To mesh or not to mesh: a review of pelvic organ reconstructive surgery

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Abstract
Pelvic organ prolapse (POP) is a major health issue with a lifetime risk of undergoing at least one surgical intervention estimated at close to 10%. In the 1990's, the risk of reoperation after primary standard vaginal procedure was estimated to be as high as 30 to 50%. Based on this estimate of recurrence and in order to reduce the risk of relapse, gynecological surgeons started to use mesh implants in pelvic organ reconstructive surgery with the emergence of new complications, also implying reoperations. With the success of mesh in reducing the risk of recurrence for abdominal hernia (75% reduction), it was hypothesized that its use could proffer similar benefits in POP surgery. Recent studies have nevertheless shown that the risk of POP recurrence requiring reoperation is lower than previously estimated, being closer to 10% rather than 30%. The development of mesh surgery, under considerable pressure and incentives from the marketing industry, was tremendous during the past decade, and preceded any studies supporting its benefit for our patients. Nowadays, randomized trials comparing the use of mesh to native tissue [...]
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“To mesh or not to mesh: a review of pelvic organ reconstructive surgery”

Thesis submitted to the Medical School of the University of Geneva

for the degree of Privat-Docent

by

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Geneva

2014
Acknowledgments

I would like to express my thanks to

- Professor Jean-Bernard Dubuisson who offered me the opportunity to start my research in the domain of Urogynecology which became my specialty.
- Professor Michel Boulvain who introduced me to clinical research and helped me with most of my publications.
- Prof Olivier Irion and Professor Patrick Petignat for their support in my application for this Privat-Docent thesis
- My wife and family who have supported me for many years in my medical career
- All the colleagues who contributed to my clinical researches.
- All the patients who participated in our studies
Abbreviations used in the manuscript

- AD: anno domini
- ASC: abdominal sacrocolpopexy
- BC: before Christ
- CMPS: chronic mesh pain syndrome
- COPD: chronic obstructive pulmonary disease
- FDA: food and drug administration
- LSC: laparoscopic sacrocolpopexy
- PFME: pelvic floor muscle exercise
- PISQ: pelvic organ prolapse/urinary incontinence sexual questionnaire
- POP: pelvic organ prolapse
- POP-Q: pelvic organ prolapse quantification
- RSC: robotic sacrocolpopexy
- SUI: stress urinary incontinence
- WHI study: women health initiative study
### Appendices

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Appendix 9</td>
<td>POP reconstructive surgery strategies according to the type of defect and associated specific factors</td>
<td>Personal view based on review of the literature</td>
</tr>
</tbody>
</table>
Contents

Acknowledgement p.2
Abbreviations p.3
Appendices p.4
Summary p.6
Introduction p.7
Definition and anatomy p.7
History of POP p.8
Diagnosis and classification p.9
Epidemiology and clinical manifestations p.10
Risk factors and physiopathology of POP p.11
Prevention p.12
True incidence and risk factors for POP recurrence p.12
Therapeutic approaches of POP p.13
  Conservative therapy p.13
  Observation p.13
  Pelvic floor rehabilitation p.14
  Pessary use p.14
Surgical treatment of POP p.15
  Indications and general approaches p.15
  Abdominal versus vaginal approach p.16
Clinical background of mesh use in POP reconstructive surgery p.17
  Differences between abdominal hernia and pelvic floor repairs p.19
Reconstructive material used in pelvic floor reconstructive surgery: p.19
  Autografts p.20
  Allografts p.21
  Xenografts p.21
  Synthetic meshes p.21
  Host response p.21
  Synthetic grafts classification and properties p.22
Effectiveness of grafts in POP surgery p.24
  Anterior compartment repair p.24
    Synthetic graft p.24
    Absorbable mesh p.24
    Bilogic grafts p.24
  Posterior compartment repair p.26
  Apical prolapse p.26
Sexual function after POP surgery with or without mesh p.28
Complications of mesh materials p.29
  Mesh erosion p.30
  Mesh contraction p.30
  Chronic mesh pain syndrome p.30
  De novo stress urinary incontinence p.31
  Risk factors of erosion p.31
Discussion and personal view on POP reconstructive surgery p.32
Future perspectives p.34
Conclusion p.35
Bibliography p.37
Summary

Pelvic organ prolapse (POP) is a major health issue with a lifetime risk of undergoing at least one surgical intervention estimated at close to 10%. In the 1990’s, the risk of reoperation after primary standard vaginal procedure was estimated to be as high as 30 to 50%. Based on this estimate of recurrence and in order to reduce the risk of relapse, gynecological surgeons started to use mesh implants in pelvic organ reconstructive surgery with the emergence of new complications, also implying reoperations. With the success of mesh in reducing the risk of recurrence for abdominal hernia (75% reduction), it was hypothesized that its use could proffer similar benefits in POP surgery. Recent studies have nevertheless shown that the risk of POP recurrence requiring reoperation is lower than previously estimated, being closer to 10% rather than 30%. The development of mesh surgery, under considerable pressure and incentives from the marketing industry, was tremendous during the past decade, and preceded any studies supporting its benefit for our patients. Nowadays, randomized trials comparing the use of mesh to native tissue repair in POP surgery have shown better anatomical outcomes, but similar functional outcomes, and that meshes are associated with more complications, in particular for transvaginal mesh implants. POP is not a life-threatening condition, but a functional problem that impairs quality of life for women. The old adage “primum non nocere” is particularly appropriate when dealing with this condition which is currently admitted to be physiological with aging when situated above the landmark of the hymen and requires no treatment when asymptomatic. Each patient and each situation must be treated specifically and the use of mesh needs to be selective and appropriate. Mesh implants are probably an important tool in pelvic reconstructive surgery, but the ideal implant has yet to be found, and the indications for its use still requires caution and discernment. This review explores the reasons behind the introduction of mesh augmentation in pelvic organ prolapse surgery, and aims to clarify the risks, benefits, and above all the recognized indications for its use.
**Introduction:**

Surgery for pelvic organ prolapse (POP) is common among women. The lifetime risk of undergoing at least one surgical intervention by the age 80 was estimated to be between 6.3% and 19% with 30% of women requiring reoperation for recurrence [1, 2]. The prevalence of reoperation after primary pelvic reconstructive surgery reported in some articles was even higher (43%-58%) [3, 4]. Over the past decade, in an attempt to improve outcomes, and based on this high estimate of recurrence, surgeons have increasingly used prosthetic materials for the treatment of POP, with the hope of limiting the risk of recurrence. The use of mesh is nevertheless associated with a non negligible risk of complications such as vaginal erosions and potential consecutive infections, granulomas, dyspareunia, vesico-vaginal fistulas and chronic pain, thereby potentially reducing the quality of life of women and leading to additional surgeries [5-8]. Based on our clinical experience, which is supported by recent medical literature, we found that these high rates of recurrence were probably overestimated. The results of previous studies addressed urinary incontinence and POP together thus overestimating the risk of reoperation for POP alone. After closer examination of the references cited in some of these articles, we found that the high recurrence rates resulted from studies including genital prolapse after Burch colposuspension which is not a primary POP surgery, but an anti-incontinence procedure [9].

The aim of this thesis was to review surgical treatments of POP, and analyze the evidence for the use of mesh material in pelvic floor reconstructive surgery.

**Definition and anatomy**

Pelvic organ prolapse (POP) is defined as the herniation of pelvic organs (bladder, uterus, bowel and rectum) in association with the corresponding vaginal wall segments through the orifices of the pelvic floor (vagina, anus). The pelvic floor is made of fascia and muscles attached to the pelvic bones, in the shape of a hammock. Anatomic support of the pelvic organs is provided by an interaction between the levator ani muscle complex (pubococcygeus, puborectalis,
iliococcygeus muscles) and connective tissue attachments to the pelvic bones. The muscles provide a firm yet elastic support of the pelvic organs and the endopelvic fascia attachments, and their condensation (referred to as the utero-sacral and cardinal ligaments) stabilizes the pelvic organs in the correct position. Due to constitutive defects, aging, and trauma, areas of weakness may arise throughout the pelvic floor with consecutive development of POP. Depending on the localization of the pelvic defect, specific sites of genital prolapse are described. Anterior compartment prolapse refers to hernia of the anterior vaginal wall often associated with descent of the bladder (cystocele). Posterior compartment prolapse represents hernia of the posterior vaginal segment often associated with descent of the rectum (rectocele). Apical compartment prolapse (uterine prolapse, vaginal vault prolapse) refers to descent of the apex of the vagina into the lower vagina, to the hymen or beyond the introitus. It is often associated with enterocele which is a hernia of the intestines to or through the vaginal wall.

Genital prolapse often involves several compartments. The innervation of the pelvic floor derives from the second, third and fourth sacral segments of the spinal cord. Neuropathy may result in levator muscles atrophy with consecutive defect in pelvic floor support. One established cause of neuropathy is pelvic floor distension during pregnancy and delivery [10-12]. Neuropathy was demonstrated after childbirth in about 30% of women of whom only a few recover.

**History of POP**

POP is not a contemporary phenomenon for women as this condition has been described for over 4 millennia. It can be traced back to ancient Egypt in 2000 BC, where it was mentioned on antique papyrus documents [13]. In Greece, Hippocrates described cases of uterine prolapse in the 5th century BC. Soranos of Ephesus, in the second century AD, stated that POP may result from an injury to the membranes and muscles or from atrophy and relaxation of the ligaments. He introduced the first surgical treatment, vaginal hysterectomy, in 120 AD [14, 15]. There was no new understanding regarding the pathophysiology of prolapse throughout the middle ages up to the 17th century. Scientific understanding of POP improved over the last two centuries, with
present understanding of the pathophiology of perineal hernias caused by pelvic floor relaxation and defects often associated with difficult labor and delivery. The first description of cystocele was made by Johan Peyer, a Swiss gynecologist in the seventeenth century [16]. He also was the first to recognize that both uterus and bladder could prolapse. In the nineteenth century, the use of anesthesia allowed major advancements in surgery and also witnessed the improvement of suture materials. The first true anterior colporraphy was probably performed by James Marion Sims in 1866, a physician born in South Carolina USA [16]. He is considered as a controversial figure by historians due to his use of African-American slaves as experimental subjects. Several variations and modifications of his technique were performed by other surgeons during the same century. In 1877 Léon Clément Le Fort, a french surgeon, innovated the first total vaginal occlusion operation [16]. During the twentieth century, procedures for apical support by the abdominal route were progressively introduced. In 1957, surgeons tried to anchor the uterine fundus to the anterior longitudinal ligament [17]. Lane and colleagues in 1962 first used an intervening graft between the vagina and the sacrum to avoid excessive tension [18]. In 1994 Nehzat and colleagues published the first report on laparoscopic sacrocolpopexy [19] and more recently, this technique was adapted to robotic surgery [20, 21].

Diagnosis and classification of POP
Diagnosis of POP is made using pelvic examination. Historically, the severity of prolapse was graded using a variety of classification systems that were imprecise and not easily reproducible. The Pelvic Organ Prolapse Quantification system (POP-Q) has become the most commonly used prolapse staging system since its introduction in 1996 [22]. It is an objective site-specific system for describing and staging POP in women. It involves measurements of various points representing anterior, apical and posterior vaginal prolapse, using the hymen as a landmark (Appendix 1). These measurements create a topographic map of the vagina and are used to determine the stage of POP. There are five stages depending on the position of the most distal part of the prolapse in reference to the hymen plane. Examination is made at rest and during
straining to demonstrate maximum degree of prolapse. In stage 0, there is no prolapse. In stage 1, the most distal portion of the prolapse is at least 1 cm above the hymen. In stage 2, the most distal end of the prolapse is ≤ 1 cm above or below the hymen. In stage 3, the most distal portion of the prolapse is more than 1 cm beyond the hymen but protrudes no further than 2 cm less than the total vaginal length. Stage 4 represents complete eversion of the vagina. The stage can also be defined for each specific compartment (anterior, apical or posterior). This system is very complete with the ability to document small degree of change or variation within or between patients and therefore has become the gold standard for research into pelvic organ support defects. However, it can be difficult to apply clinically without practice and repetition. This has led to concerns regarding its widespread use by clinicians and in 2006, a simplified technique (S-POP-Q) for using the POP-Q system was introduced measuring four points in the vagina instead of nine [23].

The Baden-Walker halfway scoring system is the next most commonly used POP staging system [24], but it lacks the precision and reproducibility of the POP-Q system. The grade of each prolapsed structure is described individually. The examination is noted while the patient is straining. The system also has five degrees and uses the hymen as a landmark. Stage 0 represents normal position for each respective site. Stage 1 refers to descent halfway to the hymen. Stage 2 is the descent to the hymen. Stage 3 represents descent half way past the hymen and stage 4 the maximum descent for each site.

**Epidemiology and clinical manifestation**

POP is a major health problem which leads to more than 300,000 surgeries in the United States, costing more than $1 billion annually [25]. Its true prevalence is difficult to determine due to varying diagnostic criteria, levels of symptoms, and population characteristics, but it is widely accepted that 50% of women will develop POP in the general population. However, only 10 to 20% of these women seek evaluation for their condition [26-29]. The prevalence increases with
age and current demographic trends predict that the demand for health care services related to pelvic floor disorders will increase markedly in the near future [30]. Wu and colleagues predicted that the number of women requiring surgery for symptomatic POP in the USA will increase by a minimum of 46% by 2050 [31, 32]. Clinical manifestations of POP include bulge or vaginal pressure, with associated urinary, defecatory or sexual dysfunction [33]. Women suffering from POP have impaired body image and an overall decrease in quality of life, and it is therefore mandatory to identify symptomatic patients and treat them appropriately [34, 35].

**Risk factors and physiopathology of POP**

Risk factors for POP include parity, advancing age and obesity [1, 28, 36-38]. History of hysterectomy is also considered as a risk factor. In a study conducted by our department and published in 2007, we found that the risk of having a subsequent pelvic floor repair after hysterectomy was 4.7 times higher in women whose initial hysterectomy was for genital prolapse [39] (Appendix 2). In this study we showed that preoperative prolapse (mainly grade 2 or more), previous prolapse or urinary incontinence surgery, and vaginal delivery were the main risk factors for POP repair after hysterectomy. An important finding was that vaginal hysterectomy, compared with abdominal hysterectomy, did not increase the risk for POP requiring surgical correction. Our findings suggested that factors related to preexisting pelvic floor weakness at the time of the hysterectomy were significantly associated with subsequent pelvic floor repair [39, 40] (Appendix 2 and 3). These findings explain why although increased parity is a risk factor for POP, nulliparity does not provide absolute protection against POP, further illustrating its multifactorial nature. Genetic predisposition plays an important role in the development of POP. Its association with inciting factors (such as pregnancy, delivery, or hysterectomy), promoting factors (such as obesity, smoking, or constipation), and decompensating factors (such as aging, menopause or, neuropathy) is responsible for the development of this condition [41].
**Prevention**

POP prevention strategies and methods preventing POP progression have not been extensively studied. Vaginal childbirth is associated with an increased risk, but it is unclear if cesarean delivery is a protective factor. Weight loss, treatment of constipation and avoiding repetitive straining (as in jobs requiring heavy weight lifting) are potential interventions which help avoid development or progression of prolapse but further studies are required to evaluate their real benefit. In one study, women using vaginal pessary had lower stage of prolapse on subsequent examinations [42]. The role of oestrogen therapy for treatment and prevention of POP in postmenopausal women is still controversial. There is limited evidence from randomized controlled trials, but a potential benefit exists in terms of reducing post-operative cystitis rates [43].

**True incidence and risk factors for reoperation of surgically treated POP**

As discussed in the introduction section, the incidence and the risk factors for reoperation of surgically treated POP were never clearly evaluated. Based on our clinical experience, we hypothesized that the risk of reoperation would be lower than some of the above mentioned estimates frequently cited in medical literature [1, 9, 44].

We conducted a nested case-control study in a cohort of 1811 women who were surgically treated for POP in our department over a 20 year period (Appendix 4). We found that the incidence of POP reoperation was 5.1 per 1,000 women-years with a cumulative incidence of 5.6% and a mean duration follow-up of more than 11 years [45]. This is much less than the 30 to 50% risk previously described. Significant risk factors were the presence of preoperative prolapse in more than two vaginal compartments, history of surgery for POP and/or urinary incontinence and the presence of sexual activity. We concluded that the risk of reoperation for recurrence was associated with preexisting weakness of pelvic floor tissues. Mechanical factors associated with sexual activity may explain the increased risk of subsequent genital prolapse, but it is also possible that women who are sexually active may overtly seek POP surgery,
thereby explaining the higher risk of reoperation in this population, independently of age as shown by the multivariable model. Corroborating our results, recent studies reported lower rates (between 1.5% and 13%) of reoperation for surgically treated POP and urinary incontinence [3, 46, 47]. In two recent studies, the risk of POP recurrence after POP specific reconstructive surgery without use of prosthetic material was estimated to be between 3 and 10% [48, 49].

Very little is known of the factors associated with surgical failure. Data comes from few studies where few risk factors are identified. Younger age, high BMI and advanced preoperative prolapse (grade III-IV) were associated with an increased risk of reoperation in some studies [4, 46, 48]. However, these results were contradicted by other studies in which these associations were not observed [2, 3].

We chose reoperation as a primary outcome because from our point of view it reflects symptomatic POP that needs to be treated. Swift et al demonstrated that when the leading edge of vaginal wall was at or above the hymen, 98% of patients had no symptoms [50, 51]. This is a very important concept. The definition of success in POP surgery is consecutive to this definition. Most articles used anatomical stage 1 or 2 of POP as a criterion of success, but the main criterion is the absence of bulge or vaginal pressure associated with urinary, defecatory or sexual dysfunction. POP staying above the hymen as a threshold for success is much better correlated with successful functional outcome. Barber and colleagues demonstrated in a recent article that leading edge at the hymen as a definition of success was correlated with 94% of successful functional outcomes, no retreatment in 97% of cases and no bulge symptoms in 92% of patients [52].

**Therapeutic approaches of POP**

The management of POP includes observation, pelvic floor rehabilitation, pessary use and surgery.

**Conservative therapy**

*Observation:*
Among ambulatory women, less than 5% of women present with POP beyond the hymen. Therefore, most POP are asymptomatic and do not need treatment [27, 53-55]. POP is progressive until menopause, after which either progression or regression is possible. This was demonstrated in a cohort of 249 women with mean age of 68 years who were followed over a three-year period. In this study, POP increased by at least 2 cm in 10% of women, and regressed by the same amount in 3% of women. Regression was more frequent for early stages (25% in stage 1) [56, 57].

**Pelvic floor rehabilitation:**

Pelvic floor muscle exercise (PFME) may result in improvements in POP stage, but mainly improves associated functional symptoms as demonstrated in two recent randomized controlled trials [58, 59]. Braekken and colleagues reported improvement of one stage with the POP-Q system in 19% of women in the intervention group compared to 8% in the controls (11% risk difference) [59]. During subgroup analysis, this effect was statistically significant for women with POP above or at the hymen but not for women presenting the distal part of POP below the hymen. However, in the latter subgroup, 0% of women in the intervention group (PFME) worsened their POP stage compared to 20% in the controls, thus showing potential benefits in preventing progression of POP. This effect was not observed in the Hagen and colleagues study [58]. Both studies showed significant improvement in prolapse, as well as bowel and urinary symptoms at 6 and 12 months. However, long term benefits are still unknown. In the Hagen and colleagues study, the number of women who required further treatment was reduced in the PFME group compared to the controls (24% versus 50%), but there was no difference between groups in the number of women who required further pelvic floor reconstructive surgery (11% in the intervention compared to 10% in the control group respectively). Further studies are needed to show if PFME could help avoid surgery in selected patients.

**Pessary use:**

Vaginal pessaries represent the main alternative to surgical treatment for POP. They are silicone devices in a variety of shapes and sizes which support the pelvic organs. They need to be
removed and cleaned on a regular basis. A pessary trial should be offered to all women presenting with POP. About half of them will continue to do so at medium term (one to two years) [60, 61]. The most common side effects include malodorous vaginal discharge, bleeding, irritating symptoms, erosions and ulcers, de novo incontinence and interference with sexual intercourse, thereby inciting preference of surgery for some women. Most minor complications however occur in the setting of vaginal atrophy and can be treated or prevented with associated local estrogen therapy.

**Surgical treatment of POP**

**Indications and general approaches**

Surgical treatment is indicated in women with symptomatic POP when conservative management has failed or has been declined. There is no indication for repair of asymptomatic POP as an isolated procedure where surgical correction is of uncertain benefit and adds peri and post-operative risks. The objective of our treatment should always aim to restore quality of life and comfort. As previously mentioned, in older women a certain degree of POP is physiological and should not be treated as long as it is asymptomatic [62, 63].

There are numerous surgical techniques for the treatment of POP, including vaginal and abdominal approaches with or without graft materials. Pelvic support may be disrupted during pregnancy and particularly after vaginal delivery. Therefore, it is commonly accepted that POP surgical treatment should be postponed or treated conservatively until childbearing is complete. Women of young age are at a higher risk of POP recurrence and are at a lower risk for surgical complications. They should thereby be treated with the more efficient procedures. Obese women have a higher risk of recurrence and should also benefit from the most effective procedures [4, 46].

The choice of primary surgical procedure includes a variety of possibilities:

- Surgery can be reconstructive or obliterative. Reconstructive procedures should be the first option, but in case of increased risk due to comorbidity and the absence of future intercourse, obliterative vaginal procedures such as colpocleisis are an option.
When there is an apical defect, a decision has to be made whether to perform a total or subtotal hysterectomy, as part of the procedure.

The choice of the surgical route (abdominal or vaginal) depends predominantly upon the optimal approach for the treatment of single or multiple sites of prolapse, patient preference, and risk factors for recurrence.

Stress urinary incontinence, and sometimes anal incontinence, often coexists with POP. When planning POP repair, treatment of SUI and/or anal incontinence must also be addressed.

Surgical meshes have been used in abdominal POP repair for decades. Their use in transvaginal POP surgery has increased over the last decade, but their safety has been questioned. Choice has to be made between native tissue repairs with standard vaginal surgery, and mesh associated repairs either through the vaginal or the abdominal route.

**Abdominal versus vaginal approaches**

The use of mesh has become common practice for abdominal repair of POP [64]. Sacrocolpopexy is used to support the vaginal apex and is not performed to repair POP that is primarily anterior or posterior. Vaginal repair of POP may be augmented with mesh or may be performed by tissue plication and sutures. In case of apical prolapse, it was demonstrated by randomized trials that abdominal reconstructive surgery using mesh (abdominal sacral colpopexy) is more effective than vaginal surgery with sacrospinous vault suspension [65-67]. Apical prolapse is often associated with anterior or posterior prolapse which can therefore be treated concomitantly through the abdominal route. However, treatment for isolated anterior or posterior prolapse are usually performed transvaginally [66, 68, 69]. Posterior repair is treated by midline fascial plication without levator plasty to reduce the risk of dyspareunia. For anterior compartment repair, anatomical results are better with mesh augmentation compared to native tissue repair at the expense of increased morbidity. However, functional and subjective outcomes were comparable in both groups in two recent studies [70, 71].
Having non exhaustively cited the large variety of types of POP and surgical techniques, this review will now specifically address the question of the real benefit of the use of mesh in POP surgery.

**Clinical background of mesh use in POP reconstructive surgery**

As discussed in the introduction of this article, the main rationale for mesh use was the hypothetical reduction of recurrence after standard vaginal surgery without mesh, which was stated to be high, with an average 30% rate of reoperation [1]. This rate was often cited in subsequent publications as an incentive to justify and sustain this new strategy. We know now that this initial postulate was probably wrong, but under mounting pressure from the industry manufacturing meshes with substantial financial benefits, production of meshes and new procedures were introduced before evidence of its benefit was established. In the 1990’s gynecological surgeons began using surgical meshes for pelvic floor reconstructive surgery encouraged by its successful use in the treatment of stress urinary incontinence (SUI) with the development of midurethral synthetic slings [72].

Figure 1 shows the increase in publications concerning mesh use in the end of the 20\textsuperscript{th} and the beginning of the 21\textsuperscript{st} century (Appendix 5).
The supposedly high failure rate of standard pelvic floor reconstructive surgery using native tissue combined with the success observed in the treatment of abdominal hernia with the use of meshes further boosted the use of prosthetic material to treat POP. Twenty years ago, abdominal hernia repair using plication of fascia transversalis (Shouldice repair) was standard in general surgery with a 4 to 6% rate of recurrence. Various mesh repairs were proposed to reduce the incidence of recurrence, with a 50 to 75% reduction rate. However, if we look at the absolute difference, it was low (2 to 4%) [73-75]. Until recently, analogously to what is being shown for vaginal meshes, articles raised the question of the validity of the use of mesh for such a minimal absolute benefit in term of recurrence. Recent publications also raised new problems that emerged with mesh in the treatment of inguinal hernia, in particular mesh related pain and nerve entrapment. If the incidence of native tissue post hernia repair pain was 2 to 4% for a risk of recurrence of 4 to 6%, the use of mesh reduced the risk of recurrence to 2% but increased mesh related inguinodynia up to 21% [73]. We will discuss this question in the setting of POP.
repair a little further in the section about mesh complications and related chronic mesh pain syndrome (CMPS).

**Differences between abdominal hernia and pelvic floor repairs**

Sexual function of the vagina represents a significant difference when comparing abdominal wall and vaginal wall repair. Vaginal skin is a thin mucosa, highly innervated and vascularized in comparison to the abdominal wall. Sexual health is an essential component of a woman’s well-being and any kind of POP surgery should take this dimension into account. Anatomical outcome of POP surgery is probably not the most important parameter that needs to be evaluated with POP reconstructive surgery. The most important consideration is to restore normal function, with disappearance of vaginal bulge, pelvic pressure but also normalization of urinary, defecatory and sexual function.

**Reconstructive material used in pelvic floor reconstructive surgery:**

The principle of using grafts in reconstructive surgery is to reinforce existing tissue. The material must be safe, biologically compatible and must provide good anatomic but also functional results, especially in pelvic floor surgery. The ideal material should be chemically and physically inert, non carcinogenic, mechanically strong while remaining flexible, non allergenic, non inflammatory, and non modifiable by body tissue. It must be sterile, convenient to use and affordable, with minimal risk of subsequent infection or rejection. Currently, no graft has all these qualities. Moreover, in POP surgery, the optimal implant should restore normal anatomy and function to the vagina and the surrounding pelvic organs and be more durable than autologous tissue. Once implanted, it should not result in adhesion formation on the visceral surfaces. The use of prosthetic material in pelvic surgery is not new. Silver mesh was used as early as in 1903, followed by nylon in 1938, dacron (Mersilene®) in 1956, polypropylene in 1958 and more recently absorbable products such as polyglactin 910 [76]. The first description of mesh used to repair cystoceles was the use of tantalum mesh in 1955 [77]. Exposure was common (4 over ten cases), but granulation tissue progressively covered the defect. In the 1970’s, the first report of
the use of collagen mesh in Urogynecology was described [78]. In the 1970s, gynecologists began using surgical mesh products indicated for abdominal hernia repair for the treatment of POP. To do so, surgeons would cut the mesh to the desired shape for POP or SUI repair and then place the mesh through a corresponding incision. Over time, manufacturers responded to this clinical practice by developing mesh products specifically designed for SUI or POP repair. Porcine collagen was then used for cystocele repair, with similar recurrence rate to the native tissue repair, and therefore this procedure was abandoned [79]. As previously stated, it was in the 1990s that gynecologists increasingly began using non absorbable meshes for surgical treatment of SUI and vaginal repair of POP. The first mesh produced for urinary incontinence treatment received clearance from the US Food and Drug Administration (FDA) in 1996. Polypropylene mesh (Marlex®) was thereby used for the treatment of cystocele with good results during the same year [80]. Due to exposure rate observed with non absorbable mesh, fully absorbable meshes were introduced by the end of the 1990's, but because of disappointing long-term results, they rapidly became unpopular [81, 82]. The first mesh product for pelvic reconstructive surgery approved by the FDA (Gynemesh®) followed in 2002 [83]. Subsequently surgical mesh products evolved into “kits” that included tools to help insert the vaginal synthetic graft material. The first mesh kits were cleared by the FDA in 2004 and marketed by the American Medical Systems (San Jose CA) under the names Apogee and Perigee systems. Since then, there have been numerous new POP reconstructive mesh devices introduced in the USA and around the world. In 2010, of the 300 000 POP surgeries in the USA, one third used mesh. Three quarters of the mesh procedures were transvaginal surgeries (approximately 75,000 procedures) [84]. Currently, there are four kind of materials used in reconstructive surgery: synthetic mesh, autografts, allografts and xenografts.

**Autografts**

They are harvested from the patient who is undergoing the procedure. Their use is limited by morbidity associated with tissue harvesting as well as the inconsistent quantity and quality of the
material. The most commonly used autografts are fascia lata and rectus fascia [85, 86]. A clear advantage is that host response is not problematic.

**Allografts**

They are most often processed from cadaveric fascia of human donors. The material has to be rendered non immunogenic by a cleaning procedure which removes cells without damaging the connective tissue scaffold. Use of this material eliminates the morbidity associated with autologous fascia harvest but presents a potential risk of donor-related viral infection. Their performance is also consistently less beneficial when compared to autologous fascia and synthetic meshes.

**Xenografts**

They consist of acellular extracts of collagen harvested from non human (bovine, porcine) sources. They pose a theoretical risk of infection. Some patients might refuse their implantation due to religious beliefs or cultural barriers.

**Synthetic meshes**

Synthetic meshes are available in both absorbable and non absorbable forms. The advantages are availability and lack of risk of donor to host infectious disease transmission. However, infectious and erosive complications exist due to bacterial colonization of foreign body.

**Host response**

The histological response to reconstructive material used in surgery depends upon the physical and structural properties of the prosthesis. Host response comprises several stages:

- **Incorporation**: infiltration of reconstructive material by host cells, allowing neovascularization and collagen deposition.
- **Encapsulation**: collagen and connective tissue deposit at the periphery of the material.
- **Mixed response**: incorporation occurs at graft pores and encapsulation occurs around the remaining material.
- **Resorption**: material is replaced by host neo-connective tissue.
Due to similarities with native tissues, biologic grafts are more likely to undergo tissue remodeling and thereby are less likely to cause erosion. They can however be costly, in limited supply and carry perioperative morbidity or theoretical infectious disease transmission. Therefore, synthetic meshes are the most popular choice both in general and in POP reconstructive surgery.

The ideal mesh should incur minimal inflammatory reaction, followed by vascular and fibroblastic ingrowths. The key factors for host response to synthetic meshes are pore size and weave.

**Synthetic grafts classification and properties**

Host response depends on absorbability, pore size (space between filaments), weave (mono or multifilament), and weight (density). Both absorbable and non absorbable meshes cause initial and chronic inflammatory reactions after implantation. Absorbable materials elicit a chronic foreign body reaction and promote fibroblast activity. After complete absorption, the material is replaced by a collagen-rich connective tissue [87]. One disadvantage is that resultant scar tissue weakens after the material is absorbed and therefore may not provide long term repair strength [88]. Some potential advantages of absorbable materials over non absorbable materials are that they are less likely to become infected and less harmful to viscera [89].

Non absorbable prosthetic materials, such as polypropylene which is widely used, are associated with more connective tissue reaction. Thus repair strength is increased due to the presence of the implant and greater scar formation. Pore size influences cellular infiltration, risk of infection and mesh density and flexibility [90]. Pore size greater than 75 microns are considered macroporous, whereas those less than 10 microns are considered microporous. Pore size determines which cells (macrophages versus bacteria) can enter the mesh and is considered the most important mesh characteristic. Most bacteria measure less than 1 micron in diameter and granulocytes and macrophages measure more than 10 micron in diameter. Seventy-five microns is considered a significant measurement, because this pore size allows entry of fibroblasts, macrophages, blood vessels and collagen fibers, thus minimizing risk of infection and optimizing collagen infiltration. Pore size also affects flexural rigidity which is
decreased with larger pore size. Micropores (< 10 microns) result in restriction of fibroblast and immune cell colonization to the material surface. Therefore, collagen and connective tissue deposition occurs at the periphery rather than by infiltration of host cells, resulting in encapsulation. In addition, microporous materials are at increased risk of infection as large immune cells cannot infiltrate the interstices to phagocyte bacteria [91]. Synthetic mesh implants are also classified as monofilament or multifilament. Multifilament materials have interstices of less than 10 microns within the filamentous fibers. These spaces theoretically allow bacteria to enter and replicate, but prevent penetration of host immune cells thus increasing the risk of infection. Mesh weight is another parameter that needs to be considered for synthetic materials. It measures the quantity of material required to produce a mesh. Meshes with larger pores have a lower weight and are more elastic. For the same reason as previously discussed for pore size and weave, light weight materials may be less prone to infection and consecutive erosion.

Non absorbable synthetic meshes are classified with respect to pore size and filamentous nature in four subtypes [92]:

- **Type I** is macroporous (>75 microns) and monofilamentous such as polypropylene and theoretically makes the best implants. It is further divided into heavy-, mid- and light-weight materials (eg Prolene®)
- **Type II** is microporous (< 10 microns) such as polytetrafluoroethylene (eg Gore-tex®)
- **Type III** is a macroporous material (>75 microns) with either multifilamentous or microporous components such as polyethylene (eg Mersilene®). Histologic behaviour is similar to type II materials. This category includes some polypropylene materials with microporous components such as Ob Tape® and IVS Tunneler® both of which were associated with an increased rate of erosion and infection.
- **Type IV** is submicronic (pore size < 1 micron) (eg polypropylene sheet Cellgard®) and associated with type 1 mesh for adhesion prevention but is not commonly used in gynecological surgery.
**Effectiveness of grafts in specific gynecologic procedures**

**Anterior compartment repair**

Anterior vaginal wall defects are the most common site of POP followed by posterior wall and apical defects affecting respectively 34%, 18% and 14 percent of women in the women health initiative (WHI) study [28]. Most mesh reports focus on treatment of anterior compartment defects. Historically, anterior colporraphy with plication of perivesical fascia (native tissue repair) was the standard procedure with success rates ranging from 80 to 100% in retrospective series [93, 94]. As discussed before, the move to prosthesis use was initiated by the Olsen and colleagues report of 29.2% of reoperation rate following POP and/or incontinence surgery and the Weber and colleagues report of a 70% failure rate after native tissue repair [1, 82]. Recent reanalysis of the Weber and colleagues paper using the hymen as a threshold for objective success, reported very different outcomes, with only 10% of anatomical recurrence beyond the hymen, 5% of symptomatic recurrence and less than 1% of reoperation for standard native tissue repair [82, 95]. The original trial compared three techniques of anterior repair (two without mesh and one with absorbable mesh) and defined recurrent prolapse as greater than stage 1, therefore overestimating the rate of clinically significant recurrence.

**Synthetic graft**

The use of popypropylene synthetic mesh in the treatment of anterior compartment prolapse was compared to standard native tissue repair in two recent randomized controlled trials with similar results [70, 71]. Nieminen and colleagues studied 202 women, 97 in the colporraphy group and 105 in the synthetic mesh group. Their study showed better anatomical outcomes at three year follow-up in the mesh group but no significant difference in subjective outcomes. The erosion rate was very high in the mesh group (19%). Of the 389 women who were randomly assigned by Altman and colleagues to a study treatment, 200 women underwent a transvaginal POP mesh repair and 189 underwent traditional colporraphy. At one year follow-up, anatomical outcome was significantly better in the mesh group, but there was no difference in the subjective outcome either. Subsequent surgery to address mesh related complication was 3% compared to
0.5% for recurrence in the standard colporraphy group. There were more perioperative complications and post-operative adverse events in the mesh group. De novo SUI was also significantly higher in the mesh group. Recent literature reviews conclude that with the use of synthetic meshes in the treatment of anterior POP, there is an improved anatomical outcome but no difference in functional outcomes, with potentially more complications, in particular a high rate of vaginal mesh exposure of around 10% [66, 68].

**Absorbable mesh**
Absorbable mesh use was adopted in order to achieve equivalent success rate with fewer complications. Very few studies have addressed this question [82, 96, 97]. Augmentation with Polyglactin 910 reduced the rate of recurrence but was also associated with mesh erosion in two of the three trials. Some authors have advocated the use of coated mesh to reduce the risk of mesh erosion. A recent trial comparing anterior colporrhaphy with collagen-coated transvaginal mesh for anterior vaginal wall prolapse showed, on the contrary, a high risk of erosion (13.3%) [98].

**Biologic grafts**
In a small series of 47 patients Cosson and colleagues described an autologous vaginal patch tucked under the anterior compartment repair with a 93% success rate at mean follow-up of more than one year [99]. The use of cadaveric fascia to correct anterior compartment prolapse compared to anterior colporraphy alone was evaluated in a randomized controlled trial by Gandhi and colleagues [100]. At one year, their study failed to demonstrate that the addition of fascia lata improved outcomes. No complications were reported, but concerns regarding latent infectious disease or residual antigenicity causing host graft rejection remains. For this reason porcine dermis has been used in some studies with very contradictory results. A retrospective study comparing anterior colporrhaphy, porcine dermis augmentation and polypropylene graft showed success rates at 13 months of 94%, 64% and 96% respectively with a 21 % rate of vaginal extrusion in the porcine dermis group [101]. A multicenter randomized trial comparing anterior colporrhaphy augmented with porcine dermis to anterior colporrhaphy with native tissue
showed a success rate of 93% in the former group compared to 81% in the latter with an erosion rate for porcine dermis of 1% [102]. Menefee and colleagues compared in a randomized controlled trial three operations: anterior colporraphy, porcine dermis graft and polypropylene graft for anterior augmentation. The objective success rate of 86% was significantly better after the use of polypropylene mesh compared to 52% for porcine dermis and 53% in the native tissue repair group [103]. The subjective failure rate was not significantly different and graft erosion rates were 13.8% in the polypropylene group and 4.3% in the porcine dermis group respectively. Another recent small randomized controlled trial comparing anterior prolapse repair using a porcine small intestine submucosa mesh-augmented procedure or the same repair without mesh did not show any significant difference in the primary outcome which was anatomical cure [104].

It transpires from these studies and from the Cochrane review that objective success rates for anterior compartment repair are better with all synthetic meshes, but that there is no significant difference in terms of subjective success [66]. The benefit of absorbable mesh and biologic grafts is not proven. All mesh types are associated with some form of mesh related complication that can cause reoperation as we will discuss further down.

**Posterior compartment repair**

There was only one trial which specifically compared posterior mesh repair to traditional repair (without concomitant repair of other compartments) [105]. This trial showed that women who underwent mesh repair had worse anatomic outcomes than those who underwent traditional repair. Two other trials combining anterior and posterior repair also found no additional benefit to mesh augmentation in the posterior compartment [97]. So far, no studies have shown any benefit of mesh in posterior compartment repair. Traditional midline plication posterior repair has a high anatomical cure rate of between 80 to 90% [97, 106, 107].

**Apical prolapse**

There is consistent and reproducible evidence that abdominal sacrocolpopexy using mesh has a higher success rate than vaginal surgery along with less post-operative dyspareunia. Vaginal
procedures to treat apical defect mainly consist in sacrospinous ligament suspension, or uterosacral ligament suspension of vaginal apex. A few randomized controlled trials compared abdominal sacrocolpopexy with vaginal surgery, and all of the trials demonstrated significantly improved anatomical but also functional outcomes [64, 108, 109]. A review by Nygaard and colleagues showed success rates for abdominal sacrocolpopexy of 78 to 100%, reoperation rates of 4.4%, and erosion rates of 3.4% [64]. Erosion rates may be increased if total concurrent hysterectomy is performed with erosion rates increased up to 27% compared to 1.3% without hysterectomy [110].

Some surgeons have attempted to decrease mesh complication associated with abdominal sacrocolpopexy using biological material instead of synthetic mesh. All biological materials whether allograft or xenograft produced inferior anatomical outcomes without decreased graft complications [111-115].

The use of a transvaginal mesh in apical prolapse was evaluated in only two randomized trials. Sokol and colleagues compared uterosacral colpopexy and native tissue repair with a monofilament kit (Prolift ®) [116]. Subjective failure rates were similar between the two groups (9.1% in the native tissue group compared to 3.8% in the mesh group), but with 15.6% of subsequent surgical interventions in the mesh group compared to 0% in the conventional surgery group at one year follow-up. Indications for reoperation were mesh exposure and recurrent prolapse. Moreover, among the 32 patients in the mesh group there were 2 inadvertent cystotomies and one transfusion for hemorrhage compared to none in the native tissue repair group. Maher and colleagues compared laparoscopic sacral colpopexy (LSC) to total vaginal mesh kit with a 77% objective success rate in the LSC group compared to 43% in the vaginal mesh kit group [117]. Reoperations were also significantly higher in the vaginal mesh group (22% compared to 5% in LSC group).

ASC, and nowadays LSC, performed with polypropylene mesh reinforcement are considered the gold standard to correct apical vaginal polapse and may also correct high cystocele and
rectocele. Further data are needed to assess its performance with preservation of the uterus, a procedure which is now frequently performed.

Although the outcomes for ASC or LSC with synthetic meshes are favorable, it is necessary to understand its risk and possible complications. The overall mesh erosion rate described in the Nygaard and colleagues review is 3.4% but may vary according to the type of mesh used [64]. Studies reporting the use of type I mesh show very low rates of erosion (0.5%) [91]. Concomitant total hysterectomy should be avoided and if necessary, a supracervical hysterectomy should be performed. Besides mesh complications, gastro-intestinal complications including ileus and small bowel obstruction are a concern. Pain syndrome and dyspareunia were rarely reported. Peri-operative hemorrhage during dissection of the promontory and bladder or rectum injury during pelvic floor dissection may also occur. To limit the risks associated with the dissection of the promontory during sacrocolpopexy, Kapandji described in 1967 an alternative technique with lateral suspension of apical prolapse [118]. It consisted in fixation of the anterior vagina and the uterus isthmus with a mesh to the anterior superior iliac bone. In 1994, Cornier and Madelanat described a new development based on the Kapandji’s technique by laparoscopy [119]. The technique was progressively modified by Dubuisson and colleagues with a higher transparietal tension-free lateral suspension, 5 cm above the anterior superior iliac spine, and showed similar results to those of sacrocolpopexy and sacrohysteropexy (Appendix 5 and 6) [120-122]. We further developed this technique with robotic assistance which allowed us to avoid the transparietal passage of the mesh which is necessary with the laparoscopic technique thereby further reducing potential complications to abdominal wall nerves (Appendix 7) [123].

**Sexual function after POP surgery with or without mesh**

There is a paucity of data on the impact of prolapse surgery on sexual function. Sexual health is an essential component of a woman’s well being. Female sexual dysfunction is defined as diminished sexual desire, orgasm or pain disorder that causes personal distress [124]. Apart from anatomical outcomes, clinicians are increasingly aware of the importance of functional
outcomes after POP surgery. Sexual function seems to improve in general after POP surgery without mesh [125, 126]. When comparing sexual function after anterior compartment POP surgery with or without mesh, no differences in de novo dyspareunia and pelvic organ prolapse/incontinence sexual questionnaire (PISQ) scores were found [70, 71, 127-129]. Most women improved or remained the same, but follow-up was short in all these studies. As erosion and contraction of mesh can occur after many years, long term outcomes are needed to fully answer this question. Sexual function was also a secondary outcome in these trials but most studies were underpowered to detect differences.

Complications of mesh materials

Despite initially reassuring data, concerns regarding the safety of transvaginal meshes arose in October 2008 with the first US food and drug administration (FDA) notification that it had received more than 1000 reports of mesh associated complications, some of which may not be correctable surgically (US FDA, March 9 available at www.fda.gov) [130]. In 2011, the FDA released two more communications highlighting the safety concerns surrounding meshes. The update stated that there were 1503 reported complications associated with mesh devices for POP during the past 3 years (01.01.2008 to 31.12.2010). The most common complications included mesh erosion through the vagina, pain, infection, bleeding, dyspareunia, organ perforation and urinary problems. There were also reports of recurrent prolapse, neuromuscular problems, vaginal scarring with shrinkage and problems related to emotional distress. Many of these complications required further surgical intervention. The FDA stated that it is not clear that mesh augmentation is more effective when compared to native tissue repair. Expert committee opinion recommended that mesh augmentation be reserved for high risk individuals in whom benefit outweighs potential risks [83]. The follow-up of most studies is close to 1 year and there are few studies with follow-up for a longer period. Therefore, the number of adverse events is probably underestimated.
**Mesh erosion**

The most commonly reported mesh complication was mesh erosion into the vagina which may require multiple surgeries with persistent sequelae despite mesh removal [131]. In a systematic review of Abed and colleagues, vaginal POP repair with mesh was associated with a summary incidence of 10.3% of erosion. The incidence did not differ between non absorbable synthetic mesh and biologic graft material [132].

A systematic review that included more than 7000 women concluded that abdominal POP surgery with mesh such as sacrocolpopexy resulted in lower rates of mesh complications compared to vaginal POP surgery with a median mesh erosion rate of 4% during a 2 years follow-up [133]. Vaginal surgery with mesh to correct apical prolapse is associated with a higher rate of complication requiring reoperation, compared to sacrocolpopexy or traditional repair (7.2% vs 4.8%, vs. 1.9% respectively) [134].

**Mesh contraction**

Mesh contraction is another specific adverse event causing vaginal tightening and consecutive pain after POP repair with mesh [135]. It can also occur after traditional repair but seems to be increased in case of mesh augmentation.

**Chronic mesh pain syndrome (CMPS)**

CMPS is a condition that develops in a small number of patients but can be very distressing. It is characterized by pain symptoms following mesh insertion persisting past the routine post-operative period (more than 90 days) and takes a chronic course [8, 136]. Pain is refractory to medical and surgical treatment and is out of proportion to physical examination findings. Regional and systemic symptoms develop as a result of neuronal sensitization, and pain centralization. CMPS is a complex multiorgan systemic process, and treatment is therefore challenging, given the cascade of events that is not entirely reversible by mesh removal. CMPS results probably from a combination of factors, including mesh material, surgical technique but also host factors. It results from abnormal neuronal activation with sensitization of pain pathways in the spinal cord and central nervous system, along with pelvic organ cross-talk. Patients often
suffer from hyperalgesia. Treatment will sometimes include mesh removal but also requires a multidisciplinary approach similar to other chronic pain syndromes. Infection, dyspareunia, urinary problems and re-surgery are other common adverse events associated with mesh POP repair but they also occur with traditional repair. There is no evidence that organ perforation, hemorrhage, and hematoma occur more often with mesh repair. However, mesh erosion into the bladder or rectum are specific adverse events which can lead to fistula formation and the need for additional corrective surgery.

**De novo stress urinary incontinence**

New onset SUI seems to occur more frequently after anterior repair with mesh compared to traditional native tissue repair [71]. On the contrary, this is not the case with mesh use by the abdominal route during sacrocolpopexy. There are nevertheless very few studies comparing sacrocolpopexy to standard vaginal surgery and all of them included SUI procedures, therefore making any comparison difficult. In two prospective randomized studies comparing these methods, both found less SUI in the sacral colpopexy group [65, 108]. In a randomized trial comparing LSC to total vaginal mesh for vaginal vault prolapse, SUI was also less frequent in the sacrocolpopexy group compared to the vaginal group [117]. However, both groups included associated SUI procedures in all women with SUI or occult stress incontinence preoperatively, but with different techniques (colposuspension in the LSC group and suburethral tape in the vaginal group). It is therefore very difficult to draw any firm conclusion. The risk of post-operative SUI is probably not associated with the use of mesh per se but more likely with the type of support achieved during pelvic reconstructive surgery.

**Risk factors for erosion**

As previously mentioned mesh erosion represents one of the main complications of mesh use in POP reconstructive surgery. Few studies have analyzed the risk factors for erosion. One study clearly identified tobacco use as a risk factor for erosion [137]. Erosion rates with synthetic meshes vary with the properties of the meshes. For example in ASC, vaginal mesh erosion has been reported to be 2% with polypropylene compared to higher rates of up to 11% with
microporous multifilament meshes such as Gore-Tex and Mersilene [138, 139]. In our local series of transobturator meshes for the treatment of SUI, we also demonstrated the importance of characteristics inherent to mesh material as a risk factor for vaginal erosion (Appendix 8) [140].

Other potential risk factors are diabetes, obesity, age, associated total hysterectomy, surgical experience, but all of them have still to be proven.

**Discussion and personal view on POP reconstructive surgery**

Our previous results, which were corroborated by other recent studies, showed that the risk of reoperation for POP recurrence in pelvic reconstructive surgery without mesh is rather low, and close to 10% rather than the 30 to 50 % as previously thought [45]. An extensive review of medical literature shows that there are currently no proven benefits in terms of functional outcomes with the use of transvaginal mesh, but on the contrary, mesh use is associated with more adverse events and consequently potential reoperations. Improved anatomical outcome is an insufficient criterion to use mesh in POP reconstructive surgery, especially in the presence of adequate demonstration of comparably successful subjective outcomes without mesh.

Therefore, the use of mesh in transvaginal surgery should be avoided, at least as first line treatment. The use of mesh should be limited to the abdominal (laparoscopic whenever possible) route for the treatment of POP including apical prolapse, where the use of mesh is associated with potentially better functional outcomes, with improved sexual function.

POP is a condition that affects quality of life but is never a life-threatening situation. Conservative measures should systematically be discussed before surgery. Therapeutic approaches should always aim to restore normal function and enhance quality of life. The use of mesh should be carefully evaluated in terms of benefits for each patient and treatment needs to be individualized. Transvaginal mesh surgery is associated with multiple potential complications in both the short and long term with adverse events requiring additional interventions which can sometimes be very difficult to perform. From my point of view, indications for the use of
transvaginal mesh for POP reconstructive surgery are currently rare. They still may represent an alternative in specific cases of recurrence after primary standard vaginal surgery or in patients where the abdominal route or laparoscopies are contra-indicated. The experience of the surgeon probably plays a major role in reducing the rate of complications and of potential adverse events related to this surgery [141, 142]. For this reason, we believe these operations should only be performed by trained pelvic surgeons. In case of recurrence, the use of mesh by the abdominal route has the best outcomes. A secondary procedure using native tissue repair is also possible with limited adverse events if life expectancy is short.

For apical compartment prolapse, abdominal (laparoscopic) cure with mesh is an appropriate solution. Mesh use seems to be safer in this situation and shows favorable functional outcomes when compared to standard vaginal surgery. Hysterectomy should probably be avoided, or if performed, should be subtotal with cervix conservation to limit the risk of vaginal erosion.

For isolated anterior or posterior compartment prolapse, native tissue repair with fascia plication is probably the primary method of choice. The use of mesh in these situations, although resulting in better anatomical outcome for anterior repair, is not indicated.

Diabetes and heavy smoking represent risk factors for erosion and mesh use should be avoided whenever possible in these cases. Young age, obesity, constipation and chronic cough probably increase the risk of recurrence, but these factors should not radically change our therapeutic approach in case of monocompartment POP.

When mesh use is indicated, a type I macroporous (>75 microns) and monofilamentous mesh such as polypropylene theoretically makes the best implant.

When planning POP surgery, one should always discuss the issue of post-operative sexual function. POP oblitative procedures (colpocleisis) represent a safe and simple alternative in older women who are not sexually active and may present other co morbidities and short life expectancies. Alternative conservative therapies such as pessary use should also be discussed. For young and sexually active women with apical prolapse, the abdominal route seems the
optimal approach as it limits the risk of dyspareunia. For posterior compartment prolapse in these patients, levator myorraphy should be avoided to limit the risk of dyspareunia.

Table 1 proposes a therapeutic strategy for reconstructive POP surgery based on review of medical literature.

*Table 1: POP reconstructive surgery strategies according to anatomical defects and patient characteristics:

<table>
<thead>
<tr>
<th>Type of POP</th>
<th>Specificity</th>
<th>Type of surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>Central defect</td>
<td>Vaginal reconstructive surgery with native tissue</td>
</tr>
<tr>
<td></td>
<td>Primary case</td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>Paravaginal defect</td>
<td>Abdominal (laparoscopic) reconstructive surgery with mesh.</td>
</tr>
<tr>
<td></td>
<td>Recurrent case†</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increase in risk factors†</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Associated apical prolapse</td>
<td></td>
</tr>
<tr>
<td>Apical</td>
<td>Long life expectancy</td>
<td>Abdominal (laparoscopic) reconstructive surgery with mesh.</td>
</tr>
<tr>
<td></td>
<td>Intensive physical activities</td>
<td>If hysterectomy, prefer subtotal hysterectomy</td>
</tr>
<tr>
<td></td>
<td>Intercourse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recurrence</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Short vagina</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increase in risk factors†</td>
<td></td>
</tr>
<tr>
<td>Apical</td>
<td>Old patient with short life expectancy</td>
<td>Vaginal reconstructive surgery with native tissue and associated apex suspension (sacrospinous fixation or utero-sacral ligament suspension) with or without vaginal hysterectomy</td>
</tr>
<tr>
<td></td>
<td>Reduced physical activities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Absence of intercourse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Primary case</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sufficient vaginal length</td>
<td></td>
</tr>
<tr>
<td>Posterior</td>
<td>Primary case</td>
<td>Vaginal reconstructive surgery with native tissue</td>
</tr>
<tr>
<td></td>
<td>Recurrence</td>
<td></td>
</tr>
<tr>
<td>Total eversion</td>
<td>Old patient with short life expectancy</td>
<td>Colpocleisis</td>
</tr>
<tr>
<td></td>
<td>No intercourse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High operative risk due to comorbidities</td>
<td></td>
</tr>
</tbody>
</table>

*In case of recurrence involving only the anterior compartment, a second vaginal surgery with native tissue is also possible.
†Risk factors include: COPD, obesity, stubborn constipation, physical activities with straining. For patients with increased risk factors of POP recurrence, abdominal approach with mesh is probably the method of choice, but vaginal reconstructive surgery with native tissue is always possible for women with short life expectancy and for women where only one compartment is involved.

Appendix 9 provides the same strategy represented as a decision tree.

**Future perspectives**

The ideal surgical treatment of POP is yet to be found. The current use of mesh is perfectible, and in order to reduce potential adverse effects and complications, research for the ideal mesh
material is ongoing. The use of mesh provides better anatomical results when compared to native tissue, especially for anterior compartment repair. However, when functional results in terms of the patient’s quality of life are considered, no significant differences are found [70, 128, 143-145]. Non absorbable meshes offer lower anatomical recurrence rates when compared to biological materials or absorbable meshes [146]. Risk of graft exposure, wound granulation, and dyspareunia, which are important complications of graft use in POP treatment, are comparable between all types of meshes, independently of their nature (synthetical or biological) [132].

Cell-based (stem cell) tissue engineering strategies may provide new alternatives to native tissue repair or mesh repair for POP. At present, in urogynecology, research is focused on SUI cell-based injection therapy to regenerate the urethral sphincter [147].

Another recent advance in POP surgery is the use of robot-assisted surgery. Treatment of apical prolapse has evolved with the adoption by some gynecologists of robot assisted laparoscopic surgery. As discussed before, we have adapted and modified the treatment of apical prolapse by lateral mesh suspension with the help of the robot [123]. Although at present robot-assisted surgery provides advantages for the surgeon’s ability and dissection with 3D vision, it does not improve the patient’s outcomes when compared to initial standard laparoscopic technique. However, robotic surgery is continuing to evolve, with the use of smaller/single site incisions, and innovative technology. Thereby, future outcomes may also prove beneficial for patients. The combination of improved robotics and stem cell tissue engineering might open new perspectives in the future of POP surgery.

**Conclusion**

POP is a multifactorial condition which may be considered as physiological so long as the threshold of the hymen is not overcome and patients are asymptomatic. When the descent is symptomatic it can affect quality of life and requires treatment. Women should always be offered conservative treatment (pessary use, physiotherapy) as first line therapy. If conservative treatment fails or if patients actively seek reconstructive surgery, standard vaginal surgery with
native tissue is still a good alternative for isolated POP of the anterior and posterior compartment. The use of reinforcement material to improve outcome has to focus on function and not only on anatomy and must be discussed with caution. Patients need to be informed about their potential complications. The principal situation in which potential benefit outweighs the risk of complication is the use of mesh in the treatment of apical prolapse by the abdominal/laparoscopic route.

Further research is ongoing to find the ideal material and the ideal approach for this condition, which can be very distressing for our patients, with the goal to preserve associated urinary, digestive and sexual functions.
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