J Robotic Surg (2010) 4:211–216
DOI 10.1007/s11701-010-0205-z

ORIGINAL ARTICLE

Robotic radical hysterectomy: comparison of outcomes and cost

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Received: 15 May 2010 / Accepted: 29 June 2010 / Published online: 20 November 2010

Abstract Operative and peri-operative outcomes, complications, and cost for radical hysterectomy for cervical cancer with negative sentinel nodes have been compared for robotics and laparotomy. Forty patients underwent radical hysterectomy with/out bilateral salpingo-oophorectomy, for early-stage cervical cancer. All cases were performed by one of two surgeons, at a single institution (16 robotic, 24 laparotomy). The data for the robotic group were collected prospectively and compared with data for a historic cohort who underwent laparotomy. The data included demographics and peri-operative variables including operative time, estimated blood loss, lymph node count, hospital stay, and complications. Additionally, real direct hospital cost was compared for both modalities. Patients undergoing robotic radical hysterectomy experienced longer operative time than the laparotomy cohort (351 min vs. 283 min $P = 0.0001$). Estimated blood loss was significantly lower for the robotic cohort than for the laparotomy cohort (106 ml vs. 546 ml $P < 0.0001$). The minor complication rate was lower in the robotic cohort than for laparotomy (19% vs. 63% $P = 0.003$). Average hospital stay for the robotic patients was significantly shorter than for those undergoing laparotomy (1.9 days versus 7.2 days, $P < 0.0001$). Lymph node retrieval did not differ between the two groups (robotic 15 nodes, laparotomy 13 nodes). The total average peri-operative costs for radical hysterectomy with lymphadenectomy completed via laparotomy was CAN $11,764 \pm 6,790$, and for robotic assistance $8,183 \pm 1,089$ ($P = 0.002$). When amortization of the robot was included, there remained a trend in favor of the robotic approach, but it did not reach statistical significance. Whereas robotics takes longer to perform than traditional laparotomy, it provides the patient with a shorter hospital stay, less need for pain medications, and reduced peri-operative morbidity. In addition real average hospital costs tend to be lower.

Keywords Radical hysterectomy · Cervical cancer · Cost · Robotics · Laparotomy · Complications, economical considerations

Abbreviations

RRH	Robotic radical hysterectomy
ORH	Open radical hysterectomy

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Introduction

Early stage cervical cancer is mostly managed with radical hysterectomy including pelvic lymphadenectomy, with cure rates of 87–92% [1]. Radical hysterectomy is not without complications. The average blood loss ranges from 500 ml to 1,500 ml [2]. Intra-operative injuries occasionally occur to the pelvic blood vessels, ureter, bladder, rectum, or obturator nerve. Urinary retention and infections, venous thrombo-embolism, genitourinary fistula, and ileus can occur postoperatively [2].

Radical hysterectomy performed via minimally invasive surgery has been associated with fewer complications compared with laparotomy [3]. Total laparoscopic radical hysterectomy has been shown to have reduced operative blood loss, postoperative infectious morbidity, and postoperative length of stay without sacrificing the size of radical hysterectomy specimen margins [3]. However laparoscopy is limited by its long learning curve, counterintuitive motion, and two-dimensional views [4]. Robotic surgery, on the other hand, maintains the many advantages of the minimally invasive approach but overcomes most of the difficulties of laparoscopic surgery by combining a three-dimensional high-definition enhanced view, the wrist like motion of the robotic arms, tremor filtration, and reduced dependence on the assistant. These advantages offer significant technical ease when performing complicated surgical procedures [4–6].

Boggess et al. [7] conducted a case–control study of robot-assisted laparoscopic radical hysterectomy compared with the laparotomy approach; this study showed that robot-assisted laparoscopic radical hysterectomy is superior to open radical hysterectomy with regard to blood loss, operative time, hospital stay, and lymph node retrieval.

In our institution, although close to 20% of patients with gynecologic malignancies were treated by laparoscopy before the introduction of robotics, radical hysterectomies were performed by traditional Cherney incision. Within two years of the introduction of robotic surgery, this surgical approach became the standard with 95% of endometrial and cervical cancers performed by minimally invasive surgery.

In this study we present data gathered prospectively on robotic radical hysterectomies for cancer of the cervix and compare the outcome with that for patients who underwent this procedure by laparotomy, emphasizing surgical endpoints and economic considerations.

Materials and methods

Between January 2008 and December 2009 we prospectively collected the perioperative data for all cases of robotic radical hysterectomy for cervical cancer in the Division of Gynecologic-Oncology of a tertiary cancer care facility. Robotic surgical procedures were performed and supervised by two primary surgeons (S.L and W.H.G.). The surgical team consisted of at least one of the primary surgeons, a gynecologic oncology fellow or resident as bedside assistant or active surgeon, and a team of nurses dedicated to robotics. We compared this group to a historic cohort of all cases of open radical hysterectomies (ORH) performed at the same institution by the same team from March 2003 to December 2007 before the robotics program was implemented.

Surgical technique

Before surgery patients are instructed to perform a bowel preparation consisting of clear fluids, mineral oil, and fleet enema before admission. All patients were given, pre-operatively, prophylactic intravenous antibiotics (cephazoline 2 g), subcutaneous heparin 5,000 units, and lower limb pneumatic compression stockings. For patients undergoing laparotomy, a low transverse incision (Cherney's) was used. Patients undergoing robotic surgery were operated using the Da-Vinci S robotic system (Intuitive Surgical, Sunnyvale, CA, USA) with a camera port (12 mm Endopath trocar; Ethicon Endo-Surgery), three robotic instrument ports, and one assistant port (12 mm Endopath trocar, Ethicon Endo-Surgery).

After entrance and exploration of the peritoneal cavity, sentinel lymph node dissection was performed, using technecium 99. We proceeded to hysterectomy only if the patients had negative sentinel nodes and there was no evidence of extra-cervical spread. For the patients that underwent robotic radical hysterectomy (RRH), the procedure was performed as described by Boggess et al. [7], with only minor modifications. Oophorectomy was done in postmenopausal patients and in the presence of adenocarcinoma with unfavorable prognostic factors. Unilateral oophoropexy was done in premenopausal patients. Complete pelvic lymph node dissection was done in all cases.

Data collection

Data were prospectively gathered for the robotic cohort and retrospectively collected for the laparotomy group from the hospital electronic chart system and from the operating room electronic data information system. For classification of surgical complications we used the modified Clavien system [8] with grade I–II complications representing minor complications and grade III–IV complications representing major complications. The lengths of hospital stay and readmissions were documented. Tumor histology subtype, grade, and FIGO stages (1994 classification) [9] were

retrieved from the final pathology reports. The volumes of uteri were calculated using the formula length × transverse diameter × anterior posterior diameter × 0.5233 [10].

The costs were divided into the following categories: radiology, pharmacy, laboratory, theater use and supplies cost, anesthesia, and room and board. The amortization cost of the daVinci Surgical System was calculated as the sum of the cost of the robotic system and the service cost of 10% per year for seven years divided the total number of cases expected to be performed during that period based on the current case load [11].

Statistical analysis

Descriptive values were expressed as mean ± standard deviation (SD). Frequencies were presented as percentages. The Student *t* test or Mann–Whitney test were used as appropriate. The Fisher exact test was used to compare frequencies. A P value of <0.05 was considered significant. The data were analyzed with the aid of the commercially available software, StatDirect (version 1.9.14; StatDirect, Cheshire, UK).

Results

Between March 2003 and December 2009, there were 119 patients with cervical cancer. Sixty-four were treated primarily by chemoradiation in view of advanced stage at diagnosis, and 55 were suitable for surgical treatment according to pre-operative evaluation. Of the 55 patients, six had radical trachelectomy, three for fertility preservation (one by robotic, two by laparotomy) and three post subtotal hysterectomy (two by robotic, one by laparotomy). There were 28 patients scheduled for ORH, between March 2003 and December 2007, four patients had positive sentinel nodes, and underwent complete pelvic and peri-aortic lymphadenectomy without removal of the uterus, and thus only 24 patients completed the ORH. Similarly, there were 21 patients scheduled for RRH from January 2008 to December 2009. At the time of surgery five were found to have positive sentinel lymph nodes, and underwent complete robotic pelvic and peri-aortic lymphadenectomy without removal of the uterus, thus only16 patients completed RRH. Patients with positive sentinel nodes were referred for further treatment with chemo-radiation. Table 1 shows the patient demographics. There was no significant difference between the two groups with regard to age, body mass index (BMI), parity, gravidity, background medical health, and number of previous pelvic and abdominal surgeries. There were also no significant differences between the groups with regard to FIGO stage, grade or histological subtype (Table 2).

Table 1 Patient demographics

	Open radical hysterectomy (N = 24)	Robotic radical hysterectomy (N = 16)	Statistics
Age (years)	47 ± 12	49 ± 10	NS
BMI (kg/m^2)	25 ± 5	26 ± 6	NS
Parity			
Mean ± SD	2 ± 1	2 ± 2	NS
Median	2	2	
Gravidity			
Mean ± SD	2 ± 2	3 ± 2	NS
Median	2	2	
Number of patients with major co-morbidities[a]	11 (46%)	7 (44%)	NS
Smokers	10 (42%)	5 (31%)	NS
ASA score			
Mean ± SD	2 ± 1	2 ± 1	NS
Median	2	1	
Number of prior abdominopelvic surgeries			
None	14 (58%)	6 (38%)	NS
1	5 (21%)	8 (50%)	NS
2	4 (17%)	2 (13%)	NS
≥3	1 (4%)	0 (0%)	NS

[a] Major co-morbidities including—hypertension, diabetes melitus, cardiovascular disease, chronic lung disease

Table 2 Pathologic and histologic characteristics according to FIGO

	Open radical hysterectomy (N = 24)	Robotic radical hysterectomy (N = 16)	Statistics
Stage			
Ia1[a]	2 (8%)	1 (6.3%)	NS
Ia2	1 (4%)	2 (12.5%)	NS
Ib1	18 (75%)	8 (50%)	NS
Ib2	2 (8%)	3 (18.8%)	NS
IIa	1 (4%)	2 (12.5%)	NS
Grade			
1	3 (13%)	6 (38%)	NS
2	10 (42%)	6 (38%)	NS
3	11 (46%)	4 (24.0%)	NS
Histological subtype			
SCC[b]	18 (75%)	10 (63%)	NS
Non SCC	6 (25%)	6 (37%)	

[a] Patients with lymphovascular invasion on cone biopsy specimen

[b] SCC, squamous cell carcinoma

The surgical and peri-operative characteristics are shown in Table 3. The total surgical times were significantly longer in the robotic group (351 min, 283 min, P = 0.0001),

Table 3 Surgical data

Parameter	Open radical hysterectomy ($N = 24$)	Robotic radical hysterectomy ($N = 16$)	Statistics
Type of hysterectomy			
Type II	5 (21%)	1 (6%)	NS
Type III	19 (79%)	15 (94%)	NS
Surgical time (min)	283 ± 63	351 ± 51	$P = 0.0001$
Blood loss (ml)			
Mean ± SD	546 ± 570	106 ± 113	$P < 0.0001$
Median	350.00	50	
Uterine weight (gr)	121 ± 73	155 ± 81	$P = 0.06$
Uterine volume (ml)	89 ± 102	120 ± 91	$P < 0.05$
Lymph node count	Mean = 13 ± 5 Median = 14 Mode = 14	Mean = 15 ± 5 Median = 15 Mode = 15	NS
Opioid use			
None used	0	3 (19%)	NS
≤1 day	1 (4%)	8 (50%)	$P = 0.0026$
2 days	7 (29%)	5 (31%)	
≥3 days	16 (67%)	0 (0%)	NS $P = 0.0001$
Time to diet (days)			
Mean ± SD	3.5 ± 1.9	1.2 ± 0.4	$P < 0.0001$
Median	3	1	
≤2 days	6 (25.0%)	16 (100%)	
≥3 days	18 (75.0%)		
Length of stay (days)			
Mean ± SD	7.2 ± 5.3	1.9 ± 0.9	$P < 0.0001$
Median	5	2	
Range	3–28	1–4	
Adjuvant treatment	6 (25.00)%	8 (50%)	NS

however patients who underwent RRH had significantly less blood loss (106 ml vs. 546 ml $P < 0.0001$). Patients in the robotic groups required less post operative narcotics. After one day more than half of the patients undergoing robotic surgery did not require any form of opioids ($P < 0.01$). In the ORH group 20 patients (83.33%) received patient-controlled analgesia for 1–3 days and four patients (16.67%) received continuous spinal analgesia for 1–3 days. In the robotic group three patients received patient-controlled analgesia (PCA) early in the series before staff stopped providing PCA, and those who received it did so for 1.5, 9, and 12 h before it was discontinued, because it was hardly used by the patients. Subsequent patients in the RRH did not receive PCA. Patients in the RRH group were able tolerate full diet sooner ($P < 0.0001$) and had a shorter hospital stay ($P < 0.0001$, Table 3).

The uterine weight and uterine volume tended to be higher in the RRH group; the lymph node count and type of hysterectomy were similar in both groups. No patient in the series had positive surgical margins on final pathology. There was no significant difference between the number of patients requiring adjuvant therapy post surgery.

The peri-operative complications are summarized in Table 4. Patients that underwent RRH had statistically significantly fewer overall complications than patients that had ORH (19% versus 71% $P = 0.003$). In the RRH group, there were no major complications whereas there were two major complications in the ORH group. Significantly lower rate of wound complications were found in the RRH group (0% versus 29%, $P < 0.03$).

The facility fee and theatre materials invoice total was $220.14 (all fees are in Canadian dollars) for ORH and $2,977.40 for RRH. The hourly anesthesia technician and nursing rates were $38.76/h and $40.66/h. The hospital cost

Table 4 Peri-operative complications

	Open radical hysterectomy ($N = 24$)	Robotic radical hysterectomy ($N = 16$)	Statistics
Fever	3 (13%)	1 (6%)	NS
Wound complications	7 (29%)	0	$P < 0.03$
Infection	3		
Seroma	1		
Hematoma	3		
UTI	3 (13%)	1 (6%)	NS
Transfusions	3 (13%)	0	NS
CVS	2 (8%)	1 (6%)	NS
DVT	1 (4%)	0	NS
Ileus/bowel obstruction	2 (8%)	0	NS
Bowel injury	0	0	NS
Reoperation	0	0	NS
Poor DM control	0	0	NS
Poor HTN control	1 (4%)	0	NS
Post op emergency room visits	3 (13%)	3 (19)	NS
Readmissions	1 (4%)	0	NS
Bladder dysfunction[a]	4 (17%)	0	NS
Other[b]	1 (4%)	0	NS
Number of patients with complications			
Major[c]	2 (8%)	0	NS
Minor	15 (63%)	3 (19%)	$P = 0.003$

[a] Transient bladder dysfunction—Two cases of bladder incontinence, three cases of retention

[b] One case of *Clostridium difficile* diarrhea

[c] Two cases of heart failure

Table 5 Hospital cost

	Open radical hysterectomy ($N = 24$)	Robotic radical hysterectomy ($N = 16$)	Statistics
Hospital accommodation	9,044 ± 6,674	2,445 ± 1,077	$P = 0.0004$
Surgeon costs	1,214	1,356	
Anesthetist costs	863 ± 190	868 ± 135	NS
Theater cost			
OT use and supplies	220 per case	2,977 per case	$P = 0.0007$
Nursing	208 ± 45	257 ± 32	
Anesthesia	199 ± 43	245 ± 31	$P = 0.0007$
Pharmacy cost	104 ± 180	10 ± 8	$P = 0.0440$
Radiology	95 ± 201	0.6 ± 2.2	NS
Labs	138 ± 163	39 ± 22	$P = 0.004$
Readmission	One case $3,787.5	No cases 0	
Total Peri Op cost($)			
Without amortization cost	11,764 ± 6,790	8,183 ± 1,089	$P = 0.002$
Amortization cost A[a]	11,764 ± 6,790	9,613 ± 1,089	NS
Amortization cost B[b]	11,764 ± 6,790	8,898 ± 1,089	NS

[a] Amortization cost A (based on hospital case load of five cases per week) = additional $1,429.70 per case

[b] Amortization cost B (based on hospital case load of ten cases per week) = additional $714.85 per case

for a surgical bed was $1,162.00/night. The anesthetist fee was calculated at $14.25 per unit. The number of units per case was a function of the anesthesia length and determined from standard tables for reimbursements according to the Province of Quebec. The cost of post-operative pain management services provided by anesthesia was also added to the anesthetist bill. Table 5 outlines the mean hospital charges.

The cost of the robot was $1,530,312.20 and the seven-year maintenance fees totaled $1,071,428.60.There was average of five robotic cases each week thus the amortization cost was $1,429.70 for each robotic case. If there were ten robotic cases per week the amortization cost would be $714.85 per case.

The average perioperative cost with and without amortization cost is shown in Table 5. The average perioperative cost without amortization charges was significantly less for RRH. When the average perioperative cost was calculated including the amortization cost for case loads of five and ten cases each week, the average cost for RRH and OR was not significantly different although the average cost of RRH was still less.

The cost of emergency room visits included a registration fee of $153.63, physician fee of $33.33 and the cost of investigations. In addition, a mean charge of $1,000.00 for each additional 24 h spent in the emergency was billed (This included the cost of investigations).

Discussion

Our results indicate that RRH is safe, and yields similar surgical results to ORH. The lymph node count, uterine weight, and volumes were similar in both groups. However, the blood loss, complication rates, hospital stay, narcotic usage and time required until normal diet was significantly less with RRH. For RRH operative times were significantly longer and surgical costs were higher. We were not able to compare long-term survival data for these patients owing to the short follow up in the RRH group.

Ko et al. [12] noted in their series longer operating times in the RRH group, with similar nodal count in both groups. The EBL, length of stay, and overall complication rates were less in the RRH group. Maggioni et al. [13] in their series also noted that compared with ORH, RRH was associated with longer operating times. However the estimated blood loss and length of hospitalization were significantly shorter in the RRH group. He noted a higher lymph node count in the RRH group. It is difficult to compare lymph node counts across series in view of the internal pathology procedures and motivation for isolating and counting lymph nodes. However, all our robotic procedures are recorded on DVD and substantiate the completeness of the lymphadenectomy with the stripping of all fat and lymph node tissue in the pelvis from the bifurcation of the common iliac artery to the circumflex iliac vein and from the genitofemoral nerve to below the obturator nerve and hypogastric/superior vesical artery in all patients. The consistency in the number of lymph nodes between the laparotomy and robotic cases at least substantiates similar efficiency.

One disadvantage of robotic surgery is the high initial cost and recurrent costs. It has been noted however that with high-volume use the cost may be less than laparoscopy [11]. In addition, high operative costs are quickly offset by a shortened hospital stay [11]. In addition, with increasing

experience surgical time should be reduced which would lower the surgical costs [11]. In one series surgical times were significantly shorter in the robotic group [7].

Robotic staging for endometrial cancer has been shown to have a lower theoretical average cost than laparotomy [14]. In our series we evaluated the real cost per patient based on hospital records. It was calculated that the shorter length of stay for patients and the lower complication rate led to an overall lower cost with RRH. We did not take into account other economic effects that would increase the differential in favor of robotic surgery, for example increased loss of wages, and the cost of the prolonged recovery period to society with traditional laparotomy [14]. We were not able to evaluate the costs of laparoscopy in this setting, because our department had never adopted radical hysterectomy by laparoscopy. Further information on perioperative outcomes, survival and cost effectiveness of RRH and total laparoscopic radical hysterectomy (TLRH) compared with ORH are eagerly awaited [15].

Although our numbers are too small to draw any definitive conclusions, this pilot project adds to data which show that robotic surgery is associated with shorter hospital stay, and less blood loss and post operative morbidity. The average costs are in favor of RRH based on real case analysis. When amortization costs are considered, our data still show a trend in favor of the robotic approach but this does not reach statistical significance. Nevertheless, in this scenario, which did not include further potential gains related to earlier recovery and return to daily activities, serious consideration should be given to the procedure that is associated with least perioperative morbidity.

Acknowledgments Establishment and maintenance of robotic surgery has been made possible in our institution thanks to the philanthropy of a group of donors who requested to remain anonymous. DH was supported by a fellowship grant from the International Gynecologic Cancer Society. This work was supported by grants from the Israel Cancer Research Foundation, the Norych Career Scientist Award, and the Schouella Distinguished Scientist Award.

Conflict of interest WHG has served as a proctor for robotics in Canada, Israel, and China.

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