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Complex Inferior Vena Cava Reconstruction during *Ex vivo* Liver Resection and Autotransplantation: Case Report and Review of Literature

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Abstract

Revascularization is a critical step in patients with end-stage hepatic Alveolar Echinococcosis (AE) during *Ex vivo* Liver Resection and Autotransplantation (ELRA). Multiple vascular fragments need to be used for complex reconstruction when the vessels are severely invaded and the residual vessel area is insufficient. This paper reports a case of a 26-year-old patient who underwent complex reconstruction of the IVC during ELRA for hepatic AE had good surgical recovery and no vascular-related complications. A retrospective chart study and long-term survival follow-up of the cited case was performed. Complex revascularization during ELRA is an extremely rare condition described in the literature. PubMed and Medline databases were searched by using key words, including "outflow tract reconstruction", "ELRA" in different combinations to identify other cases. We found three publications detailing complex revascularization of the IVC, including two patients operated for hepatic AE, none of whom had complications associated with complex revascularization. Overall, the literature shows a good prognosis for complex revascularization. This report and systematic review demonstrate that complex IVC reconstruction with multiple autologous venous fragments is safe and feasible during ELRA in patients with end-stage hepatic AE.

Keywords: Hepatic alveolar echinococcosis; *Ex vivo* liver resection and autotransplantation; Inferior vena cava; Revascularization; Complication

Abbreviations

AE: Alveolar Echinococcosis; CT: Computed Tomography; DCD: Donation after Cardiac Death; ELRA: *Ex vivo* Liver Resection and Autotransplantation; HV: Hepatic Vein; IVC: Inferior Vena Cava; LTH: Ligamentum Teres Hepatis; PV: Portal Vein

Introduction

Hepatic Alveolar Echinococcosis (AE) is a rare zoonotic infection caused by *Echinococcus multilocularis* [1]. A series of previous studies have shown that for patients with end-stage hepatic AE, *Ex vivo* Liver Resection and Autotransplantation (ELRA) may be effective alternatives to allotransplantation [2]. Compared with allotransplantation, ELRA overcome the problems of shortage of liver sources and long-term postoperative immunosuppression [3-5]. Therefore, ELRA is a better choice for patients with end-stage hepatic AE where complete resection of the lesion is not possible and technical problems such as *in vivo* revascularization are difficult to surmount [4,6,7]. End-stage hepatic AE has often invaded major bile ducts and blood vessels, requiring additional repair and reconstruction procedures of the vessels during ELRA [1,8,9], in which case the correct selection of the appropriate revascularization material is significant. According to the different degrees of vascular invasion, reconstruction materials could be selected from autologous vessels, allogeneic vessels and artificial vessels. Complex revascularization with multiple vascular

remnants can also be an effective treatment option when the area of lesion invasion is too large, and a single vascular patch is not sufficient for revascularization.

The present study presents case of complex reconstruction of the Inferior Vena Cava (IVC) using autologous Portal Vein (PV) fragments, umbilical vein within the Ligamentum Teres Hepatis (LTH), and disease-free IVC during ELRA. Furthermore, the literature on complex reconstruction of the IVC during ELRA was reviewed to summarize the experience of complex reconstruction of the IVC.

Case Presentation

Patient, a 26-year-old woman came to our center on July 8, 2015 with the chief complaint of right upper abdominal pain for 2 weeks. Abdominal color Doppler ultrasound revealed a moderate to high echogenic lesion in the right lobe of the liver, measuring approximately 9.5 cm × 8.7 cm. Abdominal Computed Tomography (CT) revealed space occupying lesions in the right posterior lobe and caudate lobe of the liver. The right branch of the PV, the middle Hepatic Vein (HV) and the initial part of the left HV were invaded. The hepatic IVC was surrounded by lesions and narrowed by compression (Figure 1A, 1B). Based on preoperative evaluations, this patient was diagnosed with hepatic AE.

On July 26th, 2015, we performed ELRA for the patient. The right posterior lobe of the liver, most of the right anterior lobe, caudate lobe and part of the left inner lobe were invaded. The right HV, the root of the middle HV and the root of the left HV were encircled, and the anterior and lateral walls of the hepatic IVC was surrounded by the lesion approximately 5 cm. After the whole liver was dissociated, transect all important vascular and remove the diseased liver. Reconstruct the hepatic IVC with artificial vessels to perform a temporary portal shunt. Isolate the whole liver and perfused through the left branch of PV with 0 to 4°C Histidine-Tryptophan-Ketoglutarate solution rapidly. The hepatic parenchyma was severed at 2.0 cm along the right edge of the falciform ligament, the vessels seen along the way were ligated, and the lesions that invaded the vessels were removed.

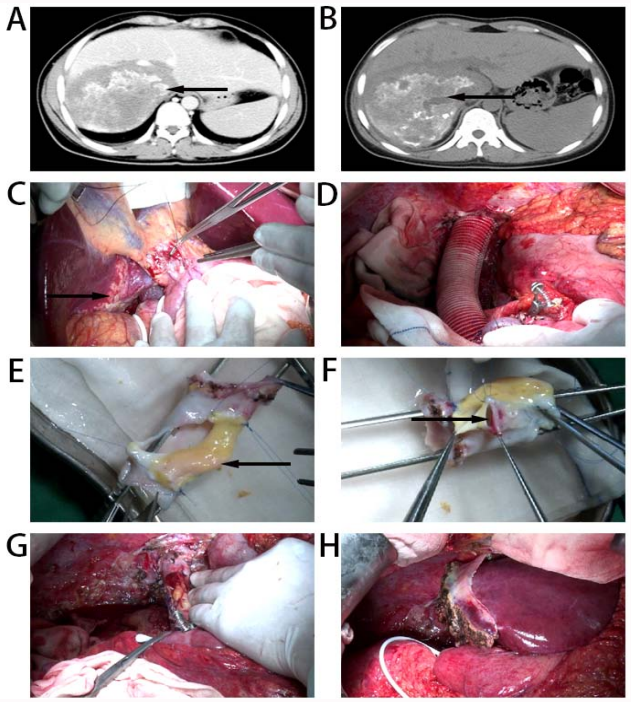

Figure 1: (A) Preoperative enhanced CT scan showed the IVC invaded by the lesion. Black arrow shows IVC. (B) Preoperative enhanced CT scan showed the hepatic AE lesion located in the right posterior lobe and caudate lobe of the liver. Black arrow shows hepatic AE lesion. (C) ELRA for the treatment of hepatic end-stage AE. Black arrow shows the lesion. (D) Reconstruct the hepatic IVC with artificial vessels to perform a temporary portal shunt. (E) Using disease-free IVC and the umbilical vein within the LTH to reconstruct the IVC. Black arrow shows the umbilical vein within the LTH. (F) Using disease-free IVC and part of the PV to reconstruct the IVC. Black arrow shows the PV. (G) The IVC was replanted back into the abdominal cavity after complex reconstruction. (H) After meticulous dissection, left lateral lobes were replanted back to the abdominal cavity.

The anterolateral wall of the hepatic IVC was invaded by lesion. Considering that the resection of the autograft iliac vein and internal jugular vein would be locally traumatic to the patient's donor area, we took the umbilical vein within the LTH, the PV fragment and the disease-free IVC to reconstruct the huge defect of the hepatic IVC. Dismantle the anastomosis between IVC and artificial blood vessel, perform end-to-end anastomosis of the upper and lower edges of the repaired hepatic IVC, anastomose PV, opening all blood vessels, and ending anhepatic phase. End-to-end anastomosis of the right branch of the proper hepatic artery with the trunk type of the proper hepatic artery was performed, and then Roux-en-Y hepatojejunostomy was used to drain the left hepatobiliary duct (Figures 1C-1H).

The whole operation lasted 14 h and 5 min with stable hemodynamics. The patients were transfused with 630 ml fresh frozen plasma and 528 ml autologous blood, with a blood loss about 700 ml. Final pathological findings confirmed hepatic alveolar echinococcosis (P4N0M0/PI-II, VI-VIII, I1V1M0).

The patient developed pleural effusion on the 6th day after surgery, which was improved after pleural puncture and catheter drainage. Ultrasonography was performed on day 0, 1, 2, 4 and 6, indicating unobstructed blood flow signals in IVC. Regular abdominal CT showed normal visualization of the IVC, no obvious stenosis and filling defect. Up to now, no complications related to

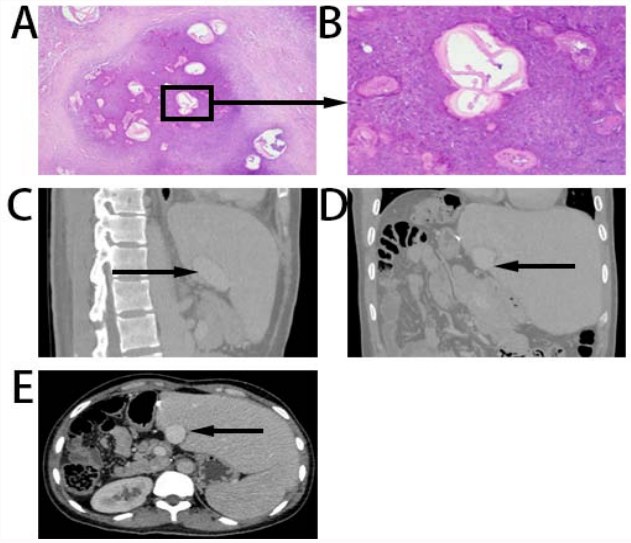

Figure 2: (A) Lesions of hepatic alveolar echinococcosis (hematoxylin and eosin, x10). (B) Lesions of hepatic alveolar echinococcosis (hematoxylin and eosin, x40). Long-term follow-up abdominal CT showed the morphology of the reconstructed IVC in the coronal plane, sagittal plane and cross section at 84 months after operation. (C, D, E) Black arrow shows reconstructed IVC.

Table 1: Intraoperative and postoperative parameters.

Variables	Case 1
Residual liver volume (m^3)	530
RLV/SLV (%)	46.2
Operation time (h)	14.08
Cold ischemia time (min)	403
Warm ischemia time (min)	18
Anhepatic phase (min)	421
Time of inferior vena cava occlusion (min)	122
Blood loss (ml)	800
Blood transfusion volume	
Suspended RBC (units)	6
Plasma (ml)	1070
Autotransfusion (ml)	750
Cryoprecipitate (units)	0
Platelet (units)	0
ICU stay time (h)	65.4
Hospital stays (day)	35
Postoperative complications	
Pulmonary infection	N
Pleural effusion	Y
Ascites	N
Outflow tract stenosis	N

vascular complex reconstruction have occurred (Table 1).

Histology

Liver tissues were fixed for more than 24 h, and then cut into 5 μm sections after paraffin embedding. Hematoxylin and eosin staining was performed according to the instructions. Hematoxylin and eosin staining showed abundant granulomatous reaction and coagulative necrosis around the laminated parasitic membranes (Figure 2A, 2B).

Long-term survival follow-up

The follow-up time for the case was 84 months. This patient had good liver function at follow-up and no complications related to revascularization. The abdominal CT of case showed good filling of the vessels after 84 months, with no obstruction or stenosis (Figures 2C-2E).

Literature Review

A total of 3 articles with detailed descriptions of complex reconstruct IVC in ELRA were identified [10-12], and 3 cases were reported in them. Table 2 presents the detailed data of these studies. Based on the specific data in these studies, the methods for complex reconstruction of the IVC in ELRA was summarized and analyzed.

Of the 3 studies from 2 countries, 2 studies from China reported on 2 patients, 1 study from UK reported on 1 case. These studies reported the complex reconstruction of the IVC in three patients during ELRA. In all three cases, two or more kinds of blood vessels except IVC were used to reconstruct IVC, as follows: Two studies from China reported two patients with hepatic AE who underwent ELRA with reconstruction of the IVC, one used the disease-free hepatic IVC, bilateral autologous saphenous veins, and unilateral common iliac vein, and the other used the bilateral saphenous, inferior and middle HV, the inferior mesenteric vein, and a portion of the lateral wall of the hepatic IVC. The UK study reported cases of patients with intrahepatic smooth muscle sarcoma during ELRA, with complex reconstruction of the IVC using the left iliac vein from 2 deceased donor, and autologous disease-free IVC. The postoperative prognosis was good in all three cases, and no complications related to complex inferior vena cava reconstruction occurred.

Discussion

Hepatic AE is a worldwide zoonosis caused by *Echinococcus multilocularis* [13], which is mainly endemic in the northern hemisphere, especially in western China. Radical surgery is still the best option to treat the condition, but because there are no obvious symptoms in the early stages, patients are sometimes deprived of radical surgery due to significant invasion of vital blood vessels by the time it is identified. Since Chui et al. achieved good results with the first ELRA in 2003 [14], this operation has gradually become an effective method for the treatment of end-stage hepatic AE. It has become a research hotspot in recent years because of its advantages of not only radical excision of lesions but also no immunosuppressive agent, and it has better long-term efficacy in the treatment of end-stage hepatic AE or benign liver tumor than allotransplantation [7]. The main issue with this operation is repairing and reconstructing the invaded blood vessels *in vitro* [2,13]. The concept of in situ hepatic resection and allotransplantation has been proposed as early as 2000 in a study by Oldhafer et al. to facilitate safe complex revascularization in hepatic occupying lesions that cannot be treated by combined liver surgery [15]. Individual management of revascularization is challenging and critical to patient prognosis [2].

The defect of key blood vessels in the healthy side of the liver is sometimes too extensive to be repaired and recreated *in vivo* due to the substantial invasion of end-stage hepatic AE lesions. As a result, with ELRA, selecting and obtaining proper blood vascular repair materials is more difficult than allotransplantation. Previously, our center has reported 24 cases that underwent ELRA with revascularization using LTH between August 2010 and October 2018 [16], and there were

Table 2: Detailed features of all published cases of complex reconstruction of IVC.

Authors (year)	Country	diagnose	cases	complex reconstruction of IVC	reconstructive method	Complications associated with outflow tract reconstruction	Survival
Lei et al, (2015)	China	Alveolar echinococcosis	1	1	bilateral great saphenous vein, part of the retro hepatic inferior vena and the middle hepatic vein, the inferior mesenteric vein, part of the infra hepatic vena cava	not mentioned	1
Hu et al, (2016)	China	Alveolar echinococcosis	12	1	disease-free RHIVC, bilateral autogenous great saphenous veins, unilateral common iliac vein	not mentioned	11
Bettina et al, (2020)	UK	Intrahepatic Caval Leiomyosarcoma	1	1	2 caval grafts and the left iliac vein of the graft	not mentioned	1

also cases of using other vessels such as internal jugular veins, iliac veins, or artificial vessels as vascular substitutes [2,17], but there are few reports of complex revascularization using multiple materials.

Due to the significant area of IVC invasion in the patient in this study, a single vascular material is insufficient for repair and reconstruction, and there are no blood vessel bank or Donation after Cardiac Death (DCD) vessels available during the operation. In this case, splicing a range of vascular substitutes that have been proven to be safe is the final option for reconstructing the inferior vena cava. The following are the reasons: 1. Using artificial blood vessels increases the risk of thrombosis and failure of vascular repair and reconstruction [18]; 2. Using a DCD vascular graft requires a blood vessel bank, which not every center has; 3. Autologous vascular grafts are used for vascular reconstruction. In allotransplantation, a great number of studies have reported the safety of IVC repair with various autologous venous grafts [19,20]. 4. The acquisition of autologous vein grafts in other parts of the patient's body such as the saphenous vein, internal jugular vein, etc. means that local surgery is required on the patient and there is additional donor area trauma to the patient. The use of perihepatic vessels such as LTH and PV can not only reduce the additional donor site trauma to the patient, but also reduce the occurrence of complications related to vascular reconstruction because of similar blood vessel endothelium. The patient's safety was preliminarily validated during long-term follow-up, with no vascular stenosis, thrombosis, or other problems.

In this study, we reviewed three case reports by reviewing the relevant literature, all of which had lesions that severely invaded the hepatic IVC and underwent complex IVC reconstruction. IVC invasion, big lesions in the central location, or lesions near the IVC and HV junction are all regarded unsuitable for surgical resection, and untreated patients have a dismal prognosis [21]. The case in this report benefited from an extracorporeal technique of ELRA and underwent complex vascular reconstruction. *Ex vivo* surgery with complicated revascularization is a complex and challenging technique, and the new idea of complex revascularization allows for a new possibility in the treatment of hepatic AE in end-stage patients for whom other conventional treatment options are not available.

There are some limitations to this research. This was a retrospective study in a small number of patients from a single center, because the sample size of this study is small and the number of the same cases reported is small, more studies with more cases and longer follow-up are expected to assess the long-term complications of complex revascularization and to confirm the safety and feasibility of complex revascularization techniques.

Conclusion

In conclusion, the experience of the case we report shows that complex IVC reconstruction using autogenous multi-vein fragments is feasible and has a good prognosis during ELRA in patients with end-stage hepatic AE. The utilization of autologous perihepatic vessels reduces donor-area trauma and avoid immune rejection and other adverse reactions. When the blood vessel is severely invaded and a single vascular material cannot repair and reconstruct the defect, this technique may provide a safe and feasible surgical option for revascularization during ELRA and has good prospects for clinical application.

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