Pelvic Anatomical Changes Caused by Radical Prostatectomy

Subjects: Urology & Nephrology

Contributor: Yoshifumi Kadono, Takahiro Nohara, Shohei Kawaguchi, Hiroaki Iwamoto, Hiroshi Yaegashi, Kazuyoshi Shigehara, Kouji Izumi, Atsushi Mizokami

After radical prostatectomy, the pelvic anatomy is altered such that the postoperative structure differs from the preoperative one, resulting in a variety of complications. In this review, the complications and mechanisms of pelvic anatomical changes associated with radical prostatectomy, as well as countermeasures, are outlined. An analysis of the anatomical mechanisms that cause complications after radical prostatectomy using imaging and other modalities is in progress. In addition, many surgical techniques that ensure the prevention of postoperative complications have been reported, and their usefulness has been evaluated. The preservation of as much periprostatic tissue and periprostatic structures as possible may lead to favorable postoperative functions, as long as the cancer condition permits.

Keywords: anatomy ; complications ; prostate cancer ; radical prostatectomy

1. Erectile Dysfunction after Radical Prostatectomy

1.1. Pathophysiology and Anatomy of Erectile Function

Erection is caused by hyperemia in the penile corpus cavernosum, which is intricately controlled by nerves and blood flow. Blood flow to the penis is supplied primarily from branches of the internal pudendal artery (IPA), which are cavernous arteries and helicine arteries involved in erection. [1]. The first step in penile erection is tumescence that occurs following vasodilation of the arteries and simultaneous relaxation of the sinusoidal smooth muscle. The second step is veno-occlusion and rigidity which occur due to an increased pressure compressing the emissary veins against the tunica albuginea [1].

The nerves involved in erection are reported to form a mesh-like network around the prostate gland, forming a plate-like structure [2]. An MRI study in a pre-radical prostatectomy (RP) case reported that more than two-thirds of the nerve fibers are located in the posterolateral area, while the rest are located in the anterolateral and anterior position [3]. In addition, immunostaining of nerve fibers using RP specimens reported that 25% of all nerves were located in the anterolateral and anterior section of the prostate, suggesting that nerve damage is inevitable during RP, although it depends on the degree of nerve-sparing (NS). It is thought that nerve damage is inevitable during RP [4].

1.2. Surgical Technique including Nerve Sparing

Walsh et al. first reported an NS technique, assuming that the main cause of erectile dysfunction (ED) is damage to the nerve plexus around the prostate [5]. Robotic surgery with high-resolution endoscopes and articulated forceps has the advantage of allowing a detailed work in the narrow pelvis, and several meta-analyses have reported the advantage of preserving the erectile function over open or conventional laparoscopic RP (LRP) [6][7][8]. It has also been reported that robot-assisted RP (RARP) can provide appropriate functional preservation depending on the cancer status by using multiple levels of NS such as intrafascial, interfascial, and extrafascial approaches [9][10]. Tewari et al. described four levels of nerve preservation using the external prostatic venous plane as the index [11].There was a significant difference across different NS grades in terms of the percentages of patients who had intercourse and returned to baseline sexual function, with those that underwent NS grade 1 having the highest rates (90.9% and 81.7%) as compared to patients who received NS grades 2 (81.4% and 74.3%), 3 (73.5% and 66.1%), and 4 (62% and 54.5%) [11].

2. Urinary Incontinence after Radical Prostatectomy

2.1. Pelvic Anatomy Affecting Urinary Incontinence after Radical Prostatectomy

The urethral sphincter is present distal to the prostatic apex and penetrates the pelvic floor muscles from the intra- and extra pelvic spaces, and the urethral sphincter itself is independent of the pelvic floor muscles [12]. The urethral sphincter has two layers: an inner layer composed of smooth muscle and an outer layer composed of striated muscle [13]. Outer rhabdomyoid fibers are omega-shaped and extend to the prostatic apex and anterior surface of the prostate [12][14][15]. The supporting structures of the male urethra can be divided into two main groups: anterior and posterior. The anterior urethral support structures include the pubourethral ligaments, comprising the pubovesical ligament, the puboprostatic ligament, and the tendinous arch of the pelvic fascia. These ligaments help stabilize the position of the bladder neck and external sphincter complex and anchor the membranous urethra to the pubic bone [16]. The posterior support consists of the perineal body (central perineal tendon), Denonvillier's fascia, the rectourethralis muscle, and the levator ani complex [17][18]. The pelvic floor is formed by the levator ani muscle and its surrounding fascia, and although it is not directly connected to the urethra that penetrates it, it is thought to play an important role in urinary continence, especially under applied abdominal pressure, due to the urethral closure mechanism from outside the urethra [19].

2.2. Mechanism of Urinary Incontinence after Radical Prostatectomy

After RP, the supporting tissues near the urethra are damaged by the removal of the prostate. This damage is thought to increase the likelihood of stress urinary incontinence, primarily due to urethral sphincter dysfunction [20][21][22][23]. Bladder function has also been implicated in urinary incontinence after RP, with adverse effects due to detrusor overactivity and decreased bladder compliance [24]. When considering urinary continence mechanisms, it may be better to consider the resting situation and the situation under applied abdominal pressure separately. A urodynamic study before and after RP reported that the maximum urethral closure pressure at rest was reduced to about 40% of the preoperative pressure immediately after RP [25][26][27][28]. Subsequently, 1 year postoperatively, the maximum urethral closure pressure had improved, but not to preoperative levels, remaining at 80% of the preoperative level [26][27][28]. The following mechanisms have been reported to explain why urethral closure pressure decreases immediately after RP and improves over time [28]. As reported for the mechanisms of penile shortening, the vesicourethral anastomosis causes the membranous urethra and urogenital diaphragm to be pulled cephalad after RP. To maintain maximum urethral closure pressure, the urogenital diaphragm, which compresses the urethra from the outside, must be in the proper position, which is probably usually the position before RP. After RP, the urethral closure pressure is expected to gradually recover as the vesicourethral anastomosis returns to its preoperative position over time [28]. During applied abdominal pressure, the pressure in the bladder increases, but at the same time the urethral closure mechanism causes an increase in the pressure in the urethra, which does not cause urinary incontinence. Urethroscopic observations revealed a shutter-like closure of the sphincter urethra in the anteroposterior direction of the body axis during abdominal pressure [14]. The mechanism of urethral closure during abdominal pressure has been observed in the pre-RP state, as well as in studies using transperineal ultrasound and dynamic MRI.

2.3. Maximum Urethral Preservation

A systematic review and meta-analysis reported that a preoperative long membranous urethral measured by MRI is favorable for urinary continence after RP [29]. It has also been reported that preserving the urethra as long as possible at the time of RP is advantageous for postoperative urinary continence [15][28][30]. The continence rates were 50.1% with full functional urethra preservation and 30.9% with the standard method 1 week after catheter removal (p < 0.0001) [15]. The two layers of muscle covering the urethral mucosa are thought to be associated with the generation of urethral closure pressure, and the longer the residual urethral length, the higher the urethral closure pressure, which may be advantageous for urinary continence [13].

2.4. Nerve-Sparing Procedure

Originally developed to preserve the erectile function, this NS technique has also been reported to provide excellent results in postoperative urinary continence [31][32]. Meta-analysis results show a consistent trend toward better urinary continence in patients undergoing NS up to 2 years postoperatively, with significantly less urinary incontinence reported with NS, especially in the early postoperative period up to 6 months postoperatively [33]. It has also been reported that the higher the grade of NS (dissecting the prostate in a line close to the prostate), the better the early postoperative urinary continence with a four-step NS technique. Return of continence ≤12 week postoperatively was achieved by 791 of 1417 men (55.8%); of those, 199 of 277 (71.8%) received NS grade 1, 440 of 805 (54.7%) NS grade 2, 132 of 289 (45.7%) NS grade 3, and 20 of 46 (43.5%) NS grade 4 [34]. There is some debate as to why postoperative urinary continence is better with NS, whether it is more important that the periprostatic nerves remain or that the periprostatic structures remain. During prostatectomy, the nerves around the prostate are damaged by the dissection maneuver, and it often takes time for the erectile function to return. It has been reported that the maximum urethral closure pressure was higher immediately after surgery in the case group receiving NS than in the case group without NS, suggesting that the preservation of as much peri-prostatic structure as possible may have a superior effect on urinary continence rather than the effect of the nerve itself [27].

2.5. Retzius Sparing Procedure

The Retzius-sparing procedure reported by Galfano et al. involves a transabdominal approach through the Douglas fossa and the removal of the prostate and vesicourethral anastomosis through this incision [35]. This technique leaves more periprostatic structures, including the anterior bladder lumen, than previously developed approaches, and better postoperative urinary continence has been reported compared to conventional methods [36][37][38]. Lee et al. reported that the continence recovery rate defined as the use of less than one safety liner per day in conventional and Retzius-sparing cases month 1 postoperatively was 9.0% and 45%, respectively, and by month 6 postoperatively, it was 77% and 98%, respectively [38]. In the Retzius-sparing procedure, the anterior wall of the bladder is not dissected, and after vesicourethral anastomosis, the anterior bladder wall is fixed in the same high position as before RP, without falling into the pelvis. This may be one of the reasons why the Retzius-sparing procedure is good for postoperative urinary continence, as it seems to work well for the urinary continence mechanism during abdominal pressure [39]. In the conventional anterior prostatic approach, the vesicourethral anastomosis is thought to be pulled cephalad dorsally by the vascular pedicle of the bladder and the surrounding connective tissue. In the Retzius-sparing procedure, the anterior bladder wall is fixed in a higher position, which is thought to increase the force of traction of the vesicourethral anastomosis in the cephaloventral direction, which in turn increases the force to compress and drain the membranous urethra in the pubic bone direction and also maintains a high resting urethral closure pressure[39]. Although transperineal RP does not open the anterior bladder space as the Retzius-sparing procedure, early urinary continence is reported to be inferior to that of conventional transabdominal RARP, possibly due to damage to the pelvic floor muscle complex that provides the pathway to the prostate gland [40]. Depending on the state of the cancer, a combination of techniques such as Retzius-sparing procedure, NS, and maximum urethral preservation may additively prevent the worsening of postoperative urinary continence [39].

2.6. Anterior and Posterior Reconstruction

Anatomically, the periurethral rabdosphincter is continuous dorsally to the median fibrous raphe and central tendon of the perineum, and further dorsally superiorly to the Denonvilliers' fascia [41]. These structures are thought to form a dynamic lifting system that helps to contract the urethral sphincter, which is destroyed during prostatectomy. Rocco et al. reported that the reconstruction of these structures (posterior reconstruction) is effective in early urinary continence [14][42]. Tewari et al. reported that preservation of the puboprosthetic ligament and puboperineal muscle, re-fixation of the puboprosthetic ligament and vesicourethral anastomosis, and re-fixation of the bladder neck and tendinous arch (anterior reconstruction) are effective for early urinary continence [43]. Validation by randomized controlled trials (RCTs) has since been reported for these techniques. Two RCTs that tested the efficacy of posterior reconstruction in RARPs found no predominant improvement in the time taken for urinary continence recovery [44][45]. Another study reported that only the duration of improvement to 1 pad per day with posterior reconstruction was significantly shorter [46]. A RARP of an extraperitoneal approach to urinary continence reported that an RCT of an additional anterior suspension technique to the pubic periosteum alone was not effective for urinary continence [47]. In an RCT of open RP series of this anterior suspension combined with posterior reconstruction, the authors reported that urinary continence was better in the reconstruction group 1 and 3 months postoperatively, although there was no significant difference in urinary continence 6 months postoperatively [48]. An RCT comparing the combinations of anterior and posterior reconstructions with conventional techniques reported no advantage in urinary continence [49]. On the other hand, an RCT on the usefulness of the Advanced Reconstruction of the Vesico-Urethral Support (ARVUS) technique with strict posterior–anterior wall reconstruction reported better urinary continence than that achieved with conventional posterior wall reconstruction up to 1 year postoperatively when no pads were used to assess urinary continence [50]. Although there was no clear advantage of anterior and posterior reconstruction with respect to urinary continence, posterior wall reconstruction may be performed by many surgeons because the tension on the vesicourethral anastomosis is relieved by posterior reconstruction, which makes the vesicourethral anastomosis easier, and is expected to decrease the incidence of urinary bladder anastomosis failure [49].

3. Inguinal Hernia

Mechanisms and Risk Factors for the Development of Inguinal Hernia

An increased incidence of inguinal hernia (IH) has been reported after RP, with most cases occurring within 2–3 years after surgery [51]. The incidence of IH was reported to be significantly higher in the RP group (11.7% vs. 3.3%) in a meta-analysis between open and no treatment groups, and by surgical technique, with 13.7% for open RP, 7.5% for LRP, and 7.9% for RARP and a higher incidence after open RP [51]. Based on previous reports, the mechanism of IH after RP is speculated to be as follows: anatomic changes due to reattachment to the pelvic wall that occur after lower abdominal incision, opening of the Retzius space, and vesicourethral anastomosis associated with prostatectomy may contribute to the development of IH. In addition, the reported increased incidence of IH after pelvic lymph node dissection or cystectomy with lower abdominal incision suggests that external migration of the internal inguinal ring due to adhesions after lower abdominal incision may also be a factor in the development of IH [52][53]. Intra-abdominal observation during laparoscopic hernia repair shows scar contraction of the intra-abdominal wall at Hesselbach's triangle and opening of the internal inguinal ring in the internal inguinal region [54]. In perineal RP and RS-RARP, the Retzius space is not opened, so the abdominal wall changes associated with reattachment do not occur. Therefore, IH due to the medial migration of tissue around the internal inguinal ring does not occur after vesicourethral anastomosis, and therefore the frequency of IH does not increase [55][56]. Risk factors for IH after RP have been reported to include older age, low body mass index (BMI), and high International Prostate Symptom Score (IPSS) [56][57][58].

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