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Laparoscopic intracorporeal rectus aponeuroplasty (LIRA technique): a step forward in minimally invasive abdominal wall reconstruction for ventral hernia repair (LVHR)

Julio Gómez-Menchero[1,4] · Juan Francisco Guadalajara Jurado[1] · Juan Manuel Suárez Grau[1] · Juan Antonio Bellido Luque[2] · Joaquin Luis García Moreno[1] · Isaías Alarcón del Agua[3] · Salvador Morales-Conde[3]

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Abstract

Background Closing the defect (CD) during laparoscopic ventral hernia repair began to be performed in order to decrease seroma, to improve the functionality of the abdominal wall, and to decrease the bulging effect. However, tension at the incision after CD in large defects is related to an increased rate of pain and recurrence. We present the preliminary results of a new technique for medium midline hernias as an alternative to conventional CD.

Methods A prospective controlled study was conducted from January 2015 to January 2017 to evaluate an elective new procedure (LIRA) performed on patients with midline ventral hernias (4–10 cm width). The posterior rectus aponeurosis was opened lengthwise around the hernia defect using a laparoscopic approach to create two flaps and was then sutured. The size of the flaps was estimated using a mathematical formula. An on-lay mesh was placed intraperitoneal overlapping the fascia defect. The data analyzed included patient demographics, operative parameters, and complications. A computerized tomography was performed preoperatively and postoperatively (1 month and 1 year) to evaluate recurrence, distance between rectus and seroma.

Results Twelve patients were included. Mean width of the defect was 5.5 cm. Average VAS (24 h) was 3.9, 1.1 (1 month), and 0 (1 year). Mean preoperative distance between rectus was 5.5 cm; postoperative was 2.2 cm (1 year). Radiological seroma at first month was detected in 50%. Mean follow-up was 15 months.

Conclusion The LIRA technique could be considered as an alternative to conventional CD or endoscopic component separation for medium defects under 10 cm in width. This technique obtained a "no tension" effect that could be related to a lower rate of postoperative pain with no recurrence or bulging, being a safe, feasible, and reproducible technique.

Keywords LIRA technique · Laparoscopy · Ventral hernia · Defect closure · Incisional hernia · Diastasis recti

Incisional hernias are currently one of the most frequent complications of abdominal surgery, with an incidence of between 10 and 20% [1]. The treatment of incisional and primary ventral hernia is currently the subject of study of many clinical and basic researchers. Current open mesh-associated techniques have reduced the recurrence rate, although the use of meshes could be related to wound morbidity due to the foreign body reaction and to the dissection necessary to place the prosthetic materials.

The initial development of laparoscopic ventral hernia repair (LVHR) [2, 3] in the early 90s added a new dimension to the treatment of ventral hernia, providing advantages over conventional repair in terms of reduction of the morbidity of the surgical wound. However, this in turn opened up a new debate as to what type of patients were candidates for LVHR and the results of this technique since the placement of an intraperitoneal mesh bridging the defect was related to a bulging effect after a certain period of time. An alternative in

✉ Julio Gómez-Menchero
gomenchero@gmail.com

1 Department of General Surgery, Riotinto General Hospital, Minas de Riotinto, Huelva, Spain

2 Department of General Surgery, University Hospital "Virgen Macarena", Seville, Spain

3 Unit of Innovation in Minimally Invasive Surgery, University Hospital "Virgen del Rocio", Seville, Spain

4 Present Address: Juan de Zoyas 6, Portal 1, 41018 Seville, Spain

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order to avoid this last problem and to increase the functionality of the abdominal wall was proposed by performing the closure of the defect (CD) [4] by laparoscopy before placing the mesh, avoiding the previously mentioned long-term complications, although some authors have suggested that the tension generated in the midline by CD could be associated with an increase in the rate of pain and recurrence [4].

Since conventional LVHR without CD in moderate or large defects is related to the occurrence of pseudo-recurrence [5], and given that pain is the main drawback of CD, we have developed a completely new laparoscopic technique for the treatment of ventral moderate defects.

This technique combines the advantages of both concepts: the minimally invasive approach and the abdominal wall reconstruction associated to CD, allowing a restoration of the midline without tension, by the plication of the posterior aponeurosis of both abdominal rectus muscles combined with a laparoscopic intraperitoneal prosthetic repair (intraperitoneal on-lay mesh).

The aim in this study was to evaluate the effectiveness and safety of our technique in medium-sized midline hernias, among individuals who were not candidates for an open or endoscopic anatomic component separation (CS), considering that this technique is used in our center for large hernias (larger than 10 cm in width).

Materials and methods

A consecutive prospective observational study of patients operated for primary and/or incisional hernia of midline by laparoscopy was performed. Patients selected for this technique included those over 18 years of age with hernias between 4 and 10 cm in width, of types M1, M2, M3, and M4 W2 according to the EHS classification [6]. Exclusion criteria were suprapubic and subxiphoid hernias, absence of posterior aponeurosis integrity of both rectus muscles detected intraoperatively, recurrence after previous open retromuscular repair or laparoscopic repair, and those cases not suitable for LVHR.

The study was carried out by two surgeons from the same research group in the General Basic Hospital of Riotinto (Minas de Riotinto, Huelva) and the Hospital Quirón Sagrado Corazón of Seville, from January 2015 to January 2017. Approval was obtained from the local ethics committee and all participants signed an informed consent form. The initial experience of this technique was carried out with a strict selection of the patients in order to show the feasibility of the technique.

Demographic variables included age, sex, Body Mass Index (BMI), American Society of Anaesthesiologist criteria (ASA), hernia etiology, hernia type, and preoperative symptoms and pain (using the visual analogue scale of pain; VAS). The study involved a preoperative assessment whereby all participants underwent abdominal computerized tomography (CT) to quantify the size of the hernia defect, the number of defects, and the contents of the sac. The CT scan was not performed under Valsalva´s maneuver, nor was the postoperative CT scan in order to be able to measure the distance of the rectus muscle under the same conditions. The intraoperative variables researched included defect size (width and length), hernia type (single or multiple), size and type of mesh, number of tackers, and the procedure developed for closing the defect. Postoperative follow-up was conducted, and all patients were examined at day 1 and 7 and at 1 month, 3 months, and 1 year after surgery, analyzing the following parameters: pain (VAS scale), clinical seroma (following Morales-Conde et al. classification [7]), absence or presence of clinical bulging and recurrence. CT scan was performed in all patients at 1 month and 1 year postoperative in order to detect recurrence, the presence of seroma and to evaluate the integrity of the midline, which was analyzed by measuring the distance between the rectus muscles.

Surgical technique (Fig. 1)

The patient was placed in supine position and the pneumoperitoneum was created using a Veress needle in the left upper quadrant. Three trocars (one 12 mm and two 5 mm) were placed in the left flank of the patient at the level of the left axillary line. A 10 mm 30° optic was used in all cases. Adhesions were released using electrocautery, ensuring that the posterior aponeurosis of both posterior rectus abdominal muscles remained intact during these maneuvers. The craniocaudal and transverse diameters of the hernia defect were measured using an extracorporeal needle introduced through the abdominal wall. Once the defect was properly measured, the flaps of the aponeurosis were dissected. Flap size (FS) is estimated based on the transverse diameter of the hernia defect (TD). This is estimated preoperatively through a CT scan using the formula FS = TD/2. The intraoperative measurement can be performed using a surgical rule. The posterior fascia of both rectus muscles were incised longitudinally and parallel to the lateral borders of the defect, creating two flaps of the aponeurosis, which were turned over to the middle line. The creation of these flaps reduces the tension of the middle line, as it is observed while dissecting them. The pneumoperitoneum is reduced to 10–11 mm of Hg and both flaps of the aponeurosis are sutured together in the middle line using a continuous suture with two different sutures, either a double-loop long-lasting absorbable monofilament (MAXON™ loop 1, Medtronic, USA) or a barbed non-absorbable monofilament suture (V-Loc™ Polybutester 1, Medtronic, Mansfield, MA, USA).

Closure of the defect procedure:

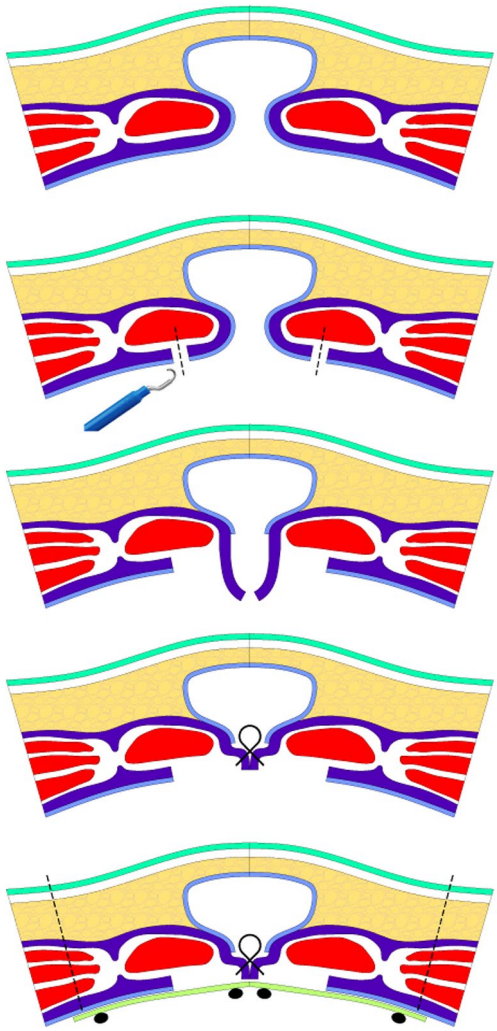

Fig. 1 LIRA technique. Step by step

a. Closure with monofilament and extracorporeal knotted suture: the needle of the double-loop suture is introduced 2 cm below the caudal end of the defect, maintaining the long threads outside the abdominal cavity, being introduced as needed. A continuous suture of both flaps is performed completely intracorporeally using a laparoscopic approach, taking into consideration that after the first bite of tissue the needle should go across the two threads of the double loop. The suture is finished cranially to the defect and both ends of the double-loop suture are knotted together in the subcutaneous tissue, after reducing the pneumoperitoneum to 8 mm of Hg, once the two threads have been exteriorized from the abdominal cavity through the same skin incision but a different incision at the fascia.
b. Closure with barbed suture: the needle is introduced through the 12 mm trocar into the abdominal cavity and the whole thread is introduced in order to pass the needle through the small loop at the end of the thread. The suture is performed under low pressure to be able to maintain the tension, without the need to tie a knot at the end.

Once the flaps of the aponeurosis are sutured together, a reinforcement of the aponeuroplasty is performed by laparoscopy using an intraperitoneal mesh (IPOM technique). The mesh size must overlap vertically by at least 5 cm over the original defect but always completely covering the area where the fascia was dissected and including the whole incision in the case of incisional hernias. The width of the mesh (WS) is calculated using the formula WS = TD + 2 (FS + 2) in order to obtain an adequate overlap of the mesh. It is recommended to use transparent meshes which will allow the proper identification of the area where the mesh will be fixed. In our series, Polyvinylidene fluoride (PVDF) mesh, Dynamesh(®)-IPOM (FEG Textiltechnik mbH, Aachen, Germany), Ventralight™ ST mesh (C.R. Bard/Davol, Warwick, RI, USA), and condensed Polytetrafluoroethylene (cPTFE) prostheses (Omyra®, B. Braun Surgical S.A, Barcelona, Spain) were used, depending on the availability of the mesh in our centers.

The mesh is rolled and introduced through a 12-mm trocar. The mesh is marked in order to orientate the placement either with drawings or with sutures at the cardinal points. Fixation of the mesh to the anterior abdominal wall is performed using non-absorbable metal helicoidal sutures, Protack™ 5 mm (Covidien, Mansfield, Mass, USA), following the criteria of the Double Crown Technique [8]. The fixation is completed using Platelet Rich Fibrin (Vivostat PRF™, MBA Group) at the edge of the mesh and covering the tackers.

The 12-mm trocar should be closed at the end of the procedure under direct vision in order to include the entire muscle layer and the peritoneum. A compressive bandage is used during 7–10 days postoperative so as to improve patient comfort.

Statistic

Data have been expressed as mean ± standard deviation (SD). Statistical analyses were performed using SPSS for windows (15.0). Analyses included descriptive analyses and hypothesis testing with non-parametric tests for related measures: Friedman test and Wilcoxon test to compare pairs of groups.

Results

Twelve patients were included in the study (7 males and 5 females). The mean age was 56.5 ± 10.5 years(33–68 years) and mean BMI was 30.12 ± 5.08 kg/m2 (22–38 kg/m2). Three patients were diagnosed with a primary hernia, while 9 of them showed an incisional hernia. A preoperative CT scan was performed on all patients, with the defects having a mean size of 6.28 ± 2.54 cm in length and 5.38 ± 1.58 cm in width, and 10 of them being associated with a rectus diastasis of a mean size of 5.1 ± 1.4 cm (3–8 cm).

Intraoperative size of the defects and mesh used

The mean length of the defect measured intraoperatively was 7.9 ± 3.0 cm (range 4–15 cm) and the mean value of the width was 5.5 ± 1.1 cm (range 4–8 cm) (Fig. 2). Eight patients showed only one defect (mode = 1), with a range of 1–4. The mean flap size of the aponeurosis performed was 3.0 ± 0.6 cm (range 2–4 cm) on each side, and the mean length of the closure of the posterior aponeurosis flaps was 13.8 ± 3.4 cm (range 10–21 cm). Three types of mesh were used: Omyra® (1 case), Ventralight™ (2 cases), and IPOM Dynamesh® (9 cases). The mean size of the mesh was as follows: length 18.8 ± 2.7 cm (range 15–25 cm) and width 15.8 ± 2.3 cm (range 12–20 cm). The mean operating time was 54 min (range 40–75 min).

Postoperative results

Seroma was present in six patients (50%). The types of seroma according to the classification by Morales-Conde et al. were as follows (Fig. 3): two were type 0b (16.6%) since they were only detected by CT scan, with only one of them (8.3%) lasting for longer than 3 months (type 3a). Retroprosthesis seroma was 0%.

All complications were classified as Clavien–Dindo grade 1 [9], including one of the previous seroma types 3a and one hematoma of the abdominal wall. No bleeding or infections were noted in any of the patients. The mean hospital stay was 36 h (range 20–50 h).

Postoperative pain is presented in Fig. 4, showing a mean VAS score on postoperative day 1 of 3.9 ± 3.5 (range 0–8), 1.1 ± 0.0 (range 0–5) on day 7, and 0.1 ± 0.0 (range 0–1) at 1 month, being 0 at 90 days and 1 year.

Bulging, rectus diastasis, and recurrence were evaluated by clinical examination and CT scan. No recurrences were detected at a medium follow-up of 15 months (range 12–24 months). There are statistically significant differences in the CT scan ($p < 0.0001$) between preoperative and postoperative distance between both abdominal rectus muscles, and in the analysis by pairs there is a statistic reduction in the distance between preoperative and postoperative at 30 days ($p < 0.003$) and between preoperative and postoperative at 365 days ($p < 0.002$). There were no significant differences between the distance of both muscles after surgery at 30 and 365 days ($p < 0.085$) (Fig. 5).

No bulging effects were detected by physical examination or image test.

Discussion

Following Le Blanc's description of laparoscopic ventral hernia repair (LVHR) in 1993, a new horizon was opened up in the treatment of incisional or primary ventral hernias. This technique provides a number of advantages over open

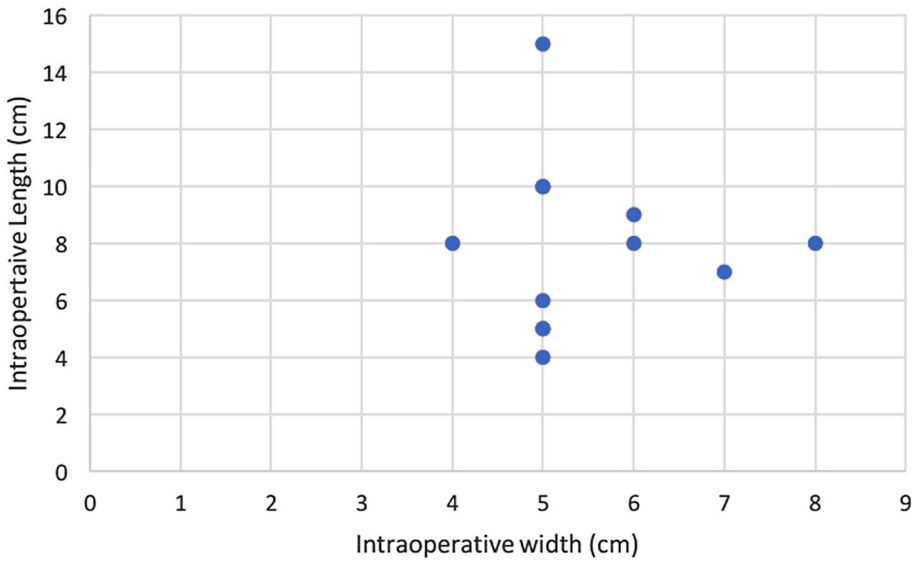

Fig. 2 Length–width defect distribution measured intraoperatively in our series

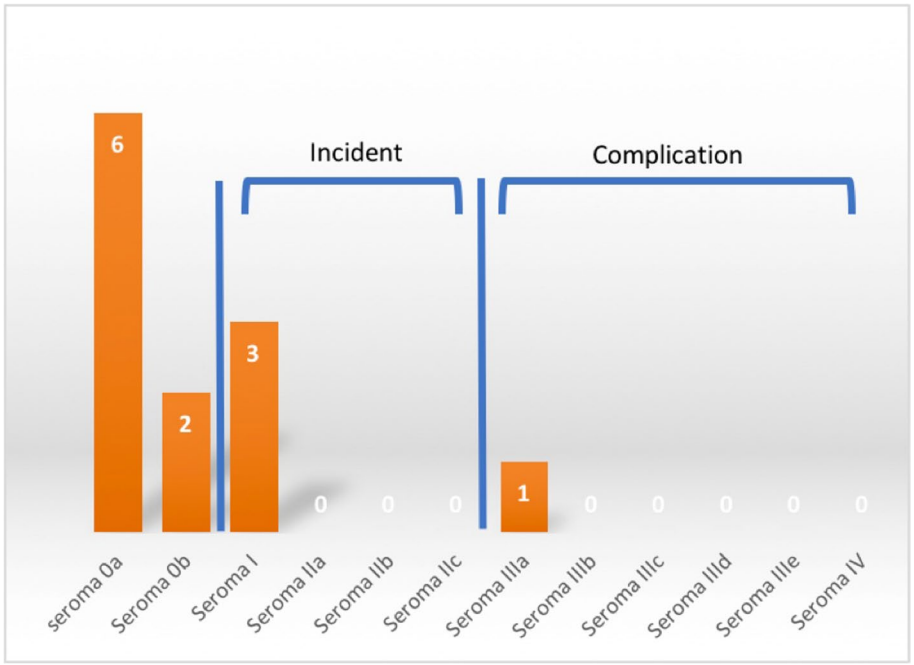

Fig. 3 Seroma distribution in our series and seroma defined as a complication according to Morales-Conde et al. Classification for Seroma in laparoscopic ventral hernia repair. [7]. The rating of seromas in our series according to Morales-Conde's classification for seroma, and classification and definitions of clinical seromas after laparoscopic ventral hernia repair, where types I and II are considered as incidents (non-complicated clinical seroma), III and IV as a complication (symptomatic seroma that may need medical treatment, puncture, or surgical drainage)

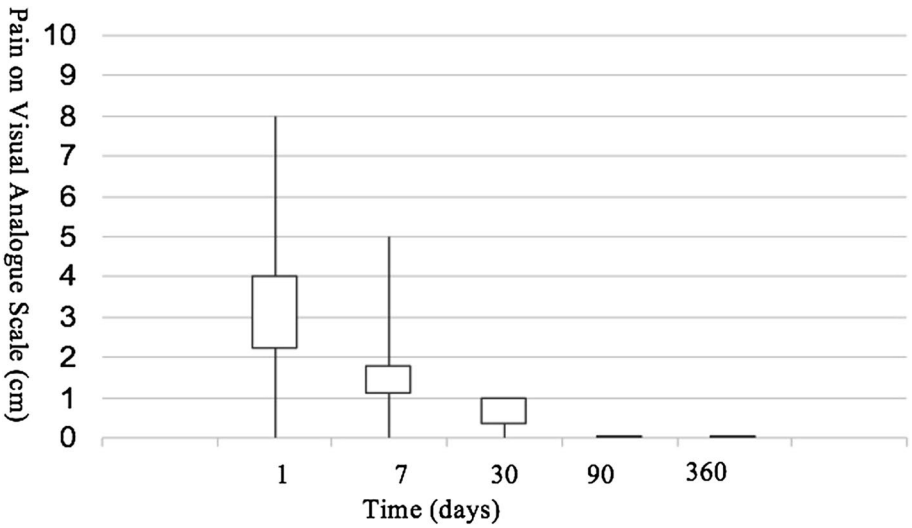

Fig. 4 VAS analysis. Boxplot is a method for graphically depicting groups of numerical data through their quartiles. Box plots are non-parametric: they display variation in samples of a statistical population without making any assumptions of the underlying statistical distribution. The spacings between the different parts of the box indicate the degree of dispersion (spread) and skewness in the data and show outliers. Box and whisker plots are uniform in their use of the box: the bottom and top of the box are always the first and third quartiles, and the band inside the box is always the second quartile (the median)

repair in terms of surgical wound morbidity, particularly related to the fact that subcutaneous and skin dissection is avoided [10–12], thus reducing hospital stay and improving postoperative comfort. LVHR also has a similar rate of recurrence compared to conventional open techniques [13].

However, new problems related to this minimally invasive approach became evident, especially due to the fact of placing an expensive mesh intraabdominally, since the mesh and the fixation devices could be related to intraabdominal complications such as adhesions and fistulas, and due to the technique itself, since this mesh was placed bridging the defect without performing the reconstruction of the abdominal wall.

As has been mentioned, one of the criticisms of LVHR is related to the use of an intraabdominal prosthetic material. For this reason, new extraperitoneal techniques have

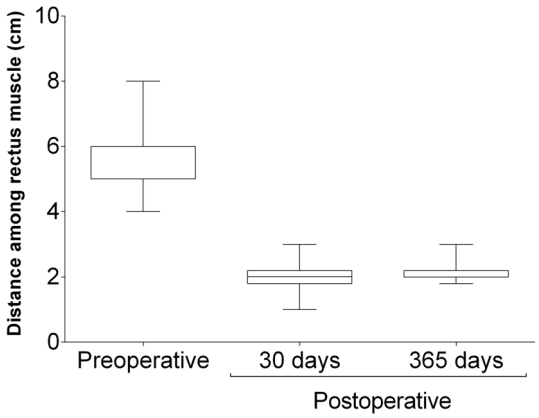

Fig. 5 Pre–postoperative distance between rectus abdominis muscles. The CT scan showed an average distance between both abdominal rectus muscles of 5.54 cm at preoperative, 2.01 cm at 30 days postoperative, and 2.2 cm at one year

emerged such as Milos and EMILOS or stapled Rives [14–16], although the new meshes and fixation devices have significantly reduced the risk of adhesions [17, 18].

On the other hand, it was criticized that LVHR does not improve the functionality of the abdominal wall and some patients showed a "bulging" effect due to the scroll of the mesh inside the sac, problems avoided by the anatomical repair of the midline reinforced by a mesh performed by open techniques. Since Chelala et al. proposed the concept of closing the defect (CD) systematically in all cases of LVHR, [19] many authors have published several different techniques involving CD in order to improve the outcomes associated with LVHR [20–22]. Nevertheless, none of these studies were able to conclude what type of defects are candidates to be closed.

Wenergen was the first to suggest that the tension generated in the midline by CD could raise new threats such as an increase in acute and chronic postoperative pain and a possible increase in recurrence [23]. Suwa et al. assert that the main limitation associated with CD is related to the size of the defect [24]. They concluded that such complications can exponentially increase when CD is performed on large defects.

Currently, there is no consensus among the different groups regarding what size of defect should be closed or not, although most authors recommend avoiding the closing of defects that are larger than 10 cm in width. A recent meta-analysis published by Tandon et al. shows that CD has some advantages over bridging in defects < 6 cm in width, including no increase of acute or chronic postoperative pain and a reduction in the seroma rate when compared to conventional LVHR [25]. This study also concluded that CD may increase the surface of contact between both the mesh and the abdominal wall, improving the integration of the mesh to the abdominal wall. The authors also concluded that the rate of complication resulting from the tension generated by CD cannot be predicted and further studies were necessary.

Overall, it could be stated that most authors conclude that CD could be safe in defects that are < 6 cm, improving the results of the conventional LVHR and maintaining the advantages of a minimally invasive approach, while those defects that are larger than 10 cm should be candidates for an open or endoscopic anatomical abdominal wall reconstruction with mesh, such as component separation techniques [26]. It is at this point that this technique finds its place, since it could be a good indication for those cases with defects between 4 and 10 cm in width, since it avoids tension at the midline associated to direct CD that could be related to an increase of postoperative pain, recurrence, and bulging at long follow-up, as shown in this preliminary series of cases, although we should be aware in the long term of the small increase of the distance between the rectus muscle observed in our series (no significance) after one year.

The laparoscopic intracorporeal rectus aponeuroplasty (LIRA) guarantees a midline reinforcement without tension since the lateral aspect of the posterior aponeurosis remains in place, facilitating a reconstruction of the linea alba including the defect, as a serious alternative to the previous technique described for this type of defect. In addition, this technique maintains the advantages of a minimally invasive approach in terms of low rate of morbidity, covering the current expectations in abdominal wall surgery of performing an abdominal wall reconstruction. Further studies are necessary to confirm these results and to analyze the effect of using different prosthetic materials and sutures. In this study, we used different types due to the availability in each center. This technique also opens the possibility of using absorbable fixation devices to fix the mesh, which has been related to a higher rate of recurrences when placing mesh bridging, instead of the permanent metal tackers [27].

In summary, the LIRA technique confers the greatest benefit for medium-sized defects between 4 and 10 cm, although our series includes hernias with a medium width of 5.5 cm, which allows for tension-free closure of the midline defect, with a low pain rate in patients, and no bulging effect. This technique retains the benefits of the laparoscopic approach (IPOM) in terms of cosmetic results, wound morbidity, infection rate, and hospital stay when compared with conventional open anatomical repairs.

The main limitations of this technique are the need for preservation of the posterior aponeurosis of the rectus and the need for the patient to have no previous intraperitoneal meshes that could frustrate the performance of both flaps. Nonetheless, randomized studies with a longer follow-up time are necessary to allow us to more conclusively evaluate the outcome of this technique. On the other hand, this technique should be also compared with other minimally

invasive techniques that place the mesh in the preperitoneal space, which also decreases the cost of the procedure since a less expensive mesh could be used and the fixation devices and glue could be avoided. Finally, even though this technique still uses an intraperitoneal mesh, it could be easier to perform than the minimally invasive technique with preperitoneal or sublay mesh placement.

Compliance with ethical standards

Disclosure Julio Gómez-Menchero, Juan Francisco Guadalajara Jurado, Juan Manuel Suárez Grau, Juan Antonio Bellido Luque, Joaquín Luis García Moreno, Isaías Alarcón del Agua, and Salvador Morales-Conde have no conflict of interest or financial ties to disclose.

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