



Laparoscopic Cholecystectomy: What has changed Over the Last Three Decades?

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Abstract

The surgical management of gallstone disease has undergone significant changes during the last three decades starting from open cholecystectomy to laparoscopic cholecystectomy and other minimally invasive techniques like single incision, robotic or natural orifice transluminal endoscopic cholecystectomy. Considering all of the outstanding features of laparoscopic cholecystectomy including less postoperative pain, low incidence of complications, similar rates of biliary injury, shorter length of hospital stay and more rapid return to full activity, it can be regarded as the gold standard and it is believed that it will continue to sustain its status until the development of a superior technique and its widespread clinical use.

Laparoscopic cholecystectomy is a rare and precious example of the surgical techniques which changed the thinking and operating habits of surgeons. Demand and praise of the patients for laparoscopic cholecystectomy has been another feature which forced the rapid acceptance of the technique all over the World.

With regard to find a new innovative technique being more minimally invasive operation than laparoscopic cholecystectomy with a lesser degree of postoperative pain and better cosmetic outcomes, even creating an incision less surgery, several modifications and techniques have been tried. However, due to the fact that safety of the patients is a vital issue, these modifications and techniques should not be performed with a presumable advantage of better cosmetic outcome or non-significant lesser degree of postoperative pain. But, the experienced surgeons can perform these innovative technological approaches due to the patient's desire or as part of ongoing clinical trials, preferably in the presence of the ethical committee approval or the institutional review board approval.

Keywords: Cholecystectomy; Laparoscopic; Minimally invasive surgical procedures; Robotic; endoscopic surgery

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Introduction

The surgical management of gallstone disease has undergone significant changes during the last three decades. A German surgeon, Carl Langenbuch, performed the first open cholecystectomy (OC) in 1882 [1]. This approach has been shown to be an effective method with low morbidity and mortality, and was accepted as "the gold standard" for the treatment of gallstone disease [2]. However, with the advent of "minimally invasive" surgical techniques, removal of the gallbladder without formal laparotomy via laparoscopically is preferred. This major change of the surgical technique for cholecystectomy has been the trigger of all subsequent developments and improvements.

Although there is still conflicting opinions about the surgeon who performed the first laparoscopic cholecystectomy (LC), it has been concluded that Muhe, a German surgeon was the person who performed the surgery in September 1985 [3,4]. Although the procedure was rejected by the German Surgical Society initially, Muhe was later officially awarded by SAGES (Society of American Gastrointestinal Endoscopic Surgeons) and he described the procedure with a presentation in 1999 entitled "The First Laparoscopic Cholecystectomy: Overcoming Roadblocks on the Road to the Future". In addition to Muhe, names of other surgeons including Mouret, Dubois, Perissat, Reddick, McKernan, Berci and Olsen should be mentioned in this context for their development and establishment of the technique in France and the United States [3,5,6]. Later, LC became the preferred method in many parts of the world and regarded as the "new" gold standard for cholecystectomy [1].

Initially, this approach was named laser LC due to the use of laser for the gallbladder dissection

from the liver bed [7-9]. In previous cholecystectomies, argon, KTP 532/YAG (neodymium: yttrium-aluminum-garnet) or potassium titanyl phosphate laser was used. But, it was shown that electrocautery is superior to laser use in LC and it has been discarded from the current practice [10]. After that, the term "laparoscopic cholecystectomy" has been used throughout the World.

It is believed that LC is a rare and precious technique in the history of surgery which changed the thinking and operating habits of surgeons quickly and on a broad scale [6]. It is also thought that the rapidity with which LC gained acceptance was almost initially consumer driven as well as its generally accepted advantages; including early discharge, rapid return to daily life and better cosmetic outcome [11]. In this respect, it has been mentioned that there is no operative procedure except LC that has been so highly praised and demanded by the patients in recent memory [12,13]. However, the issues with regard to the safety and ethics were also questioned during the introduction and emergence of the technique [1]. Many surgeons welcomed this approach with skepticism and total disdain, especially from academic institutions [6,11]. In a meeting of the German Surgical Society in 1986, the presentation of Muhe was met with ridicule and his procedure was described as "Mickey Mouse surgery" or was remarked as "small brain-small incision" [4]. Several authors tried to explain the role of this new technique as either a milestone or a dangerous innovation [14]. However, the younger generation, especially working in the private arena, displayed more enthusiasm to develop and refine the technique [6,15]. Due to these drawbacks, it was recommended that it should be introduced by adequately trained biliary surgeons with laparoscopic expertise due to morbidity including common bile duct damage and life threatening intra-operative bleeding [14]. At least diagnostic laparoscopic expertise, attending a course for LC or observing an expert on LC at a major center were regarded as the minimum requirements reported during the World Congress Symposium in 1990 and by the other authors [8,14]. Additionally, it was also recommended that it should be performed only by surgeons who can complete the operation in the standard open fashion [2].

It is noteworthy that an operation can be regarded as the gold standard shortly after its clinical use even though it has been met with skepticism initially. Therefore, surgeons should approach new technological developments with a more informed approach in the presence of a well-established effective surgical technique, avoid adopting total accepting or rejecting behavior and encourage careful and cautious experience in the light of evidence-based medicine [16,17].

Surgical Outcome of Laparoscopic Cholecystectomy over the Decades

Early data showed that some complications are more common after LC which can be attributed to the learning curve of experience when compared to OC [7,11,18,19]. In Martin's review in 1994, it was reported that the incidence of major bile duct injury after OC was thought to be fairly steady at 0.2% to 0.3% [20]. In accordance with these findings, Deziel reported the contemporary rates of bile duct injury during OC as 0.1% to 0.2% [21]. Therefore, the rate of 0.1% to 0.3% was the acceptable range for this complication after OC. However, in the initial reports, the incidence of common bile duct injury was found to be ten times more common after LC [2,22]. In Gadacz's review, the rates of major complications and common bile duct injury after LC were shown to be 2% (range 1.3-11.2%) and 0.59

% (range 0-1.0%), respectively [16,23]. Based on Deziel's large survey series, the rate of bile duct injury after the advent of laparoscopic surgery was found to be 0.6%, or about twice that associated with OC [23]. In Lee's study, the rates of biliary injury and biliary leak were reported up to 0.5% and 1%, respectively [15]. Additionally, major intraoperative bleeding and conversion to open surgery could be seen in up to 4.3% and 5% of the cases, respectively [16,17]. As a conclusion, the incidence of major bile duct injury was estimated approximately as 0.5% (range from 0.1% to 0.6%), based on the large series published up to 1993 [21]. However, it has been also shown that these complications were going to decrease with expertise [11]. In the Southern Surgeons Club's study, it was found that the incidence of bile duct injury among the first 13 patients and the subsequent patients operated on by each surgical group were 2.2% and 0.1%, respectively [7]. In another study of the same group, they found that 99% of the biliary injuries were performed within the first 30 cases of each individual surgeon [24]. By using a regression model, they calculated that a surgeon had a 1.7% and 0.17% chance of a bile duct injury occurring in the first and 50th cases, respectively. In the Cochrane review published in 2006, the bile duct injury proportions were reported as 0.2% for both open and laparoscopic groups [25]. Contrary to the early years of LC in which both lacking of laparoscopic experience and the learning curve negatively affects the outcomes, today surgeons who are trained in laparoscopy are more familiar with both anatomic view laparoscopically and the lack of depth perception [26,27]. Therefore, it can be accepted that laparoscopy does not inherently place the common bile duct at greater risk, but rather experience and critical dissection principles are the most important considerations [28,29]. Therefore, considering 0.1-0.2% of common bile duct injury after OC, LC with 0.2% incidence of this type of injury and low incidence of other complications can be regarded as the gold standard for the surgical removal of the gallbladder [7,15,25,30].

Additionally, because of the perceived improvement in outcome, the prospect of conducting a randomized trial of LC as compared with OC quickly became an unrealistic goal [17]. However, small randomized studies have shown the superiority of LC over OC with regard to an earlier consumption of a full diet, more rapid discharge and a shorter convalescence [31,32]. Besides these issues, LC has been rapidly adopted by most surgeons worldwide and has been embraced enthusiastically by the public [5,17,27]. Nowadays, it has been known that LC causes less postoperative pain, low incidence of complications, similar rates of biliary injury, shorter length of hospital stay and more rapid return to full activity based on data taken from retrospective studies [7,17]. Therefore, considering all these outstanding features, LC will continue to be the gold standard for the surgical technique of cholecystectomy until the development of a superior technique and its widespread clinical use.

Other Minimal Invasive Cholecystectomies

Mini-laparotomy cholecystectomy

If cholecystectomy is performed through smaller incisions over the abdomen, this type of surgery is called a mini-laparotomy cholecystectomy (MLC) [33]. Although the length of the incision varied from one study to another, 3.5 to 6 cm was regarded as the acceptable range for mini-laparotomy incisions. In selected series, this approach has been shown to have several advantages like an improved cosmetic outcome over OC, shorter hospitalization and no need for sophisticated expensive technology like LC [33]. In Ros's randomized study, the outcomes of LC and MLC were

almost similar [34]. Although this approach has been used for both elective and emergent cases, it has been known that obesity has some negative impact on the success of MLC [35]. Although there were some reports in which MLC has been recommended due to several advantages like lower morbidity, shorter operation time and lower cost, it has been also shown that MLC has similar outcomes with LC in a meta-analysis of randomized studies [36-39]. Cochrane reviews showed that MLC has similar surgical outcomes with OC and LC. However, quicker recovery compared with OC and shorter operation time and lower cost compared with LC were the important parameters favoring MLC [40,41]. Therefore, this approach can be a viable, safe and cheap alternative to laparoscopic surgery in patients who cannot tolerate laparoscopic procedures as their exposure can be succeeded with smaller incisions [42]. But, recent review of medical literature revealed that MLC is performed rarely nowadays. In two studies in which MLC was performed in 383 patients with chronic and acute cholecystitis in 2014 and 121 patients with high risk in 2010, respectively, this technique was regarded as a reliable and cost-effective alternative [43,44]. A small randomized study of MLC and LC to evaluate the effect of ultrasonic dissection also showed similar results with the previous reports [45]. Due to the lack of experience with MLC for the last several years and similar outcomes with LC in the previously published studies, recommendation of the technique does not appear to be a reasonable and valid approach in the current surgical practice which is dominated by conventional laparoscopic and minimally invasive laparoscopic approaches.

Mini- or micro-laparoscopic cholecystectomy (MLSC)

It can be possible to perform LC with similar surgical outcomes using a 1.2-3mm mini laparoscope and four-ports (an 11 mm sub-umbilical working port, a 2-mm sub-xiphoid video port, one 2-mm mid-clavicular retraction port, and one anterior auxiliary retraction port) in selected patients [46-50]. The success rate with this approach was shown to be almost 80%. Although there has been no advantage with regard to surgical outcomes, there was also a modest increase in operation time [51]. It has been previously shown that this approach can be a feasible procedure with nearly scarless wounds, especially in young female and pediatric patients [46]. Postoperative pain and patient satisfaction with the cosmetic result have been reported as the two important issues with regard to using such mini-invasive techniques [52]. However, studies have failed to show the superiority of MLSC over LC. In addition, use of thinner instruments than that of conventional LC has been reported as a limitative factor for performing the surgery especially in obese patients and in the acute setting. Several authors recommended MLSC only for special situations including young and thin patients and in elective, non-complicated cases due to the fragility of the instruments and longer operation times [53]. But more research and technical improvement are required to recommend mini-laparoscopic surgery routinely to patients due to the technical limitations [54].

Reduced-port laparoscopic cholecystectomy

Although LC has been performed through four ports (two 10 mm and two 5 mm ports), there have been many studies using less than four ports for LC [55]. In literature, great variances with regard to the number and diameter of the trocars have been seen. In studies using two or three ports, a percutaneous sling or traction sutures to retract the gallbladder for better visualization of the Calot's triangle were also needed [56-58]. Although it could be possible to perform LC via two or three ports in most of the cases, it has been recommended to use this approach in simple, uncomplicated cases

due to the demanding nature of the technique. Three-port LC without any traction suture also has been described [59]. Kagaya's study via two ports using the twin-port system may be regarded as the premise form of single incision laparoscopic surgery (SILS) [60]. In randomized studies comparing two- and three-port methods with standard four-port LC, it has been shown that these approaches with similar outcomes cause less pain, are less expensive, and leave fewer scars [61-63]. In combined studies using needlescopic instruments via two-port method, it has been shown that two-port needlescopic cholecystectomy is technically safe and feasible and it can be considered for routine practice by surgeons who are familiar with the two-port approach [64]. However, a modified port for both telescope and grasping instruments, and traction sutures were needed to perform this operation. In Cochrane analysis, it has been concluded that there was insufficient data to determine any significant clinical benefit in using fewer than four ports during LC [65]. In accordance with these conclusions, it is believed that there is no major advantage in reducing one 5 mm right lumbar port as it neither reduces pain nor alters the postoperative recovery and it is cosmetically not superior to the standard four-port LC [46]. There have been very small statistically significant differences without clinical benefit with regard to severity of pain, length of hospital stay and cosmetic outcome in the studies favoring the reduced port LC [66]. Therefore, reduced port LC cannot be recommended for routine practice except in a few selected young, female patients or in patients with a short gallbladder and a floppy liver or in the presence of adhesions between the liver and the parietal peritoneum preventing traction of the gallbladder [46,67].

Single port/incision laparoscopic surgery for cholecystectomy

With the advent of minimally invasive techniques, single wound, port or incision LC is performed via placement of several trocars at the umbilicus or using special port systems. In these circumstances, single skin and sheath incision or single skin and separate sheath incisions at least 2 mm apart from each other or separate skin and sheath incisions at least 2 mm apart from each other at the same umbilical site can be performed [46,68-72]. The main advantage of single incision technique has been thought as the better cosmetic outcome and lowered incision risks including incisional hernia comparing four incisions at LC and one incision at SILS [73,74]. However, the term "lowered incision risks" should be evaluated in detail with prospective studies due to the necessity of a longer incision at one point. In Christoffersens' study, no difference in long-term incidence of port site hernia after single incision and four-port LC was found [75]. The incidence of incisional hernia was reported as 4% and 6% after SILS and four-port LC, respectively. It may be expected to see lower incidence of incisional hernia in four-port LC due to the smaller length of the incisions. The surgical techniques for fascial closures in this study were not mentioned in the text; therefore, this issue should be taken into consideration before a final conclusion. In Agaba's study, the port-site hernia rate was found as 2.9% at 30 to 36 months follow-up after single incision surgery [76]. Marks's study revealed significant hernia rates after single incision LC compared with four-port LC at the first year follow-up (8.4% and 1.2%, respectively) [77]. Although scores for cosmetic outcome and patient preference favor single incision LC, port-site incisional hernia remains a major setback for patients.

In the initial case series for single incision LC, modified instruments with angulated shafts, magnetic anchors, traction sutures and loop retractors have been used for the retraction of the gallbladder

with variable success rates [78-81]. There have also been some modifications for single incision LC including extra-small wound retractor and a surgical glove as the single port [82]. It is believed that all of these modifications seem to be the biggest obstacles to reach a definitive judgment for the recommendation of SILS routinely for the patients. Although single incision LC has been reported to be safe, feasible and a promising alternative method for scarless abdominal surgery, longer operation times and cost due to the technologically demanding instruments are the main issues for generally using single incision techniques. Therefore, it is advisable to use this approach for patients who have a special cosmetic interest. Additionally, this technique can be routinely performed by experienced surgeons of laparoscopy and single incision approach.

In Allemann's review, the analysis of single incision LC on 895 patients revealed that the feasibility of this approach is lacking due to the absence of standardization and technical variation [83]. In recent meta-analyses and systematic reviews of single incision LC, it has been found that this approach offers only a better cosmetic result. However, it was associated with higher procedure failure, longer operation times and additional expensive instruments. Significant benefits in patient overall satisfaction, postoperative pain and hospital stay have not been shown [84-88]. With regard to the degree of postoperative pain after single incision and conventional four-port LC, a significant difference has been detected in SPOCC trial favoring the former one. However, the difference in mean visual analog scores was only 1 point (1 and 2 for single incision and four-port LC, respectively) [89]. With regard to the safety of single incision LC, although the incidence of common bile duct injury and the overall biliary complication has been shown to be higher in single incision LC compared with four-port LC, these differences were not statistically significant [90]. In another study, higher bile duct injury rate was shown after single incision LC [91]. Based on these results, it has been concluded that this new technology cannot be recommended as a standard technique for LC [46,55].

It is believed that studies should focus on solving the physical and technical problems encountered during single incision and reduced-port laparoscopic surgery and to improving technical properties of the instruments. Achievement of adequate triangulation and an adequate working space are the main principles for successful laparoscopic surgery. However, operating through a single incision with several instruments would be a challenging procedure due to a parallel positioning of the instruments; conflict between instruments and camera or a crossing arrangement and the fact that the left hand of the surgeon controls the right instrument. To overcome these technical difficulties, flexible, curved or the crossed-over articulating instruments, and semi-flexible endoscopic camera systems have been developed [73]. However, use of such instruments with lesser degrees of strength resulted in longer operation times for careful and precise dissection. In spite of improvements, problems with regard to triangulation, ergonomics and range of motion of instruments are still present, so new instruments should be developed appropriate for this type of surgery.

Robotic Cholecystectomy

Different types of robotic systems during laparoscopic surgery have been used since 1998. In the previously published reports, it has been thought that voice controlled robot or self-guided robotic camera causes better intraoperative ergonomics and optimal camera guidance, allows the practice of solo-surgery or tele-mentoring and

help to maintain the surgeon's concentration [92,93]. The first two international tele-surgical, tele-mentored, robot-assisted LC's were the Johns Hopkins Institute, Baltimore, Maryland, USA and the National University Hospital, Singapore in 2000 [94]. Initially, this approach was named as computer assisted surgery using the computer-surgeon interface of a surgical robotic system [95]. In the first experiences with this technology, it was concluded that computer-assisted surgery is safe and feasible although it offers no obvious advantages to patients. However, it has been mentioned that the ability to convert the surgical act to digitized data or the transmission over a distance has the potential for revolution of surgical techniques. Later, with the advent of robotic-assisted technology, the robotic surgical systems including ZEUS[®], AESOP[®] and da Vinci have been developed [95,96]. Each system has some advantages and disadvantages [97]. AESOP robot replaces the camera person with its voice-controlled property. The tele-robotic ZEUS and da Vinci systems permit solo surgery by a surgeon from a remote sight. The main benefits of these systems are three dimensional imaging, endo-wrist full movement capability, and superior ergonomic conditions for surgeons and prevention of tremor [66].

It has been shown that use of robotic camera assistant instead of human camera assistant has small but significant decrease in operation times (66 minutes versus 74 minutes respectively) [98]. Robot related tasks including set-up of the equipment, sterile draping of the system, robotic trocar placement, docking and undocking the robot leading to time loss have been reported as some of the main disadvantages of the robotic surgical systems [99]. Early comparative studies revealed that robot-assisted LC requires significantly more time than conventional LC [100]. Cochrane analysis showed no significant differences for morbidity, conversion to OC, total operating time, or hospital stay [101]. Any significant advantages of robot-assisted LC over human assisted LC have still not been shown in an update from the Cochrane review [102]. The cost of robots for LC has been evaluated in several studies [103]. The results showed that the costs are high and do not justify the use of robots considering the lack of benefits for the patients.

Hybrid approaches using a combination of robot assisted surgery with single port have been described and performed by several authors [104,105]. Although there was no significant difference in operating times for both single-port robotic cholecystectomy and multiport robotic LC, the operation times are still not comparable to the times for standard LC [66]. In Konstantinidis' study, a novel robotic platform has been developed and used to get a potentially more stable and reliable environment for obese patients or with difficult cholecystectomies [106]. Therefore, there should be more research to improve single-port robotic technology for achievement of widespread applicability and acceptance of the technique.

There have been many limitations of the studies using robot-assisted or single port robot-assisted LC. All the cases in these trials were usually elective, uncomplicated and non-inflamed cases [66]. The surgeries in these studies have been performed by a limited number of experienced surgeons, thereby preventing a wide application of external validity. The operation times, techniques and instruments have had great variability. In this way, generalizability of these studies is going to be limited [107]. Although robot-assisted LC has not been shown to be inferior for the outcomes of conventional LC, due to the lack of data with regard to generalizability and external validity, there is a need to perform long term outcome and financial benefit studies to reach a decision favoring or against these new technologies.

Therefore, clinical use outside trials cannot be recommended, as its advantages over LC are not evident [66]. In future, the next generation robots are expected to be more improved leading to a widespread acceptability [107].

Natural Orifice Transluminal Endoscopic Cholecystectomy

During the evolution of gallbladder surgery, starting from OC to single incision robotic cholecystectomy, most technical advances in this area have been met initially with skepticism [108,109]. At the convergence point of both the gallbladder surgery and the use of flexible endoscopy, a novel approach using endo-luminal endoscopic surgical techniques without a visible scar was developed after the first experience of trans-gastric peritoneoscopy in an animal [110]. It has been believed that such incision less techniques named as "Natural Orifice Transluminal Endoscopic Surgery (NOTES)" could help to reduce surgical pain, decrease anesthesia, shorten recovery time, avoid hernia formation and adhesions, and eliminate any surgical site infection and visible scarring [111-113].

It should be mentioned that NOTES technique shares similar physical and technical limitations with single incision laparoscopic surgery. The same principles including achievement of adequate triangulation and an adequate working space are also valid for NOTES. The parallel positioning of the instruments and crossing arrangement have tried to be solved by using flexible, curved or the crossed-over articulating instruments, and semi-flexible endoscopic camera systems. Nevertheless, the problems with regard to triangulation, ergonomics and range of motion of instruments are still present.

Following the animal survival studies, cholecystectomy as a technically challenging procedure has been performed through a trans-gastric incision or via transvaginal route in animals [114-116]. Before the advent of totally NOTES, transvaginal hybrids including culdolaroscopic cholecystectomy via transvaginal route have been performed in humans [117]. Earliest NOTES cholecystectomy in humans was reported by Marescaux and Zorrón [118,119]. Beside the use of NOTES in animals and humans for the last decade, it has been believed that the technique is still in its infancy [46]. Although various routes including transvaginal, trans-gastric or trans-colonic have been used, at least one 3 mm or 5 mm umbilical port is also needed as an initial guide to puncture the peritoneum and at the end to assist in closure of the defect [46,120]. Initial case series using transvaginal and trans-umbilical (laparoscopy assisted) routes revealed that cholecystectomy with NOTES can be routinely performed to reach an incision less outcome. But, for the hybrid approaches using both NOTES and assisted laparoscopy, the incision on the umbilicus was ignored due to the presence of an invisible scar within the umbilicus. Another hybrid technique including trans-umbilical flexible endoscopic cholecystectomy with transcutaneous trocar has been described. The outcomes of this study were reported to be poor. Four out of 10 patients were converted to conventional LC due to difficulty in dissection and uncontrollable hemorrhage. Postoperatively, there was one hemorrhage from the cystic artery and one cystic duct leak. The authors concluded that endoscope-based trans-umbilical cholecystectomy yielded unsatisfactory results in humans. Therefore, improvement of the instruments and accessories are required for the success of the technique yielding acceptance and feasibility [121]. In earlier series, NOTES transvaginal cholecystectomy using a transvaginal 12 mm and two abdominal trocars (2 mm and 5 mm) has been regarded as an efficient and safe technique [122,123]. Some

researchers have tried to develop totally NOTES cholecystectomy using two flexible endoscopes through transvaginal route [124,125]. Although the mean operation time was 210 minutes, postoperative course was uneventful. In Asakuma's paper, the authors performed more than 250 cholecystectomies in pigs before the clinical application of NOTES technique [126]. They believed that such stepwise experience is an important step in the development of methods and devices to enable the evaluation of an incision less NOTES surgery. Review of the medical literature also revealed that there were many animal non-survival and survival studies with regard to NOTES before human use [127-130]. NOTES technique is a condition in which researchers believe that more experimental training on animals is needed to validate the technique on humans due to the presence of ethical and technical questions. Initial large series concluded that NOTES cholecystectomy and appendectomy via trans-gastric or transvaginal routes are feasible surgeries although operation times were longer than that of conventional laparoscopic surgeries [131]. In a German registry with regard to NOTES, it has been reported that transvaginal hybrid cholecystectomy is a practicable and safe alternative to laparoscopic surgery. Among the 572 cases, 488 were operated on for cholelithiasis with a conversion rate of 4.7%. Complications mostly related to the natural orifice access occurred in 3.1% of all cases [132]. In the earlier studies comparing transvaginal LC with conventional LC, it has been found that transvaginal LC is as successful as conventional LC. Although it was a more time consuming procedure, it can be regarded as an ideal surgery due to the absence of a visible scar [133-136]. However, these conclusions should be evaluated with caution due to the small number of the patients in each group causing underestimated results [137].

Some specific issues with regard to patient selection and technical variability in these studies should be questioned. First, the patients with uncomplicated gallbladder diseases have been included. Additionally, there have been several modifications including differences in access points and instruments. Therefore, it seems to be difficult and problematic to reach a generalizable conclusion from these findings even though there was no bile duct injury [138]. Although the reports published previously suggested a promising future for NOTES, due to significant ethical, procedural, and technological questions, the benefit of this innovative technique has not been shown. Larger series and prospective randomized trials are needed to delineate the exact risks and the safety of this approach, because the supposed benefits of better cosmetic outcome should not outweigh the risks of potential immature application [138,140]. To overcome all of these problems associated with NOTES, the approach used during the introduction and emergence of LC can be taken into consideration. Due to the fact that an increased rate of major bile duct injury and other technical problems for LC were real issues at the beginning, teaching programs organized by the surgical scientific community were started all over the world to adopt the technique [141]. With the help of such programs, it has been possible to interest the academic communities in the widespread application of LC with great success.

A Summarized Approach to Modified LC Techniques

After the introduction and emergence of LC, there have been many modifications using different port numbers, variable sized instruments and ports, different combinations of these parameters, and various techniques like NOTES. The idea of all these modifications

is to perform a more minimally invasive operation with a lesser degree of postoperative pain and better cosmetic outcomes, even creating an incision less surgery [142]. However, the established and accepted principles of LC should be provided. Safety of the patients especially with regard to the risk of major bile duct injury during LC is a vital issue. These modifications should not be performed with a presumable advantage of better cosmetic outcome only. Additionally, clinically significant difference in the degree of postoperative pain favoring these modified LC approaches has not been shown by previous studies. Therefore, modified LC techniques should be performed only by experienced surgeons in selected circumstances. In cases of any difficulty, the team should not hesitate to place additional trocars or to convert to open surgery.

Conclusion

After its introduction and emergence, LC has been accepted as the gold standard for surgical treatment of gallbladder disease. During the initial period of LC between 1993 and 1994, it was mentioned that surgeons should approach new technological developments in a more attentive manner i.e. LC in the presence of a well-established effective surgical method or OC, avoid adopting total accepting or rejecting behavior and encourage careful and cautious practice in light of evidence-based medicine. However, these phrases didn't lose their value. It is still possible to state that surgeons should approach new technological developments in a more attentive manner, like single incision laparoscopic surgery, robotic surgery or NOTES in the presence of a well-established effective surgical practice i.e. LC. Therefore, it is believed that LC is the current gold standard technique and surgeons should perform LC routinely for their patients first. However, the experienced surgeons can perform these innovative technological approaches due to the patient's desire or as part of ongoing clinical trials, preferably in the presence of the ethical committee approval or the institutional review board approval.

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