Original Article

The application of virtual reality training for anastomosis during robot-assisted radical prostatectomy

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Abstract *Objective:* To investigate the application of virtual reality training in vesicourethral anastomosis during robot-assisted radical prostatectomy (RARP).

Methods: Three certified robotic urologists who underwent virtual reality training were enrolled in the study group. The other three without training were enrolled in the control group. Parameters were recorded before and after the training. Then a total of 18 patients undergoing RARP were enrolled and randomized assigned to receive anastomosis procedures with certified urologists who either obtained or did not obtain training. The quality of the anastomosis was evaluated.

Results: For the virtual training evaluation, the overall score was significantly improved from 65.0 ± 10.8 to 92.7 ± 3.5 ($p=0.014$); the time of anastomosis was shortened; the economy of motion improved; instrument collisions decreased after training ($p<0.05$). Besides, the effectiveness of the virtual training was evaluated in the 18 real anastomosis procedures which were completed either by three urologists with training or three urologists without training. Most intriguingly, the average time of anastomosis was shortened from 40.0 ± 12.4 min to 25.1 ± 7.1 min ($p=0.015$). The parameters including time of operation, creatinine level of drainage, postoperative hospital stay and duration of catheter drainage were comparable before and after training. Two leakages, which were observed in procedures by doctors without training, needed salvage sutures by a senior doctor.

Conclusions: Virtual reality training enabled surgeons to become quickly familiar with robotic system manipulation, improved their skills for vesicourethral anastomosis and shortened the learning curve, thus helping them operate with high efficacy and quality.

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1. Introduction

Prostate cancer is one of the most common malignancies in men worldwide [1]. Radical prostatectomy is an effective treatment option for localized prostate cancer [2]. In 1999, the first robot-assisted radical prostatectomy (RARP) was performed [3]. Compared with laparoscopic radical prostatectomy, the robotic system has the advantages of flexible operation and favorable stabilities. The prostate resides in the pelvis, surrounded by a steep and narrow space, and thus it is the optimal candidate for robotic surgeries [4]. Vesicourethral anastomosis is one of the most difficult parts of radical prostatectomy. The robotic system can decrease its degree of difficulty and improve its quality due to the three-dimensional vision and "wristed instruments". In recent years, the robotic system has been widely adopted in urological surgeries. There are currently more than 2000 robotic systems in the United States and 500 in Europe [5]. With the increased adoption of the da Vinci Robotic System in China, robotic surgeries are growing exponentially. An increasing number of urologists are learning to master this system. At present, Intuitive Surgical Inc. (Sunnyvale, CA, USA) provides trainees with a 2-day training course. On Day 1, trainees are taught fundamental knowledge, including an "overview of the robotic system", "trouble-shooting", and "robotic system installment". On Day 2, trainees attend a full day of hands-on training sessions using a porcine subject at a da Vinci Training Center. After the course, trainees are certified to operate with the robotic system. Compared with laparoscopic surgery, the robotic system is quite different in that it takes more time for trainees to master control of the third arm and adapt to three-dimensional vision and control of the camera, which cannot be accomplished in a 2-day training course. Limited experience of the surgeon with a robotic system could result in increased perioperative and postoperative complications. The robotic system provides multiple virtual reality training modules, enabling novice urologists to master basic skills quickly and shortening their learning curve. With these goals achieved, urologists can offer patients operations with optimal safety and quality. In this study, we trained certified robotic urologists with a virtual reality training course. The certified robotic urologists subsequently performed vesicourethral anastomosis with high quality.

2. Patients and methods

2.1. Patients

Six certified robotic urologists were enrolled in the study. Three urologists who underwent virtual reality training were enrolled in the study group. The other three urologists without training were enrolled in the control group. All six urologists have laparoscopic radical prostatectomy experience but no RARP experience.

2.2. Methods

2.2.1. Phase one: Fundamental skills training
Three urologists were trained using virtual reality training to become familiar with the "Surgeon Console Overview", "EndoWrist Manipulation", "Camera and Clutching", "Energy and Dissection" and "Needle Control and Suturing".

2.2.2. Phase two: Virtual anastomosis
A total of 20 "Tubes" exercises were completed using the robotic virtual reality training system for each trainee. Parameters, such as overall score, time of anastomosis, economy of motion, instrument collisions, instrument out of view and missed targets were recorded before and after training. Data before and after training were compared to assess the quality of the virtual training.

2.2.3. Phase three: Clinical implementation
A total of 18 patients undergoing RARP were enrolled and grouped to receive the anastomosis procedures with urologists who were either certified with (study group) or without (control group) virtual reality training. The detailed information of patients' background was summarized in Table 1. All 18 procedures were supervised by an experienced senior doctor. The suture technique we used is the Van Velthoven Single-Knot Running Suture without bladder neck reconstruction and posterior rhabdosphincter reconstruction. This study is approved by the institutional review board (IRB) of Changhai Hospital, Shanghai, China (No: B2018-026A). All patients gave written informed consents. Nine vesicourethral anastomosis procedures were completed by three certified urologists without virtual reality training, and the other nine procedures were completed by three certified urologists after virtual reality training. Lymph node dissection was not performed in enrolled patients. Time of anastomosis and the entire operation, creatinine of drainage, postoperative hospital stay and duration of catheter drainage were recorded and compared between the two counterparts. The leakage tests were administered using a 60 mL 0.9% NaCl vesicourethral anastomosis.

2.3. Data analysis

SPSS software ver. 16.0 (SPSS Inc., Chicago, IL, USA) was used to perform the statistical analysis. Continuous and normally distributed variables were expressed as the mean±standard deviation. Baseline variables in patients of study and control group were compared using independent-samples t-test or Pearson's Chi-square test. Parameters

Table 1 Baseline variables in 18 patients undergoing RARP.

Variable	Without training (n=9)	Training (n=9)	p-Value
Age (year)	67.8±4.9	65.1±5.6	0.302
Serum PSA (ng/mL)	12.5±4.6	12.2±4.1	0.232
Prostate volume (cm^3)	33.3±5.9	35.3±9.8	0.618
BMI (kg/m^2)	23.3±2.3	24.2±2.0	0.401
Clinical stage (%)			0.672
T1c	3 (33.3)	2 (22.2)	
T2a	3 (33.3)	4 (44.4)	
T2b	2 (22.2)	3 (33.3)	
T2c	1 (11.1)	0 (0)	
Gleason score (%)			0.492
6	1 (11.1)	2 (22.2)	
7	7 (77.8)	6 (66.7)	
8	1 (11.1)	0 (0)	
9−10	0 (0)	1 (11.1)	

RARP, robot-assisted radical prostatectomy; BMI, body mass index; PSA, prostate-specific antigen.

before and after the virtual reality training for anastomosis were compared using paired-sample *t*-test. Parameters with and without training for anastomosis were compared using independent-samples *t*-test. Values of $p<0.05$ were considered statistically significant.

3. Results

3.1. Parameters were improved after virtual reality training

All urologists successfully completed the fundamental skills and virtual anastomosis training. After the 20 virtual anastomosis training sessions, the overall score improved from 65.0±10.8 to 92.7±3.5 ($p=0.014$), the average time of anastomosis decreased from 279.0±48.0 s to 119.3±12.5 s ($p=0.005$), and the economy of motion improved from 459.0±59.2 cm to 239.3±33.9 cm ($p=0.008$). There were also significantly fewer instrument collisions ($p=0.018$). Instrument out of view and missed targets were comparable before and after virtual training. The results are summarized in Table 2.

3.2. Surgical skills were improved after virtual reality training

A total of 18 operations of RARP were completed. The parameters of the two groups were comparable in terms

of age, body mass index, tumor stage and Gleason score. The six urologists completed 18 vesicourethral anastomosis procedures without complications. Most intriguingly, the average time of anastomosis was shortened from 40.0±12.4 min to 25.1±7.1 min ($p=0.015$). The parameters time of operation, creatinine level of drainage, postoperative hospital stay and duration of catheter drainage were comparable before and after virtual reality training (Table 3). However, two leakages were observed after the leakage tests during the operations. Salvage sutures were given by a senior doctor. The creatinine level of drainage was within the normal range. No leakage of urine was observed.

4. Discussion

In recent years, robotic systems have become widely installed across China. Prostatectomy is best suited for robotic systems as the prostate resides in the narrow and steep pelvis. By analogy with laparoscopic surgery, RARP is advantageous in decreasing the intraoperative blood loss, shortening the urethral catheter indwelling time and reducing perioperative complications [6]. Therefore, the robotic system is widely adopted in urological surgeries. As the robotic system has been used for only a few years, experience in its training is limited. Efficient training of young surgeons on this technology has become a major concern [7]. For urologists with previous experience in

Table 2 Parameters before and after the virtual reality training.

Parameter	1st training	20th training	p-Value
Overall score	65.0±10.8	92.7±3.5	0.014
Time of anastomosis (s)	279.0±48.0	119.3±12.5	0.005
Economy of motion (cm)	459.0±59.2	239.3±33.9	0.008
Instrument collisions	7.0±2.0	1.3±1.5	0.018
Instrument out of view	0±0	0±0	>0.05
Missed targets	4.7±0.6	3.3±1.2	0.148

Table 3   Parameters with and without the virtual reality training.

Parameter	Without training	Training	p-Value
Time of anastomosis (min)	40.0±12.4	25.1±7.1	0.015
Time of operation (min)	162.2±26.3	144.2±24.2	0.162
Estimated blood loss (mL)	121.1±40.14	130.0±55.22	0.701
Blood transfusion	0	0	N/A
Creatinine of drainage (μmol/L)	66.7±11.5	63.8±13.1	0.545
Postoperative hospital stay (day)	4.2±1.0	3.6±1.1	0.111
Duration of catheter drainage (day)	4.3±0.5	3.8±0.8	0.095

N/A, not available.

open and laparoscopic radical prostatectomy, their main concern is how to proficiently and accurately manipulate the robotic system, as they are already familiar with surgical anatomy and steps. It is generally accepted that a minimum of 10 h of training is required to become familiar with the robotic system [8]. Furthermore, vesicourethral anastomosis needs to be performed in a narrow space with great accuracy, which sets a high standard for the urologist's skills. It is of utmost importance to improve the urologist's skills in anastomosis, as the quality of vesicourethral anastomosis has a direct impact on patients' postoperative continence and quality of life. Simulators and animal models for robotic surgeries have become highly developed in recent years. However, these simulators are not widely installed, preventing urologists from receiving better training. Virtual reality training has overcome this shortcoming because urologists can be trained at any time with this technology [9]. It has greatly shortened the learning curve and decreased perioperative complications [10,11]. Thiel et al. [12] reported that approximately 84% of trainees believed that the simulation replicated real-life operation and more than 90% of trainees regarded the training as helpful. Shetty et al. [13] reported that more than 95% trainees believed that virtual reality training improved their laparoscopic skills and that the skills learned during the training were transferrable to the operating room.

In this study, we adopted virtual reality training to teach vesicourethral anastomosis step by step. First, the trainees quickly familiarize themselves with fundamental skills through modules, such as "Camera and Clutching", "EndoWrist Manipulation", and "Needle control and Suturing". Subsequently, they can tailor the camera to the operation field and suture proficiently using EndoWrist. Vesicourethral anastomosis differs from ordinary sutures in that it is performed in a narrow space and requires high accuracy. The key is to expose the operation field and suture meticulously. The "Tubes" exercise provided by Mimic™ replicates vesicourethral anastomosis. Our study indicates that trainees' skills improved significantly through virtual reality training. The average time of anastomosis decreased from 279.0±48.0 s to 119.3±12.5 s with a 57.2% reduction (p=0.005), and the average time of anastomosis during real operations also decreased significantly (p=0.015). More importantly, all vesicourethral anastomosis procedures in nine patients were successfully performed by trainees after virtual reality training without the intervention of a senior doctor.

However, two leakages were observed in procedures by doctors without training and needed salvage sutures by a senior doctor. This indicates that virtual reality training enabled surgeons to become quickly familiar with the robotic system manipulation and helped them to operate vesicourethral anastomosis with high efficacy and quality.

This study has a few limitations. First, there are few young certified robotic urologists; therefore, our study included only six urologists (three urologists in the study group and the other three urologists in the control group). Consequently, the results may be biased. Second, only one procedure, vesicourethral anastomosis, was evaluated in the study, which may hinder us from qualitatively evaluating the improvement of robotic skills. Third, although the simulator could enable surgeons to improve their skills for vesicourethral anastomosis and may shorten the learning curve, learners should always bear in mind there are some drawbacks of the virtual training. The procedure of real suture technique is much more complex than that of the virtual training. Besides, the virtual training could not simulate the preparations of bladder and urethra ends before suture and the various urgent situations that surgeons may encounter during suture, which will elicit much more barriers for surgeons to complete the procedures. Further large-scale multi-center study is needed to confirm our findings.

5. Conclusion

Virtual reality training enabled surgeons to become quickly familiar with robotic system manipulation. It also improved their skills for vesicourethral anastomosis and shortened the learning curve, thus helping them operate with high efficacy and quality.

Author contributions

Study concept and design: Fubo Wang, Fei Guo, Xiaoying Lu, Bo Yang.
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Conflicts of interest

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