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Reconstructive

A Herniorrhaphy Lamination Technique for the Reconstruction of Midline Abdominal Wall Defects

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Summary: The primary goal of abdominal wall reconstruction is to prevent hernia recurrence through robust and durable repair. Synthetic mesh utilization can provide sound strength but is susceptible to extrusion, infection, and intestinal fistulization. The use of autologous fasciae latae to reinforce the primary fascial reapproximation has mostly been abandoned, presumably because synthetic patches are readily available. There is a specific demand for a sustainable, less-invasive, and ready-to-use repair method without mesh. The authors devised a herniorrhaphy lamination technique using local musculofascial flaps inspired by composite laminates. In this procedure, the primary fascial reapproximation is reinforced with 3 additional laminated musculofascial layers: (1) turnover hinge flaps of the anterior sheath of the rectus abdominis, (2) bilateral rectus abdominis, and (3) advancement flaps of newly generated edges of the fascia of the rectus sheath. Our technique's stability is essentially due to the mechanical superiority of the centralized pipe-like structure of musculofascia. Between February 2009 and November 2019, we used the lamination technique to repair midline incisional hernias in 10 patients. The operative procedure was successful in all patients, and there has been no evidence of recurrence. The follow-up period ranged from 12 to 69 months, with a mean follow-up of 35 months. The herniorrhaphy lamination technique to reinforce the primary repair can help prevent hernia recurrence. Although our technique is suitable for a small-sized defect, it is less invasive, and can be readily applied. Because it does not include any mesh, it is suitable for the contaminated abdominal wall reconstruction. *(Plast Reconstr Surg Glob Open 2021;9:e3558; doi: 10.1097/GOX.0000000000003558; Published online 23 April 2021.)*

INTRODUCTION

The primary goal of abdominal wall reconstruction is the prevention of hernia recurrence through robust and durable repair. Janis et al emphasized that most repairs should be reinforced with mesh.[1] However, no widely accepted consensus or guidelines exist regarding mesh placement in contaminated wounds. It is directly because the synthetic material is susceptible to extrusion, intestinal fistulization, and infection.[2] Although biologic mesh is a promising tool for contaminated ventral hernia repair, Rosen et al reported its less favorable long-term durability with >50% recurrence at three years.[3] Alternatively, autologous fasciae latae can offer adequate strength to reinforce the primary fascial reapproximation.[4–8] Nonetheless, there has been a tendency to avoid using the fasciae latae graft probably because of its inferior usability to mesh and donor site morbidity. Therefore, there is a specific demand for a sustainable, less-invasive, and ready-to-use repair method without mesh.

In materials science, laminates are composites in which layers of different materials bond together to give added strength, durability, or other benefits. Laminated floors are excellent examples of laminates. Inspired by tough composite laminates, the authors devised a herniorrhaphy lamination technique.

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PATIENTS AND METHODS

A retrospective review of 10 consecutive patients who underwent ventral hernia repair with our technique described below with at least a 12-month follow-up was performed. Preoperative patient and hernia characteristics and postoperative complications were collected.

Surgical Technique

The surgical technique is outlined in Figure 1. The hernia sac is freed from the rim of the fascia and reduced. The bilaterally separated fascia edges are then reapproximated in the midline. This primary fascial reapproximation is reinforced with 3 additional laminated musculofascial layers. Firstly, turnover hinge flaps of the anterior sheath of the rectus abdominis are elevated by incising the sheath approximately 1 cm lateral to the primary suture, reflected inwards, and approximated in the midline. Then, bilateral rectus abdominis are advanced medially and coaptated along the medial edges in the midline. Lastly, the free margins of the anterior rectus sheath are brought into coaptation in the midline. The subcutaneous tissue and skin were closed in the usual fashion. Suction drains are placed in the subcutaneous

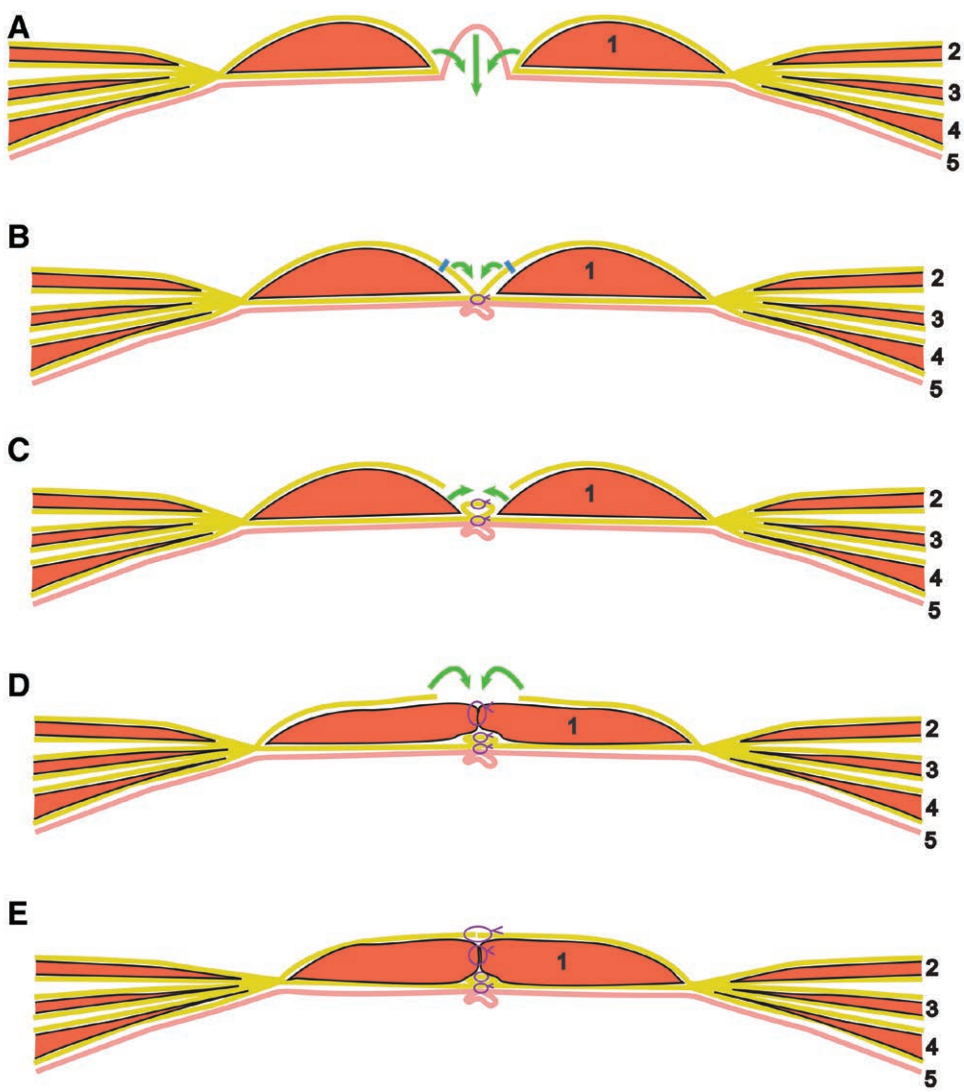

Fig. 1. Schematic diagrams of the herniorrhaphy lamination technique in the axial sectional view. 1 = rectus abdominis, 2 = external oblique, 3 = internal oblique, 4 = transversus abdominis, 5 = peritoneum. Blue lines show incision lines. Green arrows suggest the direction of advancement or elevation of flaps. A, The two edges of the fascia are reapproximated in the midline after the hernia sac is reduced. B, Turnover hinge flaps of the anterior sheath of the rectus abdominis are elevated by incising the sheath approximately 1 cm lateral to the primary suture and reflected inwards. C, Turnover hinge flaps are approximated in the midline. The bilateral rectus abdominis are advanced medially. D, The medial edges of the rectus abdominis are coaptated in the midline. The free margins of the anterior rectus sheath are brought into coaptation in the midline. E, The edges of the anterior rectus sheath are coaptated.

Table 1. Summary of Patients: Herniorrhaphy Lamination Technique Repair

Patient	Age	Gender	BMI (kg/m²)	Size of Defect* (cm²)	Medical History	Preoperative Infection	Postoperative Wound Complications	Follow-up (mo)	Mesh Removal	Prior Attempts at Hernia Repair	Hernia Recurrence	Thickness of the Wall† (mm)
1	28	F	25	8 × 17	Wound sepsis; cesarian section	Yes	None	69	No	No	No	7
2	47	F	39	3 × 6	Wound sepsis; endometrial cancer; hypothyroidism; pulmonary embolism; ex-smoker	Yes	None	47	No	No	No	8
3	72	M	22	9 × 23	Polycystic kidney; idiopathic perforation of the sigmoid colon; chronic kidney disease on hemodialysis; ex-smoker	Yes	Abscess	36	Yes	Yes (once)	No	6
4	45	M	29	5×5	Umbilical hernia; smoker	No	None	24	No	Yes (once)	No	12
5	76	F	27	4 × 7	Ovarian cyst	No	None	41	No	No	No	13
6	76	M	24	6 × 7	Perforated diverticulitis	No	Hematoma	30	No	No	No	6
7	43	F	23	3 × 3	Peritoneal dialysis catheter removal	No	None	31	No	No	No	9
8	17	F	22	4 × 12	Strangulated hernia	No	None	17	No	No	No	9
9	58	M	26	10 × 10	Appendicitis; diaphragmatic hernia; ex-smoker	No	None	45	No	No	No	N/A
10	79	M	22	5 × 11	Enterocutaneous fistula; mesh infection; bile duct cancer; ascending colon cancer; ex-smoker	Yes	Abscess	12	Yes	Yes (twice)	No	10

* First number is horizontal dimension, and second is the vertical dimension.

†The centrally assembled rectus muscles' thickness in the midline on the CT after more than 6 months postoperatively.

plane. We instructed patients to wear an abdominal binder for at least 3 months (Fig. 1).

RESULTS

Between February 2009 and November 2019, we used the lamination technique to repair midline abdominal wall incisional hernias in 10 patients. (**See Video [online],** which shows the intraoperative procedure in Patient 10.) Table 1 summarizes their characteristics and clinical outcomes. The patients' age at the time of surgery ranged from 17 to 79 years, with a mean of 54 years. There were 5 men and 5 women. The follow-up period ranged from 12 to 69 months, with a mean follow-up of 35 months. The average BMI was 26 kg/m², and the mean defect size and width were 67 cm² and 6 cm, respectively. One patient became pregnant and gave birth by cesarean section 69 months postoperatively (Patient 1). Four patients suffered from contaminated wounds (Patients 1, 2, 3, and 10). Two of these cases were associated with mesh infection (Patients 3 and 10). In both cases, the abdominal wall was devastatingly infected. The mesh removal from the abdominal wall was tedious, and complete removal of it was almost impossible. Postoperative wound complications were observed in 3 cases. Local abscesses were found in 2 cases with mesh infection (Patient 3 and 10), but each lesion healed with drainage. The fragmented mesh microfibers are an inevitable source of infection. Minor abscesses were unavoidable even with autologous repairs in these harsh conditions. Although hematoma formation occurred in 1 case (Patient 6), the wound was treated with conservative management. The operative procedure was successful in all patients, and there has been no evidence of recurrence (Table 1).

Fig. 2. Axial computed tomographic scan of the abdomen demonstrates the reconstructed abdominal wall with the "herniorrhaphy lamination technique 10 months postoperatively (Patient 10). The adequate thickness of the musculofascial layers was maintained in the midline abdominal wall.

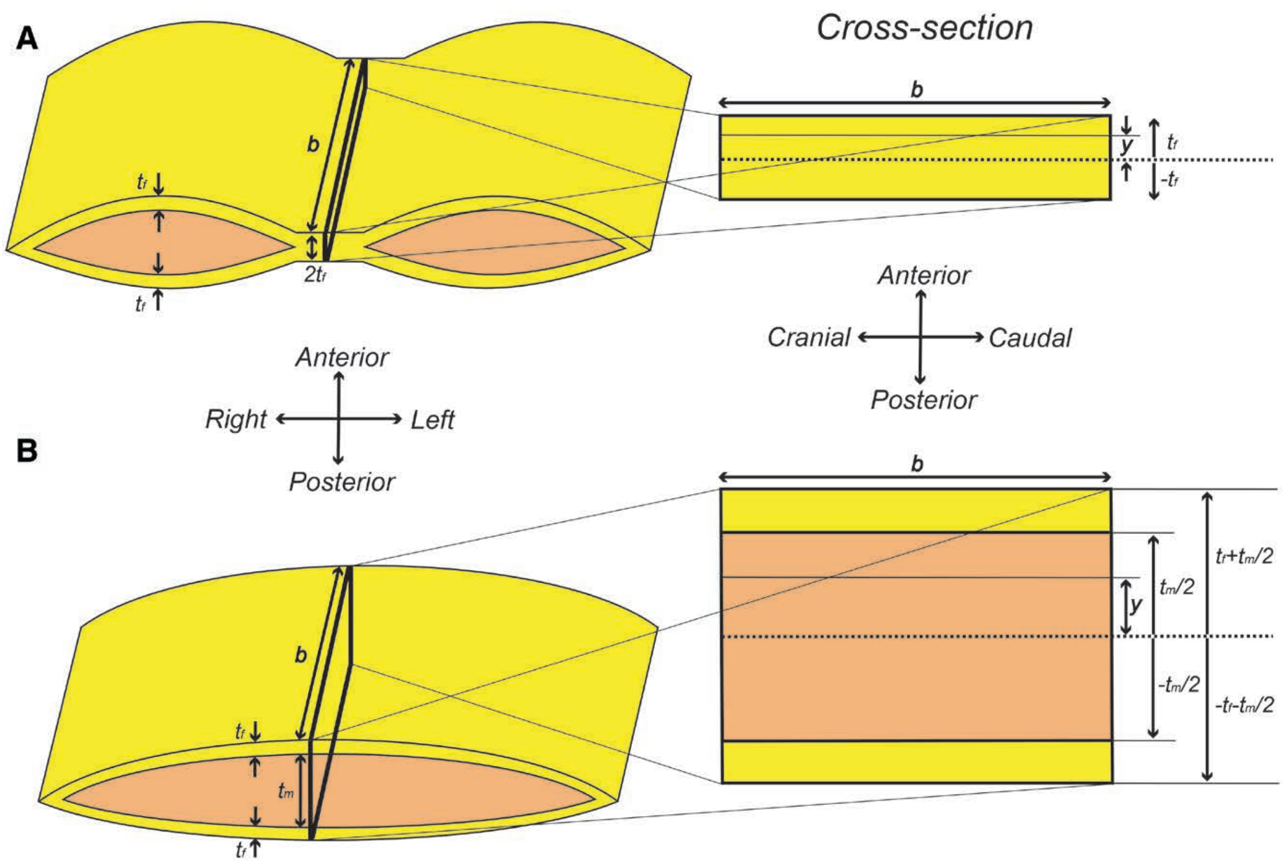

Fig. 3. Cross-sections of the midline abdominal wall (yellow area, fascia; orange area, muscle). b = breadth of an abdominal beam, t_f = the thickness of the fascia, t_m = the thickness of the rectus abdominis muscle. Dotted lines show the neutral layers. A, The abdominal wall after the primary fascial reapproximation. B, The reconstructed abdominal wall with the "Herniorrhaphy Lamination Technique." For a rectangular beam section width b and thickness t and at distance y from the neutral layer, the second moment of area (I) is given by the following formula:

$$I = \int_{-t/2}^{t/2} by^2 dy = \frac{bt^3}{12}. \quad (1)$$

Then, the flexural stiffness of the midline abdominal wall after primary fascial reapproximation $\{(EI)_p\}$ and the reconstructed abdominal wall with our technique $\{(EI)_r\}$ can be calculated as follows:

$$(EI)_p = E_f \frac{b(2t_f)^3}{12} = \frac{2}{3} E_f b t_f^3, \quad (2)$$
$$(EI)_r = E_m \frac{bt_m^3}{12} + E_f \left(\int_{-t_f - t_m/2}^{t_f + t_m/2} by^2 dy - \int_{-t_m/2}^{t_m/2} by^2 dy \right)$$

$$= E_m \frac{bt_m^3}{12} + E_f \frac{b}{12} \left\{ \left(2t_f + t_m\right)^3 - t_m^3 \right\}, \quad (3)$$

where E_f and E_m are the moduli of elasticity of the fascia and the rectus abdominis muscle. For simplicity, elasticities of all the fasciae in the abdominal wall are assumed to be the same.
Hence, provided that $E_f = 10E_m$ and $t_m = 5t_f$, Equations (2) and (3) can be simplified to give:

$$(EI)_p = \frac{20}{3} E_m b t_f^3, \quad (4)$$

$$(EI)_r = \frac{2305}{12} E_m b t_f^3, \quad (5)$$

Thus,

$$(EI)_r = \frac{461}{16} (EI)_p \approx 30(EI)_p. \quad (6)$$

DISCUSSION

The authors devised a herniorrhaphy lamination technique for the reconstruction of midline abdominal wall defects. Although the method does not require a synthetic mesh that is susceptible to extrusion, infection, and intestinal fistulization, it shows an excellent ability to reconstruct the abdominal wall. Additionally, unlike autologous fasciae latae, fascial flaps can be used without considering donor site morbidity.

In our method, the primary fascial reapproximation is reinforced with 3-layered musculofascial flaps: (1) turnover hinge flaps of the anterior sheath of the rectus abdominis, (2) bilateral rectus abdominis, and (3) advancement flaps of newly generated edges of the fascia of the rectus sheath. These laminated musculofascial reinforcements are mechanically reasonable because our method fundamentally shares the joint strategy with the long bones, which have hollow-pipe structures. The most efficient cross-section is when most of the stiff material is located as far as possible from the neutral axis. Thus, our procedure's main point is the distance between the separated pairs of fascial layers in the midline abdominal wall. The product of the modulus of elasticity (E) and the second moment of area (I) is known as the flexural stiffness (EI) in structural mechanics. As the flexural stiffness is high, a structure becomes stiffer to deformational force. Materials science can appropriately address biological tissues because these are undeniably materials of the body. Here we assume the two approximations which are rough but never widely different from the reality[9–13] (Fig. 2, Table 1): (1) the modulus of elasticity of the fascia is 10 times higher than that of the rectus abdominis muscle, (2) the rectus abdominis muscle is 5 times thicker than the fascia. Then, a reconstructed abdominal wall with our technique can be about 30 times as rigid as the primary fascial reapproximation, according to the equation (6) in the legend of Figure 3. The predominance of stability is always right in any individual, even with low-quality tissue, which has a certain level of strength to constitute a part of the human body. The overwhelming structural advantage can also offset the vulnerability of the sutured wound. Be aware that centrally assembled rectus muscles are not expected to provide mechanical strength but act as spacers between fascial layers. The muscles are like air in a hollow steel pipe. Therefore, our technique does not intend to disrupt the midline abdominal wall anatomy but reconstruct the structure to a more mechanically favorable one. Studies comparing mesh and suture repair demonstrated that the use of mesh could reduce hernia recurrence. These results were regarded as a matter of course because these were answers to easy additions. Suture repair plus mesh is more robust than suture repair alone. Therefore, due to the similarity to the mesh addition problem, suture repair reinforced with our procedure can be a useful reconstructive option.

Our technique is feasible when both of the medial edges of the rectus sheath are not cleaved. Therefore, our technique is suitable for a small-sized defect. Although hernias smaller than 3 cm may be closed primarily, the Ventral Hernia Working Group suggested that mesh repair confers a substantial benefit in reducing hernia recurrence rates.[14] Nevertheless, most surgeons and patients prefer a primary repair for a small defect. Bondre et al reviewed a multicenter database of 761 open ventral hernia repair.[15] They found out that suture repairs was the overwhelming practice pattern for small defects in contaminated and dirty-infected wounds. In case the use of mesh seems to be overindicated for a small fascial defect, our readily available procedure is just the right way to reinforce the abdominal wall. Our study is retrospective and describes a small number of patients. The follow-up in our study was short. Therefore, our results can only be considered preliminary evidence of the herniorrhaphy lamination technique's effectiveness.

CONCLUSIONS

The herniorrhaphy lamination technique can have efficacy in the prevention of hernia recurrence. Although our technique is suitable for small-sized defects, it is less invasive and can be readily applied. As it does not include any mesh, it is suitable for the contaminated abdominal wall reconstruction.

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