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"Slim-Mesh" Technique for Diastasis Recti Abdominis, Including Obesity-Related Cases

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ABSTRACT

Background and Objective: We operated on a series of mostly obese patients with diastasis recti abdominis using the "Slim-Mesh" technique to repair/reinforce the diastasis and linea alba/recti muscles without plicating and traumatizing them. Additional objectives were to decrease operation time and intra- and postoperative complications.

Methods: We considered T1 cases diastasis after pregnancy and T2 cases obesity (BMI $\geq$ 30 mg/kg^2); D1, D2, and D3 when the diastasis measured 2–3, 3–5, and $\geq$ 5 cm, respectively; H0 and H1 without and concomitant umbilical and/or epigastric hernia, respectively. At our Department, between May 2010 and November 2022, 47 patients with diastasis recti were operated on with the "Slim-Mesh" technique to reinforce/repair the traumatized linea alba/recti muscles, without plicating them. This was a prospective (83%)-retrospective study.

Results: We studied 23 males and 24 females. Mean age and BMI was 58 years and 29 kg/m^2, respectively. Groups D1, D2, and D3 comprised 6, 23 and 18 patients, respectively; groups T1, T2, H0 and H1 comprised 22, 25, 13 and 34 patients, respectively. Mean operation time for all cases was 100 minutes. Mean length of hospital stay was 2.3 days and follow-up time was 5 years. We had 6 late postoperative complications: 3 hernia recurrences and 3 trocar site hernias.

Conclusion: Considering the lack of agreement on the best surgery for diastasis recti abdominis repair, in our experience the "Slim-Mesh" technique is a valid, safe and easy-to-reproduce way to save, repair and reinforce linea alba/recti muscles in diastasis recti patients, including the obese population (53%).

Key Words: Chronic postoperative abdominal-wall pain, Diastasis recti abdominis, Operation time, Postoperative complications, Slim-mesh technique, Ventral hernia.

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Ethical approval: all procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any experimental studies with human participants and/or animals performed by the author. This study was approved by the Institutional Ethics Committee of the Province of Padua, contract no. 3902/AO/16, July 28, 2016.

Author contribution: Dr. Silvio Alen Canton invented the "Slim-Mesh" technique in 2009. He was responsible for clinical management, wrote the manuscript, and supervised the editing. He presented the above abstract as a scientific paper at SLS MIS Week Congress in Orlando, October 5, 2023.

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INTRODUCTION

Diastasis recti abdominis (DRA) is an acquired disease of the anterior abdominal-wall (AW) characterized by a widening of the linea alba (LA) exceeding 2 cm[1] due to a separation of the recti muscles by an abnormal distance along their length.[2] When patients have this condition, all layers of the AW are present unlike in cases of ventral hernia (VH), nevertheless DRA may lead to the herniation of the abdominal viscera (**Figures 1** and **2**).[3]

DRA may extend to the upper abdomen, from the xiphoid region to the umbilicus, or as far as the hypogastric region when the separation of the recti muscles affects the whole LA. DRA may also extend to the lower abdomen, from the umbilicus to hypogastric region.

Concomitant umbilical and/or epigastric hernia (45%) may be associated with (**Figures 1** and **2**).[1,2]

Women suffer predominantly from DRA, especially during pregnancy, with the female-to-male ratio being almost 3:1; it regresses spontaneously after childbirth in most

Figure 1. Preoperative photo of a young athletic mother who is tensing her abdomen and showing a symptomatic massive diastasis recti abdominis.

cases.[2] However, DRA may also affect 33% of mothers after pregnancy,[2] increasing progressively after subsequent pregnancies and worsening over the years, especially when DRA is associated with obesity.[4]

In addition to being female, pregnant and obese,[2,4] other contributing factors for DRA onset are being an over 50-year-old postmenopausal woman[5], congenital transmission,[6] multiple pregnancies,[7] having had a caesarean section and a twin pregnancy,[8] natural childbirths at a late age, heavy physical occupational work, overly strenuous and intense physical activity, e.g., body-building.

DRA can cause discomfort in the abdomen[8,9] and a great loss of function of the AW muscles with abdominal and back pain, as well as respiratory disorders,[10] fecal and urinary incontinence, and a gynecological complaint called pelvic organ prolapse.[9]

In DRA patients, back pain is due to the occurrence of spinal troubles because of a dynamic imbalance of the forces generated by the front and rear muscles of the trunk. Consequently, this AW dysfunction may contribute to restricting a patient's everyday physical activity, such as standing, walking, running, working, lifting weights,[8–10] especially in cases of mothers when they are caring for their newborns, e.g., picking them up, or jogging.

Considering the explicit request for "Slim-Mesh" ("SM") repair from my DRA patients, generally the main criterion for having an "SM" operation was their DRA-related cosmetic damage, which was worsened by an associated umbilical hernia in 90% of cases, especially when the abdomen

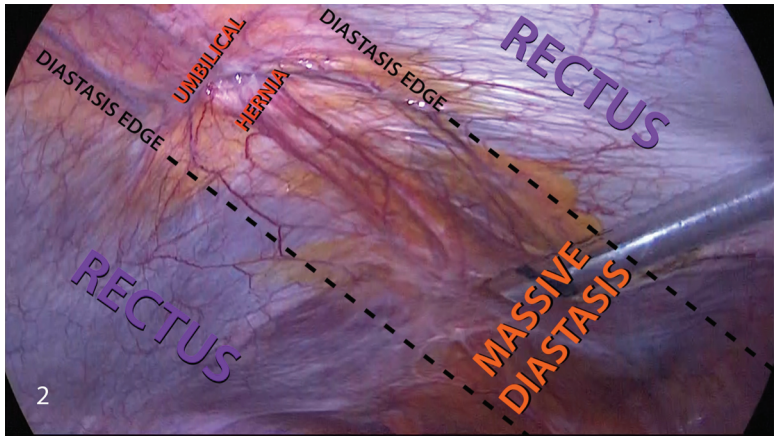


Figure 2. Laparoscopic view of a massive diastasis recti abdominis with umbilical hernia; the edges of the diastasis recti and the recti muscles are shown.

was tense (see "SM" YouTube video: https://www.youtube.com/watch?v=w6Ywy7KHJNg&t=4s). Moreover, other criteria were abdominal pain due to the umbilical hernia, the risk of increased separation between the recti muscles and the enlargement of the umbilical hernia defect with aesthetic deterioration, hernia incarceration, and intestinal obstruction (30%) and strangulation, especially when the hernia-neck was small (2–4.9 cm Ø).

DRA may be diagnosed by physical examinations and/or AW ultrasound studies; other more accurate diagnosis methods include AW computed tomography (CT)-scan and/or magnetic resonance imaging studies.[11]

There is a number of surgical solutions available for DRA repair.

Open surgery has obvious downsides, including postoperative AW seroma, hematoma, mesh infection, pain, long hospital stay, and poor cosmesis.[12]

Recently, researchers have come up with a range of laparoscopic approaches, e.g., intraperitoneal onlay mesh placement (IPOM) and IPOM plus,[13] as well as several new mini-invasive techniques, including preaponeurotic endoscopic repair (REPA),[14] subcutaneous onlay laparoscopic approach (SCOLA),[15] totally endoscopic assisted LA reconstruction (TESLAR),[16] minimally invasive LA reconstruction (MILAR),[17] and hybrid techniques, with all of them showing promising results in terms of recurrence and cosmesis.

However, the low number of cases studied with the above techniques in literature and their unproven scientific and methodological quality do not provide an adequate degree of scientific evidence.[1,18]

I treated DRA patients with the "Slim-Mesh" ("SM") technique[10,19–29] to repair/reinforce the diastasis and LA/recti muscles of the AW without plicating and traumatizing them, which does not occur with "SM" (**Figures 3**, **4**, and **5**, see "SM" YouTube video: https://www.youtube.com/watch?v=w6Ywy7KHJNg&t=4s).[27]

My primary goal was to empirically test the technical feasibility/reliability of the "SM" sutureless technique for patients with DRA, mostly obese, by exploiting the well-known advantageous qualities of laparoscopy combined with the "SM" technique's benefits in reducing intra- and postoperative complications and operation time.[10,19–29]

My secondary goal was to verify the "SM" technique's outcomes in DRA patients, including obese ones, with a 13-year follow-up study.

METHODS

At our Department of Surgery, between May 2010 and November 2022, 47 mostly obese patients with diastasis recti abdominis (DRA) were operated on with the "Slim-Mesh" ("SM") technique to reinforce/repair the traumatized linea alba (LA)/recti muscles without plicating them, which the "SM" technique does not require (**Figures 1–5**, see "SM" YouTube videos: https://www.youtube.com/watch?v=cd1fDhD_RAw, https://www.youtube.com/watch?v=squBJ5nP5s0&t=1s, https://www.youtube.com/watch?v=w6Ywy7KHJNg&t=4s). This was a prospective (83%)-retrospective nonrandomized descriptive study involving a single center.

From May 2010 to August 2016, I conducted a pilot retrospective study on 17% of the DRA patients described

Figure 3. External view of the set of 3 ports introduced into the right abdominal-wall region for "Slim-Mesh" repair of a massive diastasis recti abdominis.

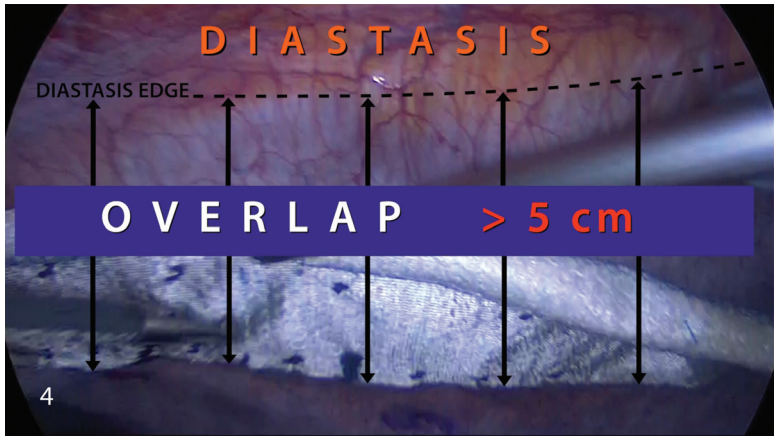


Figure 4. Laparoscopic view of a massive diastasis recti abdominis, umbilical hernia and a giant (26 × 26 cm) "Slim-Mesh" partially fixed on the left abdominal-wall region.

herein and operated on them with the "SM" technique. Then, in September 2016, this study was approved by our Ethics Committee (contract no. 3902/AO/16), becoming a prospective study with "SM" protocol, which included the "SM" informed consent.

From September 2016 to November 2022, this informed consent for DRA repair with the "SM" technique was expressly given to the remaining 83% of DRA patients described herein, who signed the consent and agreed to allow their details to be added to our institutional board-approved Microsoft Excel database, as per the "SM" protocol.

The following variables were entered in our "SM" registry: gender, age, body mass index (BMI), normal-weight (BMI 18.5–24.9 kg/m^2), overweight (BMI 25.0–29.9 kg/m^2), and class of obesity, as per the World Health Organization (Class I BMI 30.0–34.9 kg/m^2, Class II 35.0–39.9 kg/m^2, Class III 40.0–49.9 kg/m^2,[30]) American Society of Anesthesiologists (ASA) score.

We considered T1 cases "diastasis after pregnancy" and T2 cases "obesity" (BMI ≥ 30 mg/kg[2,1,30]) time of incisional hernia onset after surgery, preoperative abdominal-wall (AW) ultrasound (US) and/or computed tomography (CT)–scan by measuring the widths of DRA and of any concomitant ventral hernia (VH),[1] DRA width divided in groups D1, D2, and D3 when at laparoscopy (LAP) it measured 2–2.9, 3–4.9, and ≥ 5 cm, respectively; H0 and H1 cases DRA without and with concomitant umbilical and/or epigastric hernia, respectively, at LAP (**Figures 1** and **2**), synthetic mesh-type (composite or noncomposite) used, type of fixation device, operation time for all cases and DRA

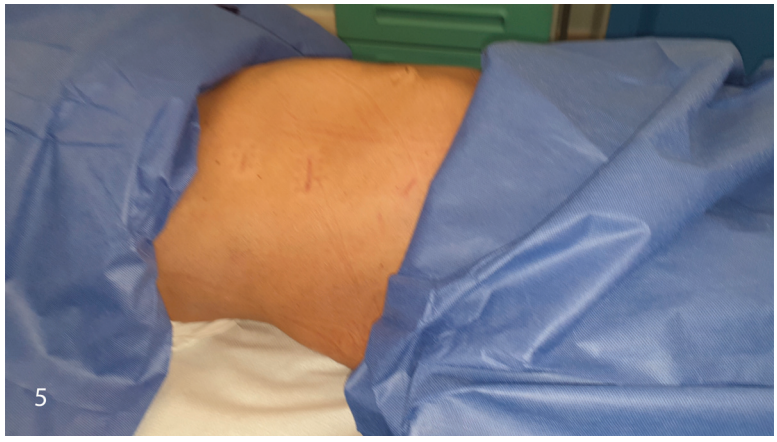


Figure 5. Postoperative photo of the same young athletic mother tensing her abdomen 3 months after "Slim-Mesh" surgery to repair her massive diastasis recti abdominis.

groups 1, 2, and 3, estimated blood loss at suction, possible conversion to open surgery, operative complications, early postoperative complications (within 30 days after operation) e.g., chronic postoperative abdominal-wall pain when it lasted ≥ 3 months,[31] hemorrhages, seromas, late postoperative complications, e.g., bowel obstructions, infections, peritonitis, trocar-site hernias, adherence syndrome, recurrences; postoperative day of return to regular diet, length of hospital stay, reoperation, readmission to hospital, and the follow-up with the final outcome, e.g., the abovementioned late complications.

The results were expressed as mean ± standard error of the mean (SEM) standard deviation (SD) and a percentage (%). In accordance with the "SM" protocol, the routine follow-up evaluation was performed by interviewing the DRA patients during an outpatients visit, which involved a physical examination at 1 and 4 weeks and 3 months postoperatively; patients underwent the same interview, including a review of AW US results, 6 months after operation, and then yearly.

SM Surgical Technique Technical Trick

The mesh used is called a "Slim Mesh" because of its thickness, becoming "slim cigarette like",[10,19–29] and not because of its composition, weight or size, even when large pieces of mesh are placed.

The "SM" technique is divided into 4 surgical phases: phase 1 or first laparoscopic step: laparoscopic exploration of the whole abdominal cavity with adhesiolysis when necessary, identification of possible additional VH, measurement of "SM" overlap for various sizes of DRA according to the "SM" technique, marking with methylene blue of 4 peritoneal axial points (PAPs), and measurement of the peritoneal (internal) "SM" application area (SMAA). Phase 2: marking the skin axial points (SAPs), and the skin measurement of the SMAA, which is the same as the peritoneal SMAA. Phase 3: preparation of "SM" on the operative bench by tailoring it to the skin SMAA from a prosthesis, and handling as per the "SM" technique, for introduction into the abdomen. Phase 4 or last laparoscopic step: "SM" port-introduction, intrabdominal orienting and fixation (see "SM" YouTube videos: https://www.youtube.com/watch?v=cd1fDhD_RAw, https://www.youtube.com/watch?v=squBJ5nP5s0&t=1s, https://www.youtube.com/watch?v=w6Ywy7KHJNg&t=4s).[10,19–29]

The "SM" technique for DRA repair does not involve the laparoscopic plication of the LA before fixing the "SM" to the AW.

Hereunder is an extensive description of a crucial technical trick that has already been published,[27] especially for the correct peritoneal fixation of a "SM," including a very large/monster (36 × 26 cm) one. During the fourth and final phase of the "SM" operation, the surgeon takes the "SM" with two grasping forceps and superimposes its first axial point (FAP) onto the first peritoneal axial point (PAP), e.g., the east or west PAP; before fixing this point, the surgeon must picture how to superimpose the "SM's" axial points (APs) onto the corresponding PAPs. He must then carefully position the "SM," making sure that its upper edge is parallel to the imaginary line between the north-south PAPs, as he views them. Only by doing so is the surgeon able to fix the FAP over the first PAP properly, and then the "SM's" free end and its second AP onto the second PAP. After the FAP and the "SM's" second AP have been superimposed and fixed onto the corresponding PAPs, as a consequence, the "SM's" remaining two APs will be superimposed perfectly onto the corresponding PAPs. Therefore, the "SM" FAP marked in blue, its second, third and fourth blue AP are superimposed and fixed progressively onto their corresponding four blue PAPs during the "SM" fixation maneuvers until the "SM" placement and fixing is completed by fixing the fourth blue "SM" AP onto the fourth blue PAP and adding a second crown of straps. This technical trick ensures that the "SM" is applied safely, without it crumpling and/or shifting; it also guarantees that the DRA is overlapped (≥ 5 cm for DRA repair, **Figure 4**, see "SM" YouTube videos: https://www.youtube.com/watch?v=cd1fDhD_RAw, https://www.youtube.com/watch?v=squBJ5nP5s0&t=1s, https://www.youtube.com/watch?v=w6Ywy7KHJNg&t=4s) correctly.[10,19–29]

RESULTS

We studied a total of 47 DRA patients (53% obese) who were operated with the "SM" technique at our institution: 23 males and 24 females with age and BMI averaging 58 ± 2.4 years (mean ± SEM; range 31–86 years) and 29 ± 0.8 kg/m^2 (mean ± SEM; range 21–51 kg/m^2), respectively.

Table 1 details the other preoperative clinical features and operative characteristics of the 47 DRA patients, with DRA divided by width into groups D1, D2, and D3.

Mean operation time for all cases, for groups D1, D2, and D3 was 100 ± 5.3 minutes (range: 55–240 minutes, mean ±

Table 1.
Patients and DRA Clinical Features

Patient and DRA Clinical Features	D1 (2–2.9 cm)	D2 (3–4.9 cm)	D3 (≥ 5 cm)
No. M/F with DRA (23/24, Total: 47 patients)	3/3 (6)	11/12 (23)	10/8 (18)
Mean Age (58 years old)	48	57	59
No. ASA 1/2/3	1/4/1	1/16/6	0/12/6
T1 cases (DRA after pregnancy, Total: 22 patients)	4	10	8
T2 cases (obesity, BMI ≥ 30 kg/m^2, Total: 25 patients)	3	14	8
Mean BMI (29 kg/m^2, 53% obese patients BMI ≥ 30 kg/m^2)	32	33	34
No. US/CT-scans/US + CT-scans	5/1/0	7/10/6	2/15/1
H0/H1 (without/with concomitant umbilical and/or epigastric hernia, respectively, Total 13 H0/34 H1 patients)	1/5	7/16	5/13
CM (91%)/Non-CM (9%)	6/0	21/2	16/2
Fixation device: TT (9%)/AS (91%)	0/6	2/21	2/16
Mean OT (Overall = 100 minutes)	75 minutes	94 minutes	117 minutes
Mean BL (ml [range])	4 (2–8)	8 (2–38)	5 (2–12)
IC (B, OL, P, C)	0, 0, 0, 0	0, 0, 0, 0	0, 0, 0, 0

Abbreviations: DRA, diastasis recti abdominis; DRA grade D1 when at laparoscopy it measured 2–2.9 cm in width, D2 3–4.9 cm, D3 ≥ 5 cm; M, male; F, female; ASA, American Society of Anesthesiologists class; T1, DRA cases after pregnancy; T2, "obesity" cases (obesity, BMI ≥ 30 kg/m^2); BMI, body mass index; O, obesity, Class I = BMI 30.0–34.9 kg/m^2, Class II: BMI 35–39.9 kg/m^2, Class III: BMI 40.0–49.9 kg/m^2; US, abdominal-wall ultrasound; CT, abdominal-wall computerized tomography; H0, DRA cases without concomitant umbilical and/or epigastric hernia; H1, DRA cases with concomitant umbilical and/or epigastric hernia; CM, synthetic composite mesh; non-CM, synthetic non composite mesh; TT, titanium tacks (used from September 1, 2009 to September 30, 2013); AS, absorbable straps (used from October 1, 2013 to November 30, 2022); OT, operation time; BL, blood loss; IC, intraoperative complications; B, bleeding; OL, organ iatrogenic lesions; P, bowel perforation; C, conversion to open surgery.

SEM), 75 ± 2 minutes (range: 60–95 minutes, mean ± SEM), 94 ± 3.8 minutes (range: 55–150 minutes, mean ± SEM) and 117 ± 6.9 minutes (range: 65–240 minutes, mean ± SEM), respectively.

A correlation between patients' age and DRA D grade and between BMI and DRA D grade is shown in Graphs 1 and 2, respectively.

In our study, 92% of patients began to eat during the first postoperative day. Mean length of hospital stay was 2.3 ± 0.1 days (mean ± SEM) and SM follow-up time was 5 years ± 5.1 months (range: 12–161 months [mean ± SEM]).

In November 2023, the last "SM" follow-up for long-term results was finished, with a minimum of one year after surgery.

The "SM" follow-up revealed 4 (8%) early postoperative seromas, 1 early DRA case of urinary retention with cystitis, and another with chronic postoperative abdominal-wall pain (2%).

In addition, the follow-up revealed that 3 (6%) DRA patients had one late postoperative recurrence, and 3 (6%) patients had one late postoperative trocar site hernia, with 1 case needing surgery.

DISCUSSION

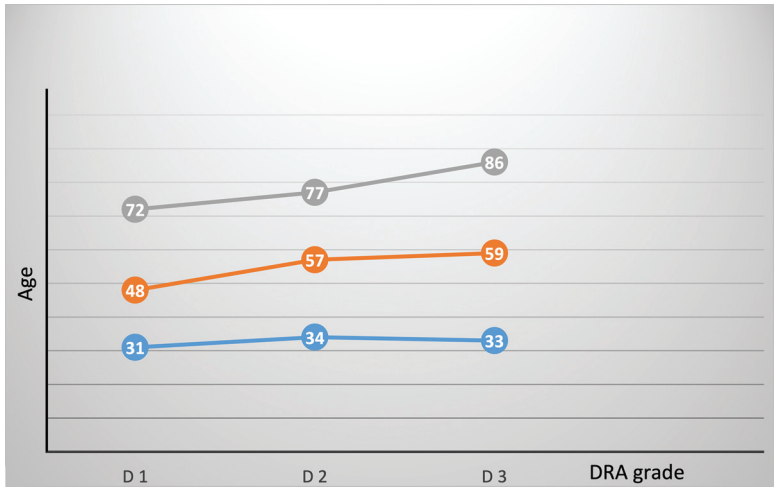
The AW consists of the following muscles: recti, internal and external oblique, transverse and pyramidal (**Figure 2**).[32]

Abdominal-wall muscles (AM) interact and act synergically with other parts of the body, e.g., the diaphragm muscle, pelvis and spine, allowing some vital functions, e.g., breathing, standing, bending, twisting, walking and lifting weights.[32]

AM make a crucial contribution to the breathing process in the exhalation phase, helping to raise the diaphragm muscle. They are also involved during coughing, laughing, urination, defecation and child-birth.

In addition, AM are essential for maintaining posture as they stabilize the pelvis and spine, and are involved in trunk movements, especially for bending both forwards and sideways and trunk rotation.[32]

Moreover, the tonic activities of the muscles of the anterior AW support and protect the intrabdominal organs. DRA is a frequent disease and leads to a functional deficit of the AM with impairment of their vital functions (**Figures 1** and **2**).

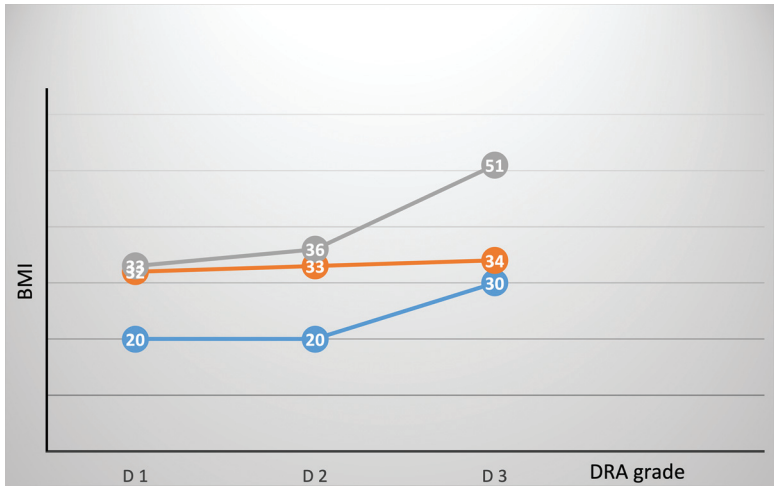


Graph 1. A comparison between patients' ages and diastasis recti abdominis (DRA) grades (D). This graph shows that as age increased, DRA grade went up as well.

Most of the surgical community believes that DRA is more of a cosmetic issue. This issue is mostly repaired by plastic surgeons with recti muscles plication during abdominoplasty, which is the fifth most common cosmetic plastic surgery procedure performed in the United States.[33] Generally, it is performed on obese patients. Differently, DRA may lead to the functional impairment above mentioned, which is worsened by associated umbilical hernia in 90% of DRA patients, potentially causing abdominal pain and hernia incarceration, as well as intestinal obstruction and strangulation.

In addition, I found a correlation between increasing age and increasing DRA grade (**Graph 1**), and as BMI increased, DRA grade went up as well (**Graph 2**).[4]

In my series, 47% of DRA patients were slim, normal-weight or overweight and they did not require abdominoplasty combined with "SM" repair, as in the remaining 53% of DRA patients who were obese. In my experience, this means that a large group of DRA patients can only be treated with laparoscopy to reduce their cosmetic and functional issue due to DRA and associated umbilical hernia. Less postoperative pain, hematoma, seroma and infection, shorter hospital stay, cosmetic advantages and quicker return-to-work are some well-known benefits of laparoscopic DRA repair over open DRA repair with mesh combined or not with abdominoplasty (see "SM" YouTube video: https://www.youtube.com/watch?v=w6Ywy7KHJNg&t=4s).



Graph 2. A comparison between patients' BMI and diastasis recti abdominis (DRA) grades (D). This graph shows that as BMI increased, DRA grade went up as well.

The trend of using laparoscopy in the treatment of DRA patients is quite recent and this explains the paucity of data in literature and why the quality of the few studies is low.[1,18]

In addition, there is a lack of agreement on the best laparoscopic technique for DRA repair and different surgical procedures are generally employed in a nonstandardized way, i.e., IPOM, IPOM plus, laparoscopic retrorectus technique.

The LA of DRA patients is often impaired, atrophied and thin, as is the overlying subcutaneous tissue; sometimes it is also traumatized by previous operations. I believe it is important to safeguard the LA without further traumatizing it with laparoscopic plication (LP), which would result in nontension free closure and increase the risk of DRA recurrence. This is one reason why I use the "SM" technique in DRA patients to reinforce and/or repair the impaired LA/recti muscles, as an "SM" can be applied without plicating them (**Figure 4**, see "SM" YouTube videos: https://www.youtube.com/watch?v=cd1fDhD_RAw, https://www.youtube.com/watch?v=squBJ5nP5s0&t=1s, https://www.youtube.com/watch?v=w6Ywy7KHJNg&t=4s).[27]

In addition, as happens after open herniorraphy and open closure of LA, the LP of LA performed during IPOM-plus operations[13] breaks open postoperatively in as much as 55% of cases, and the harmful effect of this complication on the underlying fixed mesh over time is currently unknown. LP also involves longer operation time.[13]

Another reason why I employ the "SM" technique is that in cases of giant DRA, LP of the LA during IPOM-plus operation[13] may lead to a postoperative bulging effect, which is eliminated by the "SM" technique with obvious aesthetic gain (**Figures 1** and **5**, see "SM" YouTube video: https://www.youtube.com/watch?v=w6Ywy7KHJNg&t=4s).

In the present study, I treated 47 mostly obese (53%) DRA patients with the "SM" technique[10,19–29] by repairing possible concomitant ventral hernia, with the aim of returning them to a normal state of health. I also analysed their long-term outcomes.

Moreover, my goals (see Introduction) were achieved. The "SM" technique proved to be easy, feasible and reliable when treating DRA patients. In fact, it allowed a reduction of intra- and postoperative complications and operation time when compared with traditional laparoscopic DRA repair with transfixation sutures (TLDRR), e.g., like that performed by Panalivelu et al.[13] Our postoperative DRA recurrence, trocar-site hernia, chronic abdominal-wall pain, infection and adherence syndrome rate was 6%, 6%, 2%, 0%, and 0%, respectively. Our outcomes regarding the rate (2%) of chronic abdominal-wall pain are lower than those of Panalivelu et al (11%).[13] In addition, our mean overall operation time (100 minutes) was lower than in Panalivelu et al's (128 minutes for 18 DRA patients).[13]

The "SM" is compact during DRA repair and creates intrabdominal space, thus expanding operating area, which is raised to the AW front and well-clear of organs during the "SM" operation's last laparoscopic step.[10,19–29]

The "SM" technique allows surgeons to see the solid abdominal organs and intestine more easily, thus reducing the risk of iatrogenic injuries. This technique simplifies the checking, calculation and measurement of the safest "SM" overlap for DRA repair, ensuring wrinkling-free "SM" unrolling, tensioning and fixing to the AW (**Figures 3** and **4**, see "SM" YouTube videos: https://www.youtube.com/watch?v=cd1fDhD_RAw, https://www.youtube.com/watch?v=squBJ5nP5s0&t=1s, https://www.youtube.com/watch?v=w6Ywy7KHJNg&t=4s).[10,19–29]

Further prospective studies are needed to replicate and extend these findings among a larger number of DRA patients.

CONCLUSIONS

Considering the lack of agreement on the best endoscopic/laparoscopic technique for DRA repair and the small number of DRA case-series studies in literature,[18] in my experience, the "SM" technique may be considered a valid way to safeguard, repair and reinforce LA/recti muscles in DRA patients, including the obese population.

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