Review Article

Literature review of factors affecting continence after radical prostatectomy

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ABSTRACT

استئصال البروستاتا هو المسبب الأكثر شيوعاً لسلسل البول لدى الرجال. العديد من الأجزاء تؤثر أو قد تؤثر على حصر البول - العضلة العاصرة الإحليلية، العضلة الرافعة للشرج والأربطة العانية البروستاتية، عنق المثانة، لفافة باطن الحوض، الحزمة الوعائية العصبية - فهم تشريح أرضية الحوض والإحليل أمر ضروري للحصول على نتائج وظيفية بعد الجراحة. صممت التقنيات الجراحية لتحسين معدلات حصر البول. تشمل هذه التقنيات اجراء حفظ الأعصاب، حفظ عنق المثانة، حفظ طول الأحليل، اعادة بناء العضلي اللفافي، الحفاظ على الأربطة العانية البروستاتية او الحفاظ على الحويصلة المنوية. تدريب عضلات الحوض في فترة ماقبل وبعد الجراحة يهدف الى تقصير فترة سلسل البول بعد الجراحة، وبالتالي تحسين معدلات حصر البول بعد الجراحة. في هذا البحث نستعرض عوامل حول الأجزاء التشريحة، اثناء الجراحة والفترة المحيطة بالجراحة، والتي تؤثر على حصر البول بعد الأستئصال، بما في ذلك وصف الهياكل التشريحية المهمة، الآثار المحتملة للتقنيات الجراحية وتقييم تدريب عضلات الحوض في الفترة المحيطة بالجراحة.

Radical prostatectomy (RP) is the most common cause of stress urinary incontinence (UI) in men. Several anatomic structures affect or may affect urinary continence - urethral sphincter, levator ani muscle, puboprostatic ligaments, bladder neck, endopelvic fascia, neurovascular bundle - and understanding of the anatomy of pelvic floor and urethra is crucial for satisfactory functional outcome of the procedure. Surgical techniques implemented to improve continence rates include nerve-sparing procedure, bladder neck preservation/plication, urethral length preservation, musculofascial reconstruction, puboprostatic ligaments preservation or seminal vesicle preservation. Perioperative (preoperative and postoperative) pelvic floor muscle training (PFMT) aims to shorten the duration of postoperative UI and thus, improve early continence rates postoperatively. In the review, complex information regarding anatomical, intra- and perioperative factors affecting urinary continence after RP is provided, including description of important anatomical structures, possible implications for surgical technique and evaluation of different PFMT strategies in perioperative period.

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Radical prostatectomy (RP) is the most common cause of sphincteric urinary incontinence (UI) in men. Advances in operative technique have reduced the rate of post prostatectomy incontinence (PPI). However, the burden of PPI remains high and is even expected to rise due to the increasing number of procedures performed.[1] Besides stress UI, overactive bladder symptoms caused by detrusor overactivity and impaired detrusor compliance *de novo* may occur during the first 12 months after RP.[2] Early PPI of different grades is higher than thought and may affect up to 96% of patients.[3] Mean continence rates 12 months after surgery are 89-100% for robot-assisted laparoscopic prostatectomy (RALP) and 80-97% for open radical retropubic prostatectomy (RRP).[4] Post prostatectomy incontinence affects both physical activity and social well-being and therefore has a significant impact on the quality of life.[5] The precise aetiology of PPI has not been completely understood. There are several risk factors, including preoperative (age, continence status prior to surgery), intraoperative (surgical technique, surgical experience), and postoperative factors.[6] Several factors and limitations must be

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considered in interpreting the assumed outcomes of RP including PPI - individual surgeon factors (level of surgical ability, completion of the learning curve, the same surgical step performed differently), variable definition of continence/incontinence, use of validated tool to evaluate PPI, methods used for data collection, clinical stage or biopsy parameters and patient's age.[7] In general, significantly better continence rates after RP are observed in men under 70 years of age than in men over 70 years.[8] There has not been sufficient evidence suggesting a significant relationship between body weight and postoperative RP, and prostate volume and PPI.[9] Neither has a relationship between preoperative physical activity and PPI been observed.[10] Preoperative detrusor overactivity (DOA) is associated with higher risk of post prostatectomy incontinence. Preoperative detrusor overactivity was found in 34% of patients still incontinent 6 months after RP on baseline urodynamic evaluation before surgery.[11] Several treatment options have been proposed for the management of PPI; pharmacotherapy, pelvic floor muscle training (PFMT), bulking agents, fixed or adjustable male slings, and compression devices including the artificial urinary sphincter (AUS). Whereas different strategies can be applied to patients with mild-to-moderate PPI, AUS is considered the standard treatment for moderate-to-severe PPI.[12] Due to different surgical approaches/modifications and PFMT strategies, the aim of the review was to summarise the anatomical, surgical, and perioperative factors that affect, or may affect, postoperative urinary continence after RP.

Anatomical aspects. ***Puboprostatic ligaments.*** Puboprostatic ligaments are paired fibrous streaks that originate from the endopelvic fascia. They attach to the lower fifth of the pubic bone, lateral to the symphysis and the junction of the external urethral sphincter and prostate.[13] They support the external sphincter and sustain the urethra in its position in the pelvic floor. It is still unclear whether they are a part of a muscle or not and whether these ligaments also contain muscle fibres.[14] Because of the direct connection between the anterior bladder wall and the pubic bone (**Figure 1**), the term "pubovesical" ligaments has been proposed.[15] The intactness of the urethral suspensory mechanism appears to have a relevant role in the preservation of urinary continence - a puboprostatic ligament-sparing approach allows the preservation of the maximal urethral length and the anterior urethral support remains intact, leading to an earlier return of continence.[16] Stolzenburg observed a significant decrease in the period to early continence in the group of patients with puboprostatic ligament-sparing nerve-sparing endoscopic extraperitoneal RP (nsEERP) compared with standard nsEERP. No difference was found between the 2 groups after 3 months (no PPI recorded).[17]

External urethral sphincter. The external urethral sphincter (EUS) surrounds the membranous urethra (**Figure 2**). Its location corresponds with the site of

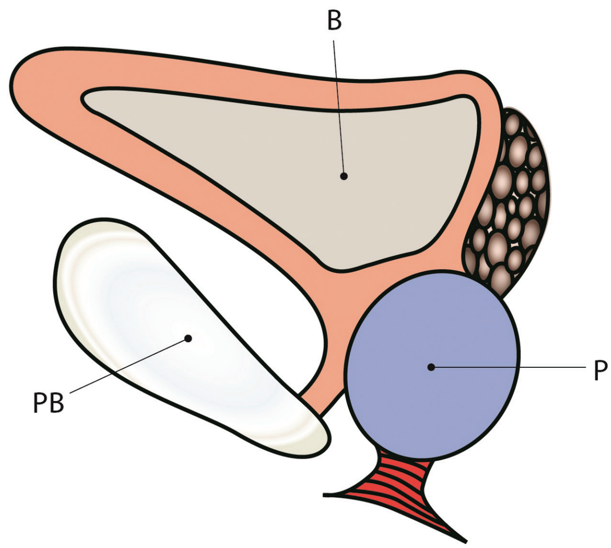

Figure 1 - Detrusor apron ending with pubic insertion - puboprostatic/pubovesical ligament. B - bladder, PB - pubic bone, P - prostate

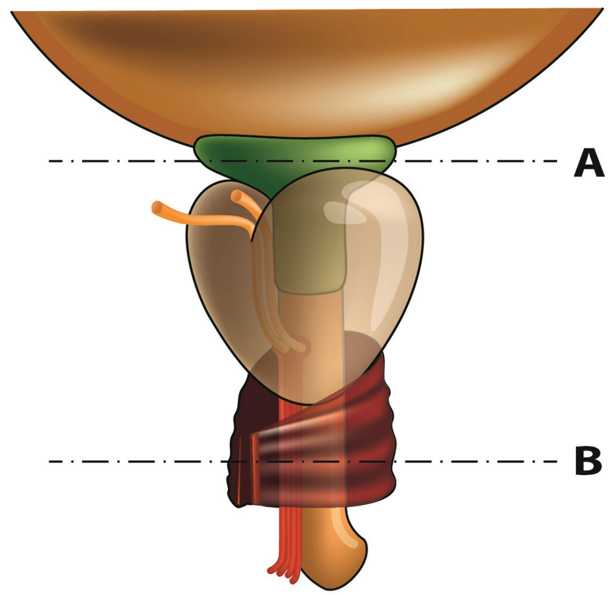

Figure 2 - Male urethral sphincter image showing: A) the internal urethral sphincter. B) the external urethral sphincter.

the peak urethral closing pressure and is considered the principal structure ensuring continence after RP.[13] Although the term "striated sphincter" has been widely used, the EUS contains both smooth muscle bundles (inner longitudinal layer and outer circular layer) and striated muscle bundles (that form a "true" rhabdosphincter separated from the muscles of the pelvic floor).[18] The EUS is horseshoe (or omega) shaped and does not connect dorsally. Despite this configuration, urethral pressure at the external sphincter increases uniformly along the entire circumference during bladder filling. The striated component exerts its function from the prostate apex to the bulb, whereas the inner muscle component extends to the verumontanum[19] (**Figure 3**). The EUS is supplied by 2 somatic nerves - the pudendal nerve and a branch of the sacral plexus running on the surface of the levator ani muscle (that is why transection of the pudendal nerve does not lead to ablation of sphincter activity).[13] Although pelvic floor muscles and the internal urethral sphincter participate in the continence mechanism, protection of the EUS should always be the main goal of the surgeon.[14] Urethral pressure profilometry (UPP) shows a significant decrease in both maximum urethral closure pressure (MUCP) and functional profile length (FPL) after RP, and lower preoperative MUCP and FPL

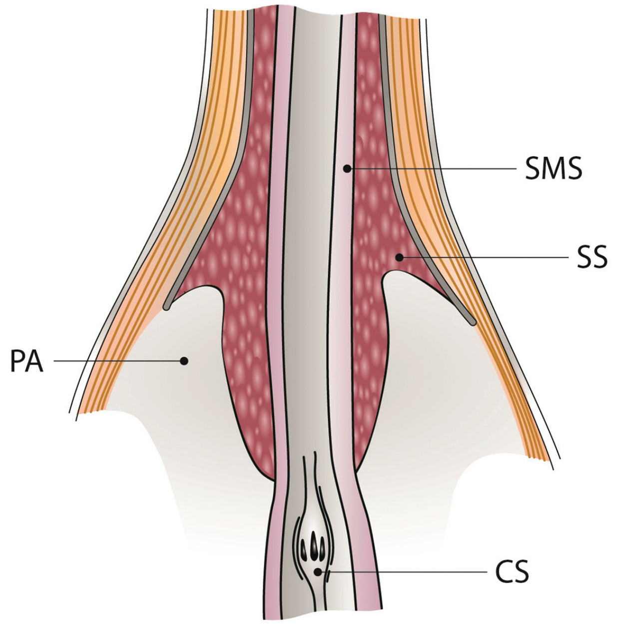

Figure 3 - The relationship between the prostatic apex and the external urethral sphincter. SMS - smooth muscle sphincter, SS - striated sphincter, PA - prostatic apex, CS - colliculus seminalis.

are associated with increased risk of PPI.[20] Another risk factor for PPI and longer time to achieve continence is the shorter length of the urethral sphincter on preoperative endorectal MRI.[21] Conversely, a longer preoperative or postoperative membranous urethral length measured by endorectal MRI is associated with superior continence.[22]

Internal urethral sphincter (vesical sphincter, musculus sphincter vesicae). The smooth muscle at the level of the bladder neck is distinct from the rest of the bladder. The middle muscular layer with circular fibres forms a preprostatic sphincter, which is generously supported by adrenergic innervation. Stimulation of adrenergic fibres produces an effective closure of the bladder neck, which avoids retrograde ejaculation and assures continuous urinary continence. It maintains urinary continence even in the case of a destroyed external urethral sphincter.[13]

Pelvic floor muscles. The levator ani muscle is the innermost muscle of the anterior pelvis. Its anteromedial component, located next to the urethral sphincter, is called the pubourethral muscle, although the term "puboperinealis" muscle has also been used.[9] This muscle is relaxed during voiding. During the volitional contraction of the pelvic floor (referring to the attempt to stop the urinary flow during voiding), the urethrovesical junction and anorectal junction move upwards and forwards, the bulb of the penis moves ventrally and there is a small displacement of the ventral urethral margin dorsally at the level of EUS, as demonstrated by perineal ultrasound.[23] Apical prostatic dissection during RP may damage the pubourethral muscle fibres and pudendal nerve branches innervating EUS, which run close to the pubourethral muscle.[24] There is a relatively solid fascia or interface between the levator ani and the EUS, which also contains veins and nerves (originating from the periprostatic neurovascular bundle).[25] Preservation of the levator ani fascia (a part of endopelvic fascia) protects the innervation of the levator ani muscle and EUS.[26] Other components of the levator ani muscle include the puborectalis muscle (PRM) located laterally and the rectourethralis muscle (RUM) located between the perineal body and anorectal junction (**Figure 4**). The anterior part of PRM inserts to the inferior pubic rami and the posterior parts connect to the anorectal junction. This muscle is important for the closure of vaginal and anal orifices, but its contribution to urethral pressure increase has also been demonstrated in the rabbit.[27] The relationship between the perineal body and RUM remains controversial and little is known of the histological relationship

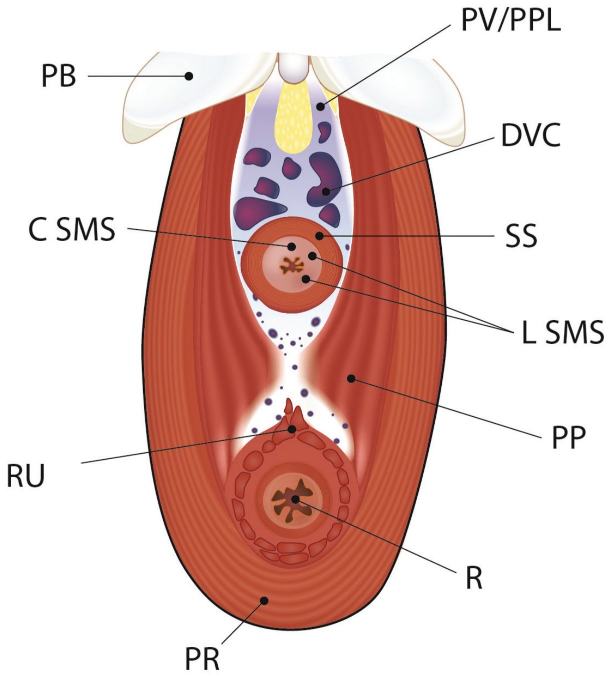

Figure 4 - Components of the levator ani muscle. RU - rectourethralis muscle, PP - puboperinealis muscle, PR - puborectalis muscle, SS - striated sphincter, C SMS - circular smooth muscle sphincter, L SMS - longitudinal smooth muscle sphincter, PV/PL - pubovesical/puboprostatic ligament, PB - pubic bone, DVC - dorsal venous complex

between EUS and RUM - the membranous urethra is attached to the rectourethralis muscle through EUS, which is closely fixed to the ventral portion of RUM.[28] However, other studies failed to demonstrate any contact of RUM with the urethra itself and suggest that the term is a misnomer.[29] When pelvic anatomy was compared by MRI study before and after recovering urinary continence after RP, both an increase in PRM thickness and movement of the bladder neck upwards and forwards was observed.[30] There was no significant change in the membranous urethral length. These results support the use of periurethral suspension and pelvic floor exercises for the resurgence of continence after RP.

Fascias around the prostate. The periprostatic fascia is located between the levator ani fascia and the prostate. In the past, it was thought that this fascia was divided into 2 layers, but histological studies have discovered that the periprostatic fascia is a multilayered connective tissue comprising collagenous fibres, fat tissue, nerves ,and blood vessels.[31] Traditionally, the standard nerve-sparing (NS) RP is based on interfascial dissection between the lateral layer and the medial layer, whereas the intrafascial technique attempts to get as close to the prostatic capsule as possible (**Figure 5**). Despite extensive research of prostate anatomy, the exact anatomy of the fascias around the prostate, as well as the exact relationship between the neurovascular bundle and the fascia remain controversial.[29]

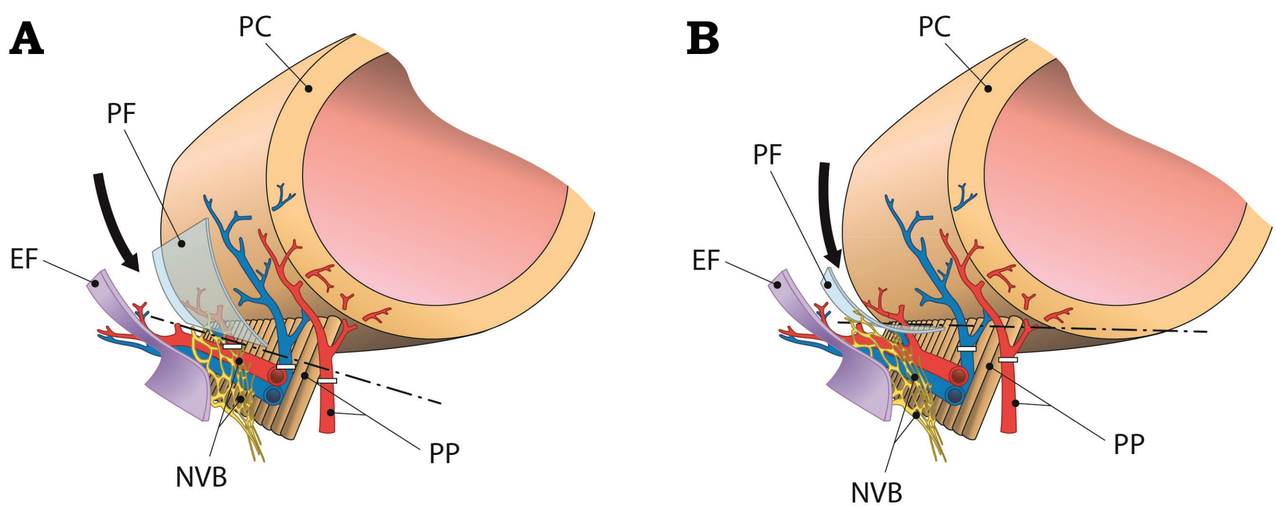

Figure 5 - Interfascial (**A**) and intrafascial (**B**) nerve-sparing radical prostatectomy. EF - endopelvic fascia, PF - prostatic fascia, PC - prostatic capsule, NVB - neurovascular bundle, PP - prostatic pedicle

Technical aspects. Various operative techniques have been proposed to improve postoperative continence rates. The basic concept of these techniques is to maintain the normal anatomy and function of pelvic structures as much as possible by their preservation, reconstruction or reinforcement.[32] The surgeon's experience is an important factor, as outcomes of RP are sensitive to small differences in performance.[33]

Bladder neck preservation/bladder neck plication. ladder neck excision may harm the internal urinary sphincter. To preserve the bladder neck (bladder neck preservation [BNP]), one should sharply dissect the bladder neck off the base of the prostate to maintain most of the circular muscle fibres. This technique seems to hasten the recovery of urinary function; however, in the long term, the continence rates with or without BNP are almost the same.[34]

Plication of the bladder neck is an effective and relatively simple technical modification to shorten the period of restoration of urinary continence after RP.[35] The anterior bladder plication stitch decreases the extension of the bladder neck and EUS at rest and increases the functional urethral length.

Urethral length preservation. To achieve the maximum urethral length, it is important to preserve both EUS and the intraprostatic portion of the membranous urethra. Full-functional urethral length preservation achieved by modified apical preparation increases early continence rates, with a possible maximal effect in patients with a long intraprostatic part of the membranous urethra.[36] Between 10-40% of the functional urethra is actually covered by the prostatic apex. Thus, the shape of the prostate can make urethral length preservation difficult, especially in the case of circumferential overlap of the apex over the EUS.[37] An advantage in long-term continence rate has not been demonstrated. Precise recognition of the junction between the membranous urethra and the prostatic apex is the most crucial point to maintain maximal urethral length without increasing the risk of positive apical surgical margins.[32] Some authors believe that it is better to cut the urethra just as it emerges from the prostatic apex or, if possible, with some dissection into the prostatic apex without any distal dissection, which will not make the actual urethra longer or the patient more continent, but will instead only cut the urethral blood supply and its innervation.[38]

Musculofascial reconstruction. Anterior reconstruction techniques are characterised by reinforcing the anterior support of the urethra. This is typically achieved by anchoring the vesicourethral anastomosis to the pubic bone or the puboprostatic ligaments.[39,40] A single puboperiurethral stitch passed between the urethra and dorsal venous complex and then through the periostium of the pubic bone results in faster recovery of continence and better continence rates at 3 months compared with no periurethral suspension.[41] After the urethra is supported ventrally, the angle of the vesicourethral junction is not too obtuse and the anastomosis is stable - an unstable anastomosis may lead to enhanced scar formation with possible anastomotic stricture as a consequence.[42] Periurethral fibrosis might also impede the recovery of continence by altering the elasticity of EUS.[22]

Preservation of the puboprostatic collar (formed by the puboprostatic ligaments, the arcus tendineus of the pelvis and the puboperinealis muscle) is performed by careful separation of the apex from the puboprostatic collar complex. In combination with puboperineoplasty (suspension of the vesicourethral anastomosis to the collar - not only to the puboprostatic ligaments - by 3 sutures on each side), it results in an immediate continence rate of 41% after catheter removal and 71% after 4 weeks.[24]

The effect of posterior musculofascial plate reconstruction on earlier continence recovery is promising but still controversial.[43] The aim of posterior reconstruction is to prevent the retraction of the urethra and EUS. It is originally based on the technique described by Rocco et al[44] "Rocco stitch", which includes 2 sutures joining the posterior semi-circumference of the sphincter to the residual Denonvillier's fascia on either side (cranial elongation of the dorsal sphincteric wall). This plane is then fixed to the posterior bladder wall with other 2 sutures placed 1 to 2 cm cranial and dorsal to the new bladder neck (EUS is anchored to the posterior aspect of the urinary bladder). The urethro-vesical anastomosis is subsequently performed.[44] Regarding postoperative continence rates, only a small statistical advantage after 1 month has been shown; the technique does not influence 3- and 6-month urinary continence.[7] Nevertheless, the reconstruction provides greater support to the vesicourethral anastomosis and may improve hemostasis. However, care must be taken not to injure the nerve fibres that run along and through the RUM with the stitches placed during the reconstruction of the dorsal musculofascial plate.[28]

Total musculofascial reconstruction combines the posterior reconstruction (as described previously) and anterior reconstruction (re-attachment of the tendinous arch of the pelvis and the puboprostatic plate to the bladder neck).[45] The cumulative analysis of comparative studies showed a minor statistically significant benefit of total (anterior and posterior) musculofascial reconstruction on urinary continence 1 month and 3 months after RP.[7] No differences were found after a longer follow-up.

Seminal vesicle preservation. Some of the neural fibres from the inferior hypogastric plexus (pelvic plexus) that supply autonomic smooth muscle fibres of the EUS are located posterolateral to the seminal vesicles and pass very close to their tips.[46] The risk of injury to these nerves can be reduced using the seminal vesicle-sparing technique. Improved postoperative continence rates were observed as well.[47]

Local hypothermia. The risk of injury to neuromuscular tissues surrounding the prostate can be decreased using local hypothermia. Cold intracorporeal irrigation along with an endorectal cooling balloon lead to effective regional pelvic cooling.[48] Despite some positive references regarding postoperative continence rates and return to continence (particularly in older patients),[49] this method is rarely used in clinical practice and therefore should be considered experimental.

Nerve-sparing RP. Although there is robust evidence that a NS RP is important for preservation of erectile function, there is controversy over whether the NS technique improves postoperative urinary incontinence.[32] Comparing bilateral NS, unilateral NS, and non-NS RALP, no significant difference was found in continence rates at one year after surgery. This suggests that baseline factors and not the physical preservation of the cavernosal nerves predict overall return to continence.[50] In comparison of interfascial and intrafascial NS RP, no statistical significance in continence rates was observed between the 2 groups at 12 months.[51] In addition, postoperative erectile function is not predictive of urinary continence, suggesting that anatomical factors, rather than innervation, are primarily responsible for continence after RP.[9]

In conclusion, the role of surgical modifications of RP remains controversial. Rather than strengthening the continence mechanism, they focus on restoration of anatomical structures to their original state as it was before the surgery. It is still unclear how all of these anatomical structures interact. It is well known to all surgeons that even if a particular anatomical structure (for example, EUS) remains intact, some patients are still incontinent postoperatively.[14] On the other hand, we have our own experience with a post-poliomyelitis patient, who is fully continent 5 years after open RP, with excellent both oncological and functional outcome, despite bladder symptoms including incontinence being found twice as often in polio survivors than in the general population and incontinence affecting 41% of men.[52] Moreover, muscle strength slowly deteriorates in post-polio patients.[53] PPI would therefore have definitely been anticipated in this patient. Nevertheless, data on pelvic floor muscle function in post-polio patients are lacking.

Open RP (ORP) versus RALP. Various studies have compared these 2 surgical approaches in terms of PPI. Some of them showed better results in terms of postoperative continence rates and time to continence in RALP groups;[54,55] others did not confirm the results.[56,57] A prospective study by Geraerts et al[58] showed that patients after RALP were prone to recover urinary continence earlier than those after ORP. However, statistically significant difference in continence rates was lost in subgroup analyses. Therefore these results must be interpreted with caution. There was no difference in PPI rates at 12 months; severity of voiding symptoms and quality of life were significantly better in the RALP subgroup.[58] Similarly, O'Neil et al[59] reported improved urinary function at 6 months, but not at 12 months, in a population-based study including patients treated with surgery for prostate cancer within the Comparative Effectiveness Analysis of Surgery and Radiation (CEASAR) and Prostate Cancer Outcomes Study (PCOS) prospective studies.[59]

Pelvic floor muscle training. The PFMT improves the function of the pelvic floor, improving urethral stability.[60] During increased activity, the urethra is stabilised by increased urethral closure pressure and downward movements are minimised. Several studies consistently demonstrated the benefit of early postoperative PFMT on recovery of PPI.[61,62] The rehabilitation program usually includes pelvic floor contractions, controlled either manually by the therapist or by electromyography biofeedback. After initial guided PFMT, patients continue with a home program of several series of exercises per day until continence is achieved. Biofeedback compared with unassisted PFMT has demonstrated statistically significant superior outcomes.[63] The necessity of physiotherapist-guided follow-up PFMT is questionable; patients who are instructed by a physiotherapist seem to adhere longer to PFMT and thereby improved continence rates are recorded, compared with patients training on their own.[64] Reports on less intense therapy (instruction and telephone support versus intensive guided PFMT) without significant difference at any time point, permit a different (and more cost-effective) strategy.[65] The effect of preoperative PFMT (in combination with postoperative PFMT) has also been investigated. Most studies found positive results.[66-68] However, due to a lot of bias, their results should be interpreted cautiously. A recent randomised controlled trial failed to demonstrate shorter duration of PPI in patients with additional preoperative PFMT (3 sessions according to the waiting time for surgery), compared with patients with only postoperative PFMT.[69] However, due to patients' satisfaction with PMFT before surgery, postoperative incontinence had less impact on quality of life in the preoperative PFMT group. Electrical stimulation of the pelvic floor (stimulation of the pudendal nerve and its branches) combined with PFMT does not improve the return to continence more than PFMT alone.[70] Behavioural therapy, including PFMT and bladder control strategies, is suitable for patients with persistent urinary incontinence after surgery (more than one year) and resulted in fewer incontinence episodes. Biofeedback and electrical stimulation did not further improve the effectiveness.[71] The most recent systematic review and meta-analysis of the effect of preoperative PFMT on PPI including 11 studies, confirmed improvement of postoperative continence at 3 months (36% reduction of PPI risk) but not at 6 months after surgery.[72]

Early postoperative pharmacotherapy. Duloxetine, a potent inhibitor of the presynaptic re-uptake of serotonin and norepinephrine, has been used for the treatment of stress UI. One study compared PFMT plus duloxetine versus PMFT plus placebo for 16 weeks early after RP (starting on day 10 after catheter removal) followed by 8 weeks of PFMT alone. The PPI was significantly improved in the former group, but the effect did not last towards the end of the study (week 24), indicating that duloxetine accelerates cure rather than increases the number of patients cured.[73] Detrusor overactivity and impaired bladder compliance after RP are the rationales for the use of antimuscarinic agents. A study comparing solifenacin versus placebo in patients after RALP who were incontinent 1 to 3 weeks after catheter removal failed to demonstrate difference in time to return to continence. However, there was a significant difference in the number of continent patients at the end of the study (week 12) favoring the solifenacin group.[74]

In conclusion, post prostatectomy incontinence may be influenced by many factors, including patient's aspects, surgeon's experience, operative technique, and continence definition/methodological aspects. There is still much to be known regarding the male continence mechanism, the role of specific structures in maintaining continence and the precise aetiology of post prostatectomy incontinence. Prediction of PPI is therefore difficult. The article reviews current anatomical knowledge and intra- and perioperative management suggested to improve continence rates after RP. Although these modifications shorten the time to continence and improve early continence rates, the long-term continence rates remain almost the same as for the standard anatomical RP.

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References

1. Wessells H, Peterson AC. Surgical Procedures for Sphincteric Incontinence in the Male. In: Wein A, Kavoussi L, Novick A, Partin A, Peters C, editors. Campbell-Walsh Urology, 10th edition. Philadelphia (PA): WB Saunders; 2012. p. 2290-2305.
2. Bauer RM, Gozzi C, Hübner W, Nitti VW, Novara G, Peterson A, et al. Contemporary management of postprostatectomy incontinence. ***Eur Urol*** 2011; 59: 985-996.
3. Khoder WY, Trottmann M, Stuber A, Stief CG, Becker AJ. Early incontinence after radical prostatectomy: a community based retrospective analysis in 911 men and implications for preoperative counseling. ***Urol Oncol*** 2013; 31: 1006-1011.
4. Mottet N, Bellmunt J, Briers E, van den Bergh R, Bolla M, van Casteren N, et al. Guidelines on prostate cancer. In: European Association of Urology Guidelines, 2015 edition. Arnhem (NL): European Association of Urology; 2015. p. 1-40.
5. Sanda MG, Dunn RL, Michalski J, Sandler HM, Northouse L, Hembroff L, et al. Quality of life and satisfaction with outcome among prostate-cancer survivors. ***N Engl J Med*** 2008; 358: 1250-1261.
6. Bauer RM, Bastian PJ, Gozzi C, Stief CG. Postprostatectomy incontinence: all about diagnosis and management. ***Eur Urol*** 2009; 55: 322-333.
7. Ficarra V, Novara G, Rosen RC, Artibani W, Carroll PR, Costello A, et al. Systematic review and meta-analysis of studies reporting urinary continence recovery after robot-assisted radical prostatectomy. ***Eur Urol*** 2012; 62: 405-417.
8. Kundu SD, Roehl KA, Eggener SE, Antenor JA, Han M, Catalona WJ. Potency, continence and complications in 3,477 consecutive radical retropubic prostatectomies. ***J Urol*** 2004; 172(6 Pt 1): 2227-2231.
9. Cambio AJ, Evans CP. Minimising postoperative incontinence following radical prostatectomy: considerations and evidence. ***Eur Urol*** 2006; 50: 903-913.
10. Mungovan SF, Huijbers BP, Hirschhorn AD, Patel MI. Relationships between perioperative physical activity and urinary incontinence after radical prostatectomy: an observational study. ***BMC Urol*** 2013; 13: 67.
11. Dubbelman Y, Groen J, Wildhagen M, Rikken B, Bosch R. Quantification of changes in detrusor function and pressure-flow parameters after radical prostatectomy: relation to postoperative continence status and the impact of intensity of pelvic floor muscle exercises. ***Neurourol Urodynam*** 2012; 31: 637-641.
12. Burkhard F, Lucas M, Berghmans L, Bosch J, Cruz F, Lemack G, et al. EAU Guidelines on Urinary Incontinence in Adults. In: European Association of Urology Guidelines. 2016 edition. Arhnem (NL): European Association of Urology; 2016. p. 46-50.

13. Chung B, Sommer G, Brooks J. Anatomy of the lower urinary tract and male genitalia. In: Wein A, Kavoussi L, Novick A, Partin A, Peters C, editors. Campbell-walsh urology, 10th edition. Philadelphia (PA): WB Saunders; 2012. p. 33-70.
14. Stolzenburg JU, Schwalenberg T, Horn LC, Neuhaus J, Constantinides C, Liatsikos EN. Anatomical landmarks of radical prostatecomy. ***Eur Urol*** 2007; 51: 629-639.
15. Myers RP. Detrusor apron, associated vascular plexus, and avascular plane: relevance to radical retropubic prostatectomy--anatomic and surgical commentary. ***Urology*** 2002; 59: 472-479.
16. Poore RE, McCullough DL, Jarow JP. Puboprostatic ligament sparing improves urinary continence after radical retropubic prostatectomy. ***Urology*** 1998; 51: 67-72.
17. Stolzenburg JU, Liatsikos EN, Rabenalt R, Do M, Sakelaropoulos G, Horn LC, et al. Nerve sparing endoscopic extraperitoneal radical prostatectomy--effect of puboprostatic ligament preservation on early continence and positive margins. ***Eur Urol*** 2006; 49: 103-111.
18. Yoshimura N, Chancellor MB. Physiology and pharmacology of the bladder and urethra. In: Wein A, Kavoussi L, Novick A, Partin A, Peters C, editors. Campbell-walsh urology, 10th edition. Philadelphia (PA): WB Saunders; 2012. p. 1786-1833.
19. Hakimi AA, Faleck DM, Agalliu I, Rozenblit AM, Chernyak V, Ghavamian R. Preoperative and intraoperative measurements of urethral length as predictors of continence after robot-assisted radical prostatectomy. ***J Endourol*** 2011; 25: 1025-1030.
20. Dubbelman YD, Groen J, Wildhagen MF, Rikken B, Bosch JL. Urodynamic quantification of decrease in sphincter function after radical prostatectomy: relation to postoperative continence status and the effect of intensive pelvic floor muscle exercises. ***Neurourol Urodynam*** 2012; 31: 646-651.
21. Dubbelman YD, Bosch JL. Urethral sphincter function before and after radical prostatectomy: Systematic review of the prognostic value of various assessment techniques. ***Neurourol Urodyn*** 2013; 32: 957-963.
22. Paparel P, Akin O, Sandhu JS, Otero JR, Serio AM, Scardino PT, et al. Recovery of urinary continence after radical prostatectomy: association with urethral length and urethral fibrosis measured by preoperative and postoperative endorectal magnetic resonance imaging. ***Eur Urol*** 2009; 55: 629-637.
23. Stafford RE, Ashton-Miller JA, Constantinou CE, Hodges PW. Novel insight into the dynamics of male pelvic floor contractions through transperineal ultrasound imaging. ***J Urol*** 2012; 188: 1224-1230.
24. Takenaka A, Tewari AK, Leung RA, Bigelow K, El-Tabey N, Murakami G, et al. Preservation of the puboprostatic collar and puboperineoplasty for early recovery of urinary continence after robotic prostatectomy: anatomic basis and preliminary outcomes. ***Eur Urol*** 2007; 51: 433-440.
25. Hinata N, Murakami G. The urethral rhabdosphincter, levator ani muscle, and perineal membrane: a review. ***Biomed Res Int*** 2014; 2014: 906921.
26. Takenaka A, Hara R, Soga H, Murakami G, Fujisawa M. A novel technique for approaching the endopelvic fascia in retropubic radical prostatectomy, based on an anatomical study of fixed and fresh cadavers. ***BJU Int*** 2005; 95: 766-771.
27. Rajasekaran MR, Sohn D, Salehi M, Bhargava V, Fritsch H, Mittal RK. Role of puborectalis muscle in the genesis of urethral pressure. ***J Urol*** 2012; 188: 1382-1388.
28. Soga H, Takenaka A, Murakami G, Fujisawa M. Topographical relationship between urethral rhabdosphincter and rectourethralis muscle: a better understanding of the apical dissection and the posterior stitches in radical prostatectomy. ***Int J Urol*** 2008; 15: 729-732.
29. Walz J, Burnett AL, Costello AJ, Eastham JA, Graefen M, Guillonneau B, et al. A critical analysis of the current knowledge of surgical anatomy related to optimization of cancer control and preservation of continence and erection in candidates for radical prostatectomy. ***Eur Urol*** 2010; 57: 179-192.
30. Sohn DW, Hong CK, Chung DJ, Kim SH, Kim SJ, Chung J, et al. Pelvic floor musculature and bladder neck changes before and after continence recovery after radical prostatectomy in pelvic MRI. ***J Magn Reson Imaging*** 2014; 39: 1431-1435.
31. Hinata N, Sejima T, Takenaka A. Progress in pelvic anatomy from the viewpoint of radical prostatectomy. ***Int J Urol*** 2013; 20: 260-270.
32. Kojima Y, Takahashi N, Haga N, Nomiya M, Yanagida T, Ishibashi K, et al. Urinary incontinence after robot-assisted radical prostatectomy: pathophysiology and intraoperative techniques to improve surgical outcome. ***Int J Urol*** 2013; 20: 1052-1063.
33. Bianco FJ Jr, Riedel ER, Begg CB, Kattan MW, Scardino PT. Variations among high volume surgeons in the rate of complications after radical prostatectomy: further evidence that technique matters. ***J Urol*** 2005; 173: 2099-2103.
34. Freire MP, Weinberg AC, Lei Y, Soukup JR, Lipsitz SR, Prasad SM, et al. Anatomic bladder neck preservation during robotic-assisted laparoscopic radical prostatectomy: description of technique and outcomes. ***Eur Urol*** 2009; 56: 972-980.
35. Lee DI, Wedmid A, Mendoza P, Sharma S, Walicki M, Hastings R, et al. Bladder neck plication stitch: A novel technique during robot-assisted radical prostatectomy to improve recovery of urinary continence. ***J Endourol*** 2011; 25: 1873-1877.
36. Schlomm T, Heinzer H, Steuber T, Salomon G, Engel O, Michl U, et al. Full functional-length urethral sphincter preservation during radical prostatectomy. ***Eur Urol*** 2011; 60: 320-329.
37. Lee SE, Byun SS, Lee HJ, Song SH, Chang IH, Kim YJ, et al. Impact of variations in prostatic apex shape on early recovery of urinary continence after radical retropubic prostatectomy. ***Urology*** 2006; 68: 137-141.
38. Kozacioglu Z, Ceylan Y. The influence of membranous stretched urethral length and urethral circumference on postoperative recovery of continence after radical prostatectomy: A pilot study. ***Can Urol Assoc J*** 2015; 9: E638.
39. Campenni MA, Harmon JD, Ginsberg PC, Harkaway RC. Improved continence after radical retropubic prostatectomy using two pubo-urethral suspension stitches. ***Urol Int*** 2002; 68: 109-112.
40. Jones JS, Vasavada SP, Abdelmalak JB, Liou L, Ahmed ES, Zippe CD, et al. Sling may hasten return of continence after radical prostatectomy. ***Urology*** 2005; 65: 1163-1167.
41. Patel VR, Coelho RF, Palmer KJ, Rocco B. Periurethral suspension stitch during robot-assisted laparoscopic radical prostatectomy: description of the technique and continence outcomes. ***Eur Urol*** 2009; 56: 472-478.
42. Park R, Martin S, Goldberg JD, Lepor H. Anastomotic strictures following radical prostatectomy: insights into incidence, effectiveness of intervention, effect on continence, and factors predisposing to occurrence. ***Urology*** 2001; 57: 742-746.
43. Rocco B, Cozzi G, Spinelli MG, Coelho RF, Patel VR, Tewari A, et al. Posterior musculofascial reconstruction after radical prostatectomy: a systematic review of the literature. ***Eur Urol*** 2012; 62: 779-790.
44. Rocco F, Carmignani L, Acquati P, Gadda F, Dell'Orto P, Rocco B, et al. Restoration of posterior aspect of rhabdosphincter shortens continence time after radical retropubic prostatectomy. ***J Urol*** 2006; 175: 2201-2206.

45. Tewari A, Jhaveri J, Rao S, Yadav R, Bartsch G, Te A, et al. Total reconstruction of the vesico-urethral junction. ***BJU Int*** 2008; 101: 871-877.
46. Costello AJ, Brooks M, Cole OJ. Anatomical studies of the neurovascular bundle and cavernosal nerves. ***BJU Int*** 2004; 94: 1071-1076.
47. John H, Hauri D. Seminal vesicle-sparing radical prostatectomy: a novel concept to restore early urinary continence. ***Urology*** 2000; 55: 820-824.
48. Finley DS, Osann K, Skarecky D, Ahlering TE. Hypothermic nerve-sparing radical prostatectomy: rationale, feasibility, and effect on early continence. ***Urology*** 2009; 73: 691-696.
49. Finley DS, Osann K, Chang A, Santos R, Skarecky D, Ahlering TE. Hypothermic robotic radical prostatectomy: impact on continence. ***J Endourol*** 2009; 23: 1443-1450.
50. Pick DL, Osann K, Skarecky D, Narula N, Finley DS, Ahlering TE. The impact of cavernosal nerve preservation on continence after robotic radical prostatectomy. ***BJU Int*** 2011; 108: 1492-1496.
51. Stolzenburg JU, Kallidonis P, Do M, Dietel A, Häfner T, Rabenalt R, et al. A comparison of outcomes for interfascial and intrafascial nerve-sparing radical prostatectomy. ***Urology*** 2010; 76: 743-748.
52. Kay L, Bertelsen M. Bladder symptoms among polio survivors. ***J Rehabil Med*** 2013; 45: 560-564.
53. Stolwijk-Swüste JM, Beelen A, Lankhorst GJ, Nollet F; CARPA Study Group. The course of functional status and muscle strength in patients with late-onset sequelae of poliomyelitis: a systematic review. ***Arch Phys Med Rehabil*** 2005; 86: 1693-1701.
54. Ficarra V, Novara G, Fracalanza S, D'Elia C, Secco S, Iafrate M, et al. A prospective, non-randomized trial comparing robot-assisted laparoscopic and retropubic radical prostatectomy in one European institution. ***BJU Int*** 2009; 104: 534-539.
55. Rocco B, Matei DV, Melegari S, Ospina JC, Mazzoleni F, Errico G, et al. Robotic vs open prostatectomy in a laparoscopically naive centre: a matched-pair analysis. ***BJU Int*** 2009; 104: 991-995.
56. Krambeck AE, DiMarco DS, Rangel LJ, Bergstralh EJ, Myers RP, Blute ML, et al. Radical prostatectomy for prostatic adenocarcinoma: a matched comparison of open retropubic and robot-assisted techniques. ***BJU Int*** 2009; 103: 448-453.
57. Ahlering TE, Woo D, Eichel L, Lee DI, Edwards R, Skarecky DW. Robot-assisted versus open radical prostatectomy: a comparison of one surgeon's outcomes. ***Urology*** 2004; 63: 819-822.
58. Geraerts I, Van Poppel H, Devoogdt N, Van Cleynenbreugel B, Joniau S, Van Kampen M. Prospective evaluation of urinary incontinence, voiding symptoms and quality of life after open and robot-assisted radical prostatectomy. ***BJU Int*** 2013; 112: 936-943.
59. O'Neil B, Koyama T, Alvarez J, Conwill RM, Albertsen PC, Cooperberg MR, et al. The comparative harms of open and robotic prostatectomy in population based samples. ***J Urol*** 2016; 195: 321-329.
60. Lucas M, Bedretdinova D, Berghmans L, Bosch J, Burkhard F, Cruz F, et al. Guidelines on urinary incontinence. In: EAU Guidelines, 2015 edition. Arnhem (NL): European Association of Urology; 2015. p. 23-24.
61. Filocamo MT, Li Marzi V, Del Popolo G, Cecconi F, Marzocco M, Tosto A, et al. Effectiveness of early pelvic floor rehabilitation treatment for post-prostatectomy incontinence. ***Eur Urol*** 2005; 48: 734-738.
62. Ribeiro LH, Prota C, Gomes CM, de Bessa J Jr, Boldarine MP, Dall'Oglio MF, et al. Long-term effect of early postoperative pelvic floor biofeedback on continence in men undergoing radical prostatectomy: a prospective, randomized, controlled trial. ***J Urol*** 2010; 184: 1034-1039.
63. Glazer HI, Laine CD. Pelvic floor muscle biofeedback in the treatment of urinary incontinence: a literature review. ***Appl Psychophysiol Biofeedback*** 2006; 31: 187-201.
64. Overgård M, Angelsen A, Lydersen S, Mørkved S. Does physiotherapist-guided pelvic floor muscle training reduce urinary incontinence after radical prostatectomy? A randomised controlled trial. ***Eur Urol*** 2008; 54: 438-448.
65. Moore KN, Valiquette L, Chetner MP, Byrniak S, Herbison GP. Return to continence after radical retropubic prostatectomy: a randomized trial of verbal and written instructions versus therapist-directed pelvic floor muscle therapy. ***Urology*** 2008; 72: 1280-1286.
66. Burgio KL, Goode PS, Urban DA, Umlauf MG, Locher JL, Bueschen A, et al. Preoperative biofeedback assisted behavioral training to decrease post-prostatectomy incontinence: a randomized, controlled trial. ***J Urol*** 2006; 175: 196-201.
67. Centemero A, Rigatti L, Giraudo D, Lazzeri M, Lughezzani G, Zugna D, et al. Preoperative pelvic floor muscle exercise for early continence after radical prostatectomy: a randomised controlled study. ***Eur Urol*** 2010; 57: 1039-1043.
68. Tienforti D, Sacco E, Marangi F, D'Addessi A, Racioppi M, Gulino G, et al. Efficacy of an assisted low-intensity programme of perioperative pelvic floor muscle training in improving the recovery of continence after radical prostatectomy: a randomized controlled trial. ***BJU Int*** 2012; 110: 1004-1010.
69. Geraerts I, Van Poppel H, Devoogdt N, Joniau S, Van Cleynenbreugel B, De Groef A, et al. Influence of preoperative and postoperative pelvic floor muscle training (PFMT) compared with postoperative PFMT on urinary incontinence after radical prostatectomy: a randomized controlled trial. ***Eur Urol*** 2013; 64: 766-772.
70. Zhu YP, Yao XD, Zhang SL, Dai B, Ye DW. Pelvic floor electrical stimulation for postprostatectomy urinary incontinence: a meta-analysis. ***Urology*** 2012; 79: 552-555.
71. Goode PS, Burgio KL, Johnson TM 2nd, Clay OJ, Roth DL, Markland AD, et al. Behavioral therapy with or without biofeedback and pelvic floor electrical stimulation for persistent postprostatectomy incontinence: a randomized controlled trial. ***JAMA*** 2011; 305: 151-159.
72. Chang JI, Lam V, Patel MI. Preoperative pelvic floor muscle exercise and postprostatectomy incontinence: A systematic review and meta-analysis. ***Eur Urol*** 2016; 69: 460-467.
73. Filocamo MT, Li Marzi V, Del Popolo G, Cecconi F, Villari D, Marzocco M, et al. Pharmacologic treatment in postprostatectomy stress urinary incontinence. ***Eur Urol*** 2007; 51: 1559-1564.
74. Bianco FJ, Albala DM, Belkoff LH, Miles BJ, Peabody JO, He W, et al. A randomized, double-blind, solifenacin succinate versus placebo control, phase 4, multicenter study evaluating urinary continence after robotic assisted radical prostatectomy. ***J Urol*** 2015; 193: 1305-1310.