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Review

Current status of robotic assisted pelvic surgery and future developments

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ABSTRACT

Aims: The aim of this review is to assess the role of robotics in pelvic surgery in terms of outcomes. We have also highlighted the issues related to training and future development of robotic systems.
Materials and methods: We searched MEDLINE, EMBASE and the Cochrane Databases from 1980 to 2009 for systematic reviews of randomised controlled trials, prospective observational studies, retrospective studies and case reports assessing robotic surgery.
Results: During the last decade, there has been a tremendous rise in the use of robotic surgical systems for all forms of precision operations including pelvic surgery. The short-term results of robotic pelvic surgery in the fields of urology, colorectal surgery and gynaecology have been shown to be comparable to the laparoscopic and open surgery. Robotic surgery offers an opportunity where many of these obstacles encountered during open and laparoscopic surgery can be overcome.
Conclusions: Robotic surgery is a continually advancing technology, which has opened new horizons for performing pelvic surgery with precision and accuracy. Although its use is rapidly expanding in all surgical disciplines, particularly in pelvic surgery, further comparative studies are needed to provide robust guidance about the most appropriate application of this technology within the surgical armamentarium.

1. Introduction

Minimally invasive surgery has expanded rapidly since the first laparoscopic cholecystectomy.[1] This was driven by the quest for smaller incisions, faster recovery, less stay related complications and improved dexterity, which gained further momentum as a result of the introduction of robotics to surgery. The era of robotic surgery dawned in early 1990s,[2] and many of the current systems emerged by the end of that decade. These include the 'master-slave robotic systems' such as the da Vinci and ZEUS surgical systems, which allowed entry to an era where poor visibility, hand tremors, limited freedom of movement and bulky instruments were not a problem.[3]

The da Vinci system, described as the "tele-presence surgery" was developed by NASA and the US defence department with the aim to allow surgeons to operate on wounded soldiers from a remote location. This system permitted real-time video image contact between the patient and surgeon. The da Vinci is not a fully automated robot in the true sense but is in fact a "master-slave" system that allows the surgeon to control the function of the robot. It consists of a cart with robotic arms delivering a variety of articulating instruments including cameras. At the console is a pair of binoculars, which displays 3D video image of the operating field. As the surgeon views the surgical field through these binoculars, he descends into the virtual 3D operative field and perceives himself to be inside the patient surrounded by the abdominal or thoracic walls.[3]

The da Vinci robotic system has been found to be extremely useful to approach and intervene in narrow cavities such as pelvis and it is gradually becoming a common practice (Fig. 1). The advantages further include stable camera platform to eliminate hand-tremor from a camera holder; hand-like motions of the instruments permitting a variety of tasks not possible with traditional straight laparoscopic instruments to facilitate dissection; a three-dimensional virtual operative field, with improved spatial awareness as compared to standard two-dimensional imaging systems; an ergonomically comfortable position to sit at the remote

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telerobotic console, reducing the shoulder and back fatigue associated with prolonged laparoscopic operations.[4] Conversion and complication rates are low and short-term outcomes are comparable to that of conventional laparoscopic surgery.[5]

We reviewed the literature with the aim to assess the current role of robotics in pelvic surgery (colorectal surgery, urology and gynaecology) in terms of its utility and outcomes. Issues pertaining to safety, reliability of robotic systems, training in robotic surgery and the future developments are also discussed.

2. Methods

We searched MEDLINE, EMBASE and the Cochrane databases from 1980 to 2009 for systematic reviews of randomised controlled trials, prospective observational studies, retrospective studies and case reports assessing robotic surgery. The search strings were defined by a combination of keywords including 'robotics' or 'robot' or 'robot-assisted' or 'da Vinci'. Additional search was performed for each of gynaecology, colorectal surgery, urology and pelvic surgery. The search was limited to articles in English language and relevant studies were evaluated including the reference lists.

3. Role in colorectal surgery

The first series of robotically assisted laparoscopic colectomy were published in March 2001.[6] Since then robotic assistance has been employed in hemicolectomies, sigmoid colectomies, proctopexies, low anterior resections and abdominoperineal resections (Table 1).[7–9]

Robot assisted anterior and abdominoperineal resections have been reported by various authors. D'Annibale et al. reported a comparison of 53 robotic and 53 laparoscopic procedures performed for colorectal diseases.[7] Although pelvic surgeries were not compared alone, 10 anterior resections and 1 abdominoperineal resection were performed in the robotic group and 15 anterior resections were performed in the laparoscopic group. No differences were seen in complication rates, estimated blood loss and lymph node harvest rates. Median length of hospital stay was 2.5 days in the robotic surgery group, vs. 3 days in the laparoscopic cohort. There was no significant difference in actual operating time (robotic group, 240 ± 61 min; laparoscopic group, 222 ± 77 min), but system and patient setup time (robotic group, 24 ± 12 min; laparoscopic group, 18 ± 7 min; $p = 0.002$), were relatively longer in the robotic group.[7]

Spinoglio et al. compared 50 robotic to 161 laparoscopic colorectal resections.[10] Similar to D'Annibale et el, pelvic surgeries were not compared separately, but there were 19 anterior resections and 1 abdominoperineal resection in the robotic group and 26 anterior resections and 7 abdominoperineal resections in the laparoscopic groups. There was a significant longer operative time in the robotic group (383.8 vs. 266.3 min, $p < 0.001$), but there were no differences in short-term outcomes such as restitution of gut function and length of hospital stay.

Pigazzi's group in California, reported by Hellan et al. and Anderson et al.,[11,12] performed 39 consecutive robotic assisted laparoscopic rectal resections with total mesorectal excision (TME) for primary rectal cancer. The study included the results of 22 low anterior, 11 intersphincteric and 6 abdominoperineal resections. The median operative time was 285 minutes (range 180–540 min) and a median robotic TME time of 60 minutes (range 35–135 mins). One patient required conversion to open surgery (conversion rate 2.6%). Ninety-five per cent of patients had a colo-anal anastomosis within 5 cm of the anal verge. Six patients had major postoperative complications (15%), including four anastomotic leaks, all requiring reoperation (12% leak rate), one delayed fistula and one patient with a neurogenic bladder and wound dehiscence. The median length of stay was 4 days. Total mesorectal excision with autonomic nerve preservation was achieved in all of the patients, and all circumferential and distal resection margins were negative. One patient died four months after surgery due to unrelated causes. There were no peri-operative (30-day) or cancer-related deaths.[11,12]

The largest series of robotic-assisted low anterior resections has been described by Baik et al.[13–15] In this prospective comparative non-randomised study consecutive rectal cancer patients were treated by laparoscopic low anterior resection (L-LAR) ($n = 57$) or robotic low anterior resection (R-LAR) ($n = 56$). There was no significant difference between mean operating time (L-LAR 191.1 ± 65.3 vs. R-LAR 190.1 ± 45.0 min). Patients who had L-LAR had significantly higher mean length of hospital stay (7.6 ± 3.0 vs. 5.7 ± 1.1 days, $p = 0.001$), open conversions (6 vs. 0 patients, $p = 0.013$) and serious complications (11 vs. 3 patients, $p = 0.025$). Serious complications included anastomotic leakage with 4 (7%) leaks in the laparoscopic group compared to 1 (2%) leak in the robotic group. TME was significantly better in the R-LAR group in comparison to the L-LAR group (52 complete, 4 nearly complete vs. 43 complete, 12 nearly complete, 2 incomplete, $p = 0.033$). However there was no difference in circumferential resection margin involvement (L-LAR 5 vs. R-LAR 3 involved).

The studies by Pigazzi et al. and Baik et al. demonstrate that robotic assisted rectal resections with TME can be performed safely and effectively using robotic assistance with lower serious complication rates than laparoscopic surgery. The reported leak rates of 2–12% is comparable to the 6–16% rate reported in open series and 13–19% in laparoscopic series.[16,17] The low conversion rate and reduced length of hospital stay in robotic surgery has important implications for clinical outcome.

4. Role in urological surgery

The fastest growing application of robotic pelvic surgery is in urological procedures such as prostatectomy and cystectomy.[18–20]

4.1. Robot-assisted radical prostatectomy for prostate cancer

Presently, radical prostatectomy (RP) is the most commonly performed robot assisted laparoscopic procedure (Table 2). Robotic RP (RRP) has traditionally been regarded as time consuming relative to open surgery. However, with increasing experience and

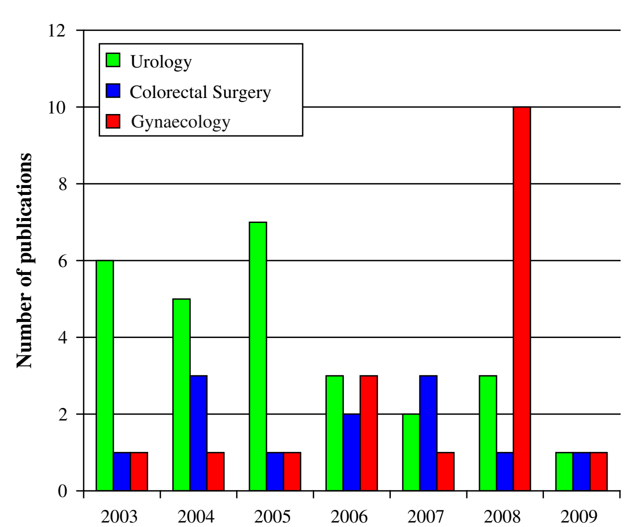

Fig. 1. Pelvic Robotic surgery in historical perspective.