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Identifying the relationship between postoperative urinary continence and residual urethra stump measurements in robot assisted radical prostatectomy patients

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Abstract
Objective: To investigate the feasibility of urethral stump length and width measurements in recorded videos of robot assisted radical prostatectomy procedures using the Kinovea software and to assess if these measurements could be used as predictors of postoperative urinary continence.
Methods: Fifty-three patients were selected from an institutional database of 1400 cases and included in the study. All videos were analysed using the computer software 'Kinovea'. All measurements were performed using the inserted bladder catheter as a reference point.
Results: The reference point (bladder catheter) was available in 33 out of 53 patients. The median surgical urethral length (SUL) was significantly higher in the continent group

(1050 vs. 1294 mm, p ¼ 0.018). The urethral width measurements did not show a difference between the groups. In order to validate the Kinovea software as an accurate tool for the measurement of the urethral stump length and width results were correlated with the magnetic resonance imaging measurements of the urethra.
Conclusions: The results of this study showed a significantly longer median SUL incontinent patients.

1 Introduction

Urinary incontinence after a robot assisted radical prostatectomy (RARP) appears to have a multifactorial origin.[1–5] Several studies have identified factors that contribute to early urinary continence in patients that underwent RARP.[1,2,6–10] One of these factors is the length of the membranous urethra (MUL).[4,11,12] There appears to be a correlation between the length of the MUL in pre and post-operative magnetic resonance imaging (MRI) and urinary continence.[4,12] The group of Song showed that a preoperative membranous urethra (MU) ≤ 13.5 mm and postoperative MU ≤ 13 mm had a negative impact on urinary continence 12 months after the surgery. The group of Kohjimoto retrospectively investigated the relation between urinary continence and the length of the resected MU evaluating the amount of rhabdomyo sphincter on the hematoxylin and eosin sections of the apical margin of prostate specimens.[11] This study showed the length of resected MUL specimen was an independent predictor of urinary incontinence. This raises the question whether assessment of the urethral length could be objectified intraoperatively by the surgeon to optimize the length of the urethra in order to reduce the risk of postoperative incontinence after RARP.

In another study by the group of Ganni, Kinovea software was used to provide an objective assessment of surgical skills during laparoscopic cholecystectomy.[13] Kinovea is a software-based video analysis system used in sports to track trajectories and speed of moving items. The authors showed that the system can be used for tracking analysis of pre-recorded surgical videos and is a viable method for the objective assessment of surgical performance.[13]

Since Kinovea uses a reference line to measure the distance, we hypothesized it could be used to measure the size of an item from a video frame, relating the measurements to the reference line. More specifically, we hypothesize Kinovea can use the diameter of the transurethral catheter during dissection of the apex of the prostate in RARP as a reference line in order to be able to measure the dimensions of the urethral stump.

The research questions are: (1) Is it possible to accurately assess the length and width of the urethral stump in the surgical videos of RARP patients using the Kinovea software? (2) Can urethral stump measurements be used to predict postoperative continence in patients after RARPy? These questions will be answered using Kinovea, a software-based system to measure the urethral stump in surgical videos of patients who underwent RARP.

2 Materials and methods

2.1 Study population

The population of our study consisted of 1400 patients who underwent RARP in the Antoni van Leeuwenhoek Hospital in Amsterdam (The Netherlands) between June 2009 and February 2017. Considering the inclusion and exclusion criteria (Figure 1), a group of patients was selected from the institutional database. All patients had localized prostate cancer (cT1c-cT3a, Nx-N0, Mx-M0) and in all cases the full-length pre-recorded video of the procedure was available. Only patients with six and 12 months postoperative PROMS data available were included. In case of unavailable surgical video or MRI patients were excluded from the study. Patients who underwent a salvage prostatectomy after radiation therapy[14] or who received adjuvant radiation therapy within 12 months from the surgery[15] were excluded from analysis due to a significant impact of these treatments on the continence status. In our study a patient with an International consultation incontinence modular questionnaire -short form (ICIQ-SF) score of zero was defined as continent, while a patient with an ICIQ-SF score of 10 or more was defined as incontinent.[16] Patients with ICIQ-SF scores at six and 12 months from 1 to 9 were excluded from the study in order to have a clear distinction between continent and incontinent patients. If the catheter was not adequately in place during the apical dissection of the prostate, the case was excluded from analysis since there was no reference point (no visualization of the trans-urethral catheter during dissection) available for the calibration of the Kinovea system.

2.2 Variations in the peri-operative process

Art of this standardization is the dorsal reconstruction, this is performed using the 'median fibrous raphe' reconstruction or 'Rocco stitch'.[17,18] The method of nerve sparing is standardized based on the publication of van der Poel et al., intrafascial dissection was performed where feasible.[19] The peri-operative implementation of physiotherapy was standardized in all patients, no additional sessions of physiotherapy were provided for incontinent patients.

2.3 Design

Data as Body mass index (BMI), Charlson comorbidity index (CCI), prostate volume, positive surgical margins, International prostate symptom score (IPSS), ICIQ-SF score, Fascia preservation score, and MRI measurements were collected.

Pre-operative and post-operative continence were defined according to the ICIQ-SF score.[16] The ICIQ-SF is a patient-reported outcome measures (PROMs) questionnaire that assesses the patient's urinary incontinence status with three questions. The cumulative scores of the three questions (0–21 points) represents the patient's experience of urinary incontinence. The study was designed as a retrospective feasibility study of patients from our institutional database.

[Figure 1]

3 Methods of measurement

The automated surgical movements tracking was performed using Kinovea 0.8.15. Kinovea was used to assess the length and width of the urethra in pre-recorded videos. In all the patients the urethral stump was measured on a video frame taken during the dissection of the urethra when the circumference of the catheter was well visible. The software was able to measure the length and width of the urethra by calibrating these measurements to the width of the transurethral catheter as shown in Figure 2b. A standardized 16 Charriere (width ¼ 53 333 mm) latex or silicone Foley catheter was used in all patients. Anatomical structures are represented in Figure 2a, Figures 2c and 2f.

[Figure 2]

The width of the catheter was subtracted from the Surgical urethral width (SUW) to obtain the accurate thickness of the urethral tissue. The measurements were performed by one rater (AB) who underwent a specific training in both the surgical procedure and the use of Kinovea software. The rater was blinded to the patient's self-reported postoperative continence status.

Pre-operative MRI measurements of the urethra were performed according to the study by Grivas (Figure 2).4 In this study, the MUL was measured from the apex of the prostate to the bulbus (midsagittal T2, Figure 2d), the Maximal urethral width (MUW) was defined as maximal diameter of urethra (axial T2), the Ventral urethral length (VUL) was measured from the apex of prostate to the pelvic floor muscles (coronal T2-weighted, Figure 2e), and the Ventral urethral width (VUW) was defined as maximal diameter of urethra at the location of the VUL measurement (axial T2, Figure 2g). These measurements were used to verify the results of the Kinovea measurements.

3.1 Ethical approval

This study was granted approval from and was in accordance with the institutional medical ethics committee. Informed consent was obtained from all participants.

3.2 Data analysis

Descriptive statistics was performed for all available patients and tumour variables. Mean and standard deviation or median and interquartile ranges were reported for continuous variables as indicated, depending on the distribution of the variables. Frequencies and proportions were used to describe categorical variables. The Pearson correlation coefficient test was used to assess the accuracy of the Kinovea measurements comparing them to the pre-operative MRI measurements. The Mann-Whitney U test was used to compare differences between continent and incontinent patients for the continuous variables and Fishers exact test for the categorical variables. Statistical significance was set at $p < 0.05$ based on a two-tailed comparison. Univariate logistic regression analysis of preoperative variables was used to identify factors that have influenced the patient's continence status. p-value for the univariate logistic regression analysis was set at 0.10. Statistical analysis was performed with SPSS software v. 23 (SPSS Inc., Chicago, IL, USA).

4 Results

A total of 53 patients were eligible based on the inclusion and exclusion criteria (Figure 1). Twenty patients were excluded from analysis after reviewing the videos as they lacked the reference structure to calibrate the measurements, and were excluded from the analysis. The remaining 33 patients were divided in a continent (N = 26) and an incontinent group (N = 7). Baseline characteristics of the patients are represented in Table 1. There were no statistically significant differences in the baseline characteristics between the two groups.

Figure 3 shows the measurements of SUL and SUW using Kinovea and the MRI measurements of the MU, VUL, and VUW in a continent patient and a incontinent patient.

A significant positive correlation of the Kinovea (MUL) and preoperative MRI (SUL) measurements of the urethral stump length ($r = 0.390$; $p = 0.025$) was found. The correlation of the VUL and SUL and urethral width measurements were not statistically significant. Moreover, a correlation between the Kinovea (SUW) and MRI (MUW) urethral width measurement was observed ($r = 0.107$; $p = 0.046$ Table 2).

The results of the pre-operative MRI measurements showed a significantly longer MUL (13.18 vs. 9.87 mm, $p = 0.001$) and VUL (10,74 vs. 6,47 mm, p = 0,009) incontinent patients compared to those with incontinence. The VUW andMUWdid not show significant difference among the continent and incontinent patients (Table 3).

The results in Table 4 show the difference in Surgical urethral measurements, performed with Kinovea software, during apical dissection between continent and incontinent patients. There is a longer SUL (difference of 2.44 mm) incontinent patients compared to incontinent patients (12.94 vs. 10.50 mm, $p = 0.018$). There was no difference in SUW between the two groups (Table 3).

4.1 Factors influencing continence

The results of the univariate logistic regression analysis of preoperatively known variables showed that the VUL (OR = 1.642; 95% C.I: 1.095–2.464 p-value = 0.017), MUL (OR = 3.156, 95% C.I: 1.324–7.527, p-value = 0.010), and SUL (OR = 1.314, 95% C.I: 0.999–1.728, p-value ¼ 0.051) could be used to predict the continence of patients (Table 4).

5 Discussion

In this study we investigated whether intraoperative urethral stump measurements can be performed using the Kinovea software from pre-recorded RARP videos and if these measurements could be used as predictors of postoperative urinary incontinence.

Our results the Kinovea software can be used to measure urethral dimensions in pre-recorded RARP videos. The results showed a weak positive correlation between the SUL measured using Kinovea and the MUL measured with MRI, the correlation between SUL and the VUL showed no significant results. The lack of correlation between the VUL and SUL could be due to the fact that during dissection of the prostatic apex the urethra is deformed due to the traction of the prostate during this step of the surgery this method could be further improved using a video frame where no tractions are applied on the prostate and on the perineum of the patient that is during vesico-urethral anastomosis.

There was a correlation between the urethral width measured with Kinovea software (SUW) and MRI (MUW) The width of SUW using Kinovea showed no correlation with the VUW measured on an MRI. This could possibly be the result of the traction on the prostate during dissection, as the diameter becomes smaller with traction and therefore the urethral tissue thinner. Another reason could be the thinning of the urethra during the apical dissection of the prostate. In this case, the selection of the video frame could have an impact on the quality of measurements of the urethral stump.

[Table 1]

The fact that the urethral stump measurements taken with Kinovea (SUL and SUW) were correlated with the MRI measurements (MUL and MUW) validate the Kinovea software as an accurate tool for the measurement of the urethral stump length and width. The performance of the measurements using Kinovea took on average 5 min per patient.

In this study in both MRI measurements (MUL and VUL) and the SUL, a significantly longer median urethral length in the continent group compared to the extremely incontinent group. Although the median difference in SUL (2.44 mm) is shorter than the median difference in MUL (3.31 mm) and the median difference in VUL (4.27 mm) the preoperative measurements show it is possible to find a measurable difference.

The influence of the urethral length on continence has been proven with different modalities[11,12] including MRI measurements. In a recent study, Kohjimoto et al. demonstrated that the length of resected MUL specimen was an independent predictor of urinary incontinence after RARP.[11] Moreover, in another recent paper Song showed that a longer preoperative and postoperative length of membranous urethra was significantly associated with urinary incontinence after RARP.[12] This shows a longer urethral length of the membranous urethra implies a long urinary sphincter that leads to better postoperative urinary continence.

[Figure 3]

The univariate logistic regression analysis showed a significant influence of the VUL (OR = 1.642; 95% C.I: 1.095–2.464), MUL (OR = 3.156, 95% C.I: 1.324–7.527), and SUL (OR = 1.314, 95% C.I: 0.999–1.728) on the patient's continence status showing a smaller risk of urinary incontinence in patients with longer urethral stump. Our findings are in contrast with the recent research by Bautista Vidal, which shows there is no correlation between continence and urethral stump length.[20] This could be due to a difference in method used for the measurement of the urethral stump in the surgical videos.[20] Additional research is needed to determine the ideal urethral length for achieving continence. If a cut-off point is determined during additional research, surgical procedures could be adjusted to standardize the dissection and mobilization of parts of the prostatic urethra in order to increase urethral stump length and increase the chances of urinary continence.

[Table 2] [Table 3] [Table 4]

The implementation of real time intra-operative measurements of the urethra integrated in the robotic system could help to adjust the surgical technique in particular during the apical dissection of the prostate. The use of a small ruler could help the surgeon to measure the urethra during surgery which could lead to an increase urethral stump length and increase the chances of urinary continence.[21,22] In the future the introduction of measurement software into the surgical robot system could lead to the implementation of a modified heads-up display in the console which can be used to measure structures during surgery in real time. Using this kind of software, the surgeon could be able to optimize the urethral length and increase the chances of continence for the patient.

The urethral width measurements (SUW, MUW, and VUW) did not show a difference between the continent and incontinent patients. To our knowledge, there are no studies showing a correlation between the intraoperative urethral width and the post-operatory continence status.

5.1 Limitations

Our study is a retrospective study in which patients of a single surgeon were analysed. The sample size was relatively small, we tried to reduce the influence of confounders by using exclusion criteria of factors which are known to influence postoperative continence (i.e. salvage RARP[14] and adjuvant radiation therapy after RARP[15]). The results of this pilot study show the absence of surgical videos, MRI measurements and a reference point (no visualization of the transurethral catheter during dissection) for Kinovea measurements lead to a relative high number of exclusions. The Kinovea analysis could only be performed when the catheter (reference point) was visible during apical dissection. There is some variation in the placement of the reference line since the diameter of the catheter was sometimes measured in less than ideal circumstances, meaning that not the entire circumference of the catheter was visible during measurement. There is also a possibility of variation in the length and width measurements due to the amount of traction on the tissue during dissection, in order to reduce this variation, the measurements were taken at the same point in the dissection of the urethral stump. The angle of the camera during measurement could influence the results of the measurement, but since the reference line was measured with the camera in the same position as the measurements of the urethra we believe this influence is negligible. The use of an intraoperative object with a known size or a ruler to measure the urethral stump could result in more accurate measurements of the urethral stump. In this study the measurements were taken by a single observer. This study was performed in cases of a single surgeon, results in multiple surgeons could vary due to variability of surgical technique. Further research of the implications of urethral stump length could result in an improvement of postoperative continence for individual patients. If the measurement of the urethral length can be performed during surgery it will be possible to adjust surgical techniques to preserve the maximal surgical urethral length.

6 Conclusion

In this study we performed intraoperative urethral stump measurements using the Kinovea software on surgical videos. The results of this study show that the length and width of the urethra can be measured in surgical videos and correlated with most of the preoperative MRI measurements. The present measurements demonstrate a longer surgical urethral length incontinent patients compared to those suffering from incontinency. Further research on the use of intraoperative urethral length measurements could elucidate whether the length of the urethral stump can be used as a predictor of continence with the surgical challenge to save as much urethral length as possible during robot assisted radical prostatectomy.

Conflicts of interest

Beulens, Brinkman, van der Poel, Umari, van Basten, Hendrikx, Koldewijn, van Merrienboer, Bangma, and Wagner have no conflicts of interest to disclose.

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Tables and figures

Figure 1 Study flow diagram–Study population selection flowchart

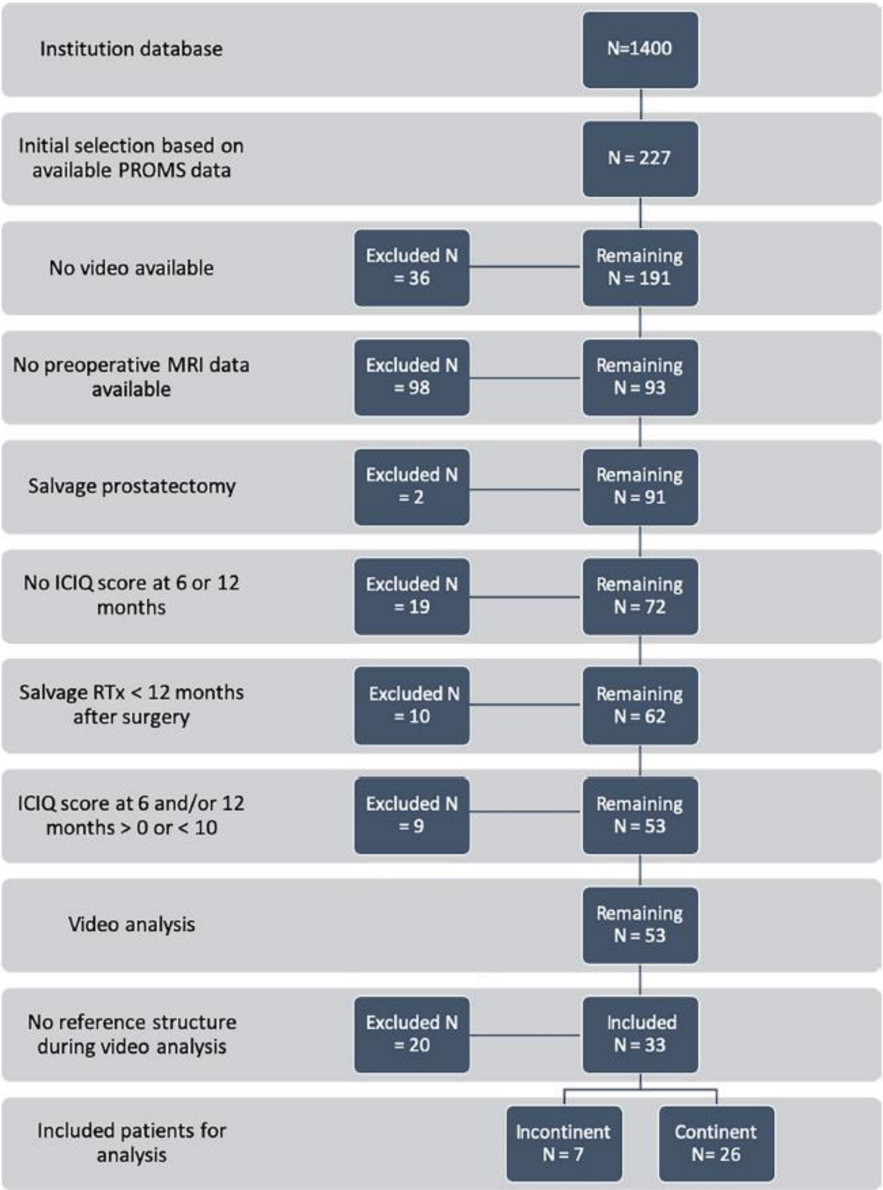

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Figure 2 A) Intraoperative image representation of important anatomical structures used as landmarks during the measurements of the urethral stump. (B) intraoperative image–calibration lines overlapping the urethral stump with Foley 16 Ch catheter inserted used as reference structure. (C) axial and. (F) coronal MRI image - representation of important anatomical structures used as landmarks during the measurements of the urethral stump. (D) MUL. (E) VUL and (G) VUW measurement method on MRI images. MRI, magnetic resonance imaging; MUL, length of the membranous urethra; VUL, ventral urethral length; VUW, ventral urethral width

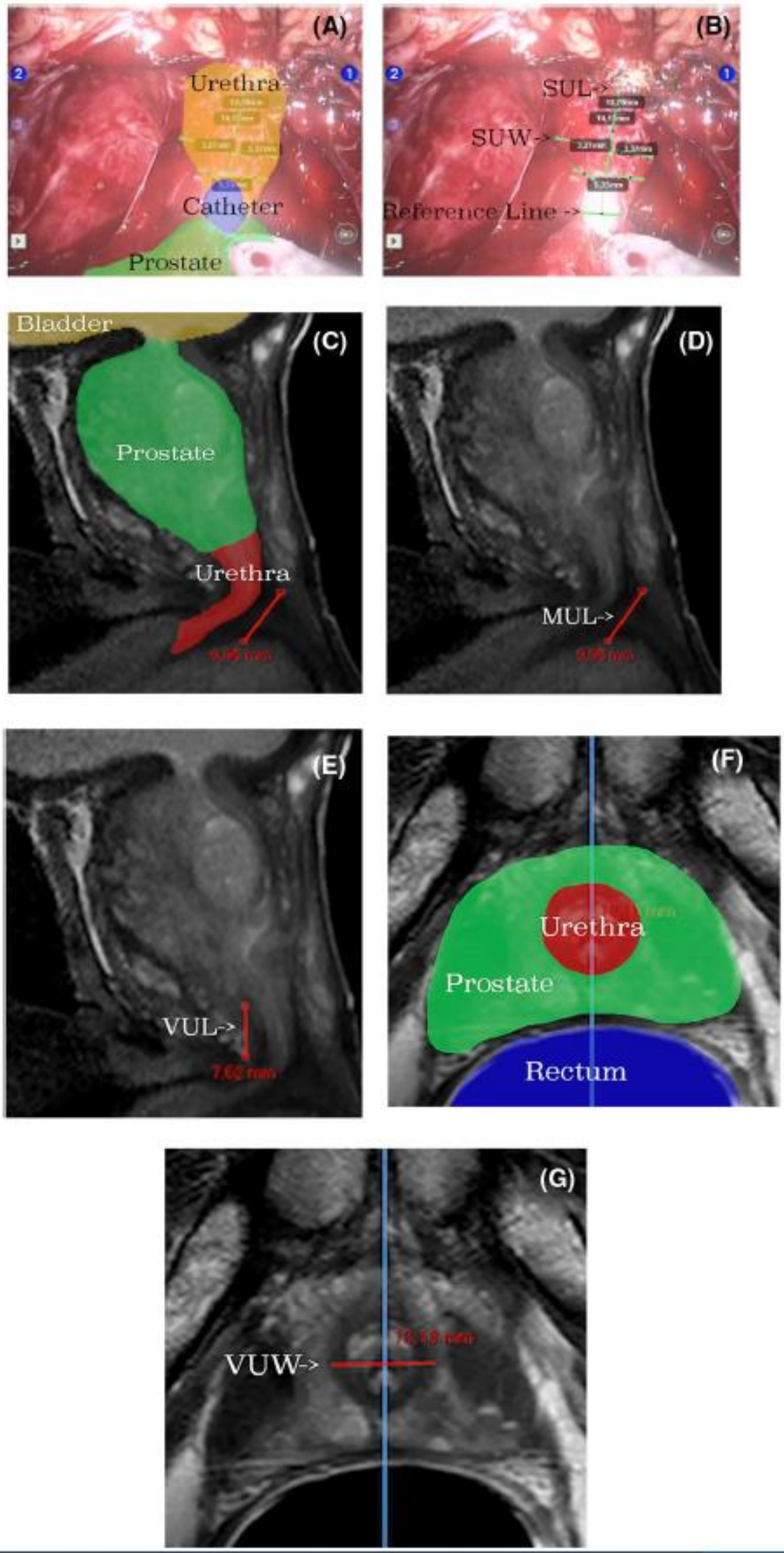

Table 1 Baseline characteristics of the patients

	Postoperative incontinent patients (ICIQ-SF>10) (*n* = 7) Median (min - max)	Postoperative continent patients (ICIQ-SF = 0) (*n* = 26) Median (min - max)	*p*-Value
Age (years)	65 (57–69)	61.5 (51–5)	0.308[1]
BMI (kg/m^2)	26.59 (20.45–32.55)	25.31 (21.15–35.06	0.880[2]
Prostate size (ml)	50 (18–81)	43 (21–90)	0.375[2]
TUC duration (days)	14 (12–41)	12.00 (7–39)	0.183[2]
Clinical tumour stage, N (%)			0.558[1]
cT1c	2 (28.6)	10 (38.5)	
cT2a	0	3 (11.5)	
cT2b	1 (14.3)	6 (23.1)	
cT2c	2 (28.6)	4 (15.4)	
cT3a	2 (28.6)	2 (7.7)	
cT4a	0	1 (3.0)	
Nerve sparing, N (%)			0.117[1]
Both	3 (42.9)	10 (38.5)	
Left only	0	7 (26.9)	
Right only	0	4 (15.4)	
Fascia preservation score	0 (0–8)	3 (0–12)	0.268[2]
Preoperative ICIQ-SF score	0 (0–0)	0 (0–0)	1.000[2]
Preoperative pad use	0 (0–0)	0 (0–0)	1.000[2]
Preoperative IPSS score	0 (0–4.5)	1.5 (0–21)	0.249[2]
6 months IPSS score	2 (0–25)	2 (08)	0.620[2]
12 months IPSS score	6 (0–21)	1.5 (0–9)	0.034[2]
6 months ICIQ-SF score	16 (16–20)	0 (0–0)	<0.001[2]
12 months ICIQ-SF score	14 (11–18)	0 (0–0)	<0.001[2]
6 months postoperative pad use	4 (3–4)	0 (0–1)	<0.001[2]
12 months postoperative pad use	3 (3–4)	0 (0–0)	<0.001[2]

Abbreviations: ICIQ-SF, international consultation incontinence modular questionnaire -short form; IPSS, international prostate symptom score; BMI; body mass index.
[1]Fisher's exact test.
[2]Mann–Whitney *U* test.

Figure 3 (A, E) Measurement of the SUL and SUW using Kinovea software in a incontinent (A) and continent (E) patient (B–D) measurement of the MUL (B), VUL (C) and VUW (D) on the MRI images of a incontinent paten (F–H) measurements of the MUL (F), VUL (G) and VUW (H) on the MRI images of a continent patient. SUL, surgical urethral length; SUW, surgical urethral width; MRI, magnetic resonance imaging; MUL, length of the membranous urethra; VUL, ventral urethral length; VUW, ventral urethral width

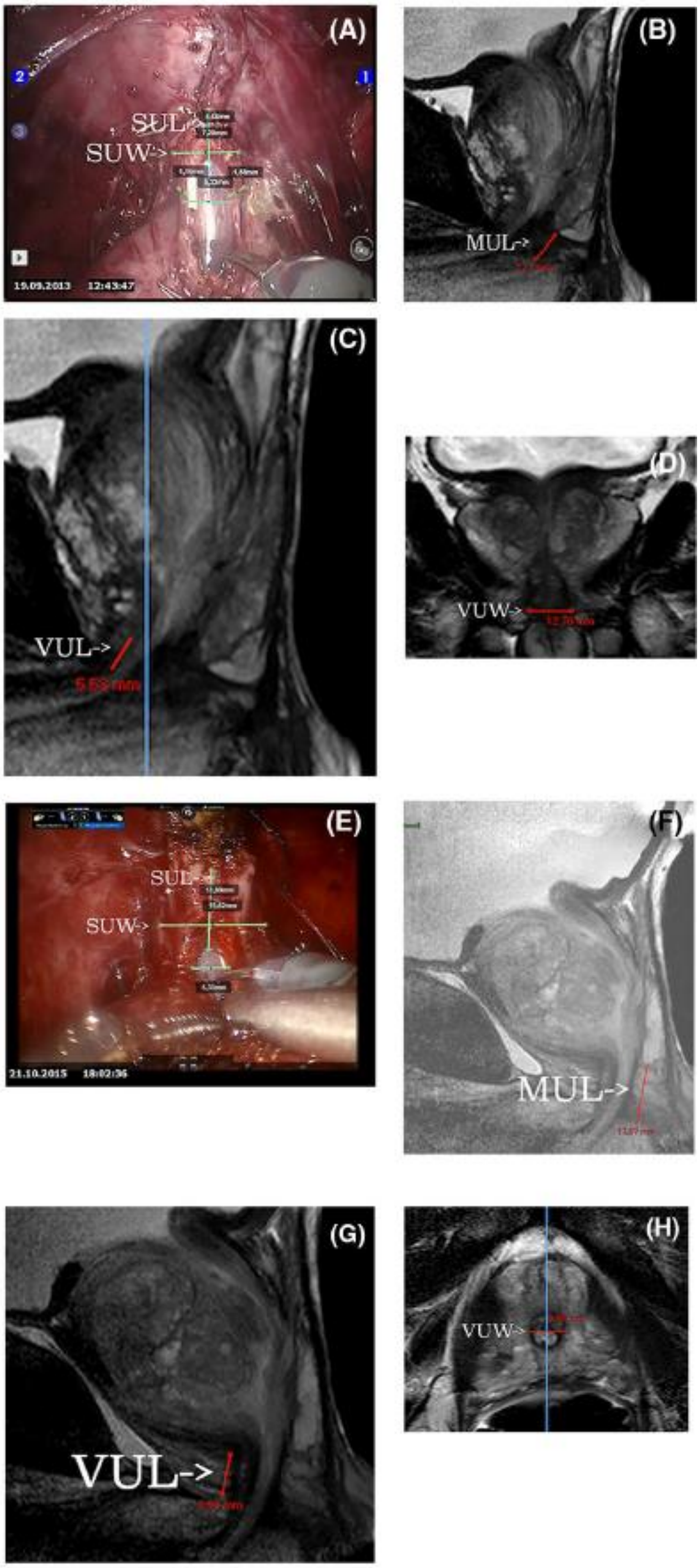

Table 2 Pearson correlations of Kinovea and the pre-operative MRI measurements in 33 selected patients

	SUW, measured using Kinovea (*p*-value)	SUL, measured using Kinovea (*p*-value)
MUL, from the apex of the prostate to the bulbus (midsagittal T2)	-	0.390 (0.025)*
VUL,measured from apex of prostate to the pelvic floor muscles (coronal T2-weighted)	-	0.148 (0.412)
VUW, defined as maximal diameter of urethra at the location of the VUL measurement (axial T2)	0.107 (0.553)	-
MUW, defined as maximal diameter of urethra (axial T2)	−0.350 (0.046)*	-

Abbreviations: MRI, magnetic resonance imaging; SUW, surgical urethral width; SUL, Surgical urethral length; MUL, length of the membranous urethra; VUL. ventral urethral length; MUW, maximal urethral width; VUW, ventral urethral width.
*p-Value <0.05.

Table 3 Difference in pre-operative MRI measurements (MUL, VUL, MUW, and VUW) and surgical urethral measurements with Kinovea software (SUL and SUW) during apical dissection between continent and incontinent patients

	Postoperative incontinent patients (ICIQ-SF>10) ($n = 7$) Median (min - max)	Postoperative continent patients (ICIQ-SF = 0) ($n = 26$) Median (min - max)	*p*-Value
MUL, length (in mm) of the membranous urethra from the apex of the prostate to the bulbus (Midsagittal T2)	9.87 (8.69–12.97)	13.18 (9.63–16.15)	0.001*
VUL, measured from apex of prostate to the pelvic floor muscles (coronal T2-weighted)	6.47 (3.75–10.35)	10.74 (5.79–14.50)	0.009*
VUW, defined as maximal diameter of urethra at the location of the VUL measurement (axial T2)	12.97 (11.13–14.86)	12.38 (9.96–13.81)	0.268
MUW, defined as maximal diameter of urethra (axial T2)	12.12 (9.22–13.15)	11.61 (9.05–14.00)	0.914
SUL, mm	10.50 (5.06–12.79)	12.94 (6.10–24.35)	0.018*
SUW, mm	6.83 (1.95–11.13)	7.37 (4.26–16.78)	0.450

Abbreviations: MRI, magnetic resonance imaging; SUW, surgical urethral width; SUL, surgical urethral length; MUL, length of the membranous urethra; VUL. ventral urethral length; VUW, ventral urethral width.
*p-Value <0.05.

Table 4 Univariate logistic regression analysis of factors possibly influencing the continence status of patients

	OR	95% C.I. for OR	*p*-Value
VUL, measured from apex of prostate to the pelvic floor muscles (coronal T2-weighted)	1.642	1.095–2.464	0.017
MUL, from the apex of the prostate to the bulbus (midsagittal T2)	3.156	1.324–7.527	0.010
SUL, measured using Kinovea	1.314	0.999–1.728	0.051
VUW, , defined as maximal diameter of urethra at the location of the VUL measurement (axial T2)	0.573	0.237–1.385	0.216
MUW, defined as maximal diameter of urethra (axial T2)	1.173	0.596–2.310	0.644
SUW, measured using Kinovea	1.156	0.840–1.592	0.374
BMI	0.950	0.768–1.174	0.633
Prostate size	0.985	0.945–1.027	0.477
Age	0.938	0.8121.084	0.386
Nerve sparing left	2.519	0.460–13.801	0.287
Nerve sparing right	1.556	0.289–8.379	0.607
Year of surgery	1.254	0.465–3.382	0.655

Abbreviations: BMI, body mass index; SUW, surgical urethral width; SUL, surgical urethral length; MUL, length of the membranous urethra; VUL, ventral urethral length; MUW, maximal urethral width; VUW, ventral urethral width.