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ORIGINAL ARTICLE

How to perform the endoscopically assisted components separation technique (ECST) for large ventral hernia repair

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Abstract
Background The components separation technique (CST) is frequently used for reconstructing large ventral hernias. Unfortunately, it is associated with a high wound complication rate up to 50 %, caused by large wound surface and inherent trauma to abdominal skin vascularization. An endoscopically assisted modification of the original technique (ECST) spares skin vascularization and reduces wound surface, supposedly reducing wound complications. This study accurately describes ECST step by step with detailed illustrations and report the results of a 27 patient cohort.
Methods Since September 2012 patients with midline hernias without previous subcutaneous dissection and a maximum diameter of approximately 10–15 cm underwent ECST in an expert centre for abdominal wall reconstructions. Prospective data was gathered during inpatient care and 3–6 monthly follow-up.
Results Twenty-seven patients (17 male/10 female) with median age of 60 years (range 35–77), average BMI 27 (SD ±2) kg/m^2 and median ASA classification 2 (range 1–3) underwent ECST. Two patients were excluded due to bilateral conversion to conventional CST and finding of peritoneal metastases. Median defect size was 116 ± 48 cm^2. Median length of stay was 5 days (range 3–15). Wound complication rate was 11 %. Recurrence rate was 29 % after a median follow-up of 13 months.
Conclusions Endoscopically assisted modification of the original technique can be used for reconstructing large and complex ventral hernias up to 15 cm in diameter. The results of this small sized cohort study showed that ECST is feasible in patients with a uro-, or enterostomy and suggest that ECST reduces wound complication rate when compared to CST.

Keywords Ventral hernia · Endoscopic components separation technique · Wound complications · Complications

Abbreviations

CST	Components Separation Technique
ECST	Endoscopically assisted Components Separation Technique
ASA	American Society of Anaesthesiologists
BMI	Body Mass Index
EHS	European Hernia Society
MDT	Multi Disciplinary Team
COPD	Chronic Obstructive Pulmonary Disorder
NPT	Negative Pressure Therapy
PDS	Polydioxanone
VC	Vital Capacity
FEV	Forced Expiratory Volume
CDC	Centre for Disease Control

Introduction

Over 20 % of midline laparotomies causes an incisional hernia within 10 years [1, 2]. Repairing large ventral hernias is challenging in terms of operation technique,

An interim analysis of this study was presented at the annual European Hernia Congress 2014.

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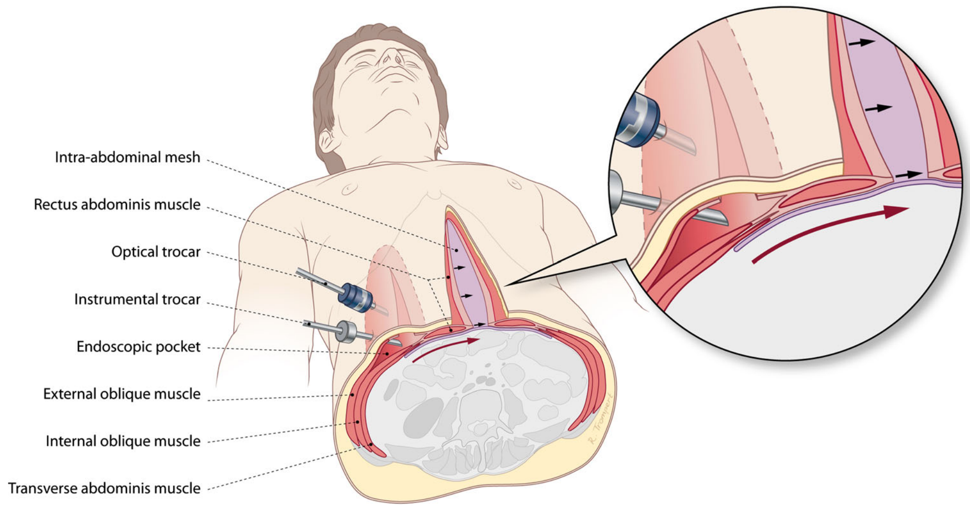

Fig. 1 Overview of anatomy and trocar placement during ECST. Trocars are placed as far lateral as possible, the endoscopic pocket ranges from the thorax (5 cm crianal of the 12th rib) until the inguinal ligament. Release of the external oblique aponeurosis creates a compound flap of the rectus abdominis muscle, the internal oblique and transverse muscles that can be advanced towards the midline approximately 6 cm at the umbilical level

complications and durability of the repair. In 1990 Ramirez et al. described the 'components separation technique' (CST) as a method for large ventral abdominal wall reconstruction [3]. This technique is based on enlargement of the abdominal wall surface by transection of the external oblique muscle to create a compound flap of the internal oblique and transverse muscle. CST can be used to close hernias up to 20 cm width, however, due to the large wound surface patients are prone for post-operative wound complications (52 % wound complications rate). In an attempt to reduce post-operative wound complications, an endoscopically assisted version of the component separation technique (ECST) was developed. ECST reduces the wound surface and spares the innervations and blood supply of the abdominal skin. ECST seems to be associated with less wound complications when compared to CST [4–14]. The present study describes the Endoscopically assisted Components Separation Technique and reports the results of a 27 patient cohort [15].

Performing ECST

- *Step 1* 'Patient preparation'

All patients received preoperative intravenous antibiotic prophylaxis in the form of Cefazoline (Kefzol®) 1000 mg and Metronidazol (Flagyl®) 500 mg. The patient is placed in a supine position, a peripheral intravenous line is placed on either arm. Both arms are tucked in alongside the trunk using a cotton sheet. A Foley Catheter is placed in the bladder and the skin is disinfected from the thorax to the pubic area with 2 % chlorhexidine in 70 % alcohol. The sterile field is created using sterile drapings and extends from the thorax to the pubic area and as far lateral as possible.

- *Step 2* 'Access the abdomen and perform adhesiolysis'

The midline scar is excised and the hernia is reduced. The hernia sac is removed and any adhesions between the intra-abdominal content and the abdominal wall are removed as far lateral as possible. The falciform ligament is dissected for optimal positioning in case an intra-abdominal mesh placement is used later on. In case a sublay mesh placement is performed the falciform ligament can stay intact.

- *Step 3* 'Create the lateral endoscopic pockets'

See Figs. 1 and 2 for optimal trocar placement and position of the 'endoscopic pocket'.

A small 1.5 cm incision is made 2 cm subcostal, approximately 5 cm lateral from the rectus muscle. Through this incision the fascia of the external oblique muscle is identified and incised. The muscle fibres are spread carefully with two blunt handheld retractors and a blunt tip balloon trocar (10 mm AutoSuture BTT, Covidien®) is placed in the plane between the external and internal oblique muscle. Insufflation commences, a 10 mm 30° endoscope is introduced and used to separate the loose connective tissue between the external and internal oblique muscle, thus creating the 'endoscopic pocket'. One 5 mm screw-type trocar is placed under direct vision 3 cm distal to the blunt-tip trocar. Using electro coagulation the pocket is extended cranially more than 5 cm above the costal margin, distally towards the inguinal ligament and laterally to the aponeurosis of the external oblique muscle (Fig. 1). The external oblique aponeurosis is now released approximately 1 cm lateral to the rectus abdominal muscle more than 5 cm cranial of the costal margin until the inguinal region to create a compound flap consisting of the internal oblique and transverse muscle. See Fig. 3 for an endoscopic view inside the endoscopic pocket after the external

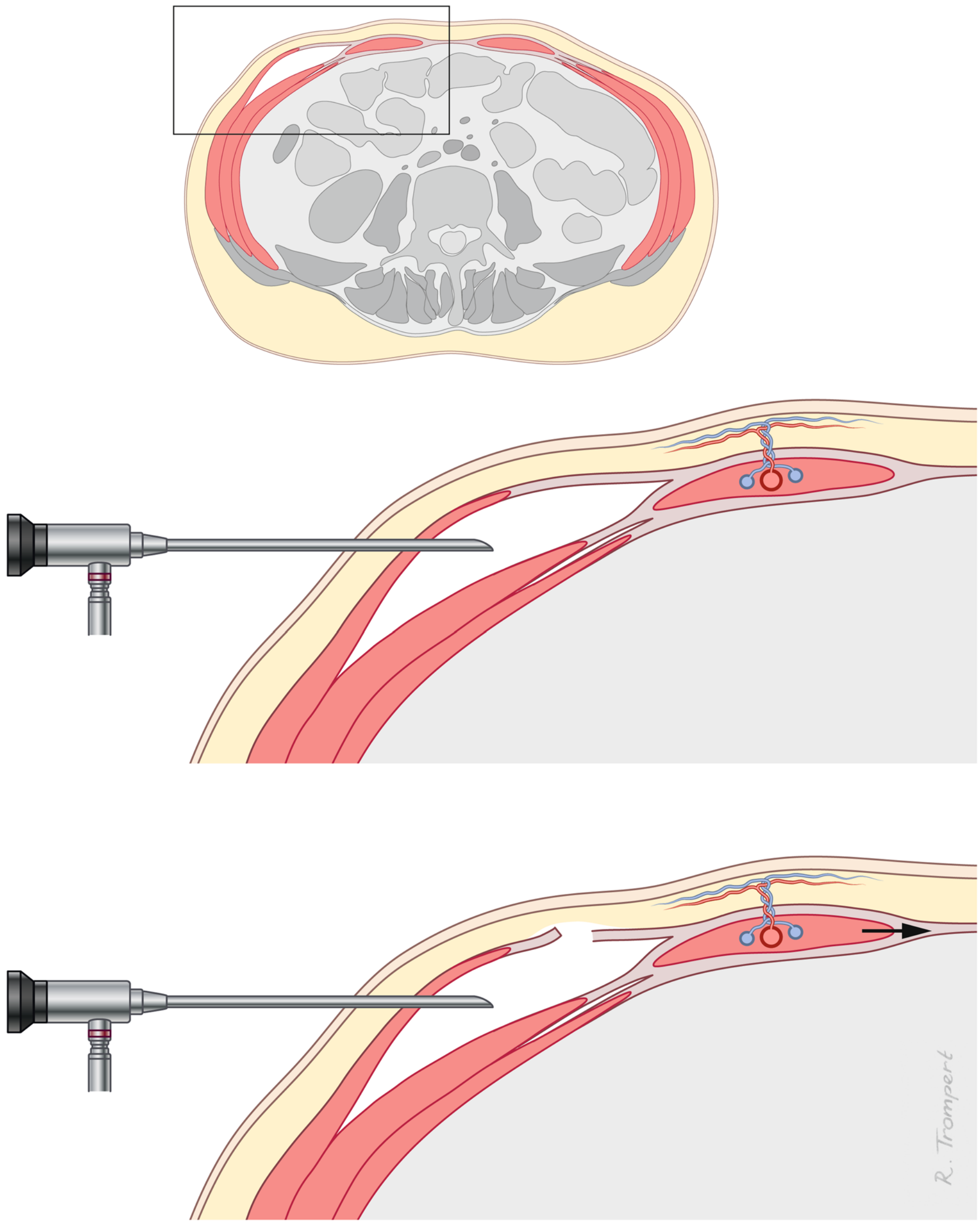

Fig. 2 Transverse view before and after release of the external oblique muscle. Transverse view of the abdomen visualizing the endoscopic pocket and the release of the external oblique aponeurosis. Note that the perforating vessels and nerves are spared

oblique muscle has been transacted. The same procedure is performed on the contralateral side.

- *Step 4* ‘Close the gap’

The newly created compound flap consisting of the rectus muscle, internal oblique muscle and transverse abdominal muscle (see enlargement in Fig. 1) can now be advanced approximately 6 cm towards the midline on either side. Closing gaps between 10 and 15 cm in width. The trocars in the endoscopic pockets can now be removed and the external oblique fascia is closed with a single resorbable suture.

Mesh reinforcement is performed using one of two mesh positions: ‘intra-abdominal’ or ‘sublay’.

Indication for an intra-abdominal mesh exists when the posterior rectus fascia cannot be closed in the midline or when the posterior rectus fascia is of poor quality for instance due to previous surgery/scarring of the posterior rectus fascia.

If an intra-abdominal mesh is placed (Ventralight ST mesh® Bard Davol inc.® of 33 × 25 cm) it is placed directly on the omentum and should cover the entire ventral exposure of the intra-abdominal compartment, ranging from xyfoid to pubic bone with a width of at least 25 cm. The mesh then fixated using approximately ten transfacial polydioxanone sutures (2/0) placed transfascially through the transverse abdominal and internal oblique muscle.

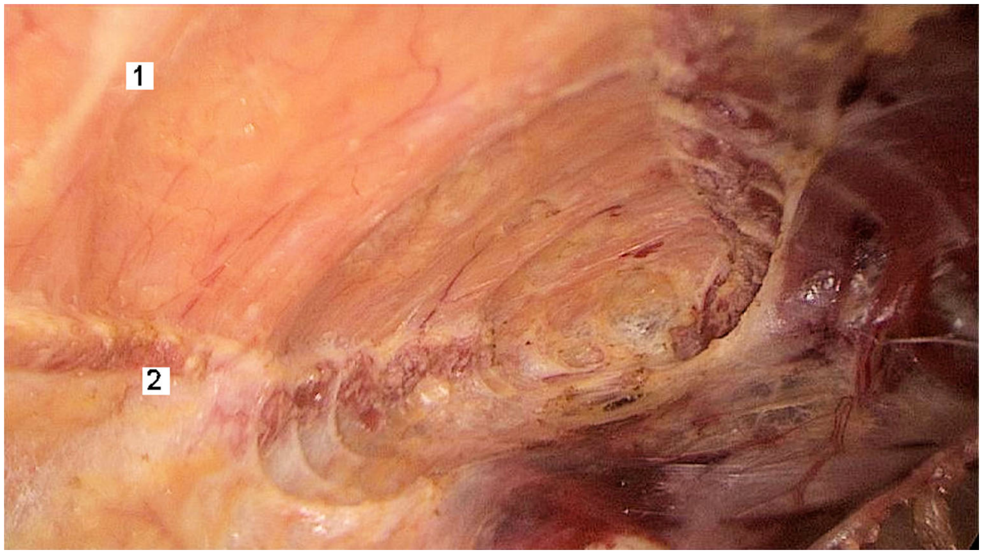

Fig. 3 Endoscopic view after release of the external oblique muscle. Endoscopic view of the 'pocket' after release of the external oblique aponeurosis. The subcutaneous fat (1) is visible as well as the medial rim of the external oblique aponeurosis (2)

In case the posterior rectus abdominis fascia is of good quality and can be closed in the midline, a sublay position of the mesh (underneath the rectus abdominis muscle, on top of the posterior rectus fascia) is preferred due to the reduced risk of bowel adhesions. For sublay placement the mesh (Bard Softmesh® Bard Davol inc.® of 30 × 30 cm) was cut to size to cover the entire posterior rectus abdominis fascia and fixated using at either end using four absorbable sutures. The anterior rectus abdominis fascia is closed using a continues resorbable PDS loop suture. The skin is closed and the wounds are dressed. The patient is advised to wear an abdominal binder for 4 weeks and avoid heavy lifting for 6 weeks.

Tips and tricks

Tip 1: 'patient selection'

ECST can be used for midline hernias approximately six to thirteen cm wide. In patient selection it is of the utmost importance that the patient is in good pulmonary condition. Ideally a multi-disciplinary approach including pulmonary screening, radiological examination using abdominal CT-scans and pre- and postoperative physical therapy are used to provide the best patient care. Patients with chronic obstructive pulmonary disease (COPD; Tiffenau index <70 %) should received perioperative pulmonary preparation (salbutamol and ipratropium) to prevent exacerbation and patients with asthma should received preoperative preparation with salbutamol to prevent bronchospastic reaction during induction. Patients with severe obesity should be stimulated to lose weight under supervision of a physical therapist, ideally the Body Mass Index (BMI) should be below 30 kg/m^2 before surgery.

Tip 2: 'presence of a uro- or enterostomy'

The presence of a uro- or enterostomy limits the surgical technique's that can be used for ventral hernia repair. However, ECST can be used in these patients if a 'sublay' position of the mesh is feasible. Therefore pre-operative evaluation should include a detailed examination of the patient history, including any previous hernia repairs and mesh positions and an abdominal CT-scan to provide inside in the quality of the abdominal muscles and the posterior rectus abdominus fascia. In step 3 of the procedure a sublay mesh position is used. After closing the posterior rectus fascia the mesh is cut to size to cover the entire posterior rectus fascia, including the 'hole' in the posterior rectus fascia where the uro- or enterostomy is located. Then, the mesh is incised at the location of the stoma and a hole is cut inside the mesh to facilitate the uro-/enterostomy. The mesh is then placed on top of the posterior rectus abdominis fascia and resembles a 'key-hole' mesh around the uro-/enterostomy. Ideally the incision in the mesh used to cut the whole and place the mesh around the uro-/enterostomy is closed using non-absorbable sutures, however, depending on the size and location of the uro-/enterostomy this is not always possible.

Tip 3: 'monitor position'

During ECST orientation inside the endoscopic pocket may be difficult for the performing surgeon. To assist the surgeon with orientation during the endoscopic release two endoscopic video monitors are used, one at the head of the operating table and one at the end of the operating table. If the surgeon point the endoscope towards the head of the patient, the monitor located at that side of the table is used and vice versa of the endoscope is pointed towards the feet op the patient.

Tip 4: 'patient position'

To ensure enough room to manipulate the endoscope during the creation of the endoscopic pocket both arms are tucked in alongside the trunk of the patient and trocars must be placed far laterally.

Tip 5: 'creating the endoscopic pocket'

The 'space' or 'pocket' between the external and internal oblique muscle may be difficult to identify due to its resemblance to the 'space' between the transverse and the internal oblique muscle. However, after placement of the balloon trocar and insufflation of the 'endoscopic pocket' the surgeon can quickly check if he is creating the endoscopic pocket between the external and internal oblique muscle or (by mistake) in between the internal oblique and the transverse abdominal muscle since the first is an avascular plane and shouldn't be accompanied by any bleeding during dissection of the connective tissue and the later isn't. One may also use the direction of the muscle fibers in the 'ceiling' of the endoscopic pocket to identify either the external or the internal oblique muscle.

Tip 6: 'use mesh'

Previous studies have demonstrated that the use a mesh is absolutely vital to create a durable hernia repair [16]. The results section below will also demonstrate that three patients who underwent a repair without mesh (two patients due to intra-abdominal contamination and one because of pain and discomfort after previous mesh repair) all had a recurrence hernia within 2 years.

Methods and results

During September 2012 and September 2015 27 patients (17 male, 10 female) with a median age of 60 years (range 35–77 years), average BMI of 27 ± 2 kg/m^2 and median ASA 2 underwent ECST for correction of a midline incisional hernia with a median defect size of 116 cm^2 (range 28–298, Table 1). Only patients with no previous subcutaneous dissection and a maximum defect diameter of approximately 10–15 cm were included.

Table 1 Demographic and perioperative details ($n = 27$)

Demographic characteristics	
Age (years), median (range)	60 (35–77)
Gender (male/female)	17/10
BMI (kg/m^2) mean (SD)	27 (2)
Smoking	5 (19 %)
Ex-smoker	6 (22 %)
Previous repair	9 (33 %)
ASA classification III or IV	2 (7 %)
Diabetes	2 (7 %)
Abnormal preoperative PFT	3 (11 %)
Recurrence hernia	8 (29 %)
Previous incarceration of hernia	1 (4 %)
Location of hernia (M2, M3, M4)	9, 17, 1
Presence of urostomy, colostomy or ileostomy[a]	4 (15 %)
Hernia width (cm), median (range)	10 (6–20)
Perioperative details	
ECST unilateral/bilateral	3/24
Concomitant enterostomy take down	2 (7 %)
Operating time (min), median (range)	110 (69–239)
Mesh placement	24 (89 %)
Contamination	
Clean-contaminated	3 (11 %)
Contaminated	0 (0 %)
Dirty	2 (7 %)
Infected mesh extirpation	2 (7 %)
Length of stay (days), median (range)	5 (3–15)

Demographic characteristics of all included patients

% percentage of total population, *SD* standard deviation, *ASA* American Society of Anesthesiologists classification, *PFT* pulmonary function test, *(E)CST* (endoscopic) components separation technique, *Smoking* occasional smoker, *Ex-smoker* stop smoking ≥3 months before surgery

[a] Four patients had uro-/enterostomy at the beginning of the procedure. Two of these patients underwent concomitant enterostomy takedown during the ECST. Location of the hernia is reported according the the European Hernia Society (EHS) classification for hernias (M2 = epigastric, M3 = umbilical, M4 = below the umbilicus). Contamination was classified according to the CDC classification

Two patients had both a midline defect (EHS M3) and a parastomal hernia (EHS L2). All patients fulfilled the criteria for 'Minor' ($n = 9$), 'moderate' ($n = 14$) or 'Major' ($n = 4$) complex hernias as formulated by Slater et al. [17]. Follow-up was obtained from 3 to 6 monthly outpatient visits.

Postoperative complications

Overall seven patients (26 %) had ten mild (Clavien Dindo class. I or II) complications within 30 days postoperative (paralytic ileus with gastric paralysis ($n = 2$), urinary tract infection ($n = 2$), pneumonia ($n = 1$), deep venous thrombosis ($n = 1$)) and 1 class III complication (subcutaneous haematoma, normalized ratio (INR) ≥ 7.5, in patient using Phenprocoumon).

Three of the previous seven patients (11 %) had four wound complications [wound dehiscence ($n = 1$), abscess ($n = 3$)] all treated with negative pressure wound therapy. These three patients all had an increased risk of infection due to perioperative intra-abdominal contamination [dirty ($n = 1$), clean-contaminated ($n = 2$)] [18].

Recurrence rate

To asses recurrence rate only patients with a follow-up of 1 year or longer that received a repair with a mesh ($n = 14$) were evaluated. Evaluation was based on clinical examination, if any doubt of recurrence existed an ultrasound was performed ($n = 2$) to evaluate recurrence rate. After a median follow-up of 13 months (range 12–34) four of the fourteen patients that underwent ECST with mesh reinforcement had a recurrence hernia after 12, 15, 18 and 26 months respectively. Three of these four patients had only a minor, 3 cm recurrence in the epigastric region.

In addition to the above mentioned recurrences, all patients that underwent a repair without mesh reinforcement ($n = 3$) had a recurrence hernia after 6, 7 and 18 months respectively.

Discussion

ECST can be used to reconstruct midline abdominal wall hernias up to approximately 15 cm in width, even in patients with a uro- or enterostomy.

Operation technique

Our technique differs from previously published methods such as performed by Lowe et al. [13]. It is the authors view that using a distension balloon to create a subcutaneous space has little advantage over the original technique described by Ramirez et al. because of trauma to the skin vascularization [3]. Rosen et al. and Fox et al. described an endoscopic method using the plane between the internal and external oblique muscles, though a dissection balloon is used and the external oblique fascia is incised in three places because an extra trocar is needed to complete transection of the external oblique aponeurosis [7, 19]. In our series ECST was successfully used in hernias of 10–15 cm in width. The maximum diameter that was reconstructed with ECST in this series was 20 cm due to a larger then expected defect during the operation. Since this diameter was only successfully reconstructed once in our series the authors do not recommend using ECST routinely for defects over 15 cm in width.

Wound complications

Our prospectively collected data shows that ECST with mesh augmentation is associated with a modest wound complication rate of 11 %. These result, and the results from Albright et al. and Jensen et al. who reported wound complication rates of 19 and 18 % respectively in the ECST group prove that ECST has a reduced wound complication rate when compared to CST [4, 9, 15, 20].

Switzer and colleagues compared length of stay, wound complications and recurrence rate in their meta-analysis between CST and ECST [15]. Despite a clear tendency in favor of ECST in the descriptive data, they were unable to provide statistically significant evidence other than a reduction in operation time and skin dehiscence in favor of ECST. This lack of statistically significant results can most likely be attributed to a shortage of patients and stipulates the need for additional data. Jensen et al. was able to provide the first statistically significant evidence for a reduction of wound complications with ECST in their meta-analysis of five comparative studies including a total of 162 patients [ECST ($n = 78$) 18 vs 43 % ($n = 84$) CST, $p < 0.001$]. They could not find statistical evidence for a reduction in hernia recurrence or length of stay. However, the result of this meta-analysis must be interpreted with caution because the included studies are no randomized controlled trials and indication for open CST differed from ECST (prior mesh infection, contaminated procedures and extensive adhesiolysis) in most of the included studies, which increases the risk of selection bias in favor of ECST.

Mesh repair

The importance of a mesh in reducing the recurrence rate after CST was demonstrated by Slater et al. [16]. In their prospective study of 75 patients. They showed a recurrence rate of 38.7 % in patients without a mesh and compared this with a literature extracted number of 14 % recurrence in patients with a mesh ($p < 0.01$). In our series we observed a 100 % recurrence rate in all patients that underwent a non-mesh repair. Once again proving that mesh is a vital part of hernia reconstruction.

Recurrence rate

The series of Harth and Rosen used a comparable surgical technique with biological sublay or intra-peritoneal mesh. They described a high recurrence rate of 29 % in both groups (ECST $n = 22$ and CST $n = 19$) and a wound complication rate of 27 and 52 % in groups respectively, with a mean follow-up of 15 months [11, 21]. The results of Rosen et al. primarily describe a single stage treatment in contaminated cases (CST 91 % vs ECST 73 % contaminated), reducing their external validity and comparability with a less complex population. Neither Jensen et al. nor Switzer et al. found a significant reduction of recurrence rate after ECST compared to CST in their meta-analysis [15, 20]. In our series the recurrence rate is 29 % after a median follow-up of 13 months, which suggests that ECST does not reduce the recurrence rate, however, due to a limited amount of patients with a follow-up of 12 month or longer no conclusive statements can be made based on our series alone.

There are several limits to this study, such as the small number of patients, with a short follow-up. The analysis included results of both unilateral and bilateral ECST combined, and did not included esthetic outcome nor quality of life. Furthermore no direct comparison to alternative hernia reconstruction methods were conducted.

In conclusion, the endoscopically assisted components separation technique can be used for reconstructing large and complex ventral hernias up to 15 cm in diameter. The results of this small sized cohort study showed that ECST is feasible in patients with a uro-, or enterostomy and suggest that ECST reduces wound complication rate when compared to CST.

Compliance with ethical standards

Conflict of interest All authors declare no conflict of interest.

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