



MINI-REVIEW

Training in robotics: The learning curve and contemporary concepts in training



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KEYWORDS

Robotic assisted;
Laparoscopic surgery;
Training;
Learning curve;
Parallel learning

ABBREVIATIONS

RALP, robot-assisted laparoscopic prostatectomy;
OT, operating time;
PSM, positive surgical margin;
RPN, robot-assisted partial nephrectomy;
RAA, robot-assisted adrenalectomy;
VR, virtual reality

Abstract Objective: To define the learning curve of robot-assisted laparoscopic surgery for prostatectomy (RALP) and upper tract procedures, and show the differences between the classical approach to training and the new concept of parallel learning.

Methods: This mini-review is based on the results of a Medline search using the keywords ‘da Vinci’, ‘robot-assisted laparoscopic surgery’, ‘training’, ‘teaching’ and ‘learning curve’.

Results: For RALP and robot-assisted upper tract surgery, a learning curve of 8–150 procedures is quoted, with most articles proposing that 30–40 cases are needed to carry out the procedure safely. There is no consensus about which endpoints should be measured. In the traditional proctored training model, the surgeon learns the procedure linearly, following the sequential order of the surgical steps. A more recent approach is to specify the relative difficulty of each step and to train the surgeon simultaneously in several steps of equal difficulty. The entire procedure is only performed after all the steps are mastered in a timely manner. Recently, a ‘warm-up’ before robotic surgery has been shown to be beneficial for successful surgery in the operating room.

Conclusion: There is no clear definition of the duration of the effective learning curve for RALP and robotic upper tract surgery. The concept of stepwise, parallel learning has the potential to accelerate the learning process and to make sure that

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initial cases are not too long. It can also be assumed that a preoperative 'warm up' could help significantly to improve the progress of the trainee.

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Introduction

The concept of the learning curve

The idea of measuring the improvement in a repeated task over time was first described in 1885 by the German psychologist Herman Ebbinghaus [1]. The term 'learning curve' was first used in 1909 by Bryan and Harter, referring to a diagram plotting the acquisition of a telegraphic language over time. Their curve showed an initial steep rise, followed by a flattening, and was thereby convex to the vertical axis.

Widespread attention was given to the concept of the learning curve in 1936, as it was used by Wright [2] to measure the effect of learning on production costs in the aircraft industry. He showed that the cost of aeroplanes decreased with the increase in the number manufactured and based his idea on the hypothesis that if an operation is repeated it would take less time to perform. The curve itself was therefore a representation of the number of repetitions needed to decrease the time spent to complete the task.

A popular understanding of the speed of acquisition of a complex task is that it follows a sigmoid shape. It has a slow rise at the beginning, where the operator becomes accustomed to the equipment. This initial phase of slow learning is followed by a steep rise of the curve with a phase of quick learning, which reaches a plateau after expertise has been gained, and further progress then becomes difficult and slow. However, this sigmoid shape has not been reproduced in relevant reports, as the speed at which the skill is acquired has not been measured, but several other surrogate variables are assessed, as discussed below.

The learning curve for robot-assisted laparoscopic radical prostatectomy (RALP) and cystectomy

RALP has become a widely accepted therapeutic option for organ-confined prostate cancer and is replacing conventional open surgery and laparoscopy [3]. Despite many publications there is still no consensus on how many procedures are needed to overcome the initial learning period, and totals of 8–150 have been reported [4,5], with most estimating that an experienced open surgeon needs 18–45 cases to safely perform RALP independently [6]. This great variability is due to the lack of a standard definition of the appropriate outcome measure [7]. For example, one commonly used endpoint is attaining the ability to perform the procedure safely

regardless of the time needed. This can lead to unfavourably long operating times (OTs) for the initial patients, with the inherent disadvantages. Therefore, in some studies a 4-h period has been used as an acceptable endpoint [4,8]. Other endpoints commonly used are oncological and functional outcomes, estimated blood loss, the rate of complications, or the surgeon's subjective feeling of being comfortable and proficient with the procedure. Interestingly, when assessing the learning curve as defined by the rate of positive surgical margins (PSMs) and the OT, many procedures seem to be needed to reach a minimum. In a recent publication the mean OT reached a plateau only after 750 procedures, and it took 1600 operations to reach a PSM rate of <10% [9].

Robot-assisted radical cystectomy is less common than RALP, but worldwide its use is increasing. Reports on the learning curve remain sparse. Interestingly, despite being a highly complex procedure, the International Radical Cystectomy Consortium reported a mean of only 30 procedures needed to reach standard endpoints of OTs, node counts and PSM rates [10].

The learning curve for robot-assisted upper tract surgery

For small renal masses, nephron-sparing surgery has become the standard treatment, and the number of centres reporting their experience with robotic partial nephrectomy (RPN) is steadily increasing. The technical advantages of the da Vinci system (Sunnyvale, CA, USA) are regarded as similarly beneficial for the precise excision of the sometimes difficult-to-reach renal masses as they are for pelvic surgery. The oncological and functional outcomes of the first published case series have been reported to be equivalent to the established techniques [11,12]. In reports assessing the learning curve of RPN the commonly used endpoints are the OT, warm ischaemia time and PSM rate, and 20–30 procedures are proposed as enough to become proficient, at least for surgeons experienced in minimally invasive procedures [13,14].

For other upper tract procedures data remain sparse but for robotic paediatric pyeloplasty, Sorensen et al. [15] showed that for experienced open surgeons there was a continued decrease of the OT with increasing experience, which became similar to that of open pyeloplasty after 15–20 procedures.

For robot-assisted adrenalectomy (RAA) there was only one report specifically assessing the learning curve. In a prospective study, 50 patients who underwent unilateral RAA were compared to 59 who underwent

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