Objective: Portal vein embolisation (PVE) represents the standard procedure for augmentation of the contralateral lobe before extended right hepatectomy. However, possible limitations for the percutaneous transhepatic approach exist, for example, large tumours of the right lobe. Here, we present our experiences with single-incision laparoscopic surgery-PVE (SILS-PVE) as an alternative approach for settings where percutaneous routes are technically not feasible.

Methods: A small umbilical incision is performed, and a GelPOINT Mini Advanced Access Platform (Santa Margarida, CA, USA) is placed. Staging laparoscopy is performed routinely followed by identification of an appropriate ileal segment, which is subsequently exteriorized through the small umbilical incision. A peripheral mesenteric vein is encircled and cannulated to access right portal vein branches. After sufficient embolisation of the right lobe, the peripheral vein is ligated, the single port is extracted and the umbilical wound is closed.

Results: SILS-PVE was successfully applied in 10 patients (median age 60.5 years) between 12/2015 and 03/2018. The technique was indicated due to extensive tumours in the right lobe (n = 8), extensive hydatid cyst (n = 1) and during SILS right hemicolectomy in Stage IV colon cancer (n = 1). Mean operative time was 184 min (range 116–315). Patients were discharged on post-operative day 4 (range 2–9). Augmentation of the future liver remnant volume was assessed by computed tomography-volumetry 3–4 weeks after SILS-PVE and showed a mean relative increase of 64.95%, future remnant liver function showed a mean increase of 120.77%.

Conclusion: The proposed SILS-PVE represents a technically simple and safe alternative to standard percutaneous transhepatic approaches. Perioperative risks can be minimised by minimally-invasive surgery, which is of explicit importance in multimodal approaches before major hepatectomy.

Keywords: Laparoscopic liver surgery, portal vein embolisation, single incision laparoscopic surgery
INTRODUCTION

There is broad evidence that complete resection of primary and secondary liver tumours is associated with favourable long-term outcomes.\(^1\) Even extended approaches with the removal of \(\sim 70\%\) of the liver volume are oncologically reasonable if tumour-free margins can be achieved. However, major liver resections are associated with an increased perioperative morbidity and mortality. Especially patients with impaired functional capacities are at high risk for post-operative liver failure (PLF), which is considered the major contributory factor for complicated and prolonged post-operative courses.

Pre-operative determination of the future liver remnant volume (FLRV) by computed tomography (CT)-volumetry in combination with a distinct evaluation of functional capacity, for example, by LiMAX, are a prerequisite for a safe planning of major liver resection.\(^2\) In cases of a predicted FLRV of <25%, or a functional capacity <40%, the risk for PLF is increased,\(^3\) and the safety of major hepatectomy can be improved by pre-operative augmentation of contralateral segments.\(^4,5\) Adequate hypertrophy of the contralateral lobe can usually be achieved within 4–6 weeks and extended right hepatectomy can be performed rather safely.\(^6\)

Pre-operative liver augmentation can routinely be achieved by the occlusion of the right portal vein branches by selective embolisation portal vein embolisation (PVE).\(^7\) In cases where standard percutaneous tranhepatic PVE is not feasible, for example, due to large tumour masses, intrahepatic portal vein branches can be accessed by cannulation of a peripheral mesenteric vein. Possible flaws of this approach include the need for abdominal

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**Figure 1:** GelPOINT Mini Advanced Access Platform (Santa Margarida, CA, USA) \textit{in situ}

**Figure 2:** Exteriorised distal ileal segment with encircled ileal vein

**Figure 3:** Cannulated ileal vein

**Figure 4:** Computed tomography-scan portal vein embolisation results
Laparoscopic techniques have gained broad acceptance over the last years, at least in parts, as they are associated with a decreased post-operative morbidity. We here report on our preliminary experiences using single-incision laparoscopic surgery (SILS) for identification of a proper ileal segment followed by subtle cannulation of an ileal vein for intraoperative PVE (SILS-PVE).

**METHODS**

Patients’ characteristics and staging
We reviewed the medical records of patients who underwent SILS-PVE before planned extended right hepatectomy for primary and secondary liver tumours. Patients’ data were analysed with regard to the feasibility and safety of this novel surgical technique. Data collection and analysis was approved by the Local Ethics Committee (EA2/006/16), written consent for data collection and photos were obtained.

Pre-operative staging included helical CT scanning of the chest, abdomen and pelvis to evaluate local resectability and to rule out extrahepatic metastatic spread. Total liver volume and the future remnant liver volume (FRLV) were estimated preoperatively according to data sets (Visage v7.1.10, Visage Imaging Inc./Pro Medicus Limited, Richmond VIC 3121, Australia), future remnant liver function (FRLF) was then estimated by correlation of LiMAx (Humedics GmbH, Berlin, Germany) and FRLV. Staging-CT, volumetry and LiMAx were repeated 3–4 weeks after PVE.

**Technical intraoperative aspects**
Patients were under general anaesthesia and in French position. A 3–5 cm umbilical incision was performed,
and a GelPOINT Mini Advanced Access Platform (Santa Margarida, CA, USA) was placed [Figure 1]. After staging laparoscopy, an ileal segment was identified laparoscopically and gently exteriorised through the umbilical port [Figure 2]. The mesenteric fat was locally removed, and a peripheral mesenteric vein was encircled and cannulated to access the mesenterico-portal system [Figure 3]. A PVE was performed intraoperatively using Contour® 500–710 µm Embolisation Particles (Boston Scientific, Marlborough, Massachusetts, United States) for selective embolisation of the peripheral right portal vein branches and Tornado® Embolisation Coils (Cook Medical Inc., Bloomington, Indiana, United States) to occlude the main right portal vein branch [Figure 4]. After sufficient PVE, the peripheral mesenteric vein was closed by ligation. The GelPOINT Mini Advanced Access Platform was removed, and the umbilical wound was closed with running sutures [Figure 5].

RESULTS

Ten patients (male, n = 7; female, n = 3) with a median age of 60.5 (range 28–74) underwent SILS-PVE between November 2015 and March 2018. Patients were scheduled for extended right hepatectomy because of malignant tumours and cystic lesions intrahepatic cholangiocarcinoma, n = 3; perihilar cholangiocarcinoma (PHC), n = 2, gallbladder cancer, n = 2; hepatocellular carcinoma, n = 1; colorectal liver metastases, n = 1; hydatid cyst, n = 1 [Table 1].

Median operative time of all patients was 184 min (range: 116–315), with 140 min (range 116–176) in patients without additional steps such as liver or peritoneal biopsy (n = 4) or hemicolecotmy (n = 1). Blood loss was marginal and no transfusion was required in any of the operations. No major complications occurred (Dindo-Clavien ≥III), and patients were discharged on post-operative days 4 (2–9 range).

Additional procedures were indicated in four patients and included liver biopsy (n = 3), peritoneal biopsy (n = 1) and oncological SILS right hemicolecotomy (n = 1). After right hemicolecotomy, an ileal mesenteric vein close to the resection margin was cannulated. Following SILS-PVE, the aboral ileal segment was resected, and isoperistaltic side-to-side ileotransversostomy was performed. Operation time was 167 min for SILS right hemicolecotomy and 150 min for the SILS-PVE.

Patients were scheduled for re-assessment of appropriate liver augmentation and function 3–4 weeks after SILS-PVE by CT-volumetry and LiMAX, which confirmed sufficient hypertrophy in the future liver remnants (mean FRLV + 64.95% [range − 39.0%–230.2%], mean FRLF + 120.77% [range 4.1%–210.0%]) [Figures 6 and 7]. Eight patients underwent consecutive major hepatectomy. Two patients presented with progressive disease, with new pulmonal (n = 1) and peritoneal metastases (n = 1), respectively.

DISCUSSION

We here report on our experiences with SILS-PVE as an alternative approach in patients with restrictions to routine percutaneous transhepatic PVE. This approach appears to be technically feasible and safe for the patient. The umbilical single incision access bears well-accepted benefits of minimally-invasive surgery and further enables delicate preparation of peripheral ileal mesenteric veins through exteriorisation of the bowel.

Although low complication rates in our series are indicative for the safety of this approach, general anaesthesia is needed and consequently patients should be well selected. Of note, ipsilateral percutaneous transhepatic cannulation of the left lateral portal branches is associated with possible serious complications, for example, portal vein thrombosis or haemorrhage, and from our point of view, does not represent an appropriate alternative.

SILS-PVE might be notably useful in patients with synchronously metastasised colorectal cancer scheduled for ‘primary first’ concepts. In patients undergoing SILS right hemicolecotomy, a mesenteric vein just before the stapled resection margin can be used for cannulation. Subsequent resection of this ileal segment minimises potential risks, for example, venous congestion and ischaemic complications, potentially leading to anastomotic insufficiency.

Furthermore, SILS-PVE as proposed in this study might offer the best possible results with regard to potential intra-abdominal adhesions before scheduled major hepatectomy. It appears obviously superior to laparoscopic portal vein ligation,[8] as it avoids hilar manipulations with resulting local adhesions. Importantly, SILS-PVE is well compatible with the ‘no touch’ concept in PHC.[9]

While laparoscopic approaches have been described accessing more proximal mesenteric veins for PVE,[10] the proposed SILS-PVE approach allows safe and selective cannulation of peripheral ileocolic veins after exteriorisation of the bowel through the single port. SILS-PVE might
therefore minimise the risk for associated complications, for example, thrombotic events or dissection of central mesenterial veins.

CONCLUSION

SILS-PVE appears to be technically feasible and safe, combining benefits from minimally-invasive surgery and established techniques of ileal venous cannulation for PVE. We propose this modification as the best possible technique for liver augmentation in multimodal concepts if an interventional percutaneous approach is considered not feasible.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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