**ISSN** 1948-5190 (online)

# World Journal of *Gastrointestinal Endoscopy*

*World J Gastrointest Endosc* 2017 September 16; 9(9): 428-498

Published by Baishideng Publishing Group Inc

WJGE

World Journal of Gastrointestinal Endoscopy

Contents

Monthly Volume 9 Number 9 September 16, 2017

*World Journal of Gastrointestinal Endoscopy*
**Volume 9 Number 9 September 16, 2017**

# Contents





NAME OF JOURNAL
*World Journal of Gastrointestinal Endoscopy*

ISSN
ISSN 1948-5190 (online)

LAUNCH DATE
October 15, 2009

FREQUENCY
Monthly



EDITORIAL OFFICE
Xiu-Xia Song, Director
*World Journal of Gastrointestinal Endoscopy*
Baishideng Publishing Group Inc
7901 Stoneridge Drive, Suite 501, Pleasanton, CA 94588, USA
Telephone: +1-925-2238242
Fax: +1-925-2238243
E-mail: editorialoffice@wjgnet.com
Help Desk: http://www.f6publishing.com/helpdesk
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PUBLISHER
Baishideng Publishing Group Inc
7901 Stoneridge Drive, Suite 501,
Pleasanton, CA 94588, USA
Telephone: +1-925-2238242
Fax: +1-925-2238243
E-mail: bpgoffice@wjgnet.com
Help Desk: http://www.f6publishing.com/helpdesk
http://www.wjgnet.com

PUBLICATION DATE
September 16, 2017



INSTRUCTIONS TO AUTHORS
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World Journal of Gastrointestinal Endoscopy

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*World J Gastrointest Endosc* 2017 September 16; 9(9): 428-437

DOI: 10.4253/wjge.v9.i9.428

ISSN 1948-5190 (online)

REVIEW

# Laparoscopic splenectomy: Current concepts

Evangelos P Misiakos, George Bagias, Theodore Liakakos, Anastasios Machairas

Evangelos P Misiakos, Anastasios Machairas, 3rd Department of Surgery, Attikon University Hospital, University of Athens School of Medicine, Attica, 12462 Athens, Greece

George Bagias, Clinic for General, Visceral and Transplant Surgery, Hannover Medical School, 30625 Hannover, Germany

Theodore Liakakos, 1st Department of Surgery, National and Kapodistrian University of Athens, Medical School, Laikon General Hospital, 11527 Athens, Greece

Author contributions: Misiakos EP contributed to study concept and design, literature review, interpretation of data; Bagias G contributed to literature review and writing of the paper; Liakakos T contributed to study supervision, mentorship, surgery part of the manuscript; Machairas A contributed to study guidance and supervision, editing the manuscript.

Conflict-of-interest statement: The authors declare they have no conflicts of interest.



Manuscript source: Invited manuscript

Correspondence to: Evangelos P Misiakos, MD, FACS, Associate Professor of Surgery, 3rd Department of Surgery, Attikon University Hospital, University of Athens School of Medicine, 76 Aigeou Pelagous Street, Agia Paraskevi, 15 341, Attica, 12462 Athens, Greece. misiakos@med.uoa.gr
Telephone: +30-210-5326419

Received: February 10, 2017
Peer-review started: February 10, 2017
First decision: May 10, 2017
Revised: May 21, 2017
Accepted: July 21, 2017
Article in press: July 24, 2017
Published online: September 16, 2017

## Abstract

Since early 1990's, when it was inaugurally introduced, laparoscopic splenectomy has been performed with excellent results in terms of intraoperative and post-operative complications. Nowadays laparoscopic splenectomy is the approach of choice for both benign and malignant diseases of the spleen. However some contraindications still apply. The evolution of the technology has allowed though, cases which were considered to be absolute contraindications for performing a minimal invasive procedure to be treated with modified laparoscopic approaches. Moreover, the introduction of advanced laparoscopic tools for ligation resulted in less intraoperative complications. Today, laparoscopic splenectomy is considered safe, with better outcomes in comparison to open splenectomy, and the increased experience of surgeons allows operative times comparable to those of an open splenectomy. In this review we discuss the indications and the contraindications of laparoscopic splenectomy. Moreover we analyze the standard and modified surgical approaches, and we evaluate the short-term and long-term outcomes.

**Key words:** Laparoscopy; Splenectomy; Splenomegaly; Hand-assisted-laparoscopic-splenectomy; Lymphoma



**Core tip:** With the advent of laparoscopic techniques, laparoscopic splenectomy has become the procedure of choice for benign and malignant diseases of the spleen. Splenomegaly can be alternatively treated with modified hand-assisted approach. In addition the introduction of advanced laparoscopic tools for ligation and electrocauterization contributed to reduced blood loss at surgery and minimal morbidity.

Misiakos EP, Bagias G, Liakakos T, Machairas A. Laparoscopic splenectomy: Current concepts. *World J Gastrointest Endosc* 2017; 9(9): 428-437 Available from: URL: http://www.wjgnet.com/1948-5190/full/v9/i9/428.htm DOI: http://dx.doi.org/10.4253/

wjge.v9.i9.428

## INTRODUCTION

Since the late 80's, minimal invasive surgical techniques have been widely used for numerous operations in General Surgery. Less intraoperative bleeding, subordinate postoperative pain, shorter hospital stay, and better cosmetic results are some of the advantages that made laparoscopy nowadays the standard approach for many surgical procedures. Therefore, laparoscopic splenectomy since 1991 when was first described by Delaitre and Maignien[1] is widely accepted as a safe and feasible technique for most splenectomy cases. Like appendix and gallbladder, spleen does not require reconstruction on removal, and its anatomic landmarks are often consistent, so it can be considered as an ideal organ for laparoscopic removal. The spleen, especially in benign diseases, can be safely morcellated prior to removal, fact that suits in laparoscopic procedures, as the specimen can be removed through a small skin incision. The development of technology and the introduction of new alternatives to classic laparoscopic splenectomy such as the single-port procedure imply that in the near future laparoscopic splenectomy will be considered as the standard approach, even in trauma cases.

In this study we review the indications for a laparoscopic splenectomy and discuss the contraindications of it. Moreover, we analyze the current technical aspects of the procedure and compare the outcomes in comparison to open splenectomy.

## INDICATIONS

In general, indications for laparoscopic splenectomy are the same as those of open splenectomy, except for the trauma cases, where the role of laparoscopy is still debatable. We can divide the indications for undergoing a splenectomy into three major categories: (1) benign hematologic diseases; (2) malignant hematologic diseases; and (3) splenic cysts.

### *Benign hematologic diseases*

It is well established that splenectomy can be a curative therapy for most of benign hematologic diseases, especially in patients with immune thrombocytopenic purpura, which is the most common indication for splenectomy (excluding trauma). ITP is an acquired autoimmune disorder characterized by a peripheral blood platelet count < $100 \times 10^9$/L, without abnormalities in the erythroid and myeloid/lymphoid lineages[2]. The incidence of ITP in adults is estimated at 2.2-3.9 per $10^5$ persons per year[3]. The curative role of splenectomy for ITP underlies in the pathophsysiology of the disease. The ITP-associated thrombocytopenia is the result of the production of antiplatelet antibodies which bind to the platelets resulting in the destruction of the platelets through phagocytosis. This phagocytosis occurs throughout the reticuloendothelial system, but spleen is considered as the primary site not only for antiplatelet antibodies production, but also for antibody-bound platelet destruction as well[4]. Therefore, removal of spleen can reverse the pathophysiology of the disease. However, splenectomy is considered a second-line therapy, mainly for patients with chronic ITP (presence of the disease for > 12 mo), as the first-line therapy consists of high doses of corticosteroids and/or intravenous immunoglobulin[5]. A decision for a splenectomy is taken when the patient has persistent thrombocytopenia after a 6-wk therapy with steroid or intravenous immunoglobulin[6], as a remission after that time is unlikely to occur. Lately however it is suggested that a remission can occur up to 1 or 2 years after onset, so a splenectomy can be preserved for thereafter[7]. A splenectomy can be suggested also in patients who receive near-toxic doses of immunosuppressive therapy[8], in order for a complete remission to be achieved. Finally, splenectomy is preferred also in patients who had achieved a remission under medical therapy, but the thrombocytopenia has relapsed. In these cases actually laparoscopic splenectomy is considered a method of choice[9]. In the above cases, the spleen is usually normal-sized, therefore splenectomy can be successively performed with laparoscopy.

It is well established that splenectomy had excellent results in terms of *ITP* remission; in some studies the rates of complete and partial remission after laparoscopic splenectomy were superior to medical therapies[10]. In the systematic review by Kojouri *et al*[11], 66% of patients who had undergone splenectomy had a complete response (defined as a platelet count of > $100 \times 10^9$/L) and 88 had a complete or partial response (defined as a platelet count of > $50 \times 10^9$/L), whereas relapse of ITP occurred in 15% of all patients. High complete remission rates were found also in the study by Vianelli *et al*[12]; complete response was found in 66% of patients and a complete or partial response in 86% of patients, although the relapse rate was higher (23% with a median time to relapse of 8 mo). Many studies have tried to find prognostic factors for complete response after splenectomy, but none of them is widely accepted. Young age (< 50 years), previous response to corticosteroid and IV Ig therapies, preoperative platelet count (> 70 ×) have been occasionally proposed as prognostic factors[13]. Nevertheless, Kojouri *et al*[11], showed that none of them is a statistically significant independent predictor of a good response to splenectomy.

Patients with hereditary spherocytosis are also candidates for laparoscopic splenectomy, again under certain circumstances, as the first line therapy is mainly medical[14]. Splenectomy is preserved for moderate or severe forms of the disease, where medical therapy has nothing more to offer. In his recent meta-analysis,

Guizzetti[15] has shown encouraging results in patients with hereditary spherocytosis undergoing total or partial splenectomy; a general qualitative resolution of anemia was reported. The hemoglobin concentration increased by an average of 2.20 g/dL in patients after partial splenectomy, and the increase of hemoglobin concentration was significantly higher (3.60 g/dL) following total splenectomy. Interestingly, splenectomy showed to have a durable result, as the hemoglobin concentration remained at almost same levels after a follow-up time of four years. Moreover, the European Association of Endoscopic Surgery states that minimal invasive surgery is safe and feasible method for total splenectomy in patients with hereditary spherocytosis[9], as perioperative and postoperative complications are found in less than 1% of all patients[15]. The laparoscopic approach allows also a simultaneous cholecystectomy, which in the majority of patients with hereditary spherocytosis is required due to symptomatic cholelithiasis.

Thrombocytopenic thrombotic purpura is another indication for laparoscopic splenectomy, although it is rarely performed, as plasma therapy has very good response rates. Splenectomy is indicated in patients with primarily refractory or with progressive disease despite plasma exchange, where perioperative and postoperative mortality can reach up to 40%[16]. The response rates however are considered decent, as relapse of the disease occurs in 8% and 17% of splenectomized patients with refractory and progressive disease respectively[17]. Patients with autoimmune hemolytic anemia can be also benefited from a laparoscopic splenectomy. Lechner *et al*[18] had proposed that splenectomy is the best second-line therapy, when glycocorticoids fail to manage adequately the disease because of a high short-term efficacy and a good evidence of a long-term response. Other benign hematologic diseases that can be partially or completely treated with a laparoscopic splenectomy are Evans syndrome and hemoglobinopathies, such as sickle cell anemia, β-thalassemia and hemoglobin sickle cell disease[19]. It is mandatory to be noted though, that for all benign hematologic diseases and especially for autoimmune hematologic disorders, a routine preoperative search for accessory splenic tissue should be undergone. Many studies have reported disease recurrence due to accessory spleen(s)[20] which were not found preoperatively or intraoperatively. Some surgeons claim that minimal invasive approach restricts spotting of accessory splenic tissue, however it is well established that a thorough search of the peritoneal cavity during the laparoscopic splenectomy has similar detection rates compared to open splenectomy[21,22]. Definitively, a preoperative screening with a high-resolution CT is obligatory, as it can detect nearly 100% of accessory splenic tissue, irrespective of their size[23].

### *Malignant hematologic diseases*

Unlike benign hematologic diseases, in malignant hematologic diseases a minimal invasive approach serves mainly diagnostic and palliative purposes but it can be also used for cure. Patients with Hodgkin's lymphoma can be benefited when the staging procedure[24], is undergone through laparoscopy, as this has fewer postoperative complications and decreased length of hospital stay[25]. Nevertheless, many surgeons hesitate to perform a staging laparoscopy for Hodgkin lymphoma, mostly for two reasons; firstly, finding infiltrated nodes, especially in iliac and celiac regions is considered to be more difficult through laparoscopy. This fact is widely accepted, however, Baccarani *et al*[25] have found that although a staging laparoscopy was associated with longer operative time, not only more infiltrated nodes were found, but also disease did not relapse in patients who underwent staging laparoscopy, proving that through a minimal invasive procedure a more accurate diagnosis can be acquired. The second reason is that when a splenectomy is required, the spleen must be removed intact for pathologic analysis and for avoiding tumor cells dissemination. Considering the fact that the majority of patients with Hodgkin's lymphoma have splenomegaly, it is proposed that an additional 8-10 cm incision should be made, in order for the spleen to be removed unattached, or alternatively a hand-assisted-laparoscopic-splenectomy (HALS) should be considered. In non-Hodgkin lymphomas the role of laparoscopic splenectomy is restricted to palliative purpose, when the patient suffers from abdominal pain and obstipation, due to splenomegaly, or for correction of cytopenia[26]. An elective laparoscopic splenectomy can be performed in patients with non Hodkin lymphoma for acquiring a histological diagnosis. In fact, a pathologic analysis of spleen tissue is considered to be the gold standard for non-Hodgkin lymphomas and additionally it is not necessary for the spleen to be removed intact[27]. It is doubtful though, whether a splenectomy is worthwhile in this case, as it may delay the curative chemotherapy[28]. The laparoscopic approach in this case may be useful, as it may minimize postoperative complications, allowing early beginning of chemotherapy.

Other malignancies in which a laparoscopic splenectomy can have a diagnostic or a therapeutic role are myeloproliferative diseases (*e.g.,* myelofibrosis*),* and lymphoproliferative diseases*, (e.g.,* chronic lymphocytic leukemia or chronic myelogenous leukemia). Lately it is believed though that splenectomy for hairy cell leukemia should be abandoned, due to efficiency of existing medical therapy. Primary splenic malignancies are very rare, comprising mostly lymphangiosarcomas, malignant vascular tumors (*e.g.,* hemangiosarcomas) or malignant lymphomas[29]. Most splenic tumors are *metastatic* (*e.g.,* of malignant melanoma or ovarian cancer)[30]. In all these malignancies, patients usually present with splenomegaly, so special issues for undergoing a laparoscopic splenectomy should be considered (see below).

Undoubtedly, laparoscopic splenectomy for mali-

gnant diseases is more challenging. Fraser *et al*[31] compared patients who underwent laparoscopic splenectomy for malignant and non-malignant diseases, and found that patients with malignant diseases were significantly older (61 years *vs* 50 years, $P = 0.0004$). Moreover, spleens removed from patients with malignancies were statistically significant larger ($P = 0.0004$) and 73% of malignant cases are considered to have splenomegaly, resulting in bigger conversion rates (30% *vs* 16%). Nevertheless, postoperative complications were not significantly increased in patients with malignant diseases, showing that although a laparoscopic splenectomy is technically more difficult in malignant cases, no difference in outcome was found. In another study by Silecchia *et al*[32] was also manifested that laparoscopic splenectomy is associated with longer operating times, larger spleen size and a higher conversion rate, the intraoperative complications were fewer though. It is generally believed that an additional incision for removal of the intact specimen for histopathologic evaluation should be made in patients with malignancies, in order to keep the conversion rate low[29,33]. Alternatively, a HALS procedure should be used, which also results in low conversion and morbidity rates[34].

### *Splenic cysts*

Nowadays the use of imaging studies is arising, and, along with the improvement of diagnostic tools such as abdominal sonography and computed tomography, has contributed to an increased incidence of splenic cysts which in the past remained undiagnosed. Splenic cysts can be classified in three large categories; infectious (abscess or hydatid cysts), nonparasitic (congenital or post-traumatic) or malignant ones. Nonparasitic cysts represent approximately 75% of splenic cysts[35] and are usually asymptomatic, therefore their true incidence can be higher, as the majority of cases remain undiagnosed or untreated. Rarely can nonparasitic cysts cause symptoms, mainly abdominal pain, fullness, nausea, vomiting, flatulence and diarrhea, and irritation of the left diaphragm followed by cough or pneumonia. It is believed that the presence of symptoms is due to the large size of cysts, usually greater than 5 cm, at which point it is unlikely that the cyst will resolve automatically, and rupture even with minor trauma is likely to occur[36]. Although a laparoscopic partial splenectomy is rarely indicated in adults[9], in cases of large nonparasitic cysts a partial splenectomy, cystectomy, or cyst decapsulation can be performed, preferably through laparoscopy[9], as this preserves the immunologic function of the spleen and therefore prevents the potentially fatal complication of postsplenectomy sepsis. In addition, laparoscopy seems to have better outcomes compared to open procedure in terms of postoperative morbidity[37]. Of course, this minimally invasive approach is associated with higher possibility of cyst recurrence[38]. In contrast to the asymptomatic course of nonparasitic cysts, patients with infectious cysts, and especially splenic abscesses, may present with sepsis, and if they remain untreated, the mortality rate is high. Infectious cysts are usually produced from septic emboli from especially in a pre-installed sepsis or immunodeficiency conditions[39]. An open splenectomy is considered still the standard approach for treatment, mainly due to the need of an emergency procedure in a usually compromised patient; however, it has been shown that infectious cysts can be successfully managed with a laparoscopic procedure and/or conservative therapy[39-41]. The lower postoperative morbidity that a minimal invasive approach can offer is of high significance for the immunocompromised patients.

Finally, splenic artery aneurysms are relatively rare, with a prevalence of 0.04%[9] and commonly asymptomatic. Treatment of splenic aneurysms is indicated if the aneurysms become symptomatic, in women of childbearing age, in the presence of portal hypertension, before liver transplantation, if the diameter exceeds 2 cm, and in case of pseudoaneurysm formation, regardless of size[42-44]. Here interventional therapies are in first line; however if these therapies are not applicable, a laparoscopic removal of the aneurysm or a laparoscopic partial splenectomy has to be undergone[9].

### *Special considerations*

**Splenomegaly:** Although splenomegaly was considered to be a contraindication for a minimally invasive approach, the evolution of the technology and the acquired experience of surgeons have allowed the use of laparoscopic splenectomy in many cases of splenomegaly. Therefore, it is strongly suggested that when the spleen is up to 1000 g (or its maximal diameter is up to 15 cm), it should be removed with the laparoscopic approach[9]. However, the laparoscopic technique is correlated with longer operative times, increased blood loss, higher conversion rates, more perioperative complications and longer total length of hospital stay[45]. For that reason, laparoscopic splenectomy in cases of splenomegaly should be performed by experienced surgeons. When the spleen size exceeds 1000 g the role of laparoscopy is controversial, as the working space in the abdominal cavity is significantly restricted, due to the spleen size, and preparation of the spleen as well as dissection around the splenic structures are burdensome, and finally the specimen cannot be removed easily. In these cases, especially when the maximal diameter of the spleen is longer than 19 cm, a HALS should be performed, for easier manipulation and removal of the organ[46]. Kaban *et al*[47] shown that when HALS is performed, a minimal invasive approach is feasible, with low conversion rates and few perioperative complications. Moreover lower operating times can be achieved through HALS[48]. Some studies have suggested that an interventional preoperative ablation of the splenic artery can reduce the size of the spleen, allowing for the completion of the operation laparoscopically[49], but this is

not well established. However, spleen weight over 2000 g (or maximal diameter > 23 cm) is considered to be a contraindication for laparoscopic splenectomy, and open laparotomy is preferable[9,50].

**Trauma:** A splenic rupture is often present in patients with blunt abdominal trauma. The management of splenic injuries has evolved considerably lately, so the classic explorative laparotomy and splenectomy, when needed, has given its place to interventional, nonoperative therapy. Splenic artery angio-embolization has been described as an alternative to operative management of splenic injuries. It is true that lower grades of injury correspond to higher success rates for this approach. However, nonoperative treatment in general fails to manage the rupture in up to 40% of all cases[51]. Unfavourable results of nonoperative treatment are mainly found in older patients (> 55 years), in patients with severe splenic trauma [Injury Severity Score (ISS) > 25], in patients in which the splenic injury is well manifested in imaging studies and in patients with evidence of hemoperitoneum in more than two recesses or in the pelvis[52,53]. In these patients, nonoperative treatment is associated with higher morbidity and mortality rates[54], therefore surgical treatment with splenorraphy or splenectomy should be done. It is widely accepted that when it comes to trauma, an open splenectomy is preferred; however there is a limited number of studies which describe a minimal invasive approach of splenectomy after trauma. This approach offers better detection and identification of possibly simultaneous diaphragmatic and visceral injuries[55], along with other general benefits of laparoscopy. Although it is not abundantly described, laparoscopic splenectomy for splenic injuries seems to be feasible, even though exploratory laparotomy remains the gold standard treatment. In a recent study by Ermolov *et al*[56], it has been shown that although a laparoscopic splenectomy for splenic injury was associated with significantly longer operating time compared to open splenectomy, patients after laparoscopy had better recovering conditions. The authors highlighted though that when a hemodynamic instability and high bleeding rate (> 500 mL/h on serial ultrasound examinations) are established, the laparoscopic approach should be avoided.

**Portal vein hypertension:** Portal hypertension is found usually in case of liver cirrhosis but it can be also the consequence of other pathologies. In an established portal hypertension, gastric varices usually coexist, therefore the risk of intraoperative hemorrhage is high[57]. Nevertheless, portal hypertension is not an absolute contraindication for laparoscopic splenectomy. In the study by Cobb *et al*[58], laparoscopic splenectomy was associated with significantly longer operative time (mean operative time 192 min), but acceptable intraoperative blood loss (mean 193 mL), and hospital length of stay (mean 3.5 d), showing that laparoscopic splenectomy for Child A and B liver cirrhosis is feasible and safe. In addition, Hashizume *et al*[59] found that although a minimally invasive procedure in patients with portal hypertension had prolonged operative times and relatively significant intraoperative blood loss, the conversion rate was relatively low (4.1%), supporting that laparoscopic splenectomy is not only safe and feasible, but also should be considered as the procedure of choice. To date the role of laparoscopy in preexisting portal hypertension is not adequately established; therefore it is still suggested that patients with portal hypertension from liver cirrhosis should undergo an open splenectomy when needed.

## SURGERY

In all patients scheduled for an elective laparoscopic splenectomy, the spleen size and volume should be preoperatively measured with an abdominal sonography. The acquired information can be very useful not only for planning the right approach, but also for diagnosing coexistent conditions, which should be intraoperatively evaluated (*e.g.,* cholelithiasis in patients with hereditary spherocytosis). As we mentioned above, patients with immune thrombocytopenic purpura or malignant diseases should undergo also a high-resolution computed tomography of abdomen, to detect any existing accessory spleens. In addition, in elective operations it is recommended that vaccination against *S. pneumoniae*, *H. influenzae* and *N. meningitidis* should be carried out preferably 15 d prior to surgery[9]. Of course vaccination can be performed also 10 d after the operation, especially when the patient is operated on an emergency basis[60]. Moreover it is recommended that patients with autoimmune thrombocytopenia and platelet count less than 20 × $10^9$/L should be preoperatively treated with corticosteroids and/or immunoglobulins, in order to reduce intraoperative blood loss.

Positioning of the patient is a matter of debate. There are three patient's position described: anterior, hemilateral and lateral. Anterior position was the first one described[1]. At this position omental pouch and splenic hilum are well visualized. Moreover, in an anterior position, concurrent procedures (*e.g.,* cholecystectomy, biopsy) and conversion to open laparotomy (if required) can be easily performed[61]. However, anterior position has the disadvantage of moderate visualization and therefore dissection of the ligament structures and dorsal vessels and procedures in the area of splenic hilum could be burdensome, especially when the hilum is close to the pancreatic tail[62]. In hemilateral position the patient is positioned in the right lateral decubitus position at an angle of approximately 45°. Hemilateral position allows easy division of short gastric vessels and better access to the posterior surface of the spleen and perisplenic ligaments. Additionally, dissection and ligation of hilar vessels is easier, because pancreatic tail is spared[63]. Hemilateral positions is currently preferred by the majority of surgeons as it is widely adjustable

and provides better access to anatomic landmarks[63,64]. In lateral position, patient's abdomen is vertical to operating table. Here the dissection of ligaments and hilar landmarks is even easier than in other positions, thus an injury to the pancreas can be avoided[65]. In a series compared lateral *vs* anterior positions, lateral position was associated with shorter operative time, fewer perioperative and postoperative complications and shorter length of hospital stay[66]. Lateral approach has the disadvantage though, that a conversion to open laparotomy may require repositioning of the patient. Nevertheless, position of the patients depends on the surgeon's preference.

### *Standard laparoscopic approach*

The operation begins with obtaining abdominal access, usually with an open cutdown technique, but the use of a Veress needle is also allowed, except for patients with massive splenomegaly, due to the high risk of injury. Regardless of checking for accessory spleens, it is recommended that before initiating splenic mobilization, diagnostic laparoscopy should be performed. Thereafter working trocars are placed; the placement depends mostly on surgeon's preference. In general, one trocar can be placed just off the midline/subxiphoid region in the left subcostal position and another one can be placed in the anterior axillary line in the left subcostal region. After mobilization of the splenic flexure, an additional trocar may be placed laterally off the tip of the 11$^{th}$ rib, as it may be highly assistive in cases of splenomegaly. Then posterior avascular attachments and short gastric vessels are divided and the spleen is retracted in order to obtain complete access to the splenic hilum and the pancreatic tail. The splenic hilum is then divided with an endoscopic stapler with a vascular load. Endovascular stapler provides easy and stable division of hilum[66]. After hilum division, hemostasis is ensured and staple line bleeding can be controlled with clips or hemostatic agents. At this point however, an injury of the pancreatic tail is possible, so when this procedure is not completely safe, the hilar vessels can be alternatively divided with an electrothermal bipolar vessel sealer or ultrasonic coagulating shears. These are reported to be safe, providing low blood loss and short operative time[67]. Now the spleen can be grasped by the handle of the splenocolic ligament placed into a strong bag. Here it is important to avoid spillage of splenic tissue, especially in patients with malignancies. The spleen is mainly removed morcellated, except cases where intact removal of the spleen is needed. A use of drainage is not recommended[9]; Delaitre *et al* has shown higher morbidity rates in cases when a drainage tube was placed[68]. Of course, when a pancreatic injury has occurred or is suspected, drainage is mandatory[9].

### *HALS*

HALS is an alternative to laparoscopic splenectomy that combines benefits of both open and laparoscopic techniques. It is used in cases of massive splenomegaly that otherwise would not be amenable to a standard laparoscopic splenectomy and a conversion would be required. (craniocaudal length > 22 cm or width > 19 cm). HALS splenectomy can be used with the anterior, hemilateral or lateral postitioning. The essential difference between HALS and standard laparoscopy is that the surgeon's nondominant hand is inserted through hand-assist devices (in order to maintain the pneumoperitoneum) into the abdominal cavity. For that reason, an additional incision, not greater than 7-8 cm (or 1 cm less than the surgeon's glove size), should be performed in upper or lower midline or right abdomen, depending on the surgeon's preference, but generally the incision should be located 2-4 cm caudal to the inferior pole of the enlarged spleen. This technique facilitates the surgical procedure and especially the medial retraction, rotation, and elevation of the spleen. Moreover, intraoperative complications such as hemorrhage may be better controlled. The removal of the spleen in this way is easier, as with the hand the spleen is placed easier and faster in the strong bag and it is removed *via* the additional incision, usually without morcellation. It has been well reported that, as we mentioned above, HALS for patients with splenomegaly is associated with fewer intraoperative complications, lower conversion rate, shorted operative time and therefore significantly shorter total length of hospital stay[47,48,69]. Interestingly, although HALS involves an additional incision, the general benefits of laparoscopic procedures such as less postoperative pain and early resumption of the oral diet are succeeded, making this approach the best alternative for patients with massive splenomegaly (maximal spleen diameter > 22 cm)[70]; however patients with smaller spleen size should not undergo HALS[9,71,72].

### *Single-incision laparoscopic splenectomy*

The rapid advance of technology has led to a struggle for an even more "scarless techniques". In that principle, single-incision laparoscopic procedures have been introduced, which have been tested successfully in various operations. Laparoscopic splenectomy has been also reported that can safely and successfully be done through a single incision, using a single port through which the working trocars are inserted in the abdominal cavity. The basic concepts of laparoscopy are also followed in single-incision laparoscopic splenectomy (SILS); an umbilical or periumbilical incision is made and a specific port system is applied; either 2 or 3 single ports through this incision only, or 1 single-incision port (*e.g.,* SILS™ port of Covidien, Mansfield, MA) are applied. Then the operation is continued just like standard laparoscopic splenectomy. Undoubtedly, a SILS is considered to be more technically challenging; Barbaros *et al*[73] compared SILS *vs* standard laparoscopic approach in patients with ITP, and they found that operative time was statistically significant longer in SILS compared to standard laparoscopy, and the blood loss during SILS was also more. These technical difficulties

come as a result of the proximity of surgical tools, which are not specially designed for SILS. Nevertheless, SILS has almost the same conversion rate, morbidity and mortality rate as standard laparoscopy[74], and patients who underwent SILS seems to have less postoperative pain[73]. Further technological evolution and more experience on single-incision procedures can make SILS more popular.

## OUTCOMES

### *Intraoperative complications*

It is widely accepted that laparoscopic splenectomy is safe, however does not lack intraoperative complications. Bleeding is the main intraoperative complication, and the main reason to convert the operation to open. It usually comes as a result of injuries of the hilar or short gastric vessels, the splenic capsule, and/or splenic parenchyma during the surgical procedures and especially during the ligation of the vessels mentioned above, or during the dissection and ligation of the splenic hilum. When an intraoperative bleeding cannot be safely and promptly managed, conversion should be considered[9]. Through a converted to open approach bleeding is easily managed, however, the postoperative complications of every open procedure are found also here[75]. Laceration of adjacent organs and structures, especially the pancreas and gastric or diaphragmatic wall damage can occur. The incidence of these complications seems not to be associated with the experience of surgeons[9], however, an enlarged spleen may be responsible for technical difficulties which can lead to injuries. In a large review of possible complications after laparoscopic splenectomy by Chand *et al*[76] the incidence of pancreatic injury was 15%, which in most cases resulted in pancreatic fistula. Therefore, it is important to place a drainage tube when a pancreatic injury is suspected; otherwise it can be placed postoperatively through a CT-guided cannulation. As we mentioned above, a HALS in cases of splenomegaly can significantly reduce the incidence of injuries.

### *Postoperative complications*

Early postoperative complications after laparoscopic splenectomy may include postoperative *bleeding*, subphrenic collections or abscess, deep vein thrombosis, thrombosis of the splenoportal axis, pneumonia and atelectasis, pancreatitis, ileus, abdominal wall infections, abdominal wall hematomas and abdominal wall hernias. These are treated according to general standards.

Special consideration should be made for portal or splenic vein thrombosis (PSVT), which may occur even within months after surgery and can be proved lethal[77]. It is a potentially life-threatening complication that can occur within months after surgery. Consequences of PSVT are intestinal infarction/intestinal ischemia and portal hypertension. The incidence rate of PSVT reported varies, from 0.7%[78] to 14%[79], but it can reach up to 80%[80]. It is unclear whether the minimal invasive approach is associated with high incidence of PSVT; nevertheless, there are some underlying diseases which are correlated with PSVT, these are myeloproliferative disorders, hemolytic anemia, hypersplenism or hematologic malignancy and splenomegaly[81]. Interestingly the bigger the size of the spleen, the higher the incidence of PSVT[80-82]. Diagnosis of PSVT may be challenging as its symptomatology is unspecified. Therefore it is recommended that patients with high risk of PSVT should receive postoperatively anticoagulation therapy as prophylaxis[9,83]. When the diagnosis of PSVT is secured, immediate anticoagulant therapy with intravenous administration of heparin should be started, in order to achieve best treatment outcomes[80].

Another splenectomy-associated postoperative complication is the overwhelming postsplenectomy infection (OPSI). OPSI is suspected when a patient after splenectomy presents with sudden systemic infection, occasionally dermatorrhagia and DIC, whereas no obvious site of the infection is present[84]. Although the pathogenesis of OPSI remains unclear, it has a fast, overwhelming onset. It starts as a simple respiratory infection, but it rapidly progresses to hyperpyrexia, headache, shivering, jaundice, anuria, septic shock, acute respiratory distress syndrome (ARDS), multiple organ dysfunction syndrome (MODS), coma, and death. The primary pathogenic bacteria of OPSI are S. pneumoniae, N. meningitides, and H. influenza. In a prospective study by Theilacker *et al*[85] it was shown that S. pneumonia was the most important cause for severe sepsis development. They also showed that due to proper vaccination of patients after splenectomy, incidence of OPSI has been substantially reduced compared to the past. Although laparoscopic splenectomy is clearly superior to standard laparotomy in terms of postoperative infections, incidence of OPSI remains similar because this complication is related more to spleen removal than to the surgical approach[86].

## CONCLUSION

Laparoscopic splenectomy has been established as a safe and feasible minimally invasive procedure. It can be used in almost all cases that a splenectomy is required, having in the majority of cases better results than open splenectomy in terms of intraoperative and postoperative complications. However, there are some special conditions, such as splenic trauma, in which the role of laparoscopy is not widely accepted. The evolution of the technology has allowed though, cases which were considered to be absolute contraindications for performing a minimal invasive procedure to be treated with modified laparoscopic approaches, such as the HALS for splenomegaly. The further improvement of laparoscopic tools as well as the increased experience of surgeons in minimal invasive procedures allows

lower operative times and conversion rates, along with less intraoperative complications, such as blood loss. Therefore it is strongly believed that laparoscopic splenectomy will become in the near future the standard procedures for almost all cases of splenectomy.

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**P- Reviewer**: Liu XF, Shehata M **S- Editor**: Kong JX **L- Editor**: A
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