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Laparoscopic parenchymal sparing resections in segment 8: techniques for a demanding and infrequent procedure

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Abstract
Background Laparoscopic liver resections for lesions in the postero-superior segments are technically demanding due their deep location and relation with the vena cava. However, previous reports have demonstrated the feasibility and safety of these resections in centres with advanced experience in laparoscopic liver surgery. In this case series, we present our results and experience of laparoscopic parenchymal sparing liver resections of lesions in segment 8.
Methods All patients undergoing laparoscopic liver resections of segment 8 lesions, alone or combined with other liver resections, between August 2003 and July 2016 were included. Analysis of baseline characteristics and perioperative results was performed for the whole cohort. A separate subgroup analysis was performed for isolated segment 8 resections. Long-term results were analyzed in patients with colorectal liver metastases. A video is attached for thorough explanation of surgical technique.
Results A total of 30 patients were included. Among them, 13 patients had isolated segment 8 resections. Operative time for the whole cohort and isolated segment 8 resections were 210 min (range 180–247 min) and 200 min (range 90–300 min), respectively. The conversion rate was 3.4% for the entire cohort and 0 for isolated segment 8 resections. Major morbidity was 7 and 0%, respectively. R0 rates were 96% for the entire cohort and 92% for isolated segment 8 resections. Recurrence free survival in the colorectal liver metastasis subgroup was 82, 71 and 54% at 1, 3 and 5 years. Overall survival was 94, 82 and 65% at 1, 3 and 5 years.
Conclusions Laparoscopic resection of lesions in segment 8 is feasible and offers the benefits of minimally invasive surgery with parenchyma sparing resections. However, advanced experience in LLR is essential to ensure safety and oncological results.

Keywords Laparoscopy · Liver · Segment 8 · Postero-superior segments · Parenchymal sparing resection

Laparoscopic liver resection (LLR) of lesions in the postero-superior segments (PSS) can be very challenging and were included in the most difficult operative category in the 2008 Lousville consensus [1]. Until recently, a laparoscopic approach to these resections was recommended only in very selected cases and even considered as a possible contraindication to a laparoscopic approach [2–4]. The complexity of these resections relates to the postero-superior location of the lesions and the resulting difficult access and associated surgical risks. However, with increasing experience and developments in surgical techniques and instruments, limited reports have shown their feasibility and safety in the last few years [4–8]. The majority of reports consider resections in the PSS as a unique category. However, despite their close anatomical location to segments 4 and 7, resections in segment 8 may require a different technique and surgical approach.

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In 2003, our centre started performing laparoscopic liver surgery (LLS). Since its uptake, we have overcome the learning curve for resections in each of the liver segments [6–11], including the technically demanding postero-superior resections [8]. In this article, we present our results and experience of laparoscopic parenchymal sparing liver resections in segment 8, describing the tips and tricks developed during our time performing these complex cases. To the best of our knowledge, this is the first case series to report specifically on LLR for lesions involving segment 8. We believe that the technical description provided will be of great value for a safe expansion of LLS. It is important to emphasize that resections in the PSS remain challenging and should only be attempted by surgeons with advanced experience in LLR. A video illustrating the technique of a laparoscopic parenchymal sparing resection of a lesion in segment 8 is included.

Materials and methods

Between August 2003 and July 2016, 650 patients underwent LLRs at Southampton University Hospital. Data were collected prospectively after the informed consent was obtained from the patients and include: baseline characteristics, pre- and post-operative information and follow-up details. All patients with tumours located in segment 8 were included in the analysis. A subgroup analysis of patients with isolated segment 8 lesions was performed. The study was approved by the Institutional Review Board. Statistical analysis was performed using SPSS (version 21.0; IBM, Chicago, Il). Continuous variables were expressed as a mean (with standard deviation) for parametric or a median (with range) for non-parametric data based upon Shapiro–Wilk Test. Categorical variables are expressed in absolute and percentage values. Patients with colorectal liver metastases (CRLM) were selected for a Kaplan–Meier survival analysis of recurrence free survival (RFS) and overall survival (OS). Median follow-up was calculated with reverse Kaplan–Meier Curve.

Technical approach

Pure laparoscopic procedures were performed in all patients using a 30° laparoscope. Patients were placed in the reverse-Trendelenburg position with the surgeon alternating between the patient's right and left side at varying stages of the procedure. A pneumoperitoneum of 13–14 mmHg is created and maintained via a 10 mm trocar in right upper quadrant. Central venous pressure (CVP) was kept between 1 and 3 cmH_2O.

At the outset of the operation, the whole liver is inspected and ultrasound is performed to evaluate the exact size, location and resection margins of the tumour and to exclude other lesions. This evaluation helps to ensure good placement of the remaining ports. A 4 or 5-port "*reversed-L*" configuration is established around the medial and inferior sides of the tumour (Fig. 1). This port placement is intended to facilitate 4 transection planes running in line with the transection device.

Unlike resections in segment 7, resections in segment 8 do not usually require a full anti-clockwise rotation of right lobe. Caudal retraction of the liver using the falciform ligament is used to enable access to the postero-superior aspect of the liver. To allow this rotation, complete division of the falciform ligament back to the vena cava and division of the right coronary and triangular ligaments is required (the round and falciform ligaments should not be divided if there is concern of cirrhosis). Following mobilization, the reverse-Trendelemburg position and retraction on the falciform ligament toward the patient's pubis help to relocate segment 8 in the natural position of the segment 5/8 border.

Following liver mobilization, ultrasound is repeated and the resection margins are marked 2–3 cm away from the borders of the lesion (Fig. 2A, B). During laparoscopic surgery, it is common for surgeons to converge on the specimen; hence, it is important to add an additional 1–2 cm to the resection margins. The resection margins should be marked on the liver surface as straight transection lines as these are easier to follow, especially during deeper dissection. The markings on the liver capsule are seen as acoustic shadows on ultrasonography, allowing the surgeon to evaluate the relationship between the tumour and the intended resection line.

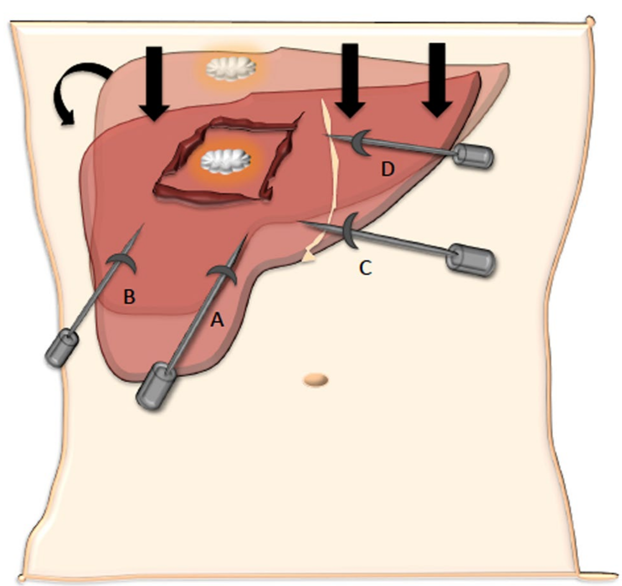

Fig. 1 The 4-port "reverse-L" configuration around the medial and inferior side of the tumour to facilitate four transection planes in line with the transection devices. The mobilization, the anti-Trendelemburg position and the retraction of the falciform ligament helps to relocate segment 8 in the natural position of the segment 5/8 border

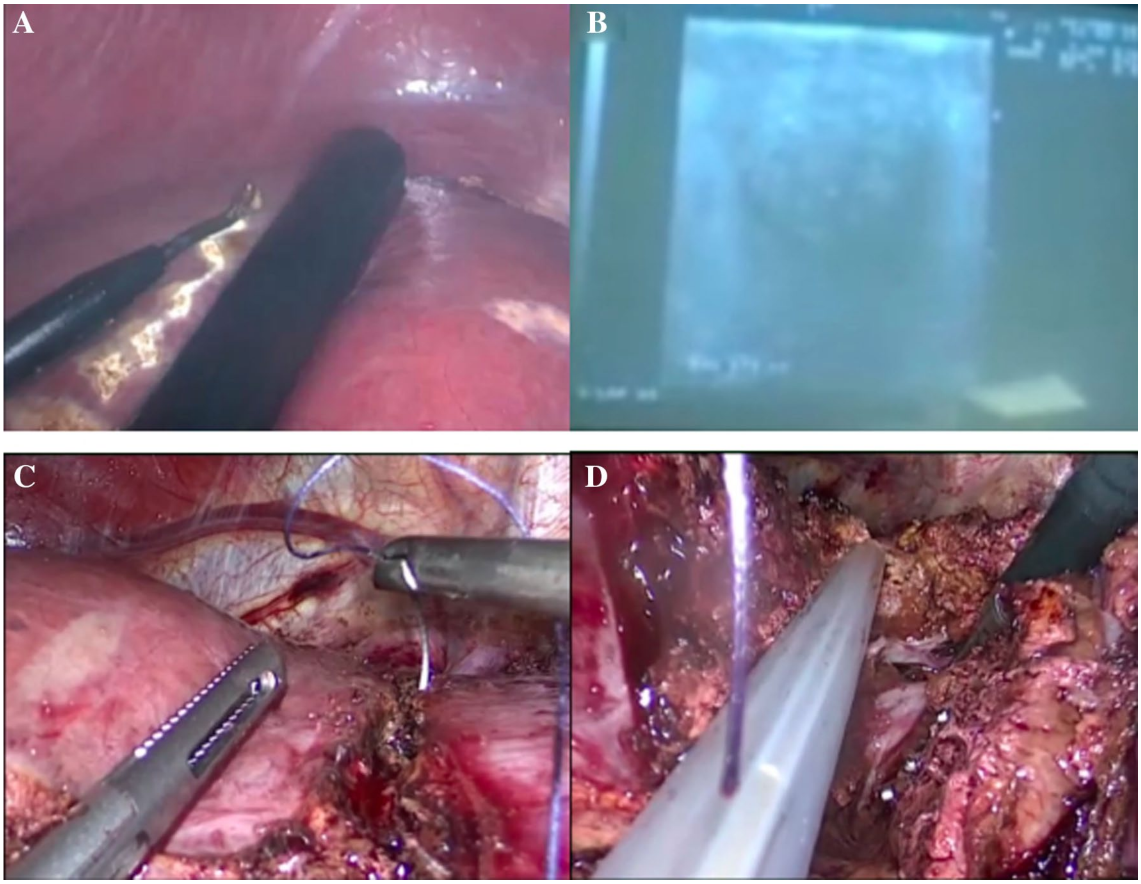

Fig. 2 Resection margins are marked 2–3 cm away from the borders of the lesion with ultrasound assistance (**A, B**). Two to four stitches are used to lift and open the resection line (**C**). Parenchymal transection is performed with ultrasonic dissector (**D**)

An intermittent Pringle's Manoeuver was freely used. To perform this manoeuvre, the hepatico-gastric ligament is opened, then, whilst lifting the liver by the falciform ligament (to provide access to the foramen of Winslow) a 5-mm nylon tape can be passed behind the portal triad and then both ends can be passed through a 10-cm rubber tube. To exteriorise the nylon tape and allow extra-corporeal control, the tape is delivered through one of the ports that is subsequently removed and replaced through the same site adjacent to the tape [12]. In the case of segment 8 resections, the port in the right flank at the level of the umbilicus is used. Pringle's Manoeuver is applied by pulling the external tape thereby pushing the internal rubber tube onto the portal triad and holding it there against the abdominal wall. This provides the necessary inflow control and also serves to move the liver to the right and inferiorly.

The parenchymal sparing transection technique has been previously described as the "*Diamond Technique*" by our group [16]. Briefly, an Ultrasonic Scalpel (LOTUS®, laparoscopic operation by torsional ultrasound; SRA Developments Ltd.) or Harmonic Ultrasonic (Harmonic ACE®; Ethicon, Johnson and Johnson) is used for the transection of the capsule and superficial plane. Two to four stitches are positioned on the edges of the specimen (away from the tumour) and used to lift and open the resection line (Fig. 2C). Cavitron Ultrasonic Surgical Aspirator (CUSA®; ValleyLab) is then used to identify deep and major vascular and biliary structures (Fig. 2D) as they can be properly controlled and divided. Using this technique allows millimetric adjustments to be made to the resection line based on the ultrasonic findings.

The lateral resection margins can be easily assessed, however, the evaluation of the deep margin can be challenging. To facilitate this, ultrasonic measurement of the distance from the liver capsule to the deepest part of the tumour can be performed and this can then provide an estimate of the depth of dissection required.

When performing deeper dissection, care must be taken and continuous ultrasonic reassessment must be performed to identify the right and middle hepatic veins (RHV, MHV). Titanium clips with 5 mm length, Hem-o-Lock® clips (Weck Closure Systems, Research Triangle Park, USA) or vascular staplers are used to divide progressively larger biliary and vascular structures (Fig. 3A).

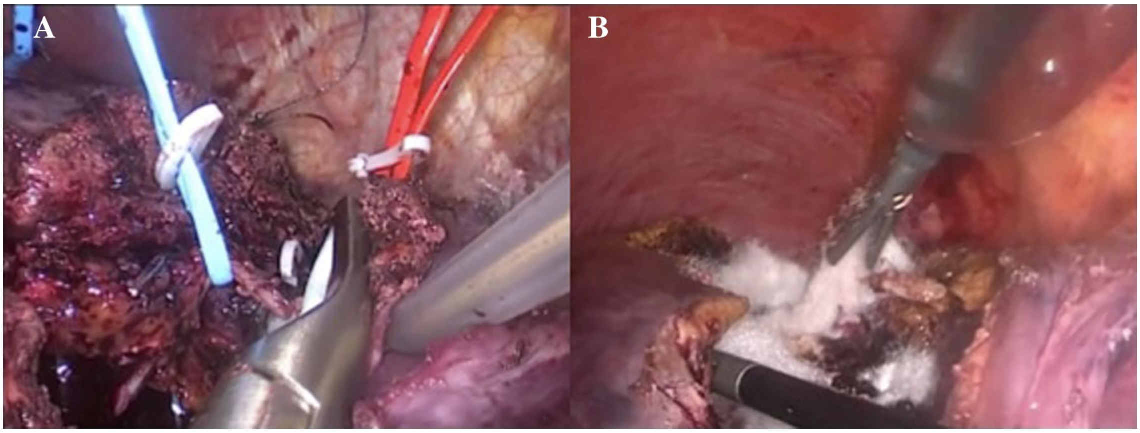

Fig. 3 Tributary branches of RHV and MHV are identified and secured with clips or staplers (**A**). Haemostatic products are administered over the transection surface (**B**)

Table 1 Baseline characteristics

Variable	S8 atypical resections, alone or with other segments ($n=30$)	S8 atypical resections ($n=13$)
Age	61 ± 13	62 ± 11.5
Women (%)	13 (45)	7 (54)
ASA 1	4	2
ASA 2	22	10
ASA 3	4	1
Tumour diameter	24 ± 14	22 ± 3.7
Preoperative Chemotherapy (%)	13 (43)	5 (17)

Table 2 Summary of liver resection

Resection	No
Segment 8	13
Segment 8 + left lateral sectionectomy	2
Segment 8 + metastasectomy in segment 4	6
Segment 8 + left hepatectomy	1
Segment 8 + segment 5/6	2
Segment 8 + segment 1 + LLS + segment 6	1
Segment 8 + wedge seg 2/3	2
Segment 8 + wedge segment 7	2
Segment 8 + segment 6/7	1

Hemostatic products such as fibrillar hemostatic (Surgicel SNoW®; Ethicon, Johnson and Johnson) or fibrin glue (Evicel®; Ethicon, Johnson and Johnson) are routinely administered over the cut surface to ensure haemostasis (Fig. 3B).

Small specimens may be retrieved from a slightly enlarged port site while larger specimens are delivered though a Pfannenstiel incision. After closing the retrieval site, haemostasis is reassessed under a normal CVP with a simultaneous Valsalva manoeuvre.

Results

Of the 650 patients undergoing LLR at our centre, 67 had resections for lesions located in postero-superior segments. Among them, 30 patients underwent right-posterior sectionectomies, 7 patients were identified with resections involving segment 7 and 30 patients had resections for lesions in segment 8. A subgroup of 13 patients underwent isolated resections of segment 8. Baseline characteristics of both groups are described in Table 1. Two patients underwent associated small bowel resection for primary Neuroendocrine tumour (NET). A summary of liver resections for patient is provided in Table 2.

Intra-operative data

One patient required conversion to open surgery due to disease burden that ultimately required a trisegmectomy of segments 6, 7 and 8. Intra-operative variables are listed in Table 3.

Post-operative outcomes

Post-operative results are described in Table 3. In our centre, the majority of patients undergoing liver resection are transferred from theatre to the high dependency unit (HDU) for their initial recovery. Post-operative complications

Table 3 Intra-operative and post-operative data

Variable	S8 atypical resections, alone or with other segments ($n=30$)	S8 atypical resections ($n=13$)
Operative time in minutes (range)	210 (90–300)	200 (90–240)
Blood loss in ml (range)	250 (20–400)	191(20–400)
Pringle manoeuver (%)	17 (57)	6 (46)
Duration of Pringle in minutes (range)	31 (20–48)	32 (30–50)
Conversion (%)	1 (3,4)	0 (0)
HDU stay in days (range)	1 (0–2)	1 (1–1)
Total stay in days (range)	4 (3–6)	4 (3–7)
Morbidity (%)	9 (30%)	3 (23%)
Minor morbidity (%)	7 (23%)	3 (23%)
Clavien Dindo I	3	2
Clavien Dindo II	4	1
Major morbidity	2 (7%)	0 (0%)
Clavien Dindo IIIa	2	0
Clavien Dindo IIIb o higher	0	0
90-day mortality	0	0

Table 4 Median margin, resection status and histology of lesions

Variable	S8 and other segments ($n=30$)	S8 resections ($n=13$)
Margin (mm)	6 (2–12)	8 (2–13)
R0 (%)	23/24 (96%)	12/13 (92%)
CRL mets	21	7
NET mets	6	4
Melanoma mets	1	1
Ovarian germ cell mets	1	1
HCC	1	0

were defined according to Clavien Dindo classification [13]. Three patients had Grade I complications: a wound haematoma, mobilization problems due to a prior sensory ganglionopathy and sore on the 6th rib. Four patients had Grade II complications: one transient atrial fibrillation, one pneumonia, one wound infection requiring antibiotic therapy and one intra-abdominal collection secondary to bile leak, treated conservatively with the surgical drain already in place from the operation.

Two patients had Grade IIIa complications: one patient was readmitted and required an image guided drainage of a collection secondary to bile leak while the other had a bile leak requiring endoscopic sphincterotomy.

Histopathology

Median margin, resection status and histology of lesions are listed in Table 4.

R0 resection margins were achieved in 23 of 24 patients where complete resection was intended. One patient with CRLM had an R1 resection (tumour margin of 0.9 mm).

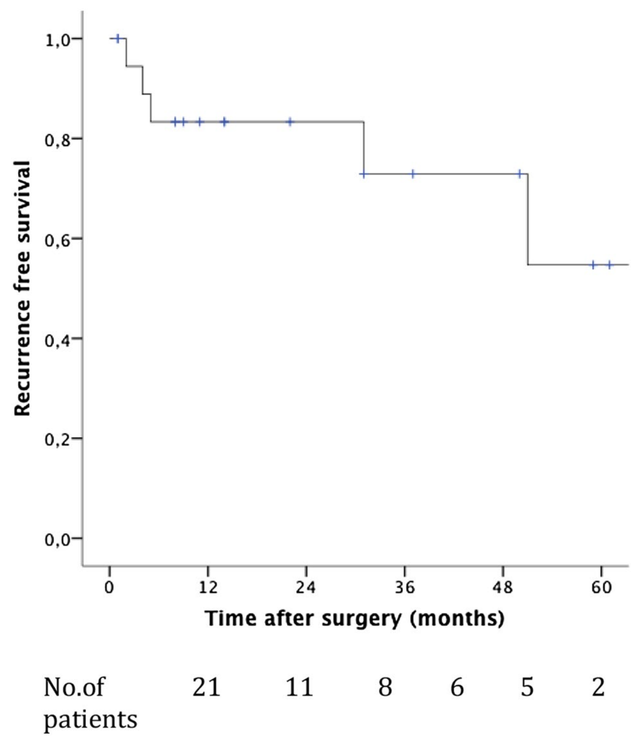

Fig. 4 RFS of patients with CRLM

Those undergoing resection for NET were treated with a debulking intention, and R1 resections (< 1 mm from resection margin) were observed in two of these patients. Both had multiple liver resections and an associated small bowel resection.

Follow-up

Long-term oncological results of the subgroup of patients with CRLM ($n=21$) were as follows: Median RFS was 59 months. RFS at 1, 3 and 5 years was 82, 71 and 54% ,respectively. Median follow-up was 31 months (Fig. 4). Median Overall Survival (OS) was 61 months. Overall survival at 1, 3 and 5 years was 94, 82 and 65%, respectively. Median follow-up was 19 months (Fig. 5).

Discussion

Laparoscopic liver surgery continues to increase in popularity, with over 9000 cases reported on a recent meta analysis [14]. When compared to open surgery, LLS has been associated with a reduced blood loss, complication rate and hospital stay with comparable operative time and resection margins [15–18]. The benefits of a minimally invasive approach continue to encourage liver surgeons to adopt laparoscopy, especially for minor liver resections.

At the Second International Consensus Conference on Laparoscopic Liver Resections, held in Morioka in October 2014, major LLR was considered as an innovative procedure to be introduced cautiously while minor LLR was confirmed as a standard practice [5]. Experience in both open liver surgery and advanced laparoscopy should be considered mandatory before commencing with LLS and complex resections should be undertaken only after gaining proficiency with minor liver resections [5].

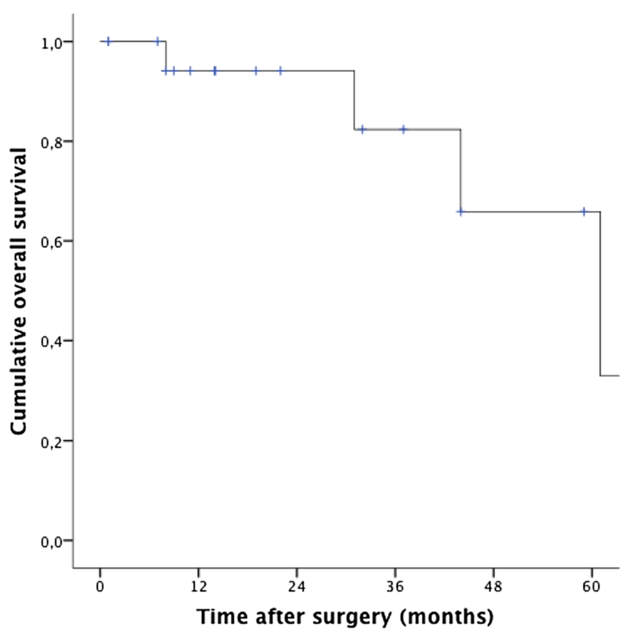

Fig. 5 OS of patients with CRLM

Our centre started performing laparoscopic liver surgery more than a decade ago. During this time, we have overcome the learning curve for minor and major resections in all segments of the liver [6–11].

Although parenchymal sparing resections in the postero-superior segments are considered as minor resections based on their anatomical size, they can be highly demanding, and we continue to consider them as "*technically major*" resections [8]. The postero-superior location and close relationship to the right and middle hepatic veins add increasing complexity to the procedure. Also does the bifurcation of the segment 8 portal pedicle, which lies deep within the hepatic parenchyma, making its resection via a Glissonean approach very difficult [16]. In addition, during transection, the branches of the right and middle hepatic vein must be divided in close proximity to the main veins.

As previously highlighted, trocar placement is variable; however, the use of the reverse-L configuration around the medial and inferior aspects of the tumour is essential. This configuration allows for four transection planes in line with the transection devices in a diamond shape to be performed. This diamond technique was originally described by our group and is well suited to these complex resections [19].

Other authors have proposed the use of intercostal trocars and a trans-thoracic approach to resections in postero-superior segments as a means of improving the view and facilitating a parenchymal sparing resection without comprising margins [20, 21]. This alternative approach could be associated with theoretical complications including lung injuries and a risk of gas leakage from the abdominal cavity into the pleural space with the subsequent subcutaneous emphysema or tension pneumothorax during surgery [20]. In our experience, the pure abdominal approach avoids these possible drawbacks and provides a parenchymal sparing resection with oncological safety. Additionally, in our series, 60% of patients underwent resections involving other liver segments limiting the possible use of the trans-thoracic approach and thus making an abdominal approach mandatory.

In this series, we report a very low conversion rate. However, conversion to open surgery should be considered when needed [22]. The operative time, even when other associated resections were needed, was in line with the current published data in LLS [23, 24] confirming the technical feasibility of this approach to resections in segment 8. In terms of blood loss, our results are consistent with other series regarding laparoscopic resections of the postero-superior segments [8, 20, 21]. Combined with a low CVP and a pneumoperitoneum the most effective strategy to reduce blood loss during liver transection is Pringle's manoeuvre. Pringle's manoeuvre was used in half of the patients and the duration of clamping was similar to that in other complex resections in segment 7 [8].

There were only small differences seen in the intra- and post-operative outcomes of patients who underwent isolated segment 8 resections and those who underwent resections involving segment 8 and other segments. Operative time, hospital stay and post-operative complications were comparable between the groups perhaps suggesting that the resection within segment 8 was the most significant part of the operation.

The morbidity rate is consistent with the published data for major LLR [14] reiterating the need for these operations to be considered as a "*technically major*" resection rather than an anatomically minor one. The results from our series confirm the safety of this procedure in centres where experience and expertise has been developed.

Laparoscopic ultrasound is essential to confirm the lesion location, to define the resection margins and to provide orientation in an area lacking in external landmarks [25, 26]. Continuous reassessment using ultrasonography, with milimetric readjustment of the transection line, is important to ensure clear resection margins. Careful dissection with the CUSA to identify and control vascular and biliary structures is required. Control of all structures is essential, not only to reduce the risk of post-operative complications, but to keep the operative field clear to facilitate vision and meticulous dissection [19].

One patient, with curative intent, had an R1 resection. However, this patient is disease free with no signs of recurrence after 4 years of follow-up. This finding is likely the result of the deeper coagulation produced at the resection margin with modern devices causing a neutralization of a microscopically positive margin. In addition, no port site metastases or peritoneal seeding were observed, confirming the oncological efficiency of the laparoscopic approach in such complex resections.

Conclusion

Our results demonstrate that laparoscopic resection of lesions in segment 8 is feasible, combining the benefits of minimally invasive surgery with parenchyma sparing resections. However, wide experience in open and laparoscopic liver surgery is essential to ensure the safety and oncological efficiency.

Compliance with ethical standards

Disclosures David Martínez-Cecilia, Martina Fontana, Najaf N. Siddiqi, Mark Halls, Salvatore Barbaro, Mohammad Abu Hilal have no conflicts of interest or financial ties to disclose.

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