Denonvilliers Fascia and Puboprostatic Ligament in Radical Prostatectomy: A Survey

www.surveyx.cn

Abstract

This survey paper explores the critical roles of Denonvilliers' fascia (DVF) and the puboprostatic ligament (PPL) in radical prostatectomy, emphasizing their significance in surgical outcomes, particularly in the context of prostate cancer treatment. DVF acts as a connective tissue barrier between the prostate and rectum, while PPL supports the prostate gland by stabilizing the urethral sphincter mechanism, both crucial for maintaining urinary continence and erectile function post-surgery. The paper highlights advancements in surgical techniques, such as nerve-sparing approaches, which have shown promise in enhancing functional outcomes by preserving these anatomical structures. The Retzius-sparing approach, for example, offers potential benefits in maintaining anatomical integrity crucial for recovery. Technological innovations, including deep learning-based computer vision, are poised to further refine surgical practices by automating skill assessment and improving precision. The survey underscores the need for multicenter clinical trials and randomized controlled trials to validate current findings and explore athermal dissection techniques and innovative technologies for nerve identification. Addressing unmeasured confounding in observational studies is vital for refining methodologies and enhancing causal inferences. The paper concludes by advocating for standardized methodologies in evaluating surgical techniques and suggests future research should focus on innovative approaches to enhance continence recovery and improve data extraction accuracy. The preservation of DVF and PPL is integral to the success of radical prostatectomy, with ongoing research and technological advancements expected to enhance patient quality of life.

1 Introduction

1.1 Significance of Denonvilliers' Fascia and Puboprostatic Ligament

Denonvilliers' fascia (DVF) and the puboprostatic ligament are pivotal anatomical structures influencing prostate anatomy and surgical outcomes in radical prostatectomy. DVF acts as a connective tissue barrier between the prostate and rectum, crucial for preserving urogenital function post-surgery [1]. Its preservation during nerve-sparing radical prostatectomy correlates with improved urogenital outcomes, significantly reducing complications such as erectile dysfunction and urinary incontinence, common challenges in prostate cancer treatment [2]. Controversies surrounding the multilayered nature of DVF further fuel discussions on its surgical significance and oncological implications [3].

The puboprostatic ligament supports the prostate by anchoring it to the pubic bone, playing a critical role in urinary continence by stabilizing the urethra and sphincter mechanism, essential for postoperative recovery [4]. A nuanced understanding of these structures is vital for surgeons employing nerve-sparing techniques, as it directly impacts the recovery of urinary continence and erectile function [5]. The balance between conserving peri-prostatic tissue and the risk of leaving cancerous tissue underscores the importance of these structures in surgical decision-making [6].

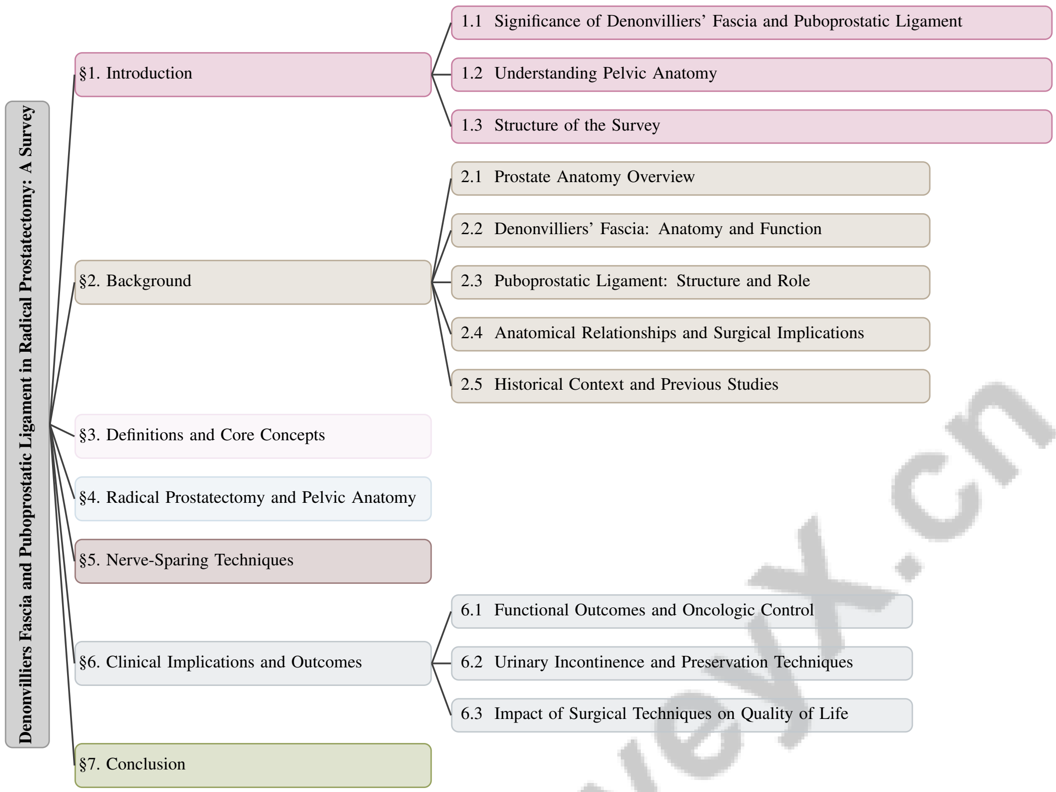


Figure 1: chapter structure

Advancements in surgical techniques, particularly robot-assisted radical prostatectomy (RARP), highlight the necessity of a detailed understanding of these anatomical features to enhance patient recovery and quality of life [7]. Modifications in RARP focus on preserving the nerves and vascular structures anterior to the prostate to optimize functional outcomes [5]. Accurate localization and preservation of DVF and the puboprostatic ligament are crucial for effective surgical outcomes, especially given the challenges in identifying cancerous sentinel lymph nodes during robotic surgeries [6].

1.2 Understanding Pelvic Anatomy

A comprehensive understanding of pelvic anatomy is essential for optimizing surgical outcomes in radical prostatectomy, where precise anatomical knowledge is crucial. Retroperitoneal anatomy significantly impacts pelvic surgeons, addressing knowledge gaps that could compromise surgical practices [8]. The precision required in Robotic-Assisted Radical Prostatectomy (RARP) further emphasizes minimizing damage to surrounding tissues [9]. The role of nerve-sparing techniques in maintaining sexual function post-surgery illustrates the delicate balance between preserving potency and continence while ensuring effective cancer control.

The nerve-sparing approach, which enhances functional outcomes in salvage robot-assisted radical prostatectomy (sRARP), demonstrates the benefits of preserving structures like Denonvilliers' fascia for urinary continence in the immediate postoperative period, underscoring the necessity of detailed anatomical knowledge [10].

Technological advancements in Robotic-Assisted Surgery (RAS) for prostate cancer treatment in the UK rely heavily on a thorough understanding of pelvic anatomy to improve surgical precision and patient outcomes [11]. The integration of artificial intelligence in diagnostics and surgical planning transforms surgical techniques, with anatomical comprehension remaining fundamental for effective healthcare delivery [12]. Automatic detection of anatomical landmarks aims to enhance pelvic anatomy understanding, refining surgical strategies [13]. Current benchmarks focusing on specific challenges rather than holistic surgical workflows are pivotal for developing autonomous robotic assistants [14], enhancing the precision and effectiveness of surgical interventions. Despite advancements, nerve damage remains a significant morbidity following nerve-sparing radical prostatectomy, affecting post-surgery quality of life [15]. This highlights the ongoing need for effective nerve-sparing techniques, such as the NeuroSAFE approach, aimed at minimizing risks and improving surgical practices [2].

1.3 Structure of the Survey

This survey is organized to comprehensively explore the roles of Denonvilliers' fascia and the puboprostatic ligament in radical prostatectomy. The **Introduction** establishes the significance of these anatomical structures in prostate surgery and their impact on surgical outcomes, emphasizing the necessity of understanding pelvic anatomy for effective nerve-sparing techniques critical for preserving erectile function and urinary continence.

The **Background** section delves into the detailed anatomy of the prostate, focusing on Denonvilliers' fascia and the puboprostatic ligament, reviewing their anatomical relationships, functions, and historical context supported by prior studies.

In the **Definitions and Core Concepts** section, key terms such as Denonvilliers' fascia, puboprostatic ligament, radical prostatectomy, and nerve-sparing techniques are defined, elucidating their relevance to prostate cancer surgery and the preservation of vital functions.

The survey transitions to , discussing the surgical procedure and emphasizing Denonvilliers' fascia as a supportive barrier for pelvic autonomic nerves, crucial for preserving urinary continence post-surgery, alongside the anatomical relationships with the puboprostatic ligament that contribute to surgical outcomes and patient quality of life [10, 16, 17, 18]. Various surgical techniques and approaches are examined, stressing the importance of anatomical considerations and preservation strategies.

The subsequent section on **Nerve-Sparing Techniques** explores methods employed during radical prostatectomy to preserve erectile function and urinary continence, comparing different techniques and technological innovations that aid in nerve-sparing.

The penultimate section, **Clinical Implications and Outcomes**, assesses clinical outcomes associated with various surgical approaches to handling Denonvilliers' fascia and the puboprostatic ligament, discussing the impact on postoperative recovery, erectile function, and urinary continence while balancing functional outcomes with oncologic control.

The highlights critical findings, underscoring the pivotal role of Denonvilliers' fascia and the puboprostatic ligament in enhancing urinary continence outcomes following radical prostatectomy. Preservation of Denonvilliers' fascia during surgery significantly improves immediate urinary continence rates, evidenced by a multicenter study reporting an 83.3

2 Background

2.1 Prostate Anatomy Overview

The prostate gland, integral to the male reproductive system, is a glandular and fibromuscular organ situated below the urinary bladder, encircling the prostatic urethra. It plays a crucial role in secreting seminal fluid, which forms a significant part of ejaculate volume. Anatomically, the prostate is divided into zones: peripheral, central, transition, and anterior fibromuscular stroma, each with distinct histological and clinical implications. The peripheral zone is predominantly associated with prostate cancer, while the transition zone is linked to benign prostatic hyperplasia [3].

Denonvilliers' fascia, a dense connective tissue posterior to the prostate and anterior to the rectum, is a critical landmark in radical prostatectomy, protecting the rectum from surgical injury [10]. The puboprostatic ligament anchors the prostate to the pubic symphysis, providing structural support and playing a vital role in urinary continence by stabilizing the urethral sphincter mechanism [4]. Understanding these structures is essential for surgeons, particularly for nerve-sparing techniques to preserve erectile function and urinary continence [5].

The prostate's vascular supply primarily comes from the inferior vesical artery, a branch of the internal iliac artery, forming an intricate network vital for function and a key consideration during

AI-generated, for reference only.

surgery to minimize blood loss [7]. Innervation from the pelvic plexus is crucial for prostate function and is a focal point in nerve-sparing surgical techniques aimed at preserving erectile function.

2.2 Denonvilliers' Fascia: Anatomy and Function

Denonvilliers' fascia (DVF), a pivotal structure in the male pelvis, consists of dense connective tissue and plays a significant role in urogenital and colorectal surgeries. Positioned posterior to the prostate and anterior to the rectum, it acts as a barrier during prostate surgeries [18]. Recent studies describe DVF as a single-layered structure forming a 'Y' shape in the sagittal plane, originating from the peritoneal reflection [3]. This understanding is critical for surgical dissection and decisions regarding DVF preservation or resection, especially in procedures like total mesorectal excision (TME) [1].

The anatomical planes of DVF enhance surgical techniques, particularly in TME, where precise dissection minimizes complications and improves oncologic outcomes [16]. DVF's relationship with the mesorectal fascia and neurovascular bundles is crucial in rectal cancer surgeries, impacting postoperative urogenital function [4]. Insufficient knowledge of the male endopelvic fascia, including DVF, links to pelvic floor dysfunctions, necessitating a comprehensive anatomical understanding for clinical practice [17].

Preservation or resection of DVF influences postoperative outcomes, especially regarding urogenital dysfunction following TME. Studies highlight the benefits of maintaining DVF for postoperative recovery and functional outcomes [1]. Challenges in computational modeling of pelvic anatomy, including sensitivity to hyperparameter choices, complicate surgical technique generalization, requiring nuanced understanding of DVF's features [19].

2.3 Puboprostatic Ligament: Structure and Role

The puboprostatic ligament (PPL) is a crucial structure within the male pelvis, providing significant support to the prostate by anchoring it to the pubic bone. It plays a pivotal role in urinary continence by stabilizing the urethra and supporting the sphincter mechanism, essential for postoperative recovery following radical prostatectomy. Maintaining PPL integrity is vital for preserving urinary function, ensuring proper alignment and support of the urethral sphincter complex [20].

The PPL parallels the pubourethral ligament (PUL) in managing stress urinary incontinence (SUI) post-prostatectomy. Insights into the PUL's role in female continence enhance understanding of the PPL's function in males, particularly in surgical interventions where preserving these ligaments mitigates SUI risk. The anatomical and functional similarities between PPL and PUL underscore their importance in pelvic floor stability and continence mechanisms [20].

A comprehensive understanding of PPL anatomy is critical for surgeons, especially when employing nerve-sparing techniques during radical prostatectomy. The ligament's role in supporting the prostate and ensuring proper urinary function is crucial in surgical planning and execution, particularly in robot-assisted radical prostatectomy (RARP) for prostate cancer. Techniques aimed at maximizing urethral length and maintaining myofascial support can significantly enhance early urinary continence recovery, improving post-surgery quality of life [21, 22, 23, 20]. Preserving the PPL during surgery is vital for optimizing patient outcomes and maintaining quality of life.

2.4 Anatomical Relationships and Surgical Implications

The anatomical relationships between Denonvilliers' fascia (DVF) and the puboprostatic ligament (PPL) are pivotal in radical prostatectomy and other pelvic surgeries. DVF, located posterior to the prostate and anterior to the rectum, acts as a barrier, aiding in safe rectum mobilization and protecting pelvic autonomic nerves during surgery [4]. The complexity of DVF's three-dimensional structure has led to varying surgical approaches and increased risks of urogenital dysfunction, necessitating precise anatomical delineation to enhance outcomes [3].

Preserving DVF is essential for maintaining urogenital function postoperatively. Its role in safeguarding neurovascular bundles (NVBs) is crucial, as these structures are integral to urinary continence and erectile function recovery following nerve-sparing radical prostatectomy [24]. The NeuroSAFE technique, emphasizing NVB preservation, addresses challenges in maintaining erectile function and urinary control, highlighting DVF's importance in surgical practice [2].

The PPL, anchoring the prostate to the pubic bone, stabilizes the urethral sphincter complex, playing a vital role in urinary continence. Surgical interventions compromising PPL integrity can adversely affect urinary function recovery, emphasizing the necessity of preserving this ligament during prostatectomy [4]. The anatomical proximity of NVBs to the prostate tumor, quantified by the neurovascular-tumor (N-T) distance, is a practical consideration for nerve-sparing technique suitability, highlighting these structures' critical role in optimizing postoperative outcomes.

2.5 Historical Context and Previous Studies

The historical exploration of Denonvilliers' fascia (DVF) and the puboprostatic ligament (PPL) has advanced the understanding of pelvic anatomy and its surgical implications. The complexity of neural networks surrounding the prostate has historically challenged surgeons, leading to refined techniques preserving anterior nerve fibers for enhanced functional recovery post-surgery, improving radical prostatectomy outcomes [25].

Historical studies have highlighted inadequacies in controlling confounding factors in prostate cancer treatment, prompting new analytical approaches to enhance surgical outcome assessments [26]. Significant variations in surgical performance have impacted quality of life and oncologic outcomes, emphasizing the need for standardized protocols and training to ensure consistent quality [27].

Technological advancements have shaped the historical narrative of DVF and PPL studies. Early reliance on manual registration of transrectal ultrasound (TRUS) and robotic systems highlighted the need for automation to improve surgical efficiency and accuracy [28]. Despite advancements, the lack of standardized AI implementation protocols in healthcare poses challenges, resulting in variability in outcomes and integration difficulties with existing systems [12].

In nerve-sparing techniques, previous research suggests these approaches during robot-assisted radical prostatectomy (RARP) do not significantly increase the risk of positive surgical margins. However, these studies face selection bias, necessitating more robust analyses for validation [29]. The debate on optimal treatment for high-risk prostate cancer, particularly the survival benefits of radical prostatectomy versus radiotherapy, persists in historical research [30].

Charles Pierre Denonvilliers' contributions to pelvic anatomy understanding, especially regarding the fascia bearing his name, are well-documented in historical studies, providing insights into DVF's anatomical features and clinical significance, informing current surgical practices [31]. Additionally, gaps in literature regarding male endopelvic fascia and ligaments, including DVF and PPL, highlight the need for further research to enhance anatomical education and surgical outcomes [17].

The surgical management of prostate cancer necessitates a comprehensive understanding of the surrounding anatomical structures. Figure 2 illustrates the key anatomical structures relevant to prostate cancer surgery, highlighting the prostate gland zones, Denonvilliers' fascia, puboprostatic ligament, and neurovascular bundles. Each component plays a critical role in surgical outcomes, influencing factors such as oncologic results, urinary continence, and erectile function. This detailed depiction not only aids in surgical planning but also underscores the importance of preserving these structures to optimize patient recovery and quality of life post-surgery.

3 Definitions and Core Concepts

3.1 Key Anatomical Structures

Prostate cancer surgery demands a thorough understanding of key anatomical structures that affect surgical outcomes and recovery. The prostate gland, central to urology, consists of the peripheral, central, transition zones, and anterior fibromuscular stroma, each influencing normal function and conditions like prostate cancer and benign prostatic hyperplasia [21, 32]. These zones are crucial for both prostate function and disease pathogenesis.

Denonvilliers' fascia (DVF), positioned posterior to the prostate and anterior to the rectum, acts as a protective connective tissue barrier in surgeries. Its 'Y'-shaped sagittal configuration aids dissection, enhances oncologic outcomes, minimizes rectal injury, and supports urogenital function preservation [18, 3].

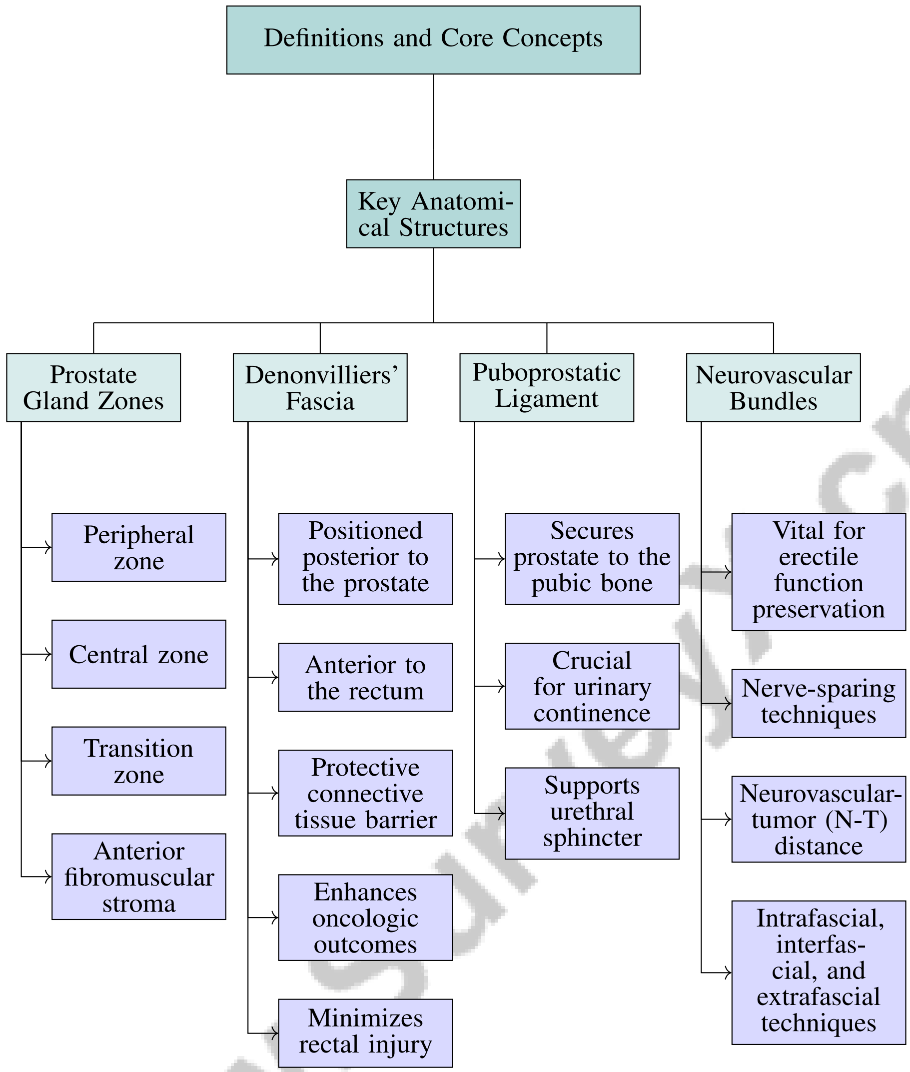


Figure 2: This figure illustrates the key anatomical structures relevant to prostate cancer surgery, highlighting the prostate gland zones, Denonvilliers' fascia, puboprostatic ligament, and neurovascular bundles. Each component plays a critical role in surgical outcomes, influencing factors like oncologic results, urinary continence, and erectile function.

The puboprostatic ligament (PPL) secures the prostate to the pubic bone, crucial for urinary continence by supporting the urethral sphincter. Preserving the PPL during surgery is essential to reduce stress urinary incontinence risk [20].

Neurovascular bundles (NVBs) are vital for erectile function preservation during prostate cancer surgery. Careful handling of these bundles in nerve-sparing techniques ensures postoperative sexual function recovery. The neurovascular-tumor (N-T) distance, indicating NVBs' proximity to tumors, is critical for assessing nerve-sparing feasibility. An N-T distance over 2 mm is a key criterion for nerve-sparing surgery, impacting erectile function and urinary continence. Understanding this distance and employing intrafascial, interfascial, and extrafascial techniques allows clinicians to optimize surgical strategies while reducing nerve damage [33, 34, 21, 35].

4 Radical Prostatectomy and Pelvic Anatomy

4.1 Surgical Techniques and Approaches

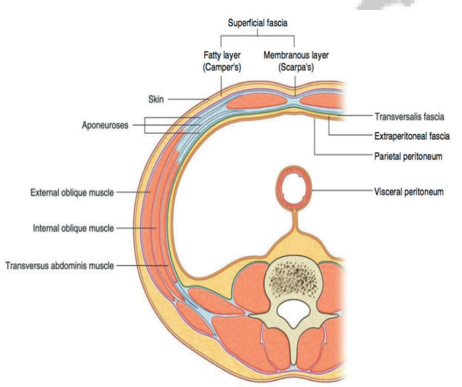
Radical prostatectomy is pivotal in prostate cancer treatment, with evolving techniques aimed at optimizing oncological and functional outcomes. The Retzius-sparing approach is notable for enhancing postoperative recovery by preserving anatomical structures essential for urinary continence and sexual function [32]. This method, alongside traditional approaches, underscores the importance of anatomical preservation in surgical decision-making.

Robotic-assisted surgery has refined prostatectomy techniques, offering enhanced precision and reduced morbidity. The Senhance Surgical System integrates laparoscopic techniques with robotic assistance, notably in non-nerve sparing extraperitoneal radical prostatectomy [36], exemplifying the role of technology in improving surgical dexterity and visualization.

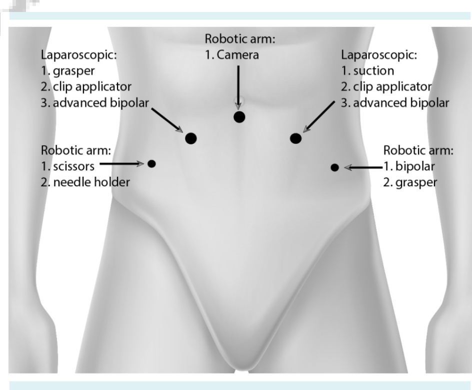
The integration of deep learning and artificial intelligence (AI) in surgical techniques has been transformative. Models like RP-Net enhance the recognition of surgical activities during complex procedures such as radical prostatectomy [37]. Convolutional layers predict anatomical landmarks, facilitating precise dissection and preservation of critical structures [13]. Deep Imitation Learning for Gamma Probe Manipulation exemplifies AI's role in surgical planning, training robotic agents to systematically scan target areas, thus improving intraoperative decision-making [11]. Nerve-specific fluorophores further aid in preserving neurovascular bundles during surgery [15].

The LDDMM-OT method, employing an atlas-based approach, combines atlas construction with optimal transport for effective vascular structure annotation during prostatectomy [38]. This method highlights the importance of vascular anatomy in surgical planning, emphasizing precise anatomical understanding to minimize complications.

Technological advancements and refined techniques continue to shape radical prostatectomy, necessitating objective assessment methods, like those for suturing gestures, to ensure consistency and quality in surgical practice [5]. The integration of cutting-edge technologies promises improved patient outcomes and advances in prostate cancer surgery.



(a) The image depicts a cross-sectional view of the abdominal wall, highlighting the layers of fascia and muscles.[8]



(b) Robotic surgery tools on a human abdomen[36]

Figure 3: Examples of Surgical Techniques and Approaches

As illustrated in Figure 3, the complexities of radical prostatectomy and pelvic anatomy highlight the significance of surgical techniques for successful outcomes. The first image provides a detailed cross-sectional view of the abdominal wall, clarifying anatomical challenges during procedures. The second image features robotic arms equipped with surgical tools, emphasizing the precision and minimally invasive nature of robotic-assisted laparoscopic surgery, which is increasingly adopted for its benefits in reducing recovery time and enhancing surgical accuracy. Together, these images reflect the fusion of anatomical knowledge and technological innovation that defines contemporary surgical practices in treating prostate conditions.

4.2 Anatomical Considerations and Preservation Strategies

Anatomical considerations are crucial in radical prostatectomy, where preserving structures such as Denonvilliers' fascia, the puboprostatic ligament, and neurovascular bundles is vital for optimizing postoperative outcomes. The Retzius-sparing approach emphasizes anatomical preservation by maintaining the integrity of structures anterior to the prostate, demonstrating advancements in surgical precision and reduced recovery times [32]. The Senhance method, utilizing advanced visualization and haptic feedback, further enhances surgical precision while reducing physical strain on the surgeon [36].

Denonvilliers' fascia, a single-layer structure with two anatomical planes for dissection, is linked to improved surgical outcomes, particularly in rectal cancer treatment [16]. Preserving this fascia is critical for maintaining urinary continence post-surgery, as it supports structures involved in continence mechanisms [10]. Strategic preservation of Denonvilliers' fascia can significantly reduce postoperative incontinence.

The NS-RARP method underscores the importance of anatomical landmarks in preserving neurovascular bundles, essential for maintaining erectile function and minimizing nerve trauma [33]. This method employs meticulous dissection and selective nerve highlighting to enhance the nerve signal-to-background ratio during surgery, improving the precision of nerve-sparing techniques [15].

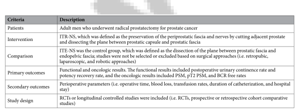
Incorporating high-dimensional covariate considerations through methods like the Orthogonal Score Method for Treatment Effect Estimation can refine surgical strategies by providing insights into treatment effects related to anatomical preservation [39]. This approach emphasizes understanding the interplay between surgical techniques and anatomical structures to optimize patient outcomes.

5 Nerve-Sparing Techniques

5.1 Comparison of Nerve-Sparing Techniques

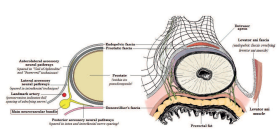
Nerve-sparing techniques in radical prostatectomy are crucial for preserving erectile function and urinary continence while ensuring effective cancer control. Studies show these techniques expedite urinary continence recovery post-surgery compared to non-nerve-sparing methods [40]. However, they pose challenges, such as potentially higher positive surgical margins [29], necessitating thorough patient counseling to balance functional benefits against oncological completeness.

Technological advancements have bolstered nerve-sparing methods, with tools like RP-Net enhancing surgical precision by accurately recognizing surgical tasks [37]. This precision facilitates meticulous neurovascular bundle preservation, minimizing nerve damage. The integration of technology and anatomical expertise is vital for optimizing outcomes, balancing functional recovery with cancer control. Continuous innovations in nerve-sparing techniques, including refined dissection strategies and advanced technologies, promise to improve postoperative quality of life [21, 2, 41, 35].

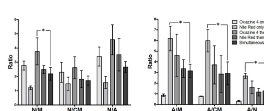


Criteria	Description
Patients	Adult men who underwent radical prostatectomy for prostate cancer
Intervention	ITR-NS, which was defined as the preservation of the periprostatic fascia and nerves by cutting adjacent prostate and dissecting the plane between prostatic capsule and prostatic fascia
Comparison	ITE-NS was the control group, which was defined as the dissection of the plane between prostatic fascia and endopelvic fascia; studies were not be selected or excluded based on surgical approaches (i.e. retropubic, laparoscopic, and robotic approaches)
Primary outcomes	Functional and oncologic results. The functional results included postoperative urinary continence rate and potency recovery rate, and the oncologic results included PSM, pT2 PSM, and BCR free rates
Secondary outcomes	Perioperative parameters (i.e. operative time, blood loss, transfusion rates, duration of catheterization, and hospital stay)
Study design	RCTs or longitudinal controlled studies were included (i.e. RCTs, prospective or retrospective cohort comparative studies)

(a) Criteria for Evaluating Radical Prostatectomy for Prostate Cancer: A Systematic Review[35]



(b) The image depicts a detailed anatomical illustration of the pelvic floor muscles and surrounding structures.[21]



(c) Comparison of Different Methods for Detecting N/A in a Sample[15]

Figure 4: Examples of Comparison of Nerve-Sparing Techniques

Figure 4 illustrates the significance of nerve-sparing techniques in prostate cancer surgery. The first image provides evaluation criteria for radical prostatectomy, crucial for assessing nerve-sparing effectiveness. The second image emphasizes the anatomical intricacies of the pelvic floor, highlighting essential structures for surgical navigation. The third image compares detection methods, illustrating technique effectiveness. These figures collectively underscore the anatomical and evaluative challenges in achieving successful surgical outcomes [35, 21, 15].

5.2 Technological Innovations in Nerve-Sparing

Technological innovations have significantly advanced nerve-sparing techniques in radical prostatectomy. Robotic-assisted systems, such as the Senhance Surgical System, enhance dexterity and visualization, essential for neurovascular bundle preservation [36]. These systems integrate traditional laparoscopic skills with robotic precision, reducing nerve damage risks.

AI and deep learning models, like RP-Net, have further refined nerve-sparing approaches by improving surgical task recognition and execution [37]. These technologies provide real-time support, aiding in the precise preservation of anatomical structures. Additionally, nerve-specific fluorophores enhance intraoperative visualization, improving nerve identification and preservation [15].

Deep Imitation Learning for Gamma Probe Manipulation represents another innovation, training robotic agents for systematic scanning and improved intraoperative decision-making [11]. These advancements are crucial for enhancing surgical accuracy and maintaining optimal control, thereby improving patient outcomes.

6 Clinical Implications and Outcomes

Evaluating clinical outcomes in radical prostatectomy requires an understanding of the interplay between functional recovery and oncologic success. This section examines functional outcomes and oncologic control, essential for patient satisfaction and long-term health post-surgery.

6.1 Functional Outcomes and Oncologic Control

Achieving a balance between functional outcomes and oncologic control is crucial in radical prostatectomy. Nerve-sparing robot-assisted radical prostatectomy (NS-RARP) has demonstrated superior erectile function recovery compared to traditional methods, underscoring the importance of precise surgical techniques and careful dissection to preserve neurovascular bundles [33]. Technological advancements, such as RP-Net, enhance surgical activity recognition, impacting both functional and oncologic outcomes [37]. Deep learning models like ProsRegNet improve MRI and histopathology alignment, aiding in accurate surgical planning and execution [19]. These innovations facilitate precise anatomical delineation, crucial for preserving urogenital function while ensuring comprehensive cancer excision.

Studies on bladder neck sparing (BNS) techniques provide insights into enhancing postoperative urinary continence, offering frameworks for clinical decision-making that prioritize functional outcomes [24]. Advanced segmentation techniques in surgical instrumentation, as highlighted in the SAR-RARP50 dataset, emphasize classification accuracy and segmentation precision for optimal surgical results [42]. The impact of additional therapies on urinary continence, potency, and quality of life (QoL) is significant, with specific rates of incontinence and potency reduction reported, necessitating careful consideration in postoperative recovery management [43]. Innovative data abstraction methods, which increase speed while maintaining high accuracy, support efficient analysis and application of surgical data in clinical settings [6].

6.2 Urinary Incontinence and Preservation Techniques

Urinary incontinence is a significant concern post-radical prostatectomy, requiring effective preservation techniques for enhanced recovery and QoL. Current research highlights the importance of successful preservation and reconstruction techniques, which have improved early recovery rates of urinary continence [22]. These techniques mitigate the adverse effects of urinary incontinence, significantly impacting patients' quality of life. Comprehensive assessments of urinary incontinence, integrating both objective and subjective measures, provide a nuanced understanding of its multifaceted impact on QoL [23]. This enables tailored interventions addressing both physical and psychological dimensions of incontinence.

Benchmarks for surgical skills assessment lay the foundation for improving training and patient outcomes, emphasizing precision and consistency in surgical practices [27]. These benchmarks guide the refinement of surgical techniques, particularly in nerve-sparing approaches aimed at preserving urinary function. Interdisciplinary collaboration between AI researchers and healthcare professionals is crucial to ensure technological advancements meet clinical needs, especially in surgical planning and execution [12]. AI applications in developing predictive models for urinary continence outcomes hold promise for enhancing surgical decision-making and patient counseling. Insights into the functional outcomes of multimodal therapy, as provided by existing benchmarks, aid in patient counseling and decision-making, ensuring patients are well-informed about the potential impacts of surgical interventions on urinary function [43].

6.3 Impact of Surgical Techniques on Quality of Life

The impact of surgical techniques on the quality of life (QoL) for patients undergoing radical prostatectomy encompasses both functional and psychological dimensions. Advanced surgical systems, like the Senhance Surgical System, offer potential for improved precision and reduced recovery times, though questions remain regarding long-term oncological outcomes and their implications for patient QoL [32]. Future research should focus on optimizing docking processes and expanding the application of the Senhance system across various procedures to fully realize its potential [36].

Preservation of Denonvilliers' fascia (DVF) is critical for maintaining postoperative urogenital function, with studies advocating for multi-center research to establish standardized protocols and explore new techniques enhancing nerve protection [18]. Such advancements are vital for improving QoL by minimizing postoperative complications like urinary incontinence, which can have profound psychological effects on patients [23]. Incorporating deep learning frameworks, such as ProsRegNet, into surgical planning can significantly enhance anatomical delineation precision, offering high accuracy and speed improvements accessible to non-experts [19]. These technological innovations promise to reduce surgical errors and improve patient outcomes, thereby enhancing QoL.

The observational nature of studies assessing functional outcomes may introduce selection bias, and awareness of the need for additional therapy can impact patient QoL, as acknowledged in existing research [43]. Future research should develop targeted interventions for managing urinary incontinence post-surgery and explore the long-term psychological effects of this condition on patients' QoL [23]. Methods like LDDMM-OT for vascular structure annotation, achieving high precision with minimal training data, underscore the potential for improving patient QoL in procedures involving complex pelvic anatomy [38]. The integration of vision-based gamma probe manipulation agents also demonstrates promising results, with potential for further improvement in prediction accuracy and real-world application [11].

7 Conclusion

This survey underscores the critical roles of Denonvilliers' fascia and the puboprostatic ligament in radical prostatectomy, highlighting their essential contributions to surgical outcomes. The preservation of these anatomical structures is crucial for optimizing recovery, particularly in maintaining urinary continence and erectile function. Denonvilliers' fascia serves as a barrier between the prostate and rectum, while the puboprostatic ligament supports the urethral sphincter, emphasizing their significance in surgical planning and execution.

Recent advancements in surgical techniques, particularly nerve-sparing methods, have shown potential in improving functional outcomes. Techniques such as Retzius-sparing radical prostatectomy demonstrate benefits in preserving anatomical structures vital for recovery. Additionally, the integration of deep learning-based computer vision technologies holds promise for enhancing surgical skill assessment and refining practices.

Future research should focus on multicenter clinical trials and randomized controlled trials to validate current findings and explore the functional anatomy associated with nerve-sparing techniques. Investigating athermal dissection methods and innovative nerve identification technologies offers promising avenues for enhancing surgical outcomes. Addressing unmeasured confounding in observational studies is also essential for improving methodological rigor and causal inferences.

The survey advocates for standardized methodologies in evaluating surgical techniques and suggests that future research should concentrate on innovative strategies to enhance continence recovery. Moreover, advancements in optical character recognition capabilities and prompt design could improve data extraction accuracy and efficiency, contributing to the refinement of surgical data analysis.

References

[1] Jiafeng Fang, Bo Wei, Zongheng Zheng, Jian'an Xiao, Fanghai Han, Meijin Huang, Qingwen Xu, Xiaozhong Wang, Chuyuan Hong, Gongping Wang, et al. Preservation versus resection of denonvilliers' fascia in total mesorectal excision for male rectal cancer: follow-up analysis of the randomized puf-01 trial. *Nature Communications*, 14(1):6667, 2023.

[2] Sophie D Fosså, Burkhard Beyer, Alv A Dahl, Kirsti Aas, Lars Magne Eri, Espen Kvan, Ragnhild Sørum Falk, Markus Graefen, Hartvig Huland, and Viktor Berge. Improved patient-reported functional outcomes after nerve-sparing radical prostatectomy by using neurosafe technique. *Scandinavian journal of urology*, 53(6):385–391, 2019.

[3] Yi Li, Ya-Min Zhao, Yan-Bing Ma, Jin-Song Zhou, Cong Tong, and Li-Kun Yan. The "y"-shaped denonvilliers' fascia and its adjacent relationship with the urogenital fascia based on a male cadaveric anatomical study. *BMC surgery*, 23(1):13, 2023.

[4] Seung Yoon Yang, Ho Seung Kim, Min Soo Cho, and Nam Kyu Kim. Three-dimensional anatomy of the denonvilliers' fascia after micro-ct reconstruction. *Scientific reports*, 11(1):21759, 2021.

[5] Francisco Luongo, Ryan Hakim, Jessica H. Nguyen, Animashree Anandkumar, and Andrew J Hung. Deep learning-based computer vision to recognize and classify suturing gestures in robot-assisted surgery, 2020.

[6] Basil Kaufmann, Dallin Busby, Chandan Krushna Das, Neeraja Tillu, Mani Menon, Ashutosh K. Tewari, and Michael A. Gorin. Validation of a zero-shot learning natural language processing tool for data abstraction from unstructured healthcare data, 2023.

[7] Kavyanjali Reddy, Pankaj Gharde, Harshal Tayade, Mihir Patil, Lucky Srivani Reddy, Dheeraj Surya, and Lucky srivani Reddy. Advancements in robotic surgery: a comprehensive overview of current utilizations and upcoming frontiers. *Cureus*, 15(12), 2023.

[8] İlker Selçuk, Burak Ersak, İlkan Tatar, Tayfun Güngör, and Emre Huri. Basic clinical retroperitoneal anatomy for pelvic surgeons. *Turkish journal of obstetrics and gynecology*, 15(4):259, 2019.

[9] Yuefeng Du, Qingzhi Long, Bin Guan, Lijun Mu, Juanhua Tian, Yumei Jiang, Xiaojing Bai, and Dapeng Wu. Robot-assisted radical prostatectomy is more beneficial for prostate cancer patients: a system review and meta-analysis. *Medical science monitor: international medical journal of experimental and clinical research*, 24:272, 2018.

[10] Xuwei Lu, Chang He, Sihong Zhang, Fan Yang, Zhuifeng Guo, Jiaqi Huang, Minke He, Jiawen Wu, Xia Sheng, Wenyao Lin, et al. Denonvilliers' fascia acts as the fulcrum and hammock for continence after radical prostatectomy. *BMC urology*, 21:1–10, 2021.

[11] Kaizhong Deng, Baoru Huang, and Daniel S. Elson. Deep imitation learning for automated drop-in gamma probe manipulation, 2023.

[12] Mehmet Erbudak and Ayse Erzan. Tracking tumor evolution via the prostate marker psa: An individual post-operative study, 2009.

[13] Bastian Bier, Mathias Unberath, Jan-Nico Zaech, Javad Fotouhi, Mehran Armand, Greg Osgood, Nassir Navab, and Andreas Maier. X-ray-transform invariant anatomical landmark detection for pelvic trauma surgery, 2018.

[14] Natalia Valderrama, Paola Ruiz Puentes, Isabela Hernández, Nicolás Ayobi, Mathilde Verlyk, Jessica Santander, Juan Caicedo, Nicolás Fernández, and Pablo Arbeláez. Towards holistic surgical scene understanding, 2024.

[15] Connor W Barth and Summer L Gibbs. Direct administration of nerve-specific contrast to improve nerve sparing radical prostatectomy. *Theranostics*, 7(3):573, 2017.

[16] María García-Gausí, Juan García-Armengol, Gianluca Pellino, Claudia Mulas, José V Roig, Alvaro García-Granero, David Moro, and Alfonso Valverde. Navigating surgical anatomy of the denonvilliers' fascia and dissection planes of the anterior mesorectum with a cadaveric simulation model. *Updates in Surgery*, 74(2):629–636, 2022.

[17] Vittorio Piloni, Matteo Mazzucco, Andrea Chiapperin, and Mattia Bergamasco. Mr anatomy of the endopelvic fascia and ligaments in males. *Pelviperineology*, 38(4):118, 2019.

[18] Zhou Chen, Xiao-Jing Zhang, Hao-Dong Chang, Xiao-Qian Chen, Shan-Shan Liu, Wei Wang, Zhi-Heng Chen, Yu-Bin Ma, and Liang Wang. From basic to clinical: Anatomy of denonvilliers' fascia and its application in laparoscopic radical resection of rectal cancer. *World Journal of Gastrointestinal Surgery*, 15(10):2108, 2023.

[19] Wei Shao, Linda Banh, Christian A. Kunder, Richard E. Fan, Simon J. C. Soerensen, Jeffrey B. Wang, Nikola C. Teslovich, Nikhil Madhuripan, Anugayathri Jawahar, Pejman Ghanouni, James D. Brooks, Geoffrey A. Sonn, and Mirabela Rusu. Prosregnet: A deep learning framework for registration of mri and histopathology images of the prostate, 2020.

[20] Ahmed Farag, Sidi Muctar, and Peter Petros. Pubourethral and uterosacral male analogues suggest parallel male/female pelvic anatomy and symptom pathogenesis. *Annals of Translational Medicine*, 12(2):40, 2024.

[21] Iason Kyriazis, Theodoros Spinos, Arman Tsaturyan, Panagiotis Kallidonis, Jens Uwe Stolzenburg, and Evangelos Liatsikos. Different nerve-sparing techniques during radical prostatectomy and their impact on functional outcomes. *Cancers*, 14(7):1601, 2022.

[22] Ashwin N Sridhar, Mohammed Abozaid, Prabhakar Rajan, Prasanna Sooriakumaran, Greg Shaw, Senthil Nathan, John D Kelly, and Tim P Briggs. Surgical techniques to optimize early urinary continence recovery post robot assisted radical prostatectomy for prostate cancer. *Current Urology Reports*, 18:1–8, 2017.

[23] Mariana Ferreira Vaz Gontijo Bernardes, Sabrina de Cássia Chagas, Lívia Cristina de Resende Izidoro, Denny Fabricio Magalhaes Veloso, Tânia Couto Machado Chianca, and Luciana Regina Ferreira da Mata. Impact of urinary incontinence on the quality of life of individuals undergoing radical prostatectomy. *Revista Latino-Americana de Enfermagem*, 27:e3131, 2019.

[24] Peng Xiang, Zhen Du, Di Guan, Wei Yan, Mingdong Wang, Danyang Guo, Dan Liu, Yuexin Liu, and Hao Ping. Is there any difference in urinary continence between bilateral and unilateral nerve sparing during radical prostatectomy? a systematic review and meta-analysis. *World Journal of Surgical Oncology*, 22(1):66, 2024.

[25] Paulo Afonso de Carvalho, Joao ABA Barbosa, Giuliano B Guglielmetti, Maurício Dener Cordeiro, Bernardo Rocco, William C Nahas, Vipul Patel, and Rafael Ferreira Coelho. Retrograde release of the neurovascular bundle with preservation of dorsal venous complex during robot-assisted radical prostatectomy: optimizing functional outcomes. *European urology*, 77(5):628–635, 2020.

[26] Linda Amoafo, Elizabeth Platz, and Daniel Scharfstein. Addressing the influence of unmeasured confounding in observational studies with time-to-event outcomes: A semiparametric sensitivity analysis approach, 2024.

[27] Andrew J Hung, Jian Chen, Anthony Jarc, David Hatcher, Hooman Djaladat, and Inderbir S Gill. Development and validation of objective performance metrics for robot-assisted radical prostatectomy: a pilot study. *The Journal of urology*, 199(1):296–304, 2018.

[28] Zijian Wu, Hamid Moradi, Shuojue Yang, Hyunwoo Song, Emad M. Boctor, and Septimiu E. Salcudean. Automatic search for photoacoustic marker using automated transrectal ultrasound, 2023.

[29] TFW Soeterik, HH E Van Melick, LM Dijksman, S Stomps, JA Witjes, and JPA Van Basten. Nerve sparing during robot-assisted radical prostatectomy increases the risk of ipsilateral positive surgical margins. *The Journal of urology*, 204(1):91–95, 2020.

[30] Zhipeng Wang, Yuchao Ni, Junru Chen, Guangxi Sun, Xingming Zhang, Jinge Zhao, Xudong Zhu, Haoran Zhang, Sha Zhu, Jindong Dai, et al. The efficacy and safety of radical prostatectomy and radiotherapy in high-risk prostate cancer: a systematic review and meta-analysis. *World journal of surgical oncology*, 18:1–13, 2020.

[31] Giorgio Di Matteo. Alla ricerca dei chirurghi perduti: Charles pierre denonvilliers e la "sua" aponeurosi. *Il Giornale di Chirurgia*, 38(2):103, 2017.

[32] Alberto Martini, Ugo Giovanni Falagario, Arnauld Villers, Paolo Dell'Oglio, Elio Mazzone, Riccardo Autorino, Marcio Covas Moschovas, Maurizio Buscarini, Carlo Andrea Bravi, Alberto Briganti, et al. Contemporary techniques of prostate dissection for robot-assisted prostatectomy. *European urology*, 78(4):583–591, 2020.

[33] Marcio Covas Moschovas and Vipul Patel. Nerve-sparing robotic-assisted radical prostatectomy: how i do it after 15.000 cases. *International braz j urol*, 48(2):369–370, 2022.

[34] Zaisheng Zhu, Yiyi Zhu, Yunyuan Xiao, and Shengye Hu. Indications for nerve-sparing surgery for radical prostatectomy: results from a single-center study. *Frontiers in Oncology*, 12:896033, 2022.

[35] Hong Weng, Xian-Tao Zeng, Sheng Li, Xiang-Yu Meng, Ming-Jun Shi, Da-Lin He, and Xing-Huan Wang. Intrafascial versus interfascial nerve sparing in radical prostatectomy for localized prostate cancer: a systematic review and meta-analysis. *Scientific reports*, 7(1):11454, 2017.

[36] Željko Kaštelan, Nikola Knežević, Tvrtko Hudolin, Tomislav Kuliš, Luka Penezić, Eleonora Goluža, Stefano Gidaro, and Ante Ćorušić. Extraperitoneal radical prostatectomy with the senhance surgical system robotic platform. *Croatian medical journal*, 60(6):556, 2019.

[37] Aneeq Zia, Andrew Hung, Irfan Essa, and Anthony Jarc. Surgical activity recognition in robot-assisted radical prostatectomy using deep learning, 2018.

[38] Pierre-Louis Antonsanti, Thomas Benseghir, Vincent Jugnon, and Joan Glaunès. Database annotation with few examples: An atlas-based framework using diffeomorphic registration of 3d trees, 2020.

[39] Jue Hou, Jelena Bradic, and Ronghui Xu. Estimating treatment effect under additive hazards models with high-dimensional covariates, 2024.

[40] Christian P Pavlovich, Bernardo Rocco, Sasha C Druskin, and John W Davis. Urinary continence recovery after radical prostatectomy–anatomical/reconstructive and nerve-sparing techniques to improve outcomes. *BJU international*, 120(2):185–196, 2017.

[41] Xavier Bonet, Gabriel Ogaya-Pinies, Tracey Woodlief, Eduardo Hernandez-Cardona, Hariharan Ganapathi, Travis Rogers, Rafael F Coelho, Bernardo Rocco, Francesc Vigués, and Vipul Patel. Nerve-sparing in salvage robot-assisted prostatectomy: surgical technique, oncological and functional outcomes at a single high-volume institution. *BJU international*, 122(5):837–844, 2018.

[42] Dimitrios Psychogyios, Emanuele Colleoni, Beatrice Van Amsterdam, Chih-Yang Li, Shu-Yu Huang, Yuchong Li, Fucang Jia, Baosheng Zou, Guotai Wang, Yang Liu, Maxence Boels, Jiayu Huo, Rachel Sparks, Prokar Dasgupta, Alejandro Granados, Sebastien Ourselin, Mengya Xu, An Wang, Yanan Wu, Long Bai, Hongliang Ren, Atsushi Yamada, Yuriko Harai, Yuto Ishikawa, Kazuyuki Hayashi, Jente Simoens, Pieter DeBacker, Francesco Cisternino, Gabriele Furnari, Alex Mottrie, Federica Ferraguti, Satoshi Kondo, Satoshi Kasai, Kousuke Hirasawa, Soohee Kim, Seung Hyun Lee, Kyu Eun Lee, Hyoun-Joong Kong, Kui Fu, Chao Li, Shan An, Stefanie Krell, Sebastian Bodenstedt, Nicolas Ayobi, Alejandra Perez, Santiago Rodriguez, Juanita Puentes, Pablo Arbelaez, Omid Mohareri, and Danail Stoyanov. Sar-rarp50: Segmentation of surgical instrumentation and action recognition on robot-assisted radical prostatectomy challenge, 2024.

[43] Meike Adam, Pierre Tennstedt, Dominik Lanwehr, Derya Tilki, Thomas Steuber, Burkhard Beyer, Imke Thederan, Hans Heinzer, Alexander Haese, Georg Salomon, et al. Functional outcomes and quality of life after radical prostatectomy only versus a combination of prostatectomy with radiation and hormonal therapy. *European urology*, 71(3):330–336, 2017.

Disclaimer:

SurveyX is an AI-powered system designed to automate the generation of surveys. While it aims to produce high-quality, coherent, and comprehensive surveys with accurate citations, the final output is derived from the AI's synthesis of pre-processed materials, which may contain limitations or inaccuracies. As such, the generated content should not be used for academic publication or formal submissions and must be independently reviewed and verified. The developers of SurveyX do not assume responsibility for any errors or consequences arising from the use of the generated surveys.

AI-generated, for reference only.