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REVIEW

# Current concepts of laparoscopic splenectomy in elective patients

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## Abstract

Formerly, open splenectomy represented the conventional surgical treatment for many hematologic diseases. Currently, thanks to permanent technical development and improved skills, also laparoscopic splenectomy (LS) has become a recognized procedure in the treatment of spleen diseases, even in case of splenomegaly. A systematic review was performed with the aim of recalling the proved concepts of this surgical treatment and to browse new devices and techniques and their impact on the surgical outcome. The literature search was initially conducted in PubMed by entering general queries related to LS. The record identified through PubMed searching ($n$ = 1599) was then screened by applying several criteria (study published in English from 1991 to 2013 with abstract available, by excluding systematic/non-systematic reviews, meta-analysis, practice guidelines, case reports, and study involving animals). The articles assessed for eligibility ($n$ = 160) were primarily evaluated by excluding studies that did not report operative time and conversion to open surgery. For articles that treated multiport LS we included only clinical trials with patients > 20. The studies included in qualitative synthesis were 23. The search strategy carried out in PubMed does not allow to obtain an overview of the items returned by the main queries. With this aim we replicated the search in the Web of Science™ database, only including the studies published in English in the period 1991-2013 with no other filter/selection criteria. The full records ($n$ = 1141) and cited references returned by Web of Science™ were analyzed with the visualization of similarities (VOS) mapping technique. Maps of title/abstract text corpus and bibliographic coupling of authors obtained by applying the VOS approach were presented. If in normal-size or moderately enlarged spleens the laparoscopic approach is unquestionable, in massive splenomegaly the optimal technique remain to be determined. In this setting, prospective randomized trials to compare open *vs* LS are needed. Between the new techniques of LS the robotic single port splenectomy has the ability to join all the positive aspects of both techniques. Data about this topic are too initial and need to be confirmed with further studies.



**Key words:** Spleen; Splenectomy; Laparoscopy; Minimally Invasive; Splenic Diseases; Splenic Neoplasms; Visualization of similarities mapping

**Core tip:** Laparoscopic splenectomy (LS) has progressively become the "gold standard" for the surgical treatment of benign hematologic diseases, regardless

of the presence or absence of splenomegaly. The majority of previous published data reflects a substantial recognition of the laparoscopic method, although several areas still remain controversial. This review aims to update the current procedures and emerging technologies concerning minimally invasive splenectomy. The main indications and concerns for LS, as well as pre- and intraoperative potential problems in case of massive splenomegaly are reviewed. An evaluation of the techniques and clinical results of multiport laparoscopic splenectomy, hand-assisted laparoscopic splenectomy, robotic splenectomy, and single-port splenectomy is carried out. Moreover, postoperative outcomes of LS are examined, together with the procedure-specific complications.

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## INTRODUCTION

Since 1991, when Delaitre and Maignien performed their first splenectomy procedure by laparoscopy, laparoscopic splenectomy (LS) has gained worldwide popularity as a feasible surgical option[1]. Currently, splenectomy is carried out either as causal or symptomatic treatment for many indications, and especially for benign hematologic disorders[2-4]. In the past, open splenectomy was the conventional treatment for both normalizing platelet count or for staging malignant diseases.

Many series suggest that LS may be considered the "gold standard" for surgical approach to benign hematologic diseases, even when not accompanied by splenomegaly. The majority of previous published data returns a substantial acceptance of the laparoscopic method, although some potential disadvantages are known (the length of operative time, or the technical difficulty in patients with splenomegaly). Even though splenomegaly has been considered for a long time a critical contraindication for LS, subsequent studies suggest that laparoscopic approach is practicable and should be used for spleens of almost any size[5,6].

Many previous series have shown that LS treatment of splenomegaly may be related with longer operative times, increased blood loss, additional perioperative complications, protracted hospital stay, and more conversion rates in comparison with LS for normal-sized spleens[7,8]. At present, technical developments as well as improved skills have generated an increase in the number of LS indications for splenic malignancies, thus demonstrating the appropriateness of laparoscopy in maintaining oncologic surgical principles. Furthermore, recent advancements in minimally invasive splenectomy has lead to the development of new laparoscopic techniques such as the robotic splenectomy and splenectomy through a single access[9,10].

## SEARCH STRATEGY, OUTCOMES AND MAPS OF KNOWLEDGE

The selection of publications was performed using the PubMed and Web of Science™ search engines during the second half of March 2014. The search was initially conducted in PubMed by entering the following queries: "laparoscopic splenectomy", "single port splenectomy", "hand assisted splenectomy", and "robotic splenectomy". Each item was enter in PubMed by using the "(MeSH Terms)" and "(All Fields)" tag. For each query, the search was then refined by applying several additional filters: (1) study published in English ["(lang)" tag], applied at the pre-screening phase}; (2) publication dates from 1991 to 2013 ["(PDAT) tag"]; (3) publication type ["(ptyp)" tag], excluding systematic/non-systematic reviews, meta-analysis, practice guidelines, case reports, letters/editorials, and study involving animals; and (4) abstract available ["(text)" tag]. The articles assessed for eligibility ($n$ = 160) were primarily evaluated by excluding studies that did not report operative time and conversion to open surgery (as number or percentage). For articles that treated multiport LS, further selection criteria were applied: (1) number of enrolled patients > 20 in clinical trials/randomized control trials (RCT); (2) no comparison between multiple accesses; and (3) no hand assisted conversion. The cut-off for enrolled patients was not applied in the records returned by the other main queries. The filter for clinical trials/RCT did not return any record in the "single port splenectomy" query, and it was not then being applied. The records processed in PubMed are showed according to PRISMA flow diagram for systematic reviews[11] (Figure 1). The studies included in qualitative synthesis ($n$ = 23) are reported in Table 1. Differently from recent reviews on minimally invasive splenectomy[12], we used more strict criteria to select studies. Moreover, the number of patients/procedure for each study included in qualitative synthesis has been clearly indicated, avoiding to report the cumulative sample size (Table 1).

The search strategy carried out in PubMed as described above does not allow to obtain an overview of the items returned by the main queries. With this aim we replicated the search by entering the main queries in the Web of Science™ search engine (records identified = 1381). By screening for the studies published in English in the period 1991-2013, without applying any other criteria, 1141 records were included. The search was performed by selecting the following citation indexes: Science Citation Index Expanded (SCIEXPANDED), Conference Proceedings Citation Index-Science (CPCI-S), and Book Citation Index-Science (BKCI-S). All records published in journals with impact factor were sharing between PubMed and Web of Science™. The full records and cited references returned by Web of Science™ were exported as a multifields tab-delimited files, suitable to be analyzed with the visualization of similarities (VOS) map-

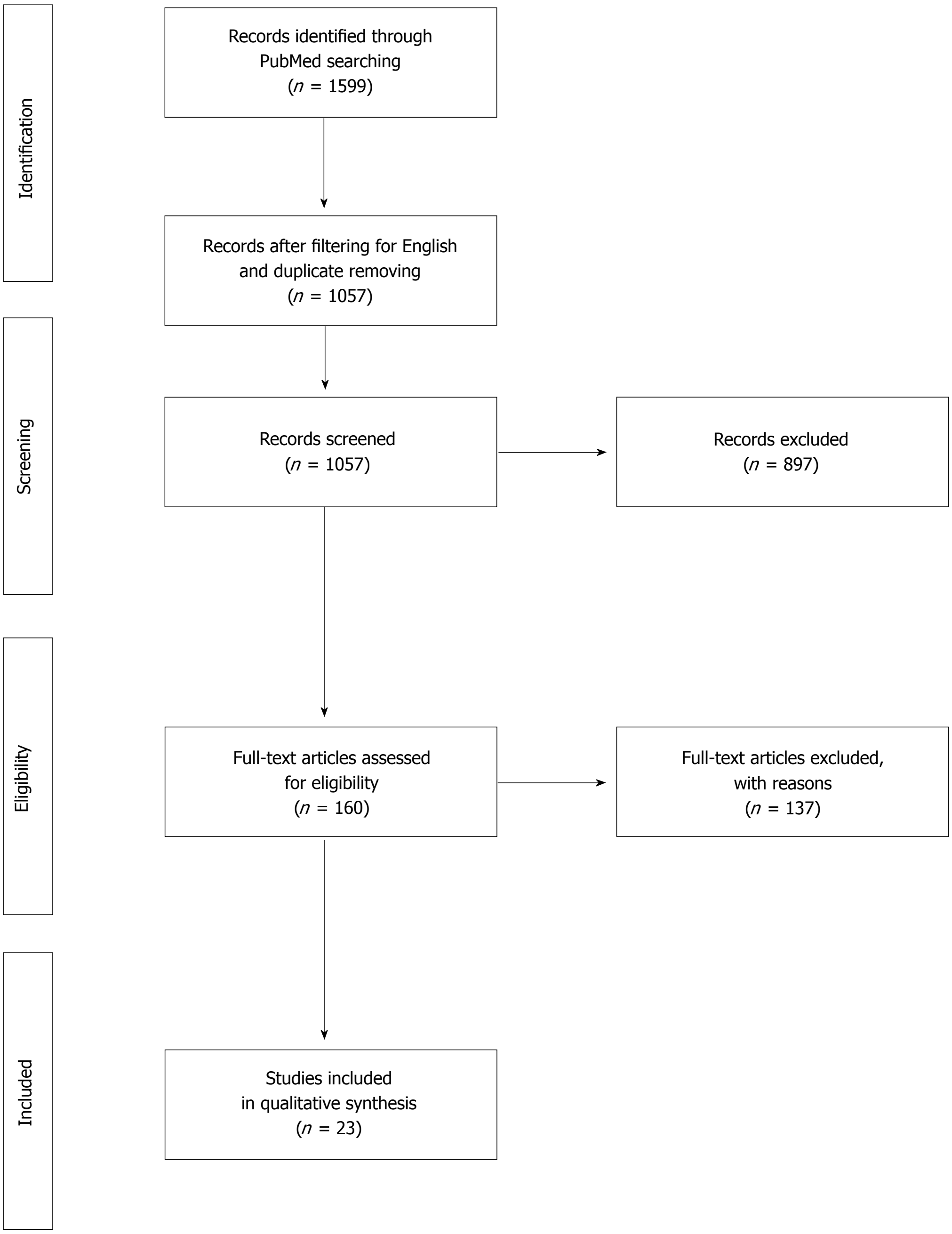


**Figure 1 PRISMA flow diagram for the search strategy in PubMed database.**

ping technique. The VOS method allows to construct maps based on a co-occurrence matrix[13,14], by applying a normalization method[15,16]. In this way, items with a high similarity are located close to each other, while items with a low similarity are located far from each other, allowing to detected clusters of related items. The records returned by the Web of Science™ searching were used to construct several VOS-based maps. In Figure 2 is showed the map created with the title/abstract text corpus of each record. For this map a binary term counting was used: only the presence/absence of a term in a record was retained, whereas the number of occurrences of a term in a single record was not taken into account. By assuming 5 as the minimum number of term occurrences, from 18145 terms 729 meet the threshold; of these, 420 terms with higher relevance/occurrence were selected. In Figure 3 is presented a bibliographic coupling of authors, assuming 5 as the minimum number of records/author. Of the 5017 authors, 126 meet the threshold.

## OPERATIVE INDICATIONS

LS represents the main surgical indication for both benign and malignant diseases. Indications for LS are similar to open splenectomy (OS) (Table 2). Splenectomy can be useful to avoid the enhanced elimination of the blood's corpuscular elements and to alleviate symptoms related to an enlarged spleen, as well as a supplementary

**Table 1 Characteristics of published studies on minimally invasive splenectomy included in qualitative synthesis**

| Ref. | Indication | Procedures | Patient No | Patient age | Operation time | Conversion | Class |
|---|---|---|---|---|---|---|---|
| Multiport LS | | | | | | | |
| Bo *et al*[56] | PI-LC | LS, OS | 40/40 | Adult | 150 | 2 | Retrospective |
| Ji *et al*[50] | Diverse | LS | 105 | Adult | 100 | 2 | Prospective |
| Zhou *et al*[112] | Diverse[1] | LS | 81 | Adult | 163 | 3 | Retrospective |
| Nobili *et al*[36] | GD | LS | 30 | Adult | 150 | 1 | Retrospective |
| Murawski *et al*[21] | Diverse | LS | 159 | Pediatric | 149 | 8 | Retrospective |
| Barbaros *et al*[51] | Diverse | LS | 29 | Adult | 71 | 1 | Retrospective |
| Park *et al*[114] | Diverse | LS | 197 | All | 145 | 6 | Prospective |
| Park *et al*[110] | Diverse | LS, OS | 147/63 | All | 77 | 4 | Prospective |
| Targarona *et al*[37] | Diverse[1] | LS, OS | 105/81 | Adult | 166 | 8[2] | Retrospective |
| Lozano-Salazar *et al*[109] | ITP | LS, OS | 22/27 | Adult | 270 | 2 | Retrospective |
| Katkhouda *et al*[20] | HD | LS | 103 | Adult | 161 | 4 | Prospective |
| Rescorla *et al*[111] | HD | LS, OS | 50/32 | Pediatric | 115 | 0 | Retrospective |
| Szold *et al*[44] | Diverse | LS | 59 | All | 79 | 1 | Retrospective |
| Brunt *et al*[108] | Diverse | LS, OS | 26/20 | All | 202 | 1 | Retrospective |
| Katkhouda *et al*[23] | Diverse | LS | 33 | Adult | 242 | 1 | Prospective |
| Single port LS | | | | | | | |
| Monclova *et al*[85] | Diverse | SPLS, LS, RPAS | 8/15/10 | Adult | 83 | 0 | Retrospective |
| Misawa *et al*[94] | Diverse | SPLS | 10 | Adult | 230 | 1 | Prospective |
| Targarona *et al*[84] | Diverse | SPLS | 8 | Adult | 97 | 2 | Retrospective |
| Hand-assisted LS | | | | | | | |
| Swanson *et al*[73] | Diverse[1] | HALS, OS | 20/19 | Adult | 135 | 1 | Retrospective |
| Barbaros *et al*[71] | Diverse | HALS, OS | 14/13 | Adult | 90 | 0 | Prospective |
| Targarona *et al*[69] | Diverse | HALS, LS | 20/36 | Adult | 135 | 1 | Retrospective |
| Robotic splenectomy | | | | | | | |
| Vasilescu *et al*[98] | HS | RS, LS | 10/22 | Adult | 107 | 1 | Retrospective |
| Giulianotti *et al*[10] | Diverse | RS | 24 | Adult | 199 | 2 | Prospective |

[1]Patients with massive splenomegaly; [2]Convertion rate estimated by calculating for patient No. and %; LS: Laparoscopic splenectomy; OS: Open splenectomy; PI: Portal hypertension; LC: Liver cirrhosis; GD: Gallbladder diseases; ITP: Idiopathic thrombocytopenic purpura; BHD: Benign hematologic disorders; HD: Hematologic disorders; RPAS: Reduced port access splenectomy; SPAS: Single port access splenectomy; HS: Hereditary spherocytosis; RS: Robotic splenectomy.

technique for staging malignant diseases[1]. Idiopatic thrombocytopenic purpura (ITP) is the most common indication among benign hematologic diseases, and the main cause for surgery (50%-80%) in the patients treated by laparoscopic splenectomy[17,18]. Spleens in patients with ITP may be only slightly enlarged, and thus they benefit from the minimally invasive surgery[1]. Also thrombotic or HIV-related thrombocytopenic purpura may be treated by splenectomy[19,20]. In addition, splenectomy is clinically indicated for hemolytic anemia (including hereditary spherocytosis), major and intermediate thalassemia with secondary hypersplenism or severe anemia, and refractory autoimmune hemolytic anemia[21].

Splenectomy may be required for therapeutic or diagnostic reasons in malignant diseases that are able to affect the spleen[7]. Indications include hematologic malignancies such as myeloproliferative disorders (myelofibrosis), as well as lymphoproliferative diseases (hairy cell leukemia, splenic lymphoma, chronic lymphocytic leukemia)[22-24]. Among malignancies, non-Hodgkin lymphoma (NHL) is by far the most represented pathology. In the patients with NHL, retroperitoneal lymphadenopathy and/or hypersplenism may occur without peripheral lymphadenopathy. Hematologic manifestations of hypersplenism consist of thrombocytopenia, neutropenia, and anemia, all difficult to treat medically. Primary splenic lymphoma may result as a lymphoma limited to the spleen, in presence or absence of hilar adenopathy. This uncommon NHL occurs in about 1% of patients with malignant lymphoma[4]. In this occurrence, splenectomy is also indicated to mitigate symptoms and to recover tissue samples for immunohistochemical and cytogenetic assays. Splenectomy alone for primary splenic lymphoma is associated with a better survival than diffuse NHL and splenomegaly.

When splenectomy is carried out for diagnostic or staging purposes, removal of the intact organ for histologic examination may be needed. This requires to perform an extra incision of 8-10 cm[25]. Conversely, no accessory incision is carried out during hand-assisted laparoscopic splenectomy (HALS), when the spleen can be directly removed via the hand port device[7]. Contraindications to LS include severe portal hypertension, uncorrectable coagulopathy, severe ascites, and traumatic spleen injuries.

## PREOPERATIVE EVALUATION AND PREPARATION

All adult patients planned for splenectomy should be examined preoperatively by ultrasound to evaluate both spleen size and volume. Thin-slice spiral computed to-

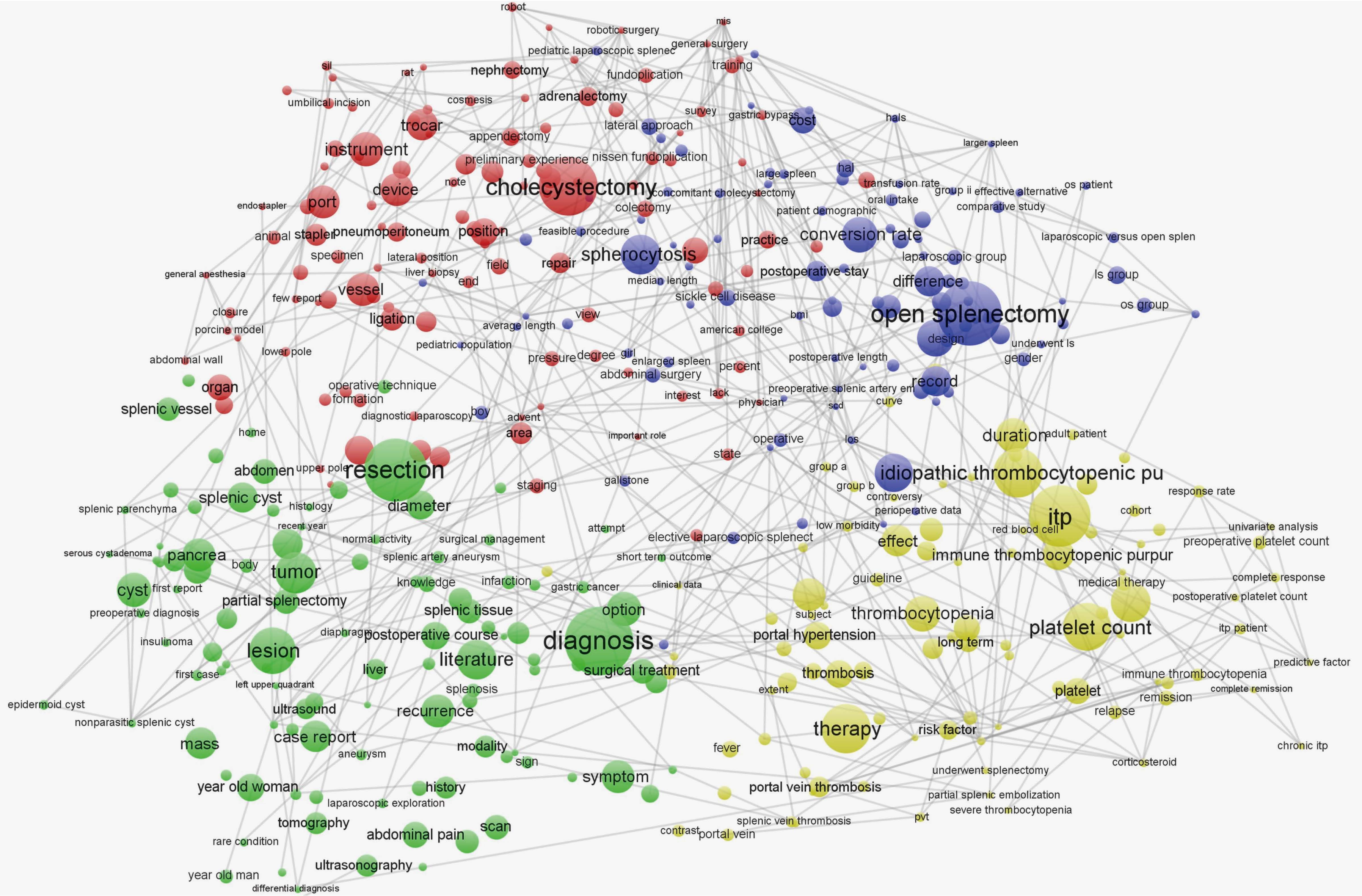


**Figure 2 Map of the terms selected ($n$ = 420) from the records included ($n$ = 1141) after searching in web of science™ (records published in English during 1991-2013).** The map was built by using the visualization of similarities approach. The terms in the title/abstract text corpus of each record were selected from 18145 terms by assuming the minimum number of term occurrences = 5; only the presence/absence of a term in a record was retained. The colors define the clusters of related items. The size of each circle is related to the number of occurrences.

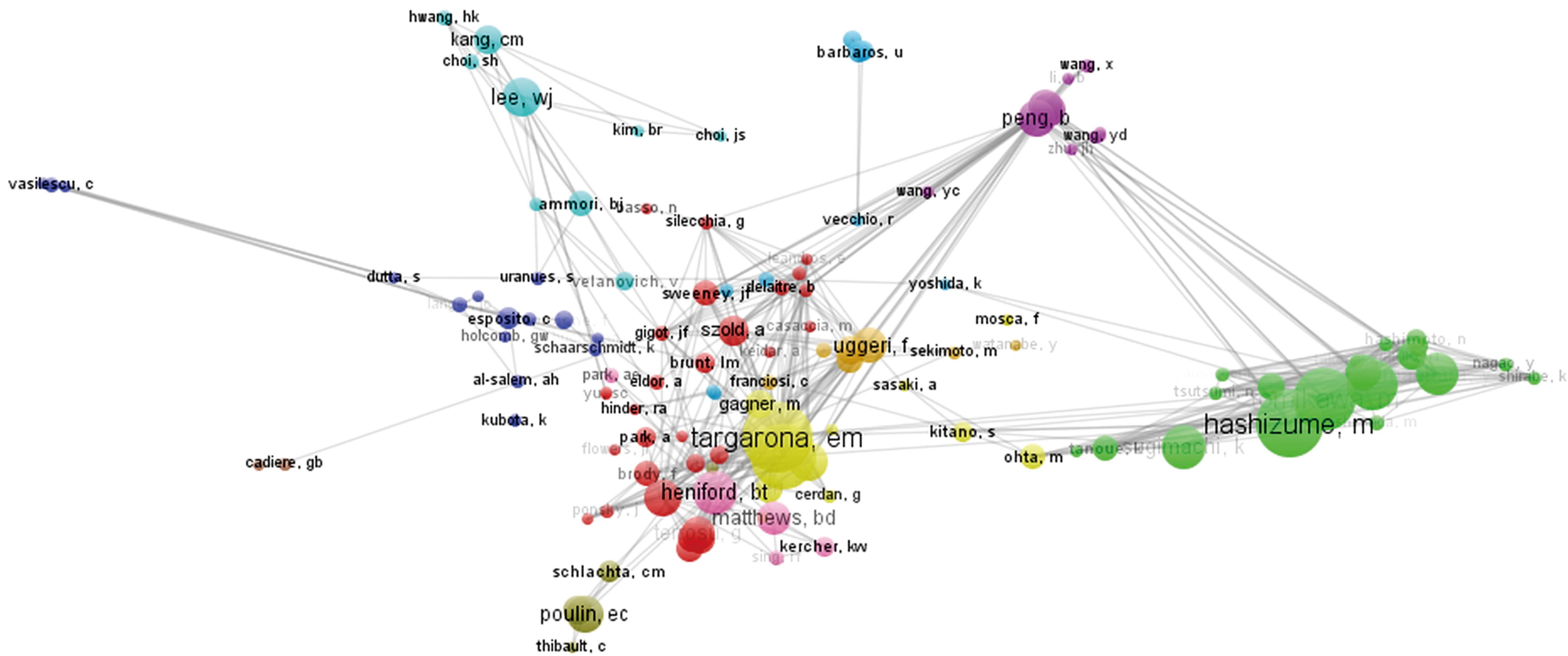


**Figure 3 Bibliographic coupling of authors (*n* = 126) from the records included (*n* = 1141) after searching in web of science™ (records published in English during 1991-2013).** The map was built by using the visualization of similarities approach. The selection was performed from a pool of 5017 authors, assuming the minimum number of records/author = 5. The colors define the clusters of related authors. The size of each circle is related to the number of links.

mography (TSSCT) should be utilized with the aim to obtain further anatomical information, or if malignancy is suspected. For autoimmune or hemolytic disease associated to massive splenomegaly, TSSCT may be useful to discover accessory spleens[26-27]. In patients affected by malignant hematologic diseases, computed tomography (CT) scan is able to provide reliable information about splenic size and volume[7]. Moreover, CT scan may be useful to detect splenic hilum lymphadenopathy, as well as to discover conditions that may responsible for critical intraoperative complications such as perisplenic inflammation or splenic infarction[7]. CT scan with three-dimensional reconstruction of the spleen and vessels may add an interesting vascular mapping useful to guide the surgical dissection in case of magistral or distributed type of vascular supply. Although recent magnetic resonance imaging techniques are able to provide excellent results in the detection of pathologic spleen states, they do not have an important part for preoperative evaluation of splenic size owing to elevated cost and/or minor accessibility in some countries.

In case of hypersplenism-induced cytopenia, a preoperative management is due to correct this state. The risk of harmful intraoperative bleeding is high when a low platelet count occurs. Treatment with prednisone (1 mg/kg per day, starting from 5 to 7 d before surgical treatment) is suggested to obtain a preoperative platelet count over $50 \times 10^9$/L. For therapy-resistant patients, platelet transfusions performed at some point in surgery, in any case following separation of the splenic pedicle, should be utilized[28]. Administration of immunoglobulins is made exclusively in case of autoimmune thrombocytopenia. Preoperative transfusions of packed erythrocytes should be considered in anemic

**Table 2 Clinical indications of laparoscopic splenectomy in elective patients (data from Italian Registry of Laparoscopic Surgery of the Spleen; period: 1993-2007; *n* = 676) Clinical indication %**

| | |
|---|---|
| TP | |
| Idiopathic thrombocytopenic purpura | 25 |
| Thrombotic thrombocytopenic purpura | 5.47 |
| HIV-related thrombocytopenia | 0.29 |
| Other thrombocytopenia | 5.62 |
| HM | |
| Non-Hodgkin's lymphoma | 20.71 |
| Hodgkin's lymphoma | 5.62 |
| Idiopathic myelofibrosis | 1.77 |
| Chronic lymphatic leukemia | 1.03 |
| Hairy-cell leukemia | 1.03 |
| Other HM | 2.66 |
| HA | |
| Hereditary spherocytosis | 9.17 |
| Major beta-thalassemia | 4.43 |
| Autoimmune hemolytic anemia | 1.77 |
| Other HA | 5.62 |
| OP | |
| Splenic cyst | 2.81 |
| Splenic angioma | 1.47 |
| Splenic artery aneurysm | 0.44 |
| Unknown | 5.03 |

IRLSS: Italian Registry of Laparoscopic Surgery of the Spleen; HM: Hematologic malignancy; TP: Thrombocytopenic purpura; HA: Hemolytic anemia; HIV: Human immunodeficiency virus; OP: Other pathologies.

patients. Vaccination against pneumococcal, meningococcal, and *Haemophilus influenzae* type B is recommended in elective cases at least 15 d before surgery[29]. For patients who underwent splenectomy, the risk of overwhelming postoperative infection able to become critical sepsis is a well-documented scenario. Preoperative antibiotic prophylaxis (PAP) is suggested to decrease infection rates. In LS procedures, PAP is conventionally based on cefazolin or clindamycin at once previous to surgery, continued by postoperative intravenous administration of amoxicillin or erythromycin.

In case of massive spleens, embolization of the preoperative splenic artery may be considered with the aim to prevent severe intraoperative bleeding and to decrease splenic size, even if no obvious advantage has been reported following this approach[30].

## LS TECHNIQUE

Once the indication to the surgical operation is posed, concerns remain on the most suitable approach, since in case of enlarged spleens laparoscopic splenectomy becomes more technically challenging. The laparoscopic seems to be preferable to the conventional open approach in many cases, in view of the lower complication rate and shorter hospitalization times. Although OS and LS were compared in only one RCT[31], there is a widespread consensus on the superiority of the LS for almost all diseases that requires splenectomy. On the other hand, some restrictions persist for patients with splenic trauma, massive splenomegaly, and severe comorbidities.

The operating times may be longer in LS than OS. This finding has been reported as directly related to the spleen mass[8]. Many studies report that LS is accompanied by a lower intraoperative blood loss, whereas the intraoperative complication rate seems to be comparable between LS and OS. The length of postoperative hospital stay is less in LS than OS[19]. The time awaiting to return to everyday activity is considerably shorter in patients treated with LS[32], and better cosmetic outcomes are also achieved. The surgery costs include operating room, hospitalization time, and costs to society (*e.g.*, caused by lost workdays). Although operating room costs are usually higher with LS than OS as a result of more expensive equipment and the utilize of not reusable pieces, the whole cost for hospitalization is not appreciably higher for LS[33,34]. Conversely, whole hospitalization costs may be even lower in LS patients because of the shorter postoperative hospital stay[35]. Other studies have reported as the costs seemed to be related to patient age, spleen size, and major complications instead of surgical technique[19].

LS may be carried out by using several approaches (lateral, hemilateral, or supine) on the basis of surgeon preferences, spleen mass, patient characteristics, and the need to associated procedures. The supine position permits a fine access to the omental pouch and a favorable view of the splenic hilum, a good condition to be searched as the first step of the procedure in massively enlarged spleens[1]. This position is used also for LS-associated procedures (cholecystectomy, biopsies of the lymph nodes and/or other organs)[36]. On the other hand, the full lateral decubitus position is not recommended in case of splenomegaly, as the organ may drop into the right upper quadrant, getting too close to the ports and making spleen manipulation impossible[37]. In the hemilateral approach the patient is positioned with the left side elevated up to a 40° to 45° angle from the table surface. Following this approach the patient position can be regulated to surgical requirements, resulting preferred by many authors for the most common indications[38]. Usually, four trocars and are used. A pneumoperitoneum up to 12 mmHg represents the standard. Trocar position should reflect patient anatomy, being able to be adjusted for both spleen size and splenic attachments. A routine exploration for accessory splenic tissue is recommended to avoid potential disease recurrence[39-43]. Use of the endovascular stapler has been reported to make easy hilar dissection compared to previous ligation or clipping techniques[44,45]. In addition, electrothermal bipolar vessel sealer (LigaSure TM) or ultrasonic coagulating shears (Ultracision Harmonic ScalpelTM, Ethicon Endosurgical, Cincinnati, OH) have been utilized for dissection of smaller polar vessels and gastric vessels[22,37,46,47], as well as for the greater hilar vessels[48]. Some authors reported the safe use of LigaSureTM for hilar vessels with a diameter up to 7 mm in patients with normal or slightly enlarged spleens, being accompanied to lower blood loss and shorter time of surgery[46,49-52]. They concluded as the utilize of the LigaSureTM vessel sealing system following a LS semilateral approach may be secure and useful, by reducing both blood loss and operating time, representing a reasonably priced alternative to endostaplers.

The spleen removal from the abdominal cavity may be a technical challenge, being a time-consuming procedure, especially in case of massive splenomegaly. In patients where a careful pathological analysis is not needed, the sample is morcellated in a commercially available bag using ring forceps or a tissue morcellator. For manifestation of lymphoma or splenic malignancy, as well as for staging reasons, the spleen should be recovered *in toto*, making a further incision necessary[41,44]. Scrupulous care must be used to avoid capsular tear and cell spillage. An undetected implantation of splenic cells may cause splenosis, as well as recurrence of benign/malignant diseases.

## MASSIVE SPLENOMEGALY, TECHNICAL CONSIDERATIONS

Although there is no agreement in literature about the terms "splenomegaly" or "massive splenomegaly", the former should be characterized by using preoperative imaging. From a surgical point of view, splenomegaly is defined when a maximum splenic diameter results over 15 cm. A maximum splenic diameter more than 20 cm should be used to define a massive splenomegaly[53]. Besides spleen longitudinal diameter, clinical parameters in predicting the feasibility of laparoscopic splenectomy include a palpable margin that does not traverse the midline or extend over the iliac crest[8]. Given that LS represents the "gold standard" approach in normal-size and moderately enlarged spleens, HALS or OS should be considered for massive splenomegaly, since the need for open surgery is directly related to the increase in spleen size[22,54,55].

Very outsized spleens represent a critical finding that tests the current confines of laparoscopic surgery. If we have chosen a totally laparoscopic approach for massive splenomegaly, no further adjustment in patient position is required. With the hemilateral approach the tilt of the table can be varied during the procedure in order to better expose the spleen. The full lateral decubitus is not achievable, as the ports are frequently placed at the midline or even on the patient's right. Similarly, a supine approach is not favorable as it can be hard to move the large spleen outside from retroperitoneum. The decisive practical variation is that the place of the ports must be adapted to the spleen position, rather than placed in the typical subcostal position[39,56]. Ports must be positioned below and medial to the spleen that is palpable to physical examination; this often pushes them away from the costal margin. It is often impracticable to position the lateral port under the lower splenic pole, which may be profound in the pelvis and best placed as low as possible. Dissection and mobilization may be performed in the standard fashion with ultrasonic coagulation or radiofrequency devices. Care must be taken for not completely detaching the large spleen from the diaphragm too early, as the heavy organ may drop into the pelvis or right upper quadrant, becoming difficult to handle.

One providential aspect of the massive spleens is that the hilar vessels are elongated and separated from the organ, as well as from stomach and retroperitoneum, making them effortless to isolate and divide early. On the other hand, difficulties can be encountered in splenic malignancy if a lymphadenopathy at the hilum is present. All the nodes macroscopically enlarged must be harvested, giving a precise contribution in disease staging[25]. Sometimes their tight relation with the splenic vessels prevents the surgeon from a correct visualization and make the hilum extremely thick, so that the tissue cannot be included in the jaws opening of the linear stapler.

Another concern arising during spleen extraction is the bag's dimension. In fact, several bags obtainable for laparoscopic surgery are unfit to provide accommodation for the massive spleens. Spleens measuring up to 25 cm in craniocaudal lenght can be extracted laparoscopically using the 15-mm Endo Catch Ⅱ (Covidien/US Surgical, Norwalk, CT) sterile bag[57]. In case of larger spleens there are not commercially available bags conceived for splenic retrieval and the surgeon has to adapt other devices for this purpose, such as organ retrieval bags or "intestinal" bags[58].

When the spleen has to be recovered *in toto*, the incision has to be extended realizing a short subcostal incision, eventually joining the incisions of the lateral trocars. Otherwise, a Pfannenstiel incision may be performed: it has an aesthetic improvement over upper abdominal incisions, it is less painful and may result in fewer pulmonary complications.

## HAND-ASSISTED LAPAROSCOPIC SPLENECTOMY

Hand-assisted laparoscopic splenectomy (HALS) may be considered as a modified LS. For this technique, the majority of authors suggest for the patient decubitus a semilateral or 45° right lateral position on the operating table[59]. A supplementary incision of 7-8 cm is made, great adequately for allowing the movement to surgeon's hand/forearm. It may be positioned in the above midline, in the right upper abdomen[6,60-62], or instead at the McBurney or Pfannenstiel site[63]. The incision place can be changed in relation to spleen size. At the chosen site the surgeon may use a hand port device for introducing into the abdomen the nondominant hand, while maintaining pneumoperitoneum. The introduced nondominant hand permit a tactile control, being useful during both many steps of the standard surgical procedure and in sudden hemorrhage or adhesions. Finally, the spleen can be taken away through the supplementary incision, frequently with no morcellation. Potential drawbacks consist in the hindrance caused by the surgeon hand/forearm, as well as in the progressively hand weakness during the procedure, as described by 21% of the surgeons[64,65]. Many splenectomy series have reported as HALS may be accompanied by a decrease in operating times, conversion rates, and peri/postoperative complications with respect to the merely laparoscopic approach[60,62,66-70]. Although HALS requires a supplementary incision, so causing a further trauma to the abdominal wall, this approach preserves the advantages of typical laparoscopic surgery in term of short hospitalization time, early return to oral diet, and limited postoperative pain[6,55,71,72]. In particular, HALS is able to make easy the surgical management of massive splenomegaly, permitting a traumatic manipulation of huge organs. In a RCT that compared HALS *vs* OS, median spleen weight was 1200 g for the patients enrolled in the HALS group, with no need for conversion to OS[26]. Furthermore, massive spleens weighting over 3000 g may be removed in safety by HALS[5,37,39,61,71]. In comparison with OS, HALS is associated to small abdominal incisions, fewer postoperative pain, and shorter hospitalization times. In comparison with LS, HALS results with smaller amounts in conversion rate to OS[31,53,71,73].

## SINGLE INCISION LAPAROSCOPIC SPLENECTOMY

Single-incision laparoscopic surgery (SILS) represents a specific variation to laparoscopic surgery, by using the same instruments and requiring only minor modifications when compared to conventional multiport technique. SILS has so far been used for a variety of procedures such as cholecystectomy, appendectomy, colectomy, and thyroidectomy[74-78], and more recently also for splenic surgery[9]. Differently from standard laparoscopy, SILS is associated to less incisional pain, avoiding complications related to port site, with a finer aesthetic appearance. In single incision lasparoscopic splenectomy (SILSp), the patient is placed in the right lateral decubitus, with the table flexed to provide a reverse Trendelenburg positioning to provide a better access the left hypochondrium[79-81]. In emaciated patients with normal-sized livers, a transumbilical approach may be considered. For patients with splenomegaly, a left-sided incision of 2 cm is carried out umbilicus area, following the midclavicular line. Two SILSp techniques have been described. A first technique requires to employ multiple trocars, introducing them one at a time through a single skin incision, after pneumoperitoneum has been obtained with a Veress needle[82,83]. A second option consists in insufflating the abdomen to realize pneumoperitoneum and introducing a multiport device[84]. The rest of the procedure is comparable to conventional multiport LS. Difficulties encountered during procedure are normally faced by inserting additional ports, by a conversion to multi-port splenectomy or to OS, with a whole conversion rate of 4.8%. Only four reports[84-88] compared the outcomes of SILSp and multi-port LS. The most frequent indication for SILSp is idiopathic thrombocytopenia followed by splenic cystic disease and hereditary spherocytosis, witnessing a prevalence of benign pathologies in normal-size spleens. Results comparing operative blood loss, hospital stay, pain medication requirements, are not univocal but analysis are accomplished on small series.

SILS has some technical weakness in comparison to multiport laparoscopic surgery. Although SILSp can be carried out with a standard rigid laparoscope and straight instruments, crowding above the access port/site usually may lead to clashing of surgical instruments. The parallel arrangement of instruments, as well as the interference between the surgeon and the camera operator, are able to increase the difficulty during the procedure. Moreover, lack of tissue triangulation considerably increases the complexity of splenic exposure and dissection. With the aim to obtain a better surgical exposure, the majority of surgeons applies 30° laparoscopes, while others use articulating or curved graspers and/or scissors[83,87,89-92]. Some investigators suggest to utilize longer laparoscopes to avoid cluttering of instruments[90]. Meanwhile, gastric suture and "tug-exposure" technique are suggested by several authors to make easy exposure during SILSp[87,93,94]. Targarona *et al*[80] suggest as although less trauma and better aesthetic results are reached throughout a standard single-access laparoscopy when the incision is performed in the navel, some dissection manoeuvres can be particularly difficult or even impossible, owing to the oblique dissection line between the umbilicus and the upper part of the spleen. Podolsky *et al*[95] describe as a low extension and length of the incisions is accompanied by a minor risk for both hernia site infections and intra-abdominal adhesions. Conversely, a bigger incision may increase the occurrence of seroma and umbilical hernia. A critical difficult for reaching a common use of SILSp is represented by the need of an extra learning curve. Moreover, there are concerns for increased complication rates that occurred when low-experienced surgeons in laparoscopic surgery tried to apply this technique.

## ROBOTIC SPLENECTOMY

Laparoscopy has some limits, such as two-dimensional (2D) visualization and stiff instrumentation, which can make whole or partial splenectomy demanding. With the aim to overcome these restrictions, robotic surgery (da Vinci®, Intuitive Surgical, Sunnyvale, CA, United States) has been developed with "wrist-like" action of the instruments and with three-dimensional (3D) visualization, producing an high-resolution binocular view of the surgical field. These robotic devices seem to be able to open the way for more complex and advanced surgical procedures. Published studies on robot-assisted splenectomy include only case reports or small series. In the literature that compares robotic splenectomy *vs* LS, no significant difference is reported about conversion rate, drain removal, hospitalization times, and occurrence of complications[96-98]. On the other hand, operative times and overall costs are higher in robotic splenectomy. Currently, robotic splenectomy does not offer any apparent advantage in terms of clinical outcome[10,97]. Giulianotti suggests that the best indications for a robotic approach are in cases of a large and friable spleen with a bulky and intrasplenic pancreatic tail, or when a partial splenectomy is planned. In fact, a partial splenectomy needs an accurate dissection of the splenic branches and the robotic technology with 3D vision and "wrist-like" instruments is particularly functional to this condition. Robotic splenectomy is performed through a multiport approach. The most recent update of this approach is robotic single-site splenectomy through the new Da Vinci Single-Site® robotic surgery platform. The Da Vinci Single-Site® robotic surgery platform could reduce the disadvantages related to the single-access surgery, such as instrument clashing, lack of triangulation, odd angles and need of space[99]. This surgical platform seems to overcome the previous robotic surgical platform for two main reasons. First, the surgeon inserts the instruments through the cannula, so that the hook (introduced on the left) intersects with the grasping forceps (introduced on the right). After tool recognition on the part of the robotic console, the surgeon can check the hook with his right hand and the forceps with his left. In addition, the new robotic tools are semi-flexible and reach the surgical field in a more natural way and closer than that of standard single-access laparoscopy. These characteristics, as also described by Morelli *et al*[100], restore the normal triangulation, making surgical procedures easier than standard single-access laparoscopy.

## POSTOPERATIVE CARE

Postoperative care after laparoscopic splenectomy is usually simple but it sometimes has to be more attentive because malignant spleens are frequently observed in older and more physiologically frail patients. Postoperative pain medication is given on an individualized basis. Most patients will not require further narcotics. Intravenous acetaminophen is administered during the first night. When pain is not adequately controlled, coanalgesia with a nonsteroidal anti-inflammatory drug (ketorolac tromethamine) may be added, producing the best clinical results[28]. The patient is allowed to drink clear fluids on the first post-operative morning; when clear fluids are well tolerated, the patient is allowed to continued to a diet if amylase and lipase levels are normal. Antibiotic administration is sustained by postoperative intravenous amoxicillin or erythromycin. Patients receiving *iv* cortisone are given oral steroids on postoperative day 1 after an overlap *iv* injection; thereafter, steroids are gradually tapered. Perioperative anticoagulant prophylaxis is recommended for all patients (low-molecular-weight heparin 100 U/kg per day) upon verification that bleeding is not occurring. Platelet count has to be monitored closely postoperatively and then with more delayed controls up to 3-6 mo for possible thrombocytosis making an antiplatelet therapy (i.i., acetylsalicylic acid) necessary.

## PROCEDURE-SPECIFIC COMPLICATIONS

Post-splenectomy related complications embrace hemorrhage, left lower lobe atelectasis/pneumonia, left pleural effusion, subphrenic collection, iatrogenic pancreatitis, gastric, and colonic injury, and venous thrombosis[101]. The occurrence of these complications increase after conversion[8]. Treatment of post-splenectomy complications should be performed following the standard clinical protocols. An incidence of 15% for pancreatic injury has been reported[55]. It is characterized by peri-pancreatic fluid collections, pancreatic abscess, and/or atypical postoperative pain, as well as hyperamylasemia and amylase-rich drain fluid. For this reason, a routine assay for amylase on day 1 after surgery is suggested to alert the surgeon and change postoperative management if necessary. Thrombosis of portal or splenic vein is a potentially life-threatening complication that can take place after several weeks/months after surgery. It can lead to intestinal infarction and portal hypertension. The reported rate of venous thrombosis ranges from 0.7% to 14%[102,103]. In all patients a perioperative anticoagulant prophylaxis based on subcutaneous heparin should be carried out. In particular, subjects at elevated risk for portal and/or splenic vein thrombosis should be treated with anticoagulant prophylaxis for 4 wk. High-risk factors for the occurrence of this complication are the presence of myeloproliferative disorders associated with hypercoagulopathy, hemolytic anemia, hypersplenism or hematologic malignancy and splenomegaly. Diagnostic difficulties may delay the optimal treatment. Diagnosis can be obtained by color Doppler ultrasonography or contrast-enhanced CT[103].

Among the long-term postoperative complications, an overwhelming infection with the features of a life-threatening sepsis is well-documented. It is caused generally by infection from encapsulated organisms that are eliminate by the spleen[104,105]. The risk of infection is highest within the first 2 years post-splenectomy, but one-third of all infections may happen until 5 years after surgery. Although the whole incidence of post-splenectomy infections is quite low (3.2%), the mortality rate is particularly high (40%-50%)[29]. As mentioned before, vaccination against *Streptococcus pneumoniae*, *Haemophilus influenzae* type B, and *Neisseria meningitidis* infections at least 15 d prior to surgery, or in case of emergency, within 30 d after splenectomy is highly recommended. Antibiotic prophylaxis should be performed before surgery, when the patient is in the operating room. The patient must be informed as the risk for post-splenectomy infections will be increased lifelong.

## CRITICAL EVALUATION

The good outcome of LS procedures is mainly conditioned by a correct preparation. As observed with other laparoscopic procedures, the key points are represented by the need to avoid complications and to reduce the probability that technical accidents may occur. Long-term outcome of the hematologic disease treated by LS has not been extensively studied. In literature, only reports about idiopathic thrombocytopenic purpura demonstrate as the long-term outcomes between LS and OS may be comparable[106,107]. In case of lymphoproliferative and myeloproliferative disease, the advantages of a minimally invasive approach on this typically immunoincompetent population have a positive impact on the postoperative morbidity and mortality rate. Furthermore, these patients are frequently subjected to adjuvant chemo- and radio-therapy, which can be done within a shorter time from the intervention. However, many studies report about the outcome of the LS procedure, comparing initially the laparoscopic approach to the open procedure[108-111].

When large series and nonrandomized clinical trials have recorded better results for LS than OS, the interest has shifted to the right splenic dimension to be treated safely by a laparoscopic approach. The clinical guidelines drawed by the European Association for Endoscopic Surgery (EAES) suggest that in case of massive splenomegaly, HALS or OS should be considered, although this statement is based on a low-quality evidence[53]. As pointed by the EAES guidelines, laparoscopic resection for massive splenomegaly represents a challenging task because of the restricted abdominal working space, as well as for the complexity to execute intraabdominal manipulation and recovery a very large organ. The conventional parameters to set the operative difficulties are represented by the extension of surgery time, the amount of blood loss, and the level of conversion rate. These parameters are directly related to increase in splenic weight and size. In a recent multicentric study[8], the underlying hematologic malignancy (HM) and body-mass index (BMI) were found indipendent factors related to surgical conversion at multivariate analysis. It has to be retained that HM patients had a 4-fold higher conversion rate if compared to the benign group (11.7% *vs* 3.2%). This suggests that besides splenic size that is constantly enlarged in malignancies, body habitus of the patient plays a relevant part for both assessing the practicability of laparoscopic surgery and predicting the early results[57,112]. With the progressive extension of technical feasibility, also morbid obesity (BMI > 35) is no longer an absolute contraindication for LS, although remains unquestionable difficulties due to limited intraabdominal working space and poor viewing[113].

There is a general consensus among authors about LS may be a safe procedure in the hands of a skilled surgeon. On the other hand, is widely accepted the need for a learning period, as demonstrated by the higher conversion rates during the first LS procedures[114]. Thus, most surgeons suggest to deal with massive splenomegaly once the procedure on smaller size spleens is mastered. If in normal-size or moderately enlarged spleens the laparoscopic approach is unquestionable, in massive splenomegaly the laparoscopic surgery creates great defiance, where the most advantageous technique and its reasons remain to be established. In this setting, it appears ethically justifiable to perform prospective randomized trials with the aim to compare OS *vs* LS. One of the large appeal of minimally invasive surgery is the expectation of a considerable decrease in full costs. While operating room costs may be higher in LS than in OS, whole hospital charges results as a rule lower with LS, mainly due to the lower hospitalization time[33]. Analogously, societal costs are reported to be lower due to fewer lost workdays[19]. In any case, a systematic cost-effectiveness analysis still is required.

The literature regarding the single-access splenectomy and robotic splenectomy is still at an earlier state. Early experiences report as both techniques are practicable and secure in experienced hands. The potential benefits associated with SILSp with respect to multi-port LS is yet to be demonstrated. Unfortunately, many publications about SILSp are case reports or small series. Similarly, larger series and prospective studies are also required to evaluate the robotic *vs* laparoscopic approaches. Robotic single-site splenectomy with the new dedicated platform seems to be practicable and secure, going beyond the restrictions of earlier robotic or conventional SILSp. On the other hand, further studies should be performed also for exploring the potential cost-effectiveness of this new high-tech based approach.

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