B ladder cancer continues to be a significant healthcare burden. According to Cancer Research UK, 10,500 new cases are diagnosed in the UK every year. One-quarter of these will be muscle invasive at diagnosis. The five-year survival of muscle-invasive bladder cancer (MIBC) is 15 per cent. Radical cystectomy (RC) remains the gold-standard treatment for the following patient groups: muscle-invasive bladder cancer, non-muscle-invasive bladder cancer that cannot be controlled endoscopically, carcinoma in situ refractory to intravesical immunotherapy – in bladder cancer, this represents a highly aggressive subtype with an average of two years to progression to muscle invasion in untreated patients.

RC in the male involves en bloc removal of the bladder and prostate. In women, both the bladder and uterus are removed. In both sexes, modifications to the standard operation have been described to maintain sexual activity.

A bilateral pelvic lymph node dissection is mandatory for staging purposes and can be extended to the aortic bifurcation in selected patients. The median number of lymph nodes retrieved should be 10–14. One-quarter of patients with MIBC who undergo RC are lymph-node positive at diagnosis. In a proportion of these patients, the lymph node dissection may be curative. The commonest urinary diversion in the UK is the ileal conduit. Orthotopic neobladders constructed

Robot-assisted radical cystectomy

PARDEEP KUMAR, HARINDERJEET SANDHU, BEN CHALLACOMBE, PETER RIMINGTON, M. SHAMIM KHAN AND PROKAR DASGUPTA

Robotic-assisted radical cystectomy for the treatment of bladder cancer combines the best of laparascopy and open surgery: patients enjoy the benefits of minimal access, while the surgeon experiences less fatigue. The authors address a number of questions regarding the new technique.

Figure 1. The da Vinci Si surgical system (courtesy of Intuitive Surgical)
from detubularised bowel segments are increasingly being used in the subset of patients suitable for this.

The standard approach to RC is via an open lower midline incision, often extending to just above the umbilicus (ORC). Satisfactory outcomes from both a functional and oncological perspective are reported. In high-volume centres, the five-year recurrence-free survival rates after ORC are 56–73 per cent.3 However, ORC remains a formidable procedure with a complication rate of around 50 per cent. Excessive bowel handling, fluid loss and opiates can lead to prolonged ileus. In spite of improvements in surgical technique, blood loss during ORC is often significant. The hospital stay can consequently be prolonged, with 18–21 days quoted as the UK average.4

MINIMALLY INVASIVE RADICAL CYSTECTOMY
The advantages of minimally invasive surgery are well recognised. They include reduced blood loss, shorter hospital stay and quicker return to normal activity postoperatively. Urologists in the UK have reported promising results utilising laparoscopy in radical cystectomy (LRC).5 The overall complications during hospital stay and after discharge have been reported as 46 per cent and 19 per cent, respectively.6 Another large LRC series of 84 patients showed that the complication rate can be reduced to 18 per cent, which is better than reported in most series of ORC.7

WHY ROBOTIC-ASSISTED RADICAL CYSTECTOMY?
The reduced manoeuvrability of laparoscopic instruments, the need to operate in several abdominal quadrants for RC and lymph-node dissection, coupled with prolonged operating times contributing to surgical fatigue during LRC, mean that traditional laparoscopy may not be the ideal solution.

The da Vinci system, with its endo-wristed, tremor-free instruments and three-dimensional high-definition magnified vision (Figure 1; Intuitive Surgical, California, USA), has the potential to overcome several of these difficulties. Robotic-assisted radical cystectomy (RARC) and urinary diversion was initially reported in 2003.8 The technique has evolved over the past seven years and is a hybrid of both open and laparoscopic RC (Figures 2 and 3).9 Most surgeons tend to perform the urinary diversion extracorporeally through a small incision, although there is renewed interest in performing the entire procedure intracorporeally with the robot.

We published the first UK experience with this system and have to date performed the procedure in over 80 patients, as well as currently conducting the first randomised trial comparing open, laparoscopic and RARC.10 In a pilot study, 30 age-matched patients (10 in each group) had ORC, LRC or RARC and ileal conduit diversion by three surgeons. RARC and LRC took longer than ORC, but were associated with less blood loss and quicker recovery. Hospital stay was shortest for RARC, which also had the lowest complication rate (Table 1).11,12

Nix and colleagues recently published the results of a pilot randomised controlled trial comparing ORC and RARC. They showed that surgical margins were negative in both groups and lymph node yield was no different between the two arms. This trial proved that RARC is not inferior to ORC as regards early oncological outcomes.13

INTERNATIONAL ROBOTIC CYSTECTOMY CONSORTIUM
The International Robotic Cystectomy Consortium (IRCC) has collected data prospectively from 14 centres internationally currently conducting RARC in an attempt to address questions raised regarding the role of this technology in the treatment of bladder cancer. It is an ongoing audit that has helped to answer a number of questions with regards to this new technique:
• What is the learning curve of RARC?
• Quality of lymphadenectomy during RARC
• Surgical margin status after RARC
• Does previous experience of robot-assisted radical prostatectomy (RARP) affect outcomes at RARC?

What is the learning curve of RARC?
Prospectively collected outcome data on 496 patients undergoing RARC by 21 surgeons at 14 institutions were analysed in an attempt to perform an appraisal of the learning curve for RARC.14 A statistical model projected patient numbers required to attain predetermined cut-off points for variables used as qualitative measures of RARC, including operative time, lymph node yield, estimated blood loss and margin positivity.

Median operative times for surgeons were 441, 368 and 307 minutes for those with experience of <30 cases, 30–50 cases and >50 cases, respectively (p<0.0001). The learning curve for operative time revealed that a time of 390 minutes could be attained after 21 cases. Mean estimated blood loss

Figure 2. Typical port placement for robotic-assisted radical cystectomy

Figure 3. Intraoperative view of robotic-assisted radical cystectomy
was 401ml, with 16 per cent of patients requiring blood transfusion, contrasting favourably with a study of ORC where mean estimated blood loss was 750ml, with a transfusion requirement in 38 per cent of cases. Mean lymph node yield in this study was 18.

The learning curve demonstrated improvement with number of cases, such that with 30 patients, lymph node yield would be in excess of 20. This study helps to demonstrate that an adequate standard of competency is achieved by the 30th case for measures of RARC quality.

**Quality of lymphadenectomy during RARC**

Increased lymph node yield at RC correlates with improved cancer-specific survival. This forms the basis for the use of lymph node yield as a quality assessment tool for RC. A total of 527 patients who underwent RARC for locally invasive bladder cancer were analysed. Of these, 83 per cent of patients underwent lymphadenectomy, with a mean of 17.8 nodes examined. There was a significant relationship between lymphadenectomy being undertaken and tumour stage, sequential case number, institutional volume and surgeon volume. The link between the latter three variables and performance of lymphadenectomy correlates well with ORC series. The multivariate model suggested that surgeon volume was the most significant association. Thus, lymphadenectomy rates at RARC are comparable to ORC.

**Surgical margin status after RARC**

Unlike radical prostatectomy, positive surgical margins at RC confer a poor prognosis, with local recurrence in most patients within two years. A total of 513 patients were included from the IRCC database and split into various cohorts (based on age, gender, pathological T stage, lymph node status, sequential case number and institutional volume). Logistic regression analysis was applied to determine whether there was any association between the aforementioned cohorts and positive surgical margin rates. A positive surgical margin was noted in 35 of the 513 patients (6.8 per cent), which is comparable to ORC. A significant relationship was noted between surgical margin status and increasing age, higher pathological T stage and positive lymph nodes.

Interestingly, surgical margin status did not correlate with case number, which is considered a surrogate for the learning curve.

**Does previous experience of RARP affect outcomes at RARC?**

A study was devised to assess the effect of preceding RARP case volume on the outcomes of RARC. Surgeons participating in the IRCC were divided into four groups based on previous RARP experience (≤50, 51–100, 101–150 and >150 cases). Using this information, a comparison was made between the four groups for primary outcome measures including intraoperative time, blood loss, lymph node yield and surgical margin status.

The operative time (mean 386 minutes) and estimated blood (mean 408ml) decreased significantly with increasing experience (p<0.001). Lymph node yield (mean 17.8) and greater pathologic stage were significantly increased (p<0.001) with greater RARP case volume. There was no statistically significant relationship between positive margins (7 per cent of all cases) and increasing caseload. Thus, increased RARP experience impacts on operative time, estimated blood loss and lymph node yield during RARC.

**QUALITY OF LIFE AND PATIENT SATISFACTION AFTER RARC**

Using quality-of-life questionnaires, time to normal activity has been estimated at around four weeks, time to driving six weeks and time to strenuous activity 10 weeks. Using the SF-8 validated questionnaire, we found no change in physical quality-of-life scores at six weeks after RARC, but significantly better mental scores. Patient satisfaction was high (median 30 out of a maximum of 32 on a validated client satisfaction-8 survey; range 27–32).

**ERGONOMICS**

One of the advantages of RARC over ORC and LRC may be reduced surgical fatigue during a long procedure. This has been studied using motion analysis and electromyographic recordings in a gait lab. These experiments showed that, while laparoscopy was associated with the most fatigue and progressive errors over time, robotics combined the best of laparoscopy and open surgery. With robotic assistance, patients enjoyed the generic benefits of minimal access, while the surgeon had the least fatigue and errors as in open surgery.

**CONCLUSIONS**

The medium-term surgical, oncological and functional outcomes of RARC are encouraging. The IRCC has helped to answer

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**Table 1. Comparison of open radical cystectomy (ORC), laparoscopic radical cystectomy (LRC) and robotic-assisted radical cystectomy (RARC)11, 12**

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<th>Blood loss (ml)</th>
<th>Complication rate (%)</th>
<th>Hospital stay (days)</th>
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BLADDER CANCER
many of the questions raised on the role of robotics in RC. Data contributing to estimated learning curves are from pioneers in the field and it is envisaged that surgeons benefiting from mentorship from those established in RARC may reduce their learning curves even further.

A randomised controlled trial of ORC, LRC and RARC is underway at Guy’s Hospital and will include detailed health economic modelling (the CORAL trial).28 A further phase 2 trial of ORC and LRC or RARC (the BOLERO trial) will assess the feasibility of randomisation in the UK and hopefully lead to a multinational phase 3 trial.

Declaration of interests
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