Review Article

Role of laparoscopy in the era of robotic surgery in urology in developing countries

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ABSTRACT

With the rapid expansion of robotic platforms in urology, there is an urgent and unmet need to review its cost and benefits in comparison to the traditional laparoscopy, especially in reference to a developing country. A nonsystematic review of the literature was conducted to compare the outcomes of pure laparoscopic and robot-assisted urologic procedures. Available literature over the past 30 years was reviewed. Robot-assisted surgery and laparoscopy were found to have similar outcomes in the areas of radical prostatectomy, partial and radical nephrectomy, radical cystectomy, retroperitoneal lymph node (LN) dissection, inguinal LN dissection, donor nephrectomy, and kidney transplantation. Robot-assisted surgery was found to be significantly costlier than pure laparoscopy. In the absence of a clear advantage of robot-assisted surgery over pure laparoscopy, lack of widespread availability and the currently prohibitive cost of robotic technology, laparoscopic urological surgery has a definite role in the developing world.

INTRODUCTION

The field of surgery has seen many advances since its inception. Minimally invasive surgery has been a definite advancement,[1] and laparoscopy has become the standard of care for most of the urological procedures in uro-oncology, ablative urology and urological reconstruction[2,3] The indications of laparoscopy are ever-expanding and it is often preferred over open surgery as it causes minimal pain, shorter convalescence, early return to work, better cosmesis and minimal morbidity.[4] However, traditional laparoscopy has some limitations in the form of limited degrees of freedom, two-dimensional vision, transmission of physiologic tremors, the fulcrum effect and so forth. With the introduction of robot-assisted surgery, a lot of these restraints seem to have been addressed. However, robotic technology is not devoid of limitations; still, it has seen a pervasive expansion in our country and worldwide. It is important to make sure that such advancements are evidence based so that decisions can be made regarding the risks and benefits of each modality. Therefore, we conducted a review of the recent available literature evaluating the current status of laparoscopic and robot-assisted surgery for various urologic procedures.

MATERIALS AND METHODS

A nonsystematic review of the literature was performed using the National Library of Medicine database (PubMed) using the terms: Laparoscopy, robotic, urology, radical prostatectomy (RP), radical nephrectomy, partial nephrectomy, radical cystectomy, neobladder, pyeloplasty, retroperitoneal lymph node (LN) dissection, inguinal LN dissection, donor nephrectomy, and kidney transplantation. A total of 2041 articles were found between January 1990 and March 2020 and additional articles were found during cross-referencing A total of 138 articles were relevant, which were reviewed. Few additional older articles were

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cited for historical purposes. Articles were excluded if they could not be viewed on PubMed. Review articles, editorial, commentaries and letter to the editor were included if relevant information was covered in them.

RESULTS

Prostate cancer

RP is the gold standard surgical treatment for localized carcinoma prostate and can be undertaken by the open, laparoscopic or the robot-assisted techniques.[3] Open perineal RP was described by Young in 1904 and was the standard route of operation for almost a century till the description of open retropubic RP by Walsh in 1982.[3] Introduction of laparoscopic RP (LRP) was reported in 1997, and finally, robot-assisted RP (RARP) was described using the DaVinci Surgical System® by Binder in 2002.[5] While LRP was thought to provide advantages of minimally invasive surgery over open RP in the terms of lower postoperative pain, lesser estimated blood loss (EBL) and earlier hospital discharge, it remained a complex laparoscopic procedure with a steep learning curve. Due to this reason, the use of LRP remained limited to experienced laparoscopic surgeons. Introduction of RARP with its advantages of better ergonomics, 3D magnified vision and greater ease of working in the narrow pelvic cavity[6] led to the rapid adoption of robotic technique all over the world. However, LRP is still routinely performed at many centres in Europe and Asia.[7] Robotic assistance is also thought to simplify the learning of this complex procedure. However, the cost of the robot is prohibitively high[8] and scientific evidence supporting one technique over the other is limited, consisting mostly of retrospective and prospective studies. Randomized controlled trials (RCT) comparing these three techniques are few and are not easily possible as patients cannot be forced to be randomized if they are ready to accept the pros and cons of a particular surgical technique. Observational studies suggest RARP and LRP to have lower EBL and transfusion requirements compared to open RP, with similar or lower complication rates.[5] Review of the observational studies also report a better urinary and sexual quality of life with RARP compared to the open RP.[9] RARP has also been found to be less stressful for the surgeons compared to the open RP.[10] In a Cochrane review[5] of two RCTs comparing LRP or RARP with open RP, the authors concluded that both LRP and RARP may benefit in terms of early postoperative pain (up to 1 week: mean difference [MD] –0.78, 95% confidence interval [CI]: –1.40 to –0.17) and blood transfusion requirement (relative risk 0.24, 95% CI: 0.12–0.46). RARP was also associated with shortened length of hospital stay (LOS) (MD –1.72, 95% CI: –2.19 to –1.25). There was no difference in the terms of urinary or sexual quality of life, postoperative complications and pain score at 12 weeks postoperatively. Direct comparisons of RARP and LRP are few. Wang *et al*.[11] reported a meta-analysis consisting of mostly observational studies comparing LRP with RARP. The authors found that EBL (95% CI, [–0.84, 0.08]) and positive surgical margin (PSM) rate (odds ratio [OR] 0.97, 95% CI, [0.76, 1.24]) was not significantly different between LRP and RARP. RARP was associated with significantly lower postoperative complications (OR 0.57, 95% CI, [0.46, 0.70]), however, the postoperative urinary continence rate at 1 year was significantly lower after RARP (OR = 2.09; 95% CI, [1.61, 2.73]). In another systematic review comprising of two RCTs comparing LRP with RARP,[12] the authors found that EBL, blood transfusion rates and mean LOS did not differ between the two techniques. Biochemical recurrence-free survival was also similar (RR 1.01; 95% CI 0.91, 1.12) and so were the PSM rates (RR 1.39; 95% CI 0.81, 2.41). RARP was found to have a significantly higher return of the erectile function (RR 1.51; 95% CI 1.19, 1.92) and continence (RR 1.14; 95% CI 1.04, 1.24) compared to the LRP. The outcomes of studies comparing LRP and robot assisted RP are detailed in Table 1. As of the current international guidelines, no surgical approach can be recommended as the best[3] and rather than the surgical technique, the experience of the treating surgeon and hospital volume may be more important to achieve the best functional and oncological outcomes.[5]

Renal cancer

Laparoscopic radical nephrectomy is the gold standard treatment for localized renal cancer.[13] The robotic platform has failed to demonstrate any specific advantage over laparoscopy for radical nephrectomy and has not been found to be cost-effective.[14]

According to the latest international guidelines,[2] partial nephrectomy (PN) is considered the standard of care for T1 renal tumors and is associated with better oncologic outcomes for T2 tumors in selected cases.[15] Laparoscopic partial nephrectomy (LPN) was first reported by Winfield *et al*. in 1993 and has significant advantages over open PN (OPN) offering lower wound morbidity, lesser postoperative pain and earlier hospital discharge.[2] Long-term oncologic safety of LPN is proven[16] and LPN is the standard treatment for T1a renal tumors. Five-year cancer-specific and overall survival (OS) of LPN and OPN have been found to be 91% versus 88% and 94% versus 91%, respectively.[17] However, LPN is both mentally and physically challenging to the operating surgeon due to the stress of performing a complex laparoscopic surgery with intra-corporeal suturing within a restricted timeframe to avoid ischemic renal injury, while ensuring good hemostasis.[18] Robot-assisted partial nephrectomy (RAPN) was first reported by Gettman *et al*.[19] in 2004. RAPN enables improved dexterity for tumor excision and easier intra-corporeal suturing.[18] However, much of the data for RAPN comes from observational studies. RCTs comparing LPN and RAPN do not exist. The efficacy of surgical modalities for PN can be measured in terms of trifecta outcomes, which consist of negative surgical margins, minimal renal functional decrease and

Table 1: Major studies comparing outcomes of laparoscopic radical prostatectomy with robot assisted radical prostatectomy

Author, Year, Journal, Country	Type of study, Methodology, Sample size	Study group	OT	EBL	LOS	Complication rate	BT rate	PSM	Continence rate/urinary QOL	Potency rate/sexual QOL	BC-RFS
Ilic *et al*., 2017,[5] BJU International, Australia	Meta-analysis of RCTs only (2 studies), LRP or RARP versus ORP	LRP or RARP versus ORP	N/R	N/R	Less in RARP versus ORP (MWD -1.72 [95% CI−2.19-−1.25])	Similar between RARP versus ORP (RR 0.41 [95% CI 0.-1.04])	Less in LRP/RARP (RR 0.24 [95% CI 0.12-0.46])	N/R	Similar between RARP versus ORP (MWD -1.30 [95% CI−4.65-2.05])	Similar between RARP versus ORP (MWD 3.9 [95% CI−1.84-9.64])	N/R
Moran *et al*., 2013,[9] International Journal if Urology, Ireland	Meta-analysis of non-RCTs and RCT (51 studies), RARP versus ORP, RARP versus LRP	RARP versus LRP	Similar (MWD −24 [95% CI −53-5])	Similar (MWD −78 [95% CI -199-43])	Less in RARP (MWD −0.7 (95% CI−1.2-−0.1])	Similar (RR 1 [95% CI 0.56-1.62])	Similar (RR 0.7 [95% CI 0.31-1.39])	Similar (pT2 RR 0.9 [95% CI 0.57-1.39]; pT3 RR 1.1 [95% CI 0.69-1.72])	Better in RARP (RR 1.1 [95% CI 1.02-1.17])	Similar (RR 1.49 [95% CI 0.60-3.73])	N/R
Wang *et al*., 2019,[11] Open Medicine, China	Meta-analysis of non-RCTs and RCTs (22 studies), RARP versus LRP	RARP versus LRP	N/R	Similar (MWD 0.38 [95% CI -0.84-0.08])	N/R	Less with RARP (OR 0.57 [95% CI 0.46-0.70])	N/R	Similar (OR 0.97 [95% CI 0.76-1.24])	Better with LRP (OR 2.09 [95% CI 1.61-2.73])	N/R	N/R
Allan *et al*., 2015,[12] Urologia Internationalis, Australia	Meta-analysis of RCTs only (2 studies, n=232)	RARP versus LRP	N/R	N/R	N/R	N/R	N/R	Similar (RR 1.39 [95% CI 0.81-2.41])	Better in RARP (RR 1.14 [95% CI 1.04-1.24])	Better in RARP (RR 1.51 [95% CI 1.19-1.92])	Similar (RR 1.01 [95% CI 0.91-1.12])

OT=Operative time, EBL=Estimated blood loss, LOS=Length of stay, BT rate=Blood transfusion rate, PSM=Positive surgical margin, QOL=Quality of life, BC-RFS=Biochemical recurrence free survival, RCT=Randomized controlled trial, LRP=Laparoscopic radical prostatectomy, RARP=Robot assisted radical prostatectomy, ORP=Open radical prostatectomy, N/R=Not reported, MWD=Mean weighted difference, CI=Confidence interval, RR=Risk ratio, , OR=Odds ratio

peri-operative safety.[20] Multiple recent meta-analyses have compared LPN and RAPN with OPN and each other and have shown mixed results. Cacciamani *et al.*[21] conducted a meta-analysis comparing OPN, LPN and RAPN. A total of 98 papers (20282 patients) were included. The incidence of hilar tumors and tumors with the higher RENAL score was greater in the RAPN cohort. RAPN was found to be superior to LPN in terms of warm ischemia time (WIT) (4.21, 95% CI 2.24, 6.17; $P < 0.00001$), transfusion requirement (OR: 1.37, 95% CI 2.23, 7.20; $P < 0.00001$), operative complications (OR: 2.05, 95% CI 1.51, 2.80; $P < 0.00001$) and rates of conversion to OPN (OR: 2.61, 95% CI 1.11, 6.15; $P = 0.03$) and radical nephrectomy (OR: 4.00, 95% CI 2.23, 7.20; $P < 0.00001$). PSM rate (OR: 2.01, 95% CI 1.52, 2.66; $P < 0.00001$) and estimated glomerular filtration rate (eGFR) % decrease (–1.97, 95% CI-3.57, –0.36; $P = 0.02$) also favoured the RAPN over LPN. Operative time (OT), EBL, 30-day readmission rate, cancer recurrences, and cancer-specific mortality were similar between the two groups. The mortality data for RAPN was available till 5 years follow-up. Another meta-analysis by Leow *et al.*[22] showed reduced complication rates, shorter WIT and lower PSM rates with RAPN compared to the LPN. The outcomes of studies comparing LPN and RAPN are detailed in Table 2. The learning curve of RAPN has also been suggested to be lower than that for LPN[23] and RAPN has led to the development of newer techniques for renorrhaphy (such as sliding clip technique[24]), thus reducing the WIT further. However, RAPN remains a much costlier option compared to the LPN[25] which limits its widespread application, particularly in the developing countries. Furthermore, the oncologic safety of RAPN has so far been addressed in studies with limited follow-up.[2]

Urinary bladder cancer

Open radical cystectomy (ORC) with urinary diversion is the gold standard treatment for muscle-invasive and high-risk non-muscle invasive bladder cancer.[26] However, ORC is one of the most complex procedures in urologic oncology and carries a high morbidity rate of over 50%.[27] Due to their minimally invasive nature, both laparoscopic radical cystectomy (LRC) and robot-assisted radical cystectomy (RARC) have gained a foothold in the management of this condition. LRC for bladder cancer was first described by Sanchez *et al.*[28] in 1993 and RARC by Menon *et al.*[29] in 2003. Although the data for LRC and RARC initially consisted of small series and single institutional studies, recently an increasing number of RCTs and meta-analyses are available comparing these modalities with ORC and to each other[30,31] LRC and RARC are compared to the ORC in the terms of three groups of outcomes– peri-operative surgical outcomes, surgical adequacy and oncologic outcomes. Peri-operative surgical outcomes are assessed on the basis of OT, EBL, transfusion rates, peri-operative complication rate and LOS. Surgical adequacy is defined in terms of PSM rate, estimated to be 1% to 6.3% with ORC[32,33] and LN) yield (10–14 LN yield is required to adequately stage the disease[34]). Oncologic

Table 2: Major studies comparing outcomes of laparoscopic partial nephrectomy with robot assisted partial nephrectomy

Author, Year, Journal, Country	Type of study, methodology, sample size	Study group	OT	EBL	WIT	LOS
Cacciamani *et al*., 2017,[21] The Journal of Urology, USA/Italy	Meta-analysis of non-RCTs, OPN versus RAPN, LPN versus RAPN, transperitoneal versus retroperitoneal PN, off-clamp vs on-clamp RAPN	LPN (*n*=3824) versus RAPN (*n*=4289)	Similar (MWD 7.68 [95% CI−10.47-25.84])	Similar (MWD −10.09 [95% CI−10.09-56.65])	Less in RAPN (MWD 4.21 (95% CI 2.24-6.17))	Similar (MWD 0.17 [95% CI−0.02-0.37])
		LPN (*n*=420) versus RAPN (*n*=468) for complex tumors (RENAL score 7 or more)	Less in RAPN (MWD 27.89 [95% CI 6.49-49.29])	Similar (MWD 8.64 [95% CI −37.43-54.70])	Less in RAPN (MWD 1.48 [95% CI 0.06-2.90])	Less in RAPN (MWD 0.27 (95% CI 0.03-0.52])
Leow *et al*., 2016,[22] The Journal of Urology, Singapore/USA	Meta-analysis of non-RCTs (25 studies), LPN (*n*=2238) versus RAPN (*n*=2681)	LPN versus RAPN	Similar (MWD −12.2 (95% CI−37.4-13))	Similar (MWD −24.6 [95% CI−57.9-8.8])	Less in RAPN (MWD −4.3 [95% CI −6.2-−2.5])	Similar (MWD −0.22 [95% CI−0.47-0.04])

Author, Year, Journal, Country	Conversion to radical nephrectomy	Complication rate	BT rate	Post-operative eGFR decrease	PSM	OM	CSS	RR
Cacciamani *et al*., 2017,[21] The Journal of Urology, USA/Italy	Less in RAPN (OR 4.00 [95% CI 2.23-7.20])	Less in RAPN (OR 2.05 [95% CI 1.51-2.80])	Less in RAPN (OR 1.37 [95% CI 1.08-1.74])	Less in RAPN (MWD −1.97 [95% CI−3.57-−0.36])	Less in RAPN (OR 2.01 [95% CI 1.52-2.66])	Less in RAPN (OR 2.98 [95% CI 1.05-8.40])	Similar (OR 2.43 [95% CI 0.83-7.12])	Similar (OR 2.36 [95% CI 0.95-5.84])
	Less in RAPN (OR 6.19 (95% CI 2.19-17.51])	Similar (OR 2.07 [95% CI 1.53-2.81])	Similar (OR 1.21 [95% CI 0.74-1.97])	Similar (MWD−1.19 [95% CI−2.87-0.49])	Similar (OR 1.73 [95% CI 1.33-2.26])	N/R	N/R	Similar (OR 1.19 [95% CI 0.34-4.17])
Leow *et al*., 2016,[22] The Journal of Urology, Singapore/USA	Similar (RR 0.44 [95% CI 0.18-1.09])	Less in RAPN (RR 0.84 [95% CI 0.73-0.95])	N/R	Similar (MWD−2.1 [95% CI−8.2-4.0])	Less in RAPN (RR 0.53 [95% CI 0.39-0.72])	N/R	N/R	N/R

OT=Operative time, EBL=Estimated blood loss, WIT=Warm ischemia time, LOS=Length of stay, BT rate=Blood transfusion rate, eGFR=Estimated glomerular filtration rate, PSM=Positive surgical margin, OM=Overall mortality, CSS=Cancer specific survival, RR=Recurrence rate, RCT=Randomized controlled trial, OPN=Open partial nephrectomy, RAPN=Robot assisted partial nephrectomy, LPN=Laparoscopic partial nephrectomy, PN=Partial nephrectomy, MWD=Mean weighted difference, CI=Confidence interval, OR=Odds ratio, N/R=Not reported, RR=Risk ratio

outcomes assessment requires longer follow-up and have been reported by only a handful of the studies. These are measured in terms of recurrence-free survival, cancer-specific survival and OS. Shi *et al*.[35] conducted a meta-analysis solely of RCTs comparing minimally invasive radical cystectomy (6 RCTs comparing RARC with ORC and 3 RCTs comparing LRC with ORC) with ORC. The authors found that both RARC and LRC offered significant benefits over ORC in terms of EBL, transfusion rate, time to regular diet and LOS. The overall complication rate of LRC was significantly lower than ORC. However, RARC had a similar complication rate as the ORC. Both the techniques had longer OT compared to ORC. The rate of PSM, LN yield, recurrence and mortality were not different between the groups. A head-to-head comparison of RARC and LRC was undertaken in a meta-analysis by Feng *et al*.,[31] which included 2 RCTs and 8 observational studies. The authors found RARC outperformed LRC in terms of LOS, complication rate and LN yield. LRC group had lower EBL. PSM rate was similar between the groups. Long term 5-year oncologic outcomes were reported by the CORAL trial[36] recently and were found to be similar between ORC, LRC and RARC. However, the trial was limited by small sample size and single institutional nature. The outcomes of the studies comparing LRC and RARC are detailed in Table 3. Majority of the evidence currently consists of extra-corporeal bowel reconstruction. Although studies have shown the feasibility of complete robotic intra-corporeal urinary diversion, most of these studies are small, single institution-based case series and lack long-term follow-up.[37] In a meta-analysis by Fonseka *et al*.,[30] the authors included 17.4% patients undergoing neobladder formation in robotic and 13.04% in the laparoscopic arm, and found similar results in terms of LOS and EBL, with a longer OT in the robotic group. However, a direct head-to-head comparison of RARC versus LRC exclusively for neobladder formation is lacking.

Testicular cancer

Post-orchidectomy management of testicular cancer varies by the stage of the disease and the treating center and consists of active surveillance, chemotherapy or retro-peritoneal LN dissection (RPLND), either alone or in combination.[38] Current indications for RPLND mainly include Stage 2A and early 2B disease in the primary setting and post-chemotherapy marker negative relapse as a salvage therapy.[39] Open RPLND is the current gold standard of treatment.[40] However, it entails a high morbidity and long recovery period. This has prompted the application of minimally invasive modalities for RPLND. LRPLND was first described in 1992.[41] Although initially feared to have minimal therapeutic potential, after the systemic literature review by Rassweiler *et al*.[42] consisting of over 800 patients, the therapeutic potential of L-RPLND has been solidified. The authors found that LN dissection performed according to the modified templates, yielded an average of 16 (5–36) LNs. Compared to the open approach, L-RPLND did not differ in terms of relapse rates, percentage of patients receiving chemotherapy (29% vs. 31%) and rate of salvage surgery (1.2% vs. 1.5%). However, L-RPLND has a steep learning curve, control of bleeding around the great vessels can be challenging and it has limited utility in bilateral template RPLND and in post-chemotherapy surgical field.[43] Therefore, the generalization of this procedure is yet to be established and currently, L-RPLND is recommended only in the expert hands, in which it offers outcomes similar to the open RPLND with reduced morbidity.[39] RA-RPLND is the latest technological advancement in this field, prompted by the advantages of 3D vision and better maneuverability of the robot.[43] However, RA-RPLND is mostly supported by case reports and small retrospective series.[44] In a review of retrospective studies (116 patients) by Tselos *et al*.,[38] the authors found similar outcomes as the L-RPLND. Median LN yield was 22.3 with an overall positivity rate of 26% and complication rate of 8%. Head-to-head comparisons between L-RPLND and RA-RPLND are sparse. In one such study, Harris *et al*. found similar outcomes between L-RPLND and RA-RPLND in terms of peri-operative morbidity and short term oncological outcomes.[45] However, the distinct disadvantages of robot include the markedly increased cost and a delay in hemostasis that may occur in case of a major vascular injury as the operating surgeon is not scrubbed.[45] At present, both L-RPLND and RA-RPLND are considered to be equivalent and offer advantages over open RPLND in expert hands.[39]

Ureteropelvic junction obstruction

Anderson-Hynes dismembered pyeloplasty was first described in 1949 for the surgical management of ureteropelvic junction obstruction (UPJO).[46] Traditionally performed via the open route, this procedure carries the significant morbidity of a flank incision and postoperative pain.[47] This has led to the introduction of laparoscopic pyeloplasty (LP), which offers considerable advantage over the open surgery in the terms of lower morbidity, lesser postoperative analgesia requirement and earlier discharge from the hospital, albeit at the cost of longer OT.[48] However, this procedure requires advanced laparoscopic suturing skills and has a steep learning curve.[49] With a growing interest in the robot-assisted procedures and the advantages of finer movement, tremor reduction and greater degrees of freedom offered by the robotic platform, a growing number of centers are offering robot-assisted pyeloplasty (RAP) in both the adult and pediatric patients. Direct comparisons between LP and RAP have mostly been observational in nature[50] and randomized trials comparing the two techniques are few.[51] Until recently, systemic reviews and meta-analysis comparing LP with RAP reported conflicting results.[52] However, Uhlig *et al*. recently performed a network meta-analysis of mostly adult patients with UPJO comparing the outcomes of open pyeloplasty, LP, RAP and endopyelotomy.[51] The authors report that RAP is associated with a significantly higher operative success rate compared to the LP, while the risk of peri-operative complications, urine leak, re-operation rate, blood transfusion rate and LOS were comparable. On including only the studies reporting 1-year

Table 3: Major studies comparing outcomes of laparoscopic radical cystectomy with robot assisted radical cystectomy

Author, Year, Journal, Country	Type of study, methodology, sample size	Study group	OT	EBL	LOS	Complication rate	BT rate	LN yield	PSM	OS/ mortality
Fonseka *et al*., 2015,[30] Archivio Italiano di Urologia e Andrologia, UK	Meta-analysis of non-RCTs and RCTs (24 studies), LRC (*n*=276) versus ORC (*n*=1100), RARC (*n*=728) versus ORC, RARC versus LRC	RARC versus LRC	Longer in RARC (MWD 47.61 [95% CI 8.83-86.40])	Similar (MWD -167.52 [95% CI −408.48-73.33])	Similar (MWD−1.95 [95% CI−9.88-5.97])	N/R	N/R	N/R	N/R	N/R
		RARC versus ORC	Longer in RARC (MWD 60.78 [95% CI 49.64-71.92])	Less in RARC (MWD −638.24 [95% CI −850.26-−426.21])	Less in RARC (MWD−1.75 [95% CI−2.94-−0.56])	Less in RARC (MWD 0.53 [95% CI 0.40-0.71])	N/R	Similar (MWD −0.22 [95% CI −2.83-2.39])	Similar (MWD 0.80 [95% CI 0.47-1.37])	N/R
		LRC versus ORC	Longer in LRC (MWD 34.93 [95% CI 12.76-57.10])	Less in LRC (MWD −480.96 [95% CI −765.04-−196.88])	Less in LRC (MWD−2.54 [95% CI −4.08-−0.99])	N/R	N/R	Similar (MWD 0.01 [95% CI −1.11-1.13])	N/R	N/R
Feng *et al*., 2020,[31] International Urology and Nephrology, China	Meta-analysis of non-RCTs and RCTs (10 studies), RARC (*n*=369) versus LRC (*n*=265)	RARC versus LRC	Similar (MWD 15.46 [95% CI −16.61-47.54])	Less in LRC (MWD 93.14 [95% CI 61.16-125.13])	Less in RARC (MWD−0.63 [95% CI −1.24-−0.03])	Less in RARC (MWD 0.65 [95% CI 0.46-0.93])	Less in RARC (RR 0.68 [95% CI 0.46-0.99])	More in RARC (MWD 2.38 [95% CI 1.89-2.87])	Similar (MWD 1.45 [95% CI 0.62-3.39])	OS more in RARC (MWD 0.26 [95% CI 0.17-0.39])
Shi *et al*., 2019,[35] Journal of International Medical Research, China	Meta-analysis of RCTs (8 studies), MIRC versus ORC	MIRC versus ORC	More in MIRC (MWD 62.90 [95% CI 36.02-89.78])	Less in MIRC (MWD −338.78 [95% CI −422.22-−255.33])	Less in MIRC (MWD−0.93 [95% CI −1.32-−0.54])	Similar (OR 0.75 [95% CI 0.54-1.03])	Less in MIRC (OR 0.46 [95% CI 0.30-0.70])	Similar (MWD−1.43 [95% CI−3.75-0.89])	Similar (OR 1.00 [95% CI 0.50-2.03])	Similar mortality (0.91 [95% CI 0.60-1.37])

OT=Operative time, EBL=Estimated blood loss, LOS=Length of stay, BT rate=Blood transfusion rate, LN yield=Lymph node yield, PSM=Positive surgical margin, OS=Overall survival, RCT=Randomized controlled trial, LRC=Laparoscopic radical cystectomy, ORC=Open radical cystectomy, RARC=Robot assisted radical cystectomy, N/R=Not reported, MWD=Mean weighted difference, CI=Confidence interval, RR=Risk ratio, MIRC=Minimally invasive radical cystectomy, OR=Odds ratio

follow up (13 of 24 studies), no difference in success rates was found between LP and RAP. Most of the included studies were retrospective in nature and only one randomized trial was included. RAP has also been found to be significantly costlier as compared to the LP.[53] Another meta-analysis consisting of 14 observational studies comparing LP with RAP in pediatric patients showed the RAP to have a higher success rate with a shorter LOS.[54]

Donor nephrectomy and kidney transplantation

Laparoscopic donor nephrectomy (LDN) is the standard of care for kidney retrieval for transplant, offering advantages such as lower blood loss, lower post-operative pain and earlier hospital discharge.[55] However, LDN is an advanced laparoscopic procedure and entails a significant learning curve.[56] Robot assisted donor nephrectomies (RADN), pioneered by Horgan *et al*.,[57] are now being performed at few centers around the world. However, conclusive superiority of RADN over LDN has not been established as yet. RCTs between the two are few[58] and are limited by small sample size. Wang *et al*.[59] performed a meta-analysis comprising of 2 RCT and 5 retrospective studies (514 patients) comparing the LDN and RADN. The authors found a significantly shorter OT, lower EBL and reduced WIT with LDN. Kidney retrieval by the assistant surgeon and de-docking of the fourth arm before the retrieval may contribute to longer WIT with RADN. RADN has also been found to be costlier.[60]

The safety and feasibility of laparoscopic kidney transplant (LKT) were initially described by Modi *et al*., and since then, reports have shown a similar outcome of LKT as open renal transplant (OKT) in terms of eGFR at 1-month and 1-year.[61] Robot-assisted kidney transplantation with regional hypothermia (RAKT) was elaborately described by Menon *et al*. in 2014, and the authors found a similar creatinine clearance as OKT from the day one onwards in the hands of the experienced robotic surgeons.[61] The number of centers performing RAKT has gradually expanded over the country, however, due to the sensitive nature of the procedure and technical difficulty in performing vascular anastomosis as compared to the open surgery, minimally invasive kidney transplant program has still not achieved widespread success. Since the introduction of RAKT program, there have not been any direct comparisons between the LKT and RAKT and we could not find any new research on LKT since 2014. Currently, OKT surgery remains the 'gold standard', although a continuing rise in the indications for RAKT is found.

Penile cancer

Penile cancer is a rare condition, and surgical excision of the penile mass with inguinal LN dissection forms the mainstay of its treatment.[62] Open inguinal LN dissection is associated with morbidity rates of around 50% including lymphedema, lymphocele (21%), wound infection (26%) and flap necrosis (41%).[62] Video endoscopic inguinal lymphadenectomy (VEIL) using the traditional laparoscopic instruments, first described in 2003, has been reported to reduce the surgical morbidity without compromising the oncologic outcomes.[63] However, the procedure is complex and ergonomically taxing. The first robot-assisted LN dissection (RAIL) was described in 2009 by Josephson *et al*.[64] Initial reports have shown the feasibility of performing RAIL, with data showing reduced complication rates and shorter LOS.[65] Data comparing VEIL and RAIL is extremely limited and retrospective. Russel *et al*. performed a retrospective comparison of VEIL with RAIL and found comparable outcomes.[66] At present, there seems to be no advantage of robotics over laparoscopy in carcinoma penis for LN dissection and further research is urgently needed to assess the same.

Ureteric reconstruction

Data comparing laparoscopic and robot-assisted approaches for ureteric reconstruction are limited. Open ureteral reimplantation is the gold standard for benign diseases such as the vesicoureteral reflux (VUR), megaureter or obstruction. Laparoscopy (LUR) has lower EBL, LOS and pain compared to the open technique.[67] Robot-assisted ureteric reimplantation (RAUR) is a new technique, first described in 2003, and multiple observational studies comparing it with the LUR have found similar mean OT, EBL and LOS between the two, with success rates approaching 100% with either of the technique.[67] The follow up period with LUR was longer than RAUR in these studies. RAUR has also been attempted for pediatric VUR; however, no consensus currently exists and RAUR has been found to have higher complication rates and lower success rates than the open approach in some reports.[68]

DISCUSSION

Traditional laparoscopy and robot-assisted surgery can be evaluated in terms of risks and benefits in three core aspects– the surgical procedure itself, the patient's perspective and the surgeon's perspective.

The robotic system provides manifold technological advancements over the traditional laparoscopy. The visual system consists of a dual 3-chip camera, and three-dimensional vision with a magnification of 10-12X provides for excellent depth perception. The "endowrist" technology of robotic instruments adds a fulcrum proximal to the instrument's tip, allowing a greater degree of freedom of movement. Furthermore, the tremor reduction and motion scaling of up to 3:1 helps in fine movements inside the operative field.[69] These features may specifically help in performing surgeries in fixed narrow cavities, such as the pelvis and therefore, robot-assisted surgery has shown maximum use in RP and gynecologic surgeries.[70] However, despite more than 30 years' worth of data, tangible advantages of robotic assistance over laparoscopy in terms of OT, EBL, PSM rates and LOS are lacking. Furthermore, the absence of haptic feedback is a major disadvantage of the robotic system.[71] Robot-assisted surgery has been found to be feasible in almost

all types of urologic surgery, but it is important to note that feasibility by itself should not be translated into superiority.

The patients' perspective has been one of the major driving forces for the rapid acquisition of robotic technology. Direct-to-patient marketing and lack of any viable competition may imbibe grandiose misconceptions regarding the efficacy of the robot. More and more patients are now seen demanding a robotic procedure, and the 'fear of missing out epidemic' may drive many hospitals in the private sector to pursue the robot and market it for indications in which it lacks a proven advantage[70,71] The approximate cost of the DaVinci surgical system (Intuitive Surgical Inc., Sunnyvale, California, USA) is around USD $2 million with an additional annual maintenance fees of USD $100,000 and a disposable supply cost of approximately $1500/case[69,71,72] Not many hospitals can afford this and recover the cost without increasing the numbers of robotic procedures conducted. This leads to an increase in the overall healthcare expenditure, which is of paramount concern in a developing country. Also, robotic surgeries are not currently reimbursed by medical insurance. The expenditure and resources required in the establishment of one robotic unit are equivalent to setting up 25–30 independent laparoscopic units, which may be more cost-effective. Since a large number of urological patients are waiting to undergo various procedures, it is wise to use our resources intelligently.[71] Any new technology must be affordable, acceptable, accessible, available and appropriate to a large number of patients across the population.[71] Furthermore, the long term safety and efficacy data of robot for many urologic oncology procedures is not yet available, compared to the traditional laparoscopy. It is important to note that the robot is after all a machine, and may be subject to technical glitches. Operative malfunctions of robotic surgery are widely underreported, and conversion to laparoscopy or open surgery in cases of emergency can be fatally time-consuming.[71]

Robotic systems have also been touted to be beneficial for the surgeon. With the surgeon sitting on a master console away from the patient, the surgery becomes ergonomically better and less stressful for the operating surgeon. However, there are contradictory surveys which suggest that more than half of the interviewed surgeons report symptoms of neck stiffness, finger and eye fatigue proportional to the number of hours spent on the console. Similarly, a higher lower back stiffness has been found in surgeons with a higher annual robotic case-load.[70] Whether robotic surgery truly offers ergonomic benefits to the surgeons needs to be evaluated and validated by uniformly applied questionnaires and measurement indices. Although the robot assistance may help in reducing the learning curve of a procedure, this advantage needs to be viewed in terms of healthcare economics and patient finances in the developing countries. The learning curve of laparoscopy may also be shortened if laparoscopic training is properly incorporated in residency programs right from the beginning. Reliance on the technology should not compensate for a lack of expertise. The large patient pool available in developing countries like India may be helpful in skill improvement and results in laparoscopy.[72] Continuous advancements happening in the field of laparoscopy, such as 4K ultrahigh-definition technology with 3D vision, advanced sealing devices, laparoscopic robotized wristed instruments with six degrees of freedom, ergonomic platforms with chest supports, armrests and camera holders, may prove to be more cost-effective with similar results compared to the robotic technology.[1,73]

Guidelines in Urology currently do not support the robot over laparoscopy, or vice versa.[3] A similar stand has been taken by nonurologic specialties and various Government bodies as well. The National Health Services in England has previously stated that there is insufficient evidence to support the funding for robot-assisted radical cystectomy.[70] Similarly, in a committee opinion by the American College of Obstetricians and Gynecologists, it was noted that the role of robotic assistance for hysterectomy for benign diseases is not clearly defined and more data is required to endorse the same.[74] In another safety and efficacy analysis by the Society of American Gastrointestinal and Endoscopic Surgeons, the Executive Board concluded that the use of robotic assistance for gastrointestinal surgery is safe, with comparable, but not superior results as the standard laparoscopic approaches and its use may be expensive for selected gastrointestinal procedures.[75]

CONCLUSION

The present review provides an updated appraisal of the comparative evidence for laparoscopy versus robot-assisted surgery in the backdrop of developing countries where robot-assisted surgery is not widely available. Current evidence suggests that surgical and patient outcomes following laparoscopic surgery compares well to the robot-assisted surgery for most of the urologic procedures. Robotic assistance definitely provides better vision, improved ergonomics and provision for finer movements; however, whether this translates into significantly improved clinical outcome parameters, requires more robust research. Even with the currently evident advantages of the robot-assisted surgery over traditional laparoscopy, the cost of the robotic systems is prohibitively high to support its widespread application. With the upcoming advancements of laparoscopic wristed instruments and 3D vision, some limitations of laparoscopy may be overcome at a significantly lower cost compared to the robotic technology. At present, laparoscopic urology seems to be a thriving option for the urologists, especially in the resource-limited settings of the developing countries. Rational thinking and evidence-based decisions should guide any investment in new technology.

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