**Ex situ** hepatectomy and liver autotransplantation for a treating giant solitary fibrous tumor: A case report

ZHONGQUAN SUN¹-³*, YUAN DING¹-³*, YUANCONG JIANG¹-³, QIYI ZHANG¹-³, ZHIWEI LI¹-³, JIE XIANG¹-³, JIXUAN DUAN¹-³, SHENG YAN¹-³ and WEILIN WANG¹-³

¹Division of Hepatobiliary and Pancreatic Surgery, Department of Surgery, First Affiliated Hospital, School of Medicine, Zhejiang University; ²Key Laboratory of Precision Diagnosis and Treatment for Hepatobiliary and Pancreatic Tumor of Zhejiang Province; ³Collaborative Innovation Center for Diagnosis and Treatment of Infectious Diseases, Hangzhou, Zhejiang 310003, P.R. China

Received March 13, 2018; Accepted September 17, 2018

DOI: 10.3892/ol.2018.9693

**Abstract.** A solitary fibrous tumor (SFT) is a rare mesenchymal tumor. Ex situ hepatectomy and liver autotransplantation are novel methods for the treatment of complicated liver tumors, for example, those involving vascular structures, including the inferior vena cava, which are unresectable by conventional approaches. The present study describes a rare case of a massive hepatic SFT in a 32-year-old female who underwent ex situ hepatectomy and liver autotransplantation to achieve a radical resection. The surgery was without complications. Post-operative histopathological and immunohistochemical examinations revealed an SFT of the liver. The patient was discharged 29 days after the surgery with fully recovered liver function. The routine check-up 3 months after surgery indicated normal liver function and no evidence of recurrence. Additionally, an exhaustive review of available literature was performed to provide a complete overview of the current status of SFTs. In summary, the present study found that ex situ hepatectomy and liver autotransplantation are suitable surgical techniques for treating a giant SFT, as well as other liver neoplasms that are considered unresectable by conventional surgery.

**Introduction**

A solitary fibrous tumor (SFT) is a rare mesenchymal tumor, which can be found in different locations within the human body (1). SFTs were first reported in the pleura and subsequently in the peritoneum, thymus, orbit, pericardium, meninges, spinal cord, and the parotid and thyroid glands (2). A tumor of this type in the liver is an extremely rare occurrence. The majority of SFTs are considered benign, while <20% are reported to be malignant and are accompanied by tumor invasion and metastasis (3). Surgical resection is the main approach for SFT treatment. Nevertheless, in certain cases where vascular structures are involved, conventional surgery may not be practical.

Ex situ hepatectomy and liver autotransplantation are novel methods for treating complicated liver tumors that are unresectable by conventional approaches, including liver transplantation, vascular reconstruction, organ perfusion, extended hepatic resection and hemodynamic management, which are considered to be some of the most complicated, difficult and risky types of surgeries. In this maneuver, the whole liver is removed and perfused with cold preservation solution. The tumor is resected ex situ on the operating table and the remaining liver is orthotopically implanted. The ex situ liver resection was first described by Pichlmayr et al (4) as a novel surgical procedure to treat a bilateral liver leiomyosarcoma. To date, only a few cases of ex situ hepatectomy and liver autotransplantation have been described worldwide (5,6). Furthermore, to the best of our knowledge, there are no reports on adopting ex situ hepatectomy and liver autotransplantation as an approach for treating hepatic SFTs. The present case study reports the first case of a giant SFT involving the inferior vena cava (IVC) of the liver in a 32-year-old female who was treated with ex situ hepatectomy and liver autotransplantation.

**Case report**

A 32-year-old female suffering from repeated abdominal distension for 3 years was found to have an oversized mass in the right hepatic lobe using a B-scan ultrasound, and was admitted on July 7, 2017 to the Outpatient Department of the First Affiliated Hospital, School of Medicine, Zhejiang University (Hangzhou, China). A physical examination revealed a large mass in the right hypochondrium, causing local discomfort. No aberration was observed regarding the medical history...
of the patient. In addition, no elevation of tumor markers, including α-fetoprotein (AFP; ARCHITECT AFP Reagent kit; cat. no. 3P36-30; Abbott Pharmaceutical Co., Ltd., Lake Bluff, IL, USA), carcinoembryonic antigen (CEA; ARCHITECT CEA Reagent kit; cat. no. 7K68-32; Abbott Pharmaceutical Co., Ltd.), cancer antigens (CA) 125 (ARCHITECT CA 125 II Reagent kit; cat. no. 2K45-35; Abbott Pharmaceutical Co., Ltd.) and 19-9 (ARCHITECT CA 19-9 XR Reagent kit; cat. no. 2K91-38; Abbott Pharmaceutical Co., Ltd.), was observed, as detected using immunofluorescence assays, according to the manufacturer's protocols. Hepatitis virus markers were all negative, as detected using an immunofluorescence assay (ARCHITECT Reagent kit; cat. nos. 6C36-44, 8L44-30, 6C34-35, 6C32-20 and 7C18-34; Abbott Pharmaceutical Co., Ltd.), according to the manufacturer's protocol. The patient underwent an enhanced abdominal computed tomography (CT) scan, which revealed a giant, hypodense, heterogeneous, cystic-solid lesion (20.0x16.0 cm), with irregular contrast enhancement, causing compression of neighboring structures. Dilation of the intrahepatic biliary ducts was also noted (Fig. 1).

A CT arteriography scan showed that the mass was supplied with blood by the left and right hepatic arteries. The right, middle and left hepatic veins were compressed by the mass and there was indication of a filling defect in the IVC. A magnetic resonance imaging scan was also performed, revealing an oversized, heterogeneous liver mass (21.2x19.7 cm). A heterogeneous high signal in the T2-weighted image and a slightly oversized, heterogeneous liver mass (21.2x19.7 cm). A hetero-

cystic-solid lesion (20.0x16.0 cm), with irregular contrast enhancement, causing compression of neighboring structures.

The immunohistochemical (IHC) examination was performed on paraffin-embedded specimens fixed in 4% buffered neutral formalin at 37°C for 24 h. Paraffin-embedded sections (3 μm) were deparaffinized and endogenous peroxidase was inactivated with 15% H₂O₂-Methanol for 5 min at room temperature. The sections were then incubated with primary antibodies at 37°C for 30 min, according to the manufacturers' protocols. Subsequently, the sections were incubated with Dako REALREEnVision Detection system, Peroxidase/DAB, Rabbit/Mouse (cat. no. K5007; Dako; Agilent Technologies, Inc., Santa Clara, CA, USA) for 30 min at room temperature. Results revealed that the sections were positive for cluster differentiation 117 (CD117; cat. no. 790-2951; dilution 1:100; Roche Diagnostics, Basel, Switzerland), CD34 (cat. no. M-0117; dilution 1:50; Shanghai Changdao Biotechnology Co., Ltd., Shanghai, China) and Caldesmon (cat. no. ZA-0535; dilution 1:100; OriGene Technologies, Inc.) and progesterone receptor (cat. no. NCL-L-PGR-312; dilution 1:300; Leica Biosystems, Ltd., Milton Keynes, UK) expression was detected. However, sections were negative for S-100 protein (cat. no. ZA-0225; dilution 1:200; OriGene Technologies, Inc.), desmin (cat. no. ZM-0091; dilution 1:100; OriGene Technologies, Inc.), deletions of G-rich-1 (cat. no. ZM-0371; dilution 1:200; ZhongshanJinqiao Bio-Reagent Company), cytokeratin (cat. no. M-0349; dilution 1:100; Shanghai Changdao Biotechnology Co., Ltd.), β-catenin (cat. no. ZM-0442; dilution 1:100; OriGene Technologies, Inc.), anaplastic lymphoma kinase (cat. no. ALK-L-CE-H; dilution 1:150; Leica Biosystems, Ltd.), estrogen receptor (cat. no. NCL-L-ER-6F11; dilution 1:100; Leica Biosystems, Ltd.), epithelial membrane antigen (cat. no. ZM-0095; dilution 1:200; ZhongshanJinqiao Bio-Reagent Company), wilms tumor type 1 (cat. no. ZM-0269; dilution 1:100; ZhongshanJinqiao Bio-Reagent Company) and CD10 (cat. no. NCL-L-CD10-270; dilution 1:100; Leica Biosystems, Ltd.). The sections were evaluated under a light microscope at x200 magnification. The mean proliferative index was 5% in the hypercellular areas, as determined by detection of antigen Ki-67 (Ki-67; cat. no. ZM-0166; dilution 1:100; ZhongshanJinqiao Bio-Reagent Company). The Ki-67 proliferative index was examined under a light microscope (BX53; Olympus Corporation, Tokyo, Japan), and was evaluated by experienced pathologists. A total of 500 tumor cells were counted both at the center and at the periphery of the tumor. The examination was repeated at least twice and the mean Ki-67 proliferative index was calculated. At least 10 mm of the margins of the resected specimen were tumor-free. Based on the pathological and IHC characteristics, the lesion was identified as an SFT.

On post-operative day 9, the patient underwent pleurocen-
tesis and received drainage tubes due to moderate right pleural effusion, which were successfully removed 16 days later. The patient recovered fully and was discharged on post-operative day 29. At the 1- and 3-month follow-ups, the patient had normal liver function and there was no evidence of recurrence. Future follow-up will be performed every 6 months.

Discussion

SFTs are mesenchymal neoplasms that typically occur in the thoracic or pleural cavities. The SFTs found in the liver may derive from the intra-hepatic connective tissue, for example Glisson's capsule or conjunctive tissue, which are rare types of liver neoplasm (7). A search of the English literature on ‘Solitary Fibrous Tumour of the Liver’ was conducted on PubMed (https://www.ncbi.nlm.nih.gov/pubmed/) and Google (https://www.google.com/). All published English articles, case reports and literature reviews, and their reference lists, were reviewed. The results indicated that only 88 cases of SFTs of the liver have been reported since 1958 (7-71). The main characteristics of these cases are listed in Table 1. The mean age of onset was 57.1 years (range, 16.0-87.0 years)
and the lesion appeared more commonly in female patients (ratio 1.4:1), with a mean tumor diameter of 18.2 cm (range, 13.5 months). The prolonged course and relatively late age of onset and large lesion size.

The prolonged course and relatively late age of onset and large lesion size, measurable structures. (D) The resected specimen was well-delimited and measuring ~19x19.5x14 cm, with a grayish-white interlaced appearance of the section plane.

Figure 1. Abdominal computed tomography scan prior to surgery and gross examination of the specimen. Abdominal computed tomography scans [(A) plain, (B) arterial and (C) portal phase] revealed a large, hypodense, heterogeneous, cystic-solid lesion measuring 20.0x16.0 cm, with irregular contrast enhancement, causing compression of the neighboring structures. (D) The resected specimen was well-delimited and measuring ~19x19.5x14 cm, with a grayish-white interlaced appearance of the section plane.

Figure 2. Histological examination showed that the tissues consisted of spindle-shaped cells that were infiltrated with lymphocytes, plasmocytes and mastocytes. The images are of hematoxylin and eosin staining at (A) x50, (B) x100, (C) x200 and (D) x400 magnification.

The gold standard for diagnosing an SFT remains as histopathological analysis combined with IHC examination. Fine-needle aspiration cytology (FNAC) is commonly performed to acquire lesion tissue for pathological diagnosis prior to surgery. Nevertheless, FNAC may be misleading or inconclusive pertaining to the diagnosis of an SFT (37). Percutaneous liver biopsy may not provide the definitive diagnosis, while increasing the risk of tumor growth and implantation (53). Histopathological findings in the present case were typical for an SFT: Diffusive proliferation of spindle-shaped mesenchymal cells with oval-fusiform nuclei along with fibrocollagenous stroma; no prominent cellular atypia, infiltrative margins or other indicative evidence of malignancy; and tumor cells of all reported cases with an SFT, including the present case, were positive for CD34, which may differentiate an SFT from other spindle cell neoplasms (12). CD99, B-cell lymphoma 2 or vimentin have also shown to be positive in almost half the cases (14-19,21,24-27,29-33,36-48,50,52-71).

Radical surgical resection is the main treatment approach. Among the reported cases listed in Table 1, 85.2% (75/88) patients received radical surgical resection and on average had ≥3 segments removed owing to the size of the SFTs. Other treatments, such as chemotherapy, which was adopted recently in two patients listed in Table 1, resulted in only 4-5 months survival following treatment. Therefore, Makino et al (67) suggested that due to the unclear effects of other treatments, including chemotherapy and radiotherapy, hepatic resection with clear margins is highly recommended in patients with large SFTs, considering the risk of urgent symptoms and the potential for malignancy. Compared with the previously reported cases, the tumor reported in the present study was difficult to resect using the conventional approach due to the advanced extent of the lesion therefore, novel techniques may be required.

Even with the vast improvement of surgical techniques, hepatic lesions abutting hepatic veins or the confluence of the IVC, as well as large centrally located lesions, fail to be managed by conventional surgery. In such cases, liver transplantation may be indicated (26). However, no liver transplantations have been performed to date for treating SFTs. In the present case, the second hepatic portal was compressed by the neoplasm, causing obstruction of the outflow tract and liver congestion. Full exposure of the second hepatic portal was achieved only after the sternum was removed. The vascular reconstruction and extended hepatic resection were extremely difficult to achieve by in situ surgical resection. Given the young age of the patient, the alternative of ex situ hepatectomy and liver autotransplantation was implemented. The surgery was performed successfully and the patient recovered without further complications. To the best of our knowledge, this is the first case report describing the adoption of ex situ hepatectomy and liver autotransplantation to treat a liver SFT, otherwise unresectable by standard surgery.
Table I. Main characteristics of reported liver solitary fibrous tumor cases.

| First author, year | Age, years | Sex | Lobe | Size, cm | Hypo | Treatment | IHC | Follow-up | (Refs.) |
|-------------------|------------|-----|------|----------|------|-----------|-----|-----------|--------|
| Edmondson, 1958   | 16         | F   | R    | 23x17    | N    | Resection | N/A | 24 months | (8)    |
| Nevius and Friedman, 1959 | 56 | M   | R    | 15x15    | Y    | Radiation | N/A | Succumbed after 2 days | (9)    |
| Ishak, 1976       | 62         | M   | L    | 24       | N    | Resection | N/A | 24 months | (10)   |
| Kim and Damjanov, 1983 | 27 | F   | L    | 27x23x15 | N    | Resection | N/A | 6 months | (11)   |
| Kottke-Marchant et al, 1989 | 84 | F   | L    | 15x9x8   | N    | Resection | V*  | 29 months | (12)   |
| Kasano et al, 1983 | 50 | M   | R    | 17x15x11 | N    | Resection | CD34+, V* | N/A | (14)   |
| Kottke-Marchant et al, 1989 | 57 | M   | L    | 10x18x8  | N    | Resection | CD34+, V* | 38 months | (15)   |
| Guglielmi et al, 1983 | 61 | F   | R    | 20x16x10 | Y    | Resection | CD34+, V* | 72 months | (16)   |
| Lecesne et al, 1998 | 69 | F   | L    | N/A      | N    | Resection | CD34+, V* | 12 months | (17)   |
| Bejarano et al, 1998 | 49 | M   | L    | 17x12x10 | N    | Resection | CD34+, V* | 15 months | (18)   |
| Moran et al, 1998  | 62         | F   | N/A  | 23x20x13 | N    | Resection | CD34+, V* | N/A | (19)    |
|                   | 34         | F   | N/A  | 2x0.5    | N    | Resection | CD34+, V* | N/A | (19)    |
|                   | 57         | F   | N/A  | 24x19x11 | N    | Resection | CD34+, V* | N/A | (19)    |
|                   | 32         | M   | N/A  | 12x9x7   | N    | Resection | CD34+, V* | N/A | (19)    |
|                   | 68         | F   | N/A  | 17x17    | N    | Resection | CD34+, V* | Succumbed after 2 days | (19)   |
|                   | 83         | F   | R    | 18       | Y    | Resection | CD34+, V* | N/A | (20)    |
|                   | 72         | F   | L    | 9        | N    | Resection | CD34+, V* | 12 months | (20)   |
|                   | 62         | M   | L    | 24       | N    | Resection | CD34+, V* | N/A | (20)    |
|                   | 50         | F   | N/A  | 3x2x1.5  | N    | Resection | CD34+, V* | N/A | (20)    |
| Fuksbrumer et al, 2000 | 40 | F   | R    | 14-17    | N    | Resection | CD34+, V*, Bcl-2* | N/A | (20)   |
|                   | 71         | F   | R    | 14-17    | N    | Resection | CD34+, V*, Bcl-2* | N/A | (20)   |
|                   | 80         | M   | R    | 14-17    | N    | Resection | CD34+, V*, Bcl-2* | N/A | (20)   |
| Yilmaz et al, 2000 | 25         | F   | R    | 32x30    | N    | Resection | V*  | 6 months | (21)   |
| Lin et al, 2001   | 75         | M   | R    | 21x20x18 | Y    | Resection | CD34* | 11 months | (22)   |
| Gold et al, 2002  | N/A        | N/A | N/A  | N/A      | N    | Resection | CD34* | N/A | N/A     |
|                   | N/A        | N/A | N/A  | N/A      | N    | Resection | CD34* | N/A | N/A     |
| Neeff et al, 2004 | 63         | F   | R    | 30x12x19 | N    | Resection | CD34+, V* | 6 months | (24)   |
| Chithriki et al, 2004 | 76 | F   | R    | 20x15x16 | Y    | Resection | CD34+, Bcl-2* | 11 months | (25)   |
| Vennarecci et al, 2005 | 65 | M   | R    | 30x28x14 | N    | Resection | CD34*, V* | 30 months | (26)   |
| Moser et al, 2005  | 73         | F   | R    | 35x20x15 | Y    | Resection | CD34*, V*, Bcl-2* | N/A | (27)   |
| Ji et al, 2006    | 42         | F   | R    | 6x5x5    | Y    | Resection | CD34* | N/A | (28)    |
| Lehmann et al, 2006 | 63 | F   | R    | N/A      | N    | Resection | CD34* | 96 months | (7)    |
| Nath et al, 2006  | 61         | F   | R    | 21x14.5x30 | N    | Resection | CD34*, V* | 10 months | (29)   |
| Terkivatan et al, 2006 | 74 | M   | L    | 24x21x15 | N    | Resection | CD34*, CD99*, V*, Bcl-2* | 12 months | (30)   |
| Chan et al, 2007  | 70         | M   | R    | 27x24x12 | Y    | Resection | CD34*, CD99*, V*, Bcl-2* | 9 months | (31)   |
Table I. Continued.

| First author, year | Age, years | Sex | Lobe | Size, cm | Hypo | Treatment | IHC | Follow-up | (Refs.) |
|--------------------|------------|-----|------|----------|------|-----------|-----|-----------|---------|
| Obuz et al, 2007   | 52         | M   | L    | 10x11x12 | N    | Resection | CD34⁺, V⁺ | 22 months | (32)    |
| Perini et al, 2008 | 40         | F   | L    | N/A     | N    | Resection | CD34⁺, V⁺ | 49 months | (33)    |
| Weitz et al, 2007  | N/A        | N/A | N/A  | N/A     | N/A  | Resection | N/A | N/A       | (34)    |
| Kandpal et al, 2008| 45         | F   | R    | N/A     | N/A  | Resection | CD34⁺ | N/A       | (35)    |
| Fama et al, 2008   | 68         | M   | R    | N/A     | Y    | Resection | CD34⁺, V⁺ | 25 months | (36)    |
| Korkolis et al, 2008| 82        | F   | L    | 18x15x8 | N    | Resection | CD34⁺, V⁺, Bcl-2⁺, desmin⁺ | 21 months | (37) |
| Chen et al, 2008   | 71         | M   | R    | 8.7x5.5x8.5 | N | Resection | CD34⁺, CD99⁺, Bcl-2⁺ | 9 months | (38) |
| El-Khouli et al, 2008| 68      | F   | L, R | 15x10.5x13 | N | TACE      | CD34⁺, V⁺ | N/A       | (39)    |
| Hoshino et al, 2009| 30         | F   | R    | 6.7x4.5x4 | N    | Nil       | CD34⁺, Bcl-2⁺ | 6 months | (40)    |
| Novais et al, 2010 | 34         | F   | R    | 25x23x13 | N    | Resection | CD34⁺, V⁺ | 24 months | (41)    |
| Brochard et al, 2010| 54        | M   | R    | 17      | N    | Resection | CD34⁺, V⁺, desmin⁺, actin⁺ | 72 months | (42) |
| Haddad et al, 2010 | 62         | M   | L    | N/A     | N    | Resection | CD34⁺ | N/A       | (43)    |
| Park et al, 2011   | 51         | F   | L    | N/A     | N    | Resection | N/A | N/A       | (44)    |
| Peng et al, 2011   | 24         | F   | R    | 30x17x15 | N    | Resection | CD34⁺, V⁺, Bcl-2⁺ | Succumbed after 16 months | (45)    |
| Sun et al, 2011    | 59         | M   | L    | 9x7x6   | N    | Resection | CD34⁺, CD99⁺, V⁺, Bcl-2⁺ | 24 months | (46)    |
| Patra et al, 2012  | 34         | F   | L    | 14.5x10x8 | N | Resection | CD34⁺, V⁺, Bcl-2⁺ | 48 months | (47)    |
| Radunz et al, 2012 | 85         | F   | L    | N/A     | Y    | Resection | CD34⁺, Bcl-2⁺ | N/A       | (48)    |
| Belga et al, 2012  | 66         | F   | R    | N/A     | N    | Resection | CD34⁺ | 30 months | (49)    |
| Morris et al, 2012 | 23         | F   | R    | 27x23.5x4 | N | Resection | CD34⁺, V⁺, Bcl-2⁺ | 10 months | (50)    |
| Beyer et al, 2012  | 46         | M   | RLig | 21x7    | N    | HRT, chemo, reseption | CD34⁺ | 10 months | (51)    |
| Soussan et al, 2013| 64         | M   | L    | N/A     | N    | Resection | CD34⁺, Bcl-2⁺ | N/A       | (52)    |
| Liu et al, 2013    | 42         | M   | L    | 1.5x1x1 | N    | Resection | CD34⁺, Bcl-2⁺ | N/A       | (53)    |
| Jakob et al, 2013  | 62         | F   | L    | N/A     | N    | Resection | CD34⁺, CD99⁺, Bcl-2⁺ | N/A       | (54)    |
| Debs et al, 2014   | 65         | M   | L    | N/A     | N    | Resection | CD34⁺, CD99⁺, Bcl-2⁺ | 12 months | (55)    |
| Guray-Durak et al, 2013| 87  | F   | R    | 14.6x12.3x17 | N | Nil       | CD34⁺, CD99⁺, SMA⁺ | N/A       | (56)    |
| Vythianathan and Jim, 2013| 78 | M   | L    | 17x13   | N    | Resection | CD34⁺, CD99⁺, V⁺, Bcl-2⁺ | N/A       | (57)    |
| Song et al, 2014   | 49         | M   | L, R | 7.6x5x4.8 | N | Resection | CD34⁺, V⁺, Bcl-2⁺ | 3 months | (58)    |
The *ex situ* hepatectomy and liver autotransplantation was initially performed by Pichlmayr *et al* (4) in 1988 for treating liver tumors involving major vascular structures. The procedure has progressed and developed over the past 30 years, and has been successfully applied for the treatment of several types of lesions, including hepatocellular carcinoma (72,73), hilar cholangiocarcinoma (74), giant hepatic hemangiomas (75) and metastatic colon cancer (72,73,76). The reported cases are listed in Table II. The median follow-up and survival times for these cases were 13 and
Table II. Data on reported ex situ liver autotransplantation cases.

| First author, year       | Age, years | Sex | Diagnosis                          | Characteristics of lesion/contraindication to traditional resection | Follow-up                        |
|--------------------------|------------|-----|------------------------------------|---------------------------------------------------------------------|----------------------------------|
| Pichlmayr et al, 1988    | 40         | N/A | Metastatic leiomyosarcoma          | Bilateral liver metastases                                          | N/A                              |
| Yagyu et al, 1994        | N/A        | N/A | Intrahepatic cholangiocarcinoma    | Involved the confluence of the 3 main hepatic veins and the retrohepatic IVC | No recurrence at 8 months        |
| Hemming and Cattral, 1999| 50         | M   | Colorectal liver metastases       | A single lesion in the caudate lobe involved the origin of all 3 hepatic veins | N/A                              |
| Lodge et al, 2000        | 55         | F   | Colorectal liver metastases       | Involvement of IVC and segments 1, 2, 3, 4a and 8                   | Post-operative chemotherapy, 30 months survival |
|                          |            |     | Colorectal liver metastases       | Involvement of segments 2 and 4-8                                   | Succumbed from complications of renal and respiratory failure on post-operative day 15 |
|                          |            |     | Colorectal liver metastases       | 17x15 cm mass involving segments 1, 2 and 4-8                      | Alive at 5 months                |
|                          |            |     | Colorectal liver metastases       | 17x13 cm mass involving segments 1, 2, 4-8                         | Alive at 5 months                |
| Oldhafer et al, 2000     | 40         | F   | Metastatic leiomyosarcoma          | Involvement of segments 2, 3 and 5-8                               | Succumbed at 36 months due to tumor recurrence |
|                          | 46         | F   | Metastatic colon cancer           | Involvement of segments 5-7                                        | Succumbed at 13 months due to tumor recurrence |
|                          | 52         | M   | Klatskin's tumor                  | Required right hepatic trisegmentectomy                            | Succumbed at 13 months due to tumor recurrence |
|                          | 58         | M   | Metastatic colon cancer           | Metastatic colon cancer infiltrating the IVC                       | Succumbed at 44 days due to sepsis and hepatic insufficiency |
|                          | 30         | F   | Focal nodular hyperplasia         | Large FNH in segment 4 with compression                            | Alive at 9 years of the IVC       |
|                          | 57         | M   | Metastatic colon cancer           | Infiltration of RHV requiring extended left hemihepatectomy        | Succumbed at 21 months due to tumor recurrence |
|                          | 48         | F   | Klatskin's tumor                  | Klatskin's tumor requiring extended left hemihepatectomy           | Succumbed on post-operative day 50 due to sepsis |
|                          | 62         | M   | Klatskin's tumor                  | Tumor invading left and right portal veins                         | Succumbed on post-operative day 113 due to sepsis |
|                          | 55         | F   | Klatskin's tumor                  | Klatskin's tumor requiring right hepatic trisegmentectomy          | Succumbed on post-operative day 35 due to sepsis |
|                          | 35         | M   | HCC                               | HCC requiring resection of segments 1-4                           | Lost to follow-up and wedge 6     |
|                          | 43         | M   | HCC                               | HCC requiring resection of segments 5 and 6                        | Succumbed at 25 months due to tumor recurrence |
| First author, year | Age, years | Sex | Diagnosis | Characteristics of lesion/contraindication to traditional resection | Follow-up | (Ref.s.) |
|-------------------|------------|-----|-----------|-------------------------------------------------|------------|---------|
| 67 M | Metastatic colon cancer | 67 M | Metastatic colon cancer | Lesions requiring resection of segments 1-4b and wedge 6-7 | Succumbed at 2 months due to intracerebral bleed | |
| 53 M | Metastatic colon cancer | 53 M | Metastatic colon cancer | Lesions requiring resection of segments 1 and 4-8 | Succumbed at 2 months due to sepsis | |
| 54 F | Focal nodular hyperplasia | 54 F | Focal nodular hyperplasia | Lesions requiring resection of segments 1, 4, 5 and 7 | Alive at 5 years | |
| 55 M | Metastatic colon cancer | 55 M | Metastatic colon cancer | Lesions requiring resection of segments 1 and 4 | Succumbed at 15 months due to tumor recurrence | |
| 55 F | Metastatic leiomyosarcoma | 55 F | Metastatic leiomyosarcoma | Lesion requiring resection of segments 2-4b and wedge 5 | Succumbed at 13 months due to tumor recurrence | |
| 52 M | Metastatic colon cancer | 52 M | Metastatic colon cancer | Lesions requiring resection of segments 1, 5 and 8 and wedge 2-3 | Succumbed at 36 months due to tumor recurrence | |
| 52 M | Metastatic colon cancer | 52 M | Metastatic colon cancer | Lesions requiring resection of segments 1 and partial 4 | Succumbed on post-operative day 14 due to pneumonia | |
| 52 M | Cholangiocarcinoma | 52 M | Cholangiocarcinoma | Lesion requiring resection of segments 1-5 and wedge 8 | Succumbed on post-operative day 41 due to sepsis | |
| 39 M | HCC | 39 M | HCC | Lesion requiring resection of segments 1-4 and partial 8 | Succumbed on post-operative day 23 due to sepsis | |
| 71 M | Metastatic colon cancer | 71 M | Metastatic colon cancer | Lesions requiring resection of segments 1 and 5-8 | Alive after 13 months | |
| 26 F | Cholangiocarcinoma | 26 F | Cholangiocarcinoma | 2.3-cm hilar mass involving the portal vein confluence and right hepatic artery | Alive with no recurrence on MRI at 17 months | (80) |
| 41 M | Cholangiocarcinoma | 41 M | Cholangiocarcinoma | 14x12 cm mass encompassing segments 4a, 4b and 5 with RHA involvement | Recurrence at 10 months and 13 months, receiving radiation; still alive at 23 months | (81) |
| 58 M | Leiomyosarcoma of the IVC | 58 M | Leiomyosarcoma of the IVC | Third attempt at resection | Discharged on post-operative day 10; long-term outcome N/A | |
| 39 F | Giant hepatic hemangiomas | 39 F | Giant hepatic hemangiomas | 4 large hemangiomas in segments 1-3, caudal 4 and 6-7 | Normal liver function with a regenerated liver graft at 8 months | (75) |
| 17 F | HCC | 17 F | HCC | 18x12 cm lesion involving IVC, RHV and first left branch of portal vein | Alive 28 months after resection; no post-operative chemotherapy | (82) |
| 38 F | Hepatic metastasis frompancreatoblastoma | 38 F | Hepatic metastasis from pancreatoblastoma | 2.5 cm lesion in left lobe and 2.7-cm lesion in right lobe involving MHV and RHV | Alive after 8 months | (83) |
| 60 F | Hepatic hemangiomas | 60 F | Hepatic hemangiomas | Lesions requiring resection of segments 4-8 | Alive at 22 months | (74) |
| 64 M | Cholangiocarcinoma | 64 M | Cholangiocarcinoma | Lesions requiring resection of segments 1-4 | Alive at 17 months | |
| 55 M | Cholangiocarcinoma | 55 M | Cholangiocarcinoma | Lesions requiring resection of segments 1, 5, 7 and 8 | Succumbed on post-operative day 1 due to liver and renal failure | |
In addition, 63.6% (28/44) patients receiving ex situ hepatectomy and liver autotransplantation were <55 years old, as was the patient reported in the present case. The common indications for this method are major vein involvement and extensive resection area, both of which were noted in the present case. Compared with conventional liver resection, ex situ hepatectomy and liver autotransplantation markedly improve the rate of successful resection and clear margins of the otherwise unresectable lesions. There is no long waiting time for a suitable allograft, as an autologous liver is implanted. In addition, the total cost is lower and no post-operative immunosuppressants are required for patients receiving ex situ hepatectomy and liver autotransplantation, compared with an allograft liver transplantation (5).

The successful establishment of venous reflux and hypothermic perfusion of the isolated liver are essential for securing a successful surgery and a good prognosis (77). As the liver resection and trimming surgery are time-consuming, the prolonged anhepatic phase can lead to hemodynamic or internal environmental disturbances. Therefore, in the present case, an artificial blood vessel was used to establish an end-to-side portocaval shunt in order to maintain the venous return of the intestinal tract and lower limbs during the anhepatic period. Compared with autologous vessels, including the great saphenous vein, use of an artificial blood vessel minimizes the invasiveness of the procedure for the patient. As the shunt is temporary, the potential tissue rejection is of no concern.

The commonly encountered complications of ex situ hepatectomy and liver autotransplantation include bile leakage, bleeding, pulmonary infection, pneumomedema, hydrothorax and renal insufficiency, with a total incidence of 58.1%. The overall mortality rate within 90 days after surgery is 19.5% (5). In the present study, the patient presented with moderate right pleural effusion following surgery, and recovered fully following pleurocentesis and drainage. No other severe complications were encountered up to 3 months after surgery.

In conclusion, this is the first report that describes the successful adoption of ex situ hepatectomy and liver autotransplantation for treating an otherwise unresectable giant SFT. The uneventful surgical course and post-operative period suggested that this procedure was suitable for managing an unresectable liver neoplasm. Furthermore, the artificial blood vessels may provide a reliable source for establishing an end-to-side portocaval shunt during the anhepatic period.

Acknowledgements
Not applicable.

Funding
This study was supported by the National Natural Science Foundation of China (grant nos. 81372626 and 81572975), the Key Research and Development Project of Science and Technology Department of Zhejiang, China (grant no. 2015C03053), and the Zhejiang Provincial Program for the Cultivation of High-level Innovative Health Talents (2016).
Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors’ contributions
SY and WW conceived and designed the study. ZS, YD, YJ, QZ, ZL, JX, JD, SY and WW performed the surgery and provided the patient care. QZ, ZL, JX and JD performed the literature review and collected the substantial data. ZS and YJ analyzed the data. ZS and YD wrote and revised the manuscript. ZS, YD and YJ organized the data and figures. SY and WW revised the final version of manuscript. All authors have read and approved the manuscript.

Ethics approval and consent to participate
The study was approved by the Ethics Committee of the First Affiliated Hospital, School of Medicine, Zhejiang University. The authors declare that they have no competing interests.

Patient consent for publication
The patient provided written informed consent for the publication of any associated data and accompanying images.

Competing interests
The authors declare that they have no competing interests.

References
1. Salas S, Ressegueur N, Blay JY, Le Cesne A, Italiano A, Cheveaux C, Rosset P, Isambert N, Souillé P, Cupissol D, et al: Prediction of local and metastatic recurrence in solitary fibrous tumor: Construction of a risk calculator in a multicenter cohort from the French Sarcoma Group (FSG) database. Ann Oncol 28: 1979-1987, 2017.
2. D’Amico FE, Ruffolo C, Romano M, DI Domenico M, Saraglia M, Del Toi AP, Garofalo T, Giordano A, Bassi I and Massani M: Rare neoplasm mimicking neuroendocrine pancreatic tumor: A case report of solitary fibrous tumor with review of the literature. Anticancer Res 37: 3093-3097, 2017.
3. Robinson LA: Solitary fibrous tumor of the pleura. Cancer Control 13: 264-269, 2006.
4. Pichlmayr R, Breitschneider HJ, Kirchner E, Ringe B, Lamesch P, Weber JC and Veillon F: Delayed enhancement pattern in a solitary fibrous tumor of the liver: A clinicopathologic and immunohistochemical study of 2 cases. Ann Diagn Pathol 2: 19-24, 1998.
5. Fukshurner MS, Klaismtra D and Panick DM: Solitary fibrous tumor of the liver: Imaging findings. AJR Am J Roentgenol 175: 1683-1687, 2000.
6. Vilmay S, Krimilis MM, Ertas E, Milimigliu F, Yildirim B, Katz D and Mizraji B: Giant solitary fibrous tumor of the liver with metastasis to the skeletal system successfully treated with trisegmentectomy. Dig Dis Sci 45: 168-174, 2000.
7. Lin YT, Lo GH, Lai KH, Tsai CC, Pan HB, Tseng HH and Lo YS: Solitary fibrous tumor of the liver: Zhonghua Yi Xue Za Zhi (Taipei) 64: 305-309, 2001.
8. Gold JS, Antonescu CR, Hajdu C, Ferrone CR, Hussain M, Lewis JJ, Brennan MF and Coit DG: Clinical-pathologic correlates of solitary fibrous tumors. Cancer 94: 1057-1068, 2002.
9. Neeff H, Obermaier R, TECHNAU-ILHING K, Werner M, Kurtz C, Imadahu A and Hopt UT: Solitary fibrous tumor of the liver: Case report and review of the literature. Langenbecks Arch Surg 389: 293-298, 2004.
10. Chithriki M, Jaibaji M and Vandermon R: Solitary fibrous tumor of the liver with presenting symptoms of hypoglycemic coma. Am J Surg 70: 291-293, 2004.
11. Vennarecci G, Ettorre GM, Giovannelli L, Del Nonno F, Perracchio L, Visca P, Corazza V, Vidiri A, Visco G and Santoro E: Solitary fibrous tumor of the liver. J Hepatology Pancreat Surg 12: 341-344, 2005.
12. Moser T, Nogueira TS, Neuvile A, Riehm S, Averous G, Wolfrich JC and Veillon F: Delayed enhancement pattern in a localised fibrous tumour of the liver. AJR Am J Roentgenol 184: 1578-1580, 2005.
13. Ji Y, Fan J, Xu Y, Zhou J, Zeng HY and Tan YS: Solitary fibrous tumor of the liver. Hepatobiliary Pancreat Dis Int 5: 151-153, 2006.
14. Nath DS, Rutzick AD and Sielaff TD: Solitary fibrous tumor of the liver: AJR Am J Roentgenol 187: 187-190, 2006.
15. Terkvatan T, Klaffen M, de Wilt JH, van Geel AN, Eggermont AM and Verhoef C: Giant solitary fibrous tumor of the liver. World J Surg Oncol 4: 81, 2006.
16. Chan G, Horton PJ, Thysen S, Lamarche M, Nahal A, Hill DJ, Marlliss EB and Metrakos P: Malignant transformation of a solitary fibrous tumor of the liver and intractable hypoglycaemia. J Hepatobiliary Pancreat Surg 14: 595-599, 2007.
17. Obuz F, Secil M, Sagol Ö, Karademir S and Topalak O: Ultrasonography and magnetic resonance imaging findings of solitary fibrous tumor of the liver. Tumori 93: 100-102, 2007.
18. Perini MV, Herman P, D'Albuquerque LA and Saad WA: Solitary fibrous tumor of the liver: Report of a rare case and review of the literature. Int J Surg 6: 396-399, 2008.
19. Weitz J, Klimstra DS, Cymes K, Larnagin WR, D'Angelica M, La Quaglia MP, Fong Y, Brennan MF, Blumgart LH and Dematteo RP: Management of primary liver sarcomas. Cancer 109: 1391-1396, 2007.
20. Randpal H, Sharma R, Gupta SD and Kumar A: Solitary fibrous tumor of the liver: A rare imaging diagnosis using MRI and diffusion-weighted imaging. Br J Radiol 81: c282-c286, 2008.
Navarro‑Soto S: Solitary fibrous tumor of the liver. Case report and presentation with hypoglycemia. Gastroenterology 148: e11‑e18, 2020.

Du EH, Walshe TM and Buckley AR: Recurring rare liver tumor de Andrade AB and da Costa FP: Fibrous solitary tumour of the liver. J Gastroenterol Clin Biol 34: 716‑720, 2010.

Hoshino M, Nakajima S, Futagawa Y, Fujioka S, Okamoto T and Yanaga K: A solitary fibrous tumor originating from the liver surface. Clin J Gastroenterol 2: 320‑324, 2009.

Novais P, Robles‑Medranda C, Pannain VL, Barbosa D, Biccas B and Fogaca H: Solitary fibrous liver tumor: Is surgical approach the best option? J Gastrointestin Liver Dis 19: 81‑84, 2010.

Brochard C, Michalak S, Aubé C, Singeozaran C, Fournier HD, Laccourreye L, Caëls P and Bouriers J: A not so solitary fibrous tumor of the liver. Gastroenterology Clin Biol 34: 716‑720, 2010.

Haddad A, Karras R, Fraimain M and Mackey R: Solitary fibrous tumor of the liver. Am Surg 76: E78‑E79, 2010.

Park HS, Kim YK, Cho BH and Moon WS: Pedunculated hepatic mass. Liver Int 31: 541, 2011.

Peng L, Liu Y, Ai Y, Liu Z, He Y and Liu Q: Skull base metastases from a solitary fibrous tumor of the liver. A case report and literature review. Diagn Pathol 6: 127, 2011.

Sun K, Liu JJ, Ying LX and Wei JF: Solitary fibrous tumor of the liver: A case report. World J Gastroenterol 14: 720, 2008.

Patra S, Vij M, Venugopal K and Rela M: Hepatic solitary fibrous tumor: A report of a rare case. Indian J Pathol Microbiol 55: 236‑239, 2012.

Radunz S, Baba HA and Sotiropoulos GC: Large tumor of the liver and hypoglycemic shock in an 85‑year‑old patient. Gastroenterology 142: e10‑e11, 2012.

Belga S, Ferreira S and Lemos MM: A rare tumor of the liver with a sudden presentation. Gastroenterology 143: e14‑e15, 2012.

Morris R, McIntosh D, Helling T and Martin JR Jr: Solid fibrous tumor of the liver: A case in pregnancy. J Matern Fetal Neonatal Med 25: 866‑868, 2012.

Beyer L, Delpero JR, Chetaille B, Sarraïn A, Perrot D, McFarland LR, Houshyar A, Raab R, Klempmann J and Pichlmayr R: Long‑term experience after ex situ liver surgery. Surgery 127: 520‑527, 2000.

Wen PH, Lin KH, Chen YL, Hsieh CE, Ko CJ and Kuo SJ: Extracorporeal hepatic resection and autotransplantation using temporary portocaval shunt provides an improved solution for conventionally unresectable HCC. Dig Dis Sci 58: 3637‑3640, 2013.

Zhang KM, Hu XW, Dong JH, Hong ZX, Wang ZH, Li GH, Qi RZ, Duan WD and Zhang SG: Ex‑situ liver surgery without veno‑venous bypass. World J Gastroenterol 18: 7290‑7295, 2012.

Ikegami T, Soejima Y, Taketomi A, Kayashima H, Sanefuji K, Yoshizumi T, Harada N, Yamashita Y and Macharya: Extracorporeal hepatic resection for unresectable giant hepatic hemangiomas. Liver Transpl 14: 115‑117, 2008.

Emmings AW and Cattral MS: Ex vivo liver resection with replacement of the inferior vena cava and hepatic vein replacement by transposition of the portal vein. J Am Coll Surg 189: 525‑529, 1999.

Patra S, Vij M, Venugopal K and Rela M: Hepatic solitary fibrous tumor: A report of a rare case. Indian J Pathol Microbiol 55: 236‑239, 2012.

Chen N and Slater K: Solitary fibrous tumour of the liver‑report on metastasis and local recurrence of a malignant case and review of literature. World J Surg Oncol 15: 27, 2017.

Surola‑Blanco KI, Lane H, Hau HG, El‑Khouli RH, Geschwind JF, Bluemke DA and Kamel IR: Inaccuracy of fine‑needle biopsy in the diagnosis of hepatic metastases from a malignant solitary fibrous tumor of the liver. A case report. World J Surg 40: 82‑87, 2016.

Kueht M, Masand P, Rana A, Cotton R and Goss J: Concurrent hepatic hemangioma and solitary fibrous tumor: Diagnosis and management. J Surg Case Rep 2: rau17, 2017.

Maccio L, Bonetti LR, Siopis E and Palmiere C: Malignant metastasizing solitary fibrous tumors of the liver: A report of three cases. Pol J Pathol 66: 72‑76, 2015.

Makino Y, Miyazaki M, Shigekawa M, Ezaki H, Sakamori R, Yakuhashi T, Ohkawa E, Okawa M, Akusaka T, Shizuki S et al: Solitary fibrous tumor of the liver from development to resection. Intern Med 54: 765‑770, 2015.

Dey B, Gochhait D, Kaushal G, Barwad A and Pottakkat B: Solitary fibrous tumor of the liver: A rare tumor in a rarer location. Rare Tumors 8: 6403, 2016.

Degnan AJ, Lee KK, Minervini MI and Borhani AA: Metastatic extrapleural malignant solitary fibrous tumor presenting with hypoglycemia (Doege‑Potter syndrome). Radiol Case Rep 12: 113‑119, 2016.

Chen N and Slater K: Solitary fibrous tumor of the liver‑report on metastasis and local recurrence of a malignant case and review of literature. World J Surg Oncol 15: 27, 2017.

Surola‑Blanco KI, Lane H, Hau HG, El‑Khouli RH, Geschwind JF, Bluemke DA and Kamel IR: Inaccuracy of fine‑needle biopsy in the diagnosis of hepatic metastases from a malignant solitary fibrous tumor of the liver. A case report. World J Surg Oncol 15: 27, 2017.

Sung L, Zhang W and Zhang Y: (18)F‑FDG PET/CT imaging in the diagnosis of fibrous tumour of the liver. Pathology 45: 86‑90, 2013.

Vythianathan M and Yong J: A rare primary malignant solitary fibrous tumor of the liver. Arch Surg 393: 611‑616, 2008.

El‑Khouli RH, Geschwind JF, Bluemke DA and Kamel IR: Solitary fibrous tumor of the liver: Magnetic resonance imaging evaluation and recurrent treatment with transarterial chemoembolisation. J Comput Assist Tomogr 32: 769‑771, 2008.

Teixeira F Jr, de Freitas Perina AL, de Oliveira Mendes G, Malavé L, Ferri V, Lazzaro S, Kalivaci D and Caruso R: Malignant metastasizing solitary fibrous tumors of the liver: A report of four case studies and a clinical review. World J Gastroenterol 14: 333‑342, 2008.