手術手順

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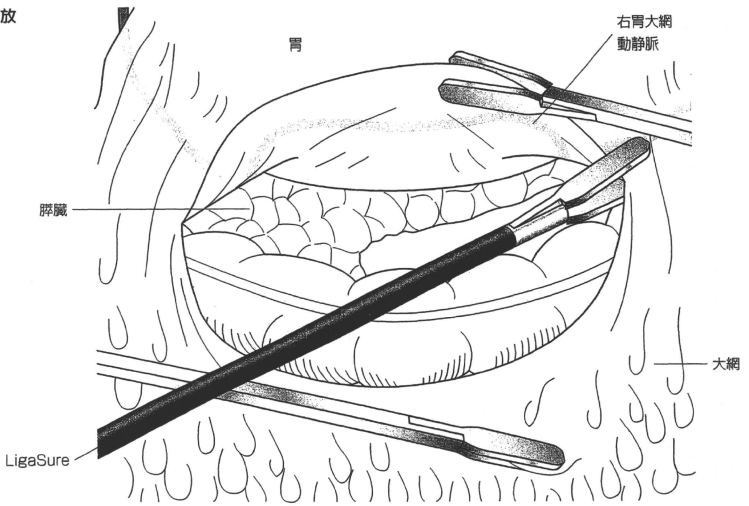
手術手技

1 網嚢の開放

頭高位とし，助手に胃を牽引させ，術者は横行結腸と大網を尾側に牽引し，横行結腸左側の適当な部位で網嚢を開放する（図3）。胃大網動静脈を損傷しないように注意しながら，網嚢の開放を左右に続け，胃十二指腸動静脈の立ち上がり付近では，結腸よりで剥離し，網嚢を完全に開放する。

HALSでは，気腹する前に，直視下で網嚢の開放，盲腸・上行結腸，S状結腸の剥離・授動を可能な限り行っておくと，その後の操作が楽で時間の短縮になる。

図3 網嚢の開放

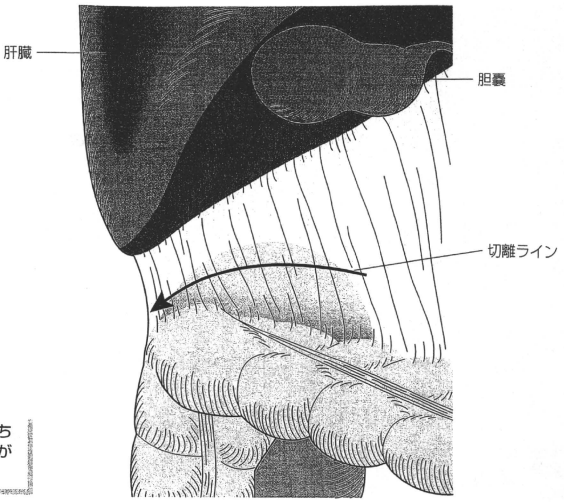


手技のポイント 胃大網動脈を助手の鉗子でしっかりと牽引し，損傷を回避する。

2 肝彎曲・右側結腸の剥離・授動

患者を左半側臥位とし，fusion fasciaを明らかにし軽く切開を加える。腎筋膜前葉から後腹膜下筋膜前面を明らかにすることが重要で。この層を維持しながら，上行結腸を尾側に向かって剥離を進める（図4）。この層を保持していれば，尿管や精巣（卵巣）動静脈を損傷することはない。

図4　肝彎曲部の授動



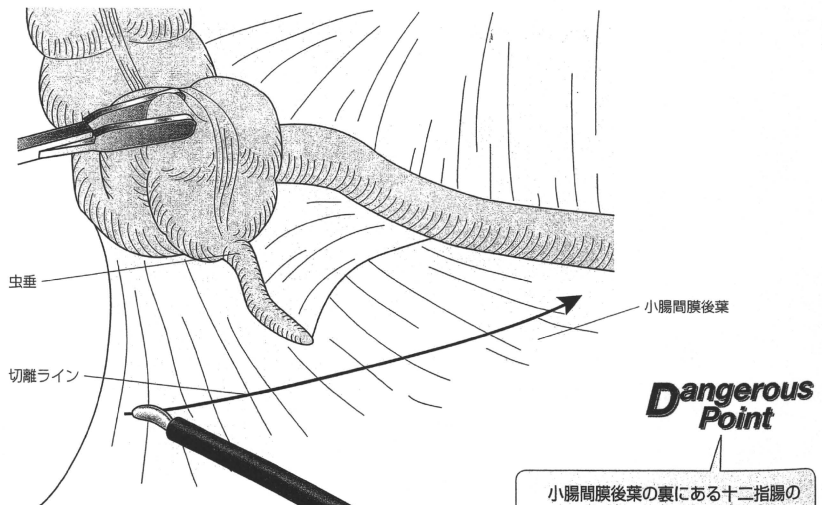
手技のポイント

できる限り薄く切開を行い，きちんと腎前筋膜前面の層に入ることが重要である。

3 回盲部の剥離・授動

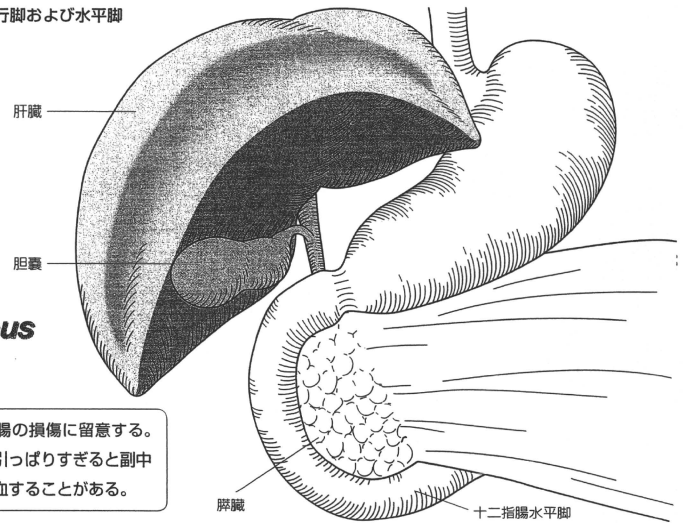
さらに尾側に向かい，総腸骨動脈前面で小腸間膜後葉から後腹膜の移行部を大動脈分岐部に向かい十分に切開する（図5）。この操作では，頭低位にし腹腔鏡を恥骨上部のトロッカーに入れ替え，虫垂根部から回盲部を頭側へ牽引すると，良好な視野が得られる。この視野

図5　回盲の剥離授動



のまま十二指腸水平脚を露出し，先ほど露出しておいた腎筋膜前葉からつながる前膵十二指腸筋膜前面で十二指腸下行脚を露出する（図6）。膵頭部を注意深く露出しながら，開放した網嚢とつなげる。

図6　十二指腸下行脚および水平脚の露出



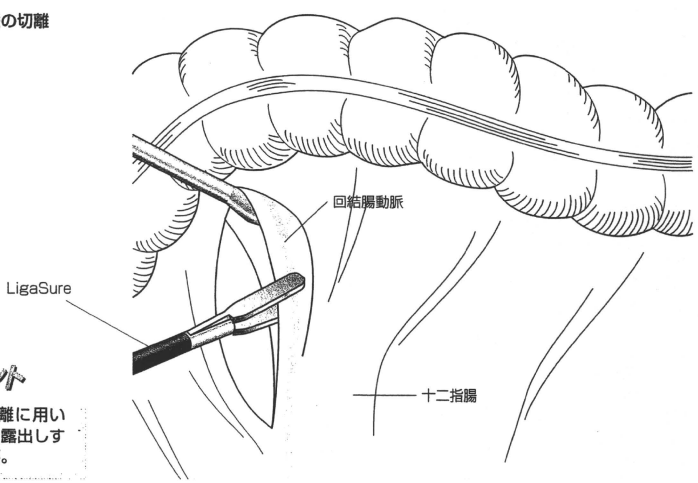
Dangerous Point

膵臓，十二指腸の損傷に留意する。横行結腸間膜を引っぱりすぎると副中結腸静脈より出血することがある。

4 右側結腸支配血管の処理

右側結腸間膜を展開し，回結腸動静脈のpedicleを明らかにし，これを右下腹部より挿入したEndo clinchで一括して把持し腹側に牽引する。十二指腸の尾側（すなわち回結腸動静脈の頭側）で間膜の薄いところを切開する。このとき背側の十二指腸を損傷しないように注

図7　回結腸動静脈の切離



手技のポイント

LigaSureを切離に用いる場合には血管を露出しすぎないことが重要。

意する。動静脈の尾側の間膜も切開し，Endo retract miniにかけかえて牽引し，回結腸動静脈をLigaSureでシールし切離する（**図7**）。さらに頭側へ向かい，結腸を腹側に牽引し，右結腸動脈があれば，膵臓，十二指腸に注意しながら，同様にシール・切離する。

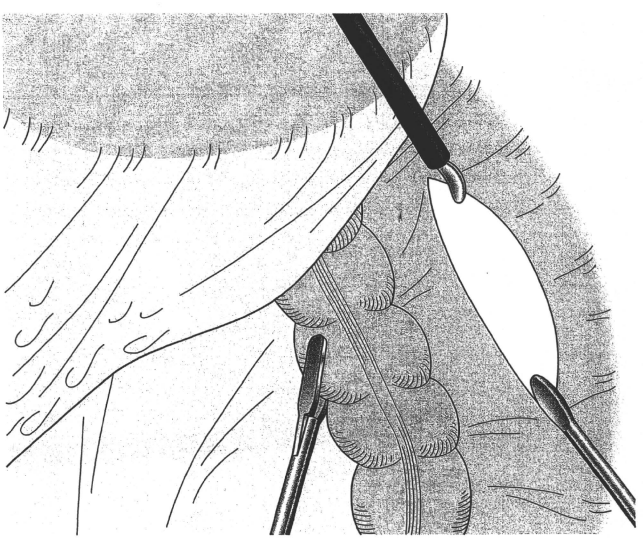
HALSでは，回結腸動静脈のpedicleを左手で把持・確認することができるのでより安心である。

5 横行結腸の展開

横行結腸を腹側に牽引し，中結腸動静脈右枝を確認し，同様にシール・切離する。次に横行結腸を尾側に牽引し，当初あけた網嚢の切開をさらに左方へ進める。ある程度までいったところで，脾彎曲部の授動に移る。下行結腸のfusion fasciaを切開し，腎筋膜前葉を明らかにする。脾彎曲部腸管を腸把持鉗子で把持して右尾側へ牽引し，脾結腸靭帯を明らかにし，これを切開する（**図8**）。大網を横行結腸の付着部で切離し，網嚢の左側を開き，脾結腸靱帯の切離線とつなげると脾彎曲部は完全に授動される。

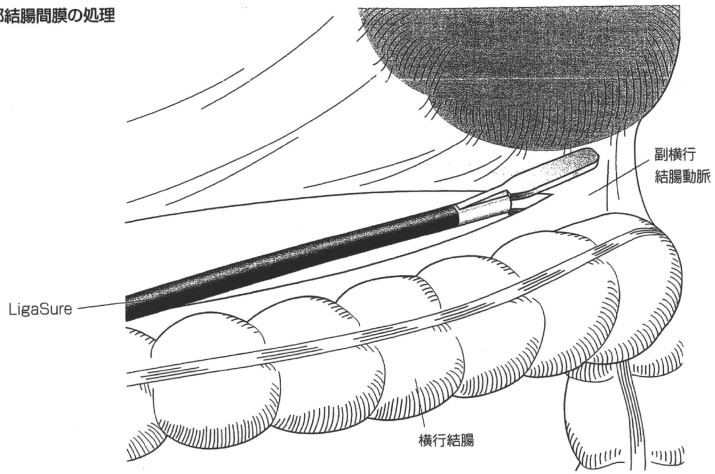
再び横行結腸を尾側へ牽引し，処理してきた結腸間膜の断端を把持し，中結腸動静脈左枝，副横行結腸動脈，副左結腸動脈をシール・切離する（**図9**）。このとき，右側腹部からLigaSureを挿入し，助手に操作させる。またこの際，Treitz靱帯から出る小腸を損傷しないように注意する。横行結腸左側の血管処理は，脾彎曲を完全に授動してから行うほうが，副左結腸動脈，下腸間膜静脈などのシーリングがしやすくなり安全である。

図8　脾結腸間膜の切開



手技のポイント　下行結腸外側の腹膜を広く切開すると脾彎曲の授動が容易になる。

図9　脾彎曲部結腸間膜の処理



Dangerous Point

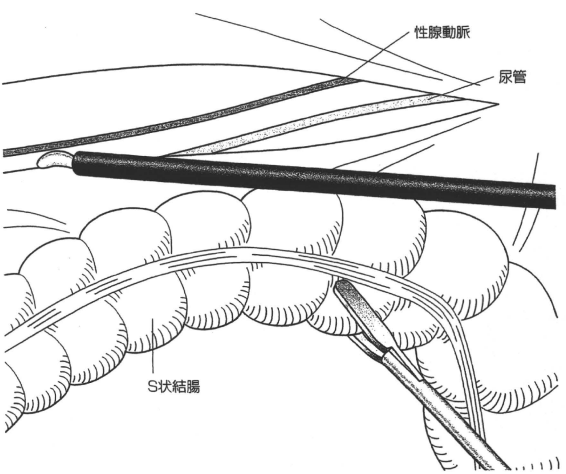
副横行結腸動脈が存在する症例では，不用意な操作により出血が生じる。しっかりとLigaSureでシーリングしていく。

6 左結腸の剥離・授動

手術台を左半側臥位に回転させ，下行結腸の剥離を腎筋膜前葉から後腹膜下筋膜前面の層を保持しながら，尾側に向かって続ける（図10）。精巣（卵巣）動脈と尿管を後腹膜下筋膜の背側に確認しながら，下腹神経の前面で大動脈分岐部付近まで剥離しておく。

HALSでも術者が右利きの場合は，ここと次の血管処理は通常の腹腔鏡補助下に行う。

図10　左側結腸の授動



手技のポイント

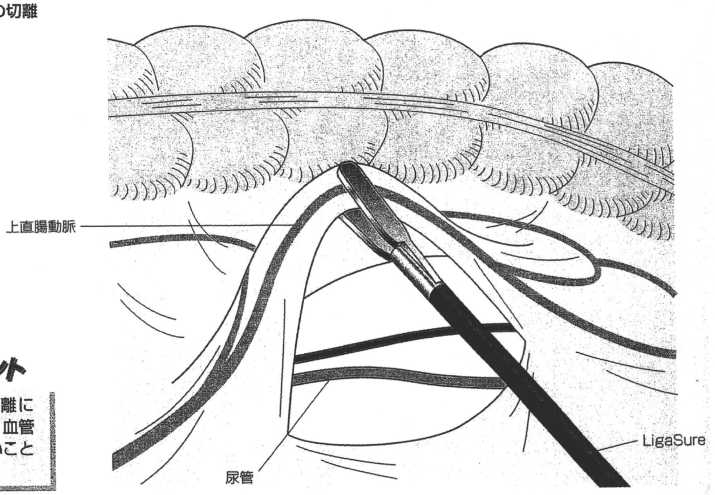
左性腺動脈，左尿管をしっかりと温存する。

7 左結腸の血管処理

S状結腸腸間膜を外側に展開し，上直腸動静脈のpedicleをEndo clinch®で把持し，腹側へ牽引する。上直腸動脈背側で，S状結腸腸間膜右側の間膜を切開し，左右を開通させる。ここでEndo clinch®をEndo retract mini®にかけかえ，上直腸動静脈をLigaSureで一括にシール・切離する（図11）。

さらに左結腸腸間膜を腹側に展開し，左結腸動脈，下腸間膜静脈をシール・切離すると，結腸の血管系を含む腸間膜がすべて処理される。根部郭清を行う必要はないので，下腹神経損傷をさけるべく，下腸間膜動脈根部には近づかない。

図11　上直腸動脈の切離



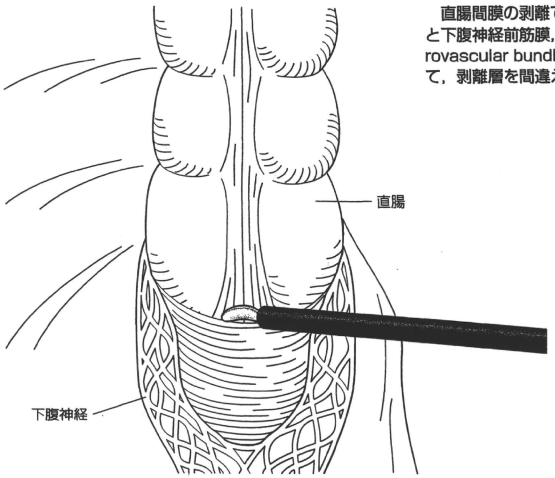
手技のポイント

LigaSureを切離に用いる場合には，血管を露出しすぎないことが重要。

8 骨盤内操作

頭低位，右半側臥位にして骨盤腔内を明らかにし，直腸右側の腹膜を切開し，直腸後壁から直腸左側へとあおるように剥離を進める（図12）。後壁の剥離は仙骨直腸靭帯を切開して直腸後腔を明らかにし，肛門挙筋群付着部まで鈍的および細かい血管は電気メスで止血し，できるだけ剥離しておく。可能であれば，後面のhiatal ligamentとよばれる筋線維を切開しておくと，このまま内外括約筋間腔に達する。後面から左右U字型に直腸固有筋膜を損傷しないように剥離を進める。次に直腸を右側に牽引すると，それまで後壁側から剥離しておいた直腸左側の間膜が1枚になっているのが認識されるので，これを尾側に向かって切開する（図13）。骨盤神経叢と直腸固有筋膜との間を電気メスにて剥離する。直腸枝は切離するがこの際神経叢によりすぎると，神経損傷や思わぬ出血をみることがあるので注意する。中結腸動脈を認めることもあるが，多くの場合電気メスで止血可能である。先ほどの側方からの剥離を進め，腹膜翻転部に達する。腹膜翻転部は直腸の牽引を少しゆるめるとくぼみとして認識されるので，これを切開し腟後壁（精嚢）と直腸前壁との間をDenonvillier's fascia（筋膜）の背側で，すなわちfasciaを残す側につけて剥離をすすめる（図14）。そうするとneurovascular bundleを損傷せず，出血することはほとんどない。男性ではDenonviller's fasciaは白色の光沢のある膜として認識できるが，女性では難しい場合がある。右側の剥離

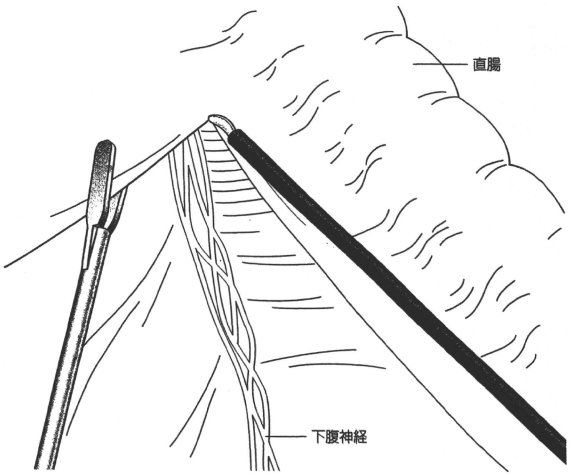
図12　直腸後腔の剥離



手技のポイント

直腸間膜の剥離では，直腸固有筋膜と下腹神経前筋膜，骨盤神経叢，neurovascular bundleとの関係に注意して，剥離層を間違えないようにする。

図13　直腸右側の切離



手技のポイント

直腸をしっかりと直線化すると正確な切離線で切離できる。

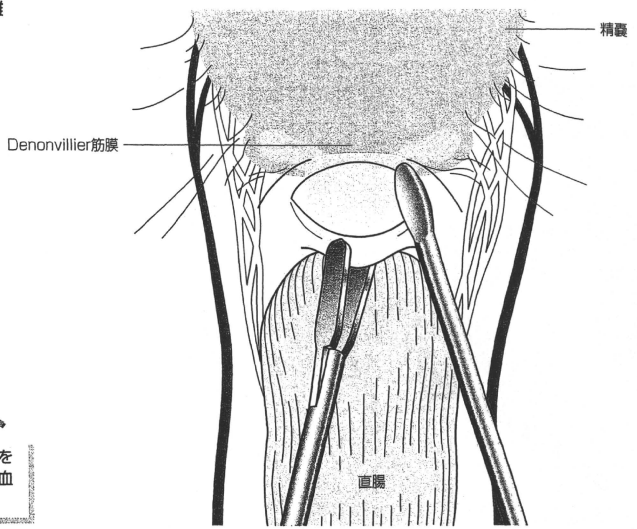
も同様に行い，前方のDenonvillers' fascia背側の剥離に至る。

前壁，側壁の剥離を行った後，hiatal ligamentを切開していなければこれを切開する。直腸の全周にわたり十分に剥離した後，恥骨上部のトロッカーより挿入した自動縫合器で，肛門管上縁の高さで直腸を切離する（図15）。通常，この部位では直腸周囲脂肪織はほとんどなくなっているが，それでも自動縫合器は最低2発必要で，2発目のステープルは1発目のステープルに重なるようにかけるのが重要である。

恥骨上部のトロッカーからEndo clinchを挿入し，切離した直腸断端を把持する。大腸を腹腔外へ露出する前に，大腸がすべて小腸の上にあり，捻れなどがないことを確認する。

HALSでは骨盤腔内の操作を，多くの場合直視下で行うことができる。直腸の切離には，開腹用のTAステイプラーなどを用いている。

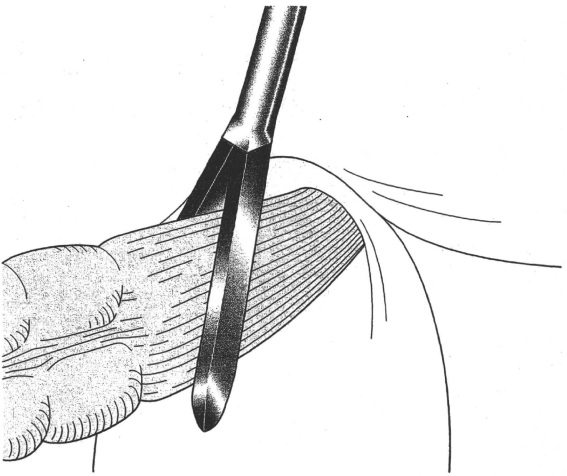
図14　直腸前壁の剥離



手技のポイント

Denonvillier筋膜を精嚢側につけると出血しない。

図15　直腸の切離



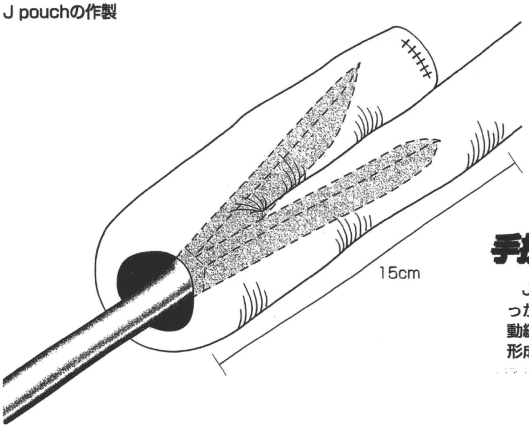
手技のポイント

直腸をしっかりと直線化すると切離しやすい。2発目のステープルは1発目のステープルに重なるようにかける。

9 / 切除・吻合

気腹を解除し，Pfannenstiel incisionから全大腸を腹腔外へ露出し，回腸末端部で自動縫合器を用いて切離する。自動縫合器を用いて，約15cmのJ pouchを作製する（図16）。pouch先端に，2/0 Proleneで巾着縫合をかけ，anvil headを装着する。pouchのstumpは4/0吸収糸により，漿膜筋層縫合をかけて埋没する。pouch先端が恥骨下縁に十分に届くことを確認する。

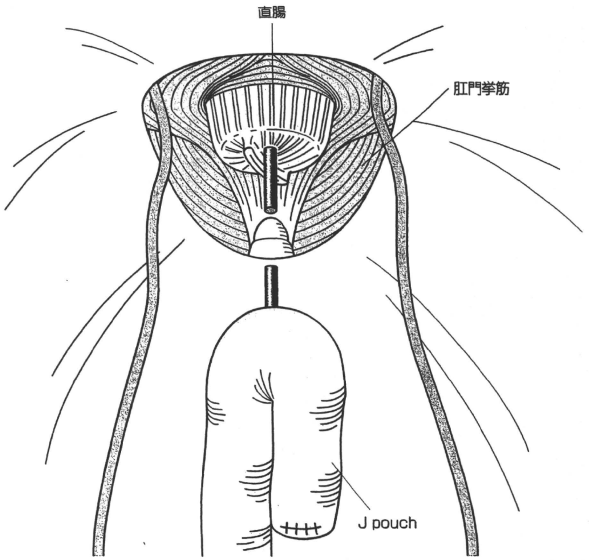
図16　J pouchの作製



手技のポイント

J pouchの長さは15cmとし，しっかりとアリス鉗子で牽引しながら自動縫合器で切離するとまっすぐな穴が形成される。

図17　吻合操作



手技のポイント

吻合器の操作は腹腔鏡モニターを確認しながら行い，ステープルラインを愛護的に扱う。

手技のポイント

吻合の前には，小腸腸間膜が捻れていないことを必ず確認する。double stapling techniqueではセンターロッドは，後壁寄りに打ち抜き，パウチ腟瘻をつくらないようにする。

どうしても緊張がある場合には，腸間膜にスリットを入れる。pouchを腹腔内へ還納し，ラップディスクを閉じて，再気腹する。

吻合前に小腸が捻れていないか，Treitzより順に追って確認する。肛門より自動吻合器を挿入して，腹腔鏡下にdouble stapling techniqueで吻合する（図17）。センターロッドは，pouch腟瘻を避けるため後壁寄りに出すようにする。HALSでは，小腸の捻れの確認，吻合操作も直視下で行える。

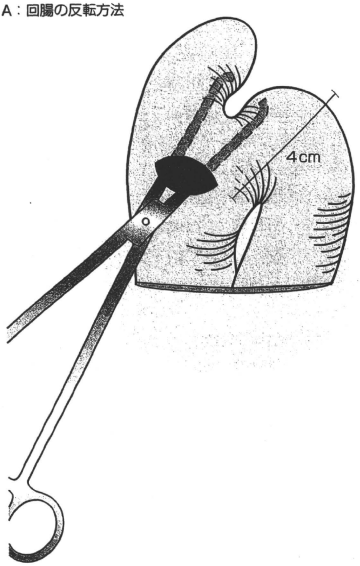
吻合終了後，人工肛門造設予定部位にトロッカーを刺入し，吻合部から約30cm口側の回腸で緊張なく創外に出せる部位をEndo clinch®で把持する。把持した部位より肛門側漿膜に電気メスでマークをつける。

左下腹部の5mmトロッカーからドレーンを挿入し，吻合部後面に留置する。また，肛門よりpouch内にネラトンあるいは太めの尿道バルーンカテーテルを挿入留置する。

残りのトロッカーを抜去し，気腹を解除後，人工肛門用のトロッカーの周囲皮膚を円形に切除する。筋膜前葉，後葉を十字に切開した後，腸管が捻れないように注意しながらEndo clinch®とともに回腸を創外に引き出す。印をつけておいた肛門側腸管を半周よりやや小さく横切開し，この切開口よりアリス鉗子を入れ，口側腸管を反転させる（図18A）。口側腸管は皮下組織，漿膜筋層，腸管全層を，肛門側腸管は皮下組織と腸管全層を吸収糸で固定し，手術を終了する（図18B，19）。

図18　回腸人工肛門の作製

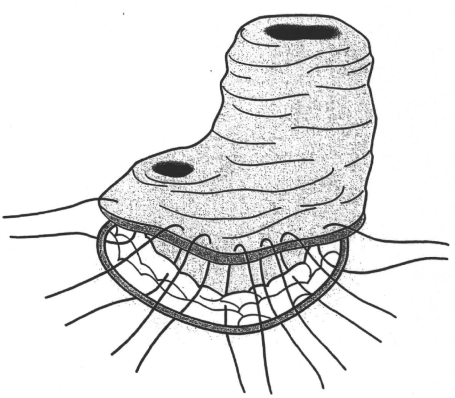
A：回腸の反転方法



手技のポイント

回腸人工肛門は十分な高さがないと管理が難しくなる。

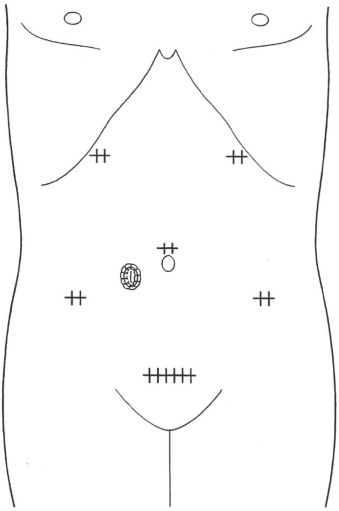
B：人工肛門の固定法



手技のポイント

一時的回腸人工肛門を造る際には，小腸が捻れないように，回腸を把持しているEndo clinch®を回転させないようする。

図19　術後創



ポイント

・潰瘍性大腸炎では腸管が脆弱になっているので，術中腸管損傷をおこさないよう，漿膜を強く把持したりせずに，脂肪垂を把持することが重要である。
・術中出血は丹念に止血することで，正しい剥離層を維持することができる。
・LigaSureを用いた血管処理は，同じ部位を2度シールすると焦げ付くことがあるので，2度シールする際には少し部位をずらすようにする。またこまめに先端部を濡れガーゼで拭うことにより，長時間の手術でも安定したシーリングが行える。
・潰瘍性大腸炎では，通常，大腸全摘術・回腸嚢肛門管吻合（ileo-anal canal anastomosis；IACA）を行うが，直腸に癌あるいは高度異型細胞を認める場合には，粘膜抜去を行い，回腸嚢肛門吻合（ileo-anal anastomosis；IAA）を行う。
・家族性大腸腺腫症では，直腸にポリープが密集する場合は，IAAを行い，直腸にポリープが散在する場合には結腸全摘術・回腸直腸吻合（ileorectal anastomosis；IRA）を行う。

術後管理

重症潰瘍性大腸炎患者で，術前にステロイド，免疫抑制剤を使用している場合，腸管蠕動の回復が通常より遅い。また，pouch内のカテーテルも，pouch内が腸液・粘液で充満し，骨盤内にしみ出し膿瘍とならないように留置している。

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Introduction of laparoscopic low anterior resection for rectal cancer early during residency: a single institutional study on short-term outcomes

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Abstract
Background Laparoscopic surgery for rectal cancer is unpopular because it is technically challenging. Suitable training systems have not been widely studied or established despite the steep learning curve for this procedure. We developed a systematic training program that enables resident surgeons to perform laparoscopic low anterior resection (LLAR) for rectal cancer and evaluated the safety and feasibility of this training program.
Methods We analyzed prospectively gathered data on all LLARs for rectal cancer performed at a single center over a 7-year period. Patients were assessed for demographic characteristics, tumor characteristics, operative procedure, operative time, blood loss, conversion to open surgery, complications, time to bowel recovery, distal margin, and number of lymph nodes harvested. We compared the early surgical, oncological, and functional outcomes of LLARs performed by expert surgeons with those of LLARs performed by resident surgeons for both intraperitoneal and extraperitoneal rectal cancer. All analyses were performed on an intention-to-treat basis.
Results A total of 137 patients met the inclusion criteria for this study. Of the 75 LLARs for intraperitoneal rectal cancer, 40 were performed by expert surgeons (I-E group) and 35 by resident surgeons (I-R group). Of the 62 LLARs for extraperitoneal rectal caner, 51 were performed by expert surgeons (E-E group) and 11 by resident surgeons (E-R group). The operative time was longer in the E-R group than in the E-E group. The time to resumption of diet was longer in the I-E group than in the I-R group. The other early outcomes, including blood loss, anastomotic leakage, conversion to open surgery, and number of lymph nodes harvested, were similar in the I-E and I-R groups and in the E-E and E-R groups.
Conclusion Our systematic training program on LLAR for rectal cancer enables resident surgeons to perform this procedure safely early during residency, with acceptable short-term outcomes.

Keywords Laparoscopic training · Low anterior resection · Rectal cancer · Education · Residency · Minimally invasive surgery

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Some authors have reported that laparoscopic surgery for rectal cancer is safe and efficacious because it is associated with less pain and blood loss, early bowel recovery, and short postoperative hospital stay [1–6]. A few randomized studies have shown that laparoscopic total mesorectal excision (TME) and lymphadenectomy can be adequate treatments for rectal cancer and that the subsequent recurrence and survival rates are similar to those after open surgery [4, 6–8]. However, laparoscopic surgery, which is the standard treatment for colon cancer, is not commonly performed for the treatment of rectal cancer. Laparoscopic surgery for rectal cancer is technically challenging and is

associated with some disadvantages such as long operative time [1, 2, 4] and increased rate of positive surgical margins [9]. Furthermore, suitable training systems for advanced laparoscopic procedures have not been widely studied.

We developed a systematic training program that offers sufficient experience in laparoscopic colorectal resections (LCRs) to resident surgeons without prior experience in open colorectal surgery and enables them to acquire the skills required to perform laparoscopic low anterior resection (LLAR) for rectal cancer. In this study we evaluated the safety and feasibility of allowing resident surgeons to perform LLAR for rectal cancer by comparing the early surgical, functional, and oncological outcomes of LLARs performed by expert surgeons with those of LLARs performed by resident surgeons for both intraperitoneal and extraperitoneal rectal cancer.

Patients and methods

Patients

We analyzed prospectively gathered data on all LLARs for rectal cancer performed at Kyoto Medical Center, Kyoto, Japan, between February 2001 and March 2008. Kyoto Medical Center actively supports an independent surgical residency program. The LLARs for intraperitoneal and extraperitoneal rectal cancer were performed by either expert surgeons (I-E group and E-E group, respectively) or resident surgeons (I-R group and E-R group, respectively).

Indication for laparoscopic surgery was rectal cancer without involvement of the lateral lymph nodes or invasion of the adjacent organs as determined during preoperative examination using computed tomography (CT) and pelvic magnetic resonance imaging (MRI). Evidence of metastatic disease that could not be curatively resected by open surgery was also an indication for laparoscopic surgery. Low anterior resection (LAR) is used for the treatment of early cancer located just above the dentate line and for treatment of advanced cancer located more than 1 cm above the dentate line; these criteria enable the acquisition of an adequate distal margin after transection of the rectum.

Patients were assessed for the following: demographic characteristics, tumor characteristics, operative time, blood loss, conversion to open LAR, complications including anastomotic leakage, and time to bowel recovery. Tumors were staged according to the sixth tumor–node–metastasis (TNM) classification of the International Union Against Cancer (UICC) based on the histological findings of the surgical specimens. Adherence to oncologic surgical principles was evaluated by analyzing the distal margin and number of lymph nodes harvested.

Operative procedure

All patients underwent bowel preparation, except those who presented with bowel obstruction. Antibiotic prophylaxis consisted of 1 g cefmetazole sodium administered intraoperatively every 3 h. The surgical team comprised an operating surgeon, an assistant surgeon, and an endoscopist. We used mainly a monopolar electrocautery for dissection and used laparosonic coagulating shears (LCS) only in specific fields since we believe that electrocautery is useful for dissecting tissues in layers. The patients were put into the extended Lloyd–Davis position, with the legs not angled too steeply, in order to prevent restriction of the surgical field. The umbilical port for the telescope was inserted using the open technique, and pneumoperitoneum was established by insufflation of carbon dioxide (8–10 mmHg). While viewing the laparoscopic image thus obtained, one port each (5–12 mm in diameter) was inserted in the left upper, left lower, right upper, and right lower abdominal quadrants. The patients were then positioned in the reverse Trendelenburg position and turned to their right. We used the mediolateral approach, beginning with central mobilization of the inferior mesenteric vessels and systematic identification of the left ureter. TME was performed in all patients, except in those in whom the tumor was confined to the upper part of the rectum; in this case, tumor-specific mesorectal excision (TSME) was performed. The Denonvilliers' fascia was preserved, except in the case of rectal cancer involving the anterior rectal wall. In women, the uterus was pulled toward the abdominal wall by using sutures. A good laparoscopic view of the surgical field and countertraction provided by the assistant surgeon enabled the identification of the dissection layers. This helped prevent injury to the neurovascular bundles and preserve the hypogastric nerves and pelvic plexus. Except in the case of very low rectal cancer, rectal transection was performed using an endoscopic linear stapler inserted through the right lower port, and the rectal specimen was exteriorized through a small incision in the left lower abdominal quadrant. A double-stapled coloanal anastomosis was created using a circular stapler, and the anastomotic rings were inspected for integrity. In the case of very low rectal cancer, transanal intersphincteric resection and hand-sewn anastomosis were performed to transect the lower rectum and obtain a longer distal margin than that obtained by intracorporeally transecting the rectum at the upper portion of the anorectal ring. A temporary ileostomy was constructed in patients who underwent preoperative radiotherapy or transanal hand-sewn anastomosis.

Training program

It is important for resident surgeons to operate on a sufficient number of patients and gradually master laparoscopic procedures. Our systematic training program for laparoscopic surgery was structured to enable stepwise acquisition of laparoscopic skills as follows:

1. In the first step, resident surgeons are required to act as endoscopists in at least 20 LCRs in order to learn the essentials of the standardized techniques used in LCRs. The surgeons also perform other basic laparoscopic procedures (e.g., cholecystectomy, stoma creation, omental patch repair for gastroduodenal perforation).
2. In the next step, the resident surgeons are required to act as operating surgeons and perform laparoscopic sigmoid colectomy and ileocecal resection and develop basic laparoscopic skills (prior experience in open colon surgery not required).
3. Thereafter, the resident surgeons perform laparoscopic hemicolectomy (both sides) and laparoscopic transverse colectomy and acquire advanced laparoscopic skills.
4. Laparoscopic surgery for rectal cancer, especially LLAR or laparoscopic abdominoperineal resection, is the most demanding among LCRs. It is therefore the last procedure that the resident surgeons perform, after they have acted as operating surgeons in at least 30 other LCRs and as endoscopists or assistant surgeons in more than 30 LCRs, including TME. The resident surgeons then perform about the same number (30) of laparoscopic procedures other than LCRs.

Resident surgeons are also encouraged to view a collection of video recordings of laparoscopic procedures. This enhances the effectiveness and quality of surgical education.

Quality assurance in the surgical procedures is very important throughout the training process. In order to maintain the quality of LCRs performed by resident surgeons, our systematic training program emphasizes the following principles:

1. In order to ensure surgical quality, we select the operating and assistant surgeons after considering the surgical skills of the expert and resident surgeons and the technical difficulty associated with patient-related factors, including adiposity, gender, tumor stage, tumor size, and tumor location.
2. Expert surgeons assist resident surgeons during the operation; they prepare the surgical field and provide continuous traction. Thus, the resident surgeons can obtain accurate magnification and correctly identify all small and important anatomical structures, even a narrow pelvis. They can also learn the techniques of precise anatomical dissection.
3. We ensure that all surgeons use the standardized techniques for LCRs. In general, it is accepted that during conventional open colorectal surgery, senior surgeons, acting as assistant surgeons, can control the quality of surgery performed by resident surgeons. However, this type of quality control is difficult during LCRs since the operating and assistant surgeons play completely different roles. The assistant surgeon cannot physically help the operating surgeon since the assistant surgeon is always occupied in developing the surgical field. Therefore, the use of standardized techniques is essential to maintain the quality of LCRs performed by resident surgeons. Standardization of the procedures also helps the expert surgeons to teach and the resident surgeons to easily understand the details of the surgical procedure.

Statistical analysis

All analyses were performed on an intention-to-treat basis, and the assessment included the patients in whom conversion to open LAR was required. Statistical analysis was performed using Student's t test and Welch's t test for continuous data and Fisher's exact test for categorical data. Continuous variables are expressed in terms of the mean (range). All statistical tests were two-sided, and differences were considered significant when $p < 0.05$.

Results

Patient demographics, tumor characteristics, and operative procedure

Between February 2001 and March 2008, 142 patients underwent LLAR for rectal cancer at Kyoto Medical Center. We excluded five patients who underwent LLAR and other major procedures simultaneously. In the E-E group, one patient underwent laparoscopic transverse colectomy and one underwent laparoscopic distal gastrectomy, in addition to LLAR. In the I-R group, two patients underwent hepatic metastasectomy and one underwent open distal gastrectomy, in addition to LLAR. We examined the remaining 137 patients: 75 with intraperitoneal rectal cancer (40 in the I-E group and 35 in the I-R group) and 62 with extraperitoneal rectal cancer (51 in the E-E group and 11 in the E-R group). Most of the LLARs in the I-E and E-E groups were performed by YS, HK, or TY, who are proficient in performing LCRs and have more than 12 years of experience. LLARs in the I-R and E-R groups

Table 1 Patient demographics, tumor characteristics, and operative procedure

	Intraperitoneal ($n = 75$)		p value	Extraperitoneal ($n = 62$)		p value
	I-E group ($n = 40$)	I-R group ($n = 35$)		E-E group ($n = 51$)	E-R group ($n = 11$)	
Age (years) (range)	62.7 (44–86)	69.7 (41–93)	0.005	62.0 (37–84)	64.2 (26–80)	NS
Gender [n (%)]						
Male	24 (60)	21 (60)	NS	27 (52.9)	5 (45.4)	NS
Female	16 (40)	14 (40)		24 (47.1)	6 (54.5)	
Previous abdominal surgery [n (%)]	4 (10)	9 (25.7)	NS	6 (11.8)	2 (18.2)	NS
Tumor size (mm) (range)	50.4 (10–90)	42.4 (0–90)	NS	37.5 (0–80)	35.3 (18–65)	NS
TNM stage [n (%)]						
0	3 (7.5)	0	NS	5 (9.8)	2 (18.2)	NS
I	7 (17.5)	12 (34.3)	NS	21 (41.2)	3 (27.3)	NS
II	8 (20)	7 (20)	NS	11 (21.6)	0	NS
III	16 (40)	10 (28.6)	NS	12 (23.5)	3 (27.3)	NS
IV	6 (15)	6 (17.1)	NS	2 (3.9)	3 (27.3)	0.049
LAR with double-stapling technique	40	35	NS	43 (84.3)	9 (81.8)	NS
LAR with transanal hand-sewn anastomosis	0	0	NS	8 (15.7)	2 (18.2)	NS
Diverting ileostomy	0	2 (5.7)	NS	13 (25.5)	2 (18.2)	NS

were performed by six resident surgeons with 2–7 years of experience; of these resident surgeons, three had no prior experience in open surgery and three had experience in open surgery and basic laparoscopic surgery.

Patient demographics, tumor characteristics including pathological staging; and operative procedure undertaken are listed in Table 1. Expert surgeons operated on a significantly larger number of patients with extraperitoneal rectal cancer than resident surgeons ($p < 0.001$). The patients were significantly younger in the I-E group than in the I-R group. The incidence of stage IV tumors was significantly higher in the E-R group than in the E-E group. No significant differences were observed between the I-E and I-R groups or between the E-E and E-R groups with regard to gender, previous abdominal surgery, tumor size, and operative procedure.

Operative time, blood loss, conversion to open LAR, and intraoperative and postoperative complications

The operative details and complications are listed in Table 2. The mean operative time was significantly shorter in the E-E group than in the E-R group, while it was similar in the I-E and I-R groups. The mean blood loss was less in the E-E group than in the E-R group, but the difference was not significant ($p = 0.45$). The incidences of conversion to open LAR, intraoperative complications, and postoperative complications, including anastomotic leakage, were similar in the I-E and I-R groups and in the E-E and E-R groups.

Of the eight intraoperative complications encountered, six were due to equipment failure, with similar incidence in the I-E and I-R groups and in the E-E and E-R groups. Of the six patients who developed complications because of equipment failure, two required conversion to open LAR and two developed anastomotic leakage. The incidence rates of conversion to open LAR and anastomotic leakage were significantly higher among the patients with complications due to equipment failure than among those without such complications [conversion to open LAR: 33.3% (2 of 6 patients) vs. 4.6% (6 of 131 patients); odds ratio (OR) = 10.417; 95% confidence interval (CI) = 1.880–61.092; Fisher's exact test, $p = 0.040$; and anastomotic leakage: 33.3% (two of six patients) vs. 4.6% (six of 131 patients); OR = 10.417; 95% CI = 1.880–61.092; Fisher's exact test, $p = 0.040$). The remaining two intraoperative complications were tumor perforation during the extraction of a large tumor through the minilaparotomy incision and bowel injury during the insertion of the first umbilical port. Most of the postoperative complications were managed conservatively; however, five patients required surgical intervention. Reoperation was performed in one patient in the I-E group because of anastomotic leakage, in one patient in the I-R group because of perforation of the small intestine, in two patients in the E-E group because of wound dehiscence and anastomotic leakage, and in one patient in the E-R group because of formation of abdominal abscess. There were no deaths in any group. The causes of conversion to open LAR are listed in Table 3.

Table 2 Operative details, conversion to open surgery, and intraoperative and postoperative complications

	Intraperitoneal ($n = 75$)		p value	Extraperitoneal ($n = 62$)		p value
	I-E group ($n = 40$)	I-R group ($n = 35$)		E-E group ($n = 51$)	E-R group ($n = 11$)	
Operative time (min) (range)	280 (156–429)	309 (195–542)	NS	301 (160–615)	357 (240–558)	0.047
Blood loss (ml) (range)	108 (0–1130)	80 (0–700)	NS	109 (0–650)	163 (0–700)	NS
Intraoperative complications [*n* (%)]	3 (7.5)	2 (5.7)	NS	2 (3.9)	1 (9.1)	NS
Dehiscence of the rectal stump (malfunction of endoscopic stapler) [*n* (%)]	2 (5.0)	2 (5.7)	NS	1 (2.0)	0 (0)	NS
Drawbacks with circular stapler	0 (0)	0 (0)	NS	1 (2.0)	0 (0)	NS
Bowel injury [*n* (%)]	0 (0)	0 (0)	NS	0 (0)	1 (9.1)	NS
Tumor perforation [*n* (%)]	1 (2.5)	0 (0)	NS	0 (0)	0 (0)	NS
Conversion [*n* (%)]	3 (7.5)	1 (2.9)	NS	3 (5.9)	1 (9.1)	NS
Postoperative complications [*n* (%)]	6 (15.0)	5 (14.3)	NS	10 (19.6)	2 (18.2)	NS
Anastomotic leakage [*n* (%)]	3 (7.5)	1 (2.9)	NS	3 (5.9)	1 (9.1)	NS
Wound infection [*n* (%)]	1 (2.5)	2 (5.7)	NS	3 (5.9)	0 (0)	NS
Bowel obstruction [n (%)]	0 (0)	1 (2.9)	NS	3 (5.9)	0 (0)	NS
Intra-abdominal abscess [*n* (%)]	0 (0)	0 (0)	NS	0 (0)	1 (9.1)	NS
Others [*n* (%)]	2 (5.0)	1 (2.9)	NS	1 (2.0)	0 (0)	NS
Reoperation [*n* (%)]	1 (2.5)	1 (2.9)	NS	2 (3.9)	1 (9.1)	NS
Mortality [*n* (%)]	0 (0)	0 (0)	NS	0 (0)	0 (0)	NS

Table 3 Causes of conversion to open surgery

	Intraperitoneal ($n = 75$)		Extraperitoneal ($n = 62$)	
	I-E group ($n = 40$)	I-R group ($n = 35$)	E-E group ($n = 51$)	E-R group ($n = 11$)
Dehiscence of the rectal stump (endoscopic stapler failure)	1	0	1	0
Involvement of the bladder	1	0	0	0
Involvement of the lateral pelvic plexus	0	0	0	1
Massive lymph node swelling	0	1	0	0
Extensive adhesions associated with multiple previous laparotomies	0		1	0
Severe endometriosis	1	0	0	0
Morbid obesity	0	0	1	0

Bowel recovery, distal margin, and number of lymph nodes harvested

The bowel function and oncological parameters are listed in Table 4. No significant differences were observed between the I-E and I-R groups or between the E-E and E-R groups with regard to the time to the passage of the first flatus and feces. The time to resumption of diet was significantly longer in the I-E group than in the I-R group. The mean number of lymph nodes harvested and the mean distal margin were similar in the I-E and I-R groups and in the E-E and E-R groups. One positive resection margin was identified in the I-R group in a patient with hypogastric nerve involvement and massive lymph node involvement.

Discussion

While laparoscopic surgery is the standard treatment for colon cancer, it is not yet popular for the treatment of rectal cancer; this is because laparoscopic rectal surgery is technically challenging and is associated with some disadvantages such as long operative time [1, 2, 4] and increased rate of positive surgical margins [9]. Even during open surgery in the deep and narrow pelvic region, it is very difficult to maintain a clear surgical field, precisely identify anatomical structures, and accurately perform rectal mobilization and excision while preserving urogenital functions. It is considered that laparoscopic surgery takes a longer time to learn than open surgery and that laparoscopic training should be initiated after open surgical procedures have been

Table 4 Bowel recovery, distal margin, and number of lymph nodes harvested

	Intraperitoneal ($n = 75$)		p value	Extraperitoneal ($n = 62$)		p value
	I-E group ($n = 40$)	I-R group ($n = 35$)		E-E group ($n = 51$)	E-R group ($n = 11$)	
Days to first flatus (range)	1.78 (0–6)	1.60 (0–5)	NS	1.65 (0–10)	2.09 (1–3)	NS
Days to first feces (range)	2.23 (0–8)	2.31 (0–8)	NS	2.33 (0–10)	3.36 (0–8)	NS
Days to diet (range)	3.40 (1–11)	2.37 (1–6)	0.024	3.49 (1–13)	3.90 (1–8)	NS
Lymph nodes harvested [n (range)]	12.7 (3–31)	14.7 (1–45)	NS	11.3 (2–41)	13.6 (2–36)	NS
Distal margin (mm) (range)	42.9 (15–110)	49.7 (15–180)	NS	22.8 (5–50)	19.7 (10–35)	NS
Positive resection margin [n (%)]	0 (0)	1 (2.9)	NS	0 (0)	0 (0)	NS

learned. Furthermore, suitable training programs for advanced laparoscopic procedures have been lacking [10–12] and have been studied in only a few reports [13]. We developed a systematic training program that offers sufficient experience in LCRs to resident surgeons without prior experience in open colorectal surgery and enables them to acquire the skills required for performing LLAR for rectal cancer. The present study was designed to evaluate the safety and feasibility of our systematic training program.

The demographic characteristics of the patients operated on by expert surgeons differed from those of the patients operated on by resident surgeons. Expert surgeons operated on a significantly larger number of patients with extraperitoneal rectal cancer than resident surgeons ($p < 0.001$). The difference may be partly explained by our policy for selecting the operating surgeons. LLAR for low rectal cancer is considered to be more demanding than that for high rectal cancer and, therefore, expert surgeons might be preferred as operating surgeons for LLAR for extraperitoneal rectal cancer. For the same reason, we analyzed the outcomes of LLARs for intraperitoneal rectal cancer and those for extraperitoneal rectal cancer separately.

The reason for the difference in the age of the patients between the I-E and I-R groups is difficult to explain. Actually, some authors have reported that laparoscopic surgery in elderly patients is not especially associated with high morbidity [14, 15], and we did not consider the age of the patients when assigning them to either group. The larger number of stage IV patients in the E-R group than in the E-E group may also be explained by our policy for selecting the operating surgeons. In LLARs for stage IV tumors, surgeons do not need to adhere to oncologic radicality so the selection of resident surgeons is easy.

All surgical outcomes, including operative time, blood loss, conversion to open LAR, and complications, were similar in the I-E and I-R groups. The operative time was significantly longer in the E-R group than in the E-E group; however, this not associated with a compromise in patient care. No significant differences were observed between the E-E and E-R groups with regard to blood loss, rate of conversion to open LAR, incidence of intraoperative complications, and incidence of postoperative complications, including anastomotic leakage. Furthermore, the values of the above parameters were satisfactory when compared with those reported in other series [1–4, 6, 9, 16–25]. The resident surgeons needed a longer operative time than the expert surgeons for LLARs for extraperitoneal rectal cancer but not for LLARs for intraperitoneal rectal cancer. This might be because LLAR for extraperitoneal rectal cancer is more demanding and can reveal unsatisfactory surgical skills of resident surgeons than that for intraperitoneal rectal cancer.

The most common intraoperative complication in all the groups was failure of the endoscopic linear stapler or circular stapler; the incidence of this complication did not differ among the four groups. In this study, intraoperative equipment failure was associated with increased risk of conversion to open LAR and anastomotic leakage. This finding reinforces the importance of the appropriate use and selection of surgical devices.

The longer time to resumption of diet in the I-E group than in the I-R group may be partly associated with the higher incidence of anastomotic leakage in the I-E group than in the I-R group (the difference was not statistically significant). The other outcomes with regard to time to bowel recovery were similar in the I-E and I-R groups and in the E-E and E-R groups, and well within the previously reported range [1–5, 9, 18, 19, 21, 22].

The mean number of lymph nodes harvested was similar in the I-E and I-R groups and in the E-E and E-R groups and was more than the adequate number, suggesting that extensive lymphadenectomy was performed. The mean distal margin was similar in the I-E and I-R groups and in the E-E and E-R groups, and its value almost agrees with that reported in other series [1, 2, 16, 18–25], suggesting that wide dissection and resection were performed.

A higher incidence of positive resection margins after laparoscopic surgery for rectal cancer than that after open surgery has been reported and may result in a higher local recurrence rate [9]. In this study, only one positive resection margin was identified in the I-R group. In all the

groups, the accepted oncologic surgical principles were adhered to during LLARs.

The results of this study confirm the findings of other studies regarding training programs for open surgical procedures for colorectal cancer [26, 27] and for laparoscopic surgical procedures including laparoscopic colectomy [28–30]. The short-term surgical and functional outcomes in the I-R and E-R groups were almost as good as those in the I-E and E-E groups, respectively, and were quite satisfactory, although the expert surgeons obtained significantly better results with respect to operative time in LLARs for extraperitoneal rectal cancer. Furthermore, oncologic requirements were fulfilled in all the groups. This study analyzed only the short-term outcomes of LLARs; long-term follow-up is required to ensure that oncological procedures during LLAR are not compromised in any group. Nonetheless, we believe that this study demonstrates the safety and feasibility of our systematic program for training resident surgeons to perform LLAR for rectal cancer.

Our systematic training program has a unique concept regarding the suitable timing for the introduction of advanced laparoscopic procedures during residency. Because of the steep learning curve for LCR, it is considered that it takes longer to learn laparoscopic surgery, especially LLAR, than to learn open surgery. Moreover, laparoscopic training is commonly initiated after completion of training for open surgery. In this study we have shown that prior experience with open surgery is not a prerequisite for training in laparoscopic surgery; furthermore, through sufficient experience, resident surgeons can acquire the skills required for performing LLAR early in their training period. We consider that with regard to the training of resident surgeons, laparoscopic surgery presents some advantages over open surgery: a magnified image of the surgical field can be obtained even in the case of a deep and narrow pelvis, and everyone involved in the surgery can view the surgical field and learn the procedure from digital records. In addition, in our systematic training program, the use of standardized techniques is emphasized and expert surgeons assist resident surgeons in order to ensure effective education and procedural safety.

There is limited evidence regarding the oncologic adequacy of LLAR for rectal cancer; however, an increasing number of institutions actually employ LLAR for the treatment of rectal cancer. Therefore, it is necessary that the quality of LLAR is ensured in each institution. It is paramount that today's general surgery residency programs incorporate training for advanced laparoscopic procedures into their curriculum and that surgical trainees are given sufficient experience in laparoscopic surgery in a properly structured training program. In summary, the present study suggests that the introduction of LLAR for rectal cancer early during residency is a feasible training concept.

Disclosures Drs. Satoshi Ogiso, Takashi Yamaguchi, Hiroaki Hata, Hiroya Kuroyanagi, and Yashiharu Sakai have no conflicts of interest or financial ties to disclose.

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