A Review of the Current Status of Laparoscopic and Robot-assisted Sacrocolpopexy for Pelvic Organ Prolapse

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**Abstract**

**Context:** Abdominal sacrocolpopexy (ASC) represents the superior treatment for apical pelvic organ prolapse (POP) but is associated with increased length of stay, analgesic requirement, and cost compared with transvaginal procedures. Laparoscopic sacrocolpopexy (LSC) and robot-assisted sacrocolpopexy (RSC) may offer shorter postoperative recovery while maintaining equivalent rates of cure.

**Objective:** This review evaluates the literature on LSC and RSC for clinical outcomes and complications.

**Evidence acquisition:** A PubMed search of the available literature from 1966 to 2013 on LSC and RSC with a follow-up of at least 12 mo was performed. A total of 256 articles were screened, 69 articles selected, and outcomes from 26 presented. A review, not meta-analysis, was conducted due to the quality of the articles.

**Evidence synthesis:** LSC has become a mature technique with results from 11 patient series encompassing 1221 patients with a mean follow-up of 26 mo. Mean operative time was 124 min (range: 55–185) with a 3% (range: 0–11%) conversion rate. Objective cure was achieved in 91% of patients, with similar satisfaction rates (92%). Six patient series encompassing 363 patients treated with RSC with a mean follow-up of 28 mo have been reported. Mean operative time was 202 min (range: 161–288) with a 1% (range: 0–4%) conversion rate. Objective cure rate was 94%, with a 95% subjective success rate. Overall, early outcomes and complication rates for both LSC and RSC appeared comparable with open ASC.

**Conclusions:** LSC and RSC provide excellent short- to medium-term reconstructive outcomes for patients with POP. RSC is more expensive than LSC. Further studies are required to better understand the clinical performance of RSC versus LSC and confirm long-term efficacy.

**Patient summary:** Laparoscopic and robot-assisted sacrocolpopexy represent attractive minimally invasive alternatives to abdominal sacrocolpopexy. They may offer reduced patient morbidity but are associated with higher costs.

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1. Introduction

Abdominal sacrocolpopexy (ASC) represents the most effective treatment for apical vaginal prolapse. Although modifications of the technique have occurred over time, the procedure continues to be associated with increased length of stay (LOS), analgesic requirements, and costs compared with transvaginal procedures [1]. A Cochrane review comparing different surgical techniques to treat pelvic organ prolapse (POP) concluded that ASC led to a lower rate of recurrent vault prolapse (relative risk [RR]: 0.23; 95% confidence interval [CI], 0.07–0.77) and postoperative dyspareunia (RR: 0.39; 95% CI, 0.18–0.86) compared with sacrospinous ligament fixation, albeit with a longer operative time, recovery period, and greater cost [2].

Laparoscopic sacrocolpopexy (LSC) avoids the need for a large abdominal incision and minimizes bowel manipulation, potentially leading to less postoperative pain and shorter recovery time. However, the decreased degrees of freedom, two-dimensional vision, and learning curve associated with the laparoscopic approach have increased operative times and limited its widespread use among surgeons [3].

More recently, the use of the da Vinci Surgical System (Intuitive Surgical Inc., Sunnyvale, CA, USA) has modified and potentially simplified LSC, adding increased magnification, three-dimensional vision, physiologic tremor filtering, and 7 degrees of freedom. These factors are believed to provide the surgeon with an enhanced ergonomic environment, simplifying complex laparoscopic tasks such as suturing and knot tying. Yet LSC, as opposed to robot-assisted sacrocolpopexy (RSC), confers tactile feedback that may be of interest, particularly with dissection or suturing.

A review of the literature was undertaken, and specific aspects of LSC and RSC were detailed, in particular technical variations, operative parameters, costs, and clinical outcomes.

2. Evidence acquisition

A PubMed search was performed using the search terms laparoscopic sacrocolpopexy, laparoscopic sacral colpopexy, robot(ic)(-assisted) sacral colpopexy, robot(ic)(-assisted) sacrocolpopexy, laparoscopic hysteropexy, and robot(ic) (-assisted) hysteropexy for English-language articles from 1966 to November 1, 2013. A total of 168, 72, 15, 88, 31, and 4 articles were initially identified, respectively (Fig. 1). The reference lists of these articles were also queried to identify additional relevant articles. Only those patient series with a duration of follow-up of at least 12 mo were included in the analysis. Articles directly comparing LSC and/or RSC to ASC were also culled. Due to the relatively small number of such studies, the duration of follow-up requirement was not applied to series comparing one technique with another.

3. Evidence synthesis

A number of methodological difficulties arise when considering the outcomes of the different patient series regarding LSC and RSC. Many of the series, particularly for RSC, are retrospective and relatively immature, with short durations of follow-up. This renders analysis and comparison of safety and efficacy outcomes problematic, particularly when long-term outcomes of prolapse repair are known to deteriorate over time [4]. Recurrence rates by compartment are not systematically reported; nor are transfusion requirements. The definitions of mesh erosion and exposure were not consistently reported across the studies. Objective and subjective success were not defined consistently across the studies. For example, a number of studies considered success as Pelvic Organ Prolapse-Quantification (POP-Q) stage 0 [5,6] versus POP-Q stage ≤1 [7–10] versus Baden-Walker stage ≤1 or ≤2 [12].

![Flowchart of studies included and excluded in the review.](image-url)
A number of studies reported their anatomic classification scheme but did not define the criteria for success or surgical cure [13–17]. Failure of surgical repair, that is, recurrence, versus persistence of prolapse was not always clearly reported. Most studies constituted only level 3 evidence, with a few notable exceptions [18–20]. This makes systematic review via meta-analysis problematic and difficult. We have therefore performed a literature review, where we categorized the outcomes by surgical technique while highlighting major trends and limitations.

### 3.1. Technique

Open ASC involves dissection of the vesicovaginal plane and the rectovaginal septum proximally, after which a mesh is secured onto the anterior spine ligament. Support in the anterior compartment can be augmented by placing the mesh more distally in the vesicovaginal space. Similarly, a posterior mesh can be used to support the posterior vaginal compartment. The current standard of care involves using a large-pore polypropylene or non–silicone-coated polyester mesh that allows for fibroblast ingrowth and entry for leukocytes and macrophages [21]. The mesh is typically retroperitonealized to reduce the risk of bowel injury.

Once support is restored, distal vaginal defects may require further attention because bladder neck/urethral and distal rectal pathology may not be adequately treated with ASC [22]. Nygaard et al., for example, reported that the addition of a Burch colposuspension during ASC resulted in a long-term significant decrease in the incidence of stress urinary incontinence (SUI) from 77% to 62% in the extended CARE trial, although this was not corroborated by other studies [4,23]. The need for concomitant SUI surgery with POP treatment is currently being studied via two additional randomized controlled trials (RCTs): CUPIDO 1 and CUPIDO 2 [24].

LSC and RSC reconstitute the steps of open ASC [13,25]. Trocar placement, use of special retractors, the type of mesh, as well as placement may all vary according to the individual surgeon and patient. The laparoscopic approach facilitates rectovaginal dissection down to the most anterior portion of the levator ani muscles, on either side of the rectum, to secure the posterior mesh as proximally as possible to prevent or treat rectoceles. The use of sacral and/or vaginal staples has been described to reduce the need for intracorporeal suturing, although they have been associated with weaker fixation and higher rates of infection, erosion, and dyspareunia [25]. In the case of uterine descent, some authors favor a simple uterine-sparing procedure (ie, hysteropexy) to preserve the uterus and hence fertility [26]. These procedures usually involve plication of the uterosacral ligaments or use of a mesh implant. One should note, however, that hysteropexies are designed to treat apical defects only; in contrast, ASC, LSC, and RSC with two meshes are designed to simultaneously repair the anterior, apical, and posterior compartments via a single surgical approach. They include either a hysteropexy when the uterus is in place or vaginal vault suspension when the uterus has been removed.

Nezhat et al. described the first case series of 15 patients who underwent LSC [27]. LSC has been further modified to incorporate more recent laparoendoscopic single-site surgery techniques [28]. The first reported use of the da Vinci Surgical System (Intuitive Surgical, Inc.) for use in RSC occurred in 2004 in a report by Di Marco et al. on five patients [29]. Average operative time was 3.7 h, with the most recent case requiring 3 h.

### 3.2. Learning curve

Mustafa et al. described the LSC learning curve with a retrospective review of 47 consecutive women undergoing LSC at a single tertiary care medical center [3]. Mean operative time significantly decreased from 196 to 162 min when comparing the first 15 versus the last 30 cases. Blood loss and complication rates were unchanged. The authors asserted that approximately 30–40 cases were necessary to master LSC. This experience was echoed by Claerhout et al., who noted an inflection point in the duration of surgery after 18–24 cases [7].

A learning curve for RSC also exists. Germain et al. reported on 52 patients undergoing RSC over a 7-yr period [30]. Mean operative time decreased from 222 min during the first 10 cases to 183 for the next 10 cases. Lenihan et al. also reported that the learning curve for RSC comprised about 50 cases [31].

### 3.3. Outcomes

#### 3.3.1. Laparoscopic sacrocolpopexy

Rozet et al. reported on the largest series of LSC patients with 363 women undergoing LSC from 1996 to 2002 with a mean follow-up of 14.5 mo [13]. Mean operative time was 97 min. There were eight conversions due to anesthetic or surgical difficulties. Average LOS was 3.7 d. Overall, 96% of patients were satisfied with the results of their operation, and no patient complained of sexual dysfunction or constipation 6 mo after surgery. There was a 4% recurrence rate of POP and a 1% vaginal erosion rate.

The largest prospective series of LSC patients was reported by Claerhout et al. on a group of 132 consecutive patients with POP undergoing LSC with a mean follow-up of 12.5 mo [7]. Mean operative time was 180.5 min. One patient (0.7%) required conversion to ASC. Although the objective cure rate at the apex was 98%, an 18% failure rate was seen mainly in the posterior compartment, although no patient underwent reintervention; this may have been due to the higher prevalence of pretreated patients in this cohort. De novo SUI was identified in 7.4% of patients postoperatively. Mesh erosion was seen in 4.5% of patients, all within 1 yr. No perioperative complications were noted, although three patients (2.7%) experienced mesh-related pain.

Other LSC patient series were typically smaller than the Rozet et al. and Claerhout et al. studies [7,13]. Nonetheless, they do demonstrate fairly similar outcomes. Only one series of laparoscopic hysteropexy with clinical outcomes could be identified; Rahmanou et al. reported on 140 patients

- [1130](#)
undergoing laparoscopic hysteropexy [32]. Mean operative time was 55 min, with 89% improvement in the Patient Global Impression of Improvement (PGI-I) score, although at least 86% of patients required a concomitant transvaginal prolapse repair. A total of 71% and 95% of the patients in the series reported by Rozet et al. and Sergent et al., respectively, also underwent uterine sparing, but their clinical outcomes could not be separated from those of other patients in the studies [7,13].

Overall, a total of 1221 patients with a mean duration of follow-up of 26.2 mo were considered, with all studies demonstrating a mean follow-up of at least 12 mo (Table 1). Conversion to ASC was fairly low across all series (≤4%) with the exception of that demonstrated by Gadonneix et al., who reported an 11% conversion rate [33]. SUI procedures were performed concurrently in 30% of patients, but the criteria used for concomitant SUI prevention/treatment were variable among the studies. Most series were European-based, with the exception of that by Ross and Preston [12]. Anatomic cure was achieved in a mean of 91% of patients, with 92% of patients reporting satisfaction with outcomes.

### 3.3.2. Robot-assisted sacrocolpopexy

A total of six studies reported on the clinical outcomes of RSC (Table 2). These studies were typically small, with a

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of patients</th>
<th>Duration of follow-up, mo</th>
<th>Operative time, min</th>
<th>Estimated blood loss, ml</th>
<th>Conversion rate (%)</th>
<th>Concomitant stress incontinence procedures (%)</th>
<th>Objective success rate with definition (%)</th>
<th>Subjective success rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moreno Sierra et al. [14]</td>
<td>31</td>
<td>25</td>
<td>186</td>
<td>NA</td>
<td>1 (3)</td>
<td>30 (97)</td>
<td>31 (100) Definition NA</td>
<td>31 (100)</td>
</tr>
<tr>
<td>Elliott et al. [34]</td>
<td>30</td>
<td>24</td>
<td>186</td>
<td>NA</td>
<td>1 (3)</td>
<td>11 (37)</td>
<td>29 (95) Baden-Walker stage not defined</td>
<td>NA</td>
</tr>
<tr>
<td>Germain et al. [30]</td>
<td>52</td>
<td>42</td>
<td>190</td>
<td>NA</td>
<td>2 (4)</td>
<td>NA</td>
<td>47 (90) Definition NA</td>
<td>47 (90)</td>
</tr>
<tr>
<td>Ploumidis et al. [16]</td>
<td>95</td>
<td>34 (median)</td>
<td>105</td>
<td>25</td>
<td>0 (0)</td>
<td>NA</td>
<td>91 (96) Baden-Walker stage 0</td>
<td>NA</td>
</tr>
<tr>
<td>Belsante et al. [15]</td>
<td>35</td>
<td>28</td>
<td>288</td>
<td>71</td>
<td>0 (0)</td>
<td>NA</td>
<td>NA NA</td>
<td>NA</td>
</tr>
<tr>
<td>Salamon et al. [10]</td>
<td>120</td>
<td>12</td>
<td>161</td>
<td>49</td>
<td>0 (0)</td>
<td>85 (71)</td>
<td>107 (89) POP-Q stage ≤1</td>
<td>113 (94)</td>
</tr>
<tr>
<td>Total or mean</td>
<td>363</td>
<td>28</td>
<td>202</td>
<td>43</td>
<td>4 (1)</td>
<td>126 (70)</td>
<td>305 (94)</td>
<td>191 (95)</td>
</tr>
</tbody>
</table>

NA = not applicable; POP-Q = Pelvic Organ Prolapse-Quantification.

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**Table 1 – Clinical outcomes of laparoscopic sacrocolpopexy patient series**

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of patients</th>
<th>Duration of follow-up, mo</th>
<th>Operative time, min</th>
<th>Estimated blood loss, ml</th>
<th>Conversion rate (%)</th>
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<th>Subjective success rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rozet et al. [13]</td>
<td>363</td>
<td>14.6</td>
<td>97</td>
<td>10–100 (&gt;100 in three patients)</td>
<td>8 (2.2)</td>
<td>163 (45)</td>
<td>312 (86) Baden-Walker stage ≤1</td>
<td>312 (86)</td>
</tr>
<tr>
<td>North et al. [5]</td>
<td>22</td>
<td>26.5</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>1 (5)</td>
<td>22 (100) POP-Q stage 0 at vault</td>
<td>21 (95)</td>
</tr>
<tr>
<td>Sarlos et al. [28]</td>
<td>101</td>
<td>12</td>
<td>141</td>
<td>95</td>
<td>2 (2)</td>
<td>30 (30)</td>
<td>99 (98) POP-Q stage 0</td>
<td>93 (92)</td>
</tr>
<tr>
<td>Sergent et al. [9]</td>
<td>116</td>
<td>34.2</td>
<td>185</td>
<td>1.3 g/dl loss</td>
<td>5 (4)</td>
<td>29 (25)</td>
<td>103 (89) POP-Q stage ≤1</td>
<td>NA</td>
</tr>
<tr>
<td>Claerhout et al. [7]</td>
<td>132</td>
<td>12.5</td>
<td>181</td>
<td>185</td>
<td>5 (0.7)</td>
<td>5 (4)</td>
<td>103 (78) POP-Q stage ≤1</td>
<td>121 (92)</td>
</tr>
<tr>
<td>Perez et al. [8]</td>
<td>94</td>
<td>12</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>37 (39)</td>
<td>88 (94) POP-Q stage ≤1</td>
<td>93 (99)</td>
</tr>
<tr>
<td>Price et al. [45]</td>
<td>84</td>
<td>43</td>
<td>64</td>
<td>75</td>
<td>0 (0)</td>
<td>8 (10)</td>
<td>74 (88) Definition NA</td>
<td>72 (86)</td>
</tr>
<tr>
<td>Granese et al. [44]</td>
<td>165</td>
<td>60</td>
<td>55</td>
<td>100–250</td>
<td>NA</td>
<td>63 (38)</td>
<td>157 (95) Definition NA</td>
<td>137 (83)</td>
</tr>
<tr>
<td>Ross et al. [12]</td>
<td>43</td>
<td>24.5</td>
<td>96</td>
<td>100</td>
<td>NA</td>
<td>NA</td>
<td>40 (93) Baden-Walker stage ≤2</td>
<td>NA</td>
</tr>
<tr>
<td>Leruth et al. [11]</td>
<td>55</td>
<td>25</td>
<td>123</td>
<td>NA</td>
<td>0 (0)</td>
<td>NA</td>
<td>55 (100) Baden-Walker stage ≤1</td>
<td>55 (100)</td>
</tr>
<tr>
<td>Gadonneix et al. [33]</td>
<td>46</td>
<td>24</td>
<td>171</td>
<td>NA</td>
<td>5 (11)</td>
<td>28 (61)</td>
<td>38 (83) Baden-Walker stage ≤1</td>
<td>36 (95)</td>
</tr>
<tr>
<td>Total or mean</td>
<td>1221</td>
<td>26.2</td>
<td>124</td>
<td>–</td>
<td>25 (3)</td>
<td>364 (30)</td>
<td>1091 (91)</td>
<td>940 (92)</td>
</tr>
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</table>

NA = not applicable; POP-Q = Pelvic Organ Prolapse-Quantification.

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**Table 2 – Clinical outcomes of robot-assisted sacrocolpopexy patient series**

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of patients</th>
<th>Duration of follow-up, mo</th>
<th>Operative time, min</th>
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<td>190</td>
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</tbody>
</table>
mean sample size of 61 patients, although most possessed a duration of follow-up >24 mo.

Salamon et al. reported on the largest series of patients \((n = 120)\) undergoing RSC with a 12-mo duration of follow-up [10]. Mean operative time was 161 min with a 0% conversion rate and minimal estimated blood loss (EBL) (<100 ml). Objective cure was seen in 89% of patients. Postoperative SUI was identified in five patients (4%). Two patients (2%) experienced dyspareunia.

These results are echoed by the other smaller series, such as those reported by Moreno Sierra et al., Ploumidis et al., and Germain et al. that noted 0%, 3%, and 4% conversion rates, respectively [14,16,30]. Decreases in RSC operative time were reported by Moreno Sierra et al. (200–179 min), Germain et al. (222–183 min), and Elliott et al. (285–186 min), with increasing surgical experience [14,30,34]. Objective success rates were >89%, with subjective success rates in a similar range (90–100%) across all of the series. Interestingly, however, LOS varied widely between the series based on geography. US-based series showed a LOS from 1 to 1.7 d [15,34]; those from Europe were >4 d [14].

No isolated series of patients undergoing robotic hysterectomy could be identified, although 60% of the patients in the series reported by Ploumidis et al. did undergo uterine sparing; their clinical outcomes could not be separated from other patients in the study [16]. One case report of robot-assisted hysterectomy was identified, although detailed clinical outcomes were not reported in the study [35].

Overall, review of the six patient series included a total of 363 patients with a mean duration of follow-up of 28 mo. Mean operative time was 202 min. The conversion rate to ASC was low, averaging 1%. SUI procedures were performed concurrently in 70% of patients. Anatomic cure was identified in five patients (4%). Two patients (2%) experienced dyspareunia.

3.3.3. Comparison series

3.3.3.1. Laparoscopic sacrocolpopexy versus abdominal sacrocolpopexy. A total of three studies compared the outcomes of LSC versus ASC [17,18,36] (Table 3). All studies are short term, with a duration of follow-up either <12 mo or unreported. Only one represents a multicenter RCT. Specifically, Freeman et al. reported on the results of 47 patients with symptomatic grade ≥2 vault prolapse randomized to LSC versus ASC in three urogynecology centers in the United Kingdom [18]. At 1 yr, objective cure was equivalent between the two groups (\(-6.65 to 6.63,\) respectively), but subjective cure (PGI-I score) was slightly superior for ASC (90% vs 80%). EBL was lower with LSC (56 vs 240 ml; \(p < 0.01\)) as was LOS (3.2 vs 4.1 d; \(p = 0.02\)). There were no cases of mesh erosion or any differences in the rates of pelvic pain, constipation, or dyspareunia (\(p\) value unspecified).

A review of the three studies in aggregate suggests that LSC and ASC operative times were roughly equivalent (182 vs 161 min), with a lower EBL seen in LSC patients (81 vs 191 ml). Patient satisfaction was comparable in both groups (64–91% vs 70–95%).

3.3.3.2. Robot-assisted sacrocolpopexy versus laparoscopic sacrocolpopexy and/or abdominal sacrocolpopexy. Six studies compared the outcomes of RSC versus ASC and/or LSC [19,20,37–40] (Table 4); only two of these studies, however, reported a duration of follow-up >12 mo [20,40]. Only the study reported by Paraizo et al. represents an RCT of 38 women randomized to LSC versus 40 to RSC for treatment by experienced surgeons, although the trial suffers from a short follow-up of only 1.4 mo [19]. RSC required a significantly higher operative time (+67 min), and interestingly it also demonstrated higher pain scores and greater analgesic requirements (20 vs 11 d) while also incurring greater costs (\(\Delta \$1936\)). Functional outcomes, however, were similar at 1 yr after surgery for both groups. In contrast, Seror et al. reported on the sole prospective but nonrandomized comparative trial with a duration of follow-up >12 mo [20]. They noted that operative time was significantly shorter for RSC compared with LSC (median: 125 vs 220 min) in a cohort of 20 patients undergoing RSC versus 47 patients undergoing LSC. No difference was observed in terms of analgesic use or LOS, although RSC did demonstrate superior EBL (median: 55 ml vs 280 ml).

Overall, a review of the six patient series includes a total of 328 versus 125 versus 449 patients undergoing RSC versus

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of patients (LSC vs ASC)</th>
<th>Duration of follow-up, mo</th>
<th>Operative time, min</th>
<th>Estimated blood loss, ml</th>
<th>Conversion rate (%)</th>
<th>Concurrent stress incontinence procedures (%)</th>
<th>Objective success (%)</th>
<th>Subjective success (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hsiao et al. [17]</td>
<td>25 vs 22</td>
<td>6 vs 11</td>
<td>220 vs 185</td>
<td>83 vs 195</td>
<td>3 (12)</td>
<td>9 (36) vs 14 (63)</td>
<td>25 (100) vs 19 (85)</td>
<td>NA</td>
</tr>
<tr>
<td>Freeman et al. [18]</td>
<td>23 vs 24</td>
<td>NA</td>
<td>144 vs 131</td>
<td>56 vs 240</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>15 (64) vs 17 (70)</td>
</tr>
<tr>
<td>Klauschie et al. [36]</td>
<td>43 vs 41</td>
<td>7 vs 11</td>
<td>183 vs 168</td>
<td>104 vs 139</td>
<td>NA</td>
<td>15 (35) vs 19 (46)</td>
<td>40 (93) vs 36 (88)</td>
<td>39 (91) vs 39 (95)</td>
</tr>
</tbody>
</table>

Total or mean 91 vs 87 – 182 vs 161 81 vs 191 – – – –

ASC = abdominal sacrocolpopexy; LSC = laparoscopic sacrocolpopexy; NA = not applicable; POP-Q = Pelvic Organ Prolapse-Quantification.
LSC versus ASC, respectively. Mean operative time averaged approximately 265 versus 135 versus 199 min with an EBL of 75 versus 70 versus 175 ml, respectively. The conversion rates to ASC were low at 7% and 3% after RSC and LSC, respectively. Anatomic and subjective cure rates were not reported consistently across the series but appeared to be >88%.

3.3.4. Complications

Most complications following sacrocolpexy can occur with either an open or a minimally invasive approach, typically at similar rates (Tables 5 and 6). These include events such as intraoperative injury to pelvic organs, infections, and thrombotic events [17]. Of note, most series did not use a standardized reporting system for complications.

3.3.4.1. Mesh-related problems.
The literature reports an increased incidence of mesh erosion when abdominal sacrocolpexies are combined with concomitant total hysterectomies (16%) versus in posthysterectomy patients (3–4%) [41]. This experience is also reflected in LSC, where mesh erosion rates as high as 32% were reported when vaginal hysterectomy is concomitantly performed [42]. Osmundsen et al. reported on the first study denoting the incidence of mesh erosion following RSC with concomitant total versus supracervical hysterectomy [43]. No mesh erosions were observed in the supracervical hysterectomy group, but mesh erosions were noted in 14% of patients undergoing total hysterectomies with RSC. In the series cited in this review, mesh erosion rates appeared to range from 0% to 12%.

Information was insufficient to calculate a mean time to erosion from these data; a distinction between mesh erosion versus extrusion was not made. Treatments for mesh erosion varied widely depending on the center and the degree of patient symptoms.

3.3.4.2. Bleeding.
Blood loss due to surgery is lower with minimally invasive techniques compared with ASC, probably as a result of the use of pneumoperitoneum. EBL with LSC or RSC appears to range from 22 to 255 ml versus 139 to 240 ml for ASC [5,7–20,28,30,33,34,36–40,44,45]. Scant data on transfusion requirements were available. However, the addition of a concomitant hysterectomy or incontinence surgery, such as placement of a pubovaginal sling, can increase blood loss.

3.3.4.3. Urinary tract complications.
Bladder injury may occur during LSC or RSC due to trocar placement, tissue dissection, or suture placement. The rates of bladder injury ranged from 0% to 11% versus 0% to 2.4% for ASC and were managed either by immediate repair or conservatively through an extended duration of indwelling catheter placement.

Postoperative voiding dysfunction represents a major morbidity after POP surgery. LUTS may develop postoperatively for reasons that are still not clearly understood. Patients are at even greater risk for LUTS if treatment for SUI is performed concomitantly, particularly with placement of
retropubic slings as opposed to transobturator sling (2.7% vs 0%; \( p = 0.004 \)); these are thought to result from denervation injury, bladder outlet obstruction, or unmasking of detrusor overactivity [46]. The rates of de novo lower urinary tract symptoms (LUTS) after LSC and RSC appear to range from 0% to 27%. SUI also represents a risk after sacrocolpopexy. Even with preoperative testing, up to half of the patients develop de novo SUI to a variable degree after sacrocolpopexy [2,11]. The rates of de novo SUI after LSC and RSC appear to range from 0% to 55% in the series reviewed.

3.3.4.4. Impaired sexual function. Traditionally, ASC preserves vaginal length and minimizes the risk of dyspareunia. When performed successfully, sacrocolpopexy regardless of technique is most likely to preserve or improve sexual function, but de novo sexual dysfunction can occur due to mesh exposure, infection, or misplacement of mesh. Postoperative sexual dysfunction was reported in multiple LSC and RSC series, although not consistently. It appears to occur in 0–9% of patients [5,7–9,11–13,17,28,33,45].

3.3.4.5. Bowel dysfunction. Bowel injury may occur intraoperatively during LSC or RSC. These injuries are typically repaired immediately upon recognition of injury (2–4%), although reports of delayed recognition requiring subsequent abdominal exploration have been reported [6,9,30].

### Table 5 – Complications of laparoscopic sacrocolpopexy patient series

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of patients</th>
<th>Mesh erosion (%)</th>
<th>Bladder injury (%)</th>
<th>Bowel injury (%)</th>
<th>De novo stress urinary incontinence (%)</th>
<th>LUTS (%)</th>
<th>Dyspareunia (%)</th>
<th>Other (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rozet et al. [13]</td>
<td>363</td>
<td>3 (1)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>21 (6)</td>
<td>0 (0)</td>
<td>1 (0.2) small bowel obstruction, 1 (0.2) port site hernia, 1 (0.2) spondylitis</td>
</tr>
<tr>
<td>North et al. [5]</td>
<td>22</td>
<td>1 (5)</td>
<td>1 (5)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (5) vault infection</td>
</tr>
<tr>
<td>Sarlos et al. [28]</td>
<td>101</td>
<td>1 (1)</td>
<td>4 (4)</td>
<td>3 (3)</td>
<td>24 (24)</td>
<td>27 (27)</td>
<td>0 (0)</td>
<td>1 (1) vaginal laceration, 1 (1) port site bleed, 1 (1) wound infection, 1 (1) ileus, 19 (19) constipation</td>
</tr>
<tr>
<td>Sergent et al. [9]</td>
<td>116</td>
<td>5 (4)</td>
<td>3 (2.6)</td>
<td>2 (1.7)</td>
<td>0 (0)</td>
<td>11 (9.5)</td>
<td>0 (0)</td>
<td>15 (13) sciatica, 1 (1) back pain, 1 (1) pelvic pain</td>
</tr>
<tr>
<td>Claerhout et al. [7]</td>
<td>132</td>
<td>6 (4)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (1) bleeding, 3 (2) nerve lesions, 2 (2) unspecified local problems</td>
</tr>
<tr>
<td>Perez et al. [8]</td>
<td>94</td>
<td>3 (3)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>6 (6)</td>
<td>1 (1)</td>
<td>0 (0)</td>
<td>1 (1) chronic pelvic pain, 1 (1) rectal discomfort</td>
</tr>
<tr>
<td>Price et al. [45]</td>
<td>84</td>
<td>5 (6)</td>
<td>2 (2)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>4 (5)</td>
<td>10 (6) fever, 5 (3) back pain, 2 (1) vaginal hematoma</td>
</tr>
<tr>
<td>Granese et al. [44]</td>
<td>165</td>
<td>12 (0.7)</td>
<td>5 (3)</td>
<td>3 (2)</td>
<td>15 (9)</td>
<td>15 (9)</td>
<td>2 (3)</td>
<td>2 (5) obstructive defecation, 1 (2) rectal splinting, 1 (2) fecal incontinence</td>
</tr>
<tr>
<td>Ross et al. [12]</td>
<td>43</td>
<td>4 (9)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (2)</td>
<td>4 (9)</td>
<td>4 (9)</td>
<td>–</td>
</tr>
<tr>
<td>Leruth et al. [11]</td>
<td>55</td>
<td>0 (0)</td>
<td>1 (2)</td>
<td>0 (0)</td>
<td>30 (55)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>–</td>
</tr>
<tr>
<td>Sarlos et al. [33]</td>
<td>46</td>
<td>0 (0)</td>
<td>3 (7)</td>
<td>0 (0)</td>
<td>2 (4)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (2) fever, 1 (2) obstructive defecation</td>
</tr>
<tr>
<td>Total or mean</td>
<td>1221</td>
<td>40 (3)</td>
<td>19 (2)</td>
<td>8 (1)</td>
<td>78 (9)</td>
<td>79 (6)</td>
<td>10 (1)</td>
<td>–</td>
</tr>
</tbody>
</table>

LUTS = lower urinary tract symptoms.

### Table 6 – Complications of robot-assisted sacrocolpopexy patient series

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of patients</th>
<th>Mesh erosion (%)</th>
<th>Bladder injury (%)</th>
<th>Bowel injury (%)</th>
<th>De novo stress urinary incontinence (%)</th>
<th>LUTS (%)</th>
<th>Dyspareunia (%)</th>
<th>Other (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moreno Sierra et al. [14]</td>
<td>31</td>
<td>0 (0)</td>
<td>2 (7)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (3.2) vaginal tear, 1 (3.2) port infection, 1 (3.2) ileus, 1 (3.2) myocardial infarction, 1 (3.2) syncope</td>
</tr>
<tr>
<td>Elliott et al. [34]</td>
<td>30</td>
<td>2 (7)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>2 (7)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (1.9) vaginal tear, 1 (1.9) UTI, 1 (1.9) wound infection</td>
</tr>
<tr>
<td>Germain et al. [30]</td>
<td>52</td>
<td>0 (0)</td>
<td>1 (2)</td>
<td>1 (2)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>–</td>
</tr>
<tr>
<td>Ploumidis et al. [16]</td>
<td>95</td>
<td>1 (1)</td>
<td>2 (2)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>11 (12)</td>
<td>0 (0)</td>
<td>1 (1) vaginal injury, 1 (1) bowel obstruction, 1 (1) UTI, 5 (5) constipation</td>
</tr>
<tr>
<td>Belsante et al. [15]</td>
<td>35</td>
<td>1 (3)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>2 (6)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>5 (14) vaginal injury, 1 (3) port site hernia</td>
</tr>
<tr>
<td>Salamon et al. [10]</td>
<td>120</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>5 (4)</td>
<td>2 (2)</td>
<td>2 (2)</td>
<td>–</td>
</tr>
<tr>
<td>Total or mean</td>
<td>363</td>
<td>4 (1)</td>
<td>5 (1)</td>
<td>1 (0.3)</td>
<td>9 (3)</td>
<td>13 (4)</td>
<td>2 (1)</td>
<td>–</td>
</tr>
</tbody>
</table>

LUTS = lower urinary tract symptoms; UTI = urinary tract infection.
Bowel dysfunction can also occur as postoperative ileus (0–6%), small bowel obstruction (0–5%), constipation (0–19%), rectal discomfort or pressure (0–5%), or fecal incontinence (0–2%). Retroperitonealization of the mesh used in LSC or RSC is thought to reduce the risk of bowel injury, although some authors have noted a lack of bowel injuries when the mesh was left exposed to the peritoneum [33].

3.4. Costs

A number of US studies have attempted to quantify the economic burden of LSC and RSC. Judd et al. reported on a cost-minimization analysis of LSC and RSC versus ASC using a decision analytic model [47]. Costs were derived from an own-institution micro-costing approach at Duke University. Their analysis suggested that RSC was most expensive at $8508 per procedure, versus $7353 for LSC versus $5792 for ASC. RSC and LSC became cost equivalent only when robotic operative time was reduced to 149 min, RSC disposables costs were reduced to $2132, or LSC disposable costs were increased to $3413. LSC and ASC became cost equivalent only when LSC disposable costs were reduced to $668, mean LOS for ASC was increased to 5.6 d, or surgeon reimbursement for ASC exceeded $2213. The addition of robotic purchase and maintenance costs resulted in an incremental increase of $581 to $1724 per procedure depending on how many robotic procedures were performed monthly.

Tan-Kim et al. reported on a retrospective two-center cohort study of 43 patients undergoing RSC versus 61 patients undergoing LSC [48]. RSC demonstrated longer operative time (281 vs 206 min), as well as greater surgical costs (2724 vs 2295 units).

Elliott et al. reported on the Stanford experience comparing RSC versus ASC [49]. Operative time was similar between the two cohorts (226 vs 221 min), although the LOS was shorter with RSC (1.0 vs 3.3 d). Cost savings were seen with RSC ($10,178) over ASC ($11,307), reflective of the institution’s 4.2% lower cost of surgery with robot-assisted compared with open surgery. Tornado analysis suggested that the annual volume of robotic cases, LOS, and cost per day of stay were the largest drivers of cost.

A cost-effectiveness analysis of LSC or RSC has not been performed to date, although the Abdominal Colpexy: Comparison of Endoscopic Surgical Strategies (ACCESS) trial recently completed enrollment of 64 patients with symptomatic stage ≥2 POP randomized to LSC versus RSC [50]. Results are currently pending. All costing studies to date only reflect the US experience and therefore may underestimate factors such as longer duration of hospitalization as may potentially be seen in Europe.

3.5. Limitations

A relative deficiency of data exists to directly compare the performance of RSC versus LSC versus ASC. Although the uptake of RSC has been significant in countries like the United States, most reports have consisted of small case series with short- and medium-term results [34]. A pressing need for long-term data (ie, ≥5 yr) regarding success rates, complications, and need for reoperation exists. Most comparative studies were not randomized, leading to the possibility of selection bias where more complicated patients may have been treated preferentially with ASC. The reporting of results was not standardized and generally incomplete. Many of the studies were reported by high-volume experienced surgeons whose experience may not be generalizable to the community.

4. Conclusions

Minimally invasive techniques for sacrocolpexy through LSC and RSC provide excellent short-term reconstructive outcomes for patients with POP, with decreased morbidity compared with traditional ASC.

The decision to undertake LSC or RSC versus ASC should revolve around the individual surgeon’s experience and comfort with a particular surgical technique in combination with the potential complexity of each case. Both minimally invasive techniques must take into account comorbidities that may affect the ability to perform minimally invasive surgery, such as severe chronic obstructive pulmonary disease, morbid obesity, prior abdominopelvic surgery, and pelvic fibrosis. The learning curve for both techniques requires approximately 30–50 cases, although their cost effectiveness is currently unclear. Further prospective RCTs are required to better understand the clinical performance of RSC and LSC versus ASC.

Author contributions: Richard K. Lee had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Lee, Mottrie, Payne, Waltregny.

Acquisition of data: Lee, Mottrie, Payne, Waltregny.

Analysis and interpretation of data: Lee, Mottrie, Payne, Waltregny.

Drafting of the manuscript: Lee, Mottrie, Payne, Waltregny.

Critical revision of the manuscript for important intellectual content: Lee, Mottrie, Payne, Waltregny.

Statistical analysis: Lee, Mottrie, Payne, Waltregny.

Obtaining funding: Lee, Mottrie, Payne, Waltregny.

Administrative, technical, or material support: Lee, Mottrie, Payne, Waltregny.

Supervision: Lee, Mottrie, Payne, Waltregny.

Other (specify): None.

Financial disclosures: Richard K. Lee certifies that all conflicts of interest, including specific financial interests and relationships and affiliations relevant to the subject matter or materials discussed in the manuscript (eg, employment/affiliation, grants or funding, consultancies, honoraria, stock ownership or options, expert testimony, royalties, or patents filed, received, or pending), are the following: None.

Funding/Support and role of the sponsor: None.

References

[1] Sze EH, Kohli N, Miklos JR, Roat T, Karram MM. A retrospective comparison of abdominal sacrocolpexy with Burch colposuspension versus sacrospinous fixation with transvaginal needle suspension for the management of vaginal vault prolapse and coexisting...


