were also administered intravenously just after the operation through POD 3 [14,15]. Immunosuppression consisted of tacrolimus and steroids [16].

Vascular flow in the transplanted liver and portal vein patency was checked by Doppler ultrasound daily until POD 14 and then at least once a week until discharge. Enhanced computed tomography was performed 1 and 3 months after LDLT to check vein graft patency [15]. Once rethrombosis or occlusion was discovered, immediate salvage was considered, including emergent relaparotomy, interventional angioplasty, thrombolytic therapy, and anticoagulant therapy.

All LDLT procedures were approved by the ethical committee of Graduate School of Medicine, University of Tokyo. Patients were informed of the risks of LDLT including surgical risks such as uncontrollable bleeding which may result in graft failure and intraoperative mortality. Written informed consent was obtained in all cases.

Surgical procedure

After laparotomy or hilar dissection, IOUS was routinely performed with an SSD 6500 or SSD-a10 with a miniconvex 7.5 MHz probe (Aloka Co. Ltd., Tokyo, Japan) to confirm the PVT. If PPVT was detected, the location and extent of the PPVT was then meticulously evaluated.

Management for PPVT was usually performed during the anhepatic phase just before transplantation of the graft. Dissection around the portal vein was performed to free the surgical field for subsequent thrombectomy. Even if the PPVT extended beyond the splenomesenteric junction, the dissection was limited up to the splenomesenteric junction to avoid unexpected injury of the pancreas parenchyma.

After clamping the main portal trunk at the most proximal point possible, the thrombus was carefully dissected from the venous wall with the closed tip of thin scissors; if necessary, eversion of the venous wall was performed. This thrombectomy was defined as a 'simple thrombectomy' in the present study. In cases in which the PPVT was located so deep in the portal vein that even eversion thrombectomy was not sufficient for adequate extraction, we applied IOUS-guided thrombectomy. With the IOUS probe fixed on the pancreas head, a blunt blade of closed thin scissors was inserted from the stump of the portal vein deeper into the lumen beyond the clamp to dissect the thrombus (Fig. 1). The portal stump had to be pinched carefully with the fingers to control bleeding. Dissected thrombi must be carefully withdrawn to minimize residual thrombi. Even if small thrombi remained at the deep internal wall, where palpation did not work as a guide, IOUS efficiently acted as a guide for removal of the residual thrombi (Fig. 2). Shifting and tilting of the IOUS probe allowed us to image and understand the 3-dimensional spatial relationship to accurately reach the thrombus itself and to avoid venous wall injury. The portal vein was occasionally flushed with saline to wash out residual thrombi or newly generated clots. The adequacy

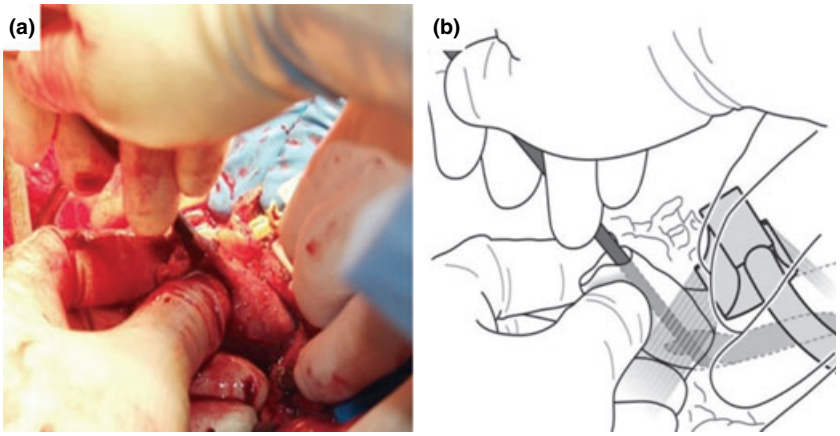

Figure 1 Intraoperative view (a) and schema (b) of intraoperative ultrasound-guided thrombectomy. Closed thin scissors were inserted into the portal vein to dissect the thrombus. The stump of the portal vein was carefully pinched with the fingers. A probe was attached to the pancreas head.

of extraction and restoration of portal flow was checked with IOUS immediately after procedure. In general, we consider thrombectomy up to the splenomesenteric junction to be sufficient.

Statistical analysis

Statistical analysis was performed using ANOVA, the Kaplan–Meier method and the generalized Wilcoxon test. A *P*-value of less than 0.05 was considered statistically significant.

Results

Baseline recipient characteristics were similar among IOUST group, ST/ET group, and vein graft group (Table 1). PPVT was classified as grade I in 16 patients, grade II in 14 patients, and grade III in four patients. There were no grade IV PVTs. Nine patients presented with minimal extension into the SMV. PPVT extended further into the spleno-mesenteric junction in three patients with grade I PPVT and in two patients with grade II PPVT. The preoperative detection rate of PPVT increased with the PPVT grade: 69% (11 patients) in grade I, 71% (10 patients) in grade II, and 100% (four patients) in grade III, although the difference between grades was not significant. The IOUST, ST/ET, and Vein graft groups contained two, eight, and six grade I patients; five, five, and four grade II patients; and three, 0, and one grade III patients, respectively (Table 1).

In the 11 patients in the vein graft group interposition technique was applied due to mismatch of the diameter of the recipient and graft portal vein in one case, and due to factors associated with thrombectomy in the remaining 10. Among the 10 cases, eight were necessitated by short length of the available donor and recipient portal vein after successful removal of the thrombus was achieved by conventional (simple or eversion) thrombectomy. Of these eight patients, five patients including two patients whose PVT extended beyond spleno-mesenteric junction was accompanied with the trimming of the recipient portal vein to simplify the subsequent thrombectomy in three, to abandon the severely stenotic portion in two after successful thrombectomy. In the remaining two of 10 thrombectomy-associated interposition cases, the use of conduit was necessary due to failure of the conventional technique in one, and IOUS guided technique in the other. Minor laceration occurred during thrombectomy in these two cases and application of interposition grafting was promptly decided. Restoration of sufficient portal flow was confirmed by immediate IOUS Doppler study in all cases.

The 3-year patency rates were 83% in the IOUST group, 83% in the ST /ET group, and 50% in the Vein graft group. IOUS-guided thrombectomy, which was applied to patients with rather severe PPVT, achieved a patency similar to that achieved with simple or eversion thrombectomy applied to partial or minimal PPVT ($P = 0.90$, Fig. 3a). The PVT grade did not influence long-term patency (Fig. 3b).

Discussion

This report demonstrates that the use of IOUS may play a beneficial role in removing a rather extensive pre-organized PVT in patients undergoing LDLT. IOUS is globally accepted as a critical tool in liver surgery [10,11]. In LDLT, IOUS is indispensable for evaluating the vascular structure and blood flow. Further expanding its use in this field, we have presented the applicability of IOUS-guided portal vein thrombectomy. Our study is based on a retrospective and non-randomized experience, and the nature of data collection hinders any conclusive

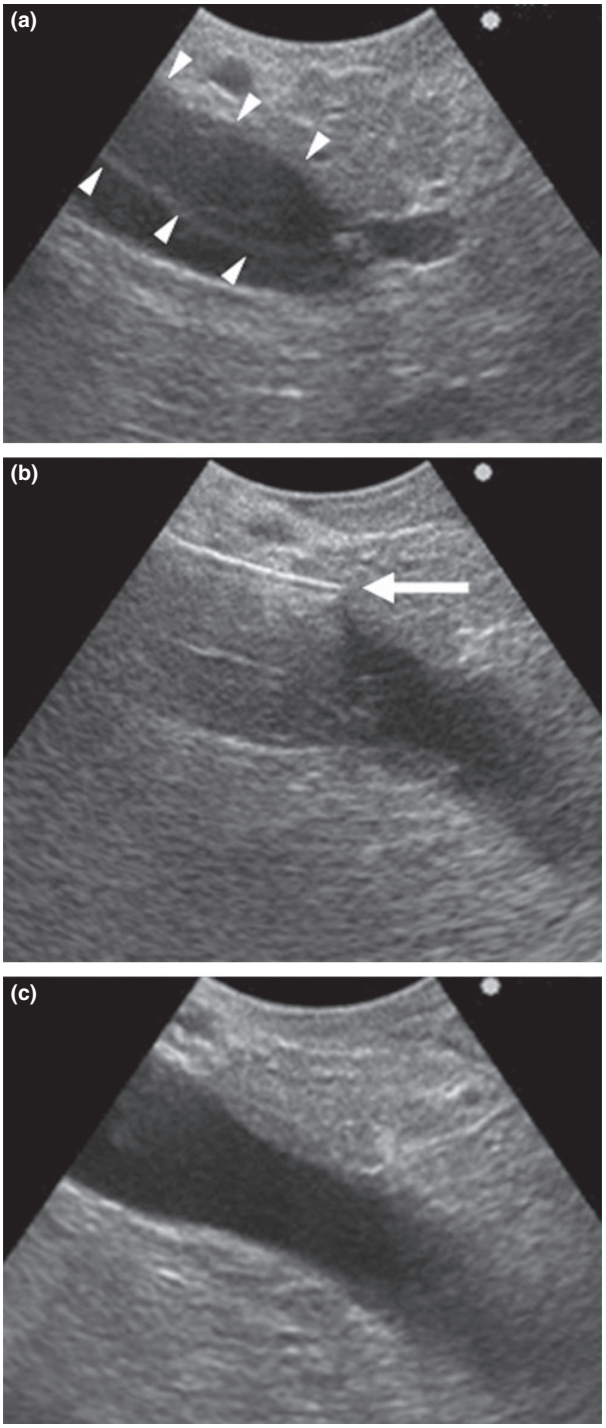

Figure 2 Images of ultrasound-guided thrombus dissection. A thrombus (a: arrowheads) is dissected with closed scissors (b: arrow) from the internal wall of the portal vein. The thrombus is completely extracted up to the splenomesenteric junction (c).

comments on the superiority of any technical options including jump graft usage or application of IOUS. The feasibility of IOUS thrombectomy has been, however,

Table 1. Baseline characteristics.

	IOUST group (n = 10)	ST/ET group (n = 13)	Vein graft group (n = 11)	P-value
Age (years)	59 (37–63)	56 (36–66)	53 (24–56)	0.11
Sex(male:female)	3/7	6/7	7/4	
Disease(viral/ cholestatic/others)	8/1/1	8/3/2	5/5/1	
Graft type				
Right liver without MHV	5	3	4	
Right liver with MHV	3	4	1	
Right lateral sector	0	0	2	
Left liver	2	6	4	
GV/SLV*(%)	52 (36–67)	43 (36–61)	44 (34–59)	0.32
PVT grade† I/II/III/IV	2/5/3/0	8/5/0/0	6/4/1/0	
PVT beyond SMJ	6	0	3	

Continuous data are shown as median with range.
IOUST, intra-operative ultra sound guided thrombectomy group; ST/ET, simple thrombectomy or eversion thrombectomy; MHV, middle hepatic vein; GV, graft volume; SLV, standard liver volume; PVT, portal vein thrombosis; SMJ, splenomesentric junction.
*Standard liver volume of the recipient was calculated by Urata's formula [12].
†Grade of PVT is based on Yerdel's system [2].

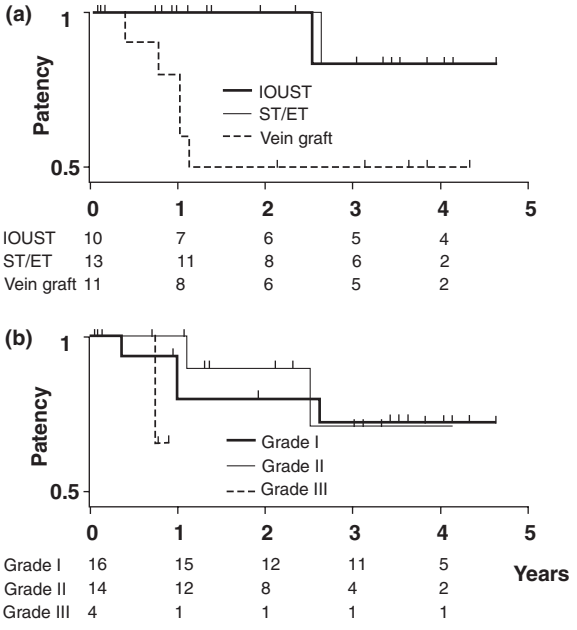

Figure 3 Patency rate of the portal vein, stratified by procedure (a) or grade of portal vein thrombosis (b). IOUST versus ST/ET (P = 0.90), IOUST versus Vein graft (P = 0.08), grade I versus grade II (P = 0.59), grade I versus grade III (P = 0.29). Numbers below the x-axis indicate the number of patients at risk. IOUST, intraoperative ultrasound-guided thrombectomy; ST/ET, simple thrombectomy including eversion.

demonstrated, and further trial of the technique may be considered acceptable.

In the current series, IOUS-guided thrombectomy achieved long-term patency comparable to that of 'simple thrombectomy'. In LDLT, the portal vein of the graft liver is limited to the first branch, which is far shorter than that of a whole liver graft. To compensate for the reconstruction length, the most reasonable material for use in LDLT is considered to be cryopreserved vein grafts. Recent reports [7,9], however, indicate a rather disappointingly high incidence of postoperative complications of portal vein reconstructions with cryopreserved vein grafts. Compatible with these previous findings, patients in the current series that required cryopreserved venous grafts as conduits in portal vein reconstruction had a higher incidence of postoperative loss of patency. Use of a fresh auto graft or allograft obtained form the donor should be considered a primary option when available, especially in countries where deceased donor transplantation is routinely performed. Techniques with extension grafts previously described by Marcos and colleagues may also be useful when applicable [17].

One other advantage of using IOUS in this procedure, aside from the direct visualization that enhances the safety of the maneuver, is the real-time, immediate evaluation of the adequacy of the thrombectomy. Although the optimal extent of thrombectomy is controversial, we consider restoration of the adequate portal flow to be of paramount importance. It may be emphasized that total extraction of the thrombus is not mandatory, but restoration of sufficient portal flow to the graft is important. In the current series, five patients presented with minute remnant of the PPVT recognized by IOUS. After anastomosis, immediate IOUS Doppler study presented with excellent portal flow without turbulence, discouraging additional maneuver including re-do of the anastomosis. After transplantation, no thrombotic complications have been found in these five patients.

Thrombectomy procedure for any PVT in liver transplantation is accompanied by a risk of failure, namely, tear or laceration of the portal vein resulting in excessive blood loss and ultimately, dismal conditions including graft failure when recovery cannot be made. The two cases encountered in our series, one during conventional thrombectomy and the other during IOUS guided thrombectomy, were successfully salvaged by the use of interposition grafts. Decision for changing the strategy was made immediate after a minor tear occurred. Further maneuver of thrombectomy was abandoned in both cases. Hemostasis with clamping and compression was obtained without delay, and interposition grafting was performed. Prompt change in strategy is important. These inherent hazards must be recognized by the surgeon and the procedure should preferably be carried out by experienced hands.

The current report does not include the most extensive PVT, i.e. grade IV PVT, which is often accompanied by a high risk of gastrointestinal bleeding. In countries where deceased donor transplantation is common, combined liver intestine or multi-visceral transplantation including the entire splanchnic system is a realistic option. Abu-Elmagd and colleagues form Pittsburgh, the pioneer in this field, have described their successful clinical experiences in challenging situations [18,19]. This approach, however, remains a future challenge in regions where deceased donor transplantation remains an unrealistic option. A recent report described an LDLT case with grade IV PVT that was successfully managed using a variceal left gastric vein and a deceased donor iliac vein conduit to create a '*de novo* portal vein' for splanchnic inflow to the right lobe. The long-term results, however, are yet to be evaluated [20].

In conclusion, IOUS may serve as a useful guide for PPVT thrombectomy in LDLT. Use of IOUS allows direct real-time visualization of thrombus removal procedure, even for those extending into SMV. This provides maximal opportunity for preserving the length of the recipient portal vein for direct anastomosis with the graft portal vein, which is very much limited in LDLT.

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Authorship

Study concept and design by YI and YS; Acquisition, analysis and interpretation of data by YI; Drafting of the manuscript by YI; Critical revision of the manuscript for important intellectual content by YS and ST; Funding obtained by YS, ST and MM; Study supervision by YS and MM.

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