



# Training for laparoscopic pancreaticoduodenectomy

Tamotsu Kuroki<sup>1</sup> · Hikaru Fujioka<sup>1</sup>

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## Abstract

In recent years, laparoscopic procedures have developed rapidly, and the reports of laparoscopic pancreatic resection including laparoscopic pancreaticoduodenectomy (LPD) have increased in number. Although LPD is a complex procedure with high mortality, the training system for LPD remains unestablished. Ensuring patient safety is extremely important, even in challenging surgeries such as a LPD. At present, several tools have been developed for surgical education to ensure patient safety preoperatively, such as video learning, virtual reality simulators, and cadaver training. Although LPD is reported as a safe and feasible choice, LPD is still a challenging operation. An LPD training system should be established with a board-certified system.

**Keywords** Laparoscopic pancreaticoduodenectomy · Training · Education · Learning curve

## Introduction

The recent development of various laparoscopic instruments, surgical techniques, and thorough knowledge of the surgical anatomy has facilitated the widespread application of laparoscopic pancreatic surgery, not only for laparoscopic distal pancreatectomy (LDP), but also laparoscopic pancreaticoduodenectomy (LPD) [1–14]. Several reports from high-volume centers have shown that LPD is a safe and feasible procedure as minimally invasive surgery [15–17]. However, PD is a technically complex operation with high mortality and morbidity rates, even when performed by experienced surgeons. Despite LPD becoming a more frequently used surgical option for the treatment of several hepato-pancreato-biliary (HPB) diseases, the number of surgical experiences for HPB surgeons' training remains insufficient.

New methods of providing education in the field of laparoscopic surgery have great potential, such as virtual reality simulators. In this review, we discuss the existing issues and future perspectives for HPB surgeon training in LPD.

## Learning curve in LPD

Estimating the learning curve is important for determining the number of surgical cases necessary for an HPB surgeon to experience. Tseng et al. [18] showed that open PD has an inherent learning curve, and after 60 cases, surgeons achieved significantly decreased intraoperative blood loss, operative times, and lengths of hospital stay and achieved margin-negative resection more frequently.

A few reports have described the learning curve for performing LPD. Speicher et al. [19] observed a significant reduction in operative times following the first 10 LPD cases, and after 50 LPDs, the operative times and estimated blood loss were consistently lower than with OPD. Sharpe et al. [20] suggested that ten cases were the minimum threshold for achieving LPD competence. Our own study showed that, with regard to the operative time and blood loss, the surgeon reached a learning curve plateau after ten cases/LPD procedures [21]. However, in these reports on the learning curve for LPD, the operator was a surgeon experienced in several pancreatobiliary procedures, including conventional OPD; therefore, the learning curve for LPD of residents is unknown. In addition, whether or not sufficient experience with OPD is necessary before LPD is also unclear. In the future, laparoscopy may be the primary surgical technique for PD, and skilled surgeons may perform LPD based on having gained experience in other non-OPD techniques

✉ Tamotsu Kuroki  
tkuroki-gi@umin.ac.jp

<sup>1</sup> Department of Surgery, Nagasaki Medical Center,  
National Hospital Organization, 2-1001-1, Kubara, Omura,  
Nagasaki 856-8562, Japan

before LPD, such as laparoscopic gastrectomy and laparoscopic colectomy.

At present, LPD remains a challenging surgical procedure. Sharpe et al. [20] reported a 30-day mortality of 5.2% in LPD based on the National Cancer Database between 2010 and 2011, with no marked difference in the 30-day mortality between LPD and OPD (5.2 vs. 3.7%). LPD requires knowledge of detailed surgical anatomy, meticulous handling, and complicated reconstruction with an associated learning curve. In our opinion, LPD should be performed after the learning curve period of OPD.

## Utilizing video training for LPD

One of the advantages of laparoscopic surgery compared with open surgery is that video can be easily recorded to allow for education using one's own and experienced surgeons' videos. In addition, everyone in the operating room can watch the same video at the same time in real time with a lecture. Van Det et al. [22] reported that training based on intraoperative instructional videos significantly enhanced the technical and procedural skill development during the early learning curve for laparoscopic surgery. At present, we use video monitors that provide three-dimensional (3D) projections of the operating field to deliver unimpaired depth perception compared with two-dimensional (2D) systems. Several recent reports revealed the utility of 3D vision on laparoscopic surgery for laparoscopic skills training [23–25]. Kinoshita et al. [26] reported the usefulness of performing 3D anatomic simulation before surgery for laparoscopic splenic hilar lymph node dissection for gastric cancer. The importance of laparoscopic 3D visualization in pancreatic surgery has already been reported [27]. A video training system using 3D visualization is expected to be useful for challenging surgeries, such as LPD.

## 3D simulation and 3D-printed models for LPD training

3D simulation, which is constructed from multiple-detector computed tomography (MDCT) scans, has become widespread, facilitating decision-making regarding surgical planning, understanding complicated anatomy, and surgeon training [28–31]. Understanding the precise location of the main pancreatic duct and the peripancreatic vessels is essential for LPD training. Miyamoto et al. [32] reported the usefulness of a fusion 3D image that combines MDCT and magnetic resonance cholangiopancreatograph images to improve understanding of the pancreatic anatomy, including the location of the main pancreatic duct. Those authors used the SYNAPS VINCENT medical imaging system (Fujifilm

Medical Co., Ltd., Tokyo, Japan) to construct 3D images. The SYNAPS VINCENT 3D image analysis proved useful for not only planning the LPD operative procedures but also preoperative training for unexperienced LPD surgeons.

Recently, the cost of 3D printers has decreased, allowing this technology to become accessible worldwide [33, 34]. Several 3D-printed models of medical applications have been reported for surgical planning, training, and patient education [35–37]. 3D-printed models are also expected to prove helpful in understanding complex anatomy and laparoscopic procedures for LPD. We believe that hands-on LPD training is very important, particularly for older surgeons who are more familiar with laparotomy surgery. Marconi et al. [38] reported an objective analysis comparing three tools (MDCT, virtual 3D reconstruction on a flat monitor, and 3D-printed model) for laparoscopic surgery education, including laparoscopic pancreatectomy, using a multi-item questionnaire. They concluded that the 3D-printed model allowed for the best anatomical understanding with a faster and clearer comprehension of the surgical anatomy, resulting in greater utility for surgical training purposes.

## Cadaver training

Using a fresh human cadaver is one of the most advanced training techniques. Sharma et al. [39] in their randomized control trial reported that training on fresh-frozen cadavers significantly improved basic laparoscopic skills compared to training using a virtual reality simulator. Training in technically challenging surgical procedures, such as LPD, should be started outside of the operating room. In addition, LPD is a complicated procedure, so the training model must resemble the actual surgery. A fresh cadaver is an ideal tool for training in LPD. This approach provides real anatomy and real tissue handling. In addition, cadaver training allows for simultaneous training in the next level of laparoscopic skills, such as teamwork and communication in the operating room [40–42]. However, fresh cadaver training is limited by the high cost and lack of many cadaver laboratories [43].

Poudel et al. [44] reported that a fresh porcine cadaver model is an important training tool in advanced laparoscopic surgery techniques. The fresh porcine cadaver model requires no special animal facility, so they recommended using a fresh porcine cadaver models for large-scale training seminars. Another alternative to fresh cadavers is embalmed cadavers, such as Thiel embalmed cadavers. Thiel embalmed cadavers can provide soft and moist tissue, making them suitable for advanced laparoscopic training and anatomical education in innovative surgical techniques, such as LPD [45, 46].

Laparoscopic training usually requires a proper working space with sufficient pneumoperitoneum. One of

the major obstacles to introducing laparoscopic cadaver training is the difficulty distending the abdominal wall to achieve a sufficient working space because the abdominal wall of the cadaver is rigid. Imakuma et al. [47], therefore, developed a unique fake abdominal wall device to make an adequate laparoscopic working space in cadavers without pneumoperitoneum.

Fresh cadaver training is also useful for developing skills to manage critical situations, such as bleeding or anatomical misunderstanding. A fresh cadaver model provides some bleeding from the blood vessels and reproduces bleeding situations that might be encountered during LPD. Furthermore, hemostasis techniques can be practiced using fresh cadaver models. Such models allow for LPD training under clinically realistic conditions.

### Stepwise training for LPD

Several reports recommended stepwise training to master surgical techniques [48, 49]. Sumida et al. [50] found no significant difference in the post-operative complications after PD between experienced teaching surgeons and fellowship surgeons taking part in the stepwise education protocol as trainees. Marangoni et al. [51] described a different nine-step surgical training program for stepwise PD. They concluded that breaking down PD into a number of different steps may help build up surgical knowledge more quickly while ensuring patients' safety and allowing the surgery to be expedited.

One advantage of stepwise training is that surgeons inexperienced in LPD had opportunities to complete the procedure step by step. Liao et al. [52] reported that stepwise procedures for LPD reduced the operative time, mainly by reducing the time required for dissection. These findings suggest that stepwise training in LPD may be useful for helping LPD trainees surmount the learning curve within an acceptable operative time period.

### Suturing training for LPD

LPD necessarily entails complex reconstruction techniques. Laparoscopic anastomosis between the pancreas and gastrointestinal system is a challenging skill, and an excellent pancreatic anastomosis is needed because pancreatic leakage is associated with lethal complications. Therefore, laparoscopic suturing training is important for LPD. Suturing training using box trainers is the universally accepted first step for reconstruction in LPD. After its mastery, laparoscopic suturing training using a fresh cadaver or animal model should be attempted, as laparoscopic pancreatic anastomosis is extremely difficult due to the fragility of the pancreatic parenchyma. However, a 3D laparoscopic display system

may be a useful tool for suturing training for pancreatic anastomosis. A 3D system can provide precise depth judgement and high visual fidelity for suturing training and may help reduce the initial steep learning curve for the highly difficult laparoscopic suturing training.

Many Japanese LPD high-volume centers choose mini-laparotomy anastomosis for reconstruction in LPD. However, we believe that it is unnecessary for LPD trainees to perform suturing training for mini-laparotomy anastomosis. In the future, suturing for LPD should shift from mini-laparotomy anastomosis to a totally laparoscopic approach for the most minimally invasive PD procedure.

### Mental skills training for LPD

Laparoscopic surgery is generally more challenging and stressful than comparable open surgery. Mental skills training, therefore, minimize trainees' performance deterioration under stress. Anton et al. [53] reported that mental skills training is effective at diminishing the deterioration of surgical performance under unexpected stressful conditions compared to controls without such mental training. We believe that mental skills training is necessary to perform appropriate trouble-shooting in difficult situations, such as in cases of massive bleeding in LPD.

### Where can LPD training be performed?

A high-volume hospital environment is an important factor regarding the surgeon experience for LPD trainees. In addition, the standardization of surgical procedures and the management of these procedures in the educational system are essential to ensure that LPD trainees can perform LPD safely. Speicher et al. [19] recommended a staged and team-based training system be applied at the experienced teaching center for LPD training. Recent reports have found that the mortality rate after LPD was increased at low-volume centers [54, 55]. Sharpe et al. [20] reported that the 30-day mortality rate for LPD in a small-volume hospital that had performed < 10 LPDs in 2 years was 7.5%; in contrast, the 30-day mortality rate for LPD in a hospital that had performed  $\geq 10$  LPDs in 2 years was 0%. As a matter of course, it is most important to ensure the safety of patients who undergo LPD in the training program. Several reports have described LPD as technically safe and feasible with an acceptable mortality and morbidity. However, in these reports, LPDs were performed by experienced HPB surgeons with highly skilled laparoscopic techniques. We believe that LPD training programs should be established in high-volume and experienced teaching centers with the

support of numerous experienced HPB surgeons as the LPD trainers.

We, therefore, recommend the establishment of a new system for LPD training, such as a nation-wide system or using invited proctors, as is already being carried out in the robotic surgery field.

## Conclusions

LPD has the potential to become the standard procedure for benign and malignant periampullary diseases. As such, establishing LPD training programs at each facility, especially high-volume centers, is an urgent issue. The need for guidelines of LPD and scoring systems to anticipate the difficulty of LPD is necessary to establish such LPD training programs. Although LPD is a feasible choice in select patients at high-volume centers with experienced HPB surgeons who have already passed the learning curve of LPD, this procedure remains a challenging operation. An LPD training system should be established with a board-certified system.

## Compliance with ethical standards

**Conflict of interest** Tamotsu Kuroki and the other co-authors have no conflicts of interest.

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