Hernia (2023) 27:181–190
https://doi.org/10.1007/s10029-022-02682-y

HOW-I-DO-IT

Novel modification of Marcy operation for indirect inguinal hernia reconstituting deep inguinal ring shutter action

K. Y. Chung[1] · S. H. Song[1] · D. Jung[1] · A. Kim[2]

Received: 23 June 2022 / Accepted: 4 September 2022 / Published online: 21 September 2022

Abstract

Purpose The two most frequent and significant complications after inguinal hernia repair are hernia recurrence and post-herniorrhaphy chronic pain. To add anatomic and physiologic strength to the tissue repair, especially in indirect inguinal herniorrhaphy, we devised a modification of Marcy operation that can reconstitute inguinal shutter action more efficiently by changing the direction of the sutures vertical to horizontal.

Methods During 36 months from 1st Jan. 2019, 148cases of 140 patients were operated for Indirect inguinal hernia or Pantaloon hernia (11 cases). 145 indirect inguinal herniorrhaphy were performed exclusively with author's modification of Marcy operation. Hernia recurrence during the follow-up period (3 months–36 months), and postoperative chronic pain at 3 months after herniorrhaphy were analyzed.

Results 104 cases among the 145 indirect inguinal hernia (71.7%) were operated with only deep inguinal ring (DIR) reconstruction as author modified. In 41 cases (28.3%), posterior wall reconstruction was done simultaneously. There was no recurrence or reoperation case during the follow-up period. The incidence of postoperative chronic pain at postoperative 3 months of VAS greater than 3.0 was 2.2% (3 cases).

Conclusions Author's modification of Marcy operation was feasible anatomically in all indirect inguinal hernia repair, which is theoretically superior to classic Marcy operation in that repositioning the DIR more laterally and securing the obliquity and shutter action of the DIR. Result is at least not inferior in the aspect of short-term recurrence and chronic post-herniorrhaphy pain.

Keywords Indirect inguinal hernia · Deep inguinal ring · Shutter action · Marcy operation

Introduction

The two most frequent and significant complications after inguinal hernia repair are hernia recurrence [1, 2] and post-herniorrhaphy chronic pain [3–6]. Till now debate is going on for the reliable solution to get two birds with one stone. As the abdominal wall hernia could be a clinical manifestation of a systemic disease, systemic biomarker predicting hernia disease would be useful to plan tailored surgical strategy for the individual patient [7]. Without clinically available biomarker, simply adding synthetic mesh for all kind of inguinal hernia is an attractable strategy. Even though applying mesh regardless of hernia subtypes is a convenient way to cover the deficient inguinal canal [8], tailored surgery, based on the differences in the etiology of the two hernia subtypes could be considered. High ligation of the hernia sac and the posterior wall repair are basic concepts of the pure tissue repair. The posterior

✉ K. Y. Chung
kuyong@ewha.ac.kr

S. H. Song
seunghwanhappy@ewha.ac.kr

D. Jung
esmjung@gmail.com

A. Kim
ak589332@gmail.com

[1] Department of Surgery, College of Medicine, Ewha Womans University, 1071 Anyangcheon-ro, Yangcheon-gu, Seoul 07985, Republic of Korea

[2] 3Rd Grade Student, College of Medicine, Ewha Womans University, Seoul, Republic of Korea

wall of Hesselbach triangle should be repaired in direct inguinal hernia or indirect inguinal hernia with weakened posterior wall. Since Bassini's introduction of the herniorrhaphy technique, various techniques to buttress this weakened wall have been developed [9, 10]. Most of these techniques are developed under same concepts of adding physical strength of the posterior wall with various tissues or synthetic substances. Compared to these achievements, we paid less attention to the peculiar anatomic structure and physiologic function of the DIR. There is a panoramic diversity in inguinal hernia manifestations and the risk of post herniorrhaphy chronic pain. Some patients exhibit direct inguinal hernia with rudimentary processus vaginalis that is popping out a few mm from the DIR, and some patients exhibit large indirect inguinal hernia with tight posterior wall. There are also various patient risk factors for post-herniorrhaphy chronic pain such as Young age, obesity, history of chronic pain syndrome, etc. [11]. One way to lower chronic pain might be to leave less material in the groin [7]. Discriminate surgical strategy focusing on the efficient closing of the DIR with less foreign material would be valuable especially in the patient with tight posterior wall and high risk of post-herniorrhaphy chronic pain. To add anatomic and physiologic strength to the tissue repair of the DIR., especially in indirect inguinal herniorrhaphy, we suggest to reconsider the importance of the DIR and its so-called "shutter action". We would recall the Marcy operation and consider one surgical technique with the point of improving Marcy's herniorrhaphy concept [12].

In 1970, Lytle had explained about DIR as a most important structure to defend inguinal hernia. He described that the U-shaped ring, composed of thickened transversalis fascia, is suspended by its two pillars, medial and lateral, to the posterior aspect of the transversus abdominis muscle. This U-shaped fold is the functional basis of the inguinal 'shutter' mechanism. Therefore, in the adult indirect inguinal hernia (IIH) (lateral hernia), he advocated the "vertical repair of the DIR". When the ring is strong it is reduced to normal size by suturing its pillars together, beginning medially and stitching laterally until the ring fits snugly around the spermatic cord. If the ring is weak it is usually the lateral pillar that is thin and friable and here the ring opening can be closed around the cord by stitching the medial pillar (which is usually strong) to the inguinal ligament. Lytle had attributed this exclusive use of transversalis fascia to Marcy and had popularized the term 'Marcy operation' [13].

In 1985, Griffith, revisiting the 'Marcy repair', suggested redirecting attention to an anatomical accurate closure of the DIR in transversalis fascia. He depicted the DIR structure as two funnels of transversalis fascia and protruding peritoneum. After flush ligation of the protruding peritoneum, the transversalis fascia was closed in vertical direction as Lytle suggested [14].

However, in 1997, Beets et al. reported unacceptably high recurrence rate of 34% after high ligation and ring narrowing operation that is similar to Lytle's idea [15]. In addition, in 1999, Jess et al. reported, in his long-term results of repair of the deep inguinal ring for primary inguinal hernia, that the overall recurrence rate calculated by life table analysis was 18%, and 68% of the recurrences were indirect type hernia [16]. Although this report represents very long-term follow-up results, it was disappointing enough to avoid this type of herniorrhaphy. In addition, the International guidelines of 2018 recommended Mesh repair as first choice in inguinal hernia repair [17].

Before abandoning the classical concept of shutter action of the DIR, we raise a question about the efficiency of the ring narrowing "vertical suture" of Marcy operation. Could this type of surgery reconstruct "the inguinal shutter action" as Lytle suggested?

We devised a modification of Marcy operation (Fig. 1B) that can reconstitute inguinal shutter action more efficiently by changing the direction of the sutures vertical to horizontal (Fig. 1C).

In terms of reconstituting the shutter action of the DIR, the previous Marcy operation -vertical narrowing of the ring (Fig. 1B) is less natural or not sufficient compared to author's modification. This modification (Fig. 1C) restores the medially displaced epigastric vessels to the original place, which can resume the tension to the upward and lateral direction congruent with muscle contraction.

Since 1 Jan. 2019, we applied this modified deep inguinal ring reconstruction exclusively to all of the IIH cases no matter how large is the DIR size.

Methods

Study population

During 36 months from 1st Jan. 2019 to 31st Dec. 2021, 216 operations for inguinal hernia were performed at Ewha Womans university Mokdong hospital. All operations were done by one senior surgeon. 148cases (69% of all inguinal hernia surgery cases) of 140 patients were IIH or Pantaloon hernia.

Three cases were treated with total laparoscopic extraperitoneal herniorrhaphy and these 3 cases were excluded in this report. 145 indirect inguinal herniorrhaphy were performed exclusively with the idea of Author's modification as follows.

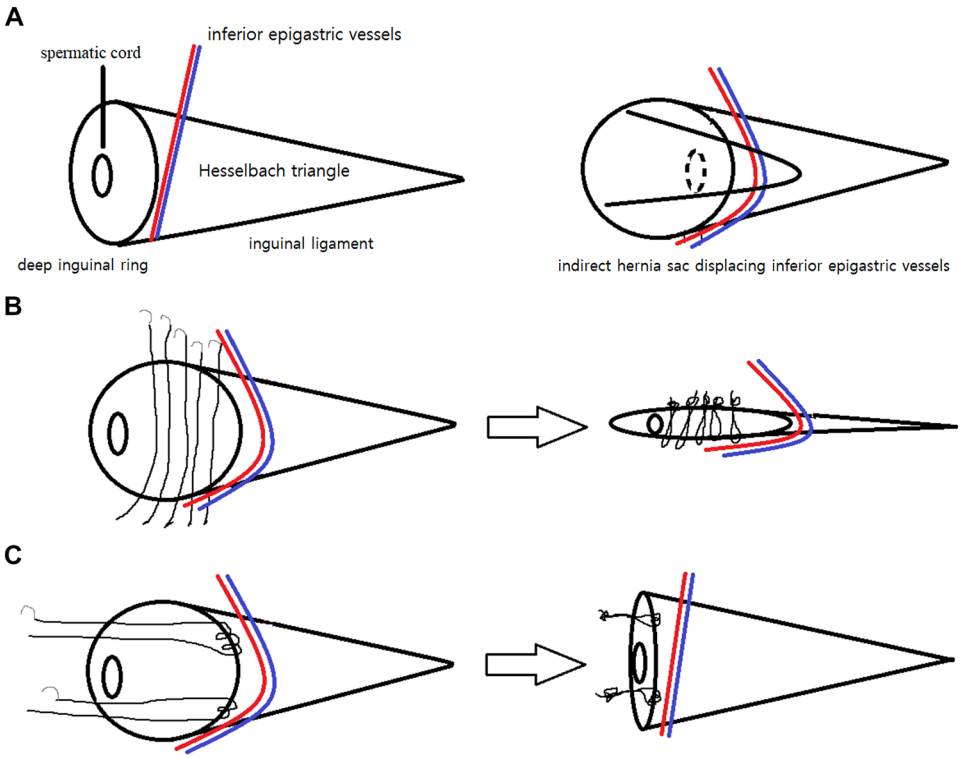

Fig. 1 Diagram of Deep Inguinal ring and Hesselbach triangle. Anatomy of Hesselbach triangle and spermatic cord, indirect hernia sac displaces the medial margin of the deep inguinal ring and inferior epigastric vessels (**A**). Marcy operation shows vertically narrowing the deep inguinal ring, the direction of the suture is not aligned to the internal oblique and transversus abdominis muscle contraction (**B**). Author's modification of Marcy operation shows pulling the deep inguinal ring medial margin laterally. This makes the tension of the suture directed upward and laterally efficiently restoring the so called "shutter action" and obliquity of the deep inguinal ring (**C**)

Surgical method

We informed patients all about the hernia repairing surgical techniques including total extraperitoneal laparoscopic herniorrhaphy, Anterior approach mesh hernioplasty, and Author's modified Marcy herniorrhaphy, and about the anesthesia method of local or general anesthesia. We explained before and after herniorrhaphy that the hernia recurrence rate is about 3–5% and post-herniorrhaphy chronic pain lasting more than postoperative 3 months is about 10%. We emphasized the importance of follow-up visit. If patient does not have any preference, we suggested Author's modified Marcy operation under local or general anesthesia.

Under the local or general anesthesia, transverse inguinal incision above the inguinal crease was made about 5–6 cm and deepened to the spermatic cord. Spermatic cord enshrouded by internal spermatic fascia (ISF) was picked up and isolated after opening the cremaster muscle parallel to the muscle fibers. The thin ISF was open near the DIR and the hernia sac was isolated and flush ligated at the DIR. The ligated peritoneum was pushed into the pelvic cavity beyond the secondary DIR [18] with gentle sweeping with gauze. The entire surrounding ISF was detached from the hernia sac, the vas deferens and testicular vessels. With this procedure, the funnel shaped ISF can be wholly identified at the base of DIR (Fig. 2A). Lower lateral part of the ISF that is transversalis fascia at the DIR was sutured two to three times to corrugate the slackened orifice. This needle was passed under the transversalis fascia, the transversus abdominis muscle, and the internal oblique muscle about 1–2 cm lateral to the stump of the hernia sac, and another end of the suture was passed in same way with empty needle, and the two ends were tied together (Fig. 2B). Another suture was done at the upper lip of the DIR and tied together making the cord lay between the two sutures (Fig. 2C, D). This procedure moves the medial end of the DIR more laterally under the thick internal oblique muscle. In the local anesthesia case, the patient was encouraged to cough so that the DIR is occluded tightly and confirmed that there is no another protruding hernia at the Hesselbach triangle. In the general anesthesia case, we checked the posterior wall weakness by digital probing with index finger over the Hesselbach triangle. If there are marked posterior wall weakness or Pantaloon hernia, posterior wall repair was done. In Pantaloon hernia, the posterior wall repair was done with classic Shouldice operation (only two-layer posterior wall repair) in whole posterior wall bulging direct hernia or modified Bassini repair (no division of the posterior wall, only suture conjoined tendon to inguinal ligament) in focally bulging direct hernia. In markedly weakened posterior wall without hernia, the posterior wall reinforcement was done with only tightening the posterior wall by continuous imbricating sutures. We used black silk 2-0 in deep inguinal ring reconstruction and Prolene 2-0 suture in posterior wall repair.

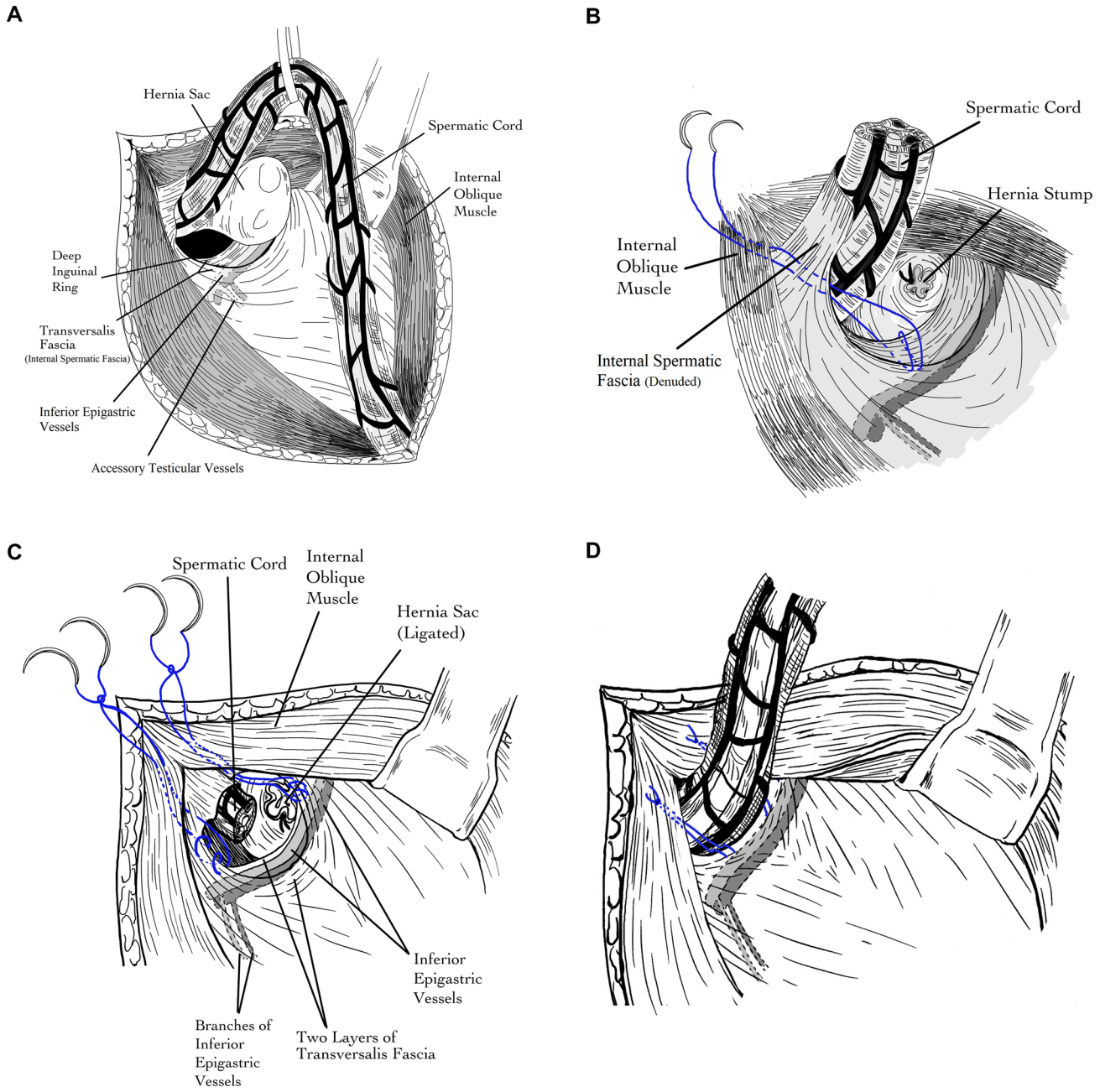

Fig. 2 **A** Procedure of Author's technique. Cremaster muscle was divided longitudinally and retracted with the internal oblique muscle. The Internal spermatic fascia, which is the extension of the transversalis fascia, was open. This picture shows the deep inguinal ring with proximal internal spermatic fascia only. The distal portion of the internal spermatic fascia is removed. **B** Procedure of Author's technique. Lowe lateral part of the internal spermatic fascia that is transversalis fascia at the deep inguinal ring was sutured two times to corrugate the slackened orifice. This needle was passed under the transversalis fascia, the transversus muscle, and the internal oblique muscle just lateral to the stump of the hernia sac. Another end of the suture was passed in same way with empty needle. **C** Procedure of Author's technique. Another suture was done at the upper medial lip of the deep inguinal ring. Pull two suture ends above and laterally, and we can confirm the lateral movement of the deep inguinal ring medial margin and tight occlusion of the deep inguinal ring. **D** Procedure of Author's technique. Two sutures tied together making the cord lay between the two sutures. Actually, the medial margin of the DIR is usually moved more laterally under the thick internal oblique muscle

Endpoints

Primary outcome was hernia recurrence during the follow-up period (3 months–36 months). Secondary outcomes were postoperative chronic pain at 3 months after herniorrhaphy in accordance with the IASP classification of chronic pain for ICD-11 [19], and any postoperative complications that patient complains of or needed to be managed.

Outcome measures

DIR size was classified as European Hernia Society (EHS) guideline [20]. 1 finger breadth (FB) for under about 1.5 cm, 2 FB for 1.5 – 3 cm, 3 FB for over 3 cm. Degrees of posterior wall weakness were classified as 0; firm, no weakness, 1; mild weakness (slight bulging vertically within 0.5 cm), 2; moderate weakness (bulging within 1 cm), 3; severe weakness (focal saccular bulging, denuded epigastric vessels, or whole posterior wall bulging more than 1 cm vertically).

All patients were recommended to revisit outpatient clinic at around postoperative 1 week, 3 months, 6 months, and 12 months, and yearly after that. Physical examination was done for hernia recurrence and any operative complications. To assess pain perception, we used 10 Visual Analogue Scale (VAS) questionnaire. Minor pain (VAS 1–2) was defined as feeling mild pain but without inconvenience of daily life, sports activity, and sexual life. Moderate pain (VAS 3–4) was defined as a pain not disturbing daily life, but hampering active sports life or sexual life. Severe Pain (VAS 5 or more) was defined as a pain that disturbs daily life and needs treatment. Postoperative chronic pain was defined as a pain greater than VAS 3 at postoperative 3 months. If the patient does not visit the outpatient clinic on the day of appointment, telephone interview was done, and with patient's agreement, we asked any symptoms related to hernia recurrence and pain.

The baseline characteristics of 145 IIH patients are summarized in Table 1. 11 cases were Pantaloon hernia and 8 cases were bilateral hernia.

Table 1 Baseline characteristics of the indirect inguinal hernia patients ($N = 145$, 140 patients)

Characteristic	Cases ($N = 145$)
Age, years	64 ± 17.6
Sex	
Male	131 (90.3%)
Female	14 (9.7%)
Direction of hernia	
Right (2 recurrent cases)	82 (56.6%)
Left (1 recurrent case)	55 (37.9%)
Bilateral	8 (5.5%)
Pantaloon hernia	11 (7.6%)
BMI (kg/m^2)	23.4 ± 3.2
< 25	38 (26.2%)
25–30	104 (71.7%)
30 <	3 (0.02%)

Results

As the mean age of this study population is 64, total 94 (67%) patients among 140 IIH patients had one or more comorbid disease. Urinary tract disease (47 patients 33.6%) was most prevalent. This could be related to the increased hernia incidence in prostate cancer surgery patients [21]. In some patients with comorbid disease such as liver cirrhosis with ascites, anterior approach with local anesthesia was definitely required (Table 2).

104 cases among the 145 indirect inguinal hernia (71.7%) were operated with only DIR reconstruction as author modified. In 41 cases, posterior wall reconstruction was done simultaneously. Local anesthesia (73.8%) was usually recommended especially when the patient has comorbid diseases (Table 3).

In 24 cases with moderate to severe posterior wall weakness, the posterior wall reinforcement was done with continuous imbricating suture. We used 3–0 absorbable suture in continuous bite from symphysis pubis to just medial to the inferior epigastric vessels. We did not approximate the conjoint tendon to the inguinal ligament in these cases (Table 3). Posterior wall reconstruction using the conjoint tendon and the inguinal ligament was done in 17(11.7%) cases. Modified Bassini repairs were done in 5 Pantaloon hernia and 3 severe posterior wall weakness cases. Two layers Shouldice repairs were done in 6 Pantaloon hernia and 3 severe posterior wall weakness cases (Table 4).

Until 31st March 2022, we have follow-up data of 144 cases at postoperative 1 week (99.3% of 145 cases, 1 case of

Table 2 Comorbidity of the indirect inguinal hernia patients ($N = 145$, 140 patients)

Diseases	*N*
Cardiovascular	40
Urinary tract	47
Other malignancy	8
Spinal problem	8
Central nervous system	11
Organ transplantation	2
CKD on dialysis	7
Liver cirrhosis	3
Diabetes mellitus	10
Pregnancy	2
Neuro-psychiatric problem	5
No comorbidity	46

Table 3 Surgical-related factor

Characteristic	Operation ($N=145$, 140 patients)
Operation time (minutes)	72.2 ± 15.3
Hospital stay (days)	3 ± 0.3
Posterior wall weakness	
0 (no weakness)	35 (24.1%)
1 (slight weakness)	63 (43.4%)
2 (moderate weakness)	28 (19.3%)
3 (severe weakness)	19 (13.1%)
Posterior wall repair	
None	104 (71.7%)
Continuous imbrication[a]	24(16.6%)
Modified Bassini method	8 (5.5%)
Shouldice method[b]	9 (6.2%)
Deep inguinal ring width	
1 finger breadth (< 1.5 cm)	30 (20.7%)
2 finger breadth (1.5-3 cm)	90 (62.1%)
3 finger breadth (> 3 cm)	25 (17.2%)
Anesthesia	
Local	107 (73.8%)
General	37 (25.5%)
Spinal	1

Continuous imbrication[a]: redundant posterior wall imbrication from symphysis pubis to inferior epigastric vessels, this suture does not include the conjoined tendon and inguinal ligament

Shouldice method[b]: classical two layers Shouldice operation

Table 4 Posterior wall repair cases ($N=17$)

Characteristic	Patients ($n=17$)
Modified Bassini operation	8
Posterior wall weakness (3 <)	3
Pantaloon hernia	5
Shouldice operation	9
Posterior wall weakness (3 <)	3
Pantaloon hernia	6
Total	17

Classic posterior wall repairs were added to the modified Marcy's operation due to the severe posterior wall weakness without direct hernia in 6 cases, and due to the combined direct hernia in 11 cases

follow-up loss, all out-patient clinic follow-up), 135 cases at postoperative 3 months (93.1% of 145 cases, 9 cases of follow-up loss, 1 death unrelated to herniorrhaphy, 7 cases with phone interview), 71 cases at postoperative 1 year (66.4% of 107 cases, 34 cases of follow-up loss, 2 death unrelated to herniorrhaphy, 6 cases with phone interview), 38 cases at postoperative 2 year (65.5% of 58 cases, 18 cases of follow-up loss, 2 death unrelated to herniorrhaphy, 4 cases with phone interview), and 6 cases at postoperative 3 years. There were no hernia recurrences or reoperations for any cause of hernia related. There were 11 cases of self-limited minor complication except 1 postoperative hematoma case. This patient complained of inguinal bulging with pain at postoperative 4th days. This patient was readmitted and treated with IV antibiotics and analgesics for 2 days (Table 5).

Table 5 Postoperative complications

Complication	Patients ($N=12$)
Recurrence	0
Reoperation	0
Readmission[a]	1
Hematoma	3
Seroma	1
Stitch exposure	4
Dysuria	1
Scrotal swelling	1
Constipation	1
Mass complaint	1
Total	12(8.3%)

Readmission[a]: readmission due to hematoma and pain, treated with IV antibiotics and analgesics

Table 6 Analgesics prescription at postoperative 1 week

Medication	Patients ($N=145$)
Acetaminophen	5
NSAID	20
Opioid analgesics	1
Lidocaine injection[a]	2
Total	28(19.3%)

Lidocaine injection[a]: One patient with spinal stenosis complained severe pain of VAS 8.5 at 1 week after operation. This patient underwent operation for spinal fusion 1 month after herniorrhaphy, and required 3 intra-incisional lidocaine injection. Inguinal discomfort symptom disappeared at 6 months after herniorrhaphy. Another patient with Parkinson's disease and prostate cancer required 2 intra-incisional lidocaine injection, and symptom disappeared at 6 months after operation

On the first follow-up visit at the postoperative 1 week, we asked if the patients need any analgesic prescription. According to the patient's need of analgesics, we prescribed acetaminophen for 5 patients, NSAID (non-steroid anti-inflammatory drug) for 20 patients, and opioid analgesics for 1 patient. And we recommended to revisit the out-patient clinic if the pain sustains or increase. When the patient revisits with sustained wound pain, we treated them with intra-incisional lidocaine injection. There were 2 patients who needed lidocaine injection. One patient with spinal stenosis complained severe pain of VAS 8.5 at 1 week

after operation. This patient underwent operation for spinal fusion 1 month after herniorrhaphy, and required 3 intra-incisional lidocaine injection. Inguinal discomfort symptom disappeared at 6 months after herniorrhaphy. Another patient with Parkinson's disease and prostate cancer required 2 intra-incisional lidocaine injections, and symptom disappeared at 6 months after operation (Table 6).

At postoperative week 1, 55 patients noted that they have no pain or discomfort, 53 patients noted that they feel minor discomfort but not hampering daily life or sports activity, 30 patients noted that their pain hampered sports activity, 6 patients noted that they feel severe pain hampering daily life and wanted medications to alleviate their symptom. These 6 patients who noted pain more than 5.0 VAS score at postoperative 1 week included two patients with spinal stenosis with back pain and two female patients. One of these patients noted mild discomforts of VAS 0.5 at postoperative 1 year, another one of these patients with spinal stenosis noted mild discomfort of VAS score 1.5 at postoperative 6 months. None of them wanted analgesics prescription at the last visit (Table 7).

Three patients (2.2%) noted that their pain or discomfort hampering sports activity (including fast walking) persisted at 3 months post-operative. So, we categorized these patients as to have chronic post-herniorrhaphy pain. Among these patients, one patient with spinal stenosis taking Neurontin® due to back pain noted inguinal discomfort of VAS 3.0, which decreased to 0.5 at 6 months and this symptom disappeared at 18 months after operation. One patient with Parkinson's disease and prostate cancer noted discomfort of VAS 4.0 and this symptom disappeared at 6 months after operation. The last female patient who has noted discomfort of VAS 3.0 at 3 months after operation is on appointment of follow-up visit at 1 year after operation. She refused taking any analgesics (Table 7).

Discussion

Restoration of physiologic structure [13, 18, 22] and/or reconstruction of tissue strength [8, 23] are two most important basic directions of inguinal hernia treatment, and each has its own rationale. We have consensus on the altered connective tissue strength observed in patients with inguinal hernia [7], and we can appreciate "why should one attempt to reconstruct normal anatomy when the mere presence of a hernia has already attested to the deficiency of the canal floor?" [8]. Preperitoneal mesh herniorrhaphy looks to be a necessary and sufficient technique fulfilling above two basic directions. However, in the vogue of endurable mesh application in hernia surgery, the proportion of inguinal hernia repairs performed for recurrence has remained constant over time in a recent large database analysis [24]. Also, Flum et al. demonstrated that even the increased use of meshes does not substantially alter the outcome but, rather, delays the onset of recurrence for 2–3 years in incisional hernia repair [25]. Although this report is confined to the patients with incisional hernia, it seems that "no single ideal operation exists for the permanent cure of hernia" [26]. If the current surgical literature on inguinal hernia repair is skewed and overly optimistic [24], and if there are some patients who are reluctant to implant synthetic mesh into their bodies or demand to take local anesthesia, it is better not to restrict the diversity of hernia surgery. Recent randomized prospective clinical trial in Japan reported that Marcy repair was comparable to Prolene Hernia System® in subjective symptoms of pain, and 3-year recurrence rate [27]. This report interestingly revives the old issue of reconstructing the posterior wall that is not bulging. Giving more strength to the Hesselbach triangle cannot completely occlude the DIR unless the spermatic cord is severed. If there is no anatomic and physiologic shutter or sphincter action of DIR,

Table 7 Postoperative pain ($N=145$)

Pain score	1 week ($N=144$)	3 months ($N=135$)	1 year ($N=71$)	2 year ($N=38$)
0	55	118	68	38
1 ~ 2	53	18	3	0
3 ~ 4	30	3**	0	0
5 ~ 10	6*	0	0	0
Mean ± SD	1.63 ± 1.65	0.26 ± 0.27		

*Included 2 patients with spinal stenosis with back pain and 2 female patients. One of these patients noted mild discomforts of VAS 0.5 at postoperative 1 year, another one with spinal stenosis noted mild discomfort of VAS score 1.5 at postoperative 6 months. none of them wanted analgesics prescription at the last visit

**One patient with spinal stenosis taking Neurontin due to back pain noted inguinal discomfort of VAS 3.0, which decreased to 0.5 at 6 months and this symptom disappeared at 18 months after operation. One patient with Parkinson's disease and prostate cancer noted discomfort of VAS 4.0 and this symptom disappeared at 6 months after operation. The last female patient who has noted discomfort of VAS 3.0 at 3 months after operation is on appointment of follow-up visit at 1 year after operation. She refused taking any analgesics

only small opening would be enough to bulge out after long duration of direct pressure. To accomplish equal satisfaction in anterior tissue repair, we focused on the more effective restoration of physiologic structure of the DIR, and we will discuss solely on the IIH repair. There are three points of discussion in the physiologic mechanism of DIR action.

First, as Lytle had suggested, the transversalis sling has shutter mechanism to prevent hernia development. As depicted in Fig. 1A, IIH displaces the inferior epigastric vessels medially. So important anatomical reconstruction should be pointed to repositioning the medially displaced epigastric vessels to the original place. This makes natural sharp angulation and obliquity of the cord structure as it was. Author's modification (Fig. 1C) was designed to corrugate slackened transversalis sling and attaches it to the natural points of muscle contraction, which can induce closure of DIR by drawing the transversalis sling upward and laterally. If the transversalis sling slackened on any causes, we need to make it tight as it was. In our cases the corrugation stitches of the DIR medial margin were all successful. Sometimes the transversalis fascia superficial to the inferior epigastric artery can be very thin or even the epigastric artery is exposed almost naked. But even in these cases usually the deeper preperitoneal fascia is sufficiently tight to pick up to suture and maintain the tensile strength.

Second, as Fowler suggested [18], there are two DIRs maintaining the obliquity of the course of the patent processus vaginalis and vas deferens. If the preperitoneal DIR loses its strength, the 2 deep inguinal rings lose their obliquity and the abdominal pressure forces directly over the transversalis DIR which is roofed only by the thin cremaster muscle. If we want to restore this amount of obliquity as it was, we need to move the medial margin of the transversalis DIR laterally, which point is roofed by the thick internal oblique muscle. Our modification technique pulls two sutures under the thick internal oblique muscle, which is effective in this lateral movement of DIR medial margin. Lichtenstein mesh hernioplasty has difficulty in this lateral movement of deep inguinal ring to beneath the thick internal oblique muscle. Marcy operation can have similar effect on moving the medial margin of the deep inguinal ring but it is not supported by the tough fascial ring and inferior epigastric artery. Another disadvantageous point of Marcy's vertical stitch is the weakness of the lateral pillar that is sometimes thin and friable. So, in these cases, Lytle advocated to use the inguinal ligament instead of the transversalis fascia. At this anatomical point, the inferior epigastric vessels are branching from the external iliac vessels. In addition, accessory testicular artery and genital branch of genitofemoral nerve are passing near this point. These complicated anatomical structures could bring about troublesome bleeding and pain. Author's modification can avoid this hazardous point. We usually preserved the accessory testicular vessels and genitofemoral nerve.

Third, when the deep inguinal ring is larger than 3FB (European guideline type I-3), previous vertical suture is more difficult, due to the displaced epigastric vessels. In these cases, the Hesselbach triangle is redundant not because of the tissue weakness of the Hesselbach triangle but because of displaced epigastric vessels. Usually severe displacement of epigastric vessels is caused by the long duration of the hernia symptom with incarcerated omentum. Even in these cases, displaced medial edge of the deep inguinal ring can be easily moved to laterally beneath the roof of the thick internal oblique muscle, which usually restore the tension of the posterior wall of Hesselbach triangle.

We added posterior wall repair in 30 cases with pure IIH and 11cases with Pantaloon hernia. In 24 case with pure IIHs, when we finished reconstructing the DIR, the posterior wall of Hesselbach triangle wrinkled due to the lateral traction of the weakened posterior wall. We added imbricating suture to give the tensile strength against vertical direction in these cases. In another 6 cases with pure IIH, we added classic posterior wall repair due to severe weakening of the posterior wall with fatty degeneration exposing inferior epigastric vessels.

Even though there is a report supporting that two-layers repair of the Shouldice operation is sufficient [28], original four-layers Shouldice operation is strongly endorsed in the Consensus meeting 2019 [23]. There are two procedures to reinforce the DIR in four-layers Shouldice operation key-points. The first is including the superior stump of the divided lateral flap of cremaster muscle in the 2nd layer, and the second is picking up some more large bites of internal oblique muscle to approximate to inguinal ligament in the 3rd layer [23]. We cautiously suggest the possible substitution of these procedures to reconstructing DIR as author modified especially in IIH.

We admit that this report reviewed relatively small number of cases and is not a comparative study with short duration of follow-up. Although lesser chronic post-herniorrhaphy pain could be easily anticipated because this modification minimized sutures and remaining foreign bodies, follow-up duration of this study is not sufficient to predict the recurrence rate favorably. Lesser short-term recurrence rate implies only technical completeness, we should wait for more long-term observation to convince that this modification of deep inguinal ring is durable under long term abdominal pressure. But, we can say that this result is at least not inferior in the aspect of short-term recurrence and chronic post-herniorrhaphy pain compared to the literature [5, 6, 29] so as to call attention to consider redeeming pure tissue repair. We should not dispose of the anatomical and physiological achievement of Lytle and Fowler et al. and the

warnings of Bendavid et al. that we must pay something for the use of meshes in the repair of hernia [13, 18, 30].

There is another pitfall of our study in the aspect of ethnicity. Korean national database registered 70 hernia operation per 100,000 population, which is much lesser incidence compared to western countries [31]. And the recurrence operation rate is only 1.9–3.2% in this national database and 5.5% in the other regional large volume data [31, 32], which looks different to the around 10% recurrence operation of United States data [24]. And our data included 148 IIH (69%) in 246 inguinal hernia operations, which looks skewed to the IIH incidence. These statistics could cast a shadow over generalizing our result. However, instead of one for all standard therapy, tailored surgery that balancing the risk of recurrences with those of mesh-related complications can be more valuable in specific age or ethnic groups with lesser recurrence rate [7].

Our data exhibits operation time of 72.2 ± 15.3 min, which is much longer if we compare to another report especially Onstep herniorrhaphy [33]. The length of our skin incision of about 5–6 cm is not so long, but usually we took sufficient time to detach the thin ISF meticulously from the inner hernia sac, vas deferens, and testicular vessels, which is mandatory procedure to view the funnel structure of the ISF around the DIR. The hernia sac, sometimes is adhered tightly with the vas deferens at around the neck of DIR, should be meticulously detached, which affords to push this hernia sac upward and laterally beyond the so-called secondary DIR [22]. Fine dissection of these structure is not only mandatory to repositioning the DIR more laterally, but also needed to understand the DIR structure especially in teaching hospitals.

Conclusions

Author's modification of Marcy operation, that is to suture the ISF not vertically but horizontally, was feasible anatomically in all IIH repair, which is theoretically superior to classic Marcy operation in that repositioning the DIR medial margin more laterally under the thick internal oblique muscle. The direction of two horizontal sutures is aligned to the internal oblique and transversus abdominis muscle contraction and sustains the tension upward and laterally. This tension reconstitutes the shutter action of the DIR as Lytle suggested and increase the obliquity of the DIR.

Although this report reviewed relatively small number of cases and is not a comparative study with short duration of follow-up, we can say that this result is at least not inferior in the aspect of short-term recurrence and chronic post-herniorrhaphy pain compared to the literature so as to call attention to consider redeeming pure tissue repair especially for the IIH patients with less weakened posterior wall.

Funding This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declarations

Conflict of interest The authors declare no conflicts of interest.

Ethical approval This study was approved by the institutional review board of Mokdong Hospital, Ewha Womans University College of Medicine, serially for retrospective study (2021-01-010-002) and prospective study (2020-08-012v005). Informed consent was waived in the retrospective study.

Statement of human and animal rights This research was conducted according to the principles of the World Medical Association Declaration of Helsinki "Ethical principles for Medical Research Involving Human.

Informed consent The authors performed this study under informed consent from the patients.

References

1. Barbaro A, Kanhere AH, Bessell J, Maddern GJ (2017) Laparoscopic extraperitoneal repair versus open inguinal hernia repair: 20-year follow-up of a randomized controlled trial. Hernia 21:723–727
2. Malik A, Bell CM, Stukel TA, Urbach DR (2016) Recurrence of inguinal hernias repaired in a large hernia surgical specialty hospital and general hospitals in Ontario, Canada. Can J Surg 59:19–25
3. Poobalan AS, Bruce J, Cairns W, Smith S, King PM, Krukowski ZH, Chambers WA (2003) A review of chronic pain after inguinal herniorrhaphy. Clin J Pain 19:48–54
4. Ssentongo AE, Kwon EG, Zhou S, Ssentongo P, Soybel DL (2020) Pain and dysfunction with sexual activity after inguinal hernia repair: systematic review and meta-analysis. J Am Coll Surg 230:237-250.e7
5. Axman E, Holmberg H, Nordin P, Nilsson H (2020) Chronic pain and risk for reoperation for recurrence after inguinal hernia repair using self-gripping mesh. Surgery 167:609–613
6. Forester B, Attaar M, Chirayil S, Kuchta K, Denham W, Linn JG, Haggerty SP, Ujiki M (2021) Predictors of chronic pain after laparoscopic inguinal hernia repair. Surgery 169:586–594
7. Öberg S, Andresen K (2017) Etiology of inguinal hernia: a comprehensive review. Front Surg 52:1–8. https://doi.org/10.3389/fsurg.2017.00052
8. Lichtenstein IL, Shore JM (1976) Exploding the myths of hernia repair. Am J Surg 132:307–315
9. Skandalakis JE, Colborn GL Skandalakis LJ, McCluski DA (2002) Nyhus & Condon's Hernia 5th edn. Lippincott Williams & Wilkins Philadelphia, PA, PP 29–43
10. Desarda MP (2001) New method of inguinal hernia repair: a new solution. ANZ J Surg 71:241–244
11. Ferzli GS, Edwards ED, Khoury GE (2007) Chronic Pain after Inguinal Herniorrhaphy. J Am Coll Surg 205:333–341
12. Marcy HO (1887) The cure of hernia. JAMA 8:589 ((Recited from Skandalakis JE, Colborn GL Skandalakis LJ, McCluski DA (2002) Nyhus & Condon's Hernia 5th edn. Lippincott Williams & Wilkins Philadelphia, PA, PP 38–38)

13. Lytle WJ (1970) The deep inguinal ring, development, function and repair. Brit J Surg 57:531–536
14. Griffith CA (1984) The Marcy repair revisited. Surg Clin North Am 64:215–227
15. Beets GL, Oosterhuis KJ, Go PM, Baeten CG, Kootstra G (1997) Long-term follow-up (12–15 Years) of a randomized controlled trial comparing Bassini-Stetten, shouldice, and high ligation with narrowing of the internal ring for primary inguinal hernia repair. J Am Coll Surg 185:352–357
16. Jess P, Hauge C, Hansen CR (1999) Long term results of repair of the internal ring for primary inguinal hernia. Eur J Surg 165:748–750
17. The HerniaSurge Group (2018) International guidelines for groin hernia management. Hernia 22:1–165
18. Fowler R (1974) The applied surgical anatomy of the peritoneal fascia of the groin and the "secondary" internal inguinal ring. Aust. N.Z. J Surg 45:8–14
19. Schug SA, Lavandhomme P, Barke A, Korwisi B, Rief W, Treede RD, The IASP Taskforce (2019) The IASP classification of chronic pain for ICD-11: chronic postsurgical or posttraumatic pain. Pain 160:45–52
20. Miserez M, Alexandre JH, Campanelli G, Corcione F, Cuccurullo D, Pascual MH, Hoeferlin A, Kingsnorth AN, Mandala V (2007) The European hernia society groin hernia classification: simple and easy to remember. Hernia 11:113–116
21. Alder R, Zetner D, Rosenberg J (2020) Incidence of inguinal hernia after radical prostatectomy: a systematic review and meta-analysis. J Urol 203:265–274
22. Mirilas P, Mentessidou A, Skandalakis JE (2008) Secondary internal inguinal ring and associated surgical planes: surgical anatomy, embryology, applications. J Am Coll Surg 206:561–569
23. Lorenz R, Arlt G, Conze J, Fortelny R, Gorjanc J, Koch A, Morrison J, Oprea V, Campanelli G (2021) Shouldice standard 2020: review of the current literature and results of an international consensus meeting. Hernia 25:1199–1207
24. Murphy BL, Ubl DS, Zhang J, Habermann EB, Farley DR, Paley K (2018) Trends of inguinal hernia repairs performed for recurrence in the United States. Surgery 163:343–350
25. Flum DR, Horvath K, Koepsell T (2003) Have outcomes of incisional hernia repair improved with time? Ann Surg 237(1):129–135
26. Zimmerman LM (1968) The use of prosthetic materials in the repair of hernias. Surg Clin North Am 48:143 (Recited from Skandalakis JE, Colborn GL Skandalakis LJ, McCluski DA (2002) Nyhus & Condon's Hernia 5th edn. Lippincott Williams & Wilkins Philadelphia, PA, PP 39–39)
27. Nakagawa M, Nagase T, Akatsu T, Imai S, Fujimura N, Asagoe T, Kanai T (2013) A randomized prospective trial comparing clinical outcomes 3 years after surgery by Marcy repair and Prolene Hernia System repair for adult indirect inguinal hernia. Surg Today 43:1109–1115
28. Varshney S, Johnson CD, Burke D (1995) Two-layer repair of the transversalis fascia is sufficient for inguinal hernia repair. Ann R Coll Surg Engl 77:305–307
29. Andresen K, Burcharth J, Fonnes S, Hupfeld L, Rothman JP, Deigaard S, Winther D, Errebo MB, Therkildsen R, Hauge D, Sørensen FS, Bjerg J, Rosenberg J (2017) Sexual dysfunction after inguinal hernia repair with the Onstep versus Lichtenstein technique: a randomized clinical trial. Surgery 161:1690–1695
30. Bendavid R, Mainprize M, Iakovlev V (2019) Pure tissue repairs: a timely and critical revival. Hernia 23:493–502
31. Han SR, Kim HJ, Kim NH, Shin S, Yoo RN, Kim G, Cho HM (2019) Inguinal hernia surgery in Korea: nationwide data from 2007–2015. Ann Surg Treat Res 97:41–47
32. Lee CS, Kim JH, Choi BJ, Lee JI, Lee SC, Lee YS (2020) Retrospective study on prevalence of recurrent inguinal hernia: a large-scale multi-institutional study. Ann Surg Treat Res 98:51–55
33. Lourenco A, da Costa RS (2013) The ONSTEP inguinal hernia repair technique: initial clinical experience of 693 patients, in two institutions. Hernia 17:357–364