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MINI REVIEW

Review of techniques and approaches for ectopic reservoir placement in inflatable penile implant

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Inflatable penile prosthesis (IPP) implantation is the gold standard treatment for patients with erectile dysfunction who are refractory to medical therapy. The standard placement of the reservoir in the space of Retzius (SOR) may be contraindicated in patients with prior pelvic or abdominal surgery due to altered anatomy and increased risk of complications. This has led to the development of alternative ectopic reservoir placement techniques. In this narrative review, we summarize the literature on various ectopic reservoir approaches, including low and high submuscular placements, submuscular techniques with counter incisions or transfascial fixation, midline submuscular placement, subcutaneous placement, and lateral retroperitoneal approaches. We describe the surgical methods, outcomes, and complication rates associated with each technique. While most methods demonstrate low complication and revision rates, direct comparisons remain limited due to heterogeneity and lack of prospective data. This review highlights the importance of individualized technique selection based on prior surgical history, body habitus, and surgeon experience. As ectopic placement becomes more widely adopted, familiarity with multiple approaches is essential for prosthetic surgeons.

Key Words: inflatable penile prosthesis, erectile dysfunction, ectopic reservoir placement, surgical techniques

Introduction

Inflatable penile prosthesis (IPP) is considered the gold standard treatment aiming to restore sexual function for motivated patients with erectile dysfunction (ED) who have not achieved satisfactory results with oral medications, penile injections, vacuum devices, or any other modality. With ED becoming increasingly prevalent, the number of penile implants is on the rise.[1,2]

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Routinely, the reservoir of the three-piece IPP is placed in the space of Retzius (SOR). Placement is performed by gaining access via an extra-peritoneal approach through the external inguinal ring and piercing the transversalis fascia.[3]

Access to the SOR can be compromised or obliterated as a result of previous abdominal/pelvic surgery such as radical prostatectomy, radical cystectomy, inguinal hernia repair, or kidney transplantation. Complications of reservoir placement in the SOR include bladder, vascular, or bowel injuries, reservoir herniation or migration, and dislocation.[4–6]

This challenge has led to the development of a myriad of techniques, with the common strategy being the use of an ectopic reservoir location.

The first description of an ectopic reservoir placement was in 2001 by Wilson et al.[7] The reservoir was placed superior to the transversalis fascia and

beneath the abdominal musculature. This method did not gain traction due to the resultant groin location of the reservoir tending to be palpable and occasionally herniating to the scrotum.[8]

Since then, many more techniques have been proposed and practiced. In this article, we review the locations and approaches described for ectopic IPP reservoirs. These include intra-abdominal, high submuscular, subcutaneous, midline sub-muscular, and within the retro-peritoneum.

Materials and Methods

A comprehensive search strategy was employed to identify relevant studies for inclusion in this review article. The search was conducted in electronic databases including PubMed/MEDLINE, Embase, Cochrane Library, and Google Scholar. Search terms were carefully selected to capture a comprehensive range of relevant articles. Medical Subject Headings (MeSH) terms and keywords were utilized, incorporating variations related to penile implants. The literature search encompassed articles published between 1990 and 2024.

Studies were included in the review if they met the following criteria: 1. Reported a novel technique/location or included a large cohort on an established technique. 2. Published in peer-reviewed journals. 3. Written in English.

Description of Approaches

Low submuscular

In 2011, Perito et al. introduced enhancements to Wilson's technique.[9] They offered two reservoir placements differing from each other based on their relationship to the transversalis fascia. Their study described a cephalad reservoir placement either posteriorly (PTF) or anteriorly (ATF) to the transversalis fascia through a penoscrotal incision. In patients who were at risk for complications with the standard SOR placement, they recommended the ATF approach. In this method, a long nasal speculum passes through the external ring, and then forcibly advances the cephalad reservoir without perforation of the transversalis fascia. Thus, the superior wall of the inguinal canal is perforated. The space is developed between the transversalis fascia and the overlying rectus abdominis muscle.

Stember et al.[10] reported their experience with this technique, they followed 447 patients who underwent reservoir placement in the ATF method. Among this cohort, only two (0.4%) patients were elected for revision surgery due to bothersome palpation of the reservoir. Fifteen patients (3%) felt the reservoir in the early postoperative period but later reported satisfaction. Six (1.3%) patients suffered reservoir herniation into the inguinal canal necessitating additional surgery.

Low submuscular with transfascial fixation

To address the goal of achieving effective reservoir concealment and minimizing reservoir herniation rates, the Low submuscular with transracial fixation technique was developed by Khoei et al.[11] In this technique, the reservoir is placed in a low submuscular position anterior to the transversalis fascia and posterior to the rectus muscle. The fascia is used to anchor the reservoir and tubing in place.

The same authors reported their experience with 31 patients.[11] In a follow-up of 15 to 34 months, 8 patients (26%) were able to palpate the reservoir, and 4 patients (15.4%) were able to see the reservoir. However, overall satisfaction with reservoir concealment was 4.5 (out of 5). One patient (3.8%) suffered pain from the reservoir with minimal severity. They reported that there were no surgical revisions required or complications.

High submuscular

The ``high sub-muscular'' approach is similar to the aforementioned techniques but with an even more cephalad location.[12] In this technique, A potential space between the transversalis fascia and rectus abdominis muscle is created through blunt dissection. A forester clamp is used to further separate these layers and then for grasping and delivering the reservoir to its final location.

Morey et al.[12] reported their experience with this technique. They implanted 120 submuscular balloons/reservoirs through a penoscrotal approach in 107 patients who underwent either IPP, artificial urinary sphincter, or both. The majority of patients were unable to palpate their reservoir/balloon. Two patients (1.6%) presented with a palpable balloon/reservoir. One had a reservoir herniation and the other was placed into a subcutaneous location. No major complications were reported.

Pagliara et al.[13] described their experience with 399 patients who underwent a high submuscular approach reservoir implantation for either IPP or artificial urethral sphincter (AUS) implantation (255 IPP, 144 AUS) With a mean follow-up of 25.6 months, repositioning was required in 8 cases (2%)-half due to pain and half due to herniation. The authors did not note any difference in complication rates between

these patients and patients who underwent a standard SOR placement in their institute.

Submuscular-counter incision

The high submuscular technique is essentially a blind placement of the reservoir. A previous cadaveric study has already called into question the accuracy of the final location of the reservoir, with only 35% of the reservoirs placed in the intended high sub-muscular position.[14]

The use of an inguinal counter incision (CI) for the sub-muscular placement of the reservoir offers a few theoretical advantages: decreased risk of vascular or organ damage during placement and decreased herniation rates due to the avoidance of external ring manipulation. These advantages come at the cost of increased risk for infection and impaired cosmetic outcomes.[15]

Grimberg et al.[15] compared the outcomes of patients undergoing counter-incision reservoir placement and those with non-counter-incision reservoir placement. The CI group, comprising 51 patients and accounting for 9.6% of the cohort, was demographically comparable to the non-CI group. Despite a higher level of complexity, as reflected by increased rates of removal and replacement cases, the CI group exhibited similar complication rates to the non-CI patients.

Lateral retroperitoneum

In 2010, Hartman et al. first published about the utilization of a counter incision.[16] They described a lateral retroperitoneal (LR) placement. In this method, the counter incision is performed 2 cm medially and inferiorly from the anterior superior iliac spine. Dissection is performed until the external oblique fascia, an incision is made, and the external and internal oblique muscles are spread traumatically. Next, the transversalis fascia is bluntly dissected and the retroperitoneal space is developed with the use of a finger.

The outcomes of 266 patients who underwent this procedure with a median follow-up of 20.1 months were published in 2021. There was one (0.3%) instance of intraoperative injury to the colon. Overall, only 6 (2.3%) of patients suffered complications related to the reservoir, such as bulge, pain, or reservoir leaks.

During follow-up, no cases of bladder, bowel, or vascular injury were reported. Compared to standard SOR replacement performed at the same institute, there were no significant differences in complications or revision rates.[17]

Midline sub-muscular reservoir (MSMR)

The midline sub-muscular rectus reservoir (MSMR) is a novel technique that obviates the need to enter the inguinal ring. In this technique, after pubic tubercle identification, dissection is carried cephalad to the level of the rectus fascia. The fascia is entered lateral to the linea alba, and the rectus sheath is bluntly separated from the posterior sheath of the rectus, creating a submuscular space between the rectus muscle and the posterior sheath.[18]

This method presents a few advantages. Reservoir placement is done under direct visualization, thus minimizing the potential pitfalls of a blind placement. The method utilizes the peno-scrotal incision without the need for a counter incision. In thin patients who may require submuscular reservoir placement, the reservoir is often visible at the level of the skin. With this approach, the reservoir is not visible, regardless of the body habitus. In addition, if the need for removal arises in the future the reservoir would be relatively easily accessible.[18]

Zisman et al.[18] retrospectively studied the data of 461 patients who underwent IPP surgery. The MSMR method was used in 48 cases (11%) and was compared to the standard SOR placement. Despite the MSMR group representing the more difficult cases, no statistical difference was found between the groups. This led the authors to conclude that the MSMR group presented a favorable safety profile with a very low complication rate.

Subcutaneous

The placement of a reservoir is technically challenging for obese male patients, especially if they have previously undergone pelvic surgery. In this case, a subcutaneous reservoir may be a valid alternative to the classic approach. In this regard, patient selection is crucial, since thin patients will suffer from a palpable and even visible reservoir.[19]

Garber et al.[19] described their experience with 8 patients who were selected to undergo this type of reservoir placement intraoperatively. The method can be performed with a scrotal or infrapubic incision. In the scrotal approach, the reservoir is tunneled medially and the neck of the tunnel is approximated with absorbable sutures. When using the infra pubic incision, Scarpa's and Camper's fascia were approximated anterior to the reservoir with 2–3 layers of absorbable sutures.

With the exception of one patient who required explantation due to infection of the penile implant. Patients healed uneventfully without reservoir hernias or palpable or visible reservoirs.

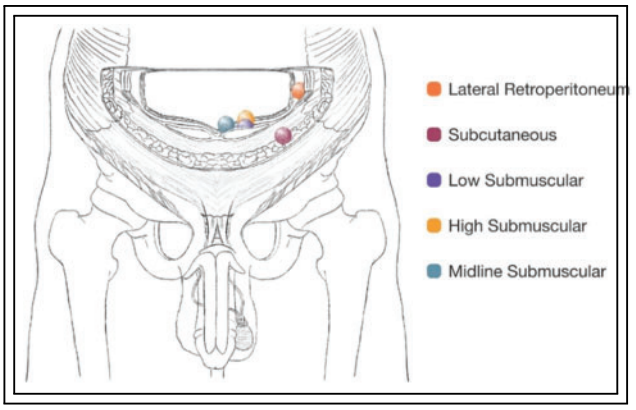

FIGURE 1. Ectopic reservoir locations

Discussion

While reservoir placement in the SOR is suitable for most patients and associated with a low risk of complications, a significant subset of patients with prior pelvic surgery may face an increased risk of adverse events. Capoccia et al.[20] compared complication rates in patients undergoing reservoir placement in the SOR, distinguishing between those with and without a history of pelvic surgery. Their findings showed a 2.8% complication rate in patients with prior pelvic surgery, compared to just 0.01% in those without. This disparity is largely attributed to anatomical alterations caused by previous surgical interventions.

Although rare, major complications can be severe and include bladder perforation,[21] bowel injury[22] due to intraperitoneal placement, and vascular injuries, particularly to the external iliac vein or its branches.[23]

Due to these risks, the need for an alternative reservoir placement arose. In the short history since the first ectopic reservoir was placed, numerous techniques have been described (Figure 1). As a general rule, a technique's simplicity and reproducibility naturally lead to a wider adoption throughout the surgical community.

The parameters used to assess the feasibility of these techniques are mostly complication and revision rates. The techniques mentioned in this review (Table 1) have all shown promising results, with low complication rates for the traditionally more challenging cases. Drawing conclusions or making recommendations regarding the superiority of one technique over the other is challenging due to the retrospective nature of these studies. Without high-quality randomized and prospective studies comparing the various techniques, it is difficult to ascertain which one may be superior.

Although direct comparisons between techniques are challenging, it is evident that some methods have been more extensively tested than others. The approach introduced by Perito et al.[9] and further evaluated by Stember et al.[10] demonstrated reliable outcomes in a cohort of 447 patients, with a remarkably low revision rate of 0.4%. Similarly, the high submuscular technique is supported by substantial evidence, including 120 cases from Morey et al.[12] and 399 cases from Pagliara et al.[13], both reporting low complication rates (2%) and minimal issues with reservoir palpation or herniation. The lateral retroperitoneal technique, initially described by Hartman et al.[16] and later expanded upon by Loh-Doyle et al.[17], achieved favorable outcomes with a 2.3% complication rate related to the reservoir. However, this series notably included a case of bowel injury, a complication not reported in other studies.

Hernández et al.[23] aimed to better characterize the complications associated with ectopic reservoir placement. In a multi-institutional study spanning five years, they reported their experience with 612 ectopic placements. Of these, 12 cases (2%) required revision due to reservoir-related complications. The most common issue was reservoir leakage, occurring in five cases. Other complications included abdominal pain, tubing torsion, and one incidentally discovered intraperitoneal placement on unrelated imaging.

Due to the proximity of ectopic reservoirs to the abdominal musculature, there was initial concern about an increased risk of herniation. However, reservoir herniation, specifically migration through the inguinal canal remains a rare complication. Karpman et al.[24] prospectively studied 759 patients who underwent either SOR or ectopic reservoir placement and found no statistically significant difference in complication rates between the groups, with two cases of herniation reported in each.

Key patient-centered outcomes in ectopic reservoir placement include reservoir palpability and overall patient satisfaction. Modern reservoirs, such as the Coloplast Cloverleaf and American Medical Systems' Conceal, are designed with a flat configuration to reduce palpability when placed ectopically. Patient satisfaction studies have shown that 94% of patients with high submuscular placement report none or minimal palpability.[25] Similarly, Stember et al.[10] found that only 2 out of 447 cases required revision due to bothersome palpation.

Currently, the "It Matters" study[26] is prospectively assessing patient satisfaction with reservoir placement. Preliminary findings from 34 respondents, including 16 with ectopic placement, indicate that 66.7% (8/12) of patients with ectopic reservoirs

TABLE 1. **Summary of studies included in the review**

Ectopic location	Incision	Author	Number of patients	Study design	Complications
Low submuscular	Transverse infrapubic	Stember et al.[10], 2014	447	Retrospective compariso	Two patients underwent revision due to palpation of the reservoir. 3.4% initially could feel the reservoir and later reported satisfaction. 1.3% developed reservoir herniation
Low submuscular with transfascial fixation	Pemoscrotal/ Infrapubic	Khoei et al.[11], 2022	31	Retrospective	There were no intra- or postoperative complications. 8 patients (26%) were able to palpate the reservoir and 4 patients (15%) were able to see it.
High submuscular	Transverse scrotal	Morey et al.[12], 2013	120	Retrospective	Two patients presented with palpable reservoirs. One had a reservoir herniation and the other had the reservoir placed in a subcutaneous location.
High submuscular	Penoscrotal	Pagliara et al.[13], 2018	399	Retrospective comparison	Reservoir repositioning was required in 2% of cases. Half due to pain and half due to reservoir herniation. There were no noted differences in complication rates between HSM and SOR groups.
Counter incision high submuscular	Counter incision	Grimberg et al.[15], 2020	51	Retrospective comparison	Cases using a CI had a higher median operative time by 17 min. Complication rates were 7.8% for the CI group. Complication rates were not higher than SOR placement.
Lateral retroperitoneum	Counter incision	Loh-Doyle et al.[17], 2021	266	Retrospective comparison	In the LR group, one patient suffered an intraoperative injury to the bowel. Overall, 2.3% of patients in the LR group experienced reservoir-related complications. Complication rates were not higher than SOR placement.
Midline sub-muscular reservoir	Vertical scrotal	Zisman et al.[18], 2022	48	Retrospective comparison	In the MSMR group two patients experienced device malfunction. There were no cases of infection/herniation or injury to nearby structures. Complication rates were not higher than SOR placement.
Subcutaneous	Scrotal/ infrapubic	Garber et al.[19], 2016	8	Retrospective	One patient required explantation due to infection of the implant. The rest of the patients did not experience complications.

reported feeling comfortable or very comfortable, compared to 54.5% (12/22) in the SOR group. However, there were no statistically significant differences in overall satisfaction with reservoir location or physical comfort between the two groups ($p = 0.134$ and $p = 0.623$, respectively).

Ectopic reservoir placement has gained widespread acceptance in the prosthetic urology community, with 97% of high-volume, experienced surgeons emphasizing the importance of incorporating ectopic reservoir placement techniques into physician training courses.[27] While the indications for the placement of an ectopic reservoir are clear, the approach and location of an ectopic IPP are not standardized. Among the factors that should be taken into account are the patient's surgical history, body habitus, and individual anatomy. It is also important to consider the surgeon's experience,

familiarity, and preferences with a particular technique when making a decision.

Conclusions

Reconstructive urologists should recognize patients with abnormal pelvic anatomy and be familiar with modern approaches to ectopic IPP placement while tailoring the procedure to suit the individual patient's needs.

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Author Contributions

Etan Eigner: conducted the initial literature search, identified relevant articles, synthesized the findings, contributed to the conceptualization and design of the review article and drafted the manuscript. **Valentin Shabataev:** contributed to the interpretation of findings, provided critical feedback on the manuscript, and assisted in finalizing the structure and organization of the review article. **Yacov Reisman:** contributed to the interpretation of findings, provided critical feedback on the manuscript, and assisted in finalizing the structure and organization of the review article. **Ariel Zisman:** contributed to the conceptualization and design of the review article, supervised the review process, provided guidance on the overall direction of the manuscript, contributed to the final editing and approval of the manuscript. **Nicola Fazza:** contributed to the conceptualization and design of the review article and played a role in drafting the manuscript. **Ameer Nsair:** contributed to the conceptualization and design of the review article and played a role in drafting the manuscript. All authors reviewed the results and approved the final version of the manuscript.

Availability of Data and Materials

The data analyzed in this review article are derived from publicly available sources, primarily peer-reviewed journal articles. All sources cited in this review are accessible through standard academic databases and repositories.

Ethics Approval

This review article did not involve primary research data or experiments involving human subjects or animals. Therefore, ethical approval was not required for the conduct of this review.

Conflicts of Interest

The authors declare no conflicts of interest to report regarding the present study.

List of Abbreviations

ED	Erectile dysfunction
IPP	Inflatable penile prosthesis
SOR	Space of Retzius
MeSH	Medical Subject Headings
PTF	Posterior to the transversalis fascia
ATF	Anterior to the transversalis fascia
AUS	Artificial uretheral sphincter
CI	Counter incision
MSMR	Midline sub-muscular rectus reservoir
LR	Lateral retroperitoneal

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