



# The value of periprostatic fascia thickness and fascia preservation as prognostic factors of erectile function after nerve-sparing robot-assisted radical prostatectomy

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## Abstract

**Purpose** To determine the correlation of preoperative fascia thickness (FT) and intraoperative fascia preservation (FP) with erectile function (EF) after nerve-sparing robot-assisted radical prostatectomy (RARP).

**Methods** Our analysis included 106 patients, with localized prostate cancer and no erectile dysfunction (ED) before RARP, assessed with preoperative 3 Tesla (3 T) multiparametric magnetic resonance imaging (MRI). FP score was defined as the extent of FP from the base to the apex of the prostate, quantitatively assessed by the surgeon. Median fascia thickness (MFT) per patient was defined as the sum of the median FT of 12 MRI regions. Preserved MFT (pMFT) was the sum of the saved MFT. The percentage of pMFT (ppMFT) was also calculated. Fascia surface (FS) was measured on MRI and it was combined with FP score resulting in preserved FS (pFS) and percentage of pFS (ppFS).

**Results** FP score, pMFT, ppMFT, pFS and ppFS were significantly lower ( $p < 0.0001$ ) in patients with ED. In the multivariate regression analysis, lower FP score [odds ratio (OR) 0.721,  $p = 0.03$ ] and lower ppMFT (OR 0.001,  $p = 0.027$ ) were independent predictors of ED. ROC analysis showed the highest area under the curve for ppMFT (0.787) and FP score (0.767) followed by pMFT (0.755) and ppFS (0.743).

**Conclusions** MRI-determined periprostatic FT combined with intraoperative FP score are correlated to postprostatectomy EF. Based on the hypothesis that a thicker fascia forms a protective layer for the nerves, we recommend assessing FT preoperatively to counsel men for the odds of preserving EF after RARP.

**Keywords** Erectile dysfunction · Fascia · Magnetic resonance imaging · Prostate cancer · Tissue preservation

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## Introduction

Prostate cancer (PCa) is the most common non-cutaneous cancer in men [1]. Radical prostatectomy is an integral part in the management of localized PCa. Nevertheless, surgery induces damage to nerves bundles surrounding the prostate and is often associated with erectile dysfunction (ED). In an attempt to increase the quality of life of patients who value their erectile function (EF), a nerve-sparing prostatectomy is performed in confined PCa [2–4].

Initially, the periprostatic nerves were considered to run mainly dorsolaterally to the prostate, but more recent studies have demonstrated that nerves exist in the entire circumference of the (multi-layered) periprostatic fascia [5–8]. Multiparametric magnetic resonance imaging (mpMRI) could be helpful to virtually prepare the best nerve-sparing approach in a patient to improve EF [9–11].

Several scoring systems for nerve preservation have been proposed: among others the risk-stratified approach described by Tewari et al. [12, 13]. We recently proposed an intraoperative scoring system that can be used by the urologist to document and quantitatively assess the extent of fascia preservation (FP) at different radial segments of the prostate [14]. We reported that FP was predictive for EF, however, extensive nerve sparing did not automatically result in better postoperative EF in all men. Therefore, other factors may determine EF. Other studies have shown that tension on the neurovascular structures surrounding the prostate adversely affect functional outcome [15, 16].

We hypothesize that a thicker fascia may (1) provide a better natural protection of periprostatic nerves during robot-assisted laparoscopic radical prostatectomy (RARP) and (2) contain more periprostatic nerves. Both may result in better EF outcome. As such, a preoperative means of analysis of fascia thickness (FT) may have predictive value for postoperative EF. The aim of our study was to determine whether the thickness of the periprostatic fascia as assessed on preoperative MRI is correlated with EF in men with PCa who underwent a nerve-sparing RARP.

## Methods

### Patient population

The study was compliant with the Health Insurance Portability and Accountability Act while informed consent was waived for each patient. We retrospectively identified 106 patients between May 2010 and November 2013 who had localized PCa (cT1c–cT2c, Nx-N0, Mx-M0) and who were offered a 3 T endorectal coil mpMRI prior to

RARP ( $\geq 6$  weeks after biopsies). Additionally, inclusion criteria were a preoperative International Index of Erectile Function–Erectile Function (IIEF-EF) [17] Questionnaire score  $\geq 20$ , an intraoperatively determined FP score and at least one follow-up visit beyond 6 months after prostatectomy in which EF was evaluated with the IIEF-EF score. Patients were excluded when they had any prior or current treatment for PCa, if prior transurethral resection of the prostate was performed, if there were factors excluding accurate reading of mpMRI such as movement artifacts and if there were contraindications for nerve-preserving prostatectomy.

### Surgical procedure-FP score assessment

All RARP procedures were performed by two experienced urologists with the da Vinci S(i) surgical robot system (Intuitive Surgical, Sunnyvale, CA, USA). During the procedures, an attempt was made to preserve the periprostatic fascia tissue, as described in our previous study [14]. In brief, the extent of preservation was scored intraoperatively at 12 positions circumferentially to the prostate. The FP score ranged from 0 to 12, scoring the intact fascia from base to apex on the dodecagon around the prostate.

### MRI measurements and image analysis

Details on MRI protocol and sequence application are presented in Supplementary Material 1. A semi-automated macro in ImageJ was constructed to measure the fascia surface (FS) and the FT in TIFF images. After manual delineation of prostate and fascia outlines, 360 lines radiating out from the centre were generated: one for each of the  $360^\circ$ . The periprostatic fascia was divided into 12 ( $30^\circ$ ) parts, corresponding to the FP score dodecagon (Supplementary Fig. 1). The distances from the intersection of the prostate contour to the intersection of the fascia boundary were collected, as well as the surface area of the prostate, the total FS and the surface area of the 12 different fascia regions. This semi-automatic method provided a standardized approach, while preserving the observer's ability to delineate the tissues. The mid-prostate level had the highest intraclass correlation coefficient (ICC) among observers during the delineation process compared to the base and axial level (Supplementary Fig. 2).

Because normal distribution did not apply to the results of the delineations, the median values of the measured thicknesses were used. The median fascia thickness (MFT) per patient was defined as the sum of the median FT of the 12 regions on MRI. The preserved median fascia thickness (pMFT) was the sum of the median thicknesses of the fascia regions which were preserved; thus the pMFT is composed of both FT and FP score. The percentage of preserved

median fascia thickness (ppMFT) was calculated as pMFT divided by MFT. The preserved fascia surface (pFS) was the sum of the FS which was preserved and the percentage of preserved fascia surface (ppFS) was calculated as pFS divided by FS.

### Periprostatic nerves and blood vessel density assessment

To provide insight in the anatomy of the fascia regions, nerves and blood vessels were stained and measured in prostatectomy midsections of ten patients who underwent a non-nerve-sparing RARP. Details of our staining method are presented in Supplementary Material 1.

### Outcome assessment

The primary outcome was postoperative EF, based on the validated IIEF-EF at 12 months follow-up. Men were subsequently divided in two groups; a group with ED (IIEF-EF score  $\leq 19$ ,  $n=66$ ) and a group without ED (IIEF-EF score  $\geq 20$ ,  $n=40$ ). Nine different factors were defined as possible predictors for postoperative ED: (1) age, (2) preoperative IIEF-EF score, (3) FP score, (4) MFT, (5) pMFT, (6) ppMFT, (7) FS, (8) pFS and (9) ppFS.

### Statistical analysis

Comparison of clinical and pathologic characteristics between ED and non-ED groups was done with Mann–Whitney  $U$  tests. The Spearman's rho correlation coefficient ( $r$ ) and the linear regression analysis ( $r^2$ ) were used to calculate correlations between the different variable measurements. A binary logistic regression analysis and the area under the curve (AUC) of the receiver operating characteristics (ROC) analysis were performed to determine the predictors of ED. Odds ratios (OR) and 95% confidence intervals (CI) were reported. Values of  $p < 0.05$  were considered statistically significant. SPSS software ver. 22.0 (SPSS Inc., Chicago, IL) and the R statistical package (R Foundation for Statistical Computing, Vienna, Austria) were used to perform the statistical analysis.

## Results

### Periprostatic distribution of peripheral nerves and blood vessels

In the ten additional patients who underwent non-nerve-sparing prostatectomy, the nerves and blood vessel densities in the different FP regions were calculated (Supplementary Fig. 3). These immunohistochemical analyses revealed

that on an average, the dorsolateral region (R4, R5, L4, L5) contained the thickest fascia, the most FS (47.7% of total amount), the highest peripheral nerve content (61.0% of total peripheral nerves) and the highest amount of blood vessels (52.5% of total number). Interestingly, a strong correlation was observed between the distribution of the peripheral nerves and the blood vessels ( $R^2=0.94$ ,  $p < 0.0001$ ). It has to be mentioned that a great variation was observed between patients. The variation in FT, FS, peripheral nerve density and blood vessel density is illustrated in Supplementary Fig. 4.

All these patients received preoperative T2-weighted MRI of the prostate (Fig. 1a). Comparisons with the pathological findings indicated that the FT and FS derived from the ten associated MRI scans generated a similar distribution pattern (Fig. 1b, c). Quantitatively, however, the median MFT and median FS as defined at pathology were 1.4 mm and 170 ( $\pm 60$ ) mm<sup>2</sup>, while the same specimens yielded values of 3.8 and 550 mm<sup>2</sup> on MRI, respectively. Comparing both datasets yielded a low correlation coefficient between MRI and immunohistology for both the FT ( $R^2=0.05$ ) and the FS ( $R^2=0.50$ ).

### Preoperative MFT assessment

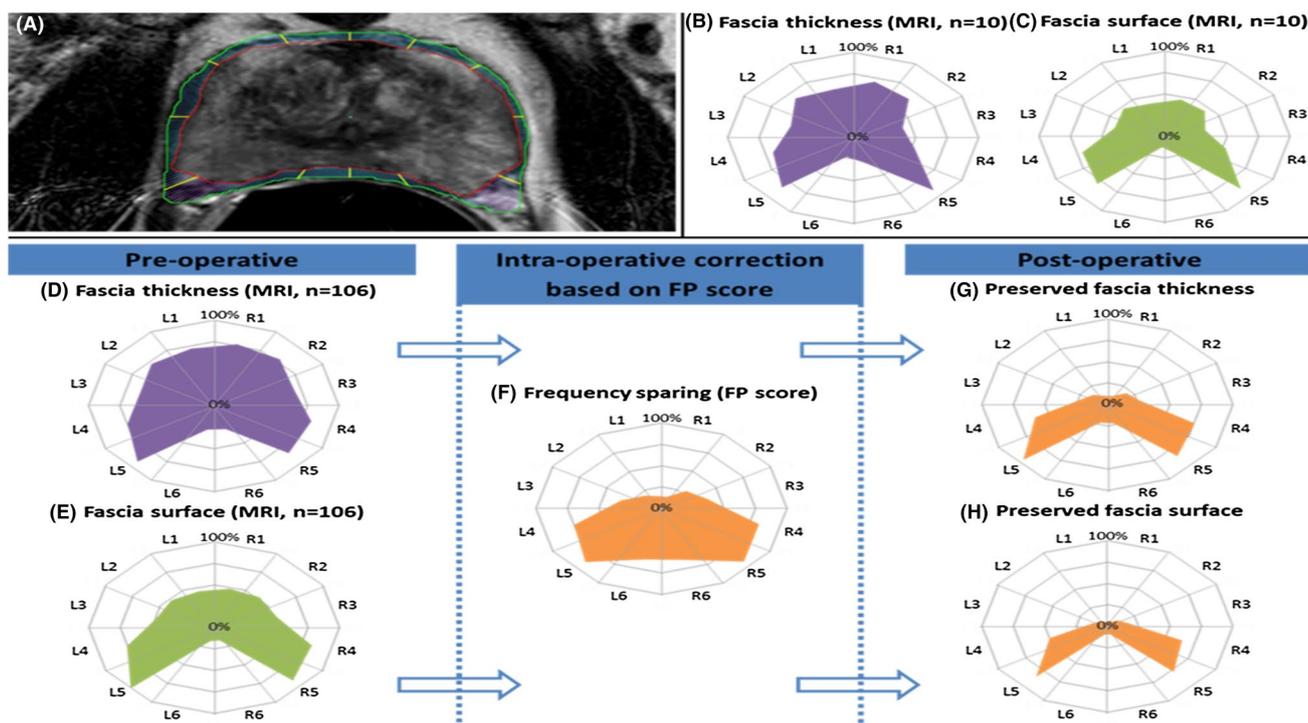
Clinical–pathological features in the study population (106 patients) are presented in Table 1. Five parameters were significantly higher ( $p < 0.0001$ ) in patients without ED compared to those with ED, namely: FP score, pMFT, ppMFT, pFS and ppFS.

Age, preoperative IIEF score, the MFT and the FS were not significantly different between patients with and without ED ( $p=0.945$ ,  $p=0.057$ ,  $p=0.053$  and  $p=0.431$ , respectively). No significant correlation between median FT and BMI [ $r=-0.072$ ,  $p=0.463$ ], age [ $r=0.123$ ,  $p=0.272$ ] and preoperative prostate volume [ $r=0.028$ ,  $p=0.778$ ] was observed.

Based on the MR images, the MFT and the FS per FP region were determined and plotted in Fig. 1d, e. Comparison of these plots revealed differences in the ventral region (R1–3, L1–3) of the prostate fascia. The fascia in the ventral region is as thick as the fascia in the dorsolateral region, however, it contained less FS compared to the dorsolateral region.

### Intraoperative FP score combined with preoperative FT

In all of the 106 patients who underwent (partly) sparing prostatectomy, one or more FP regions were spared; the FP score range was 1–12 (mean  $5.7 \pm 2.5$ ). The frequency of sparing plotted per region is presented in Fig. 1f, revealing that most sparing occurred in the dorsal region (R4–6,



**Fig. 1** **a** A preoperative MRI of the prostate, the boundary of the prostate and the fascia are drawn to determine the fascia thickness. **b**, **c** These spiderplots show the **(b)** FT and the **(c)** FS of the ten patients who underwent a non-sparing prostatectomy. **d**, **e** These spiderplots show the **(d)** FT and the **(e)** FS of the 106 patients who underwent (partly) fascia-sparing prostatectomy. **f** This spiderplot shows how

often the 12 FP regions are spared during the (partly) fascia sparing prostatectomy. **g** In this spiderplot, the thicknesses **(d)** of the spared regions **(f)** are summed up. **h** In this spiderplot, the surface **(e)** of the spared regions **(f)** is summed up. All graphs are normalized. *FP* fascia preservation, *FS* fascia surface, *FT* fascia thickness

L4–6). On average, 21.49 ( $\pm 10.98$ ) mm FT and 329 ( $\pm 168$ ) mm<sup>2</sup> FS were spared on a patient scale. In Fig. 1g, h, the spared FT and FS of the spared regions (based on FP score) is summed up, which showed that most fascia was preserved in the dorsolateral region.

### Predictors for postoperative ED

In the univariate binary logistic regression analysis (Supplementary Table 1), lower IIEF-EF score (OR 0.829, CI 0.701–0.980,  $p = 0.028$ ), lower FP score (OR 0.694, CI 0.571–0.843,  $p < 0.001$ ), lower pMFT (OR 0.923, CI 0.884–0.963,  $p < 0.001$ ), lower ppMFT (OR 0.007, CI 0.001–0.884,  $p < 0.001$ ), lower pFS (OR 0.996, CI 0.993–0.998,  $p = 0.002$ ) and lower ppFS (OR 0.009, CI 0.001–0.095,  $p < 0.001$ ) were predictors of ED. In the multivariate regression analysis, lower FP score (OR 0.721, CI 0.537–0.968,  $p = 0.03$ ) and lower ppMFT (OR 0.001, CI 0.000–0.374,  $p = 0.027$ ) were independent predictors of ED.

The predictive value of the five factors which were different between the two groups (FP score, pMFT, ppMFT, pFS and ppFS) was assessed using ROC analysis. This analysis showed the highest AUC for ppMFT (0.787) and FP score

(0.767) followed by pMFT (0.755), ppFS (0.743), and pFS (0.703). These findings indicate that the predictive value of the FP score can be further improved when the thickness (or to a lesser extent the surface) of the saved fascia regions is taken into account during the planning of the procedure.

ROC analysis with ED as outcome (cut-off IIEF score  $\leq 19$ ) showed also that the AUC of pMFT remained 0.755 if the thickness of the regions R&L 1–3 was not taken into account. However, after removing the influence of the thickness of the regions R4 and L4, the AUC dropped to 0.724 and it dropped even further after removing the influence of the regions R5 and L5 (0.706). Hence, these results (Formulas in Supplementary Material 1) underline the importance of the dorsolateral region in the postoperative IIEF.

### Cut-off IIEF score

Patients were divided into groups (ED or no ED postoperatively) based on their IIEF score, the cut-off IIEF score  $\leq 19$  for ED was based on the literature. When the cut-off was varied in the range IIEF score  $\leq 1$  to  $\leq 29$ , the predictive values of the five predictors from the previous ROC analysis varied

**Table 1** Summary of patient characteristics

	Men without erectile dysfunction (n = 40)	Men with erectile dysfunction (n = 66)	P value
No. clinical stage (%)			
cT1c	13 (32.5)	19 (28.8)	
cT2a	8 (20)	15 (22.7)	
cT2b	13 (32.5)	16 (24.2)	
cT2c	6 (15)	16 (24.2)	
Median age at time of RARP, years (IQR)	63.5 (58–63)	63.9 (59.5–67.7)	0.945
Median preoperative IIEF-EF score (IQR)	29 (27.2–30)	28 (25–30)	0.057
Median prostate volume (TRUS), cc (IQR)	39 (30–49)	40 (29–50)	0.924
Median BMI, kg/m <sup>2</sup> (IQR)	25.7 (23.7–26.7)	26.2 (24.8–28)	0.096
Median area of prostate, mm <sup>2</sup> (IQR)	1322 (1014–1604)	1341 (1066–1611)	0.605
Median FP score (IQR)	6 (7–8)	4.5 (3–6)	<0.001
Median MFT, mm (IQR)	46.7 (40.9–55.4)	40.7 (35.2–51)	0.053
Median pMFT, mm (IQR)	25 (18.2–34.2)	16.3 (11.5–21.6)	<0.001
Median ppMFT (IQR)	0.59 (0.48–0.72)	0.41 (0.28–0.53)	<0.001
Median FS, mm <sup>2</sup> (IQR)	635.7 (483.2–857.7)	571 (468–743)	0.431
Median pFS, mm <sup>2</sup> (IQR)	365 (266–510)	260 (172–377)	<0.001
Median ppFS (IQR)	0.63 (0.49–0.78)	0.44 (0.31–0.6)	<0.001

*BMI* body mass index, *FP* fascia preservation, *FS* fascia surface, *FT* fascia thickness, *MFT* median fascia thickness, *IIEF-EF* International Index of Erectile Function-Erectile Function, *IQR* interquartile range, *pFS* preserved fascia surface, *pMFT* preserved median fascia thickness, *ppMFT* percentage of preserved median fascia thickness, *ppFS* percentage of preserved fascia surface, *RARP* robot-assisted laparoscopic radical prostatectomy, *TRUS* transrectal ultrasound

with an optimum at the cut-off IIEF score  $\leq 12$  or  $\leq 13$ . At this optimum, the AUC for the five factors (Supplementary Fig. 5) which were significantly related to postoperative ED were: FP score (0.812), pMFT (0.834), ppMFT (0.818), pFS (0.777) and ppFS (0.815). The differences between the AUC values depended on the cut-off chosen, but were most consistent in the range of a cut-off IIEF score  $\leq 10$  to  $\leq 20$ . In this range, the mean difference in AUC values between the FP score and pMFT was 0.015, whereby the pMFT proved to be a slightly stronger predictor than the FP score.

## Discussion

To our knowledge, this is the first study that examines the correlation of preoperative MRI-assessed FT and intraoperative FP score with postoperative EF. Preoperative MRI enabled quantification of periprostatic anatomy that allowed a better prediction of postoperative EF outcome. Patients without ED after nerve-sparing prostatectomy had a thicker fascia on preoperative MRI compared with ED patients independent of the extent of nerve preservation, although this difference was at the edge of statistical significance ( $p=0.053$ ). Moreover, FT was not correlated with established prognostic factors of ED such as body mass index (BMI), age and preoperative prostate volume.

To find an explanation for the association between FT and ED we studied vessel and nerve density. We observed that there was poor correlation between histological- and MRI-determined FT while vessel and nerve density overlapped. Based on these observations from histology, we studied the role of location of FP on outcome and we confirmed earlier findings that, regardless of FT sparing, the dorsolateral tissue is strongly correlated with improved erectile function outcome [14]. We assume that FT itself contributes to preservation of EF by forming a solid, protective layer for the neurovascular bundles that withstands extensive traction and manipulation during surgery. Kwon et al. [18] made observations that support our hypothesis but did only assess the thickness of the dorsolateral fascia on the prostate where the neurovascular bundle was assumed. In our analysis, we present data of the entire circumference of the prostate.

Based on the results of bivariate and ROC analyses FP score, ppMFT, pFMT and ppFS were the best predictors of postoperative EF preservation accounting for the observation that the preservation of a thicker and more dense fascia are inversely correlated with ED outcome. These observations emphasize our theory about the fascia as a protective layer additionally enhanced by higher nerve density. In accordance to our results, Di Paolo et al. [19] recently observed that the decrease in MRI-measured periprostatic neurovascular fibers was correlated with ED. Our method of measuring FT could be combined with the risk-stratified approaches such as the

neural-hammock sparing of Tewari et al. [4] for optimal prediction of ED outcome.

## Limitations

Several limitations to the present study are evident. We have not taken into account the intraoperative use of bipolar or monopolar coagulation or the use of surgical clips. To assess EF, we used the IIEF-EF questionnaire which does not take into account possible social–psychological issues as a reason for ED. In addition, the interobserver correlation for the FT assessment was poor to moderate, which could be attributed to the complex anatomy of the prostate and adjacent structures [6, 20]. Interobserver variability in target definition has been demonstrated in a multitude of studies and at various anatomic sites [21–23]. A more reproducible delineation of structures can be achieved by specific educational interventions [24–26]. Finally, FP score does not take into account the location of the preserved fascia in the circumference of the prostate. Moreover, FP score and our predictive model should be validated in larger patients' populations in other institutes.

## Conclusion

Periprostatic FT determined in MR images combined with intraoperative FP score were correlated to postprostatectomy EF outcome. The MRI analysis indicated a large anatomical heterogeneity in FT between patients, as was the case in histologic evaluation of the fascia. This study is a step closer to provide a more personalized approach in counseling a patient who consider RARP as treatment for PCa.

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**Author contributions** Project development: all authors. Data collection: NG, RVDR, CK, GK, HVDP. Data analysis: all authors. Manuscript writing & approval: all authors.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Informed consent** For this type of study formal consent is not required.

## References

- Siegel RL, Miller KD, Jemal A (2017) Cancer statistics, 2017. *CA Cancer J Clin* 67:7–30
- Savera AT, Kaul S, Badani K et al (2006) Robotic radical prostatectomy with the “Veil of Aphrodite” technique: histologic evidence of enhanced nerve sparing. *Eur Urol* 49:1065–1073
- Stolzenburg JU, Rabenalt R, Do M et al (2008) Intrafascial nerve-sparing endoscopic extraperitoneal radical prostatectomy. *Eur Urol* 53:931–940
- Tewari A, Peabody JO, Fischer M et al (2003) An operative and anatomic study to help in nerve sparing during laparoscopic and robotic radical prostatectomy. *Eur Urol* 43:444–454
- Villeirs GM, Verstraete LK, De Neve WJ, De Meerleer GO (2005) Magnetic resonance imaging anatomy of the prostate and periprostatic area: a guide for radiotherapists. *Radiother Oncol* 76:99–106
- Secin FP, Bianco FJ (2010) Surgical anatomy of radical prostatectomy: periprostatic fascial anatomy and overview of the urinary sphincters. *Arch Esp Urol* 63:255–266
- Eichelberg C, Erbersdobler A, Michl U et al (2007) Nerve distribution along the prostatic capsule. *Eur Urol* 51:105–110
- Sievert KD, Hennenlotter J, Laible I et al (2008) The periprostatic autonomic nerves—bundle or layer? *Eur Urol* 54:1109–1116
- de Rooij M, Hamoen EH, Fütterer JJ et al (2014) Accuracy of multiparametric MRI for prostate cancer detection: a meta-analysis. *AJR Am J Roentgenol* 202:343–351
- McClure TD, Margolis DJ, Reiter RE et al (2012) Use of MR imaging to determine preservation of the neurovascular bundles at robotic-assisted laparoscopic prostatectomy. *Radiology* 262:874–883
- Tanaka K, Shigemura K, Muramaki M et al (2013) Efficacy of using three-tesla magnetic resonance imaging diagnosis of capsule invasion for decision-making about neurovascular bundle preservation in robotic-assisted radical prostatectomy. *Korean J Urol* 54:437–441
- Tewari AK, Srivastava A, Huang MW et al (2011) Anatomical grades of nerve sparing: a risk-stratified approach to neural-hammock sparing during robot-assisted radical prostatectomy (RARP). *BJU Int* 108:984–992
- Schatloff O, Chauhan S, Sivaraman A et al (2012) Anatomic grading of nerve sparing during robot-assisted radical prostatectomy. *Eur Urol* 61:796–802
- van der Poel HG, de Blok W (2009) Role of extent of fascia preservation and erectile function after robot-assisted laparoscopic prostatectomy. *Urology* 73:816–821
- Kowalczyk KJ, Huang AC, Hevelone ND et al (2013) Effect of minimizing tension during robotic-assisted laparoscopic radical prostatectomy on urinary function recovery. *World J Urol* 31:515–521
- Asimakopoulos AD, Corona Montes VE, Gaston R (2012) Robot-assisted laparoscopic radical prostatectomy with intrafascial dissection of the neurovascular bundles and preservation of the pubovesical complex: a step-by-step description of the technique. *J Endourol* 26:1578–1585
- Rosen RC, Riley A, Wagner G et al (1997) The international index of erectile function (IIEF): a multidimensional scale for assessment of erectile dysfunction. *Urology* 49:822–830
- Kwon T, Lee C, Jung J, Kim CS (2017) Neurovascular bundle size measured on 3.0-T magnetic resonance imaging is associated with the recovery of erectile function after robot-assisted radical prostatectomy. *Urol Oncol* 35:542
- Di Paola V, Cybulski A, Belluardo S et al (2018) Evaluation of periprostatic neurovascular fibers before and after radical prostatectomy by means of 1.5 T MRI diffusion tensor imaging. *Br J Radiol* 91:20170318
- Ficarra V, Novara G, Ahlering TE et al (2012) Systematic review and meta-analysis of studies reporting potency rates after robot-assisted radical prostatectomy. *Eur Urol* 62:418–430
- Walz J, Burnett AL, Costello AJ et al (2010) 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* 57:179–192
22. Weiss E, Hess CF (2003) The impact of gross tumor volume (GTV) and clinical target volume (CTV) definition on the total accuracy in radiotherapy theoretical aspects and practical experiences. *Strahlenther Onkol* 179:21–30
  23. Fuller CD, Nijkamp J, Duppen JC et al (2011) Prospective randomized double-blind pilot study of site-specific consensus atlas implementation for rectal cancer target volume delineation in the cooperative group setting. *Int J Radiat Oncol Biol Phys* 79:481–489
  24. Kalpathy-Cramer J, Awan M, Bedrick S et al (2014) Development of a software for quantitative evaluation radiotherapy target and organ-at-risk segmentation comparison. *J Digit Imaging* 27:108–119
  25. Bekelman JE, Wolden S, Lee N (2009) Head-and-neck target delineation among radiation oncology residents after a teaching intervention: a prospective, blinded pilot study. *Int J Radiat Oncol Biol Phys* 73:416–423
  26. Li XA, Tai A, Arthur DW et al (2009) Variability of target and normal structure delineation for breast cancer radiotherapy: an RTOG Multi-Institutional and Multiobserver Study. *Int J Radiat Oncol Biol Phys* 73:944–951