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Endoscopic versus open component separation: systematic review and meta-analysis

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Abstract
Background The component separation technique (CST) was developed to improve the integrity of abdominal wall reconstruction for large, complex hernias. Open CST necessitates large subcutaneous skin flaps and, therefore, is associated with significant ischemic wound complications. The minimally invasive or endoscopic component separation technique (MICST) has been suggested in preliminary studies to reduce wound complication rates post-operatively. In this study, we systematically reviewed the literature comparing open versus endoscopic component separation and performed a meta-analysis of controlled studies.
Methods A comprehensive search of electronic databases was completed. All English, randomized controlled trials, non-randomized comparison study, and case series were included. All comparison studies included in the meta-analysis were assessed independently by two reviewers for methodological quality using the Cochrane Risk of Bias tools.
Results 63 primary studies (3,055 patients) were identified; 7 controlled studies and 56 case series. The total wound complication rate was lower for MICST (20.6 %) compared to Open CST (34.6 %). MICST compared to open CST was shown to have lower rates of superficial infections (3.5 vs 8.9 %), skin dehiscence (5.3 vs 8.2 %), necrosis (2.1 vs 6.8 %), hematoma/seroma formation (4.6 vs 7.4 %), fistula tract formation (0.4 vs 1.0 %), fascial dehiscence (0.0 vs 0.4 %), and mortality (0.4 vs 0.6 %.) The open component CST did have lower rates of intra-abdominal abscess formation (3.8 vs 4.6 %) and recurrence rates (11.1 vs 15.1 %). The meta-analysis included 7 non-randomized controlled studies (387 patients). A similar suggestive overall trend was found favoring MICST, although most types of wound complications did not show to significance. MICST was associated with a significantly decreased rate of fascial dehiscence and was shown to be significantly shorter procedure.
Conclusion This systematic review and meta-analysis comparing MICST to open CST suggests MICST is associated with decreased overall post-operative wound complication rates. Further prospective studies are needed to verify these findings.

Keywords Component separation · Endoscopic · Minimally invasive · Systematic review

Incisional hernias are a common post-operative complication, with an incidence of 5–15 % following open abdominal procedures and 1–3 % following minimally invasive abdominal procedures [1]. Large abdominal wall defects pose a challenging problem to correct for general surgeons. The options for closing these complicated defects, including primary repair, mesh, and distant muscle

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flaps, have yielded suboptimal results, therefore, in 1990, Ramirez et al. [2] first developed the component separation technique (CST) to address this issue. CST is based on the concept of re-establishing a functional abdominal wall with an autologous tissue repair. The procedure involves dividing the relatively fixed external oblique aponeurosis, elevating the rectus abdominus muscle from its posterior rectus sheath, and then mobilizing the myofascial flap consisting of the rectus, internal oblique, and transverse abdominus medially [2]. Allowing for approximately 10 cm of mobilization on each side, this procedure allows for a tension-free midline fascial closure [2]. CST avoids the absolute use of prosthetic material, which can be beneficial in contaminated fields [3].

Unfortunately, CST is not without its own procedural morbidity. The extensive lateral dissection required to create large subcutaneous skin flaps leads to marked wound complications [3]. Specifically, ligating a significant proportion of the perforating abdominal wall blood vessels predisposes the flap to ischemia and infection, in addition to potential formation of hematomas and seromas in the dead space [3, 4]. Wound infections rates have been shown to range from 25 to 57 % [4–7].

Minimally invasive component separation technique (MICST) was developed in efforts to address wound complications associated with necrosis. Introduced as a modification to the classic CST, usually coined endoscopic component separation (ECST), this new technique preserves the perforating abdominal wall vessels [3, 8]. Bilateral incisions are made at the medial insertion of the external oblique aponeurosis to the rectus sheath, an endoscopic balloon insufflator then separates the avascular plane between the external oblique and the internal oblique, and the external oblique is transected from pubic symphysis to costal margin using an endoscope. ECST has been suggested in preliminary studies to reduce wound complication rates post-operatively [4, 5]. To date, there has not been a systematic review and subsequent meta-analysis to critically assess the effectiveness of endoscopic compared to the classic open component separation. In this study, we systematically reviewed the literature comparing open versus minimally invasive component separation and performed a meta-analysis of controlled studies.

Methods

A comprehensive search of electronic databases (e.g., MEDLINE, EMBASE, SCOPUS, Web of science, and the Cochrane Library) using search terms "component separation" was completed. All randomized controlled trials, non-randomized comparison study, and case series were included. All human studies limited to English were included. Two independent reviewers screened abstracts, reviewed full text versions of all studies, classified and extracted data. All comparison studies included in the meta-analysis were assessed independently by two reviewers for methodological quality using the Cochrane Risk of Bias tools. Disagreements were resolved by re-extraction, or third party adjudication. Where possible and appropriate, a meta-analysis was conducted.

Assessment of study eligibility

We systematically reviewed each study according to the following criteria: (1) There were no study format restrictions for the systematic review, but the meta-analysis contained only controlled studies; (2) Involved either open or minimally invasive component separation or both; (3) The study report at least one of the desired wound complication outcome mentioned below; (4) Enrolled at least 5 patients; (5) Studies that involved significant variations in the open or minimally invasive technique, as determined by the two reviewers or third party adjudicators were also excluded.

Outcomes of interest

The primary outcomes of interest were wound complications: superficial wound infection, skin dehiscence, necrosis requiring debridement, hematoma or seroma formation, abscess formation, fascial dehiscence, and fistula formation. Secondary outcomes included mortality, recurrence rates of hernia re-operation rate for hernia rates, age, sex, BMI, operating room time, number of previous surgeries, number of previous incisional hernia repairs, length of stay in hospital, defect size, the use of reinforcing mesh, the type of mesh (biologic or synthetic), and follow-up time.

Results

Search results

A total of 722 studies were identified using our search criteria for screening (Fig. 1). After an assessment according to our exclusion criteria, 402 were excluded based on abstract alone and not meeting the basic requirement of data on open or minimally invasive component separation. Of 320 remained for review, 257 were excluded based on insufficient primary outcomes, enrollment of less than 5 patients, and results published in another included trial. Thus, a total of 63 primary studies (3,055 patients) were identified that met our inclusion criteria for the systematic review and were assessed by full manuscript. These included no randomized controlled

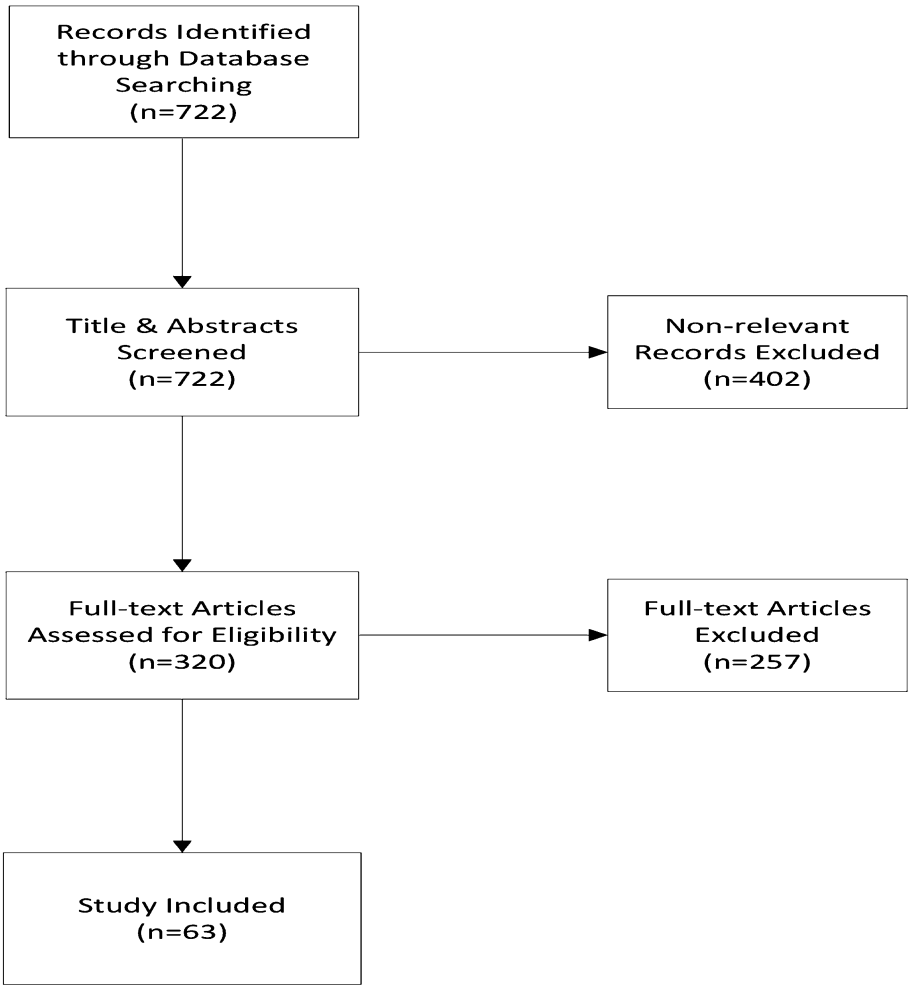

Fig. 1 Systematic review search results

trials, 7 controlled studies [5–11], and 56 case series [3, 12–64].

Included studies: systematic review

All 63 included studies reported wound complication outcome data following endoscopic and/or open component separation. The baseline patient characteristics and wound complication data in the included studies are listed in Table 1. A total of 3,055 patients were assessed and number of patients ranged from 5 to 545. The average age in the MIS and Open groups were 57.8 years and 55.7 years, respectively; with 55 and 52 % of the patients were male, respectively. The patients had a mean follow-up time of 15.5 months (MIS) and 25.8 months (Open).

The primary outcome was wound complication following MIS versus Open CST (Table 1). The total wound complication rate was lower for ECST (20.6 %) compared to Open CST (34.6 %). MICST compared to open CST was shown to have lower mean rates of superficial wound infections (3.5 vs 8.9 %), skin dehiscence (5.3 vs 8.2 %), necrosis/debridement (2.1 vs 6.8 %), hematoma/seroma formation (4.6 vs 7.4 %), fistula tract formation (0.4 vs 1.0 %), fascial dehiscence (0.0 vs 0.4 %), and mortality (0.4 vs 0.6 %). The open component CST did have lower rates of intra-abdominal abscess formation (3.8 vs 4.6 %) and recurrence rates (11.1 vs 15.1 %).

Secondary outcomes included mortality, recurrence of hernias, and reoperation rate for hernia. Mortality rates were lower with MICST (0.4 vs 0.6 %), while recurrence (15.0 vs 11.1 %) and reoperation (4.7 vs 2.6 %) favored the open technique.

Included studies: meta-analysis

The meta-analysis included 7 non-randomized controlled studies (387 patients). The basic demographic data as well as wound complication data are shown in Table 2. A similar overall trend was found that suggests Minimally Invasive CST has decreased wound infection rates, although most types of wound complications did not show to significance. MICST was associated with a significantly

Table 1 Study characteristics of patients with minimally invasive or open components separation technique

	Minimally invasive	Open
Age, mean (range)	57.8 (45–67)	55.7 (36.4–68)
Male (%)	54.6 (20–83)	51.9 (15–88)
BMI	31.1 (24.5–43)	32.5 (21.7–61)
OR time (min)	264 (105–377)	207 (92–348)
Previous abdominal surgery (*n*)	2.4 (0.93–7)	1.8 (0.2–4.6)
Previous incisional hernia repair (*n*)	0.5 (0.23–4)	1.0 (0.17–2.9)
Length of hospital stay (day)	7.7 (5.4–57.5)	9.1 (3–28.5)
Defect size (cm^2)	310.9 (132–767)	297.3 (101–525)
Patients with mesh (%)	46.5 (0–100)	61.9 (0–100)
Biology mesh (%)	66.0 (0–100)	51.9 (0–100)
Synthetic mesh (%)	34.0 (0–100)	48.1 (0–100)
Superficial wound infection (%)	3.5 (0–18.2)	8.9 (0–40)
Skin dehiscence (%)	5.3 (0–15.8)	8.2 (0–44.4)
Abscess (%)	4.6 (0–20)	3.8 (0–20)
Necrosis/debride (%)	2.1 (0–50)	6.8 (0–35.7)
Hematoma/seroma (%)	4.6 (0–20)	7.4 (0–35.7)
Chronic Fistula (%)	0.35 (0–16.7)	1.0 (0–21.4)
Fascial dehiscence (%)	0	0.4 (0–15)
Follow-up (month)	15.5 (4.5–38)	25.8 (6.7–108)
Recurrent (%)	15.1 (0–60)	11.1 (0–52.6)
Re-operation (%)	4.7 (0–40)	2.6 (0–23.1)
Mortality (%)	0.37 (0–1.5)	0.6 (0–5)
Total wound complications (%)	20.6 (0–57.1)	34.6 (0–83.3)

BMI body mass index, *OR* operating room, *LOS* length of stay

decreased rate of fascial dehiscence (odds ratio = 3.18, $p = 0.02$) and was shown to be significantly shorter procedure ($p = 0.02$). Forest plots were constructed of wound complication data (Figs. 2, 3, 4, 5, 6).

Discussion

Component separation repair of abdominal wall hernias allows for restoration of a functional, muscular abdominal wall that can provide dynamic support to counter fluctuations in intra-abdominal pressures [7]. It is quickly becoming a safe and effective approach to closing larger abdominal defects, especially in previously infected fields. De Vries Reilingh et al. [33] published the results of a randomized controlled trial comparing mesh prosthetic repairs versus the CST for giant abdominal wall defects, the results favored the use of CST over mesh repair due to the frequency of mesh infections.

Table 2 Study characteristics of patients included in meta-analysis

	META MIS	META open	*p* value
Age (mean)	61.8	59.8	0.97
Male (%)	49.5	43.6	0.51
BMI	31.2	31.3	0.52
OR time (min)	260.9	290.7	0.02*
Length of hospital stay (day)	8.2	11.5	0.51
Defect size (cm^2)	274.3	221.6	0.07
Patients with mesh (%)	60.7	73.2	0.22
Superficial wound infection (%)	4.6	11.4	0.26
Skin dehiscence (%)	4.0	14.6	0.02*
Abscess (%)	4.6	3.2	0.84
Necrosis/debride (%)	1.7	11.9	0.26
Hematoma/seroma (%)	4.0	4.9	0.74
Chronic fistula (%)	0	0.5	
Fascial dehiscence (%)	0	0	
Recurrence (%)	10.9	14.1	0.44
Re-operation (%)	5.2	3.9	0.52
Wound complications (n)	6.6	16.9	
Wound complications (%)	14.4	43.3	

BMI body mass index, *OR* operating room, *LOS* length of stay

* $p < 0.05$

However, the advantages of the classic CST over other possible hernia repair techniques are mitigated with the high prevalence of wound infections as shown in single institution studies controlled studies [4–7] Therefore, MICST was introduced to improve on this deficiency of the classical technique [3, 8]. From the few controlled trials comparing the techniques and the limited number of patients enrolled in those studies, it appears that wound infections are decreased using the endoscopic approach. Our systematic review and meta-analysis is the first paper to systematically review the literature to formally compare the two techniques.

The systematic review showed that wound complications were almost halved in the minimally invasive group, with 20 % of patients suffering a wound complication following endoscopic intervention compared to 34 % in open. With the exception of abscess formation and recurrence of hernia, all other wound complications were decreased with MICST compared to the classical technique. While the meta-analysis did not find a significant difference with the exception of a decreased rate of skin dehiscence, it appears that most wound complications tend to trend toward favoring the minimally invasive procedure. We suspect that with an increase in the number of primary studies, this trend will reach significance. This lack of

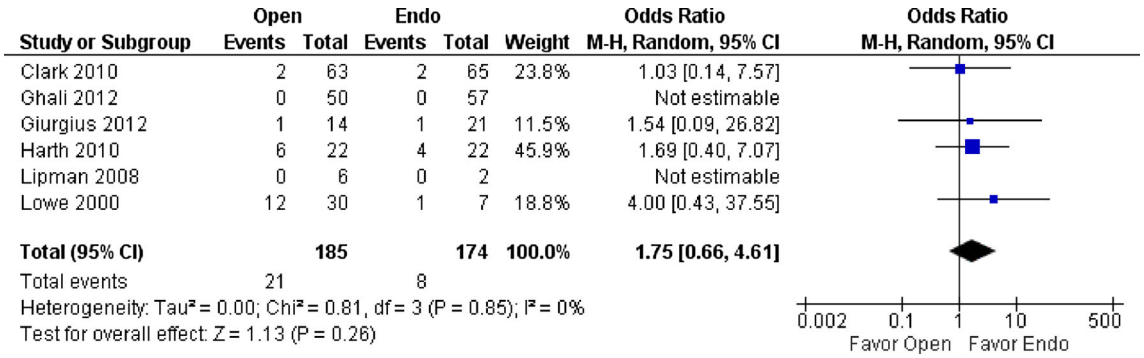

Fig. 2 Superficial wound infection rate in open versus minimally invasive component separation

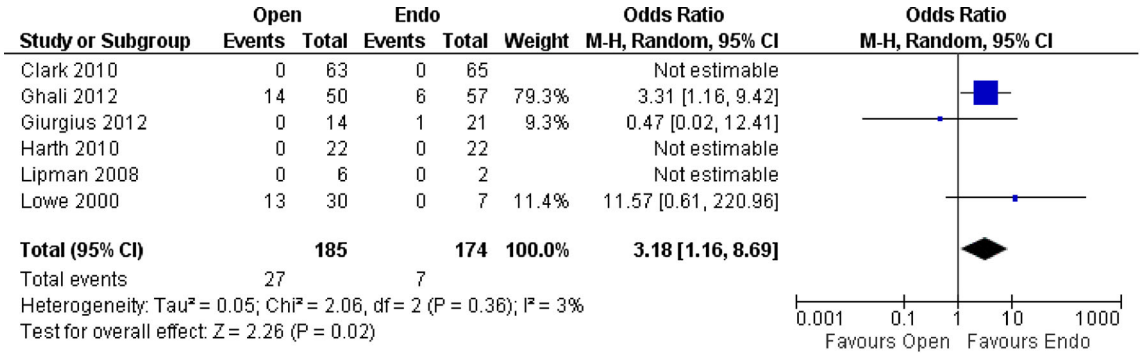

Fig. 3 Skin dehiscence rate in open versus minimally invasive component separation

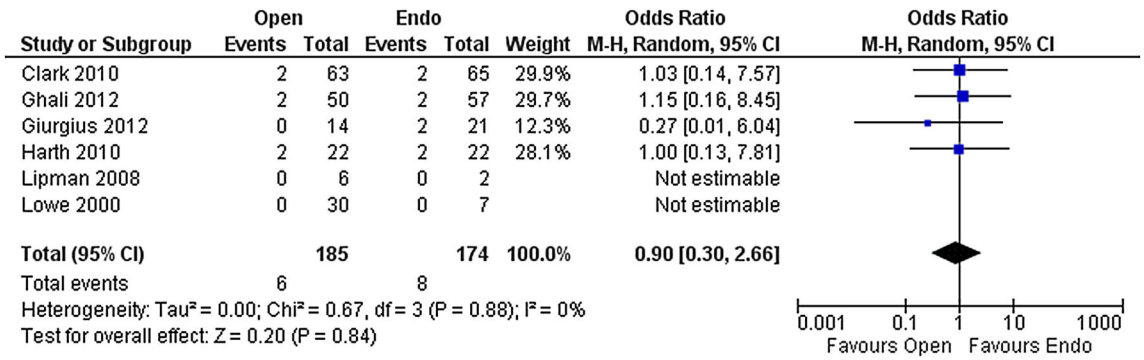

Fig. 4 Abscess formation rate in open versus minimally invasive component separation

apparent significance is most likely related to the lack of sufficient primary studies, only 7 studies meeting our inclusion criteria, with an adequate amount of enrolled patients, with less than 400 patients included. In addition, there remains a paucity in the literature for randomized controlled trials comparing the two techniques.

Avoiding large myofascial skin flaps, in the minimally invasive approach, that widely ligate the abdominal wall perforators leads to adequate tissue blood supply, improved cellular function, resistance to infection, and tissue healing [60]. Studies have shown that tissue hypoxia cause by disrupted vasculature leads to increased wound infection rates, this is explained on a cellular level as oxygen is converted to cellular messengers called reactive oxygen species which promote processes that support wound healing including cytokine action, angiogenesis, cell motility, and extracellular matrix formation [65].

The trend for an increase in hernia recurrence with the endoscopic approach could be explained be a few factors. First off, only 47 % of MICST patients received mesh placement compared to 62 % of patients following open component, leading to the possibility of decreased rectus

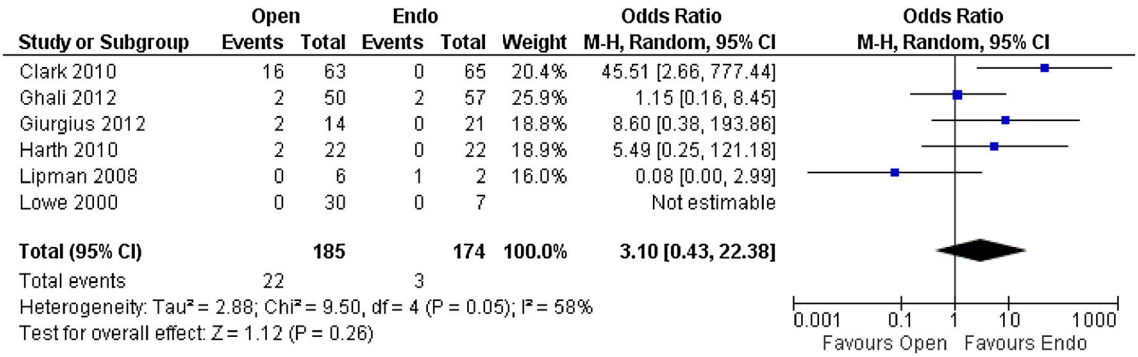

Fig. 5 Tissue necrosis requiring debridement rate in open versus minimally invasive component separation

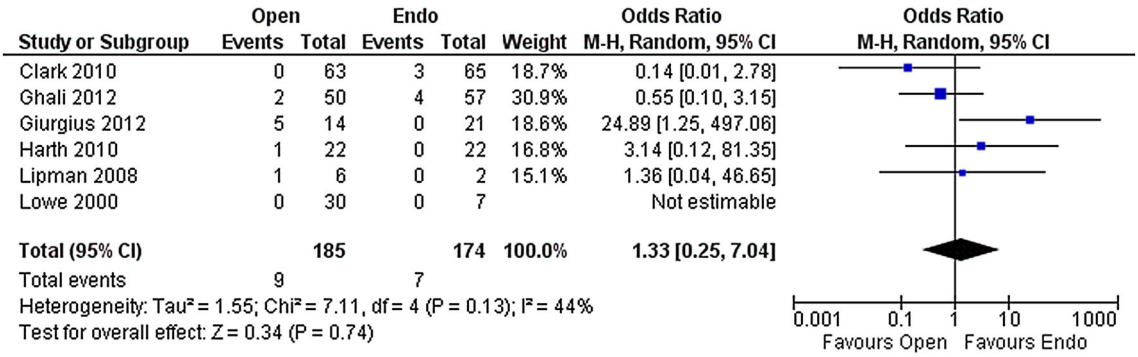

Fig. 6 Hematoma or seroma formation rate in open versus minimally invasive component separation

reinforcement and increased hernia occurrence. In addition, MICST might be substituting one ventral hernia for another one, as the site of the lateral release of the external oblique has the potential for creating abdominal wall weakness [5]. Unlike in the open technique, where the operator has the ability to reinforce the potential defect with mesh, such is a drawback of the endoscopic approach. Clarke et al. [5] reported 22 % of recurrences in the perforator preserving group were due to hernias at the lateral release point.

In addition to avoiding large potentially hypoxic tissue flaps, another theoretical advantage of MICST, proposed by Rosen et al., is that the lateral tunnels provide a clean space away from the midline wound in the event of a previously infected or contaminant centralized abdominal field and might decrease the complexity of any subsequent wound infection, in the event that they do develop [23].

In the patient population with previous ostomy sites, there is considerable debate to whether the MICST is advantageous or not. Theoretically, MICST avoids dissection over the scarred anterior rectus sheath that is required in creating large tissue flaps [6]. However, scarring from lateral ostomies and previous lateral incisions would make performing lateral tunnels extremely challenging [12]. Nevertheless, Ghali et al. [6] argue that MICST is actually valuable in general in cases, where the rectus sheath has encountered scarring from previous incisions and ostomies, as it avoids the dissection over the anterior sheath to create large tissue flaps. Therefore, it seems that previous midline incisions and ostomies favor MICST, while old ostomy sites and incisions more laterally favor open.

An important disadvantages of the MICST are that studies have shown that endoscopic techniques are not able to achieve the amount of midline mobilization compared to open, as endoscopic techniques only have a reported 86 % of the release in comparison to open [12]. This could limit their utility in the larger, giant hernias.

Since its introduction by Ramirez et al. [2], there have been slight modifications to the classical, open technique. One of the enhancements of the classic technique is mesh reinforcement of the midline abdominal wound. Reinforcing mesh can be placed either anterior to the rectus fascia or in the recto-rectus space (underlay versus onlay) based mostly on surgeon preference [6, 9]. Another point of potential diversion is whether or not to divide the posterior rectus sheath as originally described. In our meta-analysis study, 86 % of authors in the meta-analysis dissected through the posterior rectus in order to gain over 3 cm of mobilization per side [12]. Other diversions include "the open book" technique, using the mobile rectus sheath as a

turn-over flap to reinforce the rectus abdominal muscle in the midline and the preservation the periumbilical perforating vessels technique [59, 60].

Slight modifications also exist in the minimally invasive techniques included in this review. The original operative technique described by Lowe et al. [8] and Maas et al. [3, 8] used balloon insufflation to expose the avascular plane and a video-endoscope to release the external oblique muscle. Other minimally invasive techniques include developing the avascular plane with Yankauer suction and dissecting with hand held electrocautery [6]. Combining ECST with laparoscopic incisional hernia repair is also becoming increasingly popular [55].

In general, suitable patient selection is crucial in deciding whether to perform a component separation in the first place. Elderly, sedentary patients would not benefit as much as a younger, active patient from a functional abdominal wall and might not handle a larger surgery as well [5].

Conclusion

This systematic review and meta-analysis comparing MICST to open CST suggests MICST is associated with decreased overall post-operative wound complication rates including superficial infections, hematoma/seroma formation, necrosis, fistula formation, and both skin and fascial dehiscence. However, further prospective studies are needed to verify these findings to significance.

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