Robot-Assisted Rectal Surgery for Malignancy: A Review of Current Literature
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Abstract
Laparoscopic colorectal surgery is rapidly gaining acceptance for the management of colorectal cancer. However, laparoscopic colorectal surgery is technically more challenging than conventional surgery. This challenge is more profound for laparoscopic rectal cancer, where there is a need to perform a total mesorectal excision (TME), in the confines of the pelvis, with the limitations of the laparoscopic system. The Da Vinci robotic surgical system was designed to overcome the pitfalls of laparoscopic surgery, hence the use of this novel system in colorectal surgery seems logical, in particular with regards to rectal cancer surgery. Recently, there have been an increasing number of reports in the literature on robotic colorectal surgery. The advantages of the robotic surgical system include; 7 degrees of movement, 3 dimensional views, tremor filtration, motion scaling and superior ergonomics. These advantages when applied to robotic TME for rectal cancer surgery may potentially translate to better outcomes. The aim of this review is to summarise the current evidence on clinical and oncological outcomes of robotic rectal cancer surgery.

Key words: Malignancy, Rectal, Robot

Introduction
Since it was first described in 1991, laparoscopic colorectal surgery has gained popularity and is becoming the standard of care for both benign and malignant colorectal disease. The major benefits of laparoscopic colorectal surgery include; less postoperative pain, better cosmesis, earlier return of normal bowel function and shorter hospital stay without sacrificing oncological clearance.1 However, despite its popularity, conventional laparoscopic surgery has its shortcomings, such as a limited 2-dimensional views, limited dexterity of instruments within the confines of the abdominal space, fixed instrument tips with only 4 degrees of freedom and possible misalignment of hands and instruments. These limitations make laparoscopic surgery more challenging and technically demanding than conventional open surgery. Total mesorectal excision (TME) introduced by Heald et al2 in 1982 has revolutionised the surgical management of rectal cancer. TME has gained worldwide acceptance as a standard surgical technique for rectal cancer.3 When performing a laparoscopic total mesorectal excision (LapTME), meticulous and precise dissection of the mesorectum in a previously irradiated rectum down to the pelvic floor within the confines of a narrow pelvis, is a technical challenge even for experienced laparoscopic colorectal surgeons.4-7 The preservation of anal sphincter function while obtaining an oncological clearance in rectal cancers can be very challenging.

The da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) was developed to overcome the shortcomings of conventional laparoscopic surgery. Compared with conventional laparoscopic surgery, the da Vinci system has several advantages such as 3-dimensional imaging, a stable camera and operating platform, articulating instruments with 7 degrees of freedom, excellent ergonomics, motion scaling and tremor free movements.8-10 Robotic total mesorectal excision (RTME) may be advantageous in the dissection of the avascular plane between the presacral fascia and the fascia propria of the rectum without injury to the integrity of the mesorectum in the narrow pelvic cavity.11 Currently, experience with robotic rectal cancer...
surgery is in its infancy.

The aim of this review is to provide a comprehensive and critical analysis of the literature on the use of robot technology in rectal cancer surgery.

Materials and Methods

A PubMed search was systemically reviewed for evidence up till May 2011, using the key words ‘robot’, ‘rectal’, cancer’ and robotic rectal surgery. The following publications types: randomised controlled trials, prospective studies, case studies and retrospective studies were considered. Studies published only as abstracts and reports from meetings were not included in this review. To be included in the review process, studies had to report outcomes on robotic rectal cancer resection surgery and were limited to those published in English. When multiple studies describing the same patient population were identified, the most recent publication was used. A total of 9 studies were identified and included in this review. Four studies were case series,12-15 5 were comparative studies, assessing robotic vs laparoscopic surgery for rectal malignancy.11,16-19 The reviewers extracted the following data from eligible studies according to a pre-specified protocol: first author, publication year, study design, number of subjects, procedures performed, operating time, length of stay, estimated blood loss, cost, conversion rates and complications.

Operative Procedure

A total of 434 patients whose data were accrued from the 9 studies have undergone robotic rectal surgery and included in this review (Table 1). All 434 patients underwent robotic assisted rectal resections for neoplastic disease. All 9 studies used the da Vinci Surgical System (Intuitive Surgical Inc., Sunnydale, CA). Five studies used a hybrid technique which comprised a laparoscopic colon mobilisation, followed by a robot-assisted TME of the rectum. Three studies used the full robot-assisted approach which includes robot assisted colonic mobilisation and robot-assisted TME of the rectum.15,17,19 One study which was a multicentre study involving 3 institutions had a mixed approach, using both techniques.14 Among the 434 patients who underwent robotic rectal resections, 302 (69.5%) patients had an anterior resection (high and low), 85 (19.6%) patients had an intersphincteric resection (ISR) with coloanal anastomosis while 47 (10.8%) patients had an abdominoperineal resection (APR).

Operating Times (Table 2)

The duration of the entire procedure is one of the key outcomes evaluated by all studies. Among the 9 studies included in this review, the operating times for rectal resections ranged from 190 to 347 minutes; however, there was considerable inconsistency in the reporting of data, as some studies expressed the timings in mean while others used median. Among the 5 studies comparing robotic and laparoscopic rectal surgery, 2 studies had a shorter operating time for robot-assisted surgery although the difference was not statistically significant.11,16 However, when Patriti et al16 performed a subset analysis on the timings for TME, they found that RTME could be performed in a significantly shorter operative time compared with LapTME. The 3 other studies report increased procedure duration with robotic procedures17-19 when compared with laparoscopic rectal surgery. In 2 of these studies,18,19 the difference was statistically significant. (270min vs 228 min, \( P<0.0001 \) and 239.1 min vs 168.6 min, \( P<0.0001 \), respectively)

Length of Stay (Table 2)

Eight studies have reported on the duration of length of stay, with results ranging from 5 to 11.9 days.11-18 Among the 5 comparative studies, only Kwak et al19 did not report the impact of robotic surgery on length of stay. The results

<table>
<thead>
<tr>
<th>Reference</th>
<th>Year</th>
<th>Study design</th>
<th>Method</th>
<th>Total</th>
<th>Type of operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ng et al12</td>
<td>2009</td>
<td>case series</td>
<td>Hybrid</td>
<td>8</td>
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<td>deSouza et al13</td>
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<td>Hybrid</td>
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<tr>
<td>Pigazzi et al14</td>
<td>2010</td>
<td>case series</td>
<td>Mixed</td>
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</tr>
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<td>Leong et al15</td>
<td>2011</td>
<td>case series</td>
<td>Full</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>Baik et al11</td>
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<td>Hybrid</td>
<td>56</td>
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</tr>
<tr>
<td>Patriti et al16</td>
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<td>Hybrid</td>
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<td>Park et al18</td>
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<td>Hybrid</td>
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<td>29</td>
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<tr>
<td>Bianchi et al17</td>
<td>2010</td>
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<td>Full</td>
<td>25</td>
<td>18</td>
</tr>
<tr>
<td>Kwak et al19</td>
<td>2011</td>
<td>comparative</td>
<td>Full</td>
<td>59</td>
<td>52</td>
</tr>
</tbody>
</table>

AR: Anterior resection; LAR: Low anterior resection; ISR: Intersphincteric resection; APR: Abdominoperineal resection
varied, with 3 studies observing a non-significant, longer length of stay after robotic surgery\textsuperscript{16-18} while another observed a statistically significant shorter length of stay after robotic surgery.\textsuperscript{11}

**Blood Loss/Haemoglobin Change**

Blood loss was reported in 4 studies\textsuperscript{13-16} with losses ranging from 50 mls to 283 mls. Conflicting results on blood loss have been reported in studies comparing robotic and laparoscopic rectal surgery. In a comparative study, the estimated blood loss was higher in robot-assisted surgery compared to laparoscopic assisted surgery.\textsuperscript{16} This difference was small and was not statistically significant (137.4 vs 127, $P > 0.05$).

**Conversion (Table 2)**

Among the 434 patients in this review, there were only 9 (2\%) conversions reported from the 2 studies.\textsuperscript{13,14} These 9 patients were converted to open surgery. The most common reason (66\%) for conversion was inability to perform pelvic dissection satisfactorily because of a heavy mesorectum from obesity or a narrow pelvis.\textsuperscript{13,14} Among the 5 comparative studies, there were no conversions for robotic rectal surgery, compared to 16 (6.2\%) conversions for laparoscopic rectal surgery. Two studies showed that these conversions were statistically significant.\textsuperscript{11,16}

**Leak Rate (Table 2)**

A total of 36 (8.3\%) leaks were reported among the 434 patients in this review. The reported leak rates among the 10 studies in this review ranged from 0\% to as high as 13.6\%. Among these reported leaks, 2 studies elaborated on the management of the leaks. For example, deSouza et al\textsuperscript{13} had 2 leaks, one was managed with laparoscopic drainage of the pelvic collection and a diverting ileostomy; the second patient required a transanal drainage of the localised pelvic collection. Bianchi et al,\textsuperscript{17} managed 1 patient with a leak by maintaining pelvic drainage until the infection had resolved clinically. Among the 5 comparative studies, 3 studies demonstrated a higher leak rate for robotic rectal surgery compared to conventional laparoscopic surgery,\textsuperscript{16,18,19} while the other 2 studies\textsuperscript{11,17} had a lower leak rate for robotic rectal surgery. None of the findings were statistically significant.

**Complication Rates/ Mortality (Table 2)**

The complication rate from robotic rectal surgery ranged from 5.4\% to 43.2\%. The overall complication rate was 31.1\%. The 4 most common complications are ileus, anastomotic leak, bleeding and wound infection. Among the 5 comparative studies, 3 studies reported a higher complication rate for robotic rectal surgery\textsuperscript{16,18,19} while 2 studies reported a lower complication rate.\textsuperscript{11,17} Only one comparative study showed a statistically significant
There was one death reported among the 9 studies in this review.\textsuperscript{13} The patient died from aspiration pneumonia on postoperative day 21.

Oncological Outcomes (Table 3)

The number of lymph nodes harvested from robotic rectal surgery ranged from 10.3 to 20 in our review. Among the 5 comparative studies, 2 studies reported a larger number of lymph nodes harvested using the robot technique,\textsuperscript{17,18} while 3 studies reported a larger number of lymph nodes harvested using conventional laparoscopic surgery.\textsuperscript{11,16,19} None of these reported differences were statistically significant.

The distal resection margins from robotic rectal resections ranged from 0.8 cm to 4.0 cm. Three case series reported a positive distal margin each.\textsuperscript{13-15} Among the 5 comparative studies, 2 studies reported better distal margin clearance with robotic resections,\textsuperscript{11,19} one study had identical results while two studies had smaller distal clearance.\textsuperscript{16,18} None were statistically significant.

There were 10 cases (2.3\%) of positive circumferential margins (CRM) among the 4 case series and 5 comparative studies. The 5 comparative studies showed that 2 studies had less CRM,\textsuperscript{11,17} while 2 studies had more involvement for robot surgery.\textsuperscript{18,19} One study had zero CRM for both robot and laparoscopic surgery.\textsuperscript{15} Baik et al\textsuperscript{11} used TME completeness instead of CRM and demonstrated a superior result with robot surgery (92.9\% vs 75.4\%). Only one of these differences was statistically significant.

Follow-up

Five studies reported results on the follow-up.\textsuperscript{11,14,16,17,19} The length of follow-up ranged from 10 months to 29.2 months. Kwak et al\textsuperscript{19} reported no difference in cancer recurrence between robot and laparoscopic rectal cancer surgery. Patriti et al\textsuperscript{16} reported no differences in overall and disease free survival but a trend towards a better disease survival in the robotic rectal surgery group. Baik et al\textsuperscript{11} reported 2 systemic recurrences in the robotic group, and 2 systemic recurrences in the laparoscopic group. Bianchi et al\textsuperscript{17} reported that all 50 patients in their comparative study were alive and disease free at 10 months. Pigazzi et al\textsuperscript{14} reported a 97\% 3-year survival rate among the 143 patients who underwent robotic rectal cancer surgery with no isolated local recurrence during a mean 17.4 month of follow-up.

Discussion

Laparoscopic resection of rectal cancer is safe but technically demanding with a steep learning curve. The technical challenges to conventional laparoscopic surgery include the limited range of motions of the instruments in a narrow pelvic cavity, an inadequate visual field with an unstable camera view, a relative loss of dexterity and an assistant’s retraction not under the direct control of the surgeon.\textsuperscript{20} The advantage of the da Vinci robotic system, such as the 7 degrees of freedom of movement mimicking the movements of the surgeon’s wrist, the 3-dimensional view, lack of tremor, scaled down movements and superior ergonomics are extremely useful for pelvic surgery. These advantages have been best demonstrated by the urologists in robot-assisted radical prostatectomy. In a short span of 3 years, robotic radical prostatectomy has increased from 41\% to nearly 80\% in 2008.\textsuperscript{21} Multiple robotic radical prostatectomy series are mature enough to demonstrate safety, efficiency and reproducibility, with oncological and functional outcome comparable to open surgery.\textsuperscript{22-24} The technological advantages of robotic surgery may

<table>
<thead>
<tr>
<th>Reference</th>
<th>Sample</th>
<th>Lymph nodes harvested</th>
<th>DRM (cm)</th>
<th>CRM (involved)</th>
<th>TME completeness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ng et al\textsuperscript{12}</td>
<td>8 Robot</td>
<td>15 (2-26)</td>
<td>NA</td>
<td>&gt;2</td>
<td>NA</td>
</tr>
<tr>
<td>deSouza et al\textsuperscript{13}</td>
<td>44 Lap</td>
<td>14 (5-45)</td>
<td>NA</td>
<td>?</td>
<td>NA</td>
</tr>
<tr>
<td>Pigazzi et al\textsuperscript{14}</td>
<td>143 Robot</td>
<td>14.1 (1-39)</td>
<td>NA</td>
<td>2.9 (0-10)</td>
<td>NA</td>
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<tr>
<td>Leong et al\textsuperscript{15}</td>
<td>29 Robot</td>
<td>16 (1-44)</td>
<td>NA</td>
<td>0.8 (0-4)</td>
<td>NA</td>
</tr>
<tr>
<td>Baik et al\textsuperscript{11}</td>
<td>56 Robot</td>
<td>18.4 ± 9.2</td>
<td>18.7 ± 12</td>
<td>4.0 (1.0-7.0)</td>
<td>3.0 (1.0-9.0)</td>
</tr>
<tr>
<td>Patriti et al\textsuperscript{16}</td>
<td>57 Robot</td>
<td>10.3 ± 4</td>
<td>11.2 ± 5</td>
<td>2.1 ± 0.9</td>
<td>4.5 ± 7.2</td>
</tr>
<tr>
<td>Park et al\textsuperscript{17}</td>
<td>82 Robot</td>
<td>17.3 ± 7.7</td>
<td>14.2 ± 8.9</td>
<td>2.1 ± 1.4</td>
<td>2.3 ± 1.5</td>
</tr>
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<td>Bianchi et al\textsuperscript{18}</td>
<td>25 Robot</td>
<td>18 (7-34)</td>
<td>17 (8-37)</td>
<td>2 (1.5-4.5)</td>
<td>2 (1.8-3.5)</td>
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<td>Kwak et al\textsuperscript{19}</td>
<td>59 Lap</td>
<td>20 (12-27)</td>
<td>21 (14-28)</td>
<td>2.2 (1.5-3.0)</td>
<td>2.0 (1.2-3.5)</td>
</tr>
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</table>
be maximised in rectal cancer surgery, as this part of the procedure occurs in the confines of the pelvis, translating the advantages to better oncological and functional outcomes.\textsuperscript{29} Other procedures such as right hemicolectomies and sigmoid colectomies are relatively straightforward procedures and can usually be performed effectively and safely with conventional laparoscopic surgery.\textsuperscript{23} However, some authors suggest a role for robotic colon surgery in the terms of intracorporeal anastomosis, splenic flexure take down and natural orifice specimen retrieval.\textsuperscript{18,26}

In general, most studies report a longer operating time for robot surgery. This is considered to be one of the disadvantages of robotic surgery, together with the lack of tactile feedback and higher cost. In this review, we found that operating time may not be longer as 2 comparative studies reported a shorter operating time for robotic surgery.\textsuperscript{11,16} Operating time may also depend on the technique used, whether fully robotic or the hybrid technique. Interestingly, studies that reported a shorter operating time used the hybrid technique. Operating time for robotic surgery is a combination of the total time to perform the abdominal part of the surgery (the inferior mesenteric artery ligation, colonic mobilisation, splenic flexure takedown when appropriate) either laparoscopically (hybrid technique) or robotically (full robot), the pelvic dissection (robotic TME dissection), laparoscopic rectal transection, anastomosis creation, ileostomy creation when appropriate, docking and undocking time. The most crucial step of robotic rectal cancer surgery is the robotic TME dissection. Because of the heterogeneity of techniques, the true benefits of robot TME may not be apparent in the literature. What would be useful and interesting would be for future studies to perform a subset analysis comparing the time taken to perform the pelvic dissection in (laparoscopic TME vs robotic TME) patients with rectal cancer.

The zero conversion rates for robotic rectal surgery have been consistent with several of the studies in this review. Two studies reported low conversion rates of 4.5% and 4.9% only.\textsuperscript{13,14} The overall conversion rates for this review were only 2%. This is very encouraging when considering that reported conversion rates for laparoscopic rectal surgery range from 12% to 20%.\textsuperscript{27,28} The conversion rates for the 5 comparative studies were 0% for the robotic group compared to 6.2% for the laparoscopic group. Two of these comparative studies showed a statistically significant difference in conversion rates. Since converted patients may have higher complication rates and poorer oncological outcomes,\textsuperscript{29,30} these better results may translate to better postoperative outcomes, superior oncological and functional outcomes. Perhaps the greatest technological advantage of the robotic system is the EndoWrist\textsuperscript{®} function with the stable, 3-dimensional imaging which allows the surgeon to perform fine and precise dissection in the pelvis.

Anastomotic leaks is one of the key surgical complications for any bowel surgery. The overall leak rate for robotic rectal cancer surgery in this study is 8.3%, while the leak rate for the robotic and laparoscopic groups in the 5 comparative studies were 7.6% and 7.3%, respectively. This compares favourably with that reported in previous large series of laparoscopic rectal resection.\textsuperscript{31-33} Other surgical complications after robotic rectal surgery have been reported but the evaluating methods are varied between the studies, making direct comparison difficult. Nevertheless, the overall complication for robotic rectal cancer appears to be similar to laparoscopic rectal surgery. In general, the length of stay and blood loss for robotic rectal surgery is similar to conventional laparoscopic surgery, with any difference being non-significant. Baik et al\textsuperscript{11} however, showed that robot rectal surgery had a significantly shorter length of stay when compared with conventional laparoscopic surgery.

These studies are based on data accrued from highly skilled and experienced laparoscopic colorectal surgeons. However, there is a difference in the surgeon’s experience between the 2 procedures as robotic surgery is a relatively novel procedure. The apparent similarity in outcome between these 2 procedures may be due to an attenuation of the benefits from the technological superiority of robotic surgery. Based on the results achieved so far, robotic rectal cancer surgery is safe and feasible when performed by the experienced and skilful laparoscopic colorectal surgeon.

Several factors regarding the resected specimen have been known to impact outcome. The College of American Pathologists recommend a minimum of 12 nodes for colorectal resection.\textsuperscript{34} Only one study in our review had a less than 12 lymph nodes harvested.\textsuperscript{39} Other parameters known to impact outcome, such as distal resection margin length and circumferential resection margin (CRM) positive rate, can also be an index of surgical quality. TME is widely accepted as the gold standard for rectal cancer surgery and is one of the most important factors in reducing local recurrences. Distal resection margin length and CRM positive rates were no different between the 2 groups. CRM may be positive despite a perfect TME dissection if the tumour extends up to or through the mesorectal fascia. Baik et al\textsuperscript{12} suggested introducing TME completeness as a marker of surgical quality in rectal cancer surgery. Therefore, macroscopic evaluation of TME completeness should be an additional parameter for assessing surgical quality especially in cases with CRM involvement.\textsuperscript{19}

Currently, the evidence of oncological outcomes for robotic rectal cancer surgery is limited.\textsuperscript{14,16,19} The biggest case series multicentre study by Pigazzi et al,\textsuperscript{14} involving 143 patients in 3 centres had a 97% 3-year overall survival, a 77.6% 3-year disease free survival, with no isolated local
recurrence detected over a mean follow-up period of 17.4 months. Such excellent results are very encouraging and suggest that robotic rectal cancer surgery may improve local disease control. Patriti et al \(^{16}\) reported a mean follow-up of 29.2 months and 18.7 months for robot and laparoscopic assisted rectal cancer surgery, respectively. They reported 1 death in each group during the follow-up and a local recurrence rate of 5.4% and 0% for laparoscopic and robotic groups, respectively. Kwak et al \(^{19}\) performed a case matched controlled study comparing robot vs laparoscopic rectal cancer surgery, which was well matched and had sufficient numbers in each group (59 in each arm). The mean follow-up period was 17 months and 13 months for robot and laparoscopic surgery respectively. During this short follow-up period, the appearance of cancer recurrence was no different between the 2 groups.

Bladder and sexual dysfunction are well known complications of rectal cancer surgery. These complications are related to avulsion or direct injury to pelvic autonomic nerves during rectal resection. Despite the autonomic nerve-preserving techniques in TME, bladder and sexual dysfunction can be up to 12% and 35%, respectively. \(^{36-40}\) Whether robotic rectal surgery with its technological superiority can result in a more precise pelvic dissection, which will ultimately translate to improved bladder and sexual function compared to the laparoscopic surgery is of great interest to the colorectal surgeons. To the best of our knowledge, there is no high level of evidence evaluating bladder and sexual function after robotic rectal cancer surgery. Patriti et al \(^{16}\) mentioned that during the follow-up period, there were no differences between the groups in the incidence of erectile dysfunction and faecal incontinence. There was no mention of any evaluation techniques, such as standardised questionnaires.

Currently, an international, multicentre randomised controlled trial of robot-assisted versus laparoscopic resection for rectal cancer (ROLARR trial) is underway to assess whether robot assistance facilitates rectal cancer resection, as measured by the need to convert to open surgery. Secondary aims of this trial include an analysis of the surgical accuracy, safety profile, quality of life and preservation of pelvic organ function between the 2 techniques used. Only prospective randomised clinical trials, with long-term follow-ups can determine if the technological advantages of the robotic surgical system can ultimately translate to better surgical/oncological outcomes and function. Hence, we eagerly await the results of this trial.

**Conclusion**

The current evidence suggests that robot rectal surgery for cancer is safe and feasible. The very low conversion rate for this procedure is the main advantage over the conventional laparoscopy. The majority of published studies are case series and non-randomised comparative studies. The available data seem to show equivalent short-term clinical outcomes. The short- and medium-term oncological outcomes are equivalent or preferable to laparoscopy. Currently, there is no data to evaluate sexual and bladder function after robotic rectal surgery. Therefore, in the absence of prospective randomised controlled trials, no definitive conclusions can be made. The data from the ROLARR trial will provide crucial information on the application of this novel surgical technique.
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