Introduction

Inguinal hernias are a common disease for which more than 20 million operations are performed annually, worldwide. Laparoscopic surgery for inguinal hernias began in Europe and the United States in the 1990s. In Japan, transabdominal preperitoneal repair (TAPP) was first performed in 1991 by Matsumoto et al. After that, the mesh plug method was introduced in 1998, and the number of tension-free repairs using the inguinal incision method increased exponentially. Although the number of laparoscopic hernia repair operations did not increase at that time, laparoscopic surgery became more popular due to the standardization of other gastrointestinal surgeries and the evolution of surgical instruments. Then, beginning around 2010, the number of laparoscopic hernia repairs performed dramatically increased.

According to the 14th Nationwide Survey of Endoscopic Surgery in Japan by the Japan Society for Endoscopic Surgery, laparoscopic hernia repair for inguinal hernias in Japan was performed in 702 cases in 2007 (4.5% of all inguinal hernia surgeries). In 2017, that number increased to 11,936 cases (37.7% of inguinal hernia surgeries). However, its popularity, due to the increased number of medical treatments covered by insurance, has led to a higher recurrence rate than that reported with the inguinal incision method. According to “The Guidelines for Endoscopic Surgical Skill Qualified Surgeons” by the Japan Society for Endoscopic Surgery, and “The Guidelines for Inguinal Hernia 2015” by the Japanese Hernia Society, laparoscopic hernia repair is recommended if performed by expert surgeons who are fully trained in groin hernias. The contents of both guidelines are very similar. The following lists some of the advantages of laparoscopic hernia repair when compared with the inguinal incision method: 1) operation time is long but it is associated with fast recovery, and postoperative pain, nerve damage, and chronic pain are mild; 2) the recurrence rate is equal or lower to that seen in the traditional method; 3) the rate of perioperative complications may be equal or higher to that in the traditional method, but the number of postoperative complications is reduced; 4) medical cost is high, but it is feasible in terms of social medical economics due to early recovery and early return to society; and 5) it is suitable for bilateral inguinal hernias. Thus, provided that resources and expertise are available, laparo-endoscopic techniques are associated with faster recovery times and lower chronic pain risk, with the added advantage of...
being cost-effective\textsuperscript{7–11}.

Although there are many different approaches, treatment indications, and a significant array of techniques for groin hernia repair, a standard repair technique for the different forms of inguinal hernia does not exist. International guidelines for groin hernia management were created in 2018 to standardize care, minimize complications, and improve results\textsuperscript{12}. In the guidelines, Lichtenstein and laparo-endoscopic repair are the best evaluated. However, many of the other techniques need further evaluation.

There are various reports on the standardization and education of TAPP\textsuperscript{13–17}. TAPP appears to have a steep learning curve compared to that for open anterior mesh repair. It is reported that after 300 repairs by the pioneers, complications and recurrences decreased significantly; these successes were then passed on to subsequent trainees under well-defined and rigorous training conditions\textsuperscript{13, 14}. The program trainees also experienced an operative time learning curve similar to that by the pioneers and were still considered trainees after they had performed > 200 individual procedures. Another study, which included data on the initial learning curve and reported on the outcomes, stated that the recurrence rates improved after 200 cases, as the mesh size was changed to a larger one\textsuperscript{15}.

Since 2013, we have performed TAPP for adult inguinal hernias, and this procedure is now the first choice for inguinal hernia treatment in our institution. Herein, we report on our approach to the standardization of TAPP, the characteristics of the procedure, and the treatment results at our hospital.

Materials and Methods

Study Design

We retrospectively investigated the clinical characteristics and outcomes of 700 patients (792 lesions) who underwent TAPP at our institution from February 2013 to July 2020. Patients whose cardiopulmonary function could withstand general anesthesia were indicated for treatment, without age restrictions. Generally, the use of antiplatelet or anticoagulant drugs was discontinued; but if drug discontinuation was not desired, the operation was performed without stopping the oral drug. Initially, recurrent inguinal hernia, giant inguinal hernia, and incarcerated hernia were exclusion criteria for surgery, but the indication gradually expanded. The follow-up time for the patients after the surgery is about 3 months.

Procedure

Operating position

The patients are placed in a supine position, with their heads kept low and both hands closed and fixed at the side of the body. The operator stands on the healthy side of the patient, and the assistant sits on the affected side.
sected, taking care not to cut into the fascia of the muscle. Inside the inferior epigastric vessels, the detachment layer was transferred to the anterior peritoneal space. It is necessary to take note of the boundary between the fat layer on the peritoneal side and the posterior side of the rectus abdominis muscle. In the dissection of the anterior space of the bladder, the Cooper ligament, pubis, bladder, rectus abdominis muscle, and iliopubic tract were confirmed (Fig. 3). Further, it is important to cover the myopectineal orifice (MPO) sufficiently and dissect the peritoneum so that there is a mesh overlap of about 3 cm. As a specific anatomical landmark, the inside is more than 3 cm from the outer edge of the rectus abdominis muscle, the ventral side is more than 3 cm cranial from the ventral edge of the internal inguinal ring, and the ventral side is just inside the superior anterior iliac spine. The direction of the dorsal vas deferens is towards the intersection of the vas deferens and the inner umbilical fold. It is difficult to set a landmark for the direction of the dorsal gonadal blood vessels; therefore, it is set to a sufficiently wide range depending on the state of the mesh used.

**Mesh placement and fixation**

Either a shape memory type mesh or flat type mesh was used, sized to sufficiently cover the MPO for each patient. For proper mesh placement, it is necessary to ensure that the mesh does not fold back on the detached edge of the peritoneum.

The fixation of the mesh is based on the tacking of the mesh to the medial and lateral sides of the inferior epigastric vessels, the posterior surface of the rectus abdominis muscle just above the pubis, the medial superior anterior iliac spine, and the Cooper ligament (Fig. 4). When tacking, it is necessary to pay attention to the damage from dead coronary arteries (collateral circulation of obturator vessels and inferior epigastric vessels) and inferior epigastric vessels. In addition, tacking on the dorsal side of the iliopubic tract and outside the testicular vessels is contraindicated because there are genital branches of the genitofemoral nerve, the lateral femoral cutaneous nerve, and the deep iliac circumflex arteries. This area is referred to as the “Triangle of pain”[25]. The triangular area surrounded by the vas deferens and testicular vessels contains the external iliac vessels; this area is referred to as the “Triangle of doom” since damage here can lead to
fatal complications\(^{19}\). The area composed of the “Triangle of pain” and the “Triangle of doom” is called the “Trapezoid of disaster”.

**Peritoneal closure**

The peritoneum is sutured closed from right to left using a 3-0 absorbable braided thread (Fig. 5). Inadequate peritoneal closure with excessive tension on the peritoneum and wide-pitch loose sutures can lead to intestinal obstruction due to incarceration of the intestine into the dehiscence of the sutured peritoneum\(^{20}\). Especially in cases where the medial umbilical fold has excessive fat, it is difficult to confirm whether the peritoneum is closed. If there is a gap in the closed peritoneum, it should be resutured. In addition, there have been reports of small bowel obstruction after TAPP using a self-anchoring barbed suture, which caused adhesion to the small bowel due to the exposure of the barb into the abdominal cavity\(^{21–24}\). In each of the above cases, there were multiple technical problems, so the needle and the thread should be used carefully and properly. When the peritoneum is closed, the suturing pitch and bite should be firmly adjusted to avoid a gap in or excessive tension of the peritoneum.

**Removal of trocars and skin closure**

The edges of the mesh through the peritoneum were checked for foldback and, if identified, corrected. After confirming hemostasis, the trocar was removed and carbon dioxide gas in the abdominal cavity completely released outside the abdominal cavity. The abdominal fascia at the umbilicus was sutured closed, and a dermal buried suture was performed to complete the abdominal closure.

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**Table 1** Patient characteristics

| Number of cases (lesion) | 700 (792) |
|-------------------------|-----------|
| Median age (range)      | 69 (18–96) |
| Male / Female           | 609 / 91  |
| Unilateral / Bilateral  | 608 / 92  |
| Initial / Recurrent     | 660 / 40  |

**Table 2** JHS classification of groin hernia

| Classification          | Number |
|-------------------------|--------|
| type I Indirect inguinal hernia | 46     |
| type I I-1               | 307    |
| type I I-2               | 176    |
| type I I-3               | 78     |
| type II Direct inguinal hernia | 19     |
| type II II-1             | 87     |
| type II II-2             | 23     |
| type III Femoral hernia  | 6      |
| type IV Combined type    | 50     |
| type V Unclassified with the upper types |       |

**Post-operation**

The patient was allowed to drink water and walk 3 hours after the operation. The patient was allowed to have dinner on the day of surgery and was discharged from the hospital the next morning.

**Results**

Among the 700 patients (792 lesions) who underwent TAPP from February 2013 to July 2020 at our institute, there were 609 males and 91 females, with a median age of 69 years. There were 660 cases of initial inguinal hernia and 40 cases of recurrent inguinal hernia; 354 of the hernias were on the right side, 254 were on the left, and 92 were bilateral (Table 1).

According to The Japan Hernia Society (JHS) classification for groin hernia, 46 lesions (5.8%) were type I-1, 307 lesions (38.8%) were type I-2, 176 lesions (22.2%) were type I-3, 78 lesions (9.8%) were type II-1, 19 lesions (2.4%) were type II-2, 87 lesions (11%) were type II-3, 23 lesions (2.9%) were type III, 50 lesions (6.3%) were type IV, and 6 lesions (0.8%) were type V (Table 2). The median operation time was 61 minutes for one side and 67 minutes for both sides. The shorter surgery times were due to the fact that senior surgeons were the ones performing the operation. Bleeding was scant (less than 5 ml), and the median length of postoperative stay was 1 day. At our hospital, a clinical pathway is used for inguinal hernia cases and the patient is discharged the day after surgery. Excluding emergency operation cases, such as incarceration, there were 676 scheduled operations, of which 7 cases (1%) deviated from the clinical pathway due to large inguinal hernias or irreducible inguinal hernias; these 7 patients were discharged from the hospital.
within 4 days after surgery. Therefore, the adherence to the pathway was 99%.

Postoperative complications included one case (0.1%) of umbilical hernia, one case (0.1%) of ileus, and two cases (0.3%) of postoperative recurrence (Table 3). No recurrence was observed in the cases after the surgical procedure was standardized. However, those recurrent cases that occurred before the standardization of procedures for TAPP were fixed using the standardized procedure. In addition, no recurrence was found following TAPP for 40 cases of recurrent inguinal hernia.

**Discussion**

We have not only standardized the surgical procedures but also mesh and energy device used in the TAPP procedure, and achieved a relatively early standardization of the procedure itself. In this report, we have described this standardized procedure and report on the treatment outcomes of 700 patients who underwent this treatment over the past 7 years at our institution.

In 2012, we initially examined the use of TAPP for inguinal hernias in adults, and we also participated in workshops, hands-on training, and live surgical demonstrations by expert surgeons. We then introduced TAPP into our practice in February 2013. During the introductory period, it was assumed that the procedure was stable; once around 50 cases were operated upon, and the operator and the assistant were limited to the same team every time. Initially, cases were limited to those patients with no history of lower abdominal surgery and those who had an initial, unilateral, and small-sized inguinal hernias. Subsequently, the indications were gradually expanded, and we began to perform TAPP even in patients with a history of lower abdominal surgery; in patients requiring emergency surgeries, such as for incarceration; and in patients with large inguinal hernias and recurrent inguinal hernia. In addition, we opened a hernia specialist outpatient clinic in April 2017 to provide hernia treatment, mainly using the TAPP approach. Currently, even in difficult cases, such as recurrent inguinal hernia or hernias following surgery for prostate cancer, which are approached via the preperitoneal cavity, if there is a request from the patient, TAPP is conducted following the receipt of sufficient informed consent. Therefore, the number of TAPP cases has gradually increased at our hospital.

Generally, an ultrasonically activated device, a hook type electric scalpel, a spatula type electric scalpel, or monopolar scissors forceps are used as energy devices in TAPP. There is also the Tumescent TAPP technique, which is performed only with scissors forceps\(^8\). Each energy device has its own advantages and disadvantages. The ultrasonically activated device is capable of simultaneous gripping, coagulation, and separation, but it is expensive. The monopolar scissors forceps is capable of weak coagulation and dissection, but lacks grasping ability. At our hospital, during the introductory period, the ultrasonically activated device was used, but now monopolar scissors forceps are more commonly employed, and the ultrasonically activated device is only used rarely, based on the symptoms of a particular case. Furthermore, as the cost of the monopolar scissors forceps is considerably less than that of the ultrasonically activated device, we think they are suitable for expert surgeons (Fig. 6).

Nevertheless, we first educate residents to perform TAPP using an ultrasonically activated device because of easy countertraction by both hands. During the TAPP procedure, it is important to maintain a constant tension on the peritoneum to get an accurate and stable dissection layer. Additionally, the area where the tension should be applied must be changed according to the surgical technique used. Expert surgeons can accurately apply tension to the key areas using only one hand, but this is quite difficult for residents. Moreover, in the case of an inguinal hernia, it may be difficult to understand the anatomy due to vast differences between cases in terms of the characteristics of the hernia orifice and sac. An incorrect peritoneal incision line may make suture closure difficult. In order to make a correct peritoneal incision line, it is necessary to pull the hernia sac into the abdominal cavity with both hands alternately. The ultrasonically activated device has an advantage in this condition.

Before our standardization, we initially inserted 12 mm trocars using the open method. Then, 12 or 5 mm trocars were inserted for a final 12-12-5 mm or 12-5-5 mm main configuration. Subsequently, we minimized the invasiveness of the entire procedure, reduced the destruction of the abdominal wall, and, gradually, reduced the diameter of the trocar. At present, 5-5-5 mm and 5-5-2 mm configurations are mainly used by inserting a 5 mm trocar into the umbilicus via the optical method.

The median operation time was 61 minutes for one side and 67 minutes for both sides, including for procedures in which young surgeons were involved, to enhance their education. Recently, a senior surgeon familiar with TAPP recorded a mean time of 43 minutes for 100 cases. TAPP has a steep learning curve; thus, experience tends to lead to gradual reduction in procedure times. The standardization of the procedure and the change from an ultrasoni-
cally activated device to the monopolar scissors forceps are also considered to have contributed to reduction of the operation time. However, it is highly likely that the time required for suturing the peritoneum closed would occupy most of the operation time; therefore, becoming more familiar with laparoscopic suturing and ligation could significantly contribute to a reduced operation time. Laparoscopic suturing and ligation are now necessary techniques for surgeons. And these techniques are needed every time at TAPP. However, laparoscopic hernia repair such as totally extraperitoneal repair (TEP) and intraperitoneal onlay mesh repair (IPOM) do not necessarily require these techniques. In this respect, TAPP with laparoscopic suturing and ligation has a clear advantage including educational significance for young surgeons compared to other laparoscopic hernia repair techniques such as TEP.

In our hospital, there were 39 (5.6%) cases of emergency or semi-emergency surgery for inguinal hernia. Although the complexity of intestinal obstruction determines the difficulty of emergency surgery for incarcerated inguinal hernia, TAPP can be performed if the operation space is maintained in the abdominal cavity. However, if intestinal necrosis has occurred, it is necessary to consider repair methods that do not use a mesh or two-stage surgery because of the risk of infection. In any case, it should be performed by an experienced surgeon, and if TAPP is difficult, an alternative procedure may be necessary. Only two cases of recurrence were observed in Clavien-Dindo class III or higher complications. They were recurrences of Japan hernia classification type II-1 and occurred before the standardization of surgical procedures. It is possible that there was insufficient overlap on the inside of the mesh at the initial surgery, or that tacking was not performed properly. Currently, we practice careful mesh placement in consideration of the relationship with the hernia orifice under sufficient dissection. Postoperatively, none of the cases reported chronic pain, which seems to be a benefit of TAPP. In the future, we would like to educate young surgeons and popularize appropriate surgical techniques, while aiming to further reduce the invasiveness of TAPP, without recurrence or chronic pain.

**Conclusion**

The short-term treatment results of TAPP for inguinal hernia at our hospital were generally satisfactory. For surgeons skilled in laparoscopic surgery, TAPP could be a reasonable first-choice treatment for inguinal hernias.

**Acknowledgements**

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![Characteristics of energy device for TAPP](image)

| Speed of cutting | Ultrasonically activated device | Monopolar scissors |
|------------------|-------------------------------|-------------------|
| Coagulation      | △                             | ○                 |
| Grasping         | ○                             | ×                 |
| Cost             | ×                             | ○                 |

Fig. 6 Characteristics of energy device for TAPP

Each energy device has its own advantages and disadvantages. The ultrasonically activated device is capable of simultaneous gripping, coagulation, and separation, but it is expensive. The monopolar scissors forceps is capable of weak coagulation and dissection, but lacks grasping ability.
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