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Introduction

When analyzing prevalence of pelvic organ prolapse (POP), anterior vaginal wall prolapse is the most common type, but loss of apical support is usually present in women with prolapse that extends beyond the hymen [1, 2]. Adequate support for the vaginal apex is an essential component of a durable surgical repair for women with advanced prolapse [3, 4]. Anterior and posterior wall repair may fail without the support of the vaginal apex at the time of surgical correction of prolapse [5, 6].

History of Sacrocolpopexy

The evolution of what has become the robotic-assisted laparoscopic sacrocolpopexy (RASC) dates back to 1957, when Arthure and Savage attempted to prevent recurrent enteroceles that

formed after standard apical prolapse procedures by anchoring the posterior uterine fundus to the sacral anterior longitudinal ligament [7]. The procedure further evolved with the addition of concomitant hysterectomy and an intervening graft between the vagina and sacrum to overcome excessive tension [8]. Birnbaum felt that the sacral promontory was too anterior for mesh placement, given that the upper vagina is normally directed into the hollow of the sacrum, and instead placed the mesh at the level of S3–S4 to recreate the natural angle [9]. Due to the increased risk of hemorrhage in the pre-sacral space at the S3–S4 site, Sutton advocated anchoring the graft higher, at the S1–S2 level, where the middle sacral artery could be visualized and avoided.

The procedure was further modified by extending the graft along the full length of the rectovaginal septum to decrease graft detachment and improve posterior vaginal wall support [10]. Addison et al. initially used a folded, conical graft configuration to maximize the surface area for mesh attachment, but due to increased risk of mesh erosion, the approach was changed to two separate graft strips sutured with monofilament sutures. This approach also allowed the surgeon to exert differential tension on the anterior and posterior grafts, thereby potentially decreasing urinary incontinence caused by an overcorrected urethrovesical angle [11]. Several surgeons used autologous or allogenic grafts in attempts to decrease mesh erosion, but better

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anatomic cure rates have been found with nonabsorbable synthetic mesh [12–16].

This procedure has been performed since 1957 when it was first described by Arthure and Savage and has been modified in technique by changing graft material and altering the approach from abdominal to laparoscopic, with and without robotic assistance [8, 17]. A review of the abdominal sacrocolpopexy literature found the surgical procedure to be a reliable procedure that effectively resolves vaginal vault prolapse [12]. In a retrospective cohort study comparing robotic to abdominal sacrocolpopexy with placement of permanent mesh, RASC demonstrated similar short-term vaginal vault support compared with abdominal sacrocolpopexy (slight improvement on Pelvic Organ Prolapse Quantification System (POP-Q) (Table 2.1) C point, -9 cm compared with -8 cm, $p = 0.008$), with longer operative time (328 ± 55 min compared with 223 ± 61 min, $p < 0.001$), less blood loss (103 ± 96 mL compared with 255 ± 155 mL, $p < 0.001$), and shorter length of stay (1.3 ± 1.8 days compared with 2.7 ± 1.4 days, $p < 0.001$) [18]. Long-term

data of surgical outcomes of women who underwent open sacrocolpopexy were compared both by objective measure of POP-Q and by validated patient questionnaires [19].

Patient Selection

Who Is a Candidate for Robotic Surgery?

Patient selection for RASC has not been well-studied. Selection depends on many factors, including the surgeon's level of expertise with this surgical technique, resources available at the hospital or surgery center, and patient factors. These include the need for concomitant procedures, age, functional status, body mass index (BMI), previous prolapse or incontinence surgery, and comorbidities that may limit the duration of the anesthesia [14] (Table 2.2). In our opinion, criteria from the Abdominal Colpopexy: Comparison of Endoscopic Surgical Strategies (ACCESS) study should be used for patient selection. Patients must have symptomatic stage II–IV pelvic organ prolapse according to the POP-Q system with significant apical descent, defined as prolapse of the vaginal apex or cervix to at least halfway into the vaginal canal (POP-Q point C \geq TVL/2) as well as vaginal bulge symptoms [20].

Table 2.1 Pelvic organ prolapse quantification (POP-Q)

Aa	Ba	C
GH	PB	TVL
Ap	Bp	D

Stage 0: no prolapse is demonstrated. Aa, Ba, Ap, Bp = -3 and C or D $\leq -(TVL-2)$ cm

Stage 1: The most distal portion of the prolapse is more than 1 cm above the level of the hymen

Stage 2: The most distal portion of the prolapse is 1 cm or less proximal or distal to the hymenal plane

Stage 3: The most distal portion of the prolapse protrudes more than 1 cm below the hymen but protrudes no farther than 2 cm less than the total vaginal length

Stage 4: Most distal edge of prolapse if $\geq + (TVL-2)$ cm

Aa point A anterior, Ap point A posterior, Ba point B anterior, Bp point B posterior, C cervix or vaginal cuff, D posterior fornix (if cervix is present), GH genital hiatus, PB perineal body, TVL total vaginal length

Table 2.2 Consideration for robotic surgery

Considerations
BMI
Comorbidities
Previous abdominal/pelvic procedures: consider extra-peritoneal
Ability to obtain informed consent for a procedure that involved surgery, mesh, morcellation
Dedicated operating room for robotics
Cost of robotic system
Robotic instrumentation and maintenance

Table 2.3 Benefits of laparoscopic and robotic surgery compared to abdominal surgery

Benefits of laparoscopic/robotic surgery
Reduced postoperative pain
Improved cosmesis (smaller incisions)
Shorter hospital stays
Faster postoperative recovery
Potentially lower costs (laparoscopic)
Improved patient satisfaction
Improved visualization for deep pelvic dissections

Benefits of Laparoscopy

Benefits of minimally invasive abdominal surgery performed laparoscopically consist of reduced postoperative pain, improved cosmesis due to smaller incisions, shorter hospital stays, faster postoperative recovery, potentially lower costs, and improved patient satisfaction [21] (Table 2.3). Laparoscopic surgery may be beneficial for obese patients compared to an open procedure where the pelvis may be deep and more difficult to visualize. For deep pelvic dissections required during a sacrocolpopexy, laparoscopy allows for a two-dimensional view of the field that can be magnified.

Laparoscopic Versus Robotic Approach in Gynecologic Surgery

In a recent meta-analysis comparing the outcomes of laparoscopic sacrocolpopexy (LSC) and RASC, data on 264 RASC and 267 LSC procedures were collected from seven studies. Pan et al. reported similarities in estimated blood loss (114.4 vs. 160.1 mL; $p = 0.36$) and incidence of intraoperative/postoperative complications ($p = 0.85$ vs. $p = 0.92$). RASC was found to be more costly ($p < 0.01$) and had a higher mean operative time (245.9 vs. 205.9 min; $p < 0.001$) [22].

In an effort to compare LSC and RASC for vaginal apex prolapse, a blinded randomized trial included participants with stage 2–4 post-hysterectomy vaginal prolapse. One year after

prolapse repair, both groups demonstrated significant improvement in vaginal support and functional outcomes, but RASC had a longer operating time, increased pain postoperatively, and a higher surgical cost [23]. Anger et al. randomized 78 women to laparoscopic ($N = 38$) and robotic ($N = 40$) sacrocolpopexies. The initial day of surgery hospital costs for RASC were \$2419 higher when robotic costs were included (\$13,992 compared with \$11,573; $p = 0.001$), and over 6 weeks, hospital costs were \$3104 higher for RASC when robotic costs were included (\$15,274 compared with \$12,170; $p < 0.001$). Both the initial and 6-week costs remain significantly higher for robotic sacrocolpopexy when robotic costs were included [24].

In a retrospective cohort study comparing abdominal sacrocolpopexy with RASC, there was similar short-term vaginal vault support but the latter had a longer operative time, less blood loss, and a shorter length of stay [18]. A cost minimization study was performed comparing open with RASC and found the robotic approach to be equal or less costly than the open approach depending on the institutional robotic case volume [25]. Although laparoscopic sacrocolpopexy has been shown to be equivalent or better in some aspects mentioned, the skills required are not easily acquired and the learning curve is long. It is technically challenging to place the large number of sutures necessary without wristed instruments, and the physical cost to the surgeon has not yet been studied in wear and tear on the neuromuscular skeletal system. Interestingly, the learning curve for RASC is shorter than LSC even though it is considered a complex robotic surgery.

Anesthetic Concerns

Despite the advantages of laparoscopic or robotic gynecologic surgery, there are concerns from the other side of the surgical curtain. Concerns from anesthesia providers range from positioning of

Fig. 2.1 Access to the patient is limited for the anesthesiology team during robotic surgery (© 2016, Intuitive Surgical, Inc)



Table 2.4 Concerns from the anesthesiology providers

Physiological effects of pneumoperitoneum in the Trendelenburg position
Restricted access to the patient due to the mass of the equipment set over the patient, tucked arms, docked robot
Patient obesity (see Table 2.5)
Prolonged lithotomy position

the patient to physiologic changes. From the beginning of the surgical procedure, the anesthesiology team has restricted access to the patient due to the mass of the equipment set over the patient (Fig. 2.1). During robotic surgery, access is even further restricted by docking the robot, as the patient cannot be moved after this point. Furthermore, the arms are completely tucked and often wrapped or padded, limiting access for intraoperative blood draws or placement of an arterial catheter or additional venous access during the procedure (Table 2.4).

Pneumoperitoneum and Trendelenburg Position

Prevention and treatment of complications due to induced pneumoperitoneum, prolonged lithotomy position, and steep Trendelenburg positions have been explored. Although apparently well-tolerated by most patients, the combined effect of the steep Trendelenburg position, which is about 40°, and carbon dioxide pneumoperitoneum during these long procedures, has not been completely defined. In one observational study of robotic endoscopic radical prostatectomy, Trendelenburg position combined with a carbon dioxide pneumoperitoneum significantly influenced cardiovascular, cerebrovascular, and respiratory homeostasis, but variables remained within a clinically acceptable range.

Mean arterial pressure is increased by increased cardiac output, systemic vascular resistance, or both. These changes have been demonstrated by an increased intra-abdominal pressure compressing the aorta and increasing

the afterload, possibly further enhanced by humoral factors during laparoscopic surgery [26]. Also, transesophageal Doppler measurements have shown a significant increase in stroke volume when patients are placed in steep Trendelenburg position [27]. Furthermore, regional cerebral oxygenation was well-preserved and the cerebral perfusion pressure remained above the lower limit of the cerebral autoregulation [28, 29].

Cardiovascular Considerations

The assessment of a patient’s cardiac risk in the perioperative period is made during the history, physical examination, and electrocardiogram. Depending on a patient’s cardiac risk, the surgeon should decide if surgery should proceed without further cardiovascular testing, or be postponed for further testing such as stress testing, echocardiography, or 24 h ambulatory monitoring. The planned surgery may have to be changed to a lesser risk surgery, or conservative management may be chosen instead of surgical treatment. In patients assessed to be at increased cardiovascular risk, a referral to a cardiologist for further evaluation may be indicated preoperatively [30].

A history of ischemic heart disease, congestive heart failure, cerebral vascular disease, renal dysfunction, and preoperative insulin treatment all increase the risk of cardiac complications. Studies have shown a 10–30% reduction in cardiac output in Trendelenburg. Parameters including heart rate, arterial pressure, stroke volume, carbon dioxide elimination, and total respiratory compliance have been measured. Using these values, mean arterial pressure, total peripheral resistance, stroke index, and cardiac index were calculated. At maximum hemodynamic strain, stroke index and cardiac index were reduced by 42%, without significant changes in heart rate and mean arterial pressure. Total peripheral resistance was increased by 50–100% [31].

The Trendelenburg position in awake and anesthetized patients increases pulmonary arte-

rial pressures, central venous pressure, and pulmonary capillary wedge pressure. The cardiac index, a parameter that relates the cardiac output from left ventricle in 1 min to body surface, decreased with anesthesia induction and then again further during laparoscopy. Soon after deflation after laparoscopy, the cardiac index returns to pre-insufflation values [32].

Obese Patients

Concerns have been raised about the applicability of robotic and laparoscopic surgery in the obese patient (Table 2.5). Arterial oxygenation and alveolar-arterial difference in oxygen tension are significantly impaired in obese patients. One study looking at the issues of obesity in a surgical population compared 15 overweight and 15 nonobese patients undergoing robot-assisted radical prostatectomy under general anesthesia. This procedure is similar to a RASC in length and in Trendelenburg positioning of the patient. The alveolar-arterial difference in oxygen tension is a measure of the difference between the alveolar concentration of oxygen and the arterial concentration of oxygen and is used in diagnosing the source of hypoxemia. This small study demonstrated that overweight (BMI of 25–29.9 kg m²) patients had impaired arterial oxygenation with a higher alveolar-arte-

Table 2.5 Considerations in obese patients

Arterial oxygenation and A(a) DO ₂ are significantly impaired in overweight patients under general anesthesia in Trendelenburg position
Pneumoperitoneum may transiently reduce impairment in arterial oxygenation and decrease A(a) DO ₂
Higher expiratory airway pressures
Increased open conversion rates
Increased airway pressures after placing a morbidly obese patient in the lithotomy and steep Trendelenburg positions, possibility of aborting or converting to an open procedure
Hemodynamic parameters are not affected by BMI

rial difference in oxygen tension levels after induction of anesthesia and Trendelenburg positioning. In these overweight patients, pneumoperitoneum reduced the impairment of arterial oxygenation as well [33].

In a study to determine the impact of BMI on perioperative functional and oncological outcomes in patients undergoing robotic laparoscopic radical prostatectomy, 945 patients were stratified by BMI: normal weight (BMI < 25 kg/m²), overweight (BMI = 25 to <30 kg/m²), and obese (BMI ≥ 30 kg/m²). Obese patients experienced increased open conversion rates (2.3%) compared with nonobese patients (0.9%), with over 80% of these open conversion cases due to higher expiratory airway pressures while in Trendelenburg [34].

Hemodynamic parameters have not been shown to be affected by BMI in laparoscopic or robotic surgeries [33, 35]. A recent retrospective study on obese patients (BMI of 30 kg/m²) followed 1032 patients who underwent robotic gynecological surgery at two institutions between 2006 and 2012 and found that 14% had any complication, but only 3% of patients had a pulmonary complication. The degree of obesity did not predict complications or success of robotic surgery. Age was significantly associated with a higher risk of pulmonary complications ($p = 0.01$). Older age ($p = 0.0001$), higher estimated blood loss ($p < 0.0001$), and longer case length ($p = 0.004$) were associated with a higher rate of all-cause complications. The authors concluded that the vast majority of obese patients can tolerate robotic gynecological surgery with low complication rates and even lower rates of pulmonary complications [36]. In a subgroup analysis, there was no clinical difference between patients who underwent robotic gynecologic surgery for oncologic versus benign indications [37].

Alternative Surgical Strategies

When considering candidacy for RASC, it is important to understand the other surgical options available for apical POP repair, as there are sev-

eral good options for surgical correction of apical prolapse with relatively high success rates.

Transvaginal Approaches

Sacrospinous Ligament Fixation

Sacrospinous ligament fixation (SSLF) is one of the most frequently performed and well-studied of the hysteropexy/colpopexy techniques. This procedure involves performing an extra-peritoneal dissection until the sacrospinous ligament is identified and exposed. The right sacrospinous ligament is often used due to the left side's proximity to the rectum. With the use of a reusable ligature carrier or a suture delivery device, the sacrospinous ligament is attached to the posterior cervix, vagina, or possibly the uterosacral ligament using a permanent monofilament suture, delayed absorbable sutures, or a combination of both (Fig. 2.2).

The safety profile, as well as the success of this procedure, has been extensively studied and described in detail in the literature. Generally, there is a low recurrence rate [38], shorter recovery times, less morbidity, shorter operating times, less pain, and a shorter hospital stay when a SSLF is performed without a hysterectomy [39]. In one randomized controlled trial, 71 women either underwent a SSLF without a hysterectomy or vaginal hysterectomy and uterosacral ligament suspension (USLS). There were no differences in quality of life, prolapse or incontinence symptoms, or reoperation rates at 1 year. Although subjectively, prolapse symptoms were the same 1 year postoperatively, 27% of the SSLF group had stage II or greater prolapse on the POP-Q (Table 2.6) compared to only 11% in the vaginal hysterectomy with USLS group. SSLF was associated with shorter hospitalization, shorter recovery with more rapid return to work, and a significantly longer mean total vaginal length of 8.8 versus 7.3 cm than the hysterectomy with apical suspension group ($p < 0.01$) [40]. Most recently, SSLF was reported to be non-inferior to vaginal hysterectomy with suspension of the uterosacral ligaments for symptomatic recurrent prolapse of the apical compartment. Although the

Fig. 2.2 Placement of suture with a suture delivery device through the sacrospinous ligament (Image used with permission from Boston Scientific, 2017)

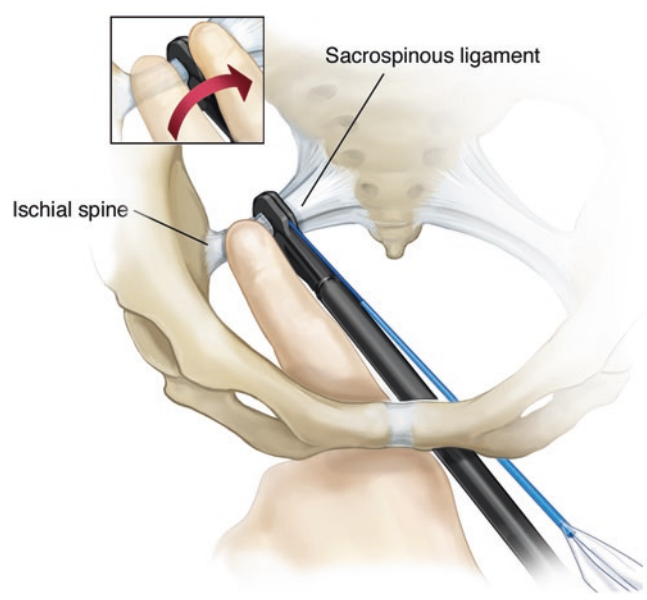


Table 2.6 Relative contraindications to laparoscopic or robotic surgery

Relative contraindications
BMI
Patient preference for Pfannenstiel/previous Pfannenstiel
Pelvic/abdominal radiation therapy
Immunosuppression: chemotherapy, chronic steroid use, immunosuppressive medications
Connective tissue disorders causing poor wound healing
Severe intra-abdominal adhesions
Compromised pulmonary status
Inability to tolerate positioning
Prior upper limb neural injury during surgery

main outcome was POP recurrence at Stage II or higher of the apical compartment, this study also reported no significant differences between anatomical recurrences, functional outcomes, or quality of life [41].

Because this procedure is short in duration, has minimal blood loss, and does not require entering the posterior cul de sac, patients with comorbidities that do not allow for long procedures or patients who have scarring in the cul de sac due to previous surgeries, endometriosis, or

pelvic inflammatory disease, may be good candidates.

Uterosacral Ligament Suspension

This technique involves entering the peritoneal cavity through the vagina at the location of the vaginal cuff in a post-hysterectomy patient, through a posterior colpotomy in a uterine-sparing procedure, or through the open cuff at the time of a vaginal hysterectomy. One to three delayed absorbable sutures and/or permanent sutures are placed through each uterosacral ligament at or above the ischial spine. The sutures are then attached either extra-peritoneally or intra-peritoneally to the cervix or vaginal apex. This procedure is done extra-peritoneally when the surgeon chooses to avoid the posterior cul de sac due to a previous history of pelvic surgery, endometriosis, pelvic inflammatory disease, or other known pelvic scarring.

One retrospective study compared 100 cases of USLS to 100 cases of USLS at the time of a vaginal hysterectomy and found similar objective results at the postoperative mark of 1.5 years. Objective apical support was 96.4%, with no difference between hysteropexy and cuff suspension (96.0% vs. 96.8%, $p = 0.90$), cystocele (86.8% vs.

93.8%, $p = 0.31$), or rectocele (97.8% vs. 100%, $p = 0.16$) at 2 years after surgery [42].

Using the POP-Q D point, which is the point of the posterior fornix, has been shown to correlate with postoperative apical support, and a clinically meaningful relationship exists between the preoperative D point and anatomic apical success. D points are only present in patients who have a uterus. Richter et al. found that a more negative preoperative D point was significantly related to improved postoperative apical support ($p = 0.0005$). This study excluded women who had a previous hysterectomy, as they did not have a preoperative D point [43]. In our experience, the outcomes are similar except when there is cervical elongation (more than 4 cm) and/or when there is a very large anterior compartment defect, in which case it is difficult to adequately elevate and support the anterior wall with the cervix in place, or even with sufficient elevation of the apex or anterior wall, the elongated cervix may cause the patient bulge symptoms.

Manchester Procedure

Originally described in 1888, the Manchester procedure involved amputation of the cervix, colporrhaphy, and attachment of the cervical stump to the transposed contralateral uterosacral-cardinal ligament complex [44]. Since then, modifications have been made, involving plication of the uterosacral ligaments instead of cutting and transposing the ligaments [45].

In a study comparing the modified Manchester to vaginal hysterectomy with uterosacral ligament suspension outcomes, 98 patients returned for a 1 year follow-up (51 in modified Manchester group and 48 in TVH with USLS group) and were included in this comparison. There were similar anterior and posterior compartment prolapse recurrences (POP stage greater than or equal to stage II) of about 50%, but no apical recurrence for the modified Manchester group. In the modified Manchester group, there was no apical recurrence versus two patients with objective apical recurrence in

the vaginal hysterectomy group. Despite more apical recurrence objectively, there was no difference in the pre- and postoperative subjective scores between groups [46]. This procedure is less commonly performed because cervical amputation has been associated with hematometra, which is retention of blood in the uterine cavity caused by obstruction to uterine flow at the level of the uterus, cervix, or vagina, infection in the uterus, infertility, miscarriage, and preterm delivery [47].

Colpocleisis

Colpocleisis is a surgical technique for POP that can be uterine-sparing, with the benefits of short operating room time, low morbidity and reoperation rates, high satisfaction rates, and improved body image. The LeFort colpocleisis leaves the uterus in situ while the total colpocleisis is performed on patients without a uterus. During both procedures, the vagina is sutured closed and the operation is, therefore, only appropriate for patients who do not wish to have vaginal intercourse. High satisfaction and low regret seen 24 weeks after surgery provide reassurance that colpocleisis is an excellent option for appropriate patients who do not desire the option of sexual intercourse [22].

Although there are no studies comparing obliterative procedures in these groups, there are many reasons to perform a concomitant TVH in appropriate patients who have risk factors for cervical cancer, such as current or recent high risk human papillomavirus infection or cervical intraepithelial neoplasia, or increased risk factors for endometrial cancer such as obesity, tamoxifen use, or Lynch syndrome. Lynch syndrome is also called hereditary nonpolyposis colorectal cancer (HNPCC) and it is an inherited disorder that increases the risk of many types of cancer, including endometrial cancer. It is advised that women who are at average risk of cervical and/or endometrial cancer consider concomitant hysterectomy at the time of colpocleisis so that cervical screening or endometrial sampling is not needed in the future.

Indications for removing the uterus are current tamoxifen therapy, familial cancer syndromes (BRCA 1, BRCA 2, Hereditary Nonpolyposis Colonic Cancer Syndrome), inability to comply with routine gynecologic exams, uterine abnormalities such as fibroids, adenomyosis, abnormal endometrial lining, or abnormal uterine bleeding [48]. If a patient is in reasonable physical health and has an extended life-expectancy, she may benefit from a hysterectomy at the time of colposcleisis. The overall rate of major perioperative and postoperative adverse events in women undergoing colposcleisis is low; however, when a hysterectomy is performed at the same time, the operative times are longer and the blood loss is greater [49].

Special Considerations of the Use of Vaginal Mesh

In 2002, the US Food and Drug Administration (FDA) approved vaginal insertion of mesh for the surgical treatment of pelvic organ prolapse, and in 2008, released a public health notification of risks associated with this use of surgical mesh. Surgical mesh placed through the abdomen for procedures, including sacrocolpopexy, had been performed for decades prior. The FDA public health notification stated that there were serious, but rare, complications associated with transvaginal placement of surgical mesh in repair of POP and stress urinary incontinence [50].

In 2011, prompted by concerns regarding the long-term safety of vaginally placed synthetic mesh, the FDA released an updated communication questioning the effectiveness of vaginal mesh for POP as compared with the non-mesh repair of POP (slings for stress urinary incontinence, with much lower complication rates, were excluded from this warning). The FDA reported a fivefold increase in mesh-related events from January 1, 2008, through December 31, 2010 [51]. The FDA's literature review found that extrusion of mesh through the vagina is the most common and consistently reported mesh-related complication from transvaginal placement of sur-

gical mesh for POP. Shortly thereafter, the American Urogynecologic Society (AUGS) released guidelines for privileging and credentialing of physicians planning to implement or continue using transvaginal mesh for pelvic organ prolapse [52].

In 2015, the FDA issued two orders to manufacturers and the public to strengthen the data requirements for transvaginal surgical mesh for POP. One order reclassifies these medical devices from class II, which generally includes moderate-risk devices, to class III, which includes high-risk devices. The second order requires manufacturers to submit a premarket approval application to support the safety and effectiveness of surgical mesh for the transvaginal repair of POP [53] (Fig. 2.3).

The use of vaginal mesh for uterovaginal prolapse is controversial, and while there are complications noted in the literature, there is also evidence of anatomic success and patient satisfaction. Although many vaginal mesh kits have been voluntarily taken off the market, some are still available [54, 55]. Studies performed earlier continue to be published and there are many more studies in progress that will be published in the future. A recent study by Huang et al. compared 24 patients who had mesh placed at the time of hysterectomy to 78 patients who had uterine-sparing surgery with anterior mesh alone. There were no differences in functional or anatomic outcomes or statistically significant differences in postoperative adverse events [56].

Another study comparing an anterior and apical mesh system in a uterine-sparing procedure to one with concomitant hysterectomy reported anatomic success along with a similar complication rate. There was a trend toward increased mesh extrusion when a hysterectomy was done at the same time, but larger studies are needed to determine the true impact [57]. Cho et al. found a 97.1% anatomic success rate 2 years after transvaginal pelvic floor repairs with an anterior vaginal mesh system. Validated

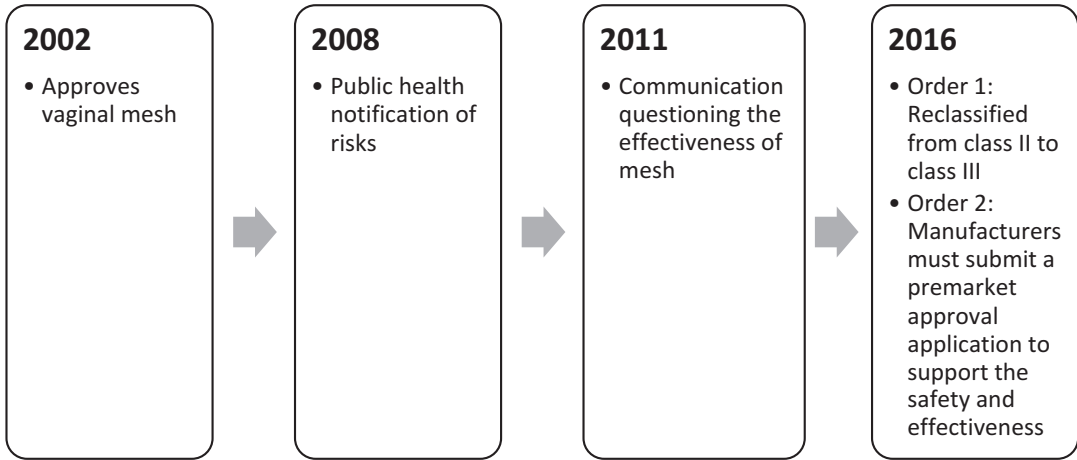


Fig. 2.3 FDA actions regarding vaginal mesh

quality of life scales improved and there was an improvement in all points when comparing the pre- and postoperative POP-Q [58]. A recent multicenter study by Jirschele et al. reported a good safety profile, as well as effective prolapse repair when the procedure was performed on 99 women with an apical polypropylene mesh kit after 12 months of follow-up [59].

Abdominal Approaches

Abdominal Sacrohysteropexy

The earliest abdominal approaches focused on transfixing the uterus to the anterior abdominal wall. However, more recently, an abdominal laparotomy incision has been used to perform a sacrohysteropexy. This procedure can be performed with or without graft material and usually involves securing mesh to both the posterior cervix and through windows made in the broad ligaments to the anterior cervix. The mesh is then attached to the anterior longitudinal ligament that runs over the sacrum. In the past decade, multiple small prospective and retrospective studies show anatomical success and symptomatic improvement for patients [60]. More recently, physicians are moving toward more minimally invasive

techniques to accomplish this, techniques which will be reviewed in another chapter of this textbook.

Laparoscopic/Robotic Uterosacral Ligament Suspension

Laparoscopic uterosacral ligament suspension was first described in 1994 and typically is performed with one to two suspension sutures that are placed in each ligament near the level of the ischial spine and then attached to the vaginal apex or cervix [60]. In a study by Krantz et al., the association between intraoperative ($\chi^2 = 0.83$, $p = 0.36$), postoperative ($\chi^2 = 1.88$, $p = 0.17$), or overall ($\chi^2 = 0.53$, $p = 0.47$) complications for those undergoing a laparoscopic ($N = 23$) or transvaginal USLS ($N = 23$) approach was not significant [61].

Laparoscopic Hysteropexy

Different methods of laparoscopic sacrohysteropexy have been described with suture, graft, and mesh and there are currently ongoing studies. In the Oxford laparoscopic sacrohysteropexy technique, the procedure is performed with graft material and involves securing mesh to both the posterior cervix and through the windows made in the broad ligaments, to the anterior cervix. The

arms of the mesh are transfixed anterior to the cervix with three nonabsorbable sutures [62].

One-year follow-up data were analyzed for women randomized to laparoscopic hysteropexy or vaginal hysterectomy with USLS. Outcomes were favorable for the laparoscopic hysteropexy showing faster return to normal activity, decreased estimated blood loss, and pain score 24 h postoperatively [63]. In another study of 140 patients who underwent laparoscopic hysteropexy for POP, 89% felt their prolapse was “very much” or “much” better and there was a statistically significant improvement in all parameters of POP-Q [64]. In a prospective, controlled study, 34 of the 72 consecutive patients with symptomatic POP were treated with sacrohysteropexy and the other 38 with hysterectomy followed by sacrocolpopexy with mesh. The authors report safety in sacrohysteropexy for women who request uterine preservation. Whether the uterus was preserved or not, patients had similar results in terms of prolapse resolution, urodynamic outcomes, and improvements in voiding and sexual dysfunctions. In the uterine-sparing surgery, the operating time was shortened and there was less blood loss [65].

Costantini et al. followed 52 patients for 60 ± 34 months who underwent sacrohysteropexy, 47 laparoscopic, and eight abdominal. The study found that anterior compartment recurrence (stage ≥ 2) was present in 4 out of 52 patients (7.7%), while posterior compartment prolapse was present in three (5.7%). Sexual activity was maintained in 28 out of 29 patients (95.5%) [66].

Robotic Sacrohysteropexy

In addition to laparoscopic techniques, some surgeons have made the transition to robotic-assisted laparoscopic approaches. A retrospective cohort study of 168 patients compared three robotic groups, total hysterectomy plus mesh sacrocolpopexy, mesh sacrohysteropexy, and hysterectomy plus uterosacral suspension and showed a sixfold increase in POP recurrence in the uterosacral suspension group. Furthermore, with a

median follow-up of 36 months in all surgery groups, there was no difference in the complication rates and functional outcomes, but operation time was longest in the hysterectomy plus sacrocolpopexy group. The authors suggest that the use of mesh, rather than hysterectomy, might be necessary for successful POP surgery [67]. Mourik et al. described the technique of robotic-assisted sacrohysteropexy in a series of 40 patients to emphasize that for those wishing to keep their uterus, success rates remain high. Before operation, overall well-being by validated questionnaires was scored at 67.7% and after surgery, this improved to 82.1% ($p = 0.03$) [68]. There is a risk of nerve damage and bleeding during the dissection to the anterior longitudinal ligament at the sacral promontory.

A Cochrane review concluded that sacrocolpopexy had superior outcomes compared to sacrospinous ligament fixation, uterosacral ligament suspension, and vaginal mesh. Due to superior results, this method is gaining popularity, but must be balanced with the increase in operating room time and higher cost of the robotic approach [69]. The popularity of RASC is increasing as transvaginal mesh is becoming less acceptable to patients and offered less often by surgeons. The ability to perform a sacral suspension procedure without a big incision appeals to women and physicians alike. It is a complicated skill set and requires adequate time and volume to learn and maintain these skills.

AUGS released Guidelines for Privileging and Credentialing Physicians for Sacrocolpopexy in 2013 for POP, which provided recommendations to assist health care institutions when considering granting privileges to perform sacrocolpopexy. The guidelines recommend that sacrocolpopexy for POP should be performed by surgeons with board certification or active candidacy for board certification in obstetrics and gynecology or urology who also have requisite knowledge, surgical skills, and experience in reconstructive pelvic surgery [70]. The surgeon should be qualified to perform the procedure open as well.

In 2012, a Cochrane review of robotic surgery for benign gynecological disease concluded that current evidence did not support the use of robotic surgery for patients with benign gynecologic disease, specifically for sacrocolpopexy and hysterectomy. The review stated that the current studies fail to show any superiority as compared to laparoscopic surgery [71]. This statement was withdrawn for an updated version of the review that was released in 2014 and included gynecologic oncology procedures. Their view was softened from the previous version with regard to sacrocolpopexy. The RASC was concluded to be a longer procedure with a shorter hospital stay, and the authors suggest further studies are warranted [72].

Conclusion

With some modifications in technique, the sacrocolpopexy has been used to correct prolapse of the vaginal apex since 1957. The operation, which is designed to restore the vagina to its normal position and function by re-suspending the vaginal apex using graft material, can be performed open, laparoscopically, and most recently with robotic-assisted technology. There is no explicit research on the topic, and more studies specifically looking at the best candidates for robotic surgery are needed. Understanding the conservative treatments of pelvic organ prolapse and the other surgical techniques help the surgeon tailor the options for apical support to individual patients.

When choosing RASC, it is important to consider the other options available for apical support, which vary from vaginal approaches to abdominal approaches, and open procedures to minimally invasive surgeries. Furthermore, patient selection should take into consideration advantages and challenges of robotic surgery along with specific patient criteria such as baseline health, cardiovascular status, BMI, and requirements for steep Trendelenburg and dorsal lithotomy patient positioning.

References

1. Swift SE. The distribution of pelvic organ support in a population of female subjects seen for routine gynecologic health care. *Am J Obstet Gynecol.* 2000;183(2):277–85.
2. DeLancey JO. Fascial and muscular abnormalities in women with urethral hypermobility and anterior vaginal wall prolapse. *Am J Obstet Gynecol.* 2002;187(1):93–8.
3. Shull BL. Pelvic organ prolapse: anterior, superior, and posterior vaginal segment defects. *Am J Obstet Gynecol.* 1999;181(1):6–11.
4. Toozs-Hobson P, Boos K, Cardozo L. Management of vaginal vault prolapse. *Br J Obstet Gynaecol.* 1998;105(1):13–7.
5. Rooney K, Kenton K, Mueller ER, FitzGerald MP, Brubaker L. Advanced anterior vaginal wall prolapse is highly correlated with apical prolapse. *Am J Obstet Gynecol.* 2006;195(6):1837–40.
6. Hsu Y, Chen L, Summers A, Ashton-Miller JA, DeLancey JO. Anterior vaginal wall length and degree of anterior compartment prolapse seen on dynamic MRI. *Int Urogynecol J Pelvic Floor Dysfunct.* 2008;19(1):137–42.
7. Arthure HG, Savage D. Uterine prolapse and prolapse of the vaginal vault treated by sacral hysteropexy. *J Obstet Gynaecol Br Emp.* 1957;64(3):355–60.
8. Lane FE. Repair of posthysterectomy vaginal-vault prolapse. *Obstet Gynecol.* 1962;20:72–7.
9. Birnbaum SJ. Rational therapy for the prolapsed vagina. *Am J Obstet Gynecol.* 1973;115(3):411–9.
10. Snyder TE, Krantz KE. Abdominal-retroperitoneal sacral colpopexy for the correction of vaginal prolapse. *Obstet Gynecol.* 1991;77(6):944–9.
11. Addison WA, Cundiff GW, Bump RC, Harris RL. Sacral colpopexy is the preferred treatment for vaginal vault prolapse. *J Gynecol Technol.* 1996;2:69–74.
12. Nygaard IE, McCreery R, Brubaker L, Connolly A, Cundiff G, Weber AM, et al. Abdominal sacrocolpopexy: a comprehensive review. *Obstet Gynecol.* 2004;104(4):805–23.
13. Ridgeway B, Chen CC, Paraiso MF. The use of synthetic mesh in pelvic reconstructive surgery. *Clin Obstet Gynecol.* 2008;51(1):136–52.
14. McDermott CD, Hale DS. Abdominal, laparoscopic, and robotic surgery for pelvic organ prolapse. *Obstet Gynecol Clin N Am.* 2009;36(3):585–614.
15. Barbolt TA. Biology of polypropylene/polyglactin 910 grafts. *Int Urogynecol J Pelvic Floor Dysfunct.* 2006;17(Suppl 1):S26–30.
16. Ostergard DR. Polypropylene vaginal mesh grafts in gynecology. *Obstet Gynecol.* 2010;116(4):962–6.

17. Barbalat Y, Tunuguntla HS. Surgery for pelvic organ prolapse: a historical perspective. *Curr Urol Rep.* 2012;13(3):256–61.
18. Geller EJ, Siddiqui NY, JM W, Visco AG. Short-term outcomes of robotic sacrocolpopexy compared with abdominal sacrocolpopexy. *Obstet Gynecol.* 2008;112(6):1201–6.
19. Siddiqui NY, Geller EJ, Visco AG. Symptomatic and anatomic 1-year outcomes after robotic and abdominal sacrocolpopexy. *Am J Obstet Gynecol.* 2012;206(5):435.
20. Anger JT, Mueller ER, Tarnay C, Smith B, Stroupe K, Rosenman A, et al. Robotic compared with laparoscopic sacrocolpopexy: a randomized controlled trial. *Obstet Gynecol.* 2014;123(1):5–12.
21. Fuchs KH. Minimally invasive surgery. *Endoscopy.* 2002;34(2):154–9.
22. Crisp CC, Book NM, Cunkelman JA, Tieu AL, Pauls RN. Body image, regret, and satisfaction 24 weeks after colpocleisis: a multicenter study. *Female Pelvic Med Reconstr Surg.* 2015. PMID: 26571434.
23. Paraiso MF, Jelovsek JE, Frick A, Chen CC, Barber MD. Laparoscopic compared with robotic sacrocolpopexy for vaginal prolapse: a randomized controlled trial. *Obstet Gynecol.* 2011;118(5):1005–13.
24. Anger J, Tarnay C, Smith B, Stroupe K, Rosenman A, Brubaker L, et al. Robotic compared with laparoscopic sacrocolpopexy: a randomized controlled trial [Erratum]. *Obstet Gynecol.* 2014;124(1):165.
25. Elliott CS, Hsieh MH, Sokol ER, Comiter CV, Payne CK, Chen B. Robot-assisted versus open sacrocolpopexy: a cost-minimization analysis. *J Urol.* 2012;187(2):638–43.
26. O'Malley C, Cunningham AJ. Physiologic changes during laparoscopy. *Anesthesiol Clin North Am.* 2001;19(1):1–19.
27. Falabella A, Moore-Jeffries E, Sullivan MJ, Nelson R, Lew M. Cardiac function during steep Trendelenburg position and CO₂ pneumoperitoneum for robotic-assisted prostatectomy: a transoesophageal Doppler probe study. *Int J Med Robot.* 2007;3(4):312–5.
28. Kalmar AF, Foubert L, Hendrickx JF, Mottrie A, Absalom A, Mortier EP, et al. Influence of steep Trendelenburg position and CO₂ pneumoperitoneum on cardiovascular, cerebrovascular, and respiratory homeostasis during robotic prostatectomy. *Br J Anaesth.* 2010;104(4):433–9.
29. Gainsburg DM. Anesthetic concerns for robotic-assisted laparoscopic radical prostatectomy. *Minerva Anesthesiol.* 2012;78(5):596–604.
30. Fleisher LA, Fleischmann KE, Auerbach AD, Barnason SA, Beckman JA, Bozkurt B, et al. ACC/AHA guideline on perioperative cardiovascular evaluation and management of patients undergoing non-cardiac surgery: a report of the American College of Cardiology/American Heart Association Task Force on practice guidelines. *J Am Coll Cardiol.* 2014;64(22):e77–137.
31. Johannsen G, Andersen M, Juhl B. The effect of general anaesthesia on the haemodynamic events during laparoscopy with CO₂-insufflation. *Acta Anaesthesiol Scand.* 1989;33(2):132–6.
32. Hirvonen EA, Nuutinen LS, Kauko M. Hemodynamic changes due to Trendelenburg positioning and pneumoperitoneum during laparoscopic hysterectomy. *Acta Anaesthesiol Scand.* 1995;39(7):949–55.
33. Meininger D, Zwissler B, Byhahn C, Probst M, Westphal K, Bremerich DH. Impact of overweight and pneumoperitoneum on hemodynamics and oxygenation during prolonged laparoscopic surgery. *World J Surg.* 2006;30(4):520–6.
34. Wiltz AL, Shikanov S, Eggener SE, Katz MH, Thong AE, Steinberg GD, et al. Robotic radical prostatectomy in overweight and obese patients: oncological and validated-functional outcomes. *Urology.* 2009;73(2):316–22.
35. Sullivan MJ, Frost EA, Lew MW. Anesthetic care of the patient for robotic surgery. *Middle East J Anaesthesiol.* 2008;19(5):967–82.
36. Wysham WZ, Kim KH, Roberts JM, Sullivan SA, Campbell SB, Roque DR, et al. Obesity and perioperative pulmonary complications in robotic gynecologic surgery. *Am J Obstet Gynecol.* 2015;213(1):33–7.
37. Gkegkes ID, Iavazzo C, Iavazzo PE. Perioperative pulmonary complications in obese patients undergoing robotic procedures for gynecological cancers. *Am J Obstet Gynecol.* 2016;214(2):296.
38. Hefni MA, El-Toukhy TA. Long-term outcome of vaginal sacrospinous colpopexy for marked uterovaginal and vault prolapse. *Eur J Obstet Gynecol Reprod Biol.* 2006;127(2):257–63.
39. Maher CF, Cary MP, Slack MC, Murray CJ, Milligan M, Schluter P. Uterine preservation or hysterectomy at sacrospinous colpopexy for uterovaginal prolapse? *Int Urogynecol J Pelvic Floor Dysfunct.* 2001;12(6):381–4.
40. Dietz V, van der Vaart CH, van der Graaf Y, Heintz P, Schraffordt Koops SE. One-year follow-up after sacrospinous hysteropexy and vaginal hysterectomy for uterine descent: a randomized study. *Int Urogynecol J.* 2010;21(2):209–16.
41. Detollenaere RJ, den BJ, Stekelenburg J, Int'Hout J, Vierhout ME, Kluivers KB, et al. Sacrospinous hysteropexy versus vaginal hysterectomy with suspension of the uterosacral ligaments in women with uterine prolapse stage 2 or higher: multicentre randomised non-inferiority trial. *BMJ.* 2015;351:h3717.

42. Romanzi LJ, Tyagi R. Hysteropexy compared to hysterectomy for uterine prolapse surgery: does durability differ? *Int Urogynecol J*. 2012;23(5):625–31.
43. Richter LA, Park AJ, Boileau JE, Janni M, Desale S, Iglesia CB. Does pelvic organ prolapse quantification examination d point predict uterosacral ligament suspension outcomes? *Female Pelvic Med Reconstr Surg*. 2016;22(3):146–50.
44. Tipton RH, Atkin PF. Uterine disease after the Manchester repair operation. *J Obstet Gynaecol Br Commonw*. 1970;77(9):852–3.
45. Khunda A, Vashisht A, Cutner A. New procedures for uterine prolapse. *Best Pract Res Clin Obstet Gynaecol*. 2013;27(3):363–79.
46. de Boer TA, Milani AL, Kluivers KB, Withagen MI, Vierhout ME. The effectiveness of surgical correction of uterine prolapse: cervical amputation with uterosacral ligament plication (modified Manchester) versus vaginal hysterectomy with high uterosacral ligament plication. *Int Urogynecol J Pelvic Floor Dysfunct*. 2009;20(11):1313–9.
47. Ridgeway BM. Does prolapse equal hysterectomy? The role of uterine conservation in women with uterovaginal prolapse. *Am J Obstet Gynecol*. 2015;213(6):802–9.
48. Kow N, Goldman HB, Ridgeway B. Management options for women with uterine prolapse interested in uterine preservation. *Curr Urol Rep*. 2013;14(5):395–402.
49. Hill AJ, Walters MD, Unger CA. Perioperative adverse events associated with colpocleisis for uterovaginal and posthysterectomy vaginal vault prolapse. *Am J Obstet Gynecol*. 2015. PMID: 26529371.
50. U.S. Food and Drug Administration. FDA Public Health Notification: serious complications associated with transvaginal placement of surgical mesh in repair of pelvic organ prolapse and stress urinary incontinence; 2008.
51. U.S. Food and Drug Administration. UPDATE on serious complications associated with transvaginal placement of surgical mesh for pelvic organ prolapse: FDA Safety Communication; 2011.
52. Guidelines for providing privileges and credentials to physicians for transvaginal placement of surgical mesh for pelvic organ prolapse. *Female Pelvic Med Reconstr Surg*. 2012;18(4):194–7.
53. Obstetrical and gynecological devices; reclassification of surgical mesh for transvaginal pelvic organ prolapse repair; final order. *Fed Regist* 2016;81(2):353–61.
54. AstoraHealth.com. Astora Women's Health: Physicians, Hospitals, Centers, Investigators FAQs; 2016.
55. Kozal S, Ripert T, Bayoud Y, Menard J, Nicolacopoulos I, Bedzmarzyck L. Morbidity and functional mid-term outcomes using Prolift pelvic floor repair systems. *Can Urol Assoc J*. 2014;8(9–10):E605–9.
56. Huang LY, Chu LC, Chiang HJ, Chuang FC, Kung FT, Huang KH. Medium-term comparison of uterus preservation versus hysterectomy in pelvic organ prolapse treatment with Prolift mesh. *Int Urogynecol J*. 2015;26(7):1013–20.
57. Stanford EJ, Moore RD, Roovers JP, VanDrie DM, Giudice TP, Lukban JC, et al. Elevate and uterine preservation: two-year results. *Female Pelvic Med Reconstr Surg*. 2015;21(4):205–10.
58. Cho MK, Kim CH, Kang WD, Kim JW, Kim SM, Kim YH. Anatomic and functional outcomes with the prolift procedure in elderly women with advanced pelvic organ prolapse who desire uterine preservation. *J Minim Invasive Gynecol*. 2012;19(3):307–12.
59. Jirschele K, Seitz M, Zhou Y, Rosenblatt P, Culligan P, Sand P. A multicenter, prospective trial to evaluate mesh-augmented sacrospinous hysteropexy for uterovaginal prolapse. *Int Urogynecol J*. 2015;26(5):743–8.
60. Gutman R, Maher C. Uterine-preserving POP surgery. *Int Urogynecol J*. 2013;24(11):1803–13.
61. Krantz TE, McKuen MJ, Medina C. Uterosacral ligament suspension complications between laparoscopic and transvaginal approaches. *J Minim Invasive Gynecol*. 2015;22(6S):S65.
62. Rahmanou P, Price N, Jackson S. Laparoscopic hysteropexy: a novel technique for uterine preservation surgery. *Int Urogynecol J*. 2014;25(1):139–40.
63. Rahmanou P, Price N, Jackson SR. Laparoscopic hysteropexy versus vaginal hysterectomy for the treatment of uterovaginal prolapse: a prospective randomized pilot study. *Int Urogynecol J*. 2015;26(11):1687–94.
64. Rahmanou P, White B, Price N, Jackson S. Laparoscopic hysteropexy: 1- to 4-year follow-up of women postoperatively. *Int Urogynecol J*. 2014;25(1):131–8.
65. Costantini E, Mearini L, Bini V, Zucchi A, Mearini E, Porena M. Uterus preservation in surgical correction of urogenital prolapse. *Eur Urol*. 2005;48(4):642–9.
66. Costantini E, Lazzeri M, Zucchi A, Bini V, Mearini L, Porena M. Five-year outcome of uterus sparing surgery for pelvic organ prolapse repair: a single-center experience. *Int Urogynecol J*. 2011;22(3):287–92.
67. Jeon MJ, Jung HJ, Choi HJ, Kim SK, Bai SW. Is hysterectomy or the use of graft necessary for the reconstructive surgery for uterine prolapse? *Int Urogynecol J Pelvic Floor Dysfunct*. 2008;19(3):351–5.
68. Mourik SL, Martens JE, Aktas M. Uterine preservation in pelvic organ prolapse using robot assisted laparoscopic sacrohysteropexy: quality of life and technique. *Eur J Obstet Gynecol Reprod Biol*. 2012;165(1):122–7.

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69. Maher C, Feiner B, Baessler K, Schmid C. Surgical management of pelvic organ prolapse in women. Cochrane Database Syst Rev. 2013;(4):CD004014.
 70. Guidelines for privileging and credentialing physicians for sacrocolpopexy for pelvic organ prolapse. Female Pelvic Med Reconstr Surg. 2013;19(2):62–5.
 71. Liu H, Lu D, Shi G, Song H, Wang L. WITHDRAWN: robotic surgery for benign gynaecological disease. Cochrane Database Syst Rev. 2014;(12):CD008978.
 72. Liu H, Lawrie TA, Lu D, Song H, Wang L, Shi G. Robot-assisted surgery in gynaecology. Cochrane Database Syst Rev. 2014;(12):CD011422.

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