11 Laparoscopic Cholecystectomy: Training, Learning Curve, and Definition of Expert

Domenico Marchi, Maria Grazia Esposito,
Ivan G. Gentile, and Francesco Gilio

Since the first laparoscopic cholecystectomy was performed, more than 20 years ago, literature validated the procedure as gold standard. Nevertheless, it continues an important discussion about methods to perform the procedure and about the best way to teach the procedure to surgical trainee. Three questions remain unanswered today that are the subjects of a heated debate: Which is the ideal learning method for a surgical trainee? What is the surgical learning curve? What is the definition of expert in laparoscopic cholecystectomy?

11.1 Training

Laparoscopic surgery is different from open surgery because of:

(a) Increased need for hand-eye coordination to perform tasks looking at a screen to compensate for not being able to operate under direct vision.

(b) Increased need for manual dexterity to compensate for the use of long instruments, which can amplify any error in movement.

D. Marchi, MD, PhD (✉) • I.G. Gentile, MD
Chirurgia Generale, U.O.C. Chirurgia Generale, d'Urgenza e Nuove Tecnologie, NOCSAE, Via P. Giardini 1355, Modena 41126, Italy
e-mail: domenico.marchi@yahoo.it; ivangabriele.gentile@gmail.com

M.G. Esposito, MD, PhD
Department of General Surgery, Center for Advanced Laparoscopic Surgery and Oncology, Villa Betania Hospital, Via Argine 604, Naples 80147, Italy
e-mail: mariagrazia.esposito@gmail.com

F. Gilio
Department of General Surgery, U.O.C. Chirurgia Generale, A.O. Regionale San Carlo, Via Potito Petrone, Potenza 85100, Italy
e-mail: gilio.f@tin.it

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(c) Fulcrum effect of the body wall: When the surgeon moves his hand to the patient's right, the operating end of the instrument moves to the patient's left on the monitor.
(d) The need for handling tissues carefully (to compensate for the lack of sensation of touch using hands).
(e) The lack of 3-dimensional images.

How to teach laparoscopic surgery to residents in a safe and efficient way is the topic of many debates, conventions, and research projects. Surgical training has traditionally been one of apprenticeship, where the surgical trainee learns to perform surgery under the supervision of a trained surgeon. Different procedures have different learning curves. Surgeons experienced in one procedure may not be experienced in another, and results improve with experience in an individual procedure. An increasing number of surgical procedures are being done laparoscopically. This includes laparoscopic cholecystectomy, laparoscopic anti-reflux procedures, laparoscopic hysterectomy, and laparoscopic nephrectomy. Learning should be gradual. For example, laparoscopic intracorporeal suturing and knot tying are considered some of the most technically demanding minimally invasive skill to acquire. Proficiency in these skills is a requirement for surgeons to perform advanced laparoscopy. Studies have demonstrated that technical aptitude in open suturing and knot tying is not transferable to the laparoscopic technique. Compounding the difficulty inherent in learning this advanced laparoscopic skill are the diminished operative opportunities for surgical residents resulting from work-hour restrictions and the ethical concerns related to trainees learning novel skills on patients. As a consequence of these pressures and the technical demands of minimally invasive surgery, alternative ex vivo training methods have been developed [1] (LoE1b). The different methods of laparoscopic surgical training include live animal training, human and animal cadaver training, training using box trainer (video trainer), and virtual reality training (training using computer simulation). Video trainer is currently being used for laparoscopic training in various courses run by the Royal College of Surgeons of England and has been shown to be better than standard training. Virtual reality training has been reported to improve the learning outcomes in different surgical procedures [2–6] (LoE4). It also offers an ethical way of assessing the competency of a surgeon in performing a procedure without a risk to the patient. There are other reports that suggest that virtual reality training alone is inferior to traditional training for certain procedures [7] (LoE3b). Virtual reality training has been mainly used for development of component skills (such as diathermy, clipping, suturing) and not training in the entire procedure (such as laparoscopic cholecystectomy). As opposed to the limited variability of data available during a flight on which a pilot requires to be trained using a custom-designed simulator, anatomical variations are common throughout the human body, and skills acquired on a single computer simulation program may not be applicable in patients. Although the price of the simulators can vary depending upon the learning outcome, traditional training is not without costs. The operating time increases significantly for junior surgeons compared to senior surgeons, and the average costs of this increased operating time is about 12,000 US dollars per year per resident during the period 1993–1997 [8] (LoE1a).

The complication rate is also higher for junior surgeons compared to senior surgeons [9] (LoE2a), [10] (LoE3a). Thus, the cost of the virtual reality training system has to be balanced against the cost of increased operating time and complication rates during traditional surgical training. The Cochrane Review [11] (LoE1) included 23 trials with 612 participants, comparing virtual reality training versus other forms of training including video trainer training, no training, or standard laparoscopic training in surgical trainees with little or no prior laparoscopic experience. Also include trials comparing different methods of virtual reality training. Four trials compared virtual reality versus video trainer training. Twelve trials compared virtual reality versus no training or standard laparoscopic training. Four trials compared virtual reality, video trainer training and no training, or standard laparoscopic training. Three trials compared different methods of virtual reality training. Most of the trials were of high risk of bias. In trainees without prior surgical experience, virtual reality training decreased the time taken to complete a task, increased accuracy, and decreased errors compared with no training; virtual reality group was more accurate than video trainer training group. In the participants with limited laparoscopic experience, virtual reality training reduces operating time and error better than standard in the laparoscopic training group; composite operative performance score was better in the virtual reality group than in the video trainer group. The conclusion is that the virtual reality training can supplement standard laparoscopic surgical training of apprenticeship and is at least as effective as video trainer training in supplementing standard laparoscopic training. Newer studies [12] (LoE3) have evaluated the benefits of haptics in VR laparoscopic surgery training. Randomly, 33 laparoscopic novice students were placed in one of three groups: control, haptics trained, and nonhaptics trained. The number of attempts required to reach proficiency did not differ between the haptics- and nonhaptics-trained groups. The haptics and nonhaptics groups exhibited no difference in performance. Both training groups outperformed the control group in number of movements as well as path length of the left instrument. In addition, the nonhaptics group outperformed the control group in total time. The conclusion in that haptics does not improve the efficiency or effectiveness of LapMentor II VR laparoscopic surgery training; the limited benefit and the significant cost suggest that haptics should not be included routinely in VR laparoscopic surgery training. Van Det et al. [13] (LoE1) have proposed a new training method called INtraoperative Video-Enhanced Surgical Training (INVEST) and have compared it with the traditional master-apprentice model (MAM). The conclusions are that INVEST significantly enhanced skill development during the early learning curve for laparoscopic cholecystectomy, but a balanced training program commences with essential basic skills training on VR and/or AR simulators. Elements of procedures should be practiced in box trainers with cadaveric models. Ideally, but is difficult in Europe, trainees should attend courses that use live animal model or human cadavers to perform specific procedures on healthy organs before they go to the operating theater to perform their first procedures on real patients with INVEST. A number of governing bodies and surgical societies have published guidelines that outline standards for training for postgraduate surgeons for skill acquisition in minimal access surgery, but these recommendations are based more on common sense and clinical experience than rigorous evidence.

Continued research is needed to determine the threshold for safe performance of this and other procedures, the most effective training methods to ensure competence, and strategies to minimize patient harm, while proceduralists gain the experience they need to be competent and to train others.

The training of surgeons is a subject of broad concern to health professionals, patients, government officials, and the public alike. Reports of medical error within the healthcare and public domains have driven the need to define objective and valid measures of competence before credentialing of surgeons for independent practice. The medical community is thus obliged to develop and maintain new training paradigms that can deliver competent practitioners without undue harm to patients during the acquisition of these skills [14] (LoE3).

Training of future surgeons is a mission of vital importance to society.

In conclusion, we believe that the most important element in training a specific surgical procedure remains the hands-on training on a real patient with an experienced surgeon at the trainee's side. Virtual reality training can supplement standard laparoscopic surgical training of apprenticeship and is as effective as video trainer training in supplementing standard laparoscopic training.

11.2 Learning Curve

The learning curve was first described by psychologist Hermann Ebbinghaus in 1885 and elaborated by psychologist Arthur Bills in 1934. The concept of the learning curve is an abstract and concrete concept at the same time. The world of politics, finance, business, and enterprise must deal daily with this concept, but what is the definition of "learning curve"? In many dictionaries, it is defined as an idea that describes how new skills or knowledge can be quickly acquired initially, but subsequent learning becomes much slower. At first, a minimal investment of resources yields significant results, but the payback from continuing effort is smaller.

The difficulties of interpretation and application of this concept are the same also in the surgical world. The theme of the learning curve in laparoscopic cholecystectomy (LC) is intimately connected with the training. The strategy search on PubMed regarding the learning curve overlaps almost completely with the search about training in LC. The need to evaluate a learning curve arises from this consideration that the training has a cost, the learning curve; no training has a higher cost, complications. All studies reported clinical outcomes, most commonly bile duct injury. EAES guidelines [15] (LoE5) indicate that a minimum of 20–35 LC are necessary for a surgical trainee to be able to use laparoscopic techniques safely. Moore and Bennett [16] (LoE3) analyze bile duct injuries (BDI) in 8,839 cholecystectomy from 55 surgeons. Fifteen BDI (by 13 surgeons) resulted with 90 % of the injuries occurring within the first 30 cases performed by an individual surgeon, and, at the multivariate analyses, the only significant factor associated with an adverse outcome was the surgeon's experience with the procedure. A regression model predicted that a surgeon had a 1.7 % chances of BDI occurring in the first cases and 0.17 % chances of BDI at the 50th case. The rapidity of learning LC was not significantly related to physician age, number of surgeons in the practice, or whether the hospital setting was academic or private practice. The results of a learning curve for LC are consistent with those reported for other surgical procedures, such as coronary artery bypass grafts, abdominal aortic aneurysm repair, and hip surgery. The functional form of the learning curve relationship for LC is of the low-threshold type whereby good outcomes are predicted to occur after 10–20 cases. Usually, the first ten cases were done with close supervision. More stringent policies requiring supervision of greater than 15 cases are predicted to have smaller effects on decreasing the expected number of BDI. Gigot et al. [17] (LoE2a) reported the incidence of bile duct injury was 1.3 % when the surgeon had performed fewer than 50 cases and 0.35 % afterward ($p < 0.001$). However, bile duct injuries still occurred with surgeons who had performed >100 case. Koulas et al. [18] (LoE2a) analyze 1,370 LC performed by trainees (33 %) and by consultants (67 %). They showed that supervised LC performed by trainees does not increase surgical morbidity and does not compromise surgical outcome. The grade of the operating surgeon has not predictive value for complications. Fahrner et al. [19] (LoE2c) show that, provided adequate training, supervision, and patient selection, surgical residents are able to perform LC with results comparable to those of experienced surgeons. The only statistically significant difference was the operative time (attending surgeons AS < resident surgeons RS).

We can conclude that the learning curve should be performed initially in only carefully selected patients under the supervision of an experienced surgeon. Virtual or standard laparoscopic training can significantly increase the skills and reduce the learning curve in LC.

11.3 Definition of "Expert"

A thorough analysis of all the literature, does not allow us to give the definition of surgeon "expert" in laparoscopic cholecystectomy. Most of the articles examined show that the results of the experts are better than those of surgeons who have not completed their learning curve, but no one specifies what is meant for "expert surgeon," and only a few specifies a minimum number of procedures required to define the "expert surgeon." Aggarval et al. [20] (LoE3) developing a virtual reality training curriculum for laparoscopic cholecystectomy divide surgeons in three groups: inexperienced, those who have performed fewer than ten laparoscopic cholecystectomies, intermediate, those who have performed between 20 and 50 cholecystectomies, and experienced, those who have performed more than 100 cholecystectomies. Schijven et al. [21] (LoE2b) evaluating the experience on simulators consider expert surgeons having performed over 100 laparoscopic cholecystectomies and novice surgeons having not performed previous laparoscopic cholecystectomies. Dagash et al. [22] (LoE1a) have tried to quantify the learning curve in laparoscopic surgery. After a systematic review of the evidence, the authors analyzed seven common laparoscopic procedures (cholecystectomy, fundoplication, colectomy, herniorrhaphy, splenectomy, appendectomy, and pyloromyotomy) and conclude that the number of procedures required to reach proficiency in laparoscopic surgery has not been defined clearly. These findings are important for training, ethical, and medicolegal issues. The word *proficient* is synonymous with *expert* in most dictionaries. In the surgical context, proficiency refers to expert, independent execution of treatment (operation). Surgical proficiency is best modeled by a zone rather than a sharp threshold, since surgeons bring different levels of innate abilities to the task (average, above average, below average) [23] (LoE2c). In this model, the proficiency zone represents what society expects of fully trained surgeons: an outcome that varies from one surgeon to another within very narrow limits defined by the upper and lower thresholds. For any given operation, there will be some surgeons who perform at the top end (at the upper threshold of the proficiency zone), the performance of the majority of surgeons for the same operations will be within the zone (acceptable standards of care), but none should be below the lower threshold [24] (LoE5). The various published reports on "learning curves" for specific operations based exclusively on incidence of iatrogenic injuries and morbidity rates and reaching conclusions/recommendations on the "x" number of operations required for acquisition of proficiency in the execution of an operation lack both science and validity. The truth is that the proficiency-gain curve is specific to the individual as it is to the intervention. We can never of course abolish surgical error completely, but we can reduce it to the as-low-as-reasonably-possible region.

We believe that the number of procedures required to reach proficiency in laparoscopic surgery cannot be defined. The expert as defined by the skills and experience cannot be numerically validated. The expert could be defined as the harmonious balance between experience, technical skills, and predispositions of the individual surgeon. However, the definition of "expert" cannot be separated from the concept hospital volume (HV) and surgeon volume (SV).

Those who call themselves experts should be careful to this regard: learned individuals have always warned us [25] (LoE5): "The greatest enemy of knowledge is not ignorance, it is the illusion of knowledge" (Stephen Hawking); "An expert is a man who has stopped thinking: he knows!" (Frank Lloyd Wright). Some general principles are fairly simple, but their translation to practical application might be very difficult. This is exactly what St. Thomas Aquinas claimed.

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