

Laparoendoscopic Extraperitoneal Surgical Techniques for Diastasis Recti Repair: Current Trends and Future Perspectives

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Abbreviations:

CT: Computer tomography;
DRA: Diastasis of the rectus abdominis;
ELAR: Endoscopic-assisted reconstruction;
EPAR: Endoscopic Pre-aponeurotic Repair;
eTEP: Enhanced-view totally extraperitoneal;
EMILOS: Endoscopic Mini- or Less-Open Sublay;
IPOM: Intraperitoneal onlay mesh;
IPOM + or IPOM Plus: Intraperitoneal onlay mesh plus,
IRD: Interrectus distance;
LIRA: Laparoscopic intracorporeal rectus aponeuroplasty;
LVHR: Laparoscopic ventral hernia repair;
MeSH: Medical subject heading;
MRI: Magnetic resonance imaging;
SCOLA: SubCutaneous OnLay Laparoscopic (or Endoscopic) Approach;
TAPP: Transabdominal preperitoneal patch plasty.

ABSTRACT

Diastasis of the rectus abdominis muscles (DRA) is a benign condition that generally occurs in 12 months post-partum women or in obese subjects who have suffered evident weight loss. Moreover, the association between rectus abdominis diastasis and ventral hernia is a common condition especially in multiparous women. Hernia correction alone without midline reinforcement increases the risk of hernia recurrence. We retrospectively evaluated PubMed databases, Embase, and the Cochrane Library by applying various combinations of the subject-related terms. The search terms identified with the medical subject heading (MeSH) were “diastasis of the rectus abdominis”, “laparoscopic repair”, “subcutaneous laparoscopic recti abdominis repair”. In this review, laparoscopic techniques used for the correction of DRA and/or hernia mesh repair are revised and compared. In particular, the SubCutaneous Onlay Laparoscopic (or Endoscopic) Approach (SCOLA), a quite new minimally invasive procedure that allows the surgeons to do simultaneous correction of rectus diastasis and hernia mesh repair with low cost without the need for large transverse abdominal incision, is highlighted, along with its advantages.

Keywords: laparoscopy, endoscopy, abdominal wall surgery, diastasis recti, SCOLA

INTRODUCTION

Pregnancy and the post-partum period lead to significant physiological, hormonal, and anatomical changes in the female body, aiming to create a favorable environment for fetal development. However, these transformations often negatively impact the musculoskeletal system. Changes in abdominal

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muscle function, pelvic floor dysfunction, and pain in the lower body are common manifestations during and after pregnancy. One notable musculoskeletal alteration is diastasis of the rectus abdominis muscles (DRA), which has gained considerable attention over the past two decades (1). According to Beer's classification, DRA is defined as a separation of more than 2.2 cm between the rectus abdominis muscles, measured 3 cm above the umbilicus with a relaxed abdomen. Although DRA is a benign condition, it frequently occurs within 12 months post-partum or in obese individuals who have experienced significant weight loss (2). The precise risk factors for DRA remain partially understood, with studies implicating pregnancy, advanced maternal age, cesarean sections, multiparity, fetal macrosomia, multiple gestations, obesity, certain exercise regimens, and ethnic background (3-5). Nevertheless, more research is required to establish definitive associations. The incidence of DRA varies depending on the diagnostic methods used, the sample size, the cutoff values for interrectus distance (IRD), and the inclusion criteria of the populations studied. Some reports suggest a negative association between DRA and abdominal muscle strength (6), while others link DRA to abdominal and pelvic pain during the early post-partum period, although the clinical significance of such pain is often minimal (7,8). Additionally, pelvic floor dysfunctions, including urinary and fecal incontinence and pelvic organ prolapse, are prevalent among post-partum women, particularly in peri and postmenopausal periods (9,10). Low back pain and pelvic girdle pain have also been associated with DRA (11). Diagnosis of DRA is typically achieved through clinical palpation, tape measurement, calipers, and ultrasound. Imaging modalities such as CT and MRI provide more precise measurements but are costly and, in the case of CT, expose patients to unnecessary radiation. During surgical procedures, intraoperative measurement tools like rulers and compasses are employed. The natural resolution of DRA commonly occurs in the initial post-partum months. However, persistent or severe cases may lead women to seek medical intervention due to functional or cosmetic concerns. Conservative therapy, including physical rehabilitation focusing on the abdominal and pelvic floor muscles, is typically the first line of treatment. Yet, when conservative management fails, surgical correction becomes necessary to restore both the functional and aesthetic integrity of the abdominal wall. Surgical approaches for DRA include open, laparoscopic, endoscopic, and hybrid techniques, each with distinct advantages and

disadvantages. The choice of technique often depends on the presence of cosmetic concerns and/or associated hernias. Plastic surgeons generally treat DRA cases involving redundant skin and require extensive excision, often employing an open approach with transverse incisions, whereas general surgeons address cases complicated by midline hernias using plication techniques, with or without mesh reinforcement (12). Postoperative complications vary depending on the surgical technique and patient characteristics. Common complications include postoperative pain, seroma formation, wound infections, hematoma, mesh extrusion, vasomotor changes, nerve injury, pneumonia, minor wound dehiscence, and altered sensation in the abdominal skin (13-15). Although recurrence rates are generally low, DRA can reappear even after surgical intervention (16,17). Several recent studies and metaanalyses have highlighted the importance of post-partum exercise therapy in improving outcomes related to pelvic floor disorders and DRA. A systematic review demonstrated that post-partum pelvic floor training significantly reduces urinary incontinence and pelvic organ prolapse risks, and abdominal exercise programs effectively decrease the IRD (18). Moreover, a randomized controlled trial indicated that curlup exercises could enhance abdominal muscle strength without worsening DRA (19). Nevertheless, a recent review emphasized limitations in the existing literature, including heterogeneity in diagnostic criteria, patient selection, and exercise protocols, which hinder the generalization of findings (20). Thus, while conservative management remains a first step, persistent symptomatic DRA, particularly when associated with hernias, often necessitates surgical intervention. A thorough understanding of both nonsurgical and surgical treatment options is essential to optimize patient outcomes.

MATERIALS AND METHODS

A retrospective review of the PubMed, Embase, and Cochrane Library databases was conducted using multiple combinations of topicspecific keywords. The search strategy incorporated medical subject headings (MeSH) such as "diastasis of the rectus abdominis", along with terms including "DRA", "laparoscopic repair", "subcutaneous laparoscopic recti abdominis repair", and "SCOLA". The literature search covered publications up to the year 2015. Studies were eligible for inclusion if they addressed diastasis recti abdominis (DRA), laparoscopic repair, or subcutaneous laparoscopic recti abdominis repair. We excluded case reports, letters,

editorials, comments, and conference abstracts. The review process followed the PRISMA guidelines, encompassing aspects such as protocol formulation, research question development, search methodology, eligibility criteria, data collection, study design evaluation, bias risk assessment, publication bias, heterogeneity, and statistical analysis.

From the initial pool of 2,100 identified articles, 290 duplicates were removed. The remaining 1,810 titles and abstracts were screened, resulting in the exclusion of 1,802 publications that did not meet the study criteria. The full text of the remaining 8 articles was reviewed, with 6 studies ultimately included in this analysis. These selected articles specifically addressed subcutaneous laparoscopic repair techniques for combined ventral hernias and rectus diastasis. We deliberately excluded intraperitoneal repair methods, considering the extraperitoneal approach a key distinguishing feature of newer techniques compared to traditional methods such as IPOM and IPOM+. Likewise, transperitoneal methods like ventral TAPP (transabdominal preperitoneal patch plasty) were excluded to maintain focus solely on total extra peritoneal procedures. Additionally, studies involving robotic surgery and the enhancedview totally extraperitoneal (eTEP) approach were omitted, as they represent widely adopted methods that require separate, comprehensive investigation. Their inclusion could introduce bias due to the greater volume and uniformity of data available on these techniques.

Studies on the Prevalence of DRA

Several investigations have sought to assess the prevalence of diastasis recti abdominis (DRA) during pregnancy and in the post-partum period. Bo et al. (2021) conducted a prospective cohort study in primiparous women, reporting a prevalence rate of 33.1% during pregnancy. Post-partum, the prevalence increased to 60% at 6 weeks, then declined to 45.4% at 6 months and 32.6% at 12 months after delivery (21). In another longitudinal observational study, da Mota et al. (2015) assessed primiparous women at the 35th gestational week and at 6-8, 12-14, and 24-26 weeks post-partum. The authors found that while all participants had DRA at 35 weeks of gestation (100%), this decreased to 39% six months after childbirth (22). Similarly, Fei et al. conducted a retrospective study that revealed a DRA prevalence of 82.6% among women within the first year post-partum (23). Beyond the quantitative data, the subjective experience of women living with DRA has been explored. Eriksson Crommert

et al. (2020) performed a qualitative study, highlighting how persistent DRA negatively impacted women's perception of their body image, physical function, and general wellbeing. Participants often reported feeling isolated and expressed frustration over the lack of medical attention to this condition (24). Taken together, these findings indicate that DRA is a frequent condition in the post-partum population, with significant variability depending on timing and measurement criteria. Furthermore, the emotional and functional consequences for affected women underscore the need for heightened clinical awareness and standardized management strategies.

Studies for the Repair of Diastasis Recti and/or Hernias

In the majority of patients with diastasis recti abdominis (DRA), symptoms related to hernias such as pain, fecal obstruction, or risk of strangulation are absent. Consequently, initial treatment is often conservative, aiming to address cosmetic complaints like abdominal bulging or the presence of a pendulous abdomen. Plastic surgeons commonly perform abdominoplasty combined with DRA repair in these cases. However, the progressive thinning of the linea alba represents a significant risk factor for the development of abdominal wall hernias, particularly in individuals with existing diastasis. The frequent association of hernias with DRA often leads patients to consult general surgeons for the simultaneous repair of both conditions. Addressing only the hernia without reinforcing the midline significantly increases the risk of recurrence. Therefore, a combined surgical approach is strongly recommended, especially considering that studies report up to 50% of patients with umbilical or epigastric hernias also exhibit DRA (25). *Table 1* lists all the main surgical techniques used for the treatment of DRA and/or hernias.

Among traditional laparoscopic techniques, the Intraperitoneal Onlay Mesh (IPOM) Plus approach carries inherent risks, including intestinal lesions, post-operative adhesions, bowel obstructions, and chronic neuralgia due to the presence of an intraperitoneal prosthesis and fixation devices. Additionally, IPOM Plus typically does not provide satisfactory cosmetic results during the early postoperative period (37).

The emergence of the preaponeurotic endoscopic approach (REPA), described by Bellido Luque et al. in 2015, marked a significant advance. This technique enables correction of DRA without entering the peritoneal cavity, thereby reducing laparoscopic

Table 1 - Common Techniques Used for the Treatment of DRA and/or Hernias

Technique	Treatments	Reference
REPA	DRA associated or not to midline hernias	(26)
ELAR	Umbilical, trocar, and/or epigastric hernias with concomitant DRA	(27,28)
ELAR plus	Umbilical and/or epigastric hernias	(27)
EMILOS	Hernias with or without DRA	(30)
EPAR	Ventral hernia and DRA	(15)
LVHR	Ventral hernia	(30)
IPOM Plus	Incisional hernias or symptomatic DRA	(31)
eTEP	Ventral hernia	(32)
LIRA	Ventral hernia	(33)
TAPP	Umbilical hernia with DRA	(34)
Slim-Mesh	Diastasis and linea alba/recti muscles	(35)
SCOLA	Ventral hernias and concomitant DRA	(16,36)

complications and minimizing mesh-related adverse events (38). Subsequent studies by Muas et al. in 2019 reinforced the safety and efficacy of REPA, particularly when combining rectus plication with prosthetic reinforcement using barbed sutures (26). A noteworthy alternative is the Subcutaneous Onlay Laparoscopic Approach (SCOLA), a minimally invasive technique that permits precise subcutaneous dissection, haemostasis, and mesh placement without penetrating the abdominal cavity (*fig. 1*). According to Claus et al. (2018) (16), SCOLA offers excellent outcomes, with a mean operative time of approximately 93.5 minutes. Seromas were the most frequent postoperative complication, occurring in 27% of cases, while surgical site infections were rare (2%). Median followup showed satisfactory results, with minimal rates of recurrence or fibrosis related complications. Similarly, Dong et al. (2021) demonstrated the safety and feasibility of robot-assisted SCOLA, particularly for small ventral hernias with concomitant DRA. They reported an average surgical time of 146 minutes, an 18.8% seroma rate, and a 12.5% hernia recurrence rate within a two-month followup period (36).

Other important techniques for treating DRA include ELAR (Endoscopic-Assisted Linea Alba Reconstruction), which combines a minimal periumbilical incision extended under endoscopic vision with direct suturing of the defect, reinforced by the placement of a polypropylene mesh (27,28). Similarly, EMILOS (Endoscopic Mini/Less Open Sublay) utilizes a hybrid approach, creating a miniincision for retro-muscular mesh placement (29). The enhanced-view totally extra-peritoneal (eTEP) approach, introduced by Belyansky and Daes, provides another promising minimally invasive solution, although it requires advanced skills due to its

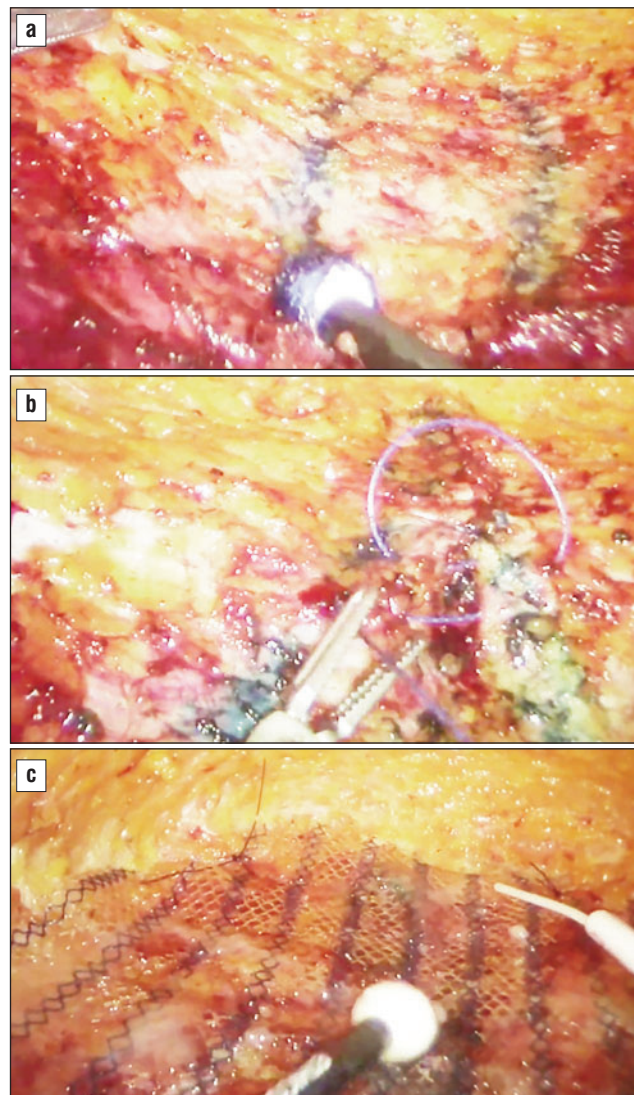


Figure 1 - SCOLA technique (U.O.C. of General Surgery, Regional Reference Center for Obesity Surgery, San Carlo Hospital, Villa d'Agri, Italy). (a) Marking of the margins of the rectus muscle; (b) Synthesis of the anterior fascia of the rectus muscles with continuous absorbable suture; (c) Placement of subcutaneous mesh

technical complexity (39).

Several factors are known to affect recurrence risk following hernia repairs, including failure to use a mesh, the use of absorbable rather than permanent sutures, and the coexistence of a diastasis recti defect. Roth et al. (2018) estimated that mesh-related complications leading to reoperation occur in approximately 5% of cases over five years, supporting the long-term safety and effectiveness of mesh reinforcement (40).

Innovative methods like the LIRA technique (Laparoscopic Intracorporeal Rectus Aponeuroplasty) aim to achieve intracorporeal midline closure using barbed sutures, offering better anatomical restoration and possibly lowering the risk of postoperative recurrence (41). Recent clinical studies have evaluated the outcomes of subcutaneous, extraperitoneal laparoscopic approaches for repairing DRA combined with ventral hernias. Claus et al. (2018) reported on 48 patients treated with the SCOLA technique, observing an average operative time of around 93.5 minutes. Seromas were the most common postoperative complication, affecting 27% of patients, while surgical site infections and subcutaneous fibrosis occurred at a rate of 2% each. Over a median followup of 8 months, functional and morphological outcomes were highly satisfactory, with a very low recurrence rate (16). In a cohort of 50 patients undergoing preaponeurotic endoscopic repair (REPA), Muas et al. (2019) documented the use of lightweight or intermediate-weight meshes in 90% of cases and heavier prostheses in 10%. Fixation was achieved with absorbable material in the majority (62%). External oblique release was required in nearly one-third of patients (32%). They reported a mean operative time of 83 minutes and a seroma incidence of 12%. No recurrences were observed after an average followup of 39 months, and most patients resumed daily activities within 16.5 days (26). Köhler et al. (2018) described a modified subcutaneous approach employing a fully absorbable synthetic mesh in a cohort of 20 patients. They reported a mean surgical duration of 79 minutes and a mean hospital stay of four days. Two cases of symptomatic seroma were observed (10%), but no recurrences occurred within the 5 month followup period (42). Dong et al. (2021) evaluated the robotic SCOLA approach for small midline hernias associated with DRA. They reported a mean operating time of approximately 146 minutes, with seromas occurring in 18.8% of cases and a recurrence rate of 12.5% during the 63 day followup (36). Collectively, these studies confirm the feasibility, safety, and positive anatomical outcomes associated with minimally invasive extra peritoneal techniques, particularly

SCOLA, which offers a promising alternative to conventional IPOM repairs, combining low morbidity with excellent cosmetic results.

CONCLUSIONS

In recent years, the ongoing pursuit of improved outcomes in ventral hernia repair has led to the development of innovative minimally invasive approaches, including endoscopic, laparoscopic, and robotic techniques. These methods aim to reduce postoperative complications, optimize anatomical restoration, and shorten recovery times compared to traditional intraperitoneal approaches. Diastasis recti abdominis (DRA), defined by Beer's classification as a separation of greater than 2.2 cm between the rectus muscles measured 3 cm above the umbilicus in a relaxed abdomen, predominantly affects women in the year following childbirth or individuals with significant weight loss. Although conservative therapies remain the first line of management, cases unresponsive to nonsurgical treatment-especially when associated with hernias-require surgical intervention to restore functional and cosmetic integrity. Among the techniques available, subcutaneous extraperitoneal repairs, particularly the Subcutaneous Onlay Laparoscopic Approach (SCOLA), have shown promising results. SCOLA offers the advantage of reinforcing the midline and repairing ventral defects without entering the peritoneal cavity, thereby minimizing the risk of intestinal adhesions, mesh-related complications, and chronic pain. Furthermore, SCOLA provides excellent cosmetic outcomes and high patient satisfaction due to its minimally invasive nature and avoidance of large incisions. Comparatively, anterior approaches such as SCOLA are technically more straightforward and associated with favorable functional and morphological results, although they present a higher incidence of seroma formation. In contrast, posterior techniques - while involving a steeper learning curve and higher bleeding risk - tend to yield lower seroma rates due to dissection confined to a single anatomical plane. Overall, the reviewed literature supports the safety and effectiveness of SCOLA as a valid alternative to traditional IPOM techniques, offering superior ergonomics for midline plication, reduced postoperative discomfort, and lower overall costs. Nevertheless, longterm followup studies remain essential to assess recurrence rates and functional outcomes over time, thereby consolidating the role of SCOLA and similar minimally invasive techniques in the future management of ventral hernias and diastasis recti.

Author's Contributions

Conceptualization, F.G. and N.P.; methodology, R.R.; software, A.T. and P.C.; validation, A.C., S.B. and C.S.; formal analysis, F.S.; investigation, L.S. and A.F.; resources, M.C.; data curation, F.G.; writing—original draft preparation, N.P.; writing—review and editing, F.G.; supervision, F.G. and M.C.; project administration, N.P. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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Data Availability Statement

Supporting data are available within the manuscript.

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