Hernia (2015) 19:423–428
DOI 10.1007/s10029-014-1311-z

ORIGINAL ARTICLE

Description of robotically assisted single-site transabdominal preperitoneal (RASS-TAPP) inguinal hernia repair and presentation of clinical outcomes

C. Engan · M. Engan · V. Bonilla · D. C. Dyer · B. R. Randall

Received: 2 March 2014 / Accepted: 12 September 2014 / Published online: 24 September 2014

Abstract
Background The aim of our study is to report our initial clinical experience with robotically assisted single-site transabdominal preperitoneal (RASS-TAPP) hernia repair, to verify the safety and efficacy of the procedure and to describe the surgical procedure.
Methods We retrospectively reviewed all patients undergoing RASS-TAPP at our institution from March 2013 through December 2013. Data regarding patient demographics, type and location of hernia, operative time and clinical outcomes were collected and analyzed.
Results Fourty five hernias were repaired in 34 patients (30M, 4F) by a single surgeon. The mean age was 49.3 years and mean BMI was 26.5. 31 lateral defects, 13 medial defects and 1 femoral defect were repaired. Three patients presented with recurrent hernias and nine had bilateral defects. The mean operative time for all cases was 80.5 min and for all unilateral hernias 69 min. Considering just the unilateral hernias without any additional procedures, operative time was 63 min. The mean follow-up time was 5.5 months. There has been one superficial surgical site infection, but no observed clinical recurrence or neuralgia to date.
Conclusion Robotically assisted single-site transabdominal preperitoneal hernia repair is safe and effective. The absence of clinical evidence of recurrence or neuralgia is encouraging and should promote further study.

Keywords Robotics · Inguinal hernia · Single-site

Introduction

Laparoscopic approaches to inguinal hernia repair were described by Ger, Fitzgibbons and others in the 1990s [1–4]. Both a total extraperitoneal repair (TEP) and a transabdominal preperitoneal repair (TAPP) have been widely adopted. Efforts to minimize risks of recurrence and postoperative pain have driven the evolution of the surgical technique. Many now feel that persistent pain seen after hernia repair has supplanted recurrence rate as the most relevant clinical outcome of hernia surgery and ample evidence suggests that laparoscopic procedures decrease the risk of persistent pain, possibly due to less nerve injury [5]. Some have reported the incidence of chronic groin pain after hernia surgery to be as high as 10–12 % [6, 7] Other potential advantages of the TAPP repair over conventional open repair may include less surgical trauma and faster return to activity [8, 9]. However, concern has been raised regarding port site herniation, the potential for visceral injury and intestinal obstructions potentially associated with the TAPP repair. Currently, laparoscopic techniques are evolving toward single-port approaches [10], which may translate to cosmetic advantages. The single-site technology offered by the Da Vinci robotic platform enables peritoneal access through a 25 mm incision. Robotic optics and instrumentation allow for precise dissection of the preperitoneal groin anatomy as well as wide exposure of all potential inguinal defects. Coupled with the self-adhering mesh, the repair achieves broad overlap of

Electronic supplementary material The online version of this article (doi:10.1007/s10029-014-1311-z) contains supplementary material, which is available to authorized users.

C. Engan (✉) · M. Engan · V. Bonilla · D. C. Dyer · B. R. Randall
Great Fall Surgical Associates, 400 13th Ave South, Suite 102, Great Falls, MT 59405, US
e-mail: cengan@hotmail.com

the defect without the need for transfascial suture or tack fixation. We believe this combination of technologies should facilitate two important goals of hernia repair: minimal rates of recurrence and minimal risk for postoperative neuralgia. The primary aim of this study is to confirm the safety and efficacy of RASS-TAPP as well as to report our initial clinical experience. The secondary goal is to describe the surgical procedure.

Methods

We retrospectively reviewed all patients undergoing RASS-TAPP at our institution from March 2013 through December 2013. This represented our initial experience with this novel technique. All cases were electively scheduled. Exclusion criteria were age <16, or any contraindications to laparoscopic surgery, including inability to tolerate general anesthetic. Patient demographics, type of hernia, operative time, complications, conversion, hospital stay and follow-up data were collected.

Materials

All cases were performed utilizing the Da Vinci Si Surgical System (Intuitive Surgical, USA), and the Progrip™ laparoscopic self-fixating, flat sheet design mesh (Covidien, USA). The textile measures 10 × 15 cm with a macropore size of 1.8 × 1.8. This mesh is composed of monofilament polyethylene terephthalate and is two sided. The visceral side is coated with a mixture of 70 % collagen and 30 % glycerol, and on the other, there are approximately 5,000 self-fixating hooks of polylactic acid that slowly dissolve over several months. The mesh is hydrophilic, and ultimately lightweight, weighing 82 g/m^2 before absorption of the hooks and 49 g/m^2 after absorption. It was easy to orient with a green border marking medial placement and, when moistened, was easily handled with robotic instrumentation. At different points in the series, either an absorbable tacker (Absorbatack, Covidien, USA) or a 3–0 V-Loc suture (Covidien, USA) was utilized for peritoneal flap closure.

Surgical technique

After obtaining informed consent, the patient was brought to the operating room and general endotracheal anesthesia established. The patient was placed supine in low lithotomy with a slight Trendelenburg position. All patients received sequential compression stockings, a Foley catheter and a first-generation cephalosporin.

Robotic single-site instrumentation includes curved cannulae which are inserted through a single-site trocar. The transfascial placement of the trocar maintains pneumoperitoneum and represents a fixed pivot point through which the working instruments cross. Robotic software enables intuitive surgical control—the surgeon's left hand controlling the left-sided, intraperitoneal instrument, which is not possible with rigid, handheld laparoscopic instruments.

A 25 mm midline, epigastric incision was made with the site determined by the distance between the fascial pivot point and the ipsilateral anterior superior iliac spine. To efficiently complete the proximal peritoneal flap dissection, the tip of the 250 mm cannula was positioned just cephalad to the anterior superior iliac spine. After digitally assessing for adhesions, the moistened textile was rolled along its long axis into a cylinder, with the hooks facing outward. Next, the V-Loc suture was driven into the textile, burying the needle tip. Finally, the textile and suture were then inserted and placed dependently in the abdomen. Inserting the mesh at this stage was easier and more time efficient than after pneumoperitoneum had been established and the robot docked.

The robotic single-site trocar was placed and pneumoperitoneum established to 15 mmHg with carbon dioxide insufflation. The cannulae were sequentially inserted and the operating table was adjusted to the lowest position, at which point the robot was docked. A hook cautery with monopolar energy was placed lateral to the side of dissection and a blunt grasper placed medially. The 30°, 8 mm scope was used in the up position for all cases.

Adhesions in the lower abdomen, if present, were taken down to expose the peritoneum deep to the inguinal canal. Beginning posterior and lateral, the peritoneum was scored with cautery. Moving anteriorly then medially, an "L-shaped" incision in the peritoneum was made and the preperitoneal plane entered. The peritoneal flap was allowed to fall posteriorly. The peritoneum was peeled off the posterior aspect of the inguinal canal, exposing the deep internal ring, the inferior epigastric vessels and any potential direct defects. If needed, the peritoneal reflections involved in a hernia sac were reduced and any cord lipomas removed. The dissection exposed the symphysis pubis medially, Cooper's ligament and the femoral canal posteromedially, the vas deferens and testicular vessels posteriorly and the retroperitoneal plane posterolaterally. The exposed area accommodated the 15 × 10 cm textile.

The suture was removed from the textile and temporarily anchored into the opposite abdominal wall, away from the dissected side. The textile was then grasped and brought adjacent to the anterior edge of the divided peritoneum. With the assistant holding the textile in place, it was unrolled, working in an anterior/posterior fashion. The

mesh was typically centered near the deep internal ring with the self-fixating surface gently pushed against the exposed tissue, allowing the coated mesh surface to face the peritoneum. The mesh broadly covered any existing or potential inguinal defects.

The suture was retrieved to close the peritoneal flap, working in a lateral to medial fashion, such that the textile was sealed in the preperitoneal plane. Several cases early on in the experience utilized an AbsorbaTack device for peritoneal closure, but the technique was modified in favor of suture closure, eliminating all tacks.

The robot was undocked, the cannulae removed and the abdomen exsufflated. The V-Loc needle was retrieved. The fascia was secured with 0 Vicryl, taking multiple, closely approximated bites of fascia in a manner consistent with the small bite—short stitch interval technique [11], and the dermis closed with a 4-0 Monocryl. Dermal glue was applied and the Foley removed. The patient was taken to the postanesthesia care unit prior to discharge. The patient was given oral analgesics and a stool softener, with a follow-up appointment scheduled 2 weeks postoperatively. The patient was also instructed to avoid lifting greater than 20 pounds for 2 weeks.

Results

A total of 45 inguinal hernia repairs were performed on 34 (30M, 4F) patients using RASS-TAPP by a single surgeon. The mean age was 49.3 years (range 16–80). 12 patients (35 %) were ASA 1, (American Society of Anesthesiologists), 14 (41 %) were ASA 2 and 8 (24 %) were ASA 3. There were no patients with higher ASA scores. The mean BMI was 26.5 (range 19.8–40.4), and five (15 %)patients were obese, with a BMI greater than 30. Nine patients (26 %) were active tobacco users and ten (29 %) required medical management for hypertension (Table 1).

Of the 45 hernias repaired, 31(69 %) were lateral or indirect, 13 (29 %)were direct or medial and 1 (2 %) was femoral. In addition, there were three (6.7 %) recurrent hernias, nine (20 %) bilateral hernias and two (4.4 %) pantaloon hernias, with right-side hernia (56 %) being more prominent (Table 2) All recurrent hernias were unilateral. The mean operative time for all cases, regardless of intraoperative findings, was 80.5 min (range 45–135). For the nine bilateral repairs, the mean operative time was 110 min (range 84–135), and for the three recurrent hernia repairs, the mean operative time was 108 min (range 67–135). A unilateral repair was performed in 25 patients (74 %), with a mean operative time of 69 min (range 45–128). For the 17 unilateral repairs (50 %) that excluded the first two patients and all those that had an additional surgery performed, the mean operative time averaged 63 min (range 45–87) (Table 3). Ten patients (29 %) had a concurrent surgical procedure performed: adhesiolysis was performed in seven patients, open repair of a small incisional hernia in one patient, removal of prior mesh in one patient and nerve biopsy in one patient. We were unable to subtract the times required to perform these incidental procedures from the times reported. There were no operative complications, conversion to open, or injury to viscera or to the inferior epigastric vessels.

The mean follow-up was 5.5 months (range 1–10 months). All patients were seen in the office 2 weeks postoperatively, and phone contacts were made as well.

Table 1 Baseline patient demographics and clinical characteristics

Characteristics	All patients ($n = 34$)
Age (years), mean (range)	49.3 (16–80)
Gender	
Male	30 (88 %)
Female	4 (12 %)
BMI (kg/m^2), mean (range)	26.5 (19.8–40.4)
ASA class	
Class 1	12 (35 %)
Class 2	14 (41 %)
Class 3	8 (24 %)
Main comorbidities	
Obesity (BMI $\geq$ 30)	5 (15 %)
Current tobacco use	9 (26 %)
Hypertension requiring medication	10 (29 %)

Table 2 Hernia details

Characteristics	All hernias ($n = 45$)
Hernia location	
Left	20 (44 %)
Right	25 (56 %)
Type of hernia	
Indirect	31 (69 %)
Direct	13 (29 %)
Femoral	1 (2 %)

Table 3 Operative times

Surgical repair	Patients (*N*)	Operating time(min), mean (range)
Bilateral	9	110 (84–135)
Recurrent	3	108 (67–135)
Solely unilateral[a]	17	63 (45–87)
All unilateral	25	69 (45–128)
All cases	34	80.5 (45–135)

[a] Excludes the first two cases performed for all cases with a second operative procedure performed

One patient had a superficial surgical site infection that presented 4 weeks postoperatively which responded to oral antibiotics without sequelae for the repair or the textile.

Thirty one patients (91 %) were discharged on the day of surgery. Three patients (9 %) went home the following day. There were no 30 days readmissions and no patients presenting in follow-up with hematomas or seromas. We have not observed any patient developing orchialgia, chronic pain, numbness or foreign body sensation. There were no port site hernias or mortality. There were also no patients presenting with a recurrence following the RASS-TAPP repair.

Discussion

Inguinal herniorrhaphy is the most commonly performed abdominal surgery in Western societies [12], with approximately 800,000 cases annually [13]. Over the years, open suture repair has undergone modifications with the addition of mesh products, and now repairs often include preperitoneal dissection and minimally invasive techniques. Factors driving the evolution of hernia repair include attempts to minimize not only recurrence risk, but more importantly the incidence of postoperative pain.

Chronic neuropathic inguinodynia may develop in response to injury to the ilioinguinal, iliohypogastric, or branches off the genitofemoral trunk and orchialgia can develop from injury to the vas deferens. All current hernia repair techniques are associated with varying incidences of chronic postoperative pain [14]. The etiology of this is likely multifactorial. Techniques of tissue dissection likely impact the development of chronic pain postoperatively. The robotics platform provides superior visualization and enhanced precision compared to open or preperitoneal balloon dissection. By leaving the loose areolar tissue and nerves of the preperitoneal plane undisturbed, tissue trauma is minimized which may decrease the likelihood of postoperative neuralgia. The rate of chronic pain may also be minimized by characteristics of the mesh itself as well as the location of placement in the abdominal wall. The textile was ultimately reduced weight and is macroporous, which are elements favorable for reducing postoperative pain risk [15]. In addition, an unanswered question is does the placement of the textile in a well-vascularized, myofascial envelope, as in an open repair, as compared to a poorly vascularized, preperitoneal location as in RASS-TAPP, impact the inflammatory pain response? Many feel, however, that chronic pain is most likely caused by tack fixation [12]. Transfascial fixation is not required because of the design of the Progrip^{TM} textile which incorporates slowly absorbing, self-fixating hooks, eliminating the need to employ tacks, suture, glue or any other fixation method. In combining the functions of a barrier and a fixation modality into the textile, utilization of the Progrip^{TM} mesh should translate into a cost savings by eliminating the need for a separate fixation device. We believe that both the precise dissection afforded by the robotic technology and the self-fixating nature of the mesh have contributed to zero occurrences in the series of postoperative neuralgia to date. It should be noted that initially, we did utilize an Absorbatack to close the peritoneal flap, but not for fixation of the textile, as we later decided to switch to suture closure to eliminate the potential for nerve injury secondary to tacks.

Utilization of mesh as opposed to suture closure of the fascial defect is recognized as the primary component to minimize the rates of hernia recurrence [16–18]. However, mesh contracture and shrinkage are well described, and retraction away from the edge of the fascial defect, may be a predisposing factor for some recurrences. The Progrip^{TM} mesh is 150 cm^2 and larger than other commonly used mesh sizes. The Lichtenstein Hernia Institute recommends a 105 cm^2 mesh, and for open repair, a mesh surface area of greater than 90 cm^2 is considered large [19]. The robotic platform enables controlled placement of the mesh, centered on the defect which translates to maximal textile overlap. Abdominal pressure promotes fixation, and encasing the textile within the preperitoneal space limits the potential of mesh migration. These elements may, in part, explain the lack of recurrences. Robotic technology and mesh design complement each other and together have the potential to achieve a durable repair with minimal risk of recurrence.

We did not include an assessment of cost, but operative time is a substantial contributor to the overall procedural costs. For the series, our operative time was 80.5 min. However, in 15 patients, either a bilateral repair, or a separate procedure, or both were performed, which added to the reported operative times. Ten patients had an additional surgery performed and it was not possible to separate the time required for this from the total reported operative time.

In the 19 patients with an uncomplicated unilateral repair, our mean operative time is 69 min, and if the first two cases in the series are excluded, the mean operative time drops to 63 min. We feel that it is reasonable to exclude the initial two cases, because both had suture closure of the peritoneum, without the benefit of the single-site needle drivers, which were developed later and have greatly facilitated this maneuver. This technical challenge, coupled with inefficiencies encountered in these being the first cases performed, results in prolonged times. We feel that the time of 63 min compares favorably with published times for laparoscopic TEP and TAPP repairs. A recent series of TEP repairs has a mean OR time of 69 min [20], and in another series that combined TEP and TAPP the

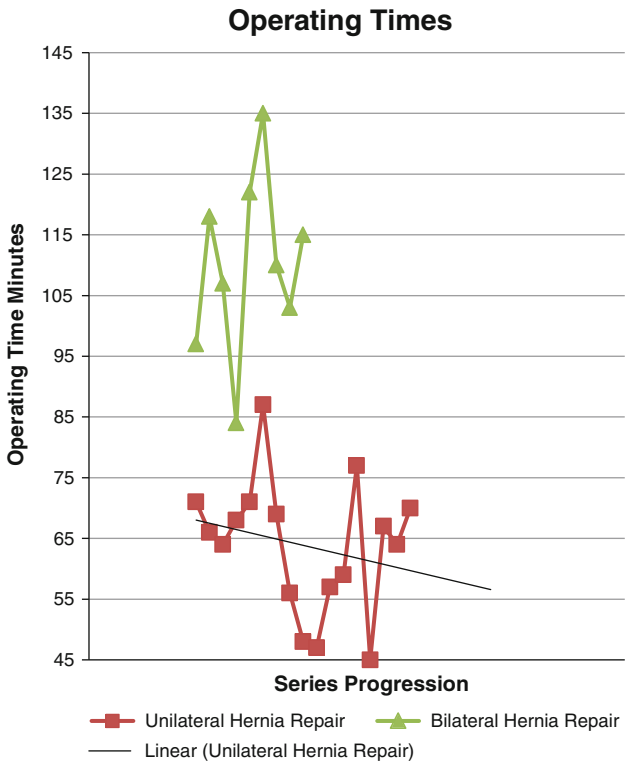

Fig. 1 Operating times

mean operating room time was 62.8 min [21]. A report looking at a similar technique, single-port endo-laparoscopic surgery, finds a mean operating time of 96 min [10]. Understandably, bilateral repairs, or those cases that require additional surgical steps, translate into longer operative times. Over the course of the series, our operative times for unilateral repairs trended down (Fig. 1), likely reflecting surgeon proficiency. We feel it is reasonable to state equivalence when comparing RASS-TAPP to laparoscopic approaches if the metric under consideration is time.

Patient selection is important for the successful application of this technique. Five (15 %) of the patients in the series were obese (BMI 30–40.4), but we employed RASS-TAPP successfully in all cases without conversion to multiport or open. The dissection and mesh deployment are not hampered, but we anticipate limitations imposed on this procedure by a thicker pannus. We recognize port site hernias as a potential complication. Our technique of suture placement is consistent with the technique advocated in the STITCH trial [11], and this may contribute to no port site herniation seen to date.

There are three patients who did not go home on the day of surgery. Two cases were performed late in the day due to scheduling issues, and these patients were discharged the following morning. The other, an 80-year-old female, was admitted overnight as a precautionary measure and discharged home the next morning without incident. We feel that this technique is suitable for same day surgery, but do acknowledge that general anesthesia is required.

There are multiple limitations to this study. The sample size is small with limited follow-up and the data were retrospectively collected. Clinical outcomes and patient satisfaction were determined from postoperative visits and phone conversations, instead of more robust tools such as the Carolina Comfort Scale. However, concerns over operator inexperience and a steep learning curve are likely to be less of an issue in this situation, because we assume any surgeon offering RASS-TAPP is already trained and experienced with the Da Vinci platform and will likely be facile performing far more technically challenging procedures.

The strengths of the study include a single surgeon series with one type of textile utilized within a standardized sequence of surgical steps.

Conclusion

Currently, several good options for anterior, posterior, open and laparoscopic repair of groin hernias exist. Our research suggests that RASS-TAPP could be considered as one of these options, with the caveat that not every patient, or surgeon, is suitable for robotics.

Potential advantages of this technique include superior visualization and enhanced precision of instrumentation, which minimize the risk for nerve trauma. In concert with the robotics platform is a self-adhering, reduced weight mesh that does not require transfascial fixation, which may further minimize the risk for chronic postoperative pain. Centering the mesh on the defect maximizes overlap and is consistent with the principles of hernia repair shown to be effective at lowering recurrence risk. The technique is suitable as a day surgery case, but we concede that general anesthesia is necessary and appropriate patient selection is important. Although not the focus of this manuscript, we recognize cost considerations as a critical component of modern health-care delivery systems. We used operative time as a metric for cost and have shown equivalence between RASS-TAPP and traditional laparoscopic cases. We anticipate that, as robotics programs mature with learned efficiencies and the streamlining of processes, the cost curve will bend downward and there will be realizable financial advantages for institutions and patients that adopt this procedure. We concede that patient characteristics and operator skill could limit the adoption and success of this technique. Furthermore, we concede that this is a small series with limited follow-up and any long-term advantages of RASS-TAPP would require additional, more robust studies to elucidate them. We find the outcome data

encouraging and hope that this promotes further evaluation of, and investigations into, the merits of this technique.

Conflict of interest CE, Declares conflict of interest not directly related to the submitted work (speaking fees, Covidien). ME, Declares no conflict of interest. VB, Declares no conflict of interest. DD, Declares conflict of interest not directly related to the submitted work (employee, Intuitive Surgical). BR, Declares no conflict of interest.

References

1. Ger R (1991) The laparoscopic management of groin hernias. Contemp Surg 39:15–19
2. Schultz L, Graber J, Pietrafitta J, Hickok D (1990) Laser laparoscopic herniorrhaphy: a clinical trial, preliminary results. J Laparosc Surg 1:41–45
3. Corbitt J (1991) Laparoscopic herniorrhaphy. Surg Laparosc Endosc 1:23–25
4. Filipi C, Fitzgibbons RJ, Salerno GM, Hart RO (1992) Laparoscopic herniorrhaphy. Surg Clin N Am 72:1109–1124
5. Kehlet H, Roumen R, Reinpold W, Miserez M (2013) Invited commentary: persistent pain after inguinal hernia repair: what do we know and what do we need to know. Hernia 17:293–297
6. Simons MP et al (2009) European Hernia Society guidelines on the treatment of inguingal hernia in adults. Hernia 13:343–403
7. Bittner R, Arregui ME et al (2011) Guidelines for laparoscopic (TAPP) and endoscopic (TEP) treatment of inguinal hernia. Surg Endosc 25:2773–2843
8. Eklund A et al (2010) Chronic pain 5 years after randomized comparison of laparoscopic and Lichtenstein inguinal hernia repair. Br J Surg 97:600–608
9. Myers E et al (2010) Laparoscopic (TEP) versus Lichtenstein inguinal hernia repair: a comparison of quality-of-life outcomes. World J Surg 34:3059–3064
10. Fuentes M, Goel R, Lee-Ong A, Cabrera E, Lawenko M, Lopez-Gutierrez J, Lomanto D (2013) Single-port endo-laparoscopic surgery (SPES) for totally extraperitoneal inguinal hernia: a critical appraisal of the chopstick repair. Hernia 17:217–221
11. van Ramshorst GH, Klop B, Hop WC, Israelsson LA, Lange JF (2013) Closure of midline laparotomies by means of small stitches: practical aspects of a new technique. Surg Technol Int Sept 23:34–38
12. Berney C, Yeo A (2013) Mesh fixation with fibrin sealant during endoscopic totally extraperitoneal inguinal hernia approach: a review of 640 repairs. Hernia 17:709–717
13. Paajanen H, Varjo R (2010) Ten-year audit of Lichtenstein hernioplasty under local anaesthesia performed by surgical residents. BMC Surg 10:24
14. Suwa K, Nakajima S, Hanyu K, Suzuki T, Okamoto T, Yanaga K (2013) Modified Kugel herniorrhaphy using standardized dissection of the preperitoneal space: long-term operative outcome inconsecutive 340 patients with inguinal hernia. Hernia 17:699–707
15. Sajid MS, Leaver C, Baig MK, Sains P (2012) Systematic review and meta-analysis of the use of light weight versus heavy weight mesh in open inguinal hernia repair. Br J Surg 99:27–37
16. Frey DM, Wildisen A, Hamel CT, Zuber M, Oertli D, Metzger J (2007) Randomized clinical trial of Lichtenstein's operation versus mesh plug for inguinal hernia repair. Br J Surg 94(1):36–41
17. Vironen J, Nieminen J, Eklund A, Paavolainen P (2006) Randomized clinical trial of Lichtenstein patch or prolene hernia system for inguinal hernia repair. Br J Surg 93(1):33–39
18. Franneby U, Sandblom G, Nordin P, Nyren O, Gunnarsson U (2006) Risk factors for long-term pain after hernia surgery. Ann Surg 244(2):212–219
19. Seker D et al (2013) Mesh size in Lichtenstein repair: a systemic review and meta-analysis to determine the importance of mesh size. Hernia 17:167–175
20. Ferzli G, Rim S, Edwards E (2013) Combined laparoscopic and open extraperitoneal approach to scrotal hernias. Hernia 17:223–228
21. Hope W, Bools L, Menon A, Scott C III, Adams A, Hooks W III (2013) Comparing laparoscopic and open inguinal hernia repair in octogenarians. Hernia 17:719–722