INTRODUCTION

Living donor liver transplantation (LDLT) is a treatment that serves as a temporary bridge for endstage liver disease patients in the event a cadaveric donor is unavailable. However, the demand for LDLT is high, especially in countries like Japan where there is a severe shortage of cadaveric donors. The most important disadvantage of LDLT is the significant risk of death incurred by the healthy living donor. Therefore, when performing LDLT, donor safety is paramount.

Information sharing, including videos of LDLT procedures, has led to rapid innovation in the technology, instruments, and surgical techniques used for LDLT, innovation that includes laparoscopic hepatectomy. Laparoscopic hepatectomy requires only a small incision and is minimally invasive, which is appealing and beneficial for both the patient and the healthy donor undergoing the procedure.

However, laparoscopic hepatectomy is still relatively new and requires special skills to be performed adequately and safely. Various techniques, such as robot-assisted surgery, are currently only performed by specialized and experienced surgeons.

Indeed, a series of mortalities following the use of laparoscopic hepatectomy at an institute in Japan resulted in a great sense of caution regarding the development and use of laparoscopic hepatobiliary and pancreatic surgery.

In this review, we summarize both the historical development and current status of laparoscopic living-donor hepatectomy.

TECHNICAL DEVELOPMENT IN LAPAROSCOPIC LIVING-DONOR HEPATECTOMY

Similar to the development of open living-donor hepatectomy, laparoscopic living-donor hepatectomy began by using a graft of the left lateral section (LLS) of the liver as was first reported by Cherqui et al in 2002.

Information and experience regarding laparoscopic major hepatectomies in nondonor patients accumulated during this
| Author       | Institution | Country | Year | PLLDRH (n) | Control (open surgery) (n) | Opt time (min) | Blood loss (ml) | WIT (min) | Conversion rate | Reasons for conversion |
|-------------|-------------|---------|------|------------|----------------------------|----------------|-----------------|-----------|-----------------|------------------------|
| Takahara T  | Iwate       | Japan   | 2017 | 5 (+9 other types) | 40 (Hybrid) | 455 vs 380 | 81 vs 239 | 9.1 ± 2.1 | 7.1%           | Difficulty with hilar dissection (n = 1) |
| Hong SK     | Seoul NU    | Korea   | 2018 | 26         | 26             | 305 vs 202 | ND             | 9.3 ± 2.5 | ND              | Not mentioned           |
| Samstein B  | NY          | USA     | 2018 | 20 (+31 LLS) | 51            | 429 vs 389 | 236 vs 405 | ND        | 9.8%           | Nonvisual HA (n = 1), parenchymal transection time (n = 2), difficulty with mobilization (n = 2) |
| Suh KS      | Seoul NU    | Korea   | 2018 | 45         | 42             | 331 vs 280 | 436 vs 338 | 12.6 ± 4.4 | 0.0%           | None                   |
| Lee KW      | Seoul NU    | Korea   | 2018 | 115        | ND             | 321          | 394          | 11.0 ± 6.7 | ND              | Not mentioned           |
| Kwon CHD    | Samsung     | Korea   | 2018 | 54         | ND             | 436          | 300          | 6 (2-12)    | 7.4%           | PV stenosis (n = 1), PV injury (n = 1), fatty liver (n = 1) |
| Park J      | Samsung     | Korea   | 2019 | 91         | 197            | 365 vs 326 | 300 vs 300 | ND        | 5.5%           | PV injury (n = 2), PV stenosis (n = 1), Remnant bile duct injury (n = 1), Small remnant volume (n = 1) |
| Lee B       | Seoul NU Bundang | Korea | 2019 | 33         | 43             | 434 vs 346 | 572 vs 559 | ND        | 6.1%           | Bleeding (n = 2)        |
| Rhu J       | Samsung     | Korea   | 2019 | 100        | 205            | 375 vs 329 | 299 vs 344 | 4.5 (1.7-31) | 6.0%           | PV stenosis (n = 1), PV injury (n = 2), fatty liver (n = 1), Left hepatic duct injury (n = 1), IVC injury (n = 1) |
| Hasegawa    | Iwate       | Japan   | 2019 | 8 (+3 Left lobe) | ND         | 387          | 75          | 5 (2-10)   | 9.1%           | RHV misfire (n = 1)     |
| Hong SK     | Seoul NU    | Korea   | 2019 | 100        | ND             | 320          | ND           | 11.3 ± 6.2 | 0.0%           | None                   |
| Rhu J       | Samsung     | Korea   | 2020 | 103        | 96             | 252 vs 301 | 200 vs 300 | 3.1 (2.7-4.2) | ND             | Not mentioned           |
| Jeong JS    | Samsung     | Korea   | 2020 | 138        | 187            | 335 vs 330 | 300 vs 334 | ND        | 3.6%           | PV stenosis (n = 2), PV injury (n = 1), left bile duct injury (n = 1), IVC injury (n = 1) |

| Morbidity (donor) ≥ CD3a | Morbidity (recipient) | 30-day mortality (recipient) | Morbidity (recipient) PV/H/A/HV | Morbidity (recipient) Bile duct | Reference |
|--------------------------|-----------------------|-----------------------------|-----------------------------|-------------------------------|-----------|
| 21.4%                    | 71.4%                 | 14.3%                       | 7.1%                        | 14.3%                         | 47        |

(Continues)
| Morbidity (donor) ≥ CD3a | Morbidity (recipient) | 30-day mortality (recipient) | Morbidity (recipient) PV/HA/HV | Morbidity (recipient) Bile duct | Reference |
|-------------------------|-----------------------|-----------------------------|-------------------------------|-------------------------------|-----------|
| 7.7%                    | 25.0%                 | 3.3%                        | 11.6%                         | 20.0%                         | 48        |
| 12.0%                   | ND                    | ND                          | 5.9%                          | ND                            | 49        |
| 2.2%                    | 24.4%                 | 2.2%                        | 11.1%                         | 2.2%                          | 50        |
| 2.6%                    | 22.6%                 | 1.7%                        | 6.9%                          | 5.2%                          | 80        |
| 16.6%                   | ND                    | 9.3%<sup>b</sup>            | 7.4%                          | 31.5%                         | 81        |
| 15.4%                   | 46.2%                 | 3.3%                        | ND                            | ND                            | 52        |
| 9.1%                    | 30.3%                 | 9.1%                        | 12.1%                         | 12.1%                         | 53        |
| 15.0%                   | 28.0%                 | 0.0%                        | 8.0%                          | 15.0%                         | 54        |
| 9.1%                    | ND                    | 0.0%                        | 0.0%                          | 27.2%                         | 78        |
| 2.0%                    | 27.0%                 | 2.0%                        | 6.0%                          | 9.0%                          | 85        |
| 4.9%                    | 56.3%                 | 3.9%                        | ND                            | ND                            | 55        |
| 11.4%                   | ND                    | ND                          | ND                            | ND                            | 56        |

HA, hepatic artery; HV, hepatic vein; IVC, inferior vena cava; LLS, left lateral sectionectomy; ND, not described; NU, national university; NY, New York; PLLDRH, pure laparoscopic living donor right hepatectomy; PV, portal vein; RHV, right hepatic vein; WIT, warm ischemic time.

<sup>a</sup>Cumulative incident ratio.

<sup>b</sup>Graft failure.
period, and laparoscopic hepatectomy gradually advanced to the point of using a pure laparoscopic approach for right lobectomies in nondonor patients. Hand-assisted laparoscopic surgery (HALS) in nondonor patients was also reported, and both HALS and pure laparoscopic lobectomies were developed concurrently. Right lobe hepatectomy in a living donor using HALS was first reported in 2006. However, despite the publication of a few additional studies, HALS hepatectomy has not been widely used after publication of this first report.

Expanding the graft type to include the left or right lobe of the liver using a pure laparoscopic approach in a living donor was not reported until 2013. This initiated the first phase of development for pure laparoscopic living donor lobectomies, which was described in multiple case reports that focused primarily on the feasibility of the procedure. A second phase followed thereafter that focused mostly on pure laparoscopic living-donor right hepatectomies (PLLDRH). After 2013, many case reports and studies comparing laparoscopic lobectomy with open lobectomy were published. Comparative studies between PLLDRH and conventional open living-donor right hepatectomy performed at experienced transplant centers were conducted, and the feasibility and safety of this technique were confirmed (Table 1). Among these reports, the largest study, by Jeong et al., used a propensity score matching analysis that determined the incidence of postoperative complications was similar between open donor right hepatectomy and PLLDRH, and less postoperative pulmonary complications, opioid requirements, and hospital stays were required for PLLDRH patients. It is worth noting that there are very few institutions, and most of these in Korea, that have reported on more than five cases of PLLDRH, suggesting that the clinical application of this procedure is still very limited, even within specific high-volume institutions.

At consensus meetings held in Morioka in 2014 and in Seoul in 2016, laparoscopic living-donor hepatectomy was discussed, and it was concluded that pure laparoscopic left lateral sectionectomy was a viable and safe procedure; however, pure laparoscopic left or right lobectomies were determined to require further clinical study and these procedures were recommended for use only at experienced transplant centers. A robot-assisted donor hepatectomy was first conducted in 2012, and additional reports regarding this procedure since then have been limited.

Parallel to the advancement of pure laparoscopic donor hepatectomy, mini-incision or hybrid donor hepatectomy was also developed and increasingly utilized, mostly in Japan. A left lateral sectionectomy via a mini-incision is feasible without laparoscopy, although laparoscopy does make the procedure easier. Furthermore, laparoscopic mobilization is more appropriate for left or right lobectomies due to the enhanced view and increased safety it provides. In the hybrid technique, laparoscopic mobilization of the liver is performed first and then a small midline incision is used to complete the rest of the procedure as an open surgery. Hybrid hepatectomy and HALS were, therefore, adopted at many centers to ensure donor safety during surgery. Nevertheless, hybrid hepatectomy is not the ultimate goal; rather, it represents an interim method that allows for smaller incisions during donor hepatectomy and results in superior outcomes regarding donor satisfaction.

3 | TWO-DIMENSIONAL EXPANSION AND THE FIVE STEPS OF LAPAROSCOPIC DONOR HEPATECTOMY

Laparoscopic donor hepatectomy has developed in two dimensions (Figure 1). The first developmental dimension involved expanding the graft type that was used and progressed from the LLS to the left lobe and the right lobe. Indeed, the overall technical difficulty associated with this surgery, as well as its incidence of morbidity and mortality, depends on the graft type and is smallest for the LLS but increases with progression to the left and right lobes. The second developmental dimension involved the type of

FIGURE 1 Two-dimensional expansion of laparoscopic donor hepatectomy. Laparoscopic donor hepatectomy development has expanded in two dimensions. One dimension is the graft type, progressing from the LLS to the left lobe and the right lobe. The second dimension is the type of laparoscopic assistance used, ranging from open, hybrid hepatectomy to pure laparoscopic procedures. Pure laparoscopic left or right hepatectomy can progress through the A, B, or C pathway. LLS: left lateral section, L/R lobe: left/right lobe.
laparoscopic assistance used and progressed from open hepatectomy to hybrid hepatectomy to pure laparoscopic hepatectomy. Figure 1 provides a visual representation of the various developmental processes that have occurred. Developmental process A focuses on the LLS, starting with open surgery and then expanding into laparoscopic and robot-assisted surgery before progressing to a left or right donor hepatectomy. In contrast, developmental process B first expands into open left or right donor hepatectomy before proceeding to pure laparoscopic hepatectomy. Processes A and B represent extreme examples and, in reality, the hepatectomy developmental process resembles process C, a process that moved back and forth between graft type and the laparoscopic assistance used. There are substantial gaps in the technical skill required for hepatectomies based on the sought-after graft type and/or the laparoscopic assistance used.

The technical steps of living-donor hepatectomy can be divided into five steps: (1) mobilization; (2) hilar dissection of the artery, portal vein, and bile duct; (3) parenchymal dissection; (4) division of the vessels and bile duct, and division of the hepatic vein; and (5) extraction of the liver graft from the abdomen (Figure 2).
The type of laparoscopic assistance used can be defined in terms of the five steps required for a living-donor hepatectomy. Hybrid hepatectomy utilizes laparoscopy for the mobilization of the liver (step 1), but hilar and parenchymal dissection, and division of the vessels (steps 2–5) are performed via direct visualization as an open surgery. Many experienced liver transplant programs quickly adopted the hybrid hepatectomy procedure because it is similar to open surgery through a small midline incision. Furthermore, laparoscopic liver mobilization is not difficult, making the hybrid technique easy to introduce. Regarding safety, this technique is more reliable than other laparoscopic procedures and has therefore been implemented in several Japanese transplant programs.5,11

For HALS, the entire surgery is performed laparoscopically with the surgeon’s hand inside the abdominal space; this requires the skin incision to be large enough for a hand.25 Pure laparoscopic procedures are considered the primary goal of minimally invasive surgery because the skin incision required for extraction of the graft can be restricted to a free site, usually a supra-pubic incision in the form of a Pfannenstiel incision.36 Robotic surgery is often included as a type of pure laparoscopic surgery.

A magnified laparoscopic view is a distinct advantage when performing steps 2 and 3 (hilar dissection of the artery, portal vein, and bile duct, and parenchymal dissection). However, unexpected bleeding and anatomical disorientation during laparoscopic procedures, including robot-assisted procedures, are the main safety concerns.48 Unexpected bleeding and/or unintended organ injury are easier to avoid during a hybrid procedure than they are during HALS or pure laparoscopy because a hybrid procedure allows for better tactile sensation and anatomical orientation. Creating effective countermeasures for these safety concerns is the most difficult and technically demanding challenge when executing a pure laparoscopic procedure.6

To avoid anatomical disorientation in a laparoscopic view, augmented reality (AR) support systems are being developed but have not yet been proven to be sufficient.75-77 Anatomical recognition during step 4 of a purely laparoscopic living-donor hepatectomy, and the devices used to cut vessels are the major safety concerns. A technical error might occur during this step, although the risk is very low. Indeed, the risk at step 4 during an open procedure is extremely low, as we have never once experienced such an error here.

4 CURRENT STATUS OF LAPAROSCOPIC DONOR HEPATECTOMY

Energy devices such as ultrasonic dissectors, soft coagulation systems, and laparoscopic surgical staplers have increased the ease of performing laparoscopic procedures, even for less skilled surgeons. Furthermore, surgical monitors have advanced extensively to allow for visualization in 4K and 8K resolution, and can even provide a 3D view in some cases. Application of robotic surgery using the da Vinci system has made a significant advance in this field, especially with the use of multifluid laparoscopic instruments and a 3D view. These developments in surgical devices and systems will facilitate pure laparoscopic hepatectomy becoming a mainstream approach in the future, even for living-donor hepatectomy. However, further careful evaluation of the safety and efficacy of these new techniques is still required.

Future safety and efficacy evaluation should focus on two aspects: first, donor outcomes including morbidity, bleeding, operative time, and living donor satisfaction. Most previous research on pure laparoscopic left and right lobectomies has shown these procedures are viable in terms of donor safety. The second aspect to focus on is recipient outcome; this aspect requires significant further investigation.

When analyzing donor outcomes, there are several major concerns during laparoscopic surgery, including: (a) anatomical disorientation; (b) parenchymal transection; (c) the length of the hepatic vein; (d) cut point of the bile duct; (e) ischemic time from inflow occlusion to graft-out through the small incision; and (f) unexpected complications such as uncontrollable bleeding or organ injury. Most previous reports did not assess these points and only compared the incidence or severity of postoperative morbidities. If any negative outcomes are revealed, even during the development phase of laparoscopic donor hepatectomy, this new technique should not be accepted. Fortunately, thus far, all results of these comparative studies between laparoscopic and conventional open donor hepatectomy have concluded that the outcomes of laparoscopic procedure are not significantly worse than for conventional open donor hepatectomy.40,47-56,78

The effects in transplant recipients are also an important measure for evaluating laparoscopic procedures. Park et al79 and several other studies,67-50,52-55,78,80,81 which mainly described donor outcomes, also reported on outcomes for the recipients and found they were similar to those for conventional open donor hepatectomy. However, these results should not be interpreted as demonstrating that laparoscopy is as effective as conventional open procedures. Recipient outcomes can be influenced by many more factors than the slight differences seen with donor hepatectomy; such as, detailed investigations of long-term recipient outcomes are necessary.

The limitations of laparoscopic procedures have been described in many articles and primarily focus on restrictions in motion, visualization, and tactile sensation.62 Hong et al reported the differences between laparoscopic and conventional open surgeries.48 They highlighted the difficulty in recognizing the right plane for parenchymal transection, the relatively horizontal cutting axis for the right portal vein and right hepatic duct, and the difficulty in determining the correct cutting point for these vessels. In this specific case, the patient experienced portal vein injury, thermal injury of the hepatic artery, and surface damage to the liver during mobilization caused by a trocar. All these issues were rectified during the surgery and caused no complications postoperatively. Further difficulty is caused by the need to manage anatomical variations. Small hepatic ducts48 and other anatomical anomalies48,54,81 can cause an increase in morbidities following pure laparoscopic procedures. This indicates that such incidents are potential problems, which may cause severe
complications postoperatively; however, very few of these anomalies have been reported.

Another concern is warm ischemic time (WIT), defined as the time from inflow occlusion to graft removal and flushing with a cold preservation solution. This time is longer for laparoscopic procedures than it is for conventional open procedures, and ranges from 3.1 to 12.6 min laparoscopically (most commonly about 10 min) (Table 1). Results regarding graft survival after transplantation in recipients have been reported in several studies; longer WIT seems to have no influence on graft function or survival. However, marginal situations, such as a small-for-size grafts or fatty liver combined with prolonged WIT, might reveal an adverse effect on graft outcomes.

Mid-surgery conversion from a laparoscopic to an open procedure is also a matter of concern. The reported rate of conversion is approximately 6%–7%, ranging from 0%–9.8% (Table 1). Most conversions resulted from unexpected injuries to major vessels (Table 1). This rate is not unexpectedly high when compared to that of non-donor major hepatectomy; however, it should be noted that rescue conversions to open surgery were necessary in patients with near-miss events. We should be aware that laparoscopic procedures carry these potential risks and we should work to minimize them. It is very important to communicate the approaches to prevent the complications, and share the reasons for conversion and to determine criteria for conversion during the safety validation phase of pure laparoscopic procedures.

Several articles describe an improvement in the results of the procedure according to a learning curve. Hong et al, Rhu et al, and Lee et al reported that an expert HBP surgeon with sufficient experience in open donor right lobectomy requires 50–60 cases of PLLDRH for technique stabilization. Lee et al reported that experience with more than 70 cases of pure laparoscopic right lobectomies should be recommended before starting PLLDRH.

Donor safety should be a top priority. Thus, any mortality or sequelae following laparoscopic surgery may influence the development and restrict the expansion of this approach unless the causes are fully disclosed and countermeasures are sufficiently established.

5 | ROBOT-ASSISTED LIVING-DONOR HEPATECTOMY

The performance of robot-assisted major hepatectomy has rapidly spread worldwide, due to the well-established da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA). The advantage of robotic surgery lies in the combination of laparoscopic technique with a magnified 3D view and less restricted surgical manipulation. However, proficiency in using the device is essential and requires intense training.

Robot-assisted living-donor hepatectomy was first reported by Giulianotti et al in 2012, which described a case of robot-assisted living donor right lobectomy subsequent to the performance of over 90 robotic minor and major hepatectomies. However, few articles on robot-assisted living-donor hepatectomy are available as of yet. Chen et al reported a series of 13 robotic living donor right hepatectomies and compared these with 54 open living donor right hepatectomies. Liao et al described a case of robotic living-donor left lateral sectionectomy. Recently, Troisi et al reported that robotic LLS for donor hepatectomy is a safe procedure, with results comparable to laparoscopy in terms of donor morbidity and overall recipient outcomes when the procedure is performed by experts.

Therefore, robot-assisted living-donor hepatectomy seems to be a minimally invasive approach that overcomes the difficulty of restricted movement experienced during “conventional” laparoscopic procedures. However, this technique is still new and should be carefully introduced in accordance with the required learning curve of the surgeons and staff involved in surgery.

6 | JAPANESE EXPERIENCE IN LAPAROSCOPIC LIVING-DONOR HEPATECTOMY

In Japan, the circumstances surrounding the development of laparoscopic procedures are different than that of other countries. Insurance coverage for laparoscopic hepatectomies was not implemented until in 2010 with laparoscopic minor hepatectomies (partial liver resection and left lateral sectionectomy). Furthermore, two different incidents where a cluster of mortalities occurred in patients who underwent laparoscopic hepatectomy in academic hospitals in Japan were widely broadcast. These events revealed the failure of local hospitals to safely manage laparoscopic surgery and, since their occurrence, have reinforced restrictions on laparoscopic hepatectomy implemented by the Japanese government.

In 2016, laparoscopic major hepatectomy was included in insurance coverage; however, as of 2020, insurance does not currently cover laparoscopic living-donor hepatectomy in Japan. Therefore, this procedure has never been performed in most of the hospitals in Japan, resulting in the development of hybrid donor hepatectomy instead and the publication of multiple studies. We demonstrated that living donors, especially young donors, strongly desire to have a smaller skin incision, and all the donors decided to undergo hybrid surgery rather than conventional open surgery.

This approach provides a temporary solution that considers the current social circumstances in Japan. However, the goal is not to perform hybrid donor hepatectomy, but pure laparoscopic or robotic donor hepatectomy is the true target.

7 | FUTURE PERSPECTIVES

Both technical innovations and the sharing of surgical experiences will promote the safety and efficacy of pure laparoscopic and robot-assisted living-donor hepatectomy. However, the safety of these procedures has not yet been established thoroughly enough for them to be applied as standard techniques at all transplant centers. This is especially true for right and left lobectomy, which is currently
recommended to be performed only at centers with adequate expertise and experience in both pure laparoscopic or robot-assisted living-donor hepatectomy and open living-donor hepatectomy. Educational methods are also rapidly developing, and surgical practices in various institutions will improve through the sharing of knowledge and practices via scientific meetings, extensive Internet access to video clips of surgical procedures, and so on. Pure laparoscopic and robot-assisted living-donor hepatectomy will likely be one of the most quickly developing fields of surgical innovation in the next decade.

CONFLICT OF INTEREST
The authors declare no conflicts of interest for this article.

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REFERENCES
1. Miller C, Florman S, Kim-Schluger L, Lento P, De La Garza J, Wu J, et al. Fulminant and fatal gas gangrene of the stomach in a healthy live liver donor. Liver Transpl. 2004;10(10):1315–9.
2. Akabayashi A, Slingsby BT, Fujita M. The first donor death after living-related liver transplantation in Japan. Transplantation. 2004;77(4):634.
3. Klintmalm GB. Primum non nocere. Am J Transplant. 2008;8(2):275–6.
4. Cheah YL, Simpson MA, Pomposelli JJ, Pomfret EA. Incidence of death and potentially life-threatening near-miss events in living-donor hepatic lobectomy: a world-wide survey. Liver Transpl. 2013;19(5):499–506.
5. Fisher RA. Living donor liver transplantation: eliminating the wait for death in end-stage liver disease? Nat Rev Gastroenterol Hepatol. 2017;14(6):373–82.
6. Marubashi S, Wada H, Kawamoto K, Kobayashi S, Eguchi H, Doki Y, et al. Laparoscopy-assisted hybrid left-side donor hepatectomy. World J Surg. 2013;37(9):2202–10.
7. Shirabe K, Eguchi S, Okajima H, Hasegawa K, Marubashi S, Umeshita K, et al. Current Status of Surgical Incisions Used in Donors During Living Related Liver Transplantation-A Nationwide Survey in Japan. Transplantation. 2018;102(8):1293–9.
8. Nguyen KT, Gamblin TC, Geller DA. World review of laparoscopic liver resection-2,804 patients. Ann Surg. 2009;250(5):831–41.
9. Wakabayashi G, Cherqui D, Geller DA, Buell JF, Kaneko H, Han HS, et al. Recommendations for laparoscopic liver resection: a report from the second international consensus conference held in Morioka. Ann Surg. 2015;261(4):619–29.
10. Hibi T, Cherqui D, Geller DA, Itano O, Kitagawa Y, Wakabayashi G. Expanding indications and regional diversity in laparoscopic liver resection unveiled by the International Survey on Technical Aspects of Laparoscopic Liver Resection (INSTALL) study. Surg Endosc. 2016;30(7):2975–83.
11. Kaneko H, Otsuka Y, Kubota Y, Wakabayashi G. Evolution and revolution of laparoscopic liver resection in Japan. Ann Gastroenterol Surg. 2017;1(1):33–43.
12. Cho JY, Han HS, Wakabayashi G, Soubrane O, Geller D, O’Rourke N, et al. Practical guidelines for performing laparoscopic liver resection based on the second international laparoscopic liver consensus conference. Surg Oncol. 2018;27(1):A5–A9.
13. Park JI, Kim KH, Kim HJ, Cherqui D, Soubrane O, Kooby D, et al. Highlights of the Third Expert Forum of Asia-Pacific Laparoscopic Hepatectomy: Endoscopic and Laparoscopic Surgeons of Asia (ELSA) Visionary Summit 2017. Ann Hepatobiliary Pancreat Surg. 2018;22(1):1–10.
14. Kim KH, Yu YD, Jung DH, Ha TY, Song G-W, Park G-C, et al. Laparoscopic living-donor hepatectomy. Korean J Hepatobiliary Pancreat Surg. 2012;16(2):47–54.
15. Cauchoy F, Schwarz L, Scotton O, Soubrane O. Laparoscopic liver resection for living donation: where do we stand? World J Gastroenterol. 2014;20(42):15590–8.
16. Han HS, Cho JY, Kaneko H, Wakabayashi GO, Okajima H, Uemoto S, et al. Expert Panel Statement on Laparoscopic Living-donor hepatectomy. Dig Surg. 2018;35(4):284–8.
17. Chen KH, Siow TF, Chio UC, Wu J-M, Jeng K-S. Laparoscopic donor hepatectomy. Asian J Endosc Surg. 2018;11(2):112–7.
18. Au KP, Chok KSH. Minimally invasive donor hepatectomy, are we ready for prime time? World J Gastroenterol. 2018;24(25):2698–709.
19. De Martin E, Hessheimer A, Chadha R, Kabacag C, Rajanayagam J, Kirchner V, et al. Report of the 24th Annual Congress of the International Liver Transplantation Society. Transplantation. 2019;103(3):465–9.
20. Soubrane O, Eguchi S, Uemoto S, Kwon CHD, Wakabayashi G, Han HS, et al. Minimally Invasive Donor Hepatectomy for Adult Living Donor Liver Transplantation: An International, Multi-Institutional Evaluation of Safety, Efficacy and Early Outcomes. Ann Surg. 2020. Online ahead of print.
21. Raia S, Nery JR, Mies S. Liver transplantation from live donors. Lancet. 1989;2(8661):497.
22. Cherqui D, Soubrane O, Husson E, Barshas E, Vignaux O, Ghimouz M, et al. Laparoscopic living-donor hepatectomy for liver transplantation in children. Lancet. 2002;359(9304):392–6.
23. O’Rourke N, Fielding G. Laparoscopic right hepatectomy: surgical technique. J Gastrointest Surg. 2004;8(2):213–6.
24. Koffron AJ, Auffenberg G, Kung R, Abecassis M. Evaluation of 300 minimally invasive liver resections at a single institution: less is more. Ann Surg. 2007;246(3):385–94; discussion 392–4.
25. Koffron AJ, Kung R, Baker T, Fryer J, Clark L, Abecassis M. Laparoscopic-assisted right lobe donor hepatectomy. Am J Transplant. 2006;6(10):2522–5.
26. Ha TY, Hwang S, Ahn CS, Kim KH, Moon DB, Song GW, et al. Role of Hand-Assisted Laparoscopic Surgery in Living-Donor Right Liver Harvest. Transplant Proc. 2013;45(8):2997–9.
27. Samstein B, Cherqui D, Rotellar F, Griesemer A, Halazun KJ, Kato T, et al. Totally laparoscopic full left hepatectomy for living donor liver transplantation in adolescents and adults. Am J Transplant. 2013;13(9):2462–6.
28. Soubrane O, Perdigao Cotta F, Scatton O. Pure laparoscopic right hepatectomy in a living donor. Am J Transplant. 2013;13(9):2467–71.
29. Rotellar F, Pardo F, Benito A, Martí-Cruchaga P, Zozaya G, Lopez L, et al. Totally laparoscopic right-lobe hepatectomy for adult living donor liver transplantation: useful strategies to enhance safety. Am J Transplant. 2013;13(12):3269–73.
30. Han HS, Cho JY, Yoon YS, Hwang DW, Kim YK, Shin HK, et al. Total laparoscopic living donor right hepatectomy. Surg Endosc. 2015;29(1):184.
31. Chen KH, Huang CC, Siow TF, Chio UC, Chen SD, Chen YD, et al. Totally laparoscopic living donor right hepatectomy in a donor with trifurcation of bile duct. Asian J Surg. 2016;39(1):51–5.
32. Li H, Wei Y, Li B, Peng B. The First Case of Total Laparoscopic Living Donor Right Hemihepatectomy in Mainland China and Literature Review. Surg Laparosc Endosc Percutan Tech. 2016;26(2):172–5.
33. Rotellar F, Pardo F, Benito A, Zozaya G, Martí-Cruchaga P, Hidalgo F, et al. Totally Laparoscopic Right Hepatectomy for Living Donor
Liver Transplantation: Analysis of a Preliminary Experience on five Consecutive Cases. Transplantation. 2017;101(3):548–54.

Kim KH, Kang SH, Jung DH, Yoon YI, Kim WJ, Shin MH, et al. Initial Outcomes of Pure Laparoscopic Living Donor Right Hepatectomy in an Experienced Adult Living Donor Liver Transplant Center. Transplantation. 2017;101(5):1106–10.

Hong SK, Suh KS, Kim HS, Yoon KC, Ahn SW, Oh D, et al. Pure 3D laparoscopic living donor right hemihepatectomy in a donor with separate right posterior and right anterior hepatic ducts and portal veins. Surg Endosc. 2017;31(11):4834–5.

Soubrene O, Kwon CH. Tips for pure laparoscopic right hepatectomy in the live donor. J Hepatobiliary Pancreat Sci. 2017;24(2):E1–E5.

Li J, Huang J, Wu H, Zeng Y. Laparoscopic living donor right hemihepatectomy with venous outflow reconstruction using cadaveric common iliac artery allograft: Case report and literature review. Medicine (Baltimore). 2017;96(7):e6167.

Rotellar F, Pardo F, Martí-Crucchaga P, Zozaya G, Valentí V, Bellver M, et al. Liver mobilization and liver hanging for totally laparoscopic right hepatectomy: an easy way to do it. Langenbecks Arch Surg. 2017;402(1):181–5.

Song JL, Yang J, Wu H, Yan LN, Wen TF, Wei YG, et al. Pure laparoscopic right hepatectomy of living donor is feasible and safe: a preliminary comparative study in China. Surg Endosc. 2018;32(11):4614–23.

Almodhaiberi H, Kim S, Kim KH. Totally laparoscopic living donor left hepatectomy for liver transplantation in a child. Surg Endosc. 2018;32(1):513.

Kim YS, Choi SH. Pure Laparoscopic Living Donor Right Hepatectomy Using Real-Time Indocyanine Green Fluorescence Imaging. J Gastrointest Surg. 2019;23(8):1711–2.

Song JL, Wu H, Yang JY. Laparoscopic donor right hepatectomy in a donor with type III portal vein anomaly: A case report. Medicine (Baltimore). 2019;98(32):e16736.

Park K, Shehta A, Lee JM, Hong SK, Yoon KC, Cho J-H, et al. Pure 3D laparoscopic versus open right hemihepatectomy in a donor with type II and III portal vein variations. Ann Hepatobiliary Pancreat Surg. 2019;23(4):313–8.

Hong SK, Suh KS, Kim KA, Lee J-M, Cho J-H, Yi N-J, et al. Pure Laparoscopic Versus Open Left Hepatectomy Including the Middle Hepatic Vein for Living Donor Liver Transplantation. Liver Transpl. 2020;26(3):370–8.

Hong SK, Suh KS, Lee JM, Cho J-H, Yi N-J, Lee K-W. New Technique for Management of Separate Right Posterior and Anterior Portal Veins in Pure 3D Laparoscopic Living Donor Right Hepatectomy. J Gastrointest Surg. 2020;24(2):462–3.

Takahara T, Wakabayashi G, Nitta H, Hasegawa Y, Katagiri H, Umemura A, et al. The first comparative study of the perioperative outcomes between pure laparoscopic donor hepatectomy and laparoscopy-assisted donor hepatectomy in a single institution. Transplantation. 2017;101(7):1628–36.

Hong SK, Lee KW, Choi Y, Kim HS, Ahn SW, Yoon KC, et al. Initial experience with purely laparoscopic living-donor right hepatectomy. Br J Surg. 2018;105(6):751–9.

Samstein B, Griesemer A, Cherqui D, Mansour T, Pisa J, Yegiants A, et al. Fully laparoscopic left-sided donor hepatectomy is safe and associated with shorter hospital stay and earlier return to work: A comparative study. Liver Transpl. 2015;21(6):768–73.

Giulianotti PC, Tzvetanov I, Jeon H, Bianco F, Spaggiari M, Oberholzer J, et al. Robot-assisted right lobe donor hepatectomy. Transpl Int. 2012;25(1):e5–9.

Chen PD, Wu CY, Hu RH, Ho C-M, Lee P-H, Lai H-S, et al. Robotic liver donor right hepatectomy: A pure, minimally invasive approach. Liver Transpl. 2016;22(11):1509–18.

Liao MH, Yang JY, Wu H, Zeng Y. Robot-assisted Living-donor Left Lateral Segmentectomy. Chin Med J (Engl). 2017;130(7):874–6.

Kurosaki I, Yamamoto S, Kitami C, Yokoyama N, Nakatsuka H, Kobayashi T, et al. Video-assisted living donor hemihepatectomy through a 12-cm incision for adult-to-adult liver transplantation. Surgery. 2006;139(5):695–703.

Baker TB, Jay CL, Ladner DP, Preczewski LB, Clark L, Holl J, et al. Laparoscopy-assisted and open living donor right hepatectomy: a comparative study of outcomes. Surgery. 2009;146(4):pp. 817–23; discussion 823–5.

Eguchi S, Takatsuki M, Soyama A, Hidaka M, Tomonaga T, Muraoka I, et al. Elective living donor liver transplantation by hybrid hand-assisted laparoscopic surgery and short upper midline laparotomy. Surgery. 2011;150(5):1002–5.

Thenappan A, Jha RC, Fishbein T, Matsumoto C, Melancon JK, Girlanda R, et al. Liver allotraft outcomes after laparoscopic-assisted and minimal access live donor hepatectomy for transplantation. Am J Surg. 2011;204(4):450–5.

Soyama A, Takatsuki M, Hidaka M, Muraoka I, Tanaka T, Yamaguchi I, et al. Standardized less invasive living donor hemihepatectomy using the hybrid method through a short upper midline incision. Transplant Proc. 2012;44(2):353–5.

Nagai S, Brown L, Yoshida A, Kim D, Kazimi M, Abouljoud MS. Mini-incision right hepatic lobectomy with or without laparoscopic assistance for living-donor hepatectomy. Liver Transpl. 2012;18(10):1188–97.

Choi HJ, You YK, Na GH, Hong TH, Shetty GS, Kim DG. Single-port laparoscopy-assisted donor right hepatectomy in living donor liver transplantation: sensible approach or unnecessary hindrance? Transplant Proc. 2012;44(2):347–52.

Zhang X, Yang J, Yan L, Li BO, Wen T, Xu M, et al. Comparison of laparoscopy-assisted and open donor right hepatectomy: a prospective case-matched study from China. J Gastrointest Surg. 2014;18(4):744–50.

Soyama A, Takatsuki M, Hidaka M, Adachi T, Kitasato A, Kinoshita A, et al. Hybrid procedure in living donor liver transplantation. Transplant Proc. 2015;47(3):679–82.
70. Suh SW, Lee KW, Lee JM, Choi YoungRok, Yi N-J, Suh K-S. Clinical outcomes of and patient satisfaction with different incision methods for donor hepatectomy in living donor liver transplantation. Liver Transpl. 2015;21(1):72–8.

71. Kitajima T, Kaido T, Iida T, Seo S, Taura K, Fujimoto Y, et al. Short-term outcomes of laparoscopy-assisted hybrid living donor hepatectomy: a comparison with the conventional open procedure. Surg Endosc. 2017;31(12):5101–10.

72. Kim SH, Cho SY, Lee KW, Park S-J, Han S-S. Upper midline incision for living donor right hepatectomy. Liver Transpl. 2009;15(2):193–8.

73. Singh MK, Lubezky N, Facciuto M, Contreras-Saldívar A, Wadhera V, Arvelakis A, et al. Upper midline incision for living donor right hepatectomy. Clin Transplant. 2016;30(9):1010–5.

74. Shinoda M, Tanabe M, Itano O, Obara H, Kitago M, Abe Y, et al. Left-side hepatectomy in living donors: through a reduced upper-midline incision for liver transplantation. Transplant Proc. 2014;46(5):1400–6.

75. Lau LW, Liu X, Plishker W, Sharma K, Shekhar R, Kane TD. Laparoscopic Liver Resection with Augmented Reality: A Preclinical Experience. J Laparoendosc Adv Surg Tech A. 2019;29(1):88–93.

76. Le Roy B, Ozgur E, Koo B, Buc E, Bartoli A. Augmented reality guidance in laparoscopic hepatectomy with deformable semi-automatic computed tomography alignment (with video). J Visc Surg. 2019;156(3):261–2.

77. Zygomalas A, Kehagias I. Up-to-date intraoperative computer assisted solutions for liver surgery. World J Gastrointest Surg. 2019;11(1):1–10.

78. Hasegawa H, Takahashi A, Kakeji Y, Ueno H, Eguchi S, Endo I, et al. Surgical outcomes of gastroenterological surgery in Japan: Report of the National Clinical Database 2011–2017. Ann Gastroenterol Surg. 2019;3(4):426–50.

79. Park J, Kwon CHD, Choi GS, Lee S-K, Kim JM, Oh J, et al. One-Year Recipient Morbidity of Liver Transplantation Using Pure Laparoscopic Versus Open Living Donor Right Hepatectomy: Propensity Score Analysis. Liver Transpl. 2019;25(11):1642–50.

80. Lee KW, Hong SK, Suh KS, Kim H-S, Ahn S-W, Yoon KC, et al. One hundred fifteen cases of pure laparoscopic living donor right hepatectomy at a single center. Transplantation. 2018;102(11):1878–84.

81. Kwon CHD, Choi GS, Kim JM, Cho CW, Rhu J, Soo Kim G, et al. Laparoscopic donor hepatectomy for adult living donor liver transplantation recipients. Liver Transpl. 2018;24(11):1545–53.

82. Nezhat C, Nezhat F, Nezhat C, Seidman SD. Operative laparoscopy: redefining the limits. JSLS. 1997;1(3):213–6.

83. Silva JP, Berger NG, Yin Z, Liu Y, Tsai S, Christians KK, et al. Minimally invasive hepatectomy conversions: an analysis of risk factors and outcomes. HPB (Oxford). 2018;20(2):132–9.

84. Jajja MR, Tariq M, Maxwell DW, Hashmi SS, Lin E, Sarmiento JM. Low conversion rate during minimally invasive major hepatectomy: Ten-year experience at a high-volume center. Am J Surg. 2019;217(1):66–70.

85. Hong SK, Suh KS, Yoon KC, Lee J-M, Cho J-H, Yi N-J, et al. The learning curve in pure laparoscopic donor right hepatectomy: a cumulative sum analysis. Surg Endosc. 2019;33(11):3741–8.

86. Fruscione M, Pickens R, Baker EH, Cochran A, Khan A, Ocuin L, et al. Robotic-assisted versus laparoscopic major liver resection: analysis of outcomes from a single center, HPB (Oxford). 2019;21(7):906–11.

87. Troisi RI, Elsheikh Y, Alnemary Y, Zidan A, Sturdevant M, Alabdad S, et al. Safety and feasibility report of robotic-assisted left lateral sectionectomy for pediatric living donor liver transplantation: a comparative analysis of learning curves and mastery achieved with the laparoscopic approach. Transplantation. 2020. Online ahead of print.

How to cite this article: Marubashi S, Nagano H. Laparoscopic living-donor hepatectomy: Review of its current status. Ann Gastroenterol Surg. 2021;00:1–10. https://doi.org/10.1002/ags3.12450