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Evolving Role of Simulators and Training in Robotic Urological Surgery

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1. Introduction

The evolution of minimally invasive urological extirpative and reconstructive surgery from the conventional laparoscopic approach to the now widely accepted robotic platforms has entered a new phase. The robotic approach is now considered the gold standard across various centres. With the current and near exponential uptake of the robotic platforms, come challenges for both trainers and trainees. Therefore a demand for up to date training and assessment curriculum is increasing. Currently, training in robotics is not globally standardised, centralised or structured.

Training can be at the work place or in a simulated environment. Whereas simulation is not purported to be an alternative, it can supplement and act as an adjunct to the 'real' environment. Like other craft disciplines such as general surgery and interventional radiology, urology is embracing the increasingly effective role in simulation-based training.

This article aims to identify available training modalities for robotics in urology, highlight deficiencies in the current literature and to provide recommendations for training in robotics based on the current evidence.

2. Available training modalities and their effectiveness

Modern urology training encompasses open surgery along with endoscopic, laparoscopic and more recently robotic surgery. As traditional apprenticeship methods has been shown to be useful for open and some laparoscopic cases, whereby the mentor 'holds' the trainee's hand during the learning phase. This has changed with the introduction of the robotic platform. There is wide variation to what is considered as the 'learning curve' for any given robotic surgical procedure. A structured training and mentoring programme can expedite a

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surgeon's progress in a safe and effective manner from preclinical to table side assistant role and finally to the robotic console.

Surgical simulators have proven to improve the performance in laparoscopic suturing techniques [1]. Virtual reality robotic surgical training offers to shorten the learning curve through repeated simulation of tasks without posing the logistical and ethical challenge of using animal models [2]. A virtual reality robotic simulator for the da Vinci system has recently been tested and appears to be promising, with further research being carried out to improve its efficiency [3].

In an American study using preclinical surgical robotic programme with animal model, the learning curve was found to be shortened whilst reducing the set-up and operative time [4]. It allows refinement of surgical technique prior to use in humans. Robotic surgical training system also allows for technical improvement whilst monitoring and reducing errors and allowing evaluation of performance [5]. An earlier study using Zeus robotic surgical system on laparoscopic trainer, showed faster timings for more experienced surgeons [6]. A systematic training approach for robotic prostatectomy with a step by step assessment and progression has been advocated for a safe and proficient training [7].

Robotic surgical training has now been incorporated in structured training programmes [7-9]. With structured training, no significant adverse impact on outcomes was seen for robotic prostatectomy done by urology fellows for over 1800 patients in a high volume centre [8]. Using a robotic surgical simulator (RoSS),'Hands-On Surgical Training (HOST)' software has been developed recently [10]. This prompts and helps in real-time during the procedure along with evaluating performance and progression. The lack of haptic feedback with traditional robotic training and surgery [11], was overcome with the dv-Trainer, a virtual reality simulator for da Vinci Surgical System [12]. Although still being developed, the authors conclude that the haptic feedback, virtual reality and instrumentation all achieved acceptability.

A 5-day mini robotic fellowship with tutorials, lectures, clinical observership, animal and cadaveric training showed 86% participants performing robotic prostatectomies at 3 years [13]. A system of extended-proctorship programme for robotic prostatectomy has been advocated as a part of post-graduate training in a 3-phase curriculum [14]. The first phase consisted of a 2-day robotic training course wherein stepwise instructions on using the da Vinci robot were given, with time to practice camera and clutching navigation. This was combined with tasks on practical skills such as dissection and suturing on a porcine model including nephrectomy and urethrovesical anastomosis. The second phase comprised of assisting the proctor in 5-6 robotic prostatectomies. Finally, more console autonomy was given as the training progressed, eventually with proctors assisting the trainees whilst providing feedback to them. With gradual progression, the steps performed increased from easier steps such as port placement to more complex difficult steps such as urethrovesical anastomosis and performing nerve-sparing technique. Their programme received a rating of 4.2/5 for effectiveness in robotic training skills, with an average of 20 cases performed in phase 3 before practicing independently.

Although the animal model and virtual reality da Vinci training can provide simulation experience, resource limitation and ethical dilemma prevent their widespread use. With robotic surgery continuing to develop and expand, there is an urgent need for investment

into other forms of simulators and training, including the use of virtual reality and synthetic models for training.

3. Trainee impact on patient outcomes

With the rapid uptake of robotic urological surgery, the question as to the impact of the learning curve on patient safety, including oncological control, is under scrutiny. Opinion varies amongst expert consensuses.

In a study looking at the pathologic outcomes during the learning curve for robotic-assisted laparoscopic radical prostatectomy, Shah et al. reported their initial experience with 62 patients undergoing robotic-assisted laparoscopic prostatectomy (RALP), focusing on the primary parameter of positive surgical margins [19]. Their study seemed to suggest that RALP could have equal if not better pathologic outcomes compared to open radical prostatectomy even during the initial series of cases. They argued that the learning curve for RALP is shorter than previously thought. They concluded that previous purported concerns with respect to oncological outcomes as a result of lack of tactile feedback were unfounded. Schroeck et al. [20] evaluated the learning curves and perioperative outcomes of an experienced laparoscopic surgeon and his trainees to gain some insight into the question of whether trainees negatively impact on the institutional learning curve for robotic prostatectomy as characterized by operative time, estimated blood loss, and positive surgical margin rate. They concluded that a structured teaching program for RALP is effective and that trainees did not negatively affect the estimated blood loss and positive surgical margin rate. Pruthi et al. sought to evaluate the learning curve of robot-assisted laparoscopic radical cystectomy by evaluating some of the surgical, oncological, and clinical outcomes in our initial experience with 50 consecutive patients [21]. In their series of 50 cases they found that despite the higher blood loss that is observed early in the learning curve, no such compromises were observed with regard to these oncological parameters even early in the experience.

Hong et al. postulated that a definitive RALP "learning curve" has not been defined and that existing learning curves do not account for urologists without prior advanced laparoscopic and robotic skills [22]. They proposed 'an easily evaluable metric' i.e. "oncological experience curve," that could potentially be clinically useful to all urologists performing RALP. They found in their study that the oncological experience curve may be much longer than the previously reported learning curves. They concluded that surgeons should consider whether they can build enough experience to minimize suboptimal oncological outcomes before embarking on or continuing a RALP program. Kwon et al. attempted to prospectively compare outcomes during robotic prostatectomy between surgeons with formal training in either robotic prostatectomy (RALP) or laparoscopic prostatectomy (LRP) [23]. Twelve urologists conducted 286 robotic prostatectomies of which 4 surgeons had formal training in RALP and 8 had formal training in LRP. They prospectively compared surgical and pathologic outcomes between these 2 groups of surgeons. They found that the robot-trained surgeons had 10%-15% shorter procedure times. There was no difference in complication rates. They concluded that formal RALP training may be beneficial for surgical and pathologic outcomes of RALP compared with formal LRP training during the initial implementation of a new robotics program.

Currently, there is no published consensus on overall impact of robotic trainees and/or early learning curve on patient outcomes. There are no well structured studies that correlate the effectiveness of training (real or simulated settings) with patient morbidity or mortality data. The few studies conducted looking at other parameters, seem to suggest that there is no adverse impact. However, most of the studies were conducted in centres of excellence and/or high volume units with seeming dedicated and structured mentoring. More studies are required to stratify the direct impact of trainees on outcomes.

4. Problems with the existing training system and tools

The future of robotic training depends on the acceptance of this technology both at the consumer and provider levels [15]. The past decade has witnessed a rapid increase in robotic surgical procedures in terms of its frequency and innovations. Several structural and organizational queries must be addressed before the acceptability and feasibility of the training methods: First, do the results of the existing methods of training are comparable to the patient outcomes? Second, is the skill training on simulators is transferable to the real settings? Third, do we know whether the learning curve can be reduced with additional training on simulators? Fourth, are the new tools cost effective and will they be acceptable by the trainers and trainees? and finally, what is the educational impact of the simulation based training? Geographical variation in the standards of training is a key factor that can affect national and international recognition of training. For instance, all of the European Union (EU) states have certification programs that are significantly different in terminology, guidelines, training and assessment frequency [16]. This may result in issues such as acceptability and feasibility. The system needs to be harmonized to increase the level of acceptability across various regions (**Figure 1**). The existing literature doesn't look into the psychological aspects of training. Training models such as Ericson theory, Schimdt theory and theory of deliberate practice need to be consulted whilst researching various training tools [17, 18].

5. Future recommendations

In a survey of Residency Training in Laparoscopic and Robotic Surgery Duchenea et al. in 2006 attempted to determine the status of residency training in laparoscopic and robotic surgery in the United States and Canada [24]. A total of 1,188 surveys were sent via the Internet to all 1,056 urology residents and 132 program directors. It was noted that a large number of laparoscopic urological procedures were being performed at training institutions with robotic procedures being performed at just over fifty percent of the facilities. Trainees were participating in most cases but only 38% consider their laparoscopic experience to be satisfactory. The study concluded that there was a need for increased laparoscopic training among residents. It was noted that one way of tackling this is to expand training facilities and increase the number of mentors actively performing and tutoring trainees.

Kommu et al. attempted to delineate a preliminary rank stratification of the top ten indices of the ideal robotic urological training programmes [25]. The trainees were asked to rank the top fifteen indices, in the first instance, which they felt represented the ideal robotic
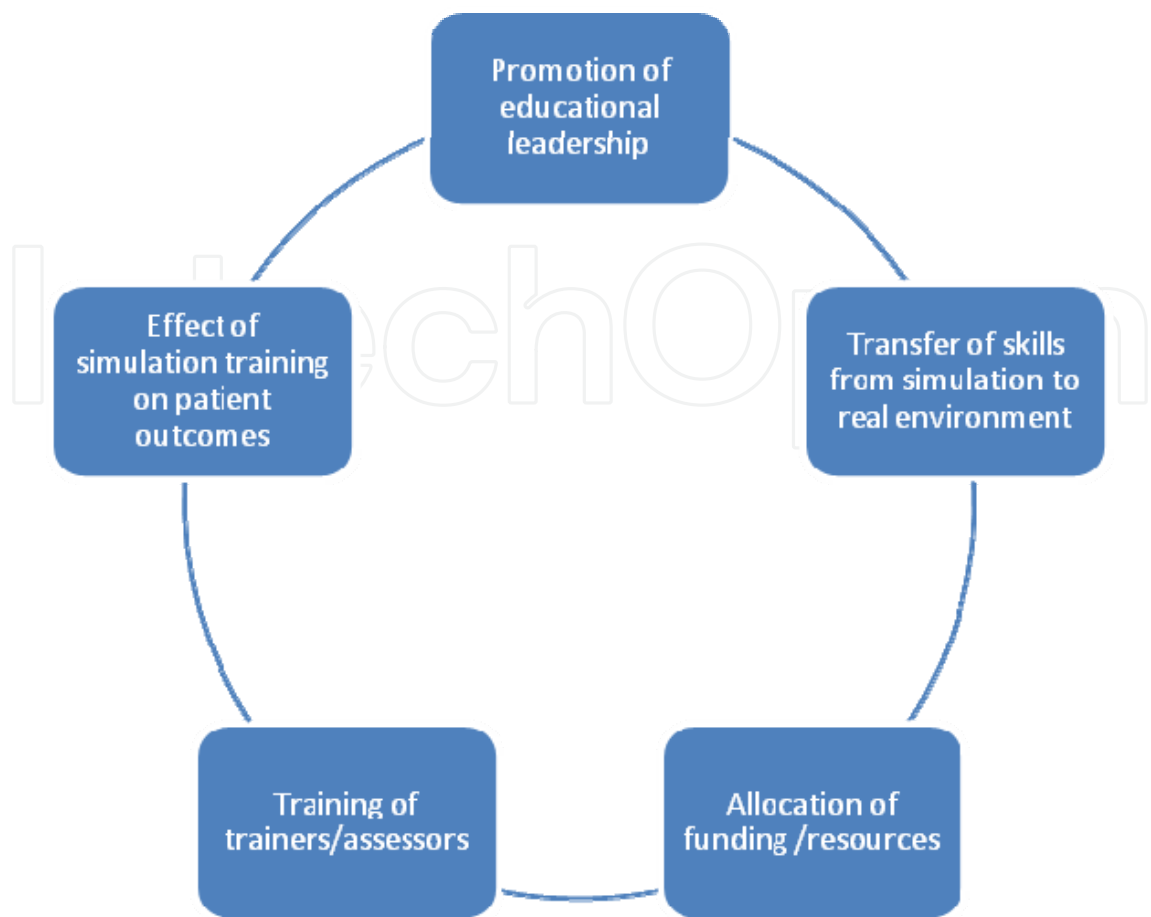
Fig. 1. Issues with the current training system/tools

urological training programmes. One hundred and eighty randomly chosen participants from a database pool of known trainees globally were sent a standard questionnaire by email. The response rate was 84%. The results when tallied in rank order of importance were as follows: 1. Funding and economic constraints, 2. Dry lab training facilities on site, 3. Courses and Meetings, 4. Wet/Animal lab training, 5. Balance and volume of cases, 5. Trainee activity restricted to RAUS only, 6. Mentor/Faculty Resources including feedback facilities, 7. High training time to service provision ratio, 8. Research activity, 9. Attendance by Global Faculty of experts and 10. Streamlining of a dedicated post/job following training period. They concluded that the top ten indices for the ideal Robotic Urological Training Programmes are based on the themes of funding and ease of accessibility to training resources such as courses, hands on training and volume of cases. Knowledge of the identified indices could help training units to further tailor their programmes. They added that their findings could act as a preliminary platform for initiation of subsequent benchmarks for optimal training. Future challenges include establishment of evidence based centralised training programmes that are cost effective. Training of the trainers and assessors is also an important issue that needs considerable research and allocation of funding by the training organisations [26]. Any established training programmes would need general acceptability by the healthcare organisations and trainees. Research to evaluate the effect of simulation training on the outcomes [27].

6. Conclusions

Because of rapidly evolving innovations, increasing recognition of adverse events, changes affecting structure of training and the more demand for objective assessment, there is an urgent need for revision of training programs [27,28,29]. Training in robotics need new set of skills that are altogether different from open technical skills (**Figure 2**). Basic-level technical skills such as hand-eye coordination can be learned on synthetic bench model simulations and animal tissue. Intermediate and advanced technical skills require high fidelity simulations. At a senior level, supervised (mentoring) robotic procedures on patients are crucial to training and should be assessed regularly using objective methods. These objectives can be achieved by introducing a more focused training and assessment pathway, with the further development and validation of simulation models.
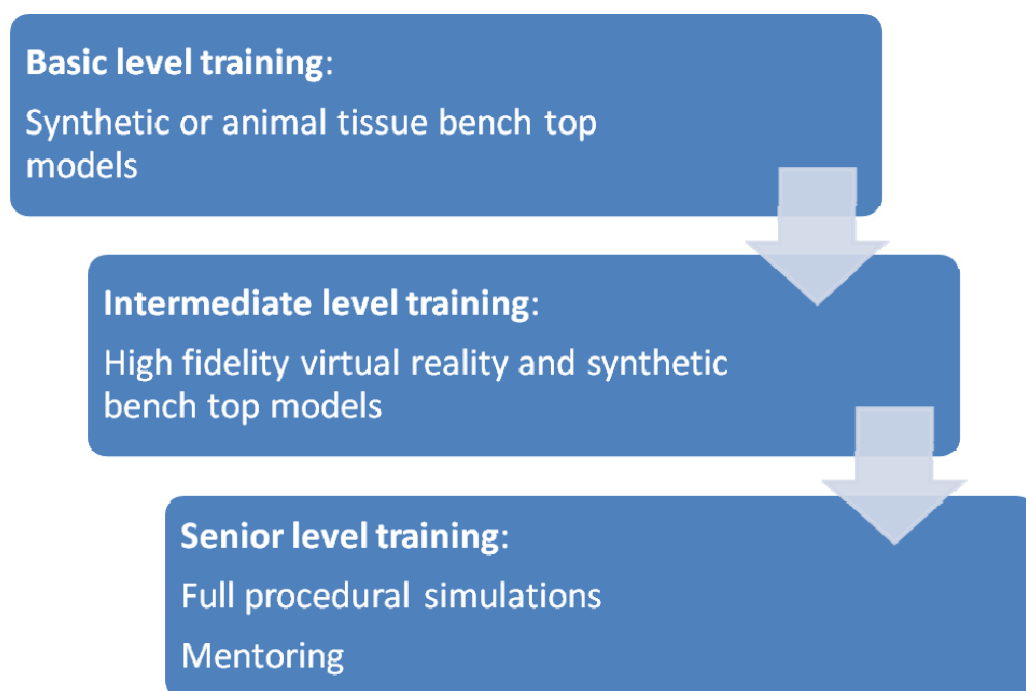
Basic level training:
Synthetic or animal tissue bench top models

Intermediate level training:
High fidelity virtual reality and synthetic bench top models

Senior level training:
Full procedural simulations
Mentoring

Fig. 2. Recommendations for training curriculum.

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