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ORIGINAL ARTICLE

Dual-console robotic surgery: a new teaching paradigm

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Abstract Robotic surgery has emerged as an alternative option in minimally invasive gynecologic surgery. The development of the dual-console da Vinci Si Surgical System® has enabled modification of the training atmosphere. We sought to investigate operative times and surgical outcomes while operating with the dual-console model in a training environment for our first fifty cases. We identified the first fifty patients who underwent robot-assisted total hysterectomy (TRH), with or without bilateral salpingo-oophorectomy (BSO), with or without pelvic and para-aortic lymph node dissection (PPALND), by use of the dual-console robotic system. Records were reviewed for patient demographics and surgical details. All surgery was conducted using the dual-console system and performed by staff physicians and fellows. Operative time was calculated from robotic docking until completion of the procedure. Cases were identified from November 2009 through July 2010. Mean age was 56.2 years (SD 13.35, 95 % CI 52.46–59.86). Mean BMI was 29.5 (SD 7.67, 95 % CI 27.35–31.61). Seventy-eight percent of these patients were considered overweight, including 12 defined as obese (BMI 30–34.9) and 10 patients classified as morbidly obese (BMI $\geq$ 35). Surgery completed included PPALND alone ($n = 1$); radical hysterectomy ($n = 1$); TRH only ($n = 3$); TRH/BSO ($n = 25$); and TRH/BSO/PPALND ($n = 20$). Mean total operating room time was 188.8 min (SD 55.31, 95 % CI 173.45–204.11). Mean total surgical time for all cases was 118.1 min (SD 44.28, 95 % CI 105.87–130.41). Two vascular injuries were encountered, with one requiring conversion to laparotomy. These results compare favorably with historically reported outcomes from single-console systems. Utilizing the dual-console enables use of an integrated teaching and supervising environment without compromising operative times or patient outcomes.

Keywords Robotic surgery · Dual-console · Teaching program

Introduction

Robotic surgery has emerged as an alternative option in minimally invasive gynecologic surgery with increasing penetration into the world of gynecologic oncology. Multiple studies have described the feasibility, efficacy, safety, and adequacy of this approach in managing gynecologic malignancies [1–4]. The da Vinci Surgical System® (Intuitive Surgical, Sunnyvale, CA, USA) has advantages over traditional laparoscopic hysterectomy, including three-dimensional imaging, instruments with wrist-like range of motion, elimination of the fulcrum effect, and faster learning [5]. In a recent survey of Society of Gynecologic Oncology (SGO) members, respondents cited an overall increase in the use of and perceived indications for minimally invasive surgery in the field of gynecologic oncology. In addition, 66 % of physician surveyed planned to increase their use of robotic assisted surgery within the upcoming year [6].

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Incorporation of robotics into a training environment has been difficult because of the one-surgeon and one-surgery mentality of robotics. Successful training programs have utilized a process involving progressive involvement of additional surgeons, fellows, and residents [7]. Reviews have shown that it can take 20–100 surgeries for a surgeon to reach stable operating times and surgical proficiency when utilizing the robot [3, 8–10]. With the release of the dual-console da Vinci Si Surgical System® (Intuitive Surgical) in 2009, a redefinition of the training atmosphere for new surgeons has emerged. We sought to investigate outcomes, specifically operative time and surgical outcomes, while operating with the dual-console model in a training environment for our first fifty cases.

Materials and methods

After obtaining Institutional Review Board approval, we retrospectively identified the first fifty patients who underwent robot-assisted surgery using the dual-console da Vinci Si Surgical System® at Magee-Womens Hospital of UPMC. No patients were excluded from analysis. Decision to perform robotic surgery was left to the discretion of the attending physician and the availability of the robot. This cohort of patients came from all staff physicians at our institution trained in use of the robot (SR, TK, and AO). These physicians were accompanied by the clinical gynecologic oncology fellow assigned to the inpatient service at the time of this review. All patients gave appropriate informed consent before the procedure.

The primary endpoint was total surgical time. Additional endpoints included estimated blood loss (EBL) and complications. Records were reviewed for patients' age, body mass index, pre-operative diagnosis, and procedure. Surgical time was calculated from robotic docking until completion of the procedure. EBL was determined by measurement as documented in the anesthesia records.

All procedures were performed with the dual-console da Vinci Si Surgical System® with two operating surgeons and at least one bedside assistant. Operating surgeons consisted of an attending staff physician and a gynecologic oncology fellow, each at their respective console. A resident physician was used as bedside assistant during these first cases for uterine manipulation, suction/irrigation, and specimen extraction as indicated. Although the staff physicians had completed the required off-site training and proctored cases to be certified for use of the robot, the cases identified in this cohort were the initial cases for each physician. Fellows and resident physicians had only received in-house training before assisting with the surgery.

The robotic surgical technique used is similar to that found on the Intuitive Surgical Instructional website for robotic hysterectomy. Uterine manipulation was accomplished with the V-Care uterine manipulator (Conmed, Utica, NY, USA). Three 8-mm robotic trochars, a 12 mm camera port, and a 12 mm bedside assistant port were used. For the purposes of these procedures, the primary surgeon controlled two robotic arms, one on either side of midline. These instruments were the primary operating instruments for the procedure. The second surgeon controlled the third robotic arm and assisted primarily with retraction and manipulation of the uterus with a da Vinci Prograsp. Parts of the surgery were shared between the operating surgeons at each console.

Before surgery all patients underwent mechanical bowel preparation and received appropriate pre-operative antibiotics. DVT prophylaxis consisted of intra-operative pneumatic compression stockings and post-operative Enoxaparin therapy. All patients were admitted after their surgery for inpatient observation. Complications were recorded up to 90 days post-operatively.

Characteristics of the study population and study endpoints were analyzed and described by use of the usual statistics: mean with standard deviation and 95 % confidence intervals (CI). All 95 % CIs for proportions were estimated using the exact binomial distribution. Linear regression analysis was used to examine associations between several variables and case number performed. Cases were identified in the order which they were performed, cases one through fifty.

Results

Of the fifty patients included in this study, the mean age was 56.2 years (SD 13.35, 95 % CI 52.46–59.86). Mean BMI was 29.5 (SD 7.67, 95 % CI 27.35–31.61). Seventy-eight percent of these patients were considered overweight, including 12 defined as obese (BMI 30–34.9) and 10 classified as morbidly obese (BMI $\geq$ 35). Demographic data are listed in Table 1.

Most of the patients in this cohort were operated on for endometrial cancer ($n = 22$), adnexal mass ($n = 12$), or endometrial hyperplasia ($n = 11$). Remaining pre-operative diagnosis included dysfunctional uterine bleeding ($n = 3$) and cervical cancer ($n = 2$; Fig. 1). Forty-six patients underwent a robotic hysterectomy with bilateral salpingo-oophorectomy and three had a robotic hysterectomy alone. Lymphatic staging occurred in 44 % (22/50) of these patients, including one patient who had an interval staging for endometrial cancer. Mean total operating room time (from induction of anesthesia to patient extubation) for the first fifty cases was 188.8 min (SD 55.31, 95 % CI 173.45–204.11). Mean total surgical time (from robotic docking to skin incision closure) for all cases was

Table 1 Pre-operative characteristics

Age (years)	
Mean	56
Median	57.5
Range	22–87
BMI (kg/m^2)	
Mean	30
Median	27.5
Range	17–49
BMI classification (*n*)[a]	
Underweight	3
Normal	8
Overweight	17
Obese	12
Morbidly obese	10
Race (*n*)	
Caucasian	49
African American	1
Pre-operative diagnosis (*n*)[b]	
Endometrial cancer	22
Pelvic mass[c]	12
Dysplasia[d]	11
Dysfunctional uterine bleeding	4
Cervical cancer	2

[a] Underweight = BMI <20; Normal = BMI 20–24.9; Overweight = BMI 25–29.9; Obese = BMI 30–34.9; Morbidly obese = BMI ≥ 35

[b] One case was performed for two pre-operative indications. As such, the total number of pre-operative diagnoses is one greater than the total number of cases included in the review

[c] Cases included those performed for known dysgerminoma, known LMP tumor of the ovary, known ovarian cyst, elevated testosterone suspicious for tumor of ovarian origin, and other uncharacterized pelvic masses

[d] Cases included those performed for endometrial complex atypical hyperplasia, cervical dysplasia, and post-menopausal bleeding

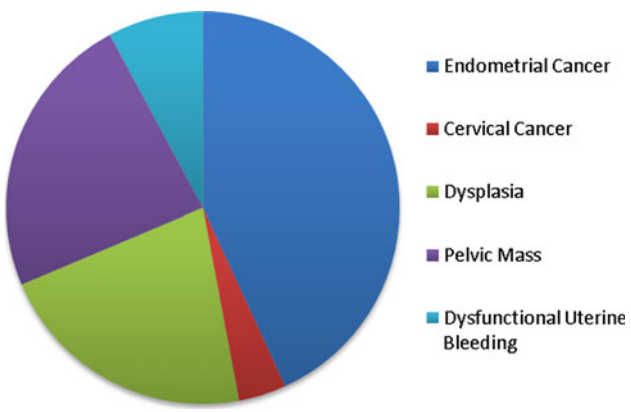

Fig. 1 Patients' pre-operative diagnosis

118.1 min (SD 44.28, 95 % CI 105.87–130.41). When cases were classified as benign or malignant, mean surgical times were 98 min (SD 40.53, 95 % CI 81.43–114.57) and 135 min (SD 40.51, 95 % CI 119.72–150.28), respectively. Mean estimated blood loss was 108.7 ml (SD 98.32, 95 % CI 81.45–135.95; Table 2). Mean number of pelvic and para-aortic lymph nodes removed were 9.3 and 4.6, respectively. Post-operative diagnosis included benign disease, Stage IA, IB, and IIB endometrial cancer, Stage IA ovarian cancer, and Stage IB1 cervical cancer (Fig. 2).

We performed linear regression analysis to study the effect of experience with the robot on total operating room time, total surgical time, LOS, and EBL. Given that the

Table 2 Operative results for 50 patients who underwent gynecologic robot-assisted surgery

Total operating room time (minutes)	
Mean	189
SD	55.32
Range	108–314
Total surgical time all cases (minutes)	
Mean	118
SD	44.28
Range	57–251
Total surgical time benign cases (minutes)	
Mean	98
SD	40.53
Range	57–209
Total surgical time malignant cases (minutes)	
Mean	135
SD	40.51
Range	57–251
Estimated blood loss (cc)	
Mean	109
SD	98.32
Range	10–600
Length of stay (days)	
Mean	1.32
SD	0.78
Range	1–4
Total pelvic lymph nodes (*n*)	
Mean	9.35
SD	5.12
Range	2–20
Total para-aortic lymph nodes (*n*)	
Mean	4.59
SD	3.83
Range	1–14

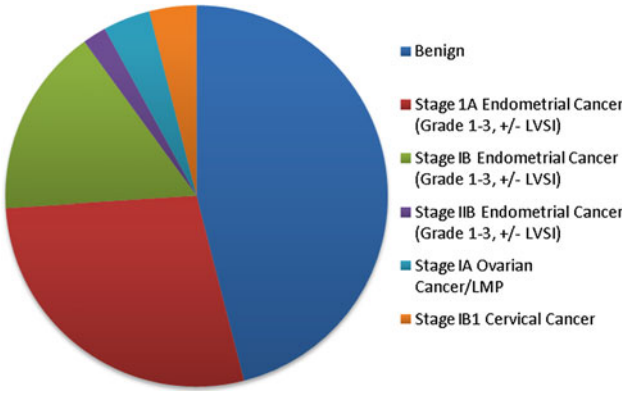

Fig. 2 Post-operative diagnosis by condition and stage

Table 3 Complications

Intra-operative complications	
Vascular injury	2
Converted to laparotomy[a]	1
Post-operative complications	
Wound cellulitis	7
Vaginal cuff complication[b]	2
Ureteral obstruction	2
Pulmonary embolus	1
Total (excluding 3 return to OR)	12

[a] Case converted to laparotomy for repair of vascular injury

[b] Vaginal cuff complications included hematoma and dehiscence

data were from our initial incorporation of the dual-console robotic model, cases were examined in the order in which they were performed (ex. 1–50) to obtain an estimate of the progression of our experience with the robot. When controlling for age, BMI, and pre-operative diagnosis, case number is a significant predictor, with negative coefficients for total surgical time and total operating room time ($p = 0.007$ and 0.0018), respectively. Case number was not associated with LOS ($p = 0.3$) or EBL ($p = 0.56$). These findings provide evidence that there was improvement in proficiency as operators were familiarized with the techniques and procedures.

Intra-operative complications included two vascular injuries, one of which required conversion to laparotomy for repair of bleeding from the external iliac vein. Neither vascular injury was a direct result of a component of the surgery performed from the dual-console, but rather bleeding encountered during normal lymphatic dissection. Post-operative complications included seven wound infections, two vaginal cuff complications, two ureteral obstructions, and one pulmonary embolism (Table 3). Detection of the first ureteral complication was noted intra-operatively at the time of cystoscopy. Bilateral ureteral jets were noted; however there was a decreased flow on the left. This patient was managed by urology with ureteral stent placement for four weeks and had no residual problems after stent removal. The second ureteral injury was noted one week post-surgery when the patient returned with flank pain and an abdominal fluid collection. On imaging, extravasation of contrast was noted and ureteral necrosis was identified on a ureteroscope by urology. The patient underwent percutaneous nephrostomy tube placement with subsequent neo-ureterocystostomy six months after the original surgery.

Discussion

The 21st century brought with it a movement toward minimally invasive surgery in gynecology and gynecologic oncology. The ultimate objective is to maximize those procedures that can be performed safely and accurately via a minimally invasive approach. In 2006, the Gynecologic Oncology Group presented results of a multi-center randomized trial which revealed favorable surgical outcomes when comparing laparoscopy and laparotomy [11, 12]. As more physicians utilized laparoscopic surgery, robot-assisted minimally invasive procedures have emerged and gained popularity after approval by the Food and Drug Administration in 2005 for gynecologic procedures [13, 14].

There is limited published data on the application of dual-console robotic surgery in gynecology. A recent publication by Marengo et al. [15] reviewed prospective data collected on 33 patients undergoing dual-console robotic surgery for varying indications at their institution. The authors cited a mean operative time of 152 min and a mean anesthesia time of 196 min. Although a dual-console robotic set-up was used, only one of the surgeons in this review performed the procedure—the other console was used for observation and verbal assistance. The authors did not note a statistically significant difference in operating time between their first 15 and last 18 cases.

Review of additional literature enables us to compare dual-console procedures with the same or similar procedures completed using a single console. The first report of TRH was by Diaz-Arrastia et al. [16]. Data published from this study combined both oncologic and benign procedures. After stratification of their results the authors reported an average EBL of 253 ml, average hospital stay of 2.5 days, and overall incidence of complications of 7.3 % when the data from all cancer patients were examined. From 2005 to 2007 Boggess et al. [17] reported an average EBL of 74.5 ml, average hospital stay of 1 day, and an average operative time of 191.2 min for their TRH with staging for endometrial cancer. In comparison, our operative time for staging procedures is significantly less at 135 min. In our

review, we specifically report our operative times using the dual-console for our first fifty cases, benign and malignant. It should also be noted that at our institution, the dual-console system is the only system available. Therefore, we are unable to perform an institutional comparison of single versus dual-console surgery.

In 2008 a survey of SGO members was performed by Mabrouk et al. [6], 76 % of respondents reported no or limited laparoscopic training during their fellowship, and 78 % now believe that maximum emphasis should be placed on laparoscopic training. When a similar survey was completed in 2004, only 55 % of respondents noted a high importance of minimally invasive surgery. From this same group surveyed, 24 % indicated they performed robot-assisted surgery. Many gynecologic and gynecologic oncology surgeons may utilize the dual-console da Vinci system to overcome the limited experience that clinicians may have faced during their training or earlier parts of their careers.

A major hurdle to success in robotic surgery is the associated learning curve, which applies to both the surgeon and the surgical team. Lenihan et al. [18] demonstrated that the learning curve for benign conditions stabilized at 95 min after having completed 50 cases. Similar improvements in operative time have been noted in gynecologic oncology; however, none of these reviews evaluated use of the dual-console system [19]. It has been determined that approximately 20–25 surgical robotic cases are required to obtain proficiency using this technique [20, 21]. A recent study by Lim et al. [22] established that learning how to perform robotic surgery at their institution required half the number of cases for proficiency compared with the same cases completed laparoscopically. This could in part be because of the overall increase in exposure of physicians to laparoscopy before adopting robotic surgery. However, the mean operative time in this study for completion of a TRH/PPLAND was 147.2 ± 48.2 min. The mean operative time differed by only 38.1 min when comparing the surgeons' times from before and after their 24th cases. We sought to examine our first 50 cases with reference to the above cited manuscripts which had previously examined proficiency and learning curves for robotic surgery. Our study shows that utilization of the dual-console system gives a second surgeon the opportunity to gain robotic experience, which in turn may result in earlier proficiency.

By improving precision and dexterity, robotic technology enables the surgeon to perform operations that were previously not amenable to minimally invasive surgery. This is especially true for patients that are morbidly obese. Use of the dual-console robotic system at our institution has enabled us to develop and optimize techniques and surgery that are safe, effective, and beneficial to our patients. It has enabled the development of a training module that can be used among physicians with different levels of experience. In our training environment, operating with the dual-console da Vinci Si® is a safe and feasible option for completion of hysterectomies and staging procedures. A new teaching paradigm has evolved, providing trainees with more exposure and experience in robotic surgeries. Use of the dual-console enables integrated teaching, surgical cooperation with proctoring, and supervision, without compromising operative times or patient outcomes.

Conflict of interest None.

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