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SINGLE INCISION ENDOSCOPIC SURGERY (SIES) IN INGUINAL HERNIA REPAIR. A TECHNICAL REVIEW

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Abstract

The Transabdominal Preperitoneal (TAPP) and Total Extraperitoneal (TEP) methods of inguinal hernia repair are well known throughout the world. The idea of combining these methods with single incision endoscopic surgery is exciting but poses important questions regarding the level of technical difficulties, learning curve and instrumentation currently available. In this article we review the solutions currently available to the obstacles that hinder the single incision endoscopic approach to TAPP and TEP inguinal hernia from becoming widely accepted.
Key words: inguinal hernia, single incision laparoscopic surgery, TAP, TEPP

Introduction

The topic of inguinal hernia repair has always been relevant in surgery. Throughout the world about twenty million inguinal hernia surgeries are performed every year. According to the concept of "Myopectineal orifice of Fruchaud" everyone has the potential to develop an inguinal hernia because of an anatomically weak area in the medial third of the inguinal region [1].

The history of hernia repair surgery was a history of failure until the introduction of Bassini's physiological and anatomical concept, developed in 1889 [2]. The next stage in hernia repair began in 1984 with the implementation of tension free techniques using mesh implants [3]. A more recent approach consists of a combination of endoscopic TAPP (Transabdominal Preperitoneal) and TEP (Total Extraperitoneal) methods [4] with a single incision technique, resulting in SIES (single incision endoscopic surgery) hernia repair. This technique has advantages over MPLS (multiport laparoscopic surgery) as it is supposed to reduce trocar site complications, give better cosmetic results, and improve the patient's comfort in the post-operative period [5].

However, the SIES approach is technically demanding due to the entry of all instruments through one site, the lack of triangulation of instruments, the conflict between the instruments and the two-dimensional image of the surgical field from one position [6].

In attempts to solve these problems various high-tech devices have been created. In this article we will examine modern technical solutions and their usefulness in performing a safe SIES hernia repair.

Development of the SIES approach

The advent of laparoscopy has affected hernia surgery. The TAPP and TEP techniques were developed in the mid 90s and gained important popularity due to the reduction of the recovery period, reduced post-operative pain and better cosmetic results [4].

Today, it seems that there are three dominant methods for the surgical treatment of inguinal hernia, namely the Liechtenstein open technique, TAPP and TEP repair. However, the desire to optimize post-operative outcomes for the patient has led to the emergence of single-port laparoscopic surgery, and in 2008 SIES – TEP was first performed by Cugura [7]. Since then, several studies have been conducted, suggesting that the use of the laparoscopic approach to recurrent inguinal hernia compared to the open approach results in less post-operative pain, quicker recovery, fewer wound infections, but at the cost of a longer operative time [8].

Single-port laparoscopy was initially reported in 1969 by Wheeless et al. [9], who performed a tubal ligation via a 1-cm wound using an endoscope equipped with an eyepiece lens.

Surgeons' desire to minimize scarring has led to operations through natural orifices. Giday et al. described the procedure for natural orifice transluminal endoscopic surgery (NOTES) in 2000. The first human transgastric appendectomy was performed in 2004 [10] and the first transvaginal sigmoidectomy in 2011 [11]. However, endoscope channels are not designed for laparoscopic instrumentation, and the NOTES technique is still associated with inability to triangulate, heavy tissue retention and traction, and excessive mobility of the flexible endoscope in confined spaces.

This led to the search for alternative techniques, resulting in single incision laparoscopic surgery. Such surgeries have received a number of acronym names: single-incision laparoscopic surgery (SILS), single-access laparoscopic surgery (SALS), single-port access (SPA) surgery, single laparoscopic incision transabdominal (SLIT) surgery, one-port umbilical surgery (OPUS), natural orifice transumbilical surgery (NOTUS), and embryonic natural orifice transumbilical endoscopic surgery (E-NOTES). The most successful acronym – LESS (laparo-endoscopic single site incision) – was promoted at a multidisciplinary meeting in 2008, when the laparo-endoscopic single-site surgery consortium for assessment and research (LESSCAR) was created [12].

However, the history of laparoscopic surgery through a single incision began a little bit earlier. In 1991, Pelosi et al. reported the use of an endoscope with a working channel in performing a total hysterectomy. The same group also reported the first appendectomy performed by this method [13]. Navarra et al. performed a single-incision laparoscopic cholecystectomy in 1997 [14]. Since then laparoscopy surgery through one skin incision (LESS) has been used most frequently for cholecystectomy. In this article we use the term "SIES" because it is easy to understand.

Advantages and problems of SIES

There are two main reasons why laparoscopic surgery hernia repair has become popular. Firstly, it allows a large piece of mesh to be placed behind the wall defect. Secondly, there are benefits to minimally invasive surgery, namely less pain, a decreased recovery period and cosmesis [5]. SIES repair minimizes trocar site complications such as wound infection and injury at trocar introduction. Furthermore, SIES improves both the cosmetic performance such that the scar becomes almost completely invisible and the comfort of the patient in the post-operative period due to the presence of only one wound.

However, with the introduction of all instruments through a single incision, there are certain technical difficulties to the procedure:

1) inserting all laparoscopic instruments through a single incision while protecting the wound's edges and eliminating the gas leak;
2) critically reducing triangulation between instruments, since they are almost parallel in the channel; when in MPLS the perfect angle approaches 90°, in SIES this angle is generally 7°–20°;
3) the conflict between the rods of the tools, i.e. "sword fighting" or "clashing instruments";
4) the camera is mounted using a single point; therefore, the surgeon can see the surgical field at the same angle in 2D.

All these factors greatly increase the learning curve [6].

Such difficulties have prevented the widespread use of SIES. Special tools have been created to solve the problem of the lack of adequate triangulation and conflict between the shafts and handles of instruments. A flexible camera could display the operating field from different angles, 3D technology helps visualize the operative filed. This arsenal of high-tech developments has solved the problems of SIES to a great extent and has brought the comfort level of the operation to that of conventional MPLS. The only remaining issue may be the financial cost of such equipment.

Types of access to the abdominal cavity for TAPP

The main access site for a single port TAPP is through the navel. This area is the thinnest part of the anterior abdominal wall, which facilitates the movement of instruments and makes it possible to operate on patients with different thicknesses of subcutaneous fat. In addition, the navel is an ideal place from which to access all quadrants of the abdominal cavity. If necessary, an easy conversion to MPLS is possible. The advantages of entry through the navel include better cosmesis and no injury to muscles and epigastric vessels compared to access through any other point of the anterior abdominal wall.

There are several ways to insert instrumentation:

1. The Multiple trocars method (MTM) consists of installing trocars through a single skin incision of about 2.5 cm and then through separate punctures of the fascia. The points of transfascial entry of the endoscope and two working instruments are located as far as possible from one another and form a triangle. This increases the maneuverability of the tools and creates a relatively good triangulation of about 20–25°. In addition, there is practically no gas leak through the fascia punctures. However, the "Swiss cheese" effect is created, which increases the chance of trocar hernia occurrence [15]. The advantage of this method is the ability to work without an expensive port device.
2. Transumbilical SPLS (single-port laparoscopy surgery) involves the use of a special multi-channel port for the introduction of all instruments. Advanced Surgical Concepts (Wicklow, United Kingdom) were the pioneers, who released R-port in May 2007. The design of the device resembled the well-known TriPort and the QuadPort, but had one gel interphase for all instruments, resulting in a gas leak. Since then, the market has begun to fill with devices of various designs, theoretically suitable for obtaining access in TAPP hernioplasty. The channels in these ports often have valves to decrease leakage which are located at different angles to reduce the interference of the instruments, so when using straight tools the triangulation reaches 5–10°, although most ports allow for the introduction of curved tools. Such inventions have various mechanisms of attachment to the abdominal wall and can be disposable or reusable. We distinguish the main subgroups of such ports according to the trocar fixation method (Table 1).

The disadvantages of multi-channel port access include the following aspects: easy displacement that leads to gas leak, considerable cost, the retractor can be easily damaged and may require replacement, significant chances of a trocar hernia and wound infection, an increase in the duration of the operation due to technical complexity and, accordingly, an increase in the surgical training curve. It should also be borne in mind that the mesh is introduced into the abdominal cavity through a 10 mm port.

In Table 2 we summarize the most common commercially available disposable and reusable devices.

Table 1. Features of the various available ports

Groups	Manufacturer	Features
First group – fixed trocar placement)	TriPort, TriPort+™, QuadPort+™ (Olympus, Center Valley, PA, USA)	consists of one inner and two outer rings with its own wound retractor/protector between them
	SILS™ Port (Covidien, Mansfield, MA, USA)	a flexible soft-foam port without wound protector
	ENDOCONE ®, X-CONE, S-PORT ® (Karl Storz-Endoskope, Tuttlingen, Germany)	these three ports have different unique metal designs
	OCTO™ Port (Dalim SurgNET, Seoul, South Korea)	feature is 360° rotation
	SPIDER™ (TransEnterix, Durham, NC, USA)	this is a sophisticated design providing excellent triangulation; however, the cost is pretty high
	x-GATE ® (Sumitomo Bakelite, Tokyo, Japan)	has a special ring-belt-barrel construction; the long distance between the channels deserves attention
Second group – free trocar placement:	GelPOINT™/ GelPOINT Mini (Applied Medical, Rancho Santa Margarita, CA, USA)	it is possible to place tools anywhere in GelSeal cap from different angles
	E•Z Access™ circular type and E•Z Access elliptical type (Hakko, Tokyo, Japan)	trocars can be positioned anywhere within the cap that maintains 35-mm trocar separation
	Free Access (TOP, Tokyo, Japan)	a silicone membrane cap that has thirteen cross-slits and allows semi-free trocar placement
	Surgical glove Port	a homemade invention that involves the use of Alexis wound retractor/protector with non-powdered surgical glove outside and trocars attached to the glove fingers

Table 2. Commonly used single- and multiple-use port devices

Disposable port devices	Reusable port devices
TriPort / TriPort+™/QuadPort+™ (Olympus, Center Valley, PA, USA)	ENDOCONE (Karl Storz-Endoskope, Tuttlingen, Germany)
SILS™ Port (Covidien, Mansfi eld, MA, USA)	X-Cone / X-Cone mini (Karl Storz-Endoskope, Tuttlingen, Germany)
GelPOINT™ / GelPOINT Mini (Applied Medical, Rancho Santa Margarita, CA, USA)	S-PORT (Karl Storz-Endoskope, Tuttlingen, Germany)
OCTO™ Port (Dalim Surgnet, Seoul, South Korea)	SPIDER™ (TransEnterix, Durham, NC, USA)
E•Z Access™ circular type / E•Z Access elliptical type (Hakko, Tokyo, Japan)	KeyPort / KeyPort flex (Richard Wolf Gmbh, Knittlingen, Germany)
x-GATE (Sumitomo Bakelite, Tokyo, Japan) Free Access (TOP, Tokyo, Japan)	

Types of access to the preperitoneal space for TEP

It is technically possible to perform an operation through access with or without the special port device. However, taking into consideration the fact that it does not open into the abdominal cavity, it would be rational to use the multitrocar method through one incision.

There are two approaches to performing the MTM TEP. The first has already been described above – the entry of trocars through different fascial punctures. In this case, you can perform the operation with ordinary straight or articulating instruments. The second option implies a parallel arrangement of the endoscope and two instruments through a single fascia incision followed by fixation with a purse-string suture. This arrangement eliminates any triangulation, although it is possible to use banded tools which are 5 mm in diameter. In addition, tools should be held constantly.

In conclusion, we have many variable ways of accessing the preperitoneal space, and there is considerable scope for future analysis and evaluation of the techniques.

Types of Cameras

The main purpose of improving laparoscopes during SIES is to create a high-quality 3D image of the operating field and to avoid instrument clashing. Rigid and flexible scopes are used for this purpose. In this section we list the properties of scopes which can facilitate single-port laparoscopic hernia repair.

Considering the tendency of instruments to clash, both inside and outside their handles, the following changes are proposed:

- The use of 5-mm scopes. It is also possible to use mini-endoscopes (less than 3 mm) which need careful handling because there is a risk of distortion.
- Conventional rigid endoscopes for MPLS have a length of 30 cm. The use of longer axes (45-cm scope from Stryker Corporation and 50-cm scope from Karl Storz-Endoscope) decreases interference between scopes and forceps' handles because they are located at a different distance from the abdominal wall.
- The light adapter angled at 90° is used for the same purpose. Usually, the light guide cable is positioned transversely to the scope, which reduces the mobility of the forceps.

The main disadvantage of rigid endoscopes is the visualization of the surgical field from one two-dimensional position; this is why they should be angled at 30° (recommended) or 45° for lateral viewing and in order to recognize the structures better. However, rigid endoscopes allow one to work in minimal spaces, are relatively inexpensive and do not require special training.

The use of flexible endoscopes is also acceptable in endoscopic single-port hernia repair. They allow the surgeon to see the surgical field from different sides and at different angles without conflict with other instruments due to the autonomous mobility of the top of the scope. Most of the instruments found on the market can bend up to 90° in four directions. A successful example is the EndoEye Flex 5 mm (Olympus, Tokyo, Japan). This allows for 100-degree angulation and an 85-degree field of view, which allows for exceptional visualization and surgical agility [16].

The disadvantages include down-up image presentation due to the influence of gravity on the endoscope shaft, the lack of experience among surgeons and its high cost in relation to rigid ones. It is also impractical to use flexible endoscopes when performing TEP hernia repair because the reduced interfascial space does not allow for full use of the mobile tip.

Recently, 3D technologies have been introduced to laparoscopic surgery with the use of special cameras and eyepieces. The downside is the price and the slightly larger diameter of the camera rod, but the surgeon can navigate the position of the tissues in the operating field.

It can be noted that the use of rigid instruments for performing single-port laparoscopic hernioplasty has more practical advantages and can be recommended for wider acceptance of TEP hernia repair considering the above requirements for instruments. The use of flexible endoscopes unambiguously gives a wider overview of the surgical field in the presence of sufficient workspace. Therefore, they can be recommended for performing TAPP groin hernia repair, given good operational support and a sufficiently experienced surgeon.

Types of Instruments

Today, the market offers rigid, articulated and flexible instruments for SIES. This diversity arises from surgeons' desire to choose the best option for high-quality and comfortable operations without "sword fighting". Here we consider the feasibility of using such tools when performing a single incision hernioplasty.

For greater convenience, the diameter of the tools should not exceed 5 mm. The developers have increased the length of rigid instruments for single-port surgery to increase the distance from the navel to the arms. Thus, the distance between the right and left handles becomes greater, giving more mobility to the hand and the interference of the instruments is reduced. It is well known that the length of conventional MPLS instruments is 30 cm, but the ordinary length of SIES forceps is 36 cm, and a number of companies sell 5-mm forceps with a 43-cm and 45-cm shaft. This lengthening of the instruments makes it easier to conduct single port hernioplasty in conditions of poor triangulation.

The main feature of articulating forceps is the change of the tip vector. This design allows one to expand traction and reduce interference. Most of the instruments have a tip bending up to 85° in all directions with the ability to be rotated up to 360° and fixed in any position. Covidien proposed a technique for crossing articulated instruments within the body. This technique eliminates flushing, although the left hand performs the usual work of the right hand, and the right hand does the work of the left hand. The advantages of using articulated instruments when performing single-port laparoscopic hernioplasty are especially evident when positioning the mesh or when suturing the peritoneum (TAPP technique). Nevertheless, the use of two articulated forceps according to the crossing method requires special experience. The most optimal is to use a parallel technique with one articulated forceps in the left hand and a rigid tool in the right hand. This method will provide the advantage of articulated instruments and each hand performs the usual work.

Bending forceps are also used in SIES to change the tip vector and prevent conflict between the handles due to good triangulation even in the smallest spaces. The effect of working with such instruments in single-port surgery may be compared to MPLS. The shaft of these forceps can have between one and four bends, depending on the tasks. To perform a single-port hernia repair efficiently one should use coaxial bending forceps, which imply a parallel arrangement of the axes of the handles and the tips of the tools. Thus, the effect of working with ordinary straight tools with excellent triangulation and without interference of the instruments is created. The fact is that to introduce bending instruments, special trocars or multichannel ports are required.

The Radius Surgical System (Tuebingen Scientific, Tuebingen, Germany) was designed to perform transurethral urological surgery. Subsequently, there were isolated reports in the literature regarding the use of the Radius Surgical System when performing laparoscopic single-port surgery, including for TAPP-hernioplasty. The system consists of two manually operated mechanical manipulators that allow several degrees of freedom to be obtained on the basis of an appropriate and rotating tool tip. When performing hernia repair, the system facilitates the process of sewing (mesh and/or peritoneum), and relieves the load on the surgeon's wrist joints. However, the system is no longer available as it has been discontinued.

Achieving a compromise between the convenience of performing SIES and the cost of equipment indicates the use of one articulated forceps and several rigid ones. If we discard the financial component, using flexible tools will be the most convenient solution for the surgeon. Furthermore, the use of reusable laparoscopic instruments will reduce financial costs by several times in the future.

SPLS-TAPP / TEP training

Training in conventional laparoscopy has proven to be effective and occupies an important place in the training curriculum of general surgeons. Likewise, the SIES technique requires specialist training to perform procedures comfortably and safely for the patients. Existing studies have shown a much greater learning curve in SIES compared to conventional MPLS procedures [23]. The increased learning curve leads to increased time and costs spent on training. Therefore, many benefits of SIES are outweighed not only by the cost of specific equipment, but also by the surgeons' training time. Fast and efficient training requires the development and implementation of programs that could significantly reduce the learning curve while remaining economically viable.

Even though SIES originates from MPLS, the skills of experienced laparoscopic surgeons hardly help them to quickly develop proficiency in SIES. There are several studies [17,18] that have compared the time of performing basic manipulations (peg transfer and cutting circles) during laboratory training among experienced laparoscopic surgeons and novices (who had no laparoscopic experience at all). It turned out that there was no significant difference in the timing of the tasks. Therefore, we can conclude that the skills required for safe SIES are unique. However, there is a noticeable difference in the timing of basic manipulations depending on the type of tools used. The execution time of a single-port manipulation with direct tools is similar to the MPLS time. Work with articulating tools with a rotating tip takes second place. Work with bending tools is the most demanding. Furthermore, it takes the most amount of time to develop the method of "crossing". Such a difference in the speed of SIES work arises from the change in the previously studied laparoscopic behavior, the change of navigation, the narrow space, different visualization of the operating field and close cooperation with the assistant. The technique of "crossing" requires a high level of ambidexterity. Because of these difficulties, laparoscopic surgeons experience a new learning curve in developing SIES skills.

The most rational element in the development of SIES seems to be the importance of sequential training even for an experienced MPLS surgeon: theoretical material (lecture course) – laboratory training – operations on animal models or cadaveric model. The choice of animal model for inguinal hernia training has not been studied well, although it seems the porcine model may be preferable [19].

Currently, different type of simulators (from camera boxes to virtual reality devices) and programs for performing laboratory laparoscopic training are available. Fortunately, some of them can be reconfigured for SIES work, which is now being done successfully. Examples are the Augmented reality SILS box trainer (ProMIS AR III) and the Modified FLS box [20].

As for laboratory training, namely SIES-TAPP/TEP, a device with detailed inguinal area modeling is still absent from the market and thus there is a great need

for it. The McGill Laparoscopic Inguinal Hernia Simulator (MLIHS) is a good example, but it needs to be modified for SIES tasks. Another topic that may greatly influence the learning curve is the choice of the type of instruments used for surgery. This depends on the need to perform complex manipulations such as sewing, which requires the involvement of articulation tools with a rotating tip. Provided that the mesh and peritoneum are secured by tackers or glue, direct tools can be used, which will probably shorten the learning curve.

No research is currently available on SIES-TAPP / TEP laboratory training that sets down the whole training program. However, there is research that has studied the SIES-TEP learning curve in real OR cases. Its results show that the novice surgeon needs to perform about 40 SIES-TEPs to reach the accepted average time of operation [21]. The authors of this study also believe that laboratory SIES training could greatly influence the learning curve by reducing its initial part, which is the steepest.

Given the uniqueness of SIES and the value-based skills and experience it affords, it is possible to anticipate wider implementation of SIES-specific training in the near future.

Conclusions

Summing up this article, we can say that SIES results from a common desire to make laparoscopic surgery less invasive. SIES has the potential to reduce post-operative pain, the recovery period, the time to return to work, the percentage of trocar complications and to give excellent cosmetic results. However, there are difficulties of a technical nature: levelling triangulation between the working tools, a conflict between instruments, and the presence of a two- dimensional image viewed from a single angle. These aspects have significantly slowed down SIES in becoming widespread. On the other hand, they have led to the development of special techniques for access, special instruments and cameras that can bring comfort to an SIES surgeon.

So, with multichannel ports, it is possible to insert the instruments conveniently through one point of access, reducing conflict and minimizing gas leak.

The creation of longer instruments has helped to reduce the conflict between arms, and engagement of the bending and articulating instruments provides adequate triangulation. The use of reusable instruments is more economically justified in comparison to disposable ones.

We can say that to employ TEP in hernia repair more efficiently one should use one straight and one articulating instrument. For TAPP hernia repair the use of two bending instruments is suggested.

The involvement of flexible cameras gives the opportunity to evaluate the surgical field from different angles. When using the direct one, 30° optics is

recommended. The involvement of 3D technology is useful for understanding the relative position of organs and tissues. In Table 3 we have summarized the main problems of SIES and their possible solutions.

It seems that the solutions to most technical problems associated with SIES hernia repair already exist. The technique of SIES-TAPP / TEP is technically demanding both in terms of instruments and surgical skills. In order to be widely accepted by surgeons proper training and the development of ergonomically designed instruments is essential.

Table 3. The main problems of SIES with respective currently available solutions

Problem	Solution to problem
Inserting all instruments through one hole	Using techniques: MTM or SPLS
Wound edge protection	Most port-devices are used with special wound extenders / wound protectors
Gas leakage	SPLS – port-devices have special valves MTM – fascia punctures and purse seam minimize the problem
Too little triangulation between instruments	Use of articulation and/or flexible instruments
Avoiding "sword fighting"	Use of finer tools Use of longer tools Use of crossing method is possible
Visualization of the operating field from one position and at one angle	Attracting flexible endoscopes 3D-technology with special cameras and eyeglasses

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Chirurgia endoskopowa z pojedynczego cięcia w powłokach w leczeniu przepuklin pachwinowych. Przegląd aspektów technicznych

Streszczenie

Metody przezbrzusznej przedotrzewnowej (TAPP) i całkowitej pozaotrzewnowej (TEP) naprawy przepukliny pachwinowej są dobrze znane na całym świecie. Pomysł połączenia tych metod z chirurgią endoskopową wykorzystującą pojedyncze nacięcie w powłokach jamy brzusznej jest bardzo interesujący, ale wiążą się z nim ważne pytania dotyczące poziomu trudności technicznych, krzywej uczenia się i dostępnego obecnie oprzyrządowania. W niniejszym artykule autorzy omawiają dostępne obecnie rozwiązania mogące pomóc w ograniczeniu przeszkód, które utrudniają dostęp endoskopowy z pojedynczym nacięciem w powłokach w leczeniu przepukliny pachwinowej TAPP i TEP.

Słowa kluczowe: przepuklina pachwinowa, chirurgia laparoskopowa z pojedynczego cięcia w powłokach, TAPP, TEP