Original Article

Robotic versus laparoscopic liver resection for huge (≥10 cm) liver tumors: an international multicenter propensity-score matched cohort study of 799 cases

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Background: The use of laparoscopic (LLR) and robotic liver resections (RLR) has been safely performed in many institutions for liver tumours. A large scale international multicenter study would provide stronger evidence and insight into application of these techniques for huge liver tumours ≥10 cm.

Methods: This was a retrospective review of 971 patients who underwent LLR and RLR for huge (≥10 cm) tumors at 42 international centers between 2002–2020.

Results: One hundred RLR and 699 LLR which met study criteria were included. The comparison between the 2 approaches for patients with huge tumors were performed using 1:3 propensity-score matching (PSM) (73 *vs.* 219). Before PSM, LLR was associated with significantly increased frequency of previous abdominal surgery, malignant pathology, liver cirrhosis and increased median blood. After PSM, RLR and LLR was associated with no significant difference in key perioperative outcomes including media operation time (242 *vs.* 290 min, P=0.286), transfusion rate rate (19.2% *vs.* 16.9%, P=0.652), median blood loss (200 *vs.* 300 mL, P=0.694), open conversion rate (8.2% *vs.* 11.0%, P=0.519), morbidity (28.8% *vs.* 21.9%, P=0.221), major morbidity (4.1% *vs.* 9.6%, P=0.152), mortality and postoperative length of stay (6 *vs.* 6 days, P=0.435).

Conclusions: RLR and LLR can be performed safely for selected patients with huge liver tumours with excellent outcomes. There was no significant difference in perioperative outcomes after RLR or LLR.

Keywords: Laparoscopic liver resection (LLR); robotic liver resection (RLR); hepatocellular carcinoma; colorectal liver metastases; huge

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Introduction

The minimally invasive approach to liver resection (MILR) for liver tumours has been proven to be safe and effective especially for minor liver resection (LR) (1-3). The short-term advantages over open surgery include less blood loss, less transfusion requirement, shorter hospital stays and less morbidities (3). The number of laparoscopic and robotic minor LR performed worldwide has proliferated in recent years. Nonetheless, most major and complex hepatectomies today are still performed via the traditional open approach (1-5). The slow development of major and complex LR by the minimally invasive approach is not surprising as the learning curve for this approach is long and steep (6-9).

A growing body of literature has demonstrated that MILR can be safely carried out in expert centers, and indications for MILR have been expanding. In Asia, for example, MILR for donor hepatectomy has been adopted cautiously in several high-volume centers (10). In a similar vein, resection of huge (≥10 cm) tumours—which were previously considered a contraindication to MILR (11)—was recently reported in a small single-surgeon study, which suggested that if surgeons can overcome the technical difficulties of resecting huge tumours via the minimally-invasive approach, the benefits of minimally invasive surgery could still be maintained (12). Given the paucity of data and potential biases inherent in small single-center studies, a large scale international multicenter study would provide stronger evidence and insight into MILR for huge tumours.

As some recent studies have suggested that robotic liver resections (RLR) may be associated with advantages over laparoscopic liver resections (LLR), we performed the present study with the primary objective of comparing the outcomes between LLR and RLR for huge liver tumours to determine if robotic assistance may be advantageous in this subset of patients. To the best of our knowledge, this study represents the largest series to date focusing on the application of LLR and RLR in this group of patients. We present the following article in accordance with the STROBE reporting checklist (available at https://hbsn.amegroups.com/article/view/10.21037/hbsn-22-283/rc).

Highlight box

Key findings

- Both robotic and laparoscopic liver resections can be performed safely for selected patients with huge liver tumours with excellent outcomes. There was no significant difference in perioperative outcomes after RLR or LLR.

What is known and what is new?

- The use of laparoscopic and robotic liver resections has been widely adopted and safely performed in many institutions. Information on the application of the minimally-invasive approach for huge (≥10 cm) tumours remains limited.
- This study provides new data demonstrating the safety and feasibility of performing laparoscopic and robotic liver resections for huge tumours.

What is the implication, and what should change now?

- Minimally-invasive surgery should be used even for huge liver tumors when performed by experienced surgeons. Future prospective studies with long-term outcomes are needed to determine its oncological safety in comparison with the open approach and to compare between the robotic and laparoscopic approach.

Methods

This was a retrospective review of 971 patients who underwent MILR for huge (≥10 cm) tumors at 42 international centers between 2002 and 2020. All institutions obtained their respective approvals according to their local center's requirements. This retrospective study on anonymized patient data was approved by the Singapore General Hospital Institution Review Board (No. 2020/2802) and the need for any further board review and patient consent was waived. The anonymized data were collected in the individual centers. These were collated and analyzed centrally at the Singapore General Hospital. The study was performed in accordance with the Declaration of Helsinki (as revised in 2013).

After exclusion of patients who underwent hepatectomy with bilio-enteric anastomoses, resection of cysts and cystic tumors such as cystadenoma, gallbladder carcinoma and intrahepatic stones; there were 853 cases. A further 24 cases of laparoscopic-assisted (hybrid) resections were excluded. Of the 829 cases, there were 699 pure LLR, 100 RLR and 30 hand-assisted laparoscopic (HAL)-LR. The 30 HAL were excluded from further analyses.

Definitions

LR were defined according to the 2000 Brisbane classification (13). Major resections were classified as resection of 3 or more contiguous segments. Additionally, right anterior and right posterior sectionectomies were also considered major resections in this study (14-16). This is due to the wide surface area for parenchymal transection associated with these resections (14-16).

Portal hypertension was defined based on clinical criteria such as the presence of ascites, varices or splenomegaly with a platelet count of less than 100,000/μL as portal pressure was not routinely measured in most centers. Diameter of the largest lesion was used in the cases of multiple tumors. Huge tumors were defined as tumors with a size ≥10 cm based on histology. Post-operative complications were classified according to the Clavien-Dindo classification and recorded for up to 30 days or during the same hospitalization (17). Difficulty of resections were graded according to the Iwate score and Institute Mutualiste Montsouris (IMM) score (18,19).

Statistical analyses

The comparisons between the robotic and laparoscopic approaches for patients with huge tumors were accomplished using propensity-score matching (PSM). Propensity-scores were developed using Firth logit modelling of all baseline characteristics shown in *Table 1*. This included variables such as age, year of surgery, gender, American Society of Anesthesiologists (ASA), previous abdominal surgery or previous liver surgery, patho, Child-Pugh status, portal hypertension, tumor size, multifocal, multiple resections, concomitant other surgery, major resection, Iwate score and IMM difficulty grade. This model exhibited excellent discrimination [area under the curve (AUC) =0.827, bias-corrected 95% confidence interval (CI): 0.788–0.866] and good calibration (P=0.512 from Hosmer-Lemeshow test with 10 deciles) (Figures S1,S2). PSM was performed using 1:3 greedy matching algorithm without replacement and with a caliper of 0.20*standard deviations of the linear predictor (i.e., log odds of the propensity score). Propensity-score distributions and covariates were well-balanced after matching (Figures S3-S5). As there was minimal missing data, complete cases analysis with no imputation was performed.

In the unmatched cohorts, comparisons of patient characteristics and peri-operative outcomes between patients were performed using the Mann-Whitney U test and Pearson's χ^2 test for continuous and categorical variables respectively. Comparisons in the matched cohorts took into account the paired nature of the data; hence, mixed-effects quantile regression (with a random-effects denoting matched sets) and conditional logit regression were used in 1:3 matched analyses of continuous and binary data respectively. Statistical analyses were done in Stata version 16.0 (StataCorp), and nominal P<0.05 were considered to indicate statistical significance.

Results

Comparison between RLR vs. LLR for huge tumors in the entire unmatched and matched cohort

Seven hundred and ninety-nine cases met study selection criteria of which 100 underwent RLR and 699 underwent LLR during the study period. LLR group patient was associated with significantly more previous abdominal surgery (P=0.006), more malignant pathology (P=0.010), more liver cirrhosis (P=0.047) and more median blood loss (300 *vs.* 200 mL, P=0.018) (*Tables 1,2*).

PSM and inverse probability of treatment-weighting (IPTW) were performed using the same demographic data criteria as mentioned above to develop propensity-scores. After 1:3 PSM with 73 patients in the RLR arm and 219 patients in the LLR arm, both groups had comparable preoperative co morbid condition, liver function, tumour size, numbers and stage of disease.

RLR and LLR were associated with no significant difference in median operation time (242 *vs.* 290 min, P=0.286), transfusion rate (19.2% *vs.* 16.9%, P=0.652), median blood loss (200 *vs.* 300 mL, P=0.694), morbidity (28.8% *vs.* 21.9%, P=0.221), major morbidity (4.1% *vs.* 9.6%, P=0.152), frequency of Pringle maneuver application (54.8% *vs.* 61.8%, P=0.264) and postoperative length of stay (6 *vs.* 6 days, P=0.435).

There were 4 in-hospital mortalities in the LLR group (1.8%) and 0 hospital mortality in the RLR group (P=0.57). The major morbidity rate (Clavien-Dindo grade >2) was 9.6% *vs.* 4.1% respectively (P=0.152). The most common major morbidities in the LLR group included bile leak (n=19), postoperative collection (n=13), pulmonary complications (n=14), postoperative liver failure (n=6), postoperative bleeding (n=5) and wound complications (n=2). The major morbidities in the RLR group included bile leak (n=2) and postoperative collection (n=2). All these results are summarized in *Tables 1,2*.

Discussion

In the current analysis after 1:3 PSM, we observed no significant difference with regards to the key perioperative outcomes such as open conversion rate, blood loss, blood transfusion rate, morbidity, major morbidity and postoperative stay between RLR and LLR for huge liver tumors.

We had previously published an international multicenter study on the application of MILR for huge liver tumours showed that with careful patient selection, MILR could be performed safely in this subset of patients. Many participating specialized centers with expertise had demonstrated the feasibility and safety of resecting huge liver tumours by the minimally invasive approach (20). In the study, comparison between MILR for 174 huge tumors with 174 large (3–9.9 cm) tumors demonstrated not unexpectedly poorer outcomes in terms of blood loss, major morbidity and length of stay. However, the perioperative outcomes of MILR for huge tumors compared favourably with previous studies reporting on open LR for huge tumours (20).

More recently, the use of the robotic platform to facilitate LR has been advocated by several centers. It

Table 1 Comparison between baseline clinicopathological characteristics of RLR *vs.* LLR for huge (≥10 cm) tumors

Baseline characteristics	Overall (n=799)	Unmatched cohort			1:3 propensity-score matched cohort		
		RLR (n=100)	LLR (n=699)	P value	RLR (n=73)	LLR (n=219)	P value
Median age [IQR], years	60 [46–61)	54 [41–66]	60 [46–71]	0.004	54 [40–66]	55 [42–68]	0.544
Year of surgery, n (%)				0.001			0.846
2002–2010	75 (9.4)	0 (0.0)	75 (10.7)		0 (0.0)	1 (0.5)	
2011–2015	175 (21.9)	20 (20.0)	155 (22.2)		17 (23.3)	51 (23.3)	
2016–2020	549 (68.7)	80 (80.0)	469 (67.1)		56 (76.7)	167 (76.3)	
Male sex, n (%)	412/798 (51.6)	48/100 (48.0)	364/698 (52.1)	0.437	34 (46.6)	105 (47.9)	0.839
ASA score, n (%)				0.938			0.649
I/II	609/798 (75.3)	75/100 (75.0)	526/698 (75.4)		51 (69.9)	159 (72.6)	
III/IV	197/798 (24.7)	25/100 (25.0)	172/698 (24.6)		22 (30.1)	60 (27.4)	
Median BMI, [IQR] kg/m^2	24.7 [22.3–27.5]	25.0 [23.0–28.5]	24.7 [22.1–27.4]	0.209	25.0 [22.6–28.5]	24.0 [21.6–27.3]	0.123
Previous abdominal surgery, n (%)	256 (32.0)	20 (20.0)	236 (33.8)	0.006	16 (21.9)	52 (23.7)	0.750
Previous liver surgery, n (%)	48 (6.0)	2 (2.0)	46 (6.6)	0.071	1 (1.4)	3 (1.4)	1.000
Malignant pathology, n (%)	560 (70.1)	59 (59.0)	501 (71.7)	0.010	41 (56.2)	140 (63.9)	0.232
Pathology type, n/n (%)				0.026			0.840
HCC	296/798 (37.1)	36/100 (36.0)	260/698 (37.2)		24 (32.9)	82 (37.4)	
Intrahepatic cholangiocarcinoma	83/798 (10.4)	12/100 (12.0)	71/698 (10.2)		8 (11.0)	26 (11.9)	
CRM and other metastases	168/798 (21.1)	10/100 (10.0)	158/698 (22.6)		8 (11.0)	29 (13.2)	
FNH/adenoma/hemangioma	223/798 (27.9)	37/100 (37.0)	186/698 (26.6)		30 (41.1)	75 (34.2)	
Others	28/798 (3.5)	5/100 (5.0)	23/68 (3.3)		3 (4.1)	7 (3.2)	
Cirrhosis, n (%)	150 (18.8)	13 (13.0)	137 (19.6)	0.114	10 (13.7)	33 (15.1)	0.774
Child-Pugh score, n (%)				0.047			0.795
No cirrhosis	651 (81.5)	87 (87.0)	564 (80.7)		63 (86.3)	186 (84.9)	
A	131 (16.4)	9 (9.0)	122 (17.5)		8 (11.0)	29 (13.2)	
B	17 (2.1)	4 (4.0)	13 (1.9)		2 (2.7)	4 (1.8)	
Portal hypertension, n (%)	15/795 (1.9)	4/100 (4.0)	11/698 (1.6)	0.097	2 (2.7)	6 (2.7)	1.000
Median tumor size, mm [IQR]	110 [100–134]	115 [100–132]	110 [100–135]	0.585	115 [100–135]	110 [100–130]	0.340
Multiple tumors, n (%)	140 (17.5)	11 (11.0)	129 (18.5)	0.067	10 (13.7)	31 (14.2)	0.922
Multiple resections, n (%)	49 (6.1)	3 (3.0)	46 (6.6)	0.163	3 (4.1)	15 (6.8)	0.411
Concomitant operation excluding cholecystectomy, n (%)	94 (11.8)	10 (10.0)	84 (12.0)	0.558	8 (11.0)	21 (9.6)	0.733
Major resection (minimally-invasive criteria), n (%)	466 (58.3)	61 (61.0)	405 (57.9)	0.562	46 (63.0)	137 (62.6)	0.945

Table 1 (*continued*)

Table 1 (*continued*)

Baseline characteristics	Overall (n=799)	Unmatched cohort			1:3 propensity-score matched cohort		
		RLR (n=100)	LLR (n=699)	P value	RLR (n=73)	LLR (n=219)	P value
Iwate score, n (%)				0.278			0.989
Low	21/797 (2.6)	1/100 (1.0)	20/697 (2.9)		1 (1.4)	4 (1.8)	
Intermediate	241/797 (30.2)	24/100 (24.0)	217/697 (31.1)		16 (21.9)	50 (22.8)	
High	154/797 (19.3)	23/100 (23.0)	131/697 (18.8)		15 (20.6)	46 (21.0)	
Expert	381/797 (47.8)	52/100 (52.0)	329/697 (47.2)		41 (56.2)	119 (54.3)	
IMM difficulty, n (%)				0.353			0.742
I	254 (31.8)	26 (26.0)	228 (32.6)		16 (21.9%)	51 (23.3)	
II	11 (23.9)	28 (28.0)	163 (23.3)		17 (23.3%)	59 (26.9)	
III	354 (44.3)	46 (46.0)	308 (44.1)		40 (54.8%)	109 (49.8)	
Type of resection, n (%)				0.070			0.993
Wedge anterolateral	46 (5.8)	4 (4.0)	42 (6.0)		4 (5.5)	15 (6.8)	
Wedge posterosuperior	25 (3.1)	8 (8.0)	17 (2.4)		3 (4.1)	12 (5.5)	
Left lateral sectionectomy	183 (22.9)	14 (14.0)	169 (24.2)		9 (12.3)	24 (11.0)	
Segmentectomy anterolateral	53 (6.6)	8 (8.0)	45 (6.4)		6 (8.2)	23 (10.5)	
Left hepatectomy	139 (17.4)	20 (20.0)	119 (17.0)		11 (15.1)	37 (16.9)	
Segmentectomy posterosuperior	27 (3.4)	5 (5.0)	22 (3.1)		5 (6.8)	8 (3.7)	
Right hepatectomy	228 (28.5)	27 (27.0)	201 (28.8)		23 (31.5)	66 (30.1)	
Extended right hepatectomy	31 (3.9)	3 (3.0)	28 (4.0)		3 (4.1)	9 (4.1)	
Right posterior sectionectomy	43 (5.4)	7 (7.0)	36 (5.2)		6 (8.2)	16 (7.3)	
Right anterior sectionectomy/ central hepatectomy	13 (1.6)	3 (3.0)	10 (1.4)		2 (2.7)	7 (3.2)	
Extended left hepatectomy	11 (1.4)	1 (1.0)	10 (1.4)		1 (1.4)	2 (0.9)	

RLR, robotic liver resection; LLR, laparoscopic liver resection; IQR, interquartile range; ASA, American Society of Anesthesiologists; BMI, body mass index; HCC, hepatocellular carcinoma; CRM, colorectal metastases; FNH, focal nodular hyperplasia; IMM, Institute Mutualiste Montsouris.

has been suggested that the use of robotic assistance may decrease the learning curve and increase the application of minimally invasive approach for LR (21-26). Hence with these results in mind, we performed the present analysis to determine if RLR was associated with any advantages over LLR in the subset patients with huge liver tumors.

LR for huge tumors larger than 10 cm was traditionally considered a contraindication for the minimally invasive approach. However as demonstrated in this study; with increasing experience, expert centers have now pushed the limits and MILR for huge tumors is no longer a rarity. Over 75% of the patients in this study were classified as of high or expert difficulty according to the Iwate system. The potential advantages of the minimally invasive approach are illustrated in the current analysis as shown by the low blood transfusion, morbidity and mortality rate. During conventional open LR, a large muscle-cutting upper abdominal wound is required in order to provide adequate exposure for meticulous dissection and haemostasis especially for huge tumours. During the minimally invasive approach, some may argue that a generous incision is still required for specimen delivery. However, the surgical incision may be transferred from an upper abdominal to a lower abdominal incision (Pfannenstiel or lower midline) resulting in less pain and better cosmesis. This may also potentially result in a reduction in pulmonary complications (8).

During MILR, it is well-known that pneumoperitoneum may reduce blood loss especially from the hepatic vein

Table 2 Comparison between perioperative outcomes of RLR *vs.* LLR for huge (≥10 cm) tumors

Perioperative outcomes	Unmatched cohort				1:3 propensity-score matching		
	Overall (n=799)	RLR (n=100)	LLR (n=699)	P value	RLR (n=73)	LLR (n=219)	P value
Median operating time [IQR], min	270 [190–346]	236 [176–337]	270 [193–349]	0.256	242 [197–359]	290 [210–360]	0.286
Median blood loss [IQR], mL	300 [150–300]	200 [100–500]	300 [150–500]	0.018	200 [100–500]	300 [110–500]	0.694
Blood loss (categories), n/n (%), mL				0.720			0.511
<500	536/742 (72.2)	73/99 (73.7)	463/643 (72.0)		50/72 (69.4)	149/204 (73.0)	
≥500	206/742 (27.8)	26/99 (26.3)	180/643 (28.0)		22/72 (30.6)	55/204 (27.0)	
Intraoperative blood transfusion, n/n (%)	140/797 (17.6)	15/100 (15.0)	125/697 (17.9)	0.471	14/73 (19.2)	37/219 (16.9)	0.652
Pringle maneuver applied, n/n (%)	424/769 (55.1)	56/100 (56.0)	368/669 (55.0)	0.852	40/73 (54.8)	131/212 (61.8)	0.264
Median Pringle duration when applied [IQR], min	40 [24–60]	40 [20–60]	40 [24–60]	0.738	45 [26–60]	45 [30–61]	0.745
Open conversion, n (%)	105 (13.1)	8 (8.0)	97 (13.9)	0.104	6/73 (8.2)	24/219 (11.0)	0.519
Median postoperative stay [IQR], days	6 [4–8]	6 [4–8]	6 [4–8]	0.505	6 [4–9]	6 [4–7]	0.435
30-day readmission, n/n (%)	40/789 (5.1)	3/100 (3.0)	37/689 (5.4)	0.313	2/73 (2.7)	17/217 (7.8)	0.133
Postoperative morbidity, n (%)	190 (23.8)	26 (26.0%)	164 (23.5)	0.577	21/73 (28.8)	48/219 (21.9)	0.221
Major morbidity (Clavien-Dindo grade >2), n (%)	72 (9.0)	4 (4.0)	68 (9.7)	0.061	3/73 (4.1)	21/219 (9.6)	0.152
Reoperation, n (%)	17 (2.1)	0 (0.0)	17 (2.4)	0.115	0/73 (0.0)	3/219 (1.4)	0.576
In-hospital mortality, n (%)	11 (1.4)	0 (0.0)	11 (1.6)	0.207	0/73 (0.0)	4/219 (1.8)	0.575
90-day mortality, n (%)	16 (2.0)	0 (0.0)	16 (2.3)	0.126	0/73 (0.0)	6/219 (2.7)	0.342
Close/involved margins (≤1 mm) for malignancies, n/n (%)	88/557 (15.8)	9/59 (15.3)	79/498 (15.9)	0.935	7/41 (17.1)	31/139 (22.3)	0.654

RLR, robotic liver resection; LLR, laparoscopic liver resection; IQR, interquartile range.

tributaries. This was supported in the present study, whereby the median blood loss after MILR for huge tumours was only 300 mL. This finding compared favorably with a recent publication on open hepatectomy for huge tumours (27).

It must be highlighted that performing MILR for huge liver tumours is extremely technically challenging and should only be performed by highly experienced expert surgeons. Numerous challenges resulting from the space-occupying effect of the huge lesion, include distortion of the normal anatomy, compression of the major portal pedicles, compression of hepatic veins leading to higher venous pressure, limited space for manipulation during surgery, development of large collateral vessels supplying the tumor and presence of tumour invasion or adhesions to adjacent structures. These challenges increase the risk of intraoperative complications such as major bleeding, tumor rupture or compromise in surgical margins (20,28).

The adoption of RLR has been increasing in recent years due to its potential advantages such as the seven degrees of freedom of the robotic system which may theoretically overcome the difficulties arising from rigid laparoscopic instruments. Robotic instruments may also facilitate the fine extrahepatic hilar dissection of individual hepatic artery and portal vein in major LR particularly when the anatomy is distorted. It may also enhance the dissection and control of short hepatic veins in the hepatocaval region and allows easier suture plication of bleeders during parenchymal transection (29). In addition, RLR is more ergonomic for the surgeon which may reduce the physical or musculoskeletal stress of surgeons and in the long run may reduce technical error as a result of human fatigue (23,30,31).

Presently, increasing evidence in the literature has demonstrated that RLR is associated with a shorter learning curve compared LLR (32-34) and it may also allow an increased proportion of hepatectomies at advanced difficulty level to be completed via purely minimally invasive approach (21,24,26,32). However, it has to be highlighted that the learning curve is unlikely to be a major confounder in this study as surgeons are less likely to attempt resections for huge tumors during their early experience. The major limitation of robotic surgery compared to laparoscopy include the limited access and availability to the platform and relative high costs of the operation (24,26,32,35). Furthermore, the choice of operating instruments specifically for liver surgery are more limited when compared to laparoscopy. Specifically, the Cavitron Ultrasonic Surgical Aspirator (CUSA) is not available in the robotic platform. However, with the introduction of several new models of surgical robots in the market, it can be anticipated that the barrier to access and cost of the robotic platform would likely decrease (22,23,35).

The main limitation of the current study is its retrospective nature and its associated biases. Despite matching, selection bias may have still have confounded the results observed. Furthermore, since this was a multi-center comparative study, there were differences in the institution or individual surgeon's MILR experience and surgical techniques deployed during MILR. Unfortunately, detailed information about individual surgeon experience was not available from this database. However, the heterogeneity in the surgical technique adopted by the different centers. enhances the external validity and generalizability of these findings as it reflects current real-world practice.

Conclusions

MILR can be safely performed in selected patients with huge liver tumours with excellent outcomes. There was no significant difference in perioperative outcomes after RLR and LLR for huge liver tumors.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://hbsn.amegroups.com/article/view/10.21037/hbsn-22-283/rc

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was performed in accordance with the Declaration of Helsinki (as revised in 2013). This retrospective study on anonymized patient data was approved by the Singapore General Hospital Institution Review Board (No. 2020/2802) and the need for any further board review and patient consent was waived.

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