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H. Heinzer · P.G. Hammerer · H. Huland

Anatomy and physiology of the male urethral sphincter and its preservation in prostatic surgery

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Abstract Radical prostatectomy is commonly used in the management of localized prostate cancer. Urinary incontinence after prostatectomy is of great concern to many patients. Improved understanding of the anatomy of the external urethral sphincter complex has resulted in a statistically significant decrease in the incidence of postprostatectomy incontinence. Most recent anatomic studies have described the external urethral sphincter complex as consisting of an intrinsic rhabdosphincter surrounding the smooth musculature of the urethra and an extrinsic sphincter incorporating the levator ani muscle and the pelvic floor. Both form a condensed striated muscle ring around the membranous urethra. Preservation of as much as possible of the normal anatomy of the sphincter mechanism and its nerve supply results in an excellent return to continence after radical prostatectomy.

Key words Prostatectomy · Urinary incontinence · Anatomy · External urethral sphincter

Introduction

Prostate cancer is the most commonly diagnosed cancer and the second leading cause of cancer in American men. An estimated 39,200 men died of prostate cancer in 1998 [15]. There has been a sharp increase in the number of radical prostatectomies throughout the United States and Europe in recent years [18]. Most urologists believe that radical prostatectomy presents the highest probability of complete cure of localized prostate cancer. Although operative mortality is low, reportedly less than 0.5% [28], treatment-related morbidity can profoundly affect the quality of life after surgery. An important drawback for many patients is the risk of urinary incontinence. The frequency and degree of this adverse event can vary substantially; it is seen in 5 to 16% of patients [9]. Although some risk factors (age, nerve-sparing technique, prior transurethral resection of the prostate, prostate weight, neurologic disorders, unstable bladder, and radiation therapy) [9] might affect postoperative urinary incontinence, the precise etiology of postprostatectomy urinary incontinence is unclear. Most of the recent urodynamic and anatomic studies implicated bladder neck dysfunction, external sphincter damage, damage to the pelvic musculature, and the denervation of the continence mechanism as causes of urinary incontinence after radical prostatectomy. Improved understanding of the anatomy and physiology of the periprostatic region resulted in a decrease in the incidence of postprostatectomy urinary incontinence. We reviewed the contemporary literature for anatomic studies in basic mechanisms that allow urinary control in men and current concepts for promoting continence after radical prostatectomy. Our conclusions are based on a combination of literature research, our own experience in about 1200 radical retropubic prostatectomies since 1988, and investigation of six male cadavers by dissection of the pelvic region.

H. Heinzer (✉) · P.G. Hammerer · H. Huland
Department of Urology,
University Hospital Eppendorf,
Martinistrasse 52, 20246 Hamburg, Germany
e-mail: heinzer@uke.uni-hamburg.de
Tel.: +49 40 42803-3443; Fax: 49 40 42803-4662

Anatomy of the prostate and the urethral sphincter mechanism

The striated sphincter of the male urethra, the rhabdosphincter, is the subject of controversy in the literature. There are two standard concepts of rhabdosphincter anatomy. In the first, presented by Henle in 1866 [10] and reinforced by other investigators [3, 19, 20, 23, 26], the sphincteric muscle fibers extend from the base of the bladder to the perineal membrane ventrally and from the prostate to the perineal membrane dorsally.

The second concept described the external striated urethral sphincter as part of the urogenital diaphragm and was widely illustrated and accepted [22], but recent ultrastructural and immunohistochemical studies could not confirm the existence of a urogenital diaphragm [2, 3]. Reconstruction of the male pelvic anatomy from the Visible Human data set [2] depicted the striated urethral sphincter as extending from the perineal membrane to the apex of the prostate and confirmed first concept.

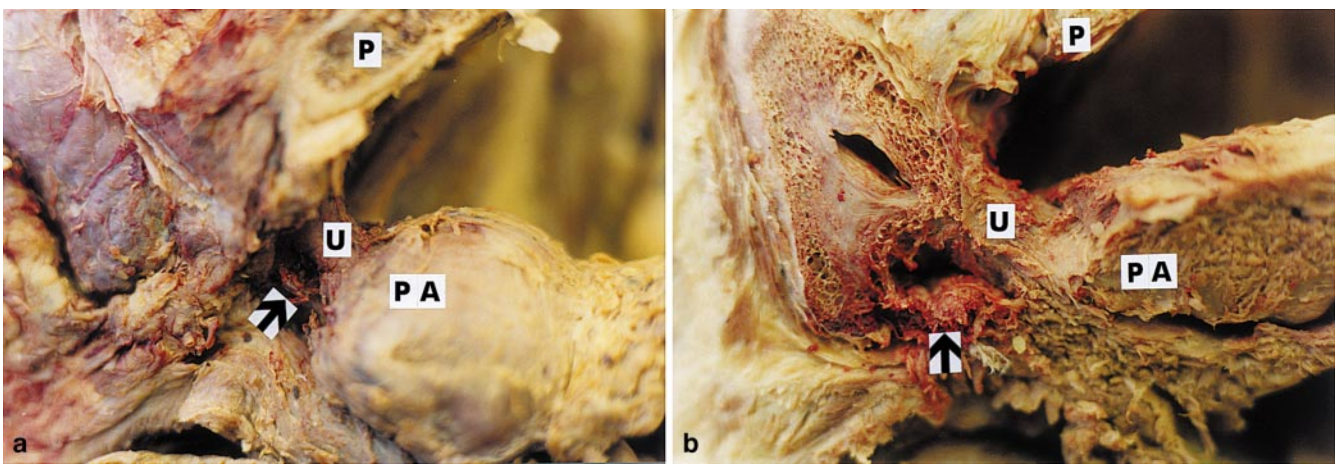
Burnett and Mostwin [3] recently described the human male urethral sphincter mechanism as a complex of multiple pelvic structures and not as a function of the rhabdosphincter alone. The whole complex works more as a "compressor" of the urethra then as a single sphincter function. They identified the male urethral sphincter complex as consisting of the prostatomembranous urethra, periurethral musculature (rhabdosphincter), and extrinsic paraurethral musculature and connective tissue structures of the pelvis. The cylindrical rhabdosphincter surrounding the prostatomembranous urethra was contained by a ligamentous framework. In the ventral aspect, these ligaments have been described as pubourethral ligaments [1, 25]. The male urethral suspensory mechanism of the pubourethral ligaments supports the proximal and membranous urethra, including the striated external urinary sphincter complex [25]. Laterally, Burnett and Mostwin [3] found a confluence of the ligamentous framework with the medial fascia of the levator ani; dorsally, they found a midline fibrous raphe as an anchor for the sphincter with the Denonvilliers'fascia. These findings, consistent with those of others [2, 7, 13, 20] indicate an important role for the levator ani in the male urethral sphincter complex. In an anatomic study using magnetic resonance imaging, Meyers and co-workers [20] found that the medial part of the levator consisted of a muscle that passed posterolaterally to the urethra. They termed the most medial, anterior component of the right and left sides of the levator the musculus puboperinealis. The puboperinealis appears to be what others have described as the levator prostatae, Wilson muscle, levator urethrae, or pubourethralis [20]. In our own cadaveric study, dissection demonstrated a sling of levator ani muscles from the pubis to the perineal body posterior to the prostatomembranous urethra (Figs. 1a, b and 2). Reconstructions from the Visible Human data set confirm these observations [2].

A distinctive pattern of musculature forms the urethral spincter complex. The external sphincter consists of a single population of type I (slow-twitch) fibers. In contrast, the levator ani contains type II (fast-twitch) fibers [5]. Those findings indicate that the rhabdosphincter is functionally adapted to maintain tone over long periods. Characteristics of the levator ani muscle fibers suggest that they actively assist in urethral closure during events that cause increased intra-abdominal pressure. Elbadawi et al. [5] demonstrated mixed slow and fast fibers in the prostatic capsule as components of the urethral sphincter system. They suggested that the capsular part of the rhabdosphincter has a role in the mechanism of urinary continence, in keeping the urethra closed during the filling phase, and in rapid responses to sudden increases in intra-abdominal pressure. During apical dissection in radical prostatectomy, the prostatocapsular component of the sphincter complex will be damaged; this could be a reason for postprostatectomy leakage of urine under stress (Fig. 3).

Innervation of the rhabdosphincter of the male urethra

The innervation of the external sphincteric muscles is a subject of some debate. Results of animal studies suggest that the external urethral sphincter is innervated by a combination of autonomic nerves via the pelvic plexus and somatic nerves via the pudendal nerve [27]. In contrast, Donker et al. [4] could find no somatic innervation of the external sphincter via pudendal nerve in humans. Recent neuroanatomic studies [11, 13, 26] have demonstrated both autonomic and somatic innervation.

Fig. 1a, b Preparation of the prostatic apex and prostatomembranous urethra in a cadaveric study showing the medial part of the levator ani, the musculus puboperinealis [20], forming sling of levator ani muscles (*arrow*) from the pubis to the perineal body posterior to the prostatomembranous urethra. *PA* prostatic apex. *U* prostatomembranous urethra. *P* pubis



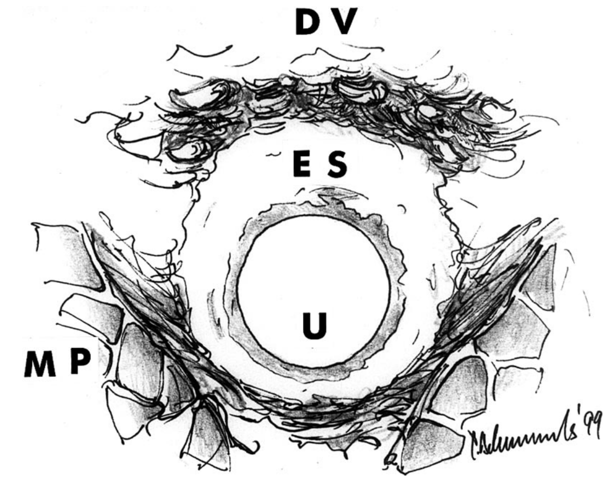


Fig. 2 Schematic transverse view of the male sphincter complex perpendicular to axis of prostatomembranous urethra immediately distal to prostate apex. Medial part of levator ani (musculus puboperinealis) passed posterolateral to the urethra. *DV* deep dorsal vein complex. *ES* external striated urethral sphincter. *MP* musculus puboperinealis (medial part of levator ani). *U* urethra

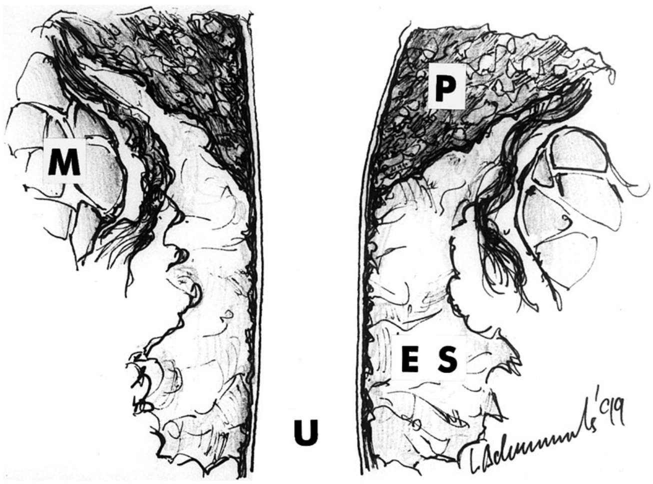


Fig. 3 Schematic coronal view of prostate apex showing a prostato-capsular component of sphincter complex, which could be damaged during apical dissection in radical prostatectomy. *ES* external striated urethral sphincter, *M* musculus puboperinealis (medial part of the levator ani), *U* urethra, *P* prostate

Narayan et al. [21] showed that the external urethral sphincter is innervated in part through special branches from the dorsal nerve of the penis after it splits from the pudendal nerve. The branches were 0.3–1.3 cm from the prostatic apex. Injury to those nerves during radical prostatectomy could explain several features of post-prostatectomy urinary incontinence. The nerve branches described are most likely sensory. Sensory innervation of the external sphincter is essential for the reflex activity of the external sphincter because the sensory fibers constitute the afferent pathway for sphincter reflex arc. The loss of the sensory pathway of the reflex arc could also explain why leakage is greater during sleep in minimal postprostatectomy incontinence. Several investigators have described careful neuroanatomic dissections of the prostate and external urethral sphincter [11, 13, 16, 21, 24, 26] with identification of nerve fibers in relation to the urethral sphincter complex, but it has yet to be resolved whether these nerves innervate corporeal or rhabdo-sphincter tissue.

Conclusion

It is generally believed that to maintain continence it is essential to preserve as much as possible of the urethra and its surrounding musculature immediately distal to the apex of the prostate. The structural components surrounding the rhabdosphincter suggest a mechanism whereby the complex is suspended and stabilized within the deep pelvis and achieves urethral closure [3]. The anatomic basis of male urinary continence has primary importance in the effort to preserve urinary function after radical prostatectomy. Improved understanding of the anatomy of the external urethral sphincter complex has already resulted in a substantial decrease in the incidence of postprostatectomy incontinence. Eastham et al. [6] showed that preservation of periurethral tissue distal to the apex as a result of a microsurgical technique could have a profound effect on recovery of continence after radical prostatectomy. Wide resection of one bundle resulted in a substantial decrease in recovery of continence in this series. It is unclear whether preservation of the neurovascular bundles themselves or the meticulous dissection required to dissect the nerves from the apex of the prostate is responsible for the improvement in continence after 'nerve-sparing' surgery.

Division of the urethra from the apex of the prostate might be important for postoperative continence. An increase in functional urethral length associated with a surgical technique to preserve periurethral tissue leads to improved continence. Urodynamic studies in postprostatectomy patients showed a statistically significant shorter functional profile in incontinent men [8]. However, preserving periurethral tissue near the apex of the prostate to maximize the length of the urethral sphincter and achieve a lower rate of postoperative incontinence should be judged in the light of positive margin rates. A low positive surgical margin rate should be considered one of the major goals in radical prostatectomy.

Lowe [17] reported that preservation of the anterior urethral attachments results in improved urinary continence without an increase in positive surgical margins.

Putative continence nerves were preserved by Hollabaugh et al. [12] during radical prostatectomy. In previous studies, putative continence nerves were demonstrated to enter the rhabdosphincter at the 5 and 7 o'clock positions [11]. During radical retropubic prostatectomy, surgical maneuvers that avoid injury of the continence nerves resulted in more rapid return of urinary control than in a control group.

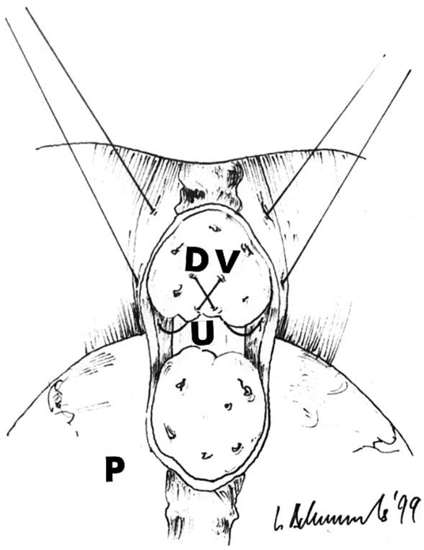


Fig. 4 After dorsal vein complex is divided sharply distal to apex of prostate, bleeding of deep dorsal vein complex is controlled without damaging sphincter complex with a suture entering the Müller's ligament directed to the midline of the plexus and kept tight. *DV* deep dorsal vein complex, *P* prostate, *U* urethra

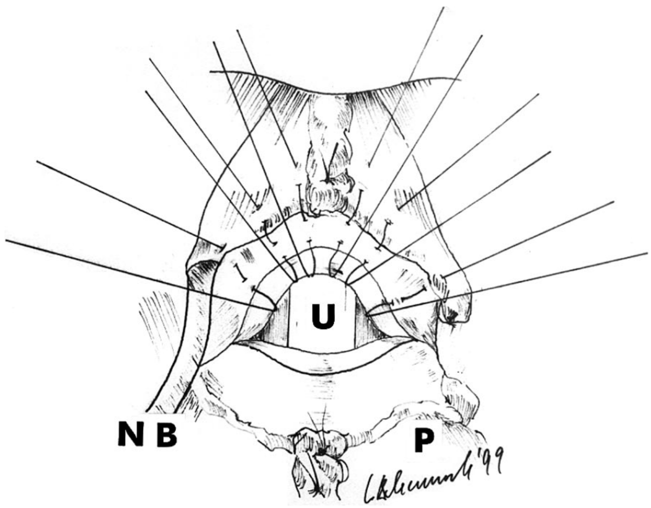


Fig. 5 View of urethra at prostate apex. Anastomotic sutures include only lateral pelvic fascia and urethral mucosa. External sphincter is positioned outside suture and preserved intact. *NB* neurovascular bundle, *U* urethral catheter, *P* prostate

Like others [6, 14] we believe that control of the deep dorsal vein complex without affecting the rhabdosphincter is of primary importance for postprostatectomy continence. After cutting the puboprostatic ligaments, we place a suture in the dorsal surface close to the base of the prostate to prevent back-bleeding. For direct control of the dorsal vein complex, another suture is placed so that the needle enters Müller's ligament and is directed to the midline of the plexus and tightened. The suture is not cut and is used for the other side in the same way. This technique does not compromise the

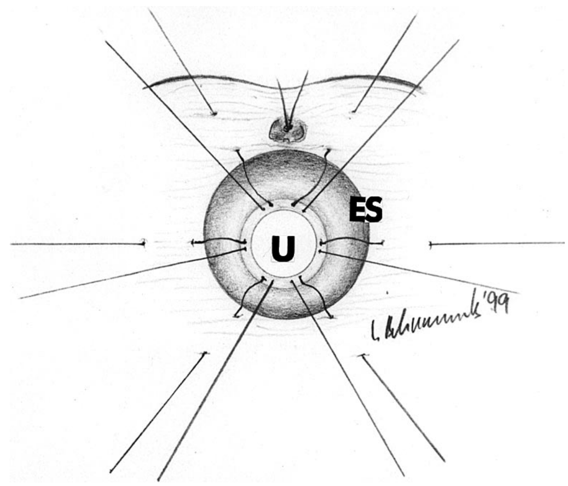


Fig. 6 Close view of urethra at prostate apex. Anastomotic sutures were placed at 1, 3, 5, 7, 9, and 11 o'clock positions. The sutures were anchored to lateral pelvic fascia, and external sphincter was preserved placing suture only at the urethral mucosa. *U* urethra, *ES* external sphincter

sphincter muscle and usually controls the dorsal vein plexus. The plexus is then cut directly cranial of the suture towards the sphincteric muscle to avoid an incision of the apex. Residual bleeding still from the plexus is controlled by suturing selectively the vessels away from the complete external sphincter muscles (Fig. 4). Placing the anastomotic sutures without damaging the external sphincter is described in Figs. 5 and 6.

Preservation of as much as possible of the normal anatomy of the sphincter mechanism and its nerve supply results in an excellent return to continence after radical prostatectomy.

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