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Spleen Preserving Surgery and Related Laparoscopic Techniques

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1. Introduction

“The spleen” whose weight once thought to have been hindering the speed of runners to its role in cleansing process as its absence could result in the loss of laughing ability was called the “mysterioplenuorganon”. Its biological function has been elusive for thousand of years and also had been assumed to have no vitality in life. It’s been centuries since its existence has been under tremendous perusal and it wasn’t until mid-twelfth century when the concept of blood purifying function was emphasized. In early 1900, however, numerous experiments have concluded its role in the host defense and immune function. Spleen surgery dates back to 1549. Zaccaelli carried out the first splenectomy in this year. In 1952, King and Schumaker reported the overwhelming postsplenectomy infection (OPSI) in children with hereditary spherocytosis who had undergone splenectomies, which caused a wide concern on the potential function of the spleen.

2. Splenic function

Immunity

The spleen richly contains T cells, B cells, K cells, macrophages/monocytes, natural killer cells, killer cells, lymphokine-activated killer (LAK) cells, dendritic cells and so forth, and in conjunction with a variety of immune factors to makes in vivo immune response. Tuftsin is a tetrapeptide produced by the spleen to stimulate phagocytosis through the activation of neutrophils, it is a typical anti-tumor substance in the spleen, and can reflect the spleen function. Spleen tyrosine kinase (SYK) is a non-receptor tyrosine kinase, initially expressed in the spleen hematopoietic cells. SYK plays an important role in the Fc-mediated phagocytosis, B cell receptor signal transduction, cytokine secretion, and integrin-mediated signal transduction.

Barrier function

Weiss first proposed in 1986 that there is a blood-spleen barrier (BSB) between the artery and vein in the spleen, which is similar to blood-brain barrier and can filter Plasmodium falciparum-infected red blood cells. Jiang and Zhu et al respectively made their study on rat spleens and set up the concept and architecture of the BSB: The blood-spleen barrier (BSB) is located in the marginal zone of the spleen, which lies at the periphery of the white pulp;

This is a biological barrier containing sinus-lining endothelial cells, basement membrane, macrophages, reticular cells, reticular fibers (reticular tissue), and collagen fibers.

Endocrine function

As an important immune organ, the spleen also has an endocrine function, and is an important part of the immuno–neuro–endocrine modulation system in the body. Normal spleen may secrete erythropoietin, colony-stimulating factor, thyroid-stimulating hormone, gonadotropin, growth hormone, etc.

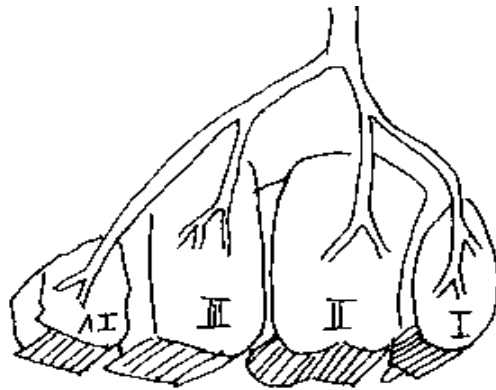
Through the nineteenth and twentieth century splenectomy had been successfully performed for trauma and hypersplenism. It was observed that the patients recovered to their usual pursuits but the life-long probability of the infection, augmented rate of long-term thromboembolic complications, enhanced arteriosclerosis, and late coronary artery disease could not be ignored and the long-term survival seemed skeptic. It's obvious that the knowledge of spleen function is getting more apparent and deep. Its importance in the host defense and immune function is absolutely undisputed. So the surgeons and researchers came up with the notion of preserving the spleen. To the matter of fact this conception didn't go in vain as it has been established now that that the preservation of at least 25% of the splenic parenchyma ensures an adequate short and long-term splenic function.

The anatomy of the spleen and its surrounding structures is indispensable. At the spleen hilum, all the vascular structures enter and divide to the related poles. Sometimes in patients the vessels divide into three branches thus any injury at the pedicle can result in the ischemia to the part supplied by the other branches (figure 1). Since, there is an ample amount of blood flow through the spleen. So, if the flow is interrupted to the part not being dissected "reperfusion injury" should be well thought-out. If the crisis is in the superior or inferior pole the dissection is not too difficult compared to the crisis at the hilum. The hilum also has the pancreatic tail landing on it; therefore, the activities at the hilum must be with care and precision so as not to injure pancreas. While draining the abscess there is an increased risk of the content to leak and reach the peritoneal cavity that is probable to cause sepsis around. Before starting the dissection of the splenic tissue, its abdominal adherence should be resected with care and after the surgery the remnant spleen should be placed carefully to the left upper quadrant to avoid rotation, which further can re-open the cut surface and vessels. The size, location of cysts, abscess, hemangioma and trauma plays an essential role in the decision for choosing the best-suited technique.

Spleen injury scale

At present, there are dozens of methods for spleen injury scaling. Main methods include Schackford Grade V (1981), Feliciano Grade V (1985), Gall & Scheele Grade IV (1986), Uranus Grade V (1990), American Association for the Surgery of Trauma (AAST, 1994 Revision) Grade V, and Patcher Grade IV (1998) and so on. These methods have different characteristics, but sometimes cannot effectively guide clinical work and operation. The 6th National Symposium on Spleen Surgery of China held in September 2000 in Tianjin adopted the spleen injury scale criteria as below. Grade I: subcapsular splenic rupture whose length $\leq 5.0\text{cm}$ & depth $\leq 1.0\text{cm}$ shown in the surgery. Grade II: the length of the spleen laceration $\geq 5.0\text{cm}$ & depth $\geq 1.0\text{cm}$, but the splenic hilum is not involved, or segmental splenic vessels are injured. Grade III: splenic rupture involves into splenic hilum, or partial spleen is broken apart, or spleen trabecular vessels are injured. Grade IV: extensive rupture exists in the spleen, or there is an injury in splenic pedicle, and main veins and arteries. Such scaling method helps to quickly determine the injury condition, but cannot cover all

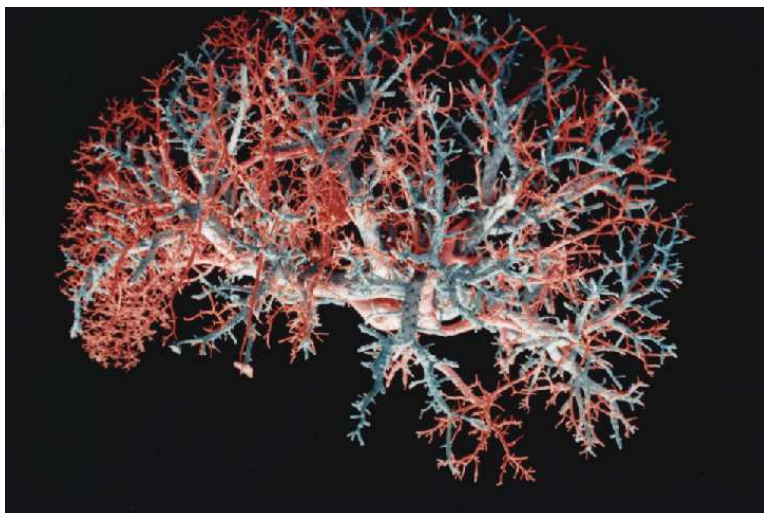
damages; so there is a need to make a revision and improvement according to actual situation in clinical work to adjust the treatment.



a)



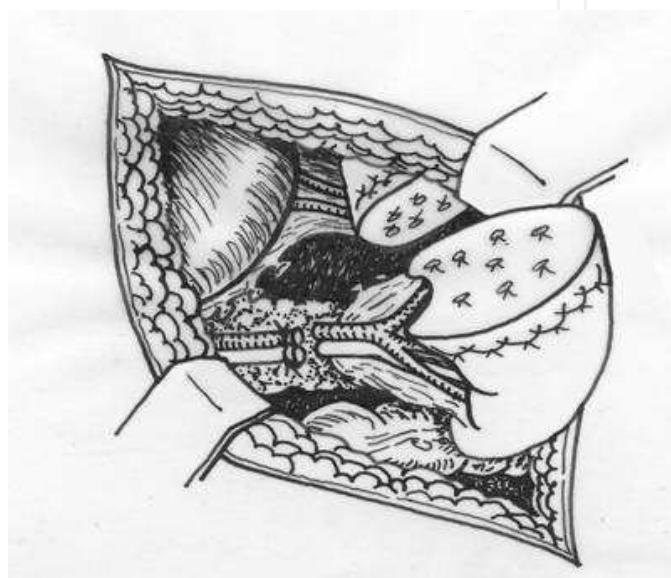
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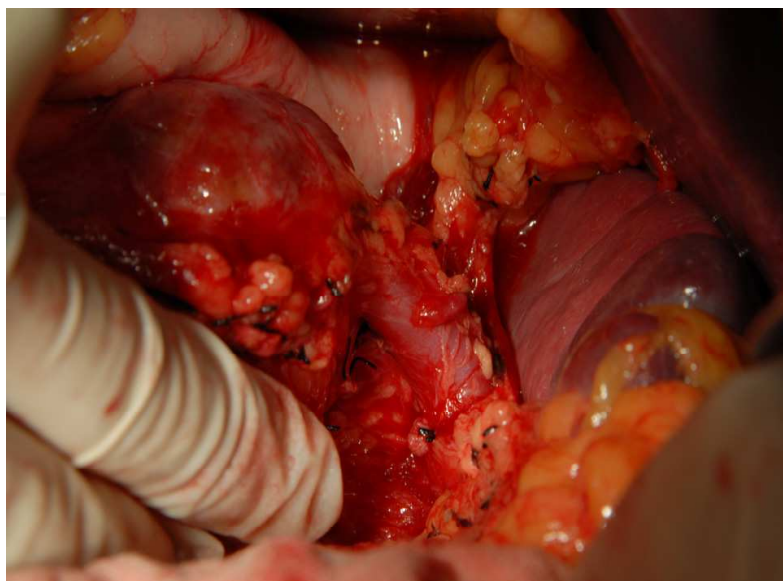
c)

Fig. 1. a) spleen artery is divided four branches into different segment , b) the anatomic basis of preseving spleen , c) model of spleen vessels

The spleen preserving surgeries of course was the remedy for many complications but with the open nature of surgery came handful of post operative complication like infection, delayed healing which at times altered the well being of the patients and “yes” the recovery. It’s evident that the spleen preserving surgeries have been evolving through decades (figure2). It’s apparent that the advents of novel laparoscopic techniques have opened new gates to the spleen preserving surgeries. The dawn of nineteenth century could see the concept of laparoscopic partial splenectomy blooming and by late nineties many centers around the world adapted it as a routine procedure. Surgery is an evolving science and in recent times there are several pioneering techniques that have minimized the technical flaws and surgical outcomes.



a)



b)

Fig. 2. a) remnant spleen section after partial splenectomy , b)conservation of the spleen with distal pancreatectomy

3. Laparoscopic surgery in spleen-preserving surgery

Carroll et al reported the laparoscopic splenectomy for the first time in 1992. Since then, the laparoscopic surgery has extended to the traditional fields covered by laparotomy, e.g. spleen adhesion, splenorrhaphy, artery ligation, partial splenectomy and the like, and has been combined with such new techniques as LigaSure, splenic arterial embolization, CUSA, radiofrequency ablation, thus adding a new vitality to the spleen-preserving surgery. The laparoscopic spleen-preserving surgery is somehow difficult, time-consuming, and costly. However, when compared to laparotomy, this surgery has more advantages, for example, clear operative field, minimal invasion, rapid recovery, and short hospital stay.

Laparoscopic inspection: To determine the extent and scope for splenic injuries or lesions; to understand injuries or lesions in the surrounding tissues or organs of spleen; to judge the extent for the bleeding area and vascular injuries; to carry out the pathological examination for the spleen or the surrounding tissues and organs under direct vision biopsy.

The laparoscopic spleen-preserving surgery has the following indications: Grade I-II splenic injuries with hemodynamic and vital sign stability; local benign lesions in the spleen, e.g. splenic cyst, splenichemangioma, echinococcosis, and etc.; hypersplenism, e.g. portal vein hypertension, hereditary spherocytosis and etc.; perisplenic tumors, e.g. pancreatic tumor, gastric cancer and etc.; splenic congenital diseases, e.g. splenectopia, accessory spleen and so on. Contraindications: Grade IV splenic injuries; severe portal hypertension; splenomegaly; severe coagulopathy.

The spleen-preserving surgery is similar to the laparotomy:

1. For Grade I spleen injuries, the bleeding can be controlled by electric coagulation, biological glue, fibrin and the like. For Grade II spleen injuries, the following methods are adopted: splenorrhaphy, partial splenectomy, splenic artery ligation and the like. For Grade III spleen injuries, the following methods are adopted: partial splenectomy, and splenic artery ligation etc.
2. For splenic benign lesions, the laparoscopic resection is conducted.
3. For hypersplenism, the laparoscopic partial splenectomy is conducted.
4. The spleen can be conserved through laparoscopic resection for perisplenic tumors.
5. For splenectopia, the laparoscopic fixation can be conducted. For accessory spleen, the laparoscopic resection can be conducted.

In the laparoscopic spleen-preserving surgery, the complications include hemorrhage, visceral injury, infection, splenic vein thrombosis and so on.

The laparoscopic spleen-preserving surgery is still in trial stage, and its efficacy is uncertain. Clinically, we should not blindly pursue new technology ignoring its efficacy; instead, we should never forget the damage control principles for splenic surgery, always save life first, and then deal with the injury.

In the current study, the spleen function is not very clear, but we begin to know it can play an important role in human body. Spleen-preserving surgeries have been widely implemented. Moreover, the extensive laparoscopic application has brought new opportunities, making the future splenic surgery more scientific and reasonable.

4. Techniques

The laparoscopic surgery is classically done via four ports (trocars) through the abdominal wall viz. 12mm left umbilical trocar, 5mm trocar positioned 5cm distal to the xiphoid process and slightly to the right of the midline, a 12 mm trocar positioned below the left costal arch

on the mammillary line and a 12mm trocar positioned below the left costal arch on the anterior axillary line. The surgery by this technique is quite efficient owing to the excellent view of abdominal anatomical landmarks. The resection is very clean and efficient with outstanding hemostasis from the cut surfaces. The 12 mm left umbilical trocar sometimes is replaced by 15mm ones for the introduction of the linear staplers. Surgical adhesives and meshes can be equally used with perfection if required. The surgery with spleen is technically challenging, thus, the electro cautery must be used efficiently with minimizing over use, because its overuse can cause the destruction of splenic parenchyma. The manipulation of the instruments should be with care at the pedicle, which may permanently disrupt the blood flow to the remnant spleen. The camera must be used in conjunction with the operator's maneuvers. The electro cautery can control the hemorrhage to some extent but if the cut surface becomes large then many surgeries are probable of becoming total. The eschar of electrocautery is a clinical concern as it may disrupt after surgery and cause future complications. The eschars at the hilum are more prone to disrupt because of the pressure in the blood vessels and rotation. The control of the suction is equally important as it may sometimes disturb the meshes and eschar.

The use of harmonic scalpel has improved the laparoscopic surgery, and because of the greater precision near the vital structures it has brought wonders to the spleen preserving surgeries. It has become an important tool in the surgical armamentarium. It doesn't produce noxious smoke plume, which makes the surgeons view even clearer. It also has the additional benefit of minimal, if any, lateral thermal tissue damage that reduces the postoperative sepsis and necrosis. It causes minimal charring and desiccation. The reduced need for ligatures has contributed to the excellent recovery. There is no escharformation, which makes this technique very advantageous as it clearly prevents its disruption, thus preventing postoperative hemorrhage. The introduction of high definition cameras has made the surgeries more vivid.

There is also a new widely adapted plasma scalpel and its use provides excellent results. Its use has the benefit of giving a better precision, which makes this technique highly promising. The comfort and ease with which it dissects the tissues is overwhelming. It nearly gives the surgeon a blood less view of the surgery field. It causes minimum scarring and has the advantage of faster healing which reduces the operating room time. Using plasma scalpel minimizes the instrument changes that are good aspects for surgeons to consider.

Radiofrequency (RF) ablation has recently evolved as a boon to the surgical world. It has advantage over other techniques because it makes the surgery merely bloodless; hence lesser post-operative complication, sepsis, and minimal hospital stay. Recently it was stated that RF is used to coagulate not the tumor itself, but a thin zone of normal organ parenchyma surrounding it, in order to achieve near bloodless division of the parenchyma. However, only case reports and small series have been reported regarding RF-assisted partial splenectomy. It is already successful on liver, brain and lungs and needs more effort, trial and expertise corresponding spleen. The preservation of splenic parenchyma is the requisite in spleen preserving surgeries and hemorrhage is yet another factor governing the success of surgery. The use of laparoscope already has minimized the bleeding, scar, pain and hospital stay and when used in symbiosis with RF ablation will undoubtedly bring better outcome to spleen preserving surgeries.

The argon beam coagulator has good effect on solid organ surfaces such as the spleen. Smoke is minimal as argon gas surrounds the target site. In a laparoscopic adaptation, 5 and

10mm diameter (disposable) probes are employed. It provides an optimum hemostasis. Argon beam coagulator uses a no-touch technique, and the stream of argon gas, as it conducts the electrical energy, simultaneously has a "blast" effect on the target tissues, momentarily blowing away blood, fluid, and debris for more efficient coagulation. The electrical generator is inexpensive but the electrode tips are relatively expensive, requiring frequent replacement. However, the efficacy of the argon beam coagulator, with its potential for a reduction of operating room time and its efficient achievement of (otherwise tedious) hemostasis, may negate these expenses.

The laparoscopic techniques have brought about essential changes in the surgery and have given a different vision and most importantly precision. The innovative robotic technologies at some centers are used in conjunction with laparoscopy. The use of robotic cameras have added the function of zoom in and zoom out and the 180 degree view have provided surgeons with the desired angle to see splenic pedicle and surrounding landmarks. Robotic cauteries, cameras can also be used with joysticks and voice activation so in delicate moments like achieving hemostasis during pedicle dissection, The surgeons just have to give a command to get the exact view thus saving time manpower and with ease. There are many centers using the davinci system to perform procedures as delicate as splenectomies. Although, it will need more trial for this technique to be worldwide adopted.

Not only the tools to obtain optimum results during the surgeries are evolving but also the laparoscopic surgery have also evolved. The minimal invasive is on a path of becoming even more minimal. The technique like SILS (single incision laparoscopic surgery) has brought revolution in the laparoscopic world. There are many literatures world wide showing the use of SILS for partial splenectomies. This technique in particular draws lot of attention owing to the fact that it's used through single trocar introduced through a small umbilical incision. From a single port three to four instruments as camera, scalpel, suction can be introduced and operated. The instruments have a multiple operating and viewing angles so the surgery doesn't need many ports. The tips of the instruments are available with multiple degree of rotation, which is the basic tenet of SILS. Partial splenectomies can be done with intricate surgical maneuvers made easy. The reduced operating room time and the nearly invisible scar also improve the pain, hospital stay and post operative complications.

During the laparoscopic surgeries there are many instances where accidents causes oozing of blood and a condition of momentary panic because of either the unsuccessful clamping of vessels or the spillage of resected spleen from the bag and also due to the deprived view of the surgical site. The new idea of HALS (hand assisted laparoscopic surgery) prevents momentary panic and also is an efficient and clever choice. In HALS there is a umbilical incision where lap pad is fixed through which gloved hands are introduced into the abdomen to improve depth perception, regain tactile sensation, aid in tissue extraction, and reduce operative time. There are two to three additional incisions for the trocars. The other hand operates the scalpel and suction. This technique can be considered as the hybrid of laparoscopic and open surgery. The surgery as delicate as spleen has a major hemostatic and technical issues. The direct introductions of hands in conjunction with the advanced laparoscopic instruments have yielded good results. For instance, the panic due to the uncontrolled hemorrhage can be stopped directly with the hands and the spleen remnant in case spillage can easily be obtained. The exact texture of the spleen can be felt and the desired amount retraction can be perfectly attained and not to forget the other hands actively dissecting through the laparoscopic ports. In this technique lap pads are used so that minimal incision is enough to introduce the hand in the abdominal cavity.

5. Discussion

As the splenic function mentioned above is better understood, spleen surgeries have developed from the early stage of random splenectomy to the second stage of non-selective spleen preserving, and to today's stage of selective spleen preserving. The concept of spleen preserving has become gradually popular, and various procedures to preserve the spleen have been widely applied which has achieved a optimal result. Current spleen- preserving methods are mainly as follows:

1. Hemostasis methods, which involve hemostatic materials (such as gelatin sponge, fibrin tissue adhesive), radiofrequency ablation, argon beam coagulator and other technical equipment.
2. Suture repair for ruptured spleen.
3. Partial splenectomy.
4. Spleen autotransplantation.
5. Selective arterial embolization.

Partial splenectomies can be successfully performed for complication like splenic cyst, splenic hemangioma, splenic mass, blunt traumas and splenic cysts. Proper hemostasis and uninterrupted view of the surgical site has always been a surgical concern. With the advent of laparoscopic techniques many flaws have been obviated which makes partial splenectomies more justifiable. The laparoscopic spleen surgeries, which once started with classical four trocars and electrocautery have evolved to have come long way. The assistance of better HD cameras with robotic zoom in and zoom out function have given the surgeons the most uninterrupted clear view of the surgical site which has brought the ease in locating a structure and active hemostasis. The cameras once used by the fellow operator can now be operated with voice commands and joysticks of the surgeon. The 180 degree rotations of the cameras have made the view extremely vivid circumventing accidents. The electro cautery had drawbacks like the eschar formation that have been eliminated with the development of harmonic and plasma scalpels. The harmonic and plasma scalpel and uses of laser prevents eschar formation, which prevents postoperative disruption and bleeding. These scalpels works with better precision near the vital structures as the pedicle of spleen. There is minimal thermal tissue damage, which is pivotal for postoperative recovery. The uses of ligatures have become least and the charring and dissection have been minimized. The postoperative healing, pain have also been greatly minimized with lesser hospital stay. A surgeon should choose a specific way depending on experience, overall cost and the simplicity in manipulating instruments. The robotic instruments, the use of harmonic and plasma scalpels in other instance needs a constant technical assistance. Robotic instruments are cumbersome and needs constant upgrading and high cost of compatible instruments prevents worldwide adoption. There is also an operative time delay when using robotics and it needs special training to surgeons.

Laser in the other hand has the advantage of checking blood loss, sealing the most small blood vessels, ability to work in relatively dry field which facilitates visibility, minimum tissue trauma less pain, edema (due to sealing of nerve endings and lymphatics) decreases chance of malignant cells to spread, scarring due to precision and most importantly decreases stenosis which is appropriate for splenic hemangiomas. The use of laser needs a surgical technologist (ST) at all times as its failure during the surgery can cause panic. Strict safety precautions must be enforced, eye protection for patients and all personnel in the room is mandatory for most lasers and flammable prep solutions and other flammable

liquids should not be used in the area where the laser is used. All dry materials in or near the operative field must be dampened with saline or water that makes the process more tedious.

The argon beam coagulator has its advantages of its own in giving a competent hemostasis with its "blast effect" which blows away the debris and coagulated blood for excellent hemostasis. It has very good results for splenic abscess as it has a large oozing surface. The major concern in this technique is the potential of gas embolism during the laparoscopic surgery. So the ultrasonography and ECG is constantly needed to check if the embolism has reached the heart and lungs to prevent further damages.

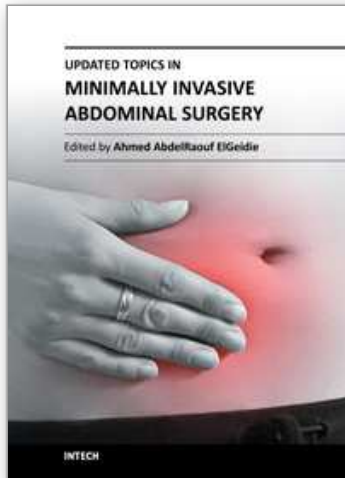
The minimal invasive surgery has become more minimal with SILS. The cameras, suction and cutting shears all fit through one trocar. The single port for the trocar has laparoscopic cutting shears (LCS) and the cameras also have all round vision, which makes this method promising. It has single small incision, therefore less invasive and traumatic. Like every technique has its advantage and disadvantages. SILS is not very efficient if the tumor size is large. It is a good option only for the spleens with normal size or only slightly enlarged. Because of the single small incision the macerated spleen is liable to spillage. In case of sudden bleeding it is difficult to control the hemostasis and still needs ergonomic improvement. The fulcrum effect should be minimized to make this technique better so robotic zoom in and zoom out cameras can be a good replacement. The hybrid technique as HALS has eliminated many shortcomings from the laparoscopic surgery. Since, one hand is inside the abdominal cavity it gives perfect retraction and uninterrupted view. The margin of tumor can be felt so dissection margin can be precise without hampering the normal spleen parenchyma. The bleeding site can be actively clamped with just a move of a finger. The splenic parenchyma is frail and the use of hands directly to retract can certainly circumvent bleeding and improper traction. There are many instances in spleen preserving surgeries when the macerated spleen within the bag gets spilled in the abdominal cavity so its recovery is quicker as the spleen gets implanted very soon. This technique can be very efficient in blunt trauma cases when laparotomy is urgently required. The camera in the other hand can work in conjunction with the hand to explore the abdominal cavity. This technique is irrespective of the size of spleen because even the bigger spleen can be handled with care and taken out without spillage and optimum safety. The pitfalls of HALS are the air leakage from the lap pads and the hands getting tired in 20% of the surgeons.

6. Conclusion

A laparoscopic spleen preserving surgery as aforementioned is a technically demanding procedure. The spleen parenchyma is frail and the tears or the parenchymal bleeding can occur. Thus, from a surgeon's point of view it requires exquisite care and control to avoid parenchymal rupture and cell spillage. There are many techniques available to do the same procedure in a logical and proficient way. The surgeons must be familiar with all the details and complications before choosing for one. Every technique has a virtue of its own over the other, so it is vital to discriminate techniques to choose the ideal one. The need of the laparoscopic surgery must be understood with the operative time and cost in mind. The postoperative outcome is the most important part of perioperative care and in the abdominal surgeries as spleen; adhesion is serious complication that affects the motility of abdominal structures later on. The complication as eschar formation, which may disrupt postoperatively is capable of causing bleeding. Thus, the technique that offers minimum adherence, eschar formation, sepsis, and necrosis should be employed.

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Edited by Prof. Ahmed Elgeidie

ISBN 978-953-307-773-4

Hard cover, 246 pages

Publisher InTech

Published online 14, November, 2011

Published in print edition November, 2011

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