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**Therapeutic advances: Single incision laparoscopic hepatopancreatobiliary surgery**

Chang SKY *et al*. Incision laparoscopic hepatopancreatobiliary surgery

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**Abstract**

Single-port laparoscopic surgery (SPLS) is proposed to be a step towards minimizing the invasiveness of surgery, and has since gained popularity in several surgical sub-specialties including hepatopancreatobiliary surgery. SPLS has since been applied to cholecystectomy, liver resection as well as pancreatectomy for a multitude of pathologies. Benefits of SPLS over conventional multi-incision laparoscopic surgery include improved cosmesis and potentially post-operative pain at specific time periods and extra-umbilical sites. However, it is also associated with longer operating time, increased rate of complications, and increased rate of port-site hernia. There is no significant difference between length of hospital stay. SPLS has a significant learning curve that affects operating time, rate of conversion and rate of complications. In this article, we review the literature on SPLS in hepatobiliary surgery – cholecystectomy, hepatectomy and pancreatectomy, and offer tips on overcoming potential technical obstacles and minimizing the complications when performing SPLS – surgeon position, position of port and instruments, instrument crossing position, standard hand grip *vs* reverse hand grip, snooker cue guide position, prevention of incisional hernia. SPLS is a promising direction in laparoscopic surgery, and we recommend step-wise progression of applications of SPLS to various hepatopancreatobiliary surgeries to ensure safe adoption of the surgical technique.

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**Key words:** Single port laparoscopic; Cholecystectomy; Hepatectomy; Pancreatectomy; Liver resection

**Core tip:** This manuscript is an up-to-date review of the recent developments in single port laparoscopic hepatopancreatobiliary surgeries. A comprehensive review of all meta-analyses published on the topic of single port laparoscopic cholecystectomy will be discussed as well as a summary of the published literature of the application of single port laparoscopic surgery in liver and pancreatic surgeries will be presented. The author who has a personal experience of more than 350 single port laparoscopic hepatopancreatobiliary surgeries will offer a detailed description of his technique and tips on how to avoid the pitfalls as well as adopting the technique easily.

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**Introduction**

Since Eric Muhe first described laparoscopic cholecystectomy in 1985[1], minimally invasive surgery has revolutionized surgical techniques, and has made a huge impact particularly in hepatopancreatobiliary surgery. Benefits over traditional open surgery include improved cosmesis, decreased post-operative pain, shortened length of hospital stay and faster return to function[2].

Single-port laparoscopic surgery (SPLS) was first described by Inoue *et al*[3] for appendectomy, and is proposed to be a step towards the same direction of minimizing the invasiveness of surgery; potentially offering benefits such as improved cosmesis, decreased post-operative pain and shorter length of hospital stay as compared to conventional multi-incision laparoscopic surgery. This technique has since gained popularity in several surgical subspecialties, including hepatopancreaticobiliary diseases. SPLS for cholecystectomy gained popularity in 2000s and has since been applied to more complex procedures, including hepatectomies and pancreatectomies.

To date, there is a significant amount of literature available on SPLS for a vast range of diseases, ranging from single case reports to meta-analyses on the feasibility and outcomes of SPLS. There is a need to consolidate the evidence available for clinicians to better understand this surgical technique and its benefits and potential risks. This article reviews the literature on SPLS in hepatobiliary surgery – cholecystectomy, hepatectomy and pancreatectomy, and offers tips in overcoming potential technical obstacles when performing SPLS.

**Single-port laparoscopic cholecystectomy**

Currently, laparoscopic cholecystectomy is the gold standard for surgical treatment of benign gallbladder diseases. SPLS for cholecystectomy was first described by Navarra *et al*[4] in 1997. Today, SPLS is most commonly applied to cholecystectomy, as clearly demonstrated by the large amount of literature on single-incision laparoscopic cholecystectomy (SILC) in contrast to other single-port laparoscopic surgeries.

There have been several meta-analyses[5-10] published comparing SILC with CLC in a large range of parameters - from operating time, complications, to cosmesis. While there are slight differences in conclusions with regards to rate of procedural failure and complications, most derive results that concur with each other.

***Safety and complications of SILC***

Safety of the procedure is commonly determined by the incidence and rate of complications. SILC is considered to be a safe and effective procedure for the treatment of carefully selected patients with uncomplicated benign gallbladder disease[5]. Although there is a reported higher complications rate with SILC as compared to CLC, it is not statistically significant. Common post-operative complications include wound site infection (4.0% *vs* 1.6%)[5] and gallbladder perforation (1.9% *vs* 1.3%)[1]. Of importance, bile duct injury is found in 0.72%[11] for SILC, compared to 0.5[12] in CLC. This is likely due to the fact that many of the studies were in their early stages of SILC, and could have experienced difficulty in visualizing the Calot’s triangle in order to facilitate safe dissection. We offer tips to overcome this obstacle in later sections. SILC is also associated with higher intra-operative blood loss (1.0% *vs* 0.9%), although not shown to be statistically significant[5].

***Procedural failure rate***

The rate of conversion to open surgery is comparable to that of CLC (mean 0.4% *vs* 0.7%)[5]. When including the addition of a port to SILC procedures or conversion to CLC as a procedural failure, the failure rate is higher (8.4% *vs* 0.7%)[6]. There is a median of 8.55% of SILCs that required an additional port[13]. Trastulli *et al*[6] also found a higher rate of failure when using a transparietal suture to anchor the gallbladder to the abdominal wall as compared to using a grasper to retract the gallbladder. The higher rate of conversions may be due to the learning curve associated with SILC. In a study of the learning curve of SILC by Tay *et al*[14], 80% of conversions took place in the surgeon’s first 20 cases, and were usually due to the obscured anatomy of Calot’s triangle. Rate of conversion is likely to decrease with experience.

***Intra-operative time and learning curve***

All meta-analyses[5-10] have shown that intra-operative time with SILC is significantly longer than CLC. A meta-analysis of prospective randomized controlled trials by Pisanu *et al*[5] found that the mean time for SILC is 63.0 min *vs* 45.8 min in CLC [SMD = 1.004 (0.434 - 1.573)]. The longer operating times have been attributed to the learning curve associated with the adoption of a new technique. A study by Tay *et al[*14] on a single institution experience of the learning curve of SILC shows that the mean operating time of a surgeon is significantly lower (62.5 min *vs* 90.6 min) after overcoming the learning curve, and continues to decrease to 37 min after performing 60 cases. As surgeons gain more experience with SPLS, the operating time consistently reduces[15,16], and the operating time for SILC decreases with experience to a comparative level of CLC[14,17]. The number of cases required to overcome the learning curve ranges from 5-10[18] to 20-25[19,20]. The wide range of learning curve may be due to the degree of ease of surgery based on the indication for surgery and patient profile (*e.g.,* high BMI), or the prior experience of the surgeon with laparoscopy.

***Post-operative pain and recovery time***

Several meta-analyses[5-9] found no statistically significant differences in post-operative pain. This may be due to the increase in total tension of the umbilical incision[21]. However, it is worth noting that the studies thus far have assessed post-operative pain as an overall score that is neither site-specific nor time-specific. Geng *et al*[10] found significant difference in post-operative pain (by VAS scores) between the SILC and CLC groups when specific time periods were analysed; patients who underwent SILC had less pain at 3-4 h (-0.704 favouring SILC), and at 6-8 h (0.613 favouring SILC).

Our institution investigated post-operative pain in SILC *vs* CLC in a randomized controlled trial[22], where we measured post-operative pain by site and severity at 4 h, 24 h, 2 wk and 6 mo. We found that at 24 h post-operatively, there is significantly less extra-umbilical pain at rest and on movement, with mean reduction of 1.988 (0.763-3.3213) and 2.182 (0.729-3.635) in pain score at rest and on movement respectively (Table 1). This could suggest superiority of pain reduction in SILC at site specific areas. Otherwise, there is also no significant difference in the length of hospital stay[5-9].

***Port site hernia***

There appears to be a higher incidence of port site hernia in patients who undergo SILC compared to CLC (1.43% *vs* 0.32%)[8], although not statistically significant. However, the length of post-operative follow-up is not known. In a systematic review by Hall *et al*[13], the overall rate of incisional hernia is 0.35%, but the 49 studies had a range of follow-up from 2 wk to 1 year. The increase in port site hernias with SILC may be due to the longer incision made for single-incision surgeries, particularly with multi-port devices. Longer length of follow-up is required to make a better conclusion on whether port site hernia is a significant long term complication with SILC. Experience in port-site close is also vital in prevention of incision hernias, and will be discussed in a later section.

***Cosmesis***

The satisfaction with cosmesis in patients who underwent SILC is undeniably greater than patients who underwent CLC, and is likely the largest benefit that SILC confers to patients. Post-operative satisfaction with cosmesis from the meta-analysis by Pisanu *et al*[5] favours the SILC group (8.2 *vs* 7.2 on a 10-point scale, SMD = -0.759), and Trastulli *et al*[6] reported that there is a significant difference in satisfaction with cosmesis from 2 wk after surgery, with an overall weighted mean difference of 0.97 [-1.51-(-0.43)] in favour of SILC (*P* < 0.001).

***Cost-effectiveness***

It is difficult to compare the cost-effectiveness of SILC with CLC as there is a wide variation of methods applied under “single-incision’. Although all SPLS make use of a single intra-umbilical incision, techniques range from using multi-port devices, to making use of surgical gloves to insert multiple ports while maintaining pneumoperitoneum[23]. The cost of using surgical gloves was shown to be one-quarter of the cost of CLC[13], while Chang *et al*[24] used ports specific to SPLS and described costs as greater than CLC (USD $2547 *vs* $1976). The use of surgical gloves is a promising method that may significantly reduce costs for the patients while providing quality results.

***SILC for complicated patients and diseases***

Currently, SILC is only performed for a select group of patients, with common exclusion criteria including BMI > 30[25], ASA > III[26] > II[27], and acute cholecystitis[25,26,28-30]. The safety of SILC on more complicated patients is not known and will require more evidence before deciding if this procedure can be more widely applicable.

Overall, SILC is proven to be safe and effective for patients with uncomplicated benign gallbladder disease, with significant benefits of improved cosmesis. The main drawback is that of longer operating time (which is associated with the learning curve), and possible long term increased risk for incisional hernia. Otherwise, the complications rate, rate of procedure failure, post-operative pain and recovery time are comparable with CLC, and post-operative pain may be superior in certain sites or time periods. It is difficult to assess cost-effectiveness due to the variety of methods used, but using ports tailored for SPLS is likely to be more expensive as compared to improvising with conventional instruments. More studies are needed to study the safety and complications of SILC with more complex patient factors and biliary pathologies.

**Single-port Laparoscopic Liver Surgeries**

SPLS for liver surgery is a fairly new application, with the first case of single-incision laparoscopic hepatectomy (SILH) being described in 2010 by Cai *et al*[31] for a liver hemangioma. In contrast to SILC, SILH is performed less commonly and literature on SILH is limited to single case reports or small case series. To date, only 31 cases of SILH have been described[31-36]. This is because SILH is a technically demanding surgery with high risk of bleeding, thus requiring strict patient selection and also the use of specific surgical instruments that may not be widely available in institutions.

SILH confers essentially the same benefits of SPLS, and has been used for a larger variety of pathological conditions, from benign cysts to metastatic liver masses and in patients with poor Child-Pugh classification grades (*i.e.*, grade C[32]). Early experience with SILH has shown that it is a safe and effective procedure for selected patients with good recovery, and has not shown to have any post-operative complications.

***Patient characteristics***

From the pooled published patient data, the age of patients ranged from 52[32] to 90[32] years old, and majority were Child-Pugh grade A, although there was 1 patient each of Child-Pugh grade B and C. The indications for SILH included benign cyst fenestration[32-34], hepatectomy for hepatocellular carcinoma, distant metastasis (ovarian, colorectal)[33], endocrine tumour[32], or hemangioma[31].

***Tumour characteristics***

In the context of conducting SILH for malignant tumours, it is imperative to select appropriate cases based on the size and position of the tumour, as well as its relation with the peripheral great vessels[37]. Currently, cut-offs for size of the lesions are < 5 cm[35] or < 4 cm[31]. There is consensus of the need for the tumour to be superficial, although authors argue about the ideal location as either antero-lateral[32] or left liver[33]. In the studies, the location of mass differs vastly between each paper (segment 4, 8[32], and segment 2, 3, 4[33,35]), but is consistent with their selection criteria. Studies that recommend SILH for the left lobe of the liver argue that the suspensory ligament aids in the surgical-site exposure[33].

***Surgical technique***

Length of initial incision ranged from 0.7 cm[32] to 3 cm[31], although the length of incisions were occasionally extended in order to deliver the specimen out of the incision. All reports[31-37] used multi-port systems for single-port laparoscopic surgery, as well as a hemostatic coagulation device or clips and staplers to control bleeding and achieve hemostasis. Technical skills must also be available to allow the surgeon to perform laparoscopic intra-corporeal stitching and knot tying through the single incision site. Some studies also created a zone of heat-coagulative necrosis along the line of intended liver parenchyma division in order to maintain a blood free division[33,35,36].Sasaki *et al*[34] also described the use of 2 trocars with a wire retractor in the same incision for deroofing of a liver cyst in order to reduce the number of instruments, hence minimizing collisions between devices. SILH for malignant tumours were performed under oncologic principles – no direct touching of tumour, and to ensure that radical excision (R0) and adequate resection margins of at least 1 cm[38,39] is achieved.

***Post-operative outcomes***

Operating time for SILH ranged from 75[31] to 235 min[32]. The operating time has a large range due to the different complexities and pathology of each surgery, and is hence difficult to comment on. There were no reported cases of significant blood loss, with no patients requiring blood transfusion. Post-operatively, none of the patients reported significant pain, and length of hospital stay ranged from 3-11 d[32]. There were also no reported cases of complications such as hematoma, vessel or bile duct injury.

***SILH with portal hypertension***

Gaujoux *et al*[33] described a patient with a child alcoholic cirrhosis and portal hypertension who underwent SILH for a 2 cm solitary hepatocellular carcinoma. To reduce the risk of transecting umbilical varices and cause bleeding or worsened portal hypertension, a supra-umbilical incision was made instead. This is useful for future cases of patients with SPLS for engorged umbilical varices.

SILH is a highly challenging procedure that is at the early stages of development and is currently limited to select groups of patients under strict criteria, due to the high risks of morbidity from bleeding and potential difficulty in accessibility and execution. Early studies of SILH have shown that it is a safe procedure for a large variety of pathologies. SILH may be useful in small lesions that are on the peripheral and anterior surfaces of the liver, and could be used for HCC lesions that may not be easily accessible by radiofrequency ablation, such as tumours in the periphery of segment 3[36]. More studies are also needed to come up with more meaningful conclusions on whether the location of the lesion is useful to determine if SILH is appropriate treatment, and if so, which location. Overall, studies of a larger scale are needed in order to provide useful evidence on the safety and outcomes of SILH.

**Single-port laparoscopic pancreatectomy**

Laparoscopic pancreatectomy is not frequently performed due to the limited cases that are suitable, the technical challenges involved and need for specialized surgical equipment[40]. Thus, single-port laparoscopic pancreatectomy (SPLP) have only been explored and described in recent years, and literature is limited mostly to single case reports or small case series, with a total of 11 cases being described[40-43].

Multi-incision laparoscopic pancreatectomy is usually performed for distal pancreatectomy, and has been performed for numerous pathologies – from benign[44,45] to malignant[46]. Laparoscopic surgery is preferred to open surgery in pancreatectomy due to benefits of decreased morbidity and faster recovery[42]. SPLP have been performed for distal pancreatectomy, including splenectomy for several cases[40,47,48]. Indications for SPLP range from benign serous cystadenomas[40,49], neuroendocrine tumours[48,49] or metastatic renal cell carcinoma[43].

***Surgical technique***

General surgical technique and difficulties faced with SPLS applies to SPLP, but surgeons have developed several ways to ensure proper traction and visualization of the lesion, which is important especially since the pancreas is a retroperitoneal organ. To achieve gastric traction, trans-abdominal sutures can be placed on the posterior gastric wall to sling it up in order to expose the pancreas[40,48], or a loop made of suture and plastic tubing from a IV serum set can be used to encircle the stomach corpus[43]. Some studies also made use of ribbon gauze to loop around the pancreas body to provide additional traction[40,48]. The pancreas was dissected either with electrocautery[40,43,48] or staplers[49], and the stump was reinforced with continuous suture and/or topical sealant[48,49].

***Operative outcomes***

There is only 1 study available comparing SPLP and conventional laparoscopic distal pancreatectomy (CLDP) by Haugvik *et al*[49]. They reported no significant differences in operating time, intra-operative bleeding, resection status, tumour size or length of hospital stay. Surgical morbidity is comparable with CLDP, and CLDP actually appears to be associated with more serious complications (2 patients with splenic artery bleeding, requiring laparoscopic revision, splenectomy and transfusion) as compared to SPLP. However, it is difficult to make a definitive evaluation given the small number of cases being compared.

***Post-operative complications***

Pancreatic fistulas are common post-operative complications in distal pancreas resection, and occur in 8%-30% of patients[50-52]. Haugvik *et al*[49] found no significant differences in occurrence of pancreatic fistulas, with 2 patients each from SILDP and CLDP groups developing post-operative pancreatic fistulas (ISGPF grade B[43]). Another complication reported was a delayed presentation of abscess formation at the pancreatic stump, which was treated with antibiotics and percutaenous catheter drainage[48].

Overall, SPLP appears to be a safe and feasible procedure for selected patients, and may potentially offer the same benefits of laparoscopic surgery with minimal abdominal trauma and improved cosmesis. More experience is needed to better evaluate the safety and morbidity of SPLP, and its applications with regards to pancreatic pathologies.

**Tips from our institution’s experience with SPLS**

In SPLS, multiple instruments (including the operating instruments and laparoscopic camera) are introduced into the same incision, the limited space is challenging for both the surgeon and assistant to work together compared to conventional multi-incision laparoscopic surgery. As such, instruments and the hands holding the instruments tend to “clash”. SILC also loses the principle of triangulation in laparoscopic surgery, and hence poses a new set of technical difficulties. The main challenges of SILC is hence to allow both surgeon and assistant to work together effectively in the space constraints, to avoid collision of instruments and to maintain adequate retraction for proper dissection. Authors have proposed different methods to overcome these difficulties, including a chopstick method[53], where instruments were crossed outside the abdomen to allow for the distal portion of the instruments within the abdomen to be further away from each other, hence minimizing instrument collisions. The use of roticulating instruments on a “mirror image”[5], as the left hand controlling the right-sided instrument on the screen and vice versa, takes time to get used to, and contributes toward the learning curve. We herein offer our techniques as practical solutions to overcome the technical obstacles.

***Surgeon’s position***

By placing the patient in a French position, it allows for adequate space for both the surgeon and assistant to work in coordination without awkward positions (Figure 1). The surgeon usually stands in between the patient’s legs while the assistant stands on the patient’s left. In the classical instrument holding position, the surgeon should be holding the 2 instruments while the assistant operates the camera seated in order to provide the surgeon maximum space for easier instrument manipulation.

***Port position and SPLS instruments***

A multi-port device for single-incision surgery is recommended. The laparoscopic camera should be placed in the most dependent position, with the instruments superior to the camera (Figure 2).

***Instrument crossing positions***

Instruments should be crossed inside the abdomen, ensuring that the distance between the crossing point and surgeon’s hand is greater than the distance between the crossing point to the effector site. This is to reduce the chance of hand clashing and more accurate movement of the effector hand.

***Standard hand grip vs reverse hand grip***

Holding instruments conventionally with the finger rings inferiorly is not ergonomic in SPLS and often results in the surgeon colliding with the laparoscopic camera. Hence, we recommend that the surgeon should hold the instruments with key rings facing outwards (Figure 3A) or superiorly in a reverse hand grip (Figure 3B).

***Snooker cue guide position***

In this position, the surgeon handles both the instrument and camera (Figure 4). Given that the field of vision is significantly narrower with SILC, this is useful in fine dissection. The assistant retracts and the surgeon dissects smoothly while being in control of the field of vision, hence ensuring optimal visualization especially of the Calot’s triangle, which is pertinent to minimize risks of bile duct injuries.

***Prevention of incisional hernia***

Early studies of long term complications with SPLS have shown an increased risk of incisional hernia compared to conventional laparoscopic surgeries. This may be due to the increased dissection of the umbilical wound with increased abdominal tension over a longer operating time, causing ischemia of the fascia. Closure technique is crucial to prevent incisional hernia, and a double figure-of-8 stitch (Figure 5) is usually needed.

**Conclusion**

SPLS is a promising direction in laparoscopic surgery, and is extending its applications to increasing types of hepatopancreaticobiliary surgeries. We recommend a step-wise approach to performing SPLS for hepatobiliary disease; starting from the least complicated cases in cholecystectomy and subsequently move to more complicated cases such as tumour removal in pancreatectomy in order to ensure a safe adoption of surgical technique. Further technical refinement of the instruments and innovations will be useful in improving the surgical technique in order to maximize the benefits of SPLS while minimizing complications and failure rates.

The evaluation of the real value of this approach will require randomized controlled trials of larger scale, with open reporting of both early and late complications. International consensus is needed before its adoption into routine practice.

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**Table comparing mean post-operative pain between study arms**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Technique** | **Reduction of pain in SILC:** | ***P-*value1** | **Conclusions regarding SILC** |
| **Mean** |
| **SILC** | **LC** | **(95%CI)** |
| **(s.d.)** | **(s.d.)** |  |
| Pain score: mean | 4 h post-procedure | Umbilical | At rest | 1.604 | 2.085 | 0.48 | 0.4 | Non-inferior |
| -1.644 | -2.275 | (-0.657-1.618) |
| On movement | 2.275 | 2.469 | 0.194 | 0.766 | Inconclusive |
| -2.063 | -2.479 | (-1.109-1.497) |
| Extra-umbilical | At rest | 0.933 | 1.631 | 0.697 | 0.272 | Non-inferior |
| -1.764 | -2.621 | (-0.567-1.962) |
| On movement | 1.258 | 1.773 | 0.515 | 0.457 | Non-inferior |
| -2.147 | -2.656 | (-0.866-1.895) |
| 24 h post-procedure | Umbilical | At rest | 2.3 | 2.652 | 0.352 | 0.593 | Non-inferior |
| -1.895 | -2.632 | (-0.965-1.669) |
| On movement | 3.613 | 3.548 | -0.065 | 0.939 | Inconclusive |
| -2.668 | -3.196 | (-1.760-1.631) |
| Extra-umbilical | At rest | 0.696 | 2.684 | 1.988 | 0.002 | Superior |
| -1.406 | -2.66 | (0.763-3.213) |
| On movement | 0.942 | 3.124 | 2.182 | 0.004 | Superior |
| -1.767 | -3.104 | (0.729-3.635) |
| 14 d post-procedure | Umbilical | At rest | 0.833 | 0.96 | 0.127 | 0.763 | Non-inferior |
| -1.465 | -1.457 | (-0.713-0.966) |
| On movement | 1.583 | 1.72 | 0.137 | 0.781 | Non-inferior |
| -1.717 | -1.696 | (-0.844-1.118) |
| Extra-umbilical | At rest | 0.167 | 0.4 | 0.233 | 0.319 | Non-inferior |
| -0.637 | -0.957 | (-0.234-0.700) |
| On movement | 0.375 | 0.64 | 0.265 | 0.495 | Non-inferior |
| -1.096 | -1.551 | (-0.510-1.040) |

1There is a significant reduction in extra-umbilical pain scores 24 h post-operatively. SILC: single-incision laparoscopic cholecystectomy.

****

**Figure 1 Surgeon standing in between patient’s legs with assistant on patient’s left.**

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**Figure 2 Position of instruments showing laparoscopic camera in most dependent position.**

** **

**A B**

**Figure 3 Surgeon demonstrating standard hand grip (A) and reverse hand grip (b).**

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**Figure 4 “Snooker cue guide” position.**

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**Figure 5 Enforced wound closure using two figure-of-8 stitches and interrupted stitch.**