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ROBOTIC RADICAL CYSTECTOMY.

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Summary.- *OBJECTIVES: The last decade has seen tremendous growth of surgical robotics. Popularized for radical prostatectomy, robotic techniques are now increasingly being applied to radical cystectomy. Herein, we review the development and current status of robotic radical cystectomy (RRC) in contemporary urological practice.*

METHODS: Between 1995 and 2007 published literature was reviewed using the National Library of Medicine database and the following key words: robotic, robot-assisted, laparoscopic and cystectomy. Since the first report in 2003, nine published original reports were identified. These were evaluated with regards to the technique, advantages and disadvantages, perioperative and oncological outcomes. Our initial experience, as yet unpublished, is also described.

RESULTS: At this writing, all published papers on RRC are based on small number of patients with short-term follow-up. Nevertheless, they have demonstrated the technical feasibility of RRC with encouraging perioperative outcomes. Compared to open radical cystectomy (ORC), RRC appears to be associated with decreased blood loss, hospital stay and analgesic requirement. These advantages are also found with laparoscopic radical cystectomy (LRC) and are a function of the minimally invasive approach. The operating time is longer, markedly so when the bowel work is performed intracorporeally.

CONCLUSIONS: RRC is in evolution. Technical feasibility has been demonstrated. Initial perioperative outcomes are encouraging. Oncological outcomes are awaited to identify the role of RRC in the management of bladder cancer. Multi-center prospective randomized trials comparing ORC with RRC and LRC are necessary.

Keywords: *Cystectomy. Laparoscopic. Robotic. Robot-assisted.*

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INTRODUCTION

In the surgically fit patient, the standard treatment of invasive organ-confined, and even recurrent high-risk superficial bladder cancer is radical cystectomy and pelvic lymphadenectomy with urinary diversion. This is traditionally performed through a long (20-30 cm) midline incision. Radical cystectomy is curative for most patients who have localized disease with 5 and 10-year recurrence free survival rates approaching 70% (1).

Minimally invasive surgical techniques attempt to duplicate the excellent oncological outcomes of open radical cystectomy (ORC) with a superior patient recovery profile, with decreased blood loss and postoperative pain, shorter hospital stay, quicker convalescence.

As laparoscopic urology became popular in the last decade of the 20th century, the first report of laparoscopic radical cystectomy (LRC) for cancer was published in 1995 (2). Since the initial report over a decade ago, LRC was slow to gain popularity in the urologic community, primarily because of the technical complexity of the procedure. With the dissemination of laparoscopic expertise, the last 5 years have seen a dramatic increase in the number of cases, with the current worldwide experience being well in excess of 500 cases. Nevertheless, LRC remains an advanced procedure, and hence is limited to centers where the requisite laparoscopic skills and experience are available.

Robotic surgery is a recent addition to the armamentarium of the minimally invasive surgeon. The current robotic platform (da Vinci, Intuitive Surgical, Sunnyvale, CA) provides 3-D vision, wristed instruments, motion scaling, and elimination of tremor. These features allow laparoscopically naïve surgeons to potentially perform advanced reconstructive laparoscopic procedures. The da Vinci robotic system consists of a remote surgeon console, 2-3 robotic manipulators and a robotic camera arm. Upon attaching end effectors to the robotic manipulators by the assistant surgeon, the primary surgeon seated at the remote console is able to control the robotic arms while looking at a 3-D image of the operative field. Some of the disadvantages of this technology include loss of haptic feedback, initial and recurring costs, as well as increased dependence on the patient-side assistant surgeon.

Building on the clinical experience with robotic-assisted laparoscopic radical prostatectomy, robotic technique is now being applied to radical cystectomy. The purpose of this review is to evaluate the current role of robotic radical cystectomy (RRC) in contemporary practice and present our results.

MATERIALS AND METHODS

Between 1995 and 2007 published literature was reviewed using the National Library of Medicine database and the following key words: robotic, robot-assisted, laparoscopic, and cystectomy. Since the first report in 2003, nine published original reports were identified on RRC. Two of these studies included retrospective non-randomized comparisons between ORC and RRC. Three review articles were also identified. These were evaluated with regards to the technical feasibility, advantages and disadvantages, perioperative and oncological outcomes.

Our institutional experience with LRC and RRC exceeds 90 cases. Of these 18 have been done robotically. Perioperative outcomes in these patients are also reported.

INDICATIONS AND CONTRAINDICATIONS

Given the requisite expertise most patients with organ-confined high-risk superficial or invasive bladder cancer are candidates for LRC or RRC. Current contraindications for these minimally invasive techniques include: a) CT scan evidence of extravesical spread or bulky lymphadenopathy, b) frozen pelvis due to prior surgery or inflammatory pathology, c) fixity of the bladder to surrounding structures and pelvic wall on bimanual palpation, and d) uncorrected bleeding diathesis. Morbid obesity can significantly complicate the technical performance of LRC/RRC. Prior aortoiliac vascular surgery and endovascular stenting can make the ureteral dissection challenging. A narrow pelvis could also make the robotic procedure more tedious.

TECHNICAL CONSIDERATIONS

The technique of robotic radical cystectomy and urinary diversion is still in evolution; hence there is no universal technique. However, there are some key steps of the operation, derived from prior experience with ORC and LRC that are summarized in Table I.

Briefly, initial laparoscopic access is obtained through a 1.5cm incision, 2 cm above the left of the umbilicus. Pneumoperitoneum is obtained to a pressure of 15mm Hg. A 12mm laparoscopic trocar is inserted through this incision and the interior of the peritoneal cavity inspected with the robotic scope. Additional trocars are then inserted as follows: an 8mm robotic trocar 10-12 cm to the right of the primary trocar, 2 finger breadths below the umbilicus, an 8mm trocar 10-12 cm to the left of the primary trocar at the same horizontal level as the right 8mm trocar, a 5 mm trocar bilaterally, cephalad to either anterior superior iliac spines, at the same horizontal level as the 8mm trocars, and finally a 12mm trocar between the primary trocar and the right 8mm trocar. The robot is then docked in the usual fashion. Attention is directed towards the right pelvic brim and the course of the ureter is identified. The posterior parietal

peritoneum over the ureter is incised at the pelvic brim and the ureter is circumferentially mobilized distally to the ureterovesical junction. The ureter is clipped and divided and a biopsy obtained for frozen section at the distal end of the proximal ureter. The left ureter is addressed in a similar fashion. The rectovesical cul-de-sac between the rectum and the bladder is incised transversely anterior to the rectum. The vasa and seminal vesicles are dissected away from the anterior rectal wall and kept en bloc with the bladder, and the fascia of Denonvilliers' is incised transversely to enter the pre-rectal fat plane. The lateral pedicles on either side are transected with 2 sequential firings of a laparoscopic stapler. The vasa are clipped and divi-

TABLE I. STEPS OF ROBOTIC RADICAL CYSTECTOMY.

Technical Step	**Caveat**
Patient in **lithotomy position** with steep **Trendelenburg** tilt	Meticulous padding of pressure points is mandatory
Robotic **access**: 6-port transperitoneal access (Two 12-mm, two 8-mm and two 5-mm ports)	Be extra careful with the Veres needle if there is an associated abdominal aortic aneurysm and the patient is thin. In a **scarred abdomen**, initial access should be through a geographically distant quadrant
Step 1: Circumferential mobilization of each ureter from pelvic brim down to the ureterovesical junction (UVJ) and division of the ureters at the UVJ	Maintain adequate peri-ureteral tissue on the mobilized ureters
Step 2: Retrovesical dissection: posterior peritoneotomy across the cul-de-sac, mobilization of bilateral vasa and seminal vesicles, and incision of Denonvilliers' fascia	Retroprostatic dissection should proceed **anterior** to the yellow pre-rectal fat to avoid rectal injury
Step 3: Lateral dissection: lateral peritoneotomy and transection of lateral pedicles with a laparoscopic stapler	Take care to avoid injury to the obturator nerve. In elderly patients atherosclerotic external iliac vessels may be tortuous and may course down into the pelvis prior to exiting the abdomen. This needs to be recognized at the outset in order to avoid injury
Step 4: Anterior dissection: anterior inverted-U shaped peritoneotomy, dissection of the space of Retzius, division of endopelvic fascia	Take care to avoid injury to the inferior epigastric vessels
Step 5: Division of dorsal venous complex (DVC) and membranous urethra, specimen entrapment	Perfect hemostasis from the DVC is necessary to avoid delayed bleeding once the pneumoperitoneum is desufflated
Extended lymphadenectomy	
Urinary diversion through a small mid-midline incision	

ded and the bladder separated from the lateral pelvic wall. The cephalad aspect of the posterior pedicles thus come into view and are transected with a laparoscopic stapler. The bladder is now dropped from the anterior abdominal wall and endopelvic fascia incised on either side. The dorsal venous complex is divided and the membranous urethra transected with cold endoshears. The caudal portion of the posterior pedicle is clipped and divided. The remaining attachments of the specimen are divided and the specimen entrapped in a specimen retrieval bag. Hemostasis is secured in the pelvis and bilateral extended lymphadenectomy is performed. The lymphadenectomy specimens are entrapped in specimen bags. The robot is undocked and a 6-8cm midline incision is made. The 3 specimen bags are removed and bowel work and ureteral anastomoses performed through this incision. If a neobladder is constructed the incision is closed and the robot re-docked. Urethro-neobladder anastomosis is performed robotically.

The potential advantages and disadvantages of RRC compared to LRC and ORC are mentioned in Table II.

Nerve-sparing Technique

The effect of nerve-sparing radical cystoprostatectomy is a rarely investigated issue. In 2006, Lane at al described the technique of nerve-sparing LRC with continent orthotopic ileal neobladder and reported early outcomes in five selected patients with bladder cancer (3). All patients were free of recurrence at a median follow-up of 30 months. At 12 months, nocturnal and daytime continence was preserved in 100% and 75% of patients, respectively. Sexual function was preserved in the one female patient and 2 of the 4 male patients. Menon et al described a technique of nerve-sparing robotic assisted radical cystoprostatectomy (4). The main principles of their technique were preservation of the capsular artery and use of the seminal vesicles as an operative landmark. However, their published results on these 14 men lack potency data.

In the female, data concerning the effect of radical cystectomy on sexual function are sparse. Menon et al described preserving the uterus and vagina in 3 women who underwent robotic cystectomy (5). Functional and oncological outcomes are awaited in these patients.

Lymph node dissection

Recent studies have suggested that an extended pelvic lymph node dissection provides survival advantage without significantly increasing the morbidity of the procedure (6). The published series' of laparoscopic and robotic radical cystectomy to date have not uniformly reported the extent of pelvic lymphadenectomy performed or the number of lymph nodes removed. Finelli et al evaluated LRC with bilateral extended pelvic lymphadenectomy (n=11) versus limited lymphadenectomy (n=11) (7). Extended lymphadenectomy added 1.5 hours to the operative time. The median number of nodes retrieved was 3 in the limited lymphadenectomy group and 21 in the extended lymphadenectomy group. Three patients per group were found to have positive nodal disease. In 1 patient undergoing extended dissection, injury to a deep pelvic vein was successfully managed by intracorporeal suturing. Two other patients had deep venous thrombosis. At a mean follow-up of 11 months there were no port site recurrences. Deger et al observed an increased lymph node yield when performing pelvic lymph node dissection after the LRC (8). Menon et al commented that bilateral pelvic lymph node dissection was the most difficult part of RRC because of the unfavourable effect of small oozing vessels around the dissection area impairing vision and obscuring tissue planes (5). They recommended leaving the perivesical fat and nodal tissue attached to the bladder in order to decrease oozing and allow a more precise anatomic dissection.

Urinary Diversion

In an attempt to decrease operative time and potential bowel-related complications, most laparoscopic and robotic surgeons perform the reconstruction extracorporeally. We have recently evaluated the outcomes of "pure laparoscopic" and "laparoscopic assisted" urinary diversion techniques after LRC in relation to perioperative outcomes and associated morbidity. Compared to "pure laparoscopic", the "laparoscopic assisted" approach was superior as regards to operative time, blood loss, transfusion rate, time to oral intake, time to ambulation, and postoperative complications. Therefore, we suggest that "laparoscopic assisted" technique is more efficient, associated with quicker recovery, and decreased complication rates compared to "pure laparoscopic" technique (9).

Although laparoscopic and robotic completely intracorporeal urinary diversion has been shown to be technically feasible, it significantly prolongs the procedure, is associated with a steep learning curve and a potentially higher risk of bowel complications.

GLOBAL EXPERIENCE

Apart from decreased pain and quicker recovery, a major advantage of LRC and RRC is decrea-

TABLE II. ADVANTAGES AND DISADVANTAGES OF RRC, LRC AND ORC.

	Robotic radical cystectomy	**Laparoscopic radical cystectomy**	**Open radical cystectomy**
Advantages	1. Decreased blood loss 2. Decreased postoperative pain 3. Faster recovery 4. Better cosmetic results 5. Shorter learning curve compared to LRC	1. Decreased blood loss 2. Decreased postoperative pain 3. Faster recovery 4. Better cosmetic results	1. Proven oncological outcomes 2. Tactile feedback 3. Easier to perform extended lymph node dissection
Potential advantages	1. Decreased hospital stay 2. Enhanced visibility of vital structures 3. 3-D visualization 4. Extended degrees of freedom 5. Precise apical dissection 6. Decreased bowel exposure outside the body 7. Superior ergonomics for the primary surgeon 8. Decreased intracorporeal suturing time	1. Decreased hospital stay 2. Enhanced visibility of vital structures 3. Precise apical dissection 4. Decreased bowel exposure outside the body	1. No additional training required
Disadvantages	1. No long-term oncological data 2. Moderate learning curve 3. High initial and procedural cost 4. Longer operative time 5. Lack of tactile feedback 6. Limited instrumentation 7. Longer set up times initially	1. No long-term oncological data 2. Steep learning curve 3. Longer operative time 4. Requires advanced laparoscopic skills	1. Increased blood loss 2. Slower recovery

KEY: RRC= robotic radical cystectomy; LRC= laparoscopic radical cystectomy; ORC= open radical cystectomy

sed blood loss and decreased transfusion requirement compared to ORC. However, this is a technically demanding procedure with a steep learning curve. The learning curve for robotic surgery is thought to be less steep than for conventional laparoscopy. The first case of da Vinci assisted laparoscopic cystectomy with ileal neobladder was performed in Frankfurt, Germany in 2002 (10). All steps of cystectomy and neobladder construction were performed in 510 minutes with an estimated blood loss of <200 cc. Menon et al performed RRC in 14 men and 3 women using a 6-port, transperitoneal, three-step approach (4). First, using the da Vinci system radical cystectomy and pelvic lymph node dissection was performed. Second, the specimen was retrieved through a small abdominal incision and the bowel was exteriorized to create either an ileal conduit or ileal neobladder extracorporeally. Finally, the neobladder was internalized, the incision closed and the urethral-neobladder anastomosis was completed with robotic assistance. The collaboration of surgeons experienced in pelvic robotic surgery and those with extensive experience in ORC aided the development of their technique. The mean operating time for the cystectomy part of the operation was 140 minutes with a mean blood loss of <150 ml.

In the same year (2003), two other groups reported their experience with RRC (11-12). Beecken et al published one case of RRC with intra-abdominal formation of Hautmann ileal orthotopic neobladder (11). This case was completed with robotic assistance in 8.5 hours with a blood loss of 200 cc. Pathologic margins were negative and reported reservoir function was very good. Yohannes et al also reported a combined approach of robotic assisted laparoscopic radical cystoprostatectomy and ileal conduit in two patients (12). The ileal conduit was created using standard laparoscopy, although the ureteroileal anastomosis was performed robotically. The operative times were 10 and 12 hours, respectively.

In 2004, Balaji et al reported the feasibility of robot-assisted totally intracorporeal laparoscopic ileal conduit in three patients of whom only one underwent LRC for bladder cancer (13). The robot was used for the ureteroileal anastomosis. The mean operative time was 691 minutes with a mean blood loss of 250 ml. The one patient who underwent LRC developed temporary ileus. In this study, the mean hospital stay was 7.3 days.

At the beginning of 2006 Hubert et al demonstrated the safety and feasibility of robot-assisted laparoscopic cystoprostatectomy with ileal conduit in two tetraplegic patients (14). The total surgical time was 9.25 and 6.75 hours. There were no intraoperative complications. In the postoperative period both patients had minor complications (pulmonary and urinary infections). The postoperative hospital stay was 13 days in both cases. The authors commented that extracorporeal bowel work was an option, but could have limitations in the presence of a short mesentery or thick abdominal wall that could prevent bowel exteriorization. Later in 2006, Sala et al reported a case of robot-assisted laparoscopic radical cystoprostatectomy and intracorporeal orthotopic ileal neobladder (15). The total operative time was 12 hours and the estimated blood loss was 100 ml. There were no complications and patient's hospital stay was five days. Early oncologic and functional results were good.

Existing robotic radical cystectomy series in the literature are summarized in the Table III.

Oncologic Outcomes

One of the current limitations of minimally invasive radical cystectomy series' is the scarcity of long-term oncologic outcomes. Gupta et al reported five cases of LRC and intracorporeal ileal conduit with 2 years follow-up (16). Of the five patients two died from unrelated causes and the remaining 3 patients were disease free with normal upper tracts. Deger et al published their results on 20 patients treated with LRC and intracorporeal rectosigmoid pouch with a median follow-up of 33 months (8). All surgical margins were negative and three patients had positive lymph nodes. At follow-up there was no evidence of local recurrence, however, three patients developed metastases and two subsequently died of the disease 15 and 24 months after surgery. Similar medium-term oncologic data are not yet available for RRC series.

Recently, we have analyzed our upto 5-year oncologic outcomes after LRC in 37 patients with a mean age of 66 years. An extended pelvic lymphadenectomy was performed in 26 patients (70%). Two patients had a positive surgical margin. Median number of lymph nodes excised was 14. Eight patients (22%) have completed 5-year follow-up. Five-year actuarial overall and cancer-specific survival was 63% and 92%, respectively (17).

How does RRC compare with ORC? To date, there are only two nonrandomized prospective studies in the literature evaluating the comparative results of RCC and ORC. Galich et al reported a comparison of 24 patients treated with ORC and 13 treated with RRC (18). In the RCC group, urinary diversion was carried out extracorporeally through a 5 cm midline

TABLE III. PUBLISHED SERIES OF ROBOTIC CYSTECTOMY.

Authors	No. of Patients	Indication for surgery	Lymph node dissection	Approach for urinary diversion	Type of urinary diversion	Mean operative time	Mean blood loss (mL)	Mean length of stay (d)	Complications or Conversion	Margins
Menon et al, 2003 (4)	14 men, 3 women	Bladder cancer	Extended; 4-27 nodes removed	Extracorporeal	IC (2) ; W-pouch (10); T-pouch (2); double-chimney (2)	RRC: 140 mins IC: 120 OIN: 168 mins	<150	NR	1 re-exploration (bleeding); 1 operation aborted (lens malfunction)	Negative; N1 disease in 1
Beecken et al, 2003 (11)	1 man	Bladder cancer	Limited	Extracorporeal	Hautmann ileal neobladder	8,5 hours	200	NR	None	Negative
Yohannes et al, 2003 (12)	2 men	Bladder cancer	Limited	Intracorporeal	IC	10 hours; 12 hours	435; 1800	6	None	Positive (1)
Balaji et al, 2004 (13)	2 men, 1 woman	Bladder cancer (1), radiation cystitis (2)	Limited	Intracorporeal	IC	691 mins	250	7.3	1 ileus (resolved with conservative treatment)	Negative
Menon et al, 2004 (5)	3 women	Bladder cancer	Extended; 3-21 nodes removed	Extracorporeal	IC (1), W-pouch (1), T-pouch (1)	RRC: 160 mins IC: 130 OIN: 180 mins	<100	6.7	None	Negative
Hubert et al, 2006 (14)	2 men	Neurogenic bladder	N/A	Intracorporeal	IC	9,25 hours; 6,75 hours 12 hours	500; <100	13	2 minor complications (1 had UTI & chest infection, 1 had chest infection)	N/A
Sala et al, 2006 (15)	1 man	Bladder cancer	Limited	Intracorporeal	W-pouch	ORC: 395	100	5	None	Negative
Galich et al, 2006 (18)	ORC (24); RRC (13)	Bladder cancer	Limited	Extracorporeal	ORC (16 IC, 7 OIN, 1 Indiana pouch); RRC (6 IC, 5 OIN, 2 Indiana pouch)	mins (median) RRC: 697 mins (median) ORC: 507	ORC: 1250 (median) RRC: 500 (median)	ORC: 10 (median) RRC: 8 (median)	ORC: 4 perioperative complications, 1 death RRC: 2 perioperative complications	ORC: 3 positive RRC: negative
Rhee et al, 2006 (19)	ORC (23); RRC (7)	Bladder cancer	Limited	Extracorporeal	IC	mins RRC: 638 mins	ORC: 1109 RRC: 479	ORC: 13 RRC: 11	NR	ORC: negative RRC: negative

RRC: Robotic Radical Cystectomy, ORC: Open Radical Cystectomy, IC: Ileal Conduit, OIN: Orthopic Ileal Neobladder, N/A: Not applicable, NR: Not reported.

incision. RRC was associated with significantly decreased blood loss, shorter hospital stay and longer operating time compared to the ORC group. There was no difference in the perioperative complications in the 2 groups. In another prospective study, Rhee et al compared 23 ORC with 7 RRC (19). All patients underwent ileal conduit diversion. The RRC group had significantly decreased blood loss and longer operative duration. However, hospital stay was similar in the two groups. The authors concluded that da Vinci-assisted cystectomy had short-term advantages over standard cystectomy.

To date there has been only one reported case of port site metastasis after RRC for muscle invasive bladder cancer. In this case, the primary bladder cancer was high stage and high grade (20). No port site metastasis has been reported in the LRC literature.

None of the RRC series discuss the financial implications of RRC. As such, these data are not available in the LRC literature either. Long-term oncological and functional outcomes as well as cost issues are critical to define the precise role of minimally invasive radical cystectomy in the management of bladder cancer.

CLEVELAND CLINIC EXPERIENCE

To date, 76 patients (56 men, 20 women) with a mean age of 66.5 years (range 26-87) underwent LRC and urinary diversion for invasive or high-risk superficial bladder cancer at our institution. In 65 patients (85.5%) extended pelvic lymphadenectomy was performed. Median number of excised lymph nodes for patients with extended lymph node dissection was 17 (10-24). Two (2.6%) patients had a positive surgical margin. Ten patients (13.1%) have completed 5-year follow-up. Mean follow-up period was 25 months (1-83 months). Overall and cancer-specific survival was 84.2% and 94.5% at 2 years, and 66.9% and 90.4% at 5 years, respectively (unpublished data).

So far we have performed 18 RRC and urinary diversions on 15 men and 3 women with a mean age of 68.7 years (range 55-81) with a mean total operative time of 7 hours. Urinary diversion included ileal neobladder in 6 and ileal conduit in 12 patients. The mean number of lymph nodes removed was 15 (range 2-26). The margins of resection were free of tumor in all patients except one. Hospital stay averaged 10 days. All patients are alive with a mean follow-up period of 4.4 months (range 1-20) (unpublished data).

FUTURE EXPECTATIONS AND CONCLUSIONS

Is RRC with intra/extracorporeal urinary diversion for bladder cancer going to stand the test of time? Despite recent enthusiasm and dissemination of robotic equipment and techniques, pertinent issues remain. Decreased blood loss is an advantage and is a function of the pneumoperitoneum pressure, excellent visualization and technical hemostatic adjuncts employed during minimally invasive cystectomy (LRC and RRC). Due to decreased bowel handling, return of bowel function is probably quicker and could translate into shorter hospital stay. Operating times clearly need to come down and will do so with increasing experience. Cost issues (the initial outlay and the recurring costs of robotic instruments) need to be addressed and rationalized. The da Vinci system has been in use for nearly a decade, and so far the expected cost reduction has not materialized. If anything, costs have increased. This is a cause for concern as global health care costs are going up and there is a clear need to cut wasteful expenditure. Long-term outcomes are awaited and are of critical importance. Whether the 3-D vision, extended degrees of freedom and 10x magnification during RRC will translate into equivalent or superior cancer control and functional outcomes along with improved quality of life, compared to ORC and LRC, remain to be seen.

As such, RRC (and surgical robotics on the whole) is set for growth. This, we expect, will occur as robotic technology will improve and surgical experience increase. Other robotic systems are likely to be developed and the competition will drive the price down and drive the quality up. Desirable improvements in robotic technology include a compact and user-friendly form factor, haptic feedback, integrated imaging and surgical navigation along with a full array of operating instruments. We believe these substantial improvements will become reality in the near future.

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