Year: 2020

Contrast media kinetics in multiparametric magnetic resonance imaging before radical prostatectomy predicts the probability of postoperative incontinence.

Schmid, Florian A ; Wettstein, Marian S ; Kessler, Thomas M ; Hermanns, Thomas ; Boss, Andreas ; Hötter, Andreas M ; Eberli, Daniel

Abstract: **PURPOSE** To evaluate the role of preoperative multiparametric magnetic resonance imaging (MRI) as predictor of post-prostatectomy incontinence (PPI). **METHODS** We analyzed patients who underwent robot-assisted radical prostatectomy for localized prostate cancer at our institution between July 2015 and April 2017. In these patients, we measured the perfusion quality of the pelvic floor with contrast media kinetics in the preoperative MRI of the prostate and compared the levator ani muscle (region of interest) to the surrounding pelvic muscle structures (reference). Prospectively collected questionnaires regarding urinary incontinence were then evaluated 1 year postoperatively. Outcomes were dichotomized into "continent" (ICIQ-Score = 0-5) and "incontinent" (ICIQ-Score ≥ 6). In each patient, we determined the perfusion ratio of the levator ani muscle divided by the surrounding pelvic muscle structures and compared them among the groups. **RESULTS** Forty-two patients were included in the study (n = 22 in "continent", n = 20 in "incontinent" group). The median perfusion ratio from the continent group was significantly higher compared to the incontinent group (1.61 vs. 1.15; 95% CI 0.09-0.81, p = 0.015). The median perfusion ratio in "excellent" (ICIQ-Score = 0) was significantly higher than in "poor" (ICIQ-Score ≥ 11) outcomes (1.48 vs. 0.94; 95% CI 0.04-1.03, p = 0.036). Further, a higher perfusion ratio was negatively correlated with ICIQ-Score (r = -0.33; 95% CI -0.58 to 0.03; p = 0.031). **CONCLUSIONS** Our data demonstrate a promising new strategy to predict PPI through the perfusion quality of pelvic muscle structures with contrast media kinetics. This may facilitate preoperative patient consulting and decision-making.

DOI: <https://doi.org/10.1007/s00345-019-02952-y>

Posted at the Zurich Open Repository and Archive, University of Zurich

ZORA URL: <https://doi.org/10.5167/uzh-174742>

Journal Article

Accepted Version

Originally published at:

Schmid, Florian A; Wettstein, Marian S; Kessler, Thomas M; Hermanns, Thomas; Boss, Andreas; Hötter, Andreas M; Eberli, Daniel (2020). Contrast media kinetics in multiparametric magnetic resonance imaging before radical prostatectomy predicts the probability of postoperative incontinence. *World Journal of Urology*, 38(7):1741-1748.

DOI: <https://doi.org/10.1007/s00345-019-02952-y>

Contrast Media Kinetics in Multiparametric Magnetic Resonance Imaging before Radical Prostatectomy Predicts the Probability of Postoperative Incontinence

Original Research Article

Florian A. Schmid¹, Marian S. Wettstein¹, Thomas M. Kessler², Thomas Hermanns¹, Andreas Boss³, Andreas M. Hötter³, Daniel Eberli¹

¹ University Hospital Zurich, Department of Urology, University of Zurich, Zurich

² Balgrist University Hospital, Department of Neuro-Urology, University of Zurich, Zurich

³ University Hospital Zurich, Department of Radiology, University of Zurich, Zurich

Corresponding author:

Daniel Eberli, MD, PhD

Department of Urology

University Hospital Zurich

Frauenklinikstrasse 10

8091 Zurich, Switzerland

Tel: +41 44 255 95 49

Email: daniel.eberli@usz.ch

Abstract

Purpose: To evaluate the role of preoperative multiparametric magnetic resonance imaging (MRI) as predictor of post-prostatectomy incontinence (PPI).

Methods: We analyzed patients who underwent robot-assisted radical prostatectomy for localized prostate cancer at our institution between July 2015 and April 2017. In these patients we measured the perfusion quality of the pelvic floor with contrast media kinetics in the preoperative MRI of the prostate and compared the levator ani muscle (region of interest) to the surrounding pelvic muscle structures (reference). Prospectively collected questionnaires regarding urinary incontinence were then evaluated 1 year postoperatively. Outcomes were dichotomized into “continent” (ICIQ-score = 0-5) and “incontinent” (ICIQ-score $\geq$ 6). In each patient, we determined the perfusion ratio of the levator ani muscle divided by the surrounding pelvic muscle structures and compared them among the groups.

Results: Forty-two patients were included in the study (n=22 in “continent”, n=20 in “incontinent” group). The median perfusion ratio from the continent group was significantly higher compared to the incontinent group (1.61 vs. 1.15; 95% CI: 0.09 to 0.81, $p = 0.015$). The median perfusion ratio in “excellent” (ICIQ-score = 0) was significantly higher than in “poor” (ICIQ-score $\geq$ 11) outcomes (1.48 vs. 0.94; 95% CI: 0.04 to 1.03, $p = 0.036$). Further, a higher perfusion ratio was negatively correlated with ICIQ-Score ($r = -0.33$; 95% CI: -0.58 to 0.03; $p = 0.031$).

Conclusions: Our data demonstrate a promising new strategy to predict PPI through the perfusion quality of pelvic muscle structures with contrast media kinetics. This may facilitate preoperative patient consulting and decision making.

Keywords: Urinary Incontinence, Prostatectomy, MRI, Contrast Media, Pelvic Floor

Introduction

Despite the recent advances in robot-assisted radical prostatectomy for the treatment of localized prostate cancer (PCa), urinary incontinence and erectile dysfunction remain major genitourinary adverse effects that influence the postoperative quality of life (QoL) [1,2]. According to the literature, up to 20 % of all males treated with radical prostatectomy (RP) for PCa have to deal with long-term side-effects. Especially urinary incontinence has a huge impact on the postoperative well-being and is rated of highest subjective and psychosocial importance [3,4,2,5].

Substantial research looked into the matter of individual surgical technique and a systematic review with meta-analysis compared different surgical approaches of RP (robot-assisted vs. laparoscopic vs. open retropubic) [6]. Nonetheless, further patient characteristics are considered as key factors that influence and predict post-prostatectomy incontinence (PPI). Age [7], body mass index (BMI) [8], comorbidities [9], prostate size [10], T-stage and Gleason Score [11], nerve sparing [12], bladder neck preservation [13], functional bladder changes [14], preoperative continence or erectile function status [15], lower urinary tract symptoms (LUTS) [16] and prior transurethral resection of the prostate (TURP) [17] are all parameters of varying importance in predicting the probability of PPI. Heesakkers et al. nicely reviewed the literature for contributing factors causing PPI, most of which are controversially discussed [18].

The integrity of the pelvic floor is an essential premise for urinary continence. Physiologically, there is a direct link from muscle function and its blood supply. We hypothesized a coherence between the perfusion quality of the pelvic floor and the anatomical structures that are responsible for urinary continence. The aim of our study was to investigate the contrast phase data of routinely performed and already available multiparametric (mp) magnetic resonance imaging (MRI) of the prostate, used to calculate the PI-RADS score (Prostate Imaging Reporting and Data System), to predict the risk of PPI.

Materials and Methods

At the University Hospital in Zurich, Switzerland, we prospectively assess all patients with a diagnosis of PCa that undergo RP, including their oncological follow-up (local ethical review board study approval: KEK-StV-Nr. 06/08). All patients suspicious for PCa are assigned to receive mp MRI and transperineal prostate fusion-biopsy to confirm the diagnosis. The first follow-up visit after the operation in the outpatient clinic takes place after 6 weeks, including the measurement of the initial postoperative PSA value. Further visits are scheduled after three, six and twelve months in the first year. At each of these follow-up visits, patients are asked to fill in a questionnaire regarding continence status (International Consultation on Incontinence Modular Questionnaire = ICIQ) [19]. The used ICIQ-Score consists of three questions focusing on the frequency and the subjective amount of involuntary urinary loss and the consecutive limitation in daily life. There is a maximum of 21 points, whereas a score of zero means “no”, 1-5 “mild”, 6-10 “intermediate” and ≥ 11 “severe” incontinence.

Design & study setting

This publication was based on retrospective analysis of prospectively gathered data. Patients who underwent robot-assisted RP between July 2015 and April 2017 and who received a preoperative mp MRI investigation in domo with a 3 Tesla MRI without rectal coil were included in the analysis. As a further inclusion criterion, they had to complete the above mentioned questionnaire at 1 year postoperative follow up. In all of these patients, we measured the membranous urethra length (MUL) and the perfusion quality of the levator ani muscle (LAM) compared to the surrounding pelvic muscle structures (gluteus maximus, inner and outer obturator muscle) with contrast media kinetics (see below).

Outcome assessment

Patients were dichotomized into two different groups with regard to the 1-year postoperative continence status on behalf of the ICIQ-score: Patients with an ICIQ-score of 0-5 points were

assigned to the “continent” (“no” – “mild”) and ≥ 6 points to the “incontinent” group (“intermediate” – “severe”) [20]. We compared the resulting perfusion ratios and the MUL of the group with “continent” patients to the measured values in “incontinent” patients. For the subgroup analysis, “excellent” and “poor” outcomes were defined as ICIQ-Score of 0 points (“no” incontinence) and ≥ 11 points (“severe” incontinence) after 1 year, respectively. The MUL was defined as the urethral distance from the distal prostate apex to the proximal penile bulb in sagittal orientation.

MRI of the prostate

All MRI examinations were performed at a field strength of 3 Tesla on Siemens Skyra MRI scanners (Siemens Healthineers, Erlangen, Germany) with a 18-channel phased-array receiver coil and featured a dedicated mp MRI protocol including high-resolution T2-weighted sequences in three orientations, a diffusion-weighted sequence and a dynamic contrast-enhanced 3D fat-saturated gradient-echo sequence with a temporal resolution < 8 s and concurrent application of gadoterate meglumine (Dotarem®, Guerbet, Roissy, France). All MRI parameters were in accordance to the technical specifications set forth in the PIRADS guidelines [21].

Using the readily available software solution Tissue4D (Siemens Healthineers, Erlangen, Germany), we measured the median initial area under the curve (iAUC) 60 seconds after wash-in of the contrast agent (adjusting for patient-specific lag time from contrast injection to first wash-in of the contrast agent) by drawing regions-of-interest (ROI) in the LAM and in the gluteus maximus as well as inner and outer obturator muscles (*Figure 1A*). The perfusion ratio was then calculated as the ratio between iAUC60 of the LAM divided by the averaged iAUC60 of the three ROIs placed in the three other pelvic muscles (*Figure 1B*). This served as estimation of the preoperative perfusion quality of the pelvic floor. The MUL (in cm) was measured on the sagittal T2-weighted MRI sequence.

Statistical analysis

Statistical analysis was performed using *R* [22]. Welch's two-sample t-test was used to compare perfusion ratio and MUL between different continence statuses. Pearson's product-moment correlation was computed to describe the association between MUL and perfusion ratio as well as ICIQ-Score and perfusion ratio. Lastly, univariable and multivariable logistic regression analysis were performed to predict incontinence by perfusion ratio and MUL adjusted for age, BMI, nerve sparing and prostate size. All p-values smaller than 0.05 were considered statistically significant (two-sided).

Results

Patient cohort and characteristics

Forty-two patients were included in the study. After dichotomization according to continence status, $n = 22$ patients belonged to the “continent” and $n = 20$ to the “incontinent” group. The groups of continent and incontinent patients were not statistically different with regard to the clinically relevant characteristics at the time of surgery such as age, BMI, prostate specific antigen (PSA), prostate size, Gleason-Score and nerve sparing. The subgroups of excellent vs. poor outcomes are also displayed (see *Table 1*).

Perfusion ratio

The comparison of the perfusion of the LAM to the surrounding pelvic muscle structures yielded a median perfusion ratio in the continent group that was significantly higher compared to the incontinent group (1.61 vs. 1.15, respectively; difference = 0.46; 95% confidence interval (CI): 0.09 to 0.81; $p = 0.015$). To examine the consistency of the observed relation, we performed a subgroup analysis of “excellent” outcomes (ICIQ = 0 points) vs. “poor” outcomes (ICIQ ≥ 11 points) of 10 patients in each group. We found that the patients with an excellent outcome had a significantly higher median perfusion ratio than those with a poor outcome (1.48 vs. 0.94, respectively; difference = 0.54; 95% CI: 0.04 to 1.03; $p = 0.036$). *Figure 2* shows density plots (A, C) and a boxplots (B, D), which both compare the perfusion ratios of the two regions (LAM vs. reference tissue) of the main and the subgroups.

Membranous urethra length

Patients’ MUL differed in relation to continence status: It was shorter in the incontinent compared to the continent patients (14.5 vs. 9.3 mm, respectively; difference = 5.2 mm; 95% CI: 4.09 to 6.40 mm; $p < 0.001$). See boxplot in *Figure 3C*. Furthermore, the perfusion ratio was positively correlated with the MUL ($r = 0.42$; 95% CI: 0.13 to 0.64; $p = 0.0054$). See correlation plot in *Figure 3A*.

ICIQ-Score

A higher perfusion ratio was negatively correlated with the ICIQ-Score of the patients in our cohort ($r = -0.33$; 95% CI: -0.58 to -0.03; $p = 0.031$). See correlation plot *Figure 3B*. In *Figure 3D* we plotted the 4 subgroups with outcomes “excellent”, “good”, “bad” and “poor” according to their postoperative median ICIQ-Score per subgroup against the perfusion ratio. We added the median ICIQ-Score per group to the subgroups of continence after 1 year. The best perfusion ratio was found in the subgroup with a “good” outcome.

Logistic regression analysis

The odds of becoming incontinent were lower in those patients with a better perfusion ratio in the preoperative MRI of the prostate compared to those with a worse perfusion ratio (odds ratio (OR) = 0.24; 95% CI: 0.06 to 0.75; $p = 0.025$). When it comes to MUL, the odds of becoming incontinent were lower in patients with a longer MUL in the preoperative MRI compared to those with a shorter MUL (OR = 0.05; 95% CI: 0.00 to 0.29; $p = 0.034$). Further, in a multivariate regression analysis of perfusion ratio adjusted for age, BMI, nerve sparing and prostate size the odds of becoming incontinent were lower in those patients with a better perfusion ratio compared to those with a worse perfusion ratio (OR = 0.11; 95% CI: 0.023 to 0.55; $p = 0.0068$). However, the multivariable regression analysis of perfusion ratio with adjusting for MUL led to overfitting and yielded inconclusive results. See *Table 2* for uni- and multivariable regression analysis.

Discussion

The usage of robot-assisted RP became increasingly popular and advanced to the standard of care in patients with localized PCa [23]. Adverse effects such as PPI still reduces the QoL in up to every fifth patient undergoing this procedure [1,4]. Therefore, the possibility to predict the chances of PPI in patients with localized PCa planned for a surgical treatment would be a valuable tool for consulting and discussing different treatment strategies in patients confronted with this disease. To the best of our knowledge, this is the first study assessing the perfusion quality of the pelvic floor as a predicting factor for PPI. Our results show, that patients with a better preoperative perfusion ratio of the relevant pelvic muscle structures belong to the “continent” subgroup one year after the intervention. Examining this circumstance, we found evidence for a negative correlation between ICIQ-score and perfusion ratio after completion of the follow-up period. The consistency of this relation was further supported by a sensitivity analysis of subgroups, which yielded similar results: Patients with an excellent outcome had a significantly better perfusion ratio than those with a poor outcome regarding urinary continence.

Continence underlies a complex interaction of neural and muscular structures in the lower pelvis [18]. Since the function of these structures also depends on adequate perfusion, we sought to investigate this relation in already available data from routine preoperative mp MRIs of the prostate. The negative influence of scar tissue or fibrosis on urinary continence is known and leads to sphincteric incompetence [24]. This also accounts for the radicalness of surgical tumor excision, whereas higher T-stages and no nerve sparing are acquainted with higher rates of PPI [25]. Therefore, the perfusion quality of important muscle structures, such as the LAM, seem to be a valuable preoperative marker. Since a prostatectomy leads to significant alteration in the perivesical and periurethral tissue, we hypothesized that a good preoperative perfusion of the sphincter muscle may be regarded as prerequisite for tissue healing and restoration of continence function. In our cohort, this was underlined by the univariable as well

as multivariable regression analysis, where a better perfusion ratio was a protective factor for incontinence, even after adjusting for the risk factors age, BMI, nerve sparing and prostate size. This supports our hypothesis of the preoperative perfusion being an independent marker for PPI.

In multiple recently published articles and a broad systematic review including a meta-analysis, the preoperative membranous urethra length (MUL) was estimated of highest relevance and clinical importance among multiple factors [26]. Compared to other independent parameters, the isolated measurement of the MUL rendered the most reliable results in accurately predicting PPI. Coakley et al. were the first to investigate the important relation of preoperative MUL in MRI and consecutive PPI [27]. Later publications compared the MUL in pre- and postoperative MRI investigations, which was related to the recovery time and level of PPI [24,28]. In line with the international data on MUL measurement [28,29], we confirmed that patients in our cohort regarded as “continent” (ICIQ-score 0-5 points) had a significantly longer preoperative MUL compared to the “incontinent” (ICIQ-Score >6 points) group. Interestingly, we found a positive correlation between the perfusion ratio and the MUL: Males with a better perfusion tended also to have a longer MUL and vice versa. Furthermore, in the univariable regression analysis, a longer MUL significantly reduced the odds of becoming incontinent 1 year postoperative. This goes along with the international data: With an extra centimeter of MUL, patients are around 200% more likely to return to continence [26].

Should we use MUL measurements or contrast media kinetics of the pelvic floor to estimate the chances of PPI in our patients? The truth lies somewhere in between, since both techniques contribute to increase the evidence and ameliorate the prediction of PPI. Hence, there is little doubt about the importance of the surgical technique for not only nerve sparing but also maximal MUL sparing to achieve the longest functional urethra length in order to improve the postoperative continence situation [30,31,12]. The anatomical predisposition, regarding the MUL in the individual patient, cannot be altered, though. The controversy

regarding the difficulty of preoperative MUL measurements is evident due to high intra- and interreader variability [26]. Even in radiological experts no exact consensus exists which technique should ideally and standardly be used for MUL measurements. Therefore, measuring by an unexperienced urologist would yield ambiguous results. Nevertheless, further parameters from dynamic contrast-enhanced MRI are readily and easily available as part of every preoperative mp MRI investigation. These parameters provide additional information on the physiological condition of the pelvic muscle structures, which are, with no doubt, important predicting factors that should be used to estimate the chances PPI. With the use of already available and easy accessible post-processing software tools to measure the relative enhancement of contrast agent over time, contrast media kinetics serves as convincing approach that tends to be more objective than isolated preoperative MUL measurements alone. All in all, we recommend linking these two techniques and using them alongside each other to establish a reliable calculator for PPI in the future.

The limitations of our study was the rather low sample size and therefore the limited statistical power. Consequently, adjusting for covariables was not feasible for all possible confounding factors in the multivariable regression analysis. Further, it is a retrospective study design and the cohort consisted of patients recruited by convenience sampling.

Conclusion

We observed that the assessment of the perfusion quality of relevant pelvic muscle structures in standard mp MRI before RP led to a reliable prediction of the postoperative continence situation. This technique is valuable and shows comparable results to the measurement of the MUL and may serve as additional predictor for the chances of PPI. Bigger sample sizes and future trials investigating this relation are needed to confirm our findings and to design an accessible and easy to use risk score for clinical practice.

Figure caption

- **Fig. 1** Assessment of preoperative perfusion quality of pelvic muscle structures (A) with relative contrast media enhancement over time (B) in the regions of interest: Levator ani muscle vs. gluteus maximus and inner/outer obturator muscle.
- **Fig. 2** Density plot (A) and boxplot (B) of perfusion ratios among the “continent” and “incontinent” group. Ratio of median iAUC 1.61 (continent) vs. 1.15 (incontinent); difference = 0.46; 95% CI: 0.09 to 0.81; $p = 0.015$. Density plot (C) and boxplot (D) of perfusion ratios among subgroups (excellent vs. poor outcome). Ratio of median iAUC 1.48 (excellent) vs. 0.94 (poor); difference = 0.54; 95% CI: 0.04 to 1.03; $p = 0.036$.
Abbreviation: iAUC = initial Area Under the Curve
- **Fig. 3** Positive correlation of perfusion ratio and MUL (A): $r = 0.42$; 95% CI: 0.13 to 0.64; $p = 0.0054$. Negative correlation of perfusion ratio and ICIQ-Score 1 year postoperative (B): $r = -0.33$; 95% CI: -0.58 to -0.03; $p = 0.031$. MUL stratified by outcome group (C): 14.5 vs. 9.3 mm, respectively; 95% CI: 4.09 to 6.40 mm; $p < 0.001$. Perfusion ratio stratified by different median ICIQ-Scores per subgroups (D).
Abbreviations: iAUC = initial Area Under the Curve, MUL = Membranous urethra length, ICIQ-Score = International Consultation on Incontinence Modular Questionnaire

Authors' contribution

FA Schmid: Protocol/project development, Data collection and management, Data analysis, Manuscript writing

MS Wettstein: Data collection and management, Data analysis, Manuscript editing

TM Kessler: Protocol/project development, Manuscript editing

T Hermanns: Project development, Manuscript editing

A Boss: Protocol/project development, Data collection and management, Manuscript editing

AM Hötter: Data analysis, Manuscript editing

D Eberli: Protocol/project development, Manuscript editing

Conflict of Interest

The authors declare that they have no conflict of interest.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (local ethical review board "Kantonale Ethikkommission Zürich", study approval: KEK-StV-Nr. 06/08) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

References

1. Ficarra V, Borghesi M, Suardi N, De Naeyer G, Novara G, Schatteman P, De Groote R, Carpentier P, Motttrie A (2013) Long-term evaluation of survival, continence and potency (SCP) outcomes after robot-assisted radical prostatectomy (RARP). *BJU Int* 112 (3):338-345. doi:10.1111/bju.12001
2. Punnen S, Cowan JE, Chan JM, Carroll PR, Cooperberg MR (2015) Long-term health-related quality of life after primary treatment for localized prostate cancer: results from the CaPSURE registry. *Eur Urol* 68 (4):600-608. doi:10.1016/j.eururo.2014.08.074
3. Sciarra A, Gentilucci A, Salciccia S, Von Heland M, Ricciuti GP, Marzio V, Pierella F, Musio D, Tombolini V, Frantellizzi V, Pasquini M, Maraone A, Guandalini A, Maggi M (2018) Psychological and functional effect of different primary treatments for prostate cancer: A comparative prospective analysis. *Urol Oncol* 36 (7):340 e347-340 e321. doi:10.1016/j.urolonc.2018.03.022
4. Liss MA, Osann K, Canvasser N, Chu W, Chang A, Gan J, Li R, Santos R, Skarecky D, Finley DS, Ahlering TE (2010) Continence definition after radical prostatectomy using urinary quality of life: evaluation of patient reported validated questionnaires. *J Urol* 183 (4):1464-1468. doi:10.1016/j.juro.2009.12.009
5. Sanda MG, Dunn RL, Michalski J, Sandler HM, Northouse L, Hembroff L, Lin X, Greenfield TK, Litwin MS, Saigal CS, Mahadevan A, Klein E, Kibel A, Pisters LL, Kuban D, Kaplan I, Wood D, Ciezki J, Shah N, Wei JT (2008) Quality of life and satisfaction with outcome among prostate-cancer survivors. *N Engl J Med* 358 (12):1250-1261. doi:10.1056/NEJMoa074311
6. Ficarra V, Novara G, Rosen RC, Artibani W, Carroll PR, Costello A, Menon M, Montorsi F, Patel VR, Stolzenburg JU, Van der Poel H, Wilson TG, Zattoni F, Motttrie A (2012) Systematic review and meta-analysis of studies reporting urinary continence recovery after robot-assisted radical prostatectomy. *Eur Urol* 62 (3):405-417. doi:10.1016/j.eururo.2012.05.045
7. Becker A, Tennstedt P, Hansen J, Trinh QD, Kluth L, Atassi N, Schlomm T, Salomon G, Haese A, Budaeus L, Michl U, Heinzer H, Huland H, Graefen M, Steuber T (2014) Functional and oncological outcomes of patients aged <50 years treated with radical prostatectomy for localised prostate cancer in a European population. *BJU Int* 114 (1):38-45. doi:10.1111/bju.12407
8. Wei Y, Wu YP, Lin MY, Chen SH, Lin YZ, Li XD, Zheng QS, Xue XY, Xu N (2018) Impact of Obesity on Long-Term Urinary Incontinence after Radical Prostatectomy: A Meta-Analysis. *Biomed Res Int* 2018:8279523. doi:10.1155/2018/8279523
9. Rajih E, Meskawi M, Alenizi AM, Zorn KC, Alnazari M, Zanaty M, Alhathal N, El-Hakim A (2018) Perioperative predictors for post-prostatectomy urinary incontinence in prostate cancer patients following robotic-assisted radical prostatectomy: Long-term results of a Canadian prospective cohort. *Can Urol Assoc J*. doi:10.5489/cuaj.5356
10. Konety BR, Sadetsky N, Carroll PR, Ca PI (2007) Recovery of urinary continence following radical prostatectomy: the impact of prostate volume--analysis of data from the CaPSURE Database. *J Urol* 177 (4):1423-1425; discussion 1425-1426. doi:10.1016/j.juro.2006.11.089
11. Kunz I, Musch M, Roggenbuck U, Klevecka V, Kroepfl D (2013) Tumour characteristics, oncological and functional outcomes in patients aged >= 70 years undergoing radical prostatectomy. *BJU Int* 111 (3 Pt B):E24-29. doi:10.1111/j.1464-410X.2012.11368.x
12. Steineck G, Bjartell A, Hugosson J, Axen E, Carlsson S, Stranne J, Wallerstedt A, Persson J, Wilderang U, Thorsteinsdottir T, Gustafsson O, Lagerkvist M, Jiborn T, Haglund E,

- Wiklund P, committee Ls (2015) Degree of preservation of the neurovascular bundles during radical prostatectomy and urinary continence 1 year after surgery. *Eur Urol* 67 (3):559-568. doi:10.1016/j.eururo.2014.10.011
13. Nyarangi-Dix JN, Radtke JP, Hadaschik B, Pahernik S, Hohenfellner M (2013) Impact of complete bladder neck preservation on urinary continence, quality of life and surgical margins after radical prostatectomy: a randomized, controlled, single blind trial. *J Urol* 189 (3):891-898. doi:10.1016/j.juro.2012.09.082
14. Shao IH, Chou CY, Huang CC, Lin CF, Chang YH, Tseng HJ, Wu CT (2015) A Specific Cystography Pattern Can Predict Postprostatectomy Incontinence. *Ann Surg Oncol* 22 Suppl 3:S1580-1586. doi:10.1245/s10434-015-4847-y
15. Gandaglia G, Suardi N, Gallina A, Capitanio U, Abdollah F, Salonia A, Nava L, Colombo R, Guazzoni G, Rigatti P, Montorsi F, Briganti A (2012) Preoperative erectile function represents a significant predictor of postoperative urinary continence recovery in patients treated with bilateral nerve sparing radical prostatectomy. *J Urol* 187 (2):569-574. doi:10.1016/j.juro.2011.10.034
16. Murphy G, Haddock P, Doak H, Jackson M, Dorin R, Meraney A, Kesler S, Staff I, Wagner JR (2015) Urinary Bother as a Predictor of Postsurgical Changes in Urinary Function After Robotic Radical Prostatectomy. *Urology* 86 (4):817-823. doi:10.1016/j.urology.2015.04.041
17. Tienza A, Robles JE, Hevia M, Algarra R, Diez-Caballero F, Pascual JI (2018) Prevalence analysis of urinary incontinence after radical prostatectomy and influential preoperative factors in a single institution. *Aging Male* 21 (1):24-30. doi:10.1080/13685538.2017.1369944
18. Heesakkers J, Farag F, Bauer RM, Sandhu J, De Ridder D, Stenzl A (2017) Pathophysiology and Contributing Factors in Postprostatectomy Incontinence: A Review. *Eur Urol* 71 (6):936-944. doi:10.1016/j.eururo.2016.09.031
19. Donovan JL, Peters TJ, Abrams P, Brookes ST, de aa Rosette JJ, Schafer W (2000) Scoring the short form ICSmaleSF questionnaire. *International Continence Society. J Urol* 164 (6):1948-1955
20. Abrams P, Avery K, Gardener N, Donovan J, Board IA (2006) The International Consultation on Incontinence Modular Questionnaire: www.iciq.net. *J Urol* 175 (3 Pt 1):1063-1066; discussion 1066. doi:10.1016/S0022-5347(05)00348-4
21. Weinreb JC, Barentsz JO, Choyke PL, Cornud F, Haider MA, Macura KJ, Margolis D, Schnall MD, Shtern F, Tempany CM, Thoeny HC, Verma S (2016) PI-RADS Prostate Imaging - Reporting and Data System: 2015, Version 2. *Eur Urol* 69 (1):16-40. doi:10.1016/j.eururo.2015.08.052
22. R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing V, Austria. URL <https://www.R-project.org/>.
23. Hatiboglu G, Teber D, Hohenfellner M (2012) Robot-assisted prostatectomy: the new standard of care. *Langenbecks Arch Surg* 397 (3):343-352. doi:10.1007/s00423-011-0743-5
24. Paparel P, Akin O, Sandhu JS, Otero JR, Serio AM, Scardino PT, Hricak H, Guillonneau B (2009) Recovery of urinary continence after radical prostatectomy: association with urethral length and urethral fibrosis measured by preoperative and postoperative endorectal magnetic resonance imaging. *Eur Urol* 55 (3):629-637. doi:10.1016/j.eururo.2008.08.057
25. Avulova S, Zhao Z, Lee D, Huang LC, Koyama T, Hoffman KE, Conwill RM, Wu XC, Chen V, Cooperberg MR, Goodman M, Greenfield S, Hamilton AS, Hashibe M, Paddock LE, Stroup A, Resnick MJ, Penson DF, Barocas DA (2018) The Effect of Nerve Sparing Status

- on Sexual and Urinary Function: 3-Year Results from the CEASAR Study. *J Urol* 199 (5):1202-1209. doi:10.1016/j.juro.2017.12.037
26. Mungovan SF, Sandhu JS, Akin O, Smart NA, Graham PL, Patel MI (2017) Preoperative Membranous Urethral Length Measurement and Continence Recovery Following Radical Prostatectomy: A Systematic Review and Meta-analysis. *Eur Urol* 71 (3):368-378. doi:10.1016/j.eururo.2016.06.023
27. Coakley FV, Eberhardt S, Kattan MW, Wei DC, Scardino PT, Hricak H (2002) Urinary continence after radical retropubic prostatectomy: relationship with membranous urethral length on preoperative endorectal magnetic resonance imaging. *J Urol* 168 (3):1032-1035. doi:10.1097/01.ju.0000025881.75827.a5
28. Kim LHC, Patel A, Kinsella N, Sharabiani MTA, Ap Dafydd D, Cahill D (2019) Association Between Preoperative Magnetic Resonance Imaging-based Urethral Parameters and Continence Recovery Following Robot-assisted Radical Prostatectomy. *Eur Urol Focus*. doi:10.1016/j.euf.2019.01.011
29. von Bodman C, Matsushita K, Savage C, Matikainen MP, Eastham JA, Scardino PT, Rabbani F, Akin O, Sandhu JS (2012) Recovery of urinary function after radical prostatectomy: predictors of urinary function on preoperative prostate magnetic resonance imaging. *J Urol* 187 (3):945-950. doi:10.1016/j.juro.2011.10.143
30. Nguyen L, Jhaveri J, Tewari A (2008) Surgical technique to overcome anatomical shortcoming: balancing post-prostatectomy continence outcomes of urethral sphincter lengths on preoperative magnetic resonance imaging. *J Urol* 179 (5):1907-1911. doi:10.1016/j.juro.2008.01.036
31. Schlomm T, Heinzer H, Steuber T, Salomon G, Engel O, Michl U, Haese A, Graefen M, Huland H (2011) Full functional-length urethral sphincter preservation during radical prostatectomy. *Eur Urol* 60 (2):320-329. doi:10.1016/j.eururo.2011.02.040