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The Impact of the Learning Curve in Laparoscopic Surgery

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Abstract: TP Wright originally introduced the concept of a learning curve in aircraft manufacturing in 1936.[1] He described a basic theory for costing the repetitive production of airplane assemblies. The term was introduced to medicine in the 1980s after the advent of minimal access surgery. It also caught the attention of the public and the legal profession when a surgeon told a public enquiry in Britain that a high death rate was inevitable while surgeons were on a learning curve.[2] Recently it has been labeled as a dangerous curve[3] with a morbidity, mortality and unproven outcomes. Yet there is no standardization of what the term means. In an endeavor to help laparoscopic surgeons towards evidence based practices this commentary will define and describe the learning curve, its drawing followed by a discussion of the factors affecting it, statistical evaluation, effect on randomized controlled trials and clinical implications for both practice and training, the limitations and pitfalls, ethical dilemmas and some thoughts to pave the way ahead.

DEFINITION AND DESCRIPTION

For the Wright learning curve, the underlying hypothesis is that the direct man-hours necessary to complete a unit of production will decrease by a constant percentage each time the production quantity is doubled. In manufacturing, the learning curve applies to the time and cost of production. Can a surgeons learning curve be described on similar lines? A simple definition would be : the time taken and/or the number of procedures an average surgeon needs to be able to perform a procedure independently with a reasonable outcome.[1] But then who is an average surgeon ? Another definition may be that a learning curve is a graphic representation of the relationship between experience with a new procedure or technique and an outcome variable such as operation time, complication rate, hospital stay or mortality.[4] A learning curve may also be operationally defined as an improvement in performance over time. Although learning theorists often disagree about what learning is, they agree that whatever the process is, its effects are clearly cumulative and may therefore be plotted as a curve. By cumulative it is meant that somehow the effects of experience carry over to aid later performance. This property is fundamental to the construction of learning curves. The improvement tends to be most rapid at first and then tails off. Hence there are three main features of a learning curve. First, the initial or starting point defines where the performance of an individual surgeon begins. Secondly, the rate of learning measures how quickly the surgeon will reach a certain level of performance and thirdly the asymptote or expert level measures where the surgeons performance stabilizes.[5] This has implications for the laparoscopic surgeon—it suggests that practice always help improve performance but the most dramatic improvement happens first. Also with sufficient practice surgeons can achieve comparable levels of performance.

THE DRAWING OF LEARNING CURVES

There are a variety of methods of constructing learning curves. They all assume that successive exposures in a learning series may be plotted on the *x*-axis, response characteristics on *y*-axis and the data points distributed in the *xy* plane may be legitimately connected by a curve. This is the Cartesian Method.[6] More recently the Cumulative Sum Method has been applied for the construction of these curves for basic skills in anesthetic procedures—the method consists of relatively simple calculations that can be easily performed on an electronic spreadsheet. Statistical inferences can be made from observed successes and failures. The method also provides both numerical and graphical representation of the learning process.[7]

The multimode learning curve is useful because several factors can be put into one graph.[8] The earlier used method of the performance analysis with its on the spot appraisals at certain time intervals has been replaced by continuous assessment. For continuous data like operation time the Moving average method is useful.[9]

FACTORS AFFECTING LEARNING CURVES

A complex hierarchy of factors are involved here.[5] At the bottom factors like guidelines, protocols and standards for clinical governance agreed upon by the medical fraternity are vital. Next the Institutional policies and cost effectiveness are contributory. Needless to say the surgical team, the case mix and public awareness are relevant. The final level in the hierarchy that can influence individual learning is the characteristics of the surgeon such as attitude, capacity for acquiring new skills and previous experience.[10]

Amongst the latter that is the characteristics of the surgeon the learning curve may depend on the manual dexterity of the individual surgeon and the background knowledge of surgical anatomy. The type of training the surgeon has received is also important[11] as training on inanimate trainers and animal tissue has been shown to facilitate the process of learning. The slope of the curve depends on the nature of the procedure and frequency of procedures performed in specific time period. Many studies suggest that complication rates are inversely proportional to the volume of the surgical workload.[12] However rapidity of learning is not significantly related to the surgeons age, size of practice or hospital setting.[13] Another important factor that affects the learning curve is the supporting surgical team. A recent observational study[14] to investigate the incidence of technical equipment problems during laparoscopic procedures reported that in 87% of procedures one or more incidents with technical equipment or instruments occurred. Hence improvement and standardization of equipment combined with incorporation of check lists to be used before surgery has been recommended.

STATISTICAL EVALUATION OF LEARNING CURVES

Various statistical methods have been reported in the assessment of the learning curve.[15] Commonly data are split into arbitrary groups and the means compared by chi-squared test or ANOVA. Some studies had data displayed graphically with no statistical analysis. Others used univariate analysis of experience versus outcome. Some studies used multivariate analysis techniques such as logistic regression and multiple regression to adjust for confounding factors. A systematic review[16] concluded that the statistical methods used for assessing learning curves have been crude and the reporting of studies poor. Recognizing that better methods may be developed in other non clinical fields where learning curves are present (psychology and manufacturing) a systematic search was made of the non clinical literature[17] to identify novel statistical methods for modeling learning curves. A number of techniques were identified including generalized estimating equations and multilevel models. The main recommendation was that given the hierarchical nature of the learning curve data and the need to adjust for covariant, hierarchical statistical models should be used.

EFFECT OF LEARNING CURVE ON RANDOMIZED CONTROLLED TRIALS

The learning curve can cause difficulties in the interpretation of RCTs by distorting comparisons. The usual approaches to designing trials of new surgical techniques has been either to provide intensive training and supervision or require participating surgeons to perform a fixed number of procedures prior to participation in a trial. Surgeons have been reluctant to randomize until they are proficient in a technique but then once convinced of its worth argue that it is too late to randomize. However the best way to address the problem is to have a statistical description of the learning curve effect within a trial and various methods can then be used. Example Bayesian hierarchical model.[5]

IMPLICATIONS FOR PRACTICE AND TRAINING

In the current era of evidence based medicine enthusiasm for laparoscopic surgery is rapidly gaining momentum. There is an immense amount of literature showing advantages of minimal access surgery and acceptance by the public. The learning curve for many procedures has been documented.[18,19,20] As far as training is concerned, the introduction of laparoscopic techniques in surgery led to many unnecessary complications. This led to the development of skills laboratories involving use of box trainers with either innate or animal tissues but lacks objective assessment of skill acquisition.[21] Virtual reality simulators have the ability to teach psychomotor skills. However it is a training tool and needs to be thoughtfully introduced into the surgical training curriculum.[22] A recent prospective randomized controlled trial[23] showed that virtual simulator combined with inanimate box training leads to better laparoscopic skill acquisition. An interesting finding reported is that in skills training every task should be repeated atleast 30 to 35 times for maximum benefit.[24] The distribution of training over several days has also been shown to be superior to training in one day.[25] Other factors enhancing training are fellowship programmer,[26] or playing video games.[27] One can also obtain feedback for improvement of training program. In one such study the deficiency factors[28] identified were lack of knowledge, lack of synchronized movement of the non dominant hand and easy physical fatigue. Incorporation of intensive, well planned invitro training into the curriculum were made and the programme reassessed.

WHAT ARE THE LIMITATIONS OR PITFALLS ?

"Steep" learning curves are usually used to describe procedures that are difficult to learn – however this is a misnomer as it implies that large gains in proficiency are achieved over a small number of cases. Instead the curve for a procedure that requires a lot of cases to reach proficiency should be described as "flattened".[29]

As long as no valid scoring system concerning the complexity of a surgical intervention exists, the learning curve cannot be used as benchmarks to compare different surgeons or clinics as legitimate instruments to rank surgeons or different hospitals.

Limitations of long learning curves, facilities for training, mistakes of pioneers, surgical techniques not being described in books are some of the limitations described.[30]

There are other limitations due to the nature of laparoscopic surgery like the lack of 3D vision and of tactile sensations,[31] difficult hand eye coordination and long instruments.

ETHICAL DILEMMAS

Many dilemmas exist[32] and many questions will always be with us—who bears the burden of the learning curve ? Are the patients aware of the risks ? Many reports validate the impression that a patient operated upon during the learning curve takes greater risks and incurs more adverse circumstances than the patient operated upon later. The issue of how informed the informed consent should be needs to be addressed. Is the integrity and conscience of a surgeon measurable? Should the forces of marketing be curtailed or regulated?

THE WAY FORWARD

Laparoscopic surgery is here to stay and success in it is determined by how quickly and effectively we learn. However certain measures may be taken to lessen some of the adverse effects of the learning curve and others to help laparoscopic surgeons ease into the specialist. Setting up[32] of minimal standards and credentialing is a must. Current guidelines in many countries are vague and general. The evidence for training is well documented. The message for individual surgeons is to identify their deficiencies, and chart a way forward for their personal graph of progress. Evaluation and monitoring in a systematic scientific manner will benefit the surgeon with a satisfactory learning curve that will ensure that patient welfare is not compromised.

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