Changes in penile length after radical prostatectomy: Investigation of the underlying anatomical mechanism

著者	Kadono Yoshifumi, Machioka Kazuaki, Nakashima Kazufumi, Iijima Masashi, Shigehara Kazuyoshi, Nohara Takahiro, Narimoto Kazutaka, Izumi Kouji, Kitagawa Yasuhide, Konaka Hiroyuki, Gabata Toshifumi, Mizokami Atsushi
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Changes in penile length after radical prostatectomy: Investigation of anatomical mechanism

Yoshifumi Kadono,[1] Kazuaki Machioka,[1] Kazufumi Nakashima,[1] Masashi Iijima,[1] Kazuyoshi Shigehara,[1] Takahiro Nohara,[1] Kazutaka Narimoto,[1] Kouji Izumi,[1] Yasuhide Kitagawa,[1] Hiroyuki Konaka,[1] Toshifumi Gabata,[2] and Atsushi Mizokami [1]

[1] *Department of Integrative Cancer Therapy and Urology, Kanazawa University Graduate School of Medical Science, Kanazawa, Japan*

[2] *Department of Radiology, Kanazawa University School of Medicine, Kanazawa, Japan*

Correspondence to:

Yoshifumi Kadono, MD. PhD;

Department of Integrative Cancer Therapy and Urology,

Kanazawa University Graduate School of Medical Science;

13-1 Takara-machi, Kanazawa, Ishikawa 920-8640, Japan.

Telephone: +81-76-265-2393; Fax: +81-76-222-6726;

E-mail: yskadono@yahoo.co.jp

Abstract

Objective: To measure chronological changes in penile length (PL) before and after radical prostatectomy (RP), and to investigate the underlying mechanisms for the same.

Patients and Methods: Stretched PL (SPL) of 102 patients was measured before, 10 days after, and at 1, 3, 6, 9, 12, 18, and 24 months after RP. The perpendicular distance from the distal end of the membranous urethra to the midline of the pelvic outlet was measured on mid-sagittal magnetic resonance imaging (MRI) slice at three time-points: preoperatively, 10 days after RP and 12 months after RP. Pre- and postoperative SPLs were compared using paired Student's *t*-test. Predictors of PL shortening at 10 days and at 12 months after RP were evaluated on univariate and multivariate analyses.

Results: The SPL was shortest at 10 days after RP (mean PL shortening from preoperative level: 19.9 mm); it gradually recovered thereafter. SPL at 12 months after RP was not significantly different from preoperative SPL. On MRI examination, the distal end of membranous urethra was found to have moved proximally (mean proximal displacement: 3.9 mm) at 10 days after RP, and to have returned to the preoperative position at 12 months after RP. Only the volume of the removed prostate was a predictor of SPL change at 10 days after operation on univariate analysis; on multivariate analysis, the association was not statistically significant. No predictor of SPL change was shown at 12 months after RP.

Conclusion: The SPL was shortest at 10 days after RP and gradually recovered thereafter in this study. Anatomically, glans and corpus spongiosum surrounding urethra is an integral structure, and the proximal urethra is drawn into pelvis during urethrovesical anastomosis. This is the first report showing that slight vertical repositioning of the membranous urethra after RP causes chronological changes in SPL. The information is useful for patients to know penile appearance changes after RP.

Key words: anatomical mechanism; membranous urethra; penile length; radical prostatectomy

Introduction

Radical prostatectomy (RP) is a standard treatment for localized prostate cancer. The main complaints after RP are urinary incontinence and erectile dysfunction [1, 2]. In addition, many patients complain of penile shortening (PS) [3]. This self-assessed PS was showed to be associated with low-to-moderate self-esteem [3]. Several studies have shown PS after RP; however, the underlying mechanism of this phenomenon is not well-elucidated [4-9].

The relationship between changes in penile length (PL) and sexual function have been reported [10], and nerve sparing (NS) procedures reportedly help minimize PS after RP [3]. On the other hand, another report mentioned no relationship between NS and PS after RP [5]. Furthermore, phosphodiesterase type 5 inhibitors (PDE5-Is) has been found to be effective for preventing PS after RP [11-13]; however, another report claimed no effect of penile rehabilitation on PS [10].

In the current study, chronological changes in PL before and after RP were measured and pelvic magnetic resonance imaging (MRI) before and after RP were compared to evaluate any anatomical changes. In addition, potential predictive factors for PS were also evaluated.

Patients and Methods

Patient Population

Patients with clinically localized prostatic cancer scheduled to undergo RP at Kanazawa University Hospital (Japan), between October 2011 and May 2014, were included in the current study. The study was approved by the institutional ethics committee. During the study reference period, all RPs were performed by robot-assisted surgery. All patients provided written informed consent. All data were collected prospectively. Patients who received pre- or postoperative androgen deprivation therapy (ADT) and/or radiation therapy, or those who had a history of penile disease or had undergone penile surgery, were excluded. Prostate-specific antigen levels were measured prior to prostate biopsy; Gleason score was determined at biopsy. Removed prostate weight was measured just after surgery. PDE5-Is were administered 1 month after operation to patients who wanted to use these (on-demand use).

Stretched PL (SPL) measurement

Stretched PL was measured from the pubopenile skin junction to the distal end of the glans with maximum extension by Y.K., who was blinded to previous measurements.

All measurements were taken with a ruler and rounded to the nearest 0.5 cm [4]. The SPL was measured in the room temperature maintained at ≥ 22 °C with the patient lying in the supine position with the penis placed at a 90° angle to the body before surgery, about 3 days after catheter removal and at 1, 3, 6, 9, 12, 18, and 24 months after RP.

Erectile function assessment

The erectile function was assessed using the erectile function domain of International Index of Erectile Function (IIEF-EFD) [14] and the erection hardness score (EHS) [15] preoperatively, about 3 days after catheter removal, and at approximately 12 months after RP.

MRI, distal end of membranous urethra to pelvic outlet (DMU-PO) distance, and thickness of the subcutaneous fat

MRI was performed with a 1.5-T MRI system (Sigma HDx; GE Medical Systems, Milwaukee, WI, USA) using a SENSE Flex-M coil (Philips Medical Systems, Amsterdam, Netherland) preoperatively, about 3 days after catheter removal, and at approximately 12 months after RP. To measure the perpendicular distance from the distal end of membranous urethra to the midline of the pelvic outlet clearly, the landmarks were defined as follows. The midline of the pelvic outlet was defined as the line between the bottom edge of the pubic bone and lowest end of the coccyx. DMU-PO distance was defined as the perpendicular distance from the most proximal attachment point of the urethra and bulb of penis, to the midline of the pelvic outlet (Fig. 1); DMU-PO distance was measured using the MRI slice in which the urethra was most observable by magnified sagittal, first-spin, echo T2-weighted imaging (repetition time, 3200 ms; echo time, 113 ms; slice thickness, 3 mm) and rounded 1 mm. The sagittal MRI slice, in which the difference between the urethra and the lowest end of the coccyx was most observable, was used to mark the lowest end of the coccyx. Leaving these markings in place, the view was shifted to the sagittal MRI slice in which the urethra was most visible, and the midline of the pelvic outlet was drawn from the mark denoting the lowest end of the coccyx to the bottom edge of the pubic bone. MRI was performed 30–60 min after urination, and estimated bladder capacity in each case was 30 - 100 mL based on MRI results. The thickness of the subcutaneous fat of each patients was also measured at lower abdomen using midsagittal plane of MRI, and the thickness of each time point was defined as the average of different 5 points at 2 cm intervals of subcutaneous fat thickness at lower abdomen (Fig. 1).

Statistical analysis

Categorical variables used to calculate the incidence and percentage of each factor and continuous variables were summarized by mean ± standard deviation. Pre- and postoperative SPL were compared using a paired Student's *t*-test. Pearson's correlation coefficient was used for univariate analysis and multiple linear regression was used for multivariate analysis. The variables assessed for potential predictive ability were: age, body mass index, preoperative EHS, NS status, and weight for the removed prostate gland at 10 days after operation and age, body mass index, preoperative EHS, NS status, and PDE5-Is use at 12 months after operation because all users were administered PDE5-Is 1 month after operation. All data analyses were performed using SPSS for Windows (SPSS Inc., Chicago, IL, USA). $P < 0.05$ was considered statistically significant.

Results

Patient Population

A total of 153 patients who underwent RP during the study reference period at the Kanazawa University Hospital, 32 patients who had received neoadjuvant ADT, 10 who underwent adjuvant ADT or radiation therapy, and nine who did not complete the 2-year follow-up, were excluded. Therefore, the SPL was measured for 102 patients 2 years post-RP. No patients had grade III and over complications of RP according to Clavian Classification. The demographics of the study population are shown in Table 1. Catheters were removed after a median period of 7 days after RP; therefore, measurements of first post-operative SPL and MRI were performed at median 10 days after RP.

Penile length

Chronological changes in SPL are shown in Figure 2. The SPL was shortest at 10 days after RP; mean shortening from pre-operative measurement was 19.9 mm, which gradually recovered in length thereafter. SPL at 12 months after RP was not statistically different from the preoperative SPL (Fig. 2).

DMU-PO distance, the thickness of subcutaneous fat and erectile function

Preoperative MRI and postoperative MRI at 10 days and 12 months after RP are shown in Figure 3. The DMU-PO distance at 10 days after RP was shorter than the preoperative measurement (mean shortening [N = 88]: 3.9 mm). However, the shortening was found to have reversed at 12 months after RP (Fig. 3) (Fig. 4). There was no significant difference between preoperative and postoperative thicknesses of subcutaneous fat (Fig. 4). IIEF-EFD and EHS deteriorated at 10 days after RP, and recovered at 12 months after RP although only slightly (Fig. 4).

Predicting SPL shortening

Results of univariate and multivariate analysis are shown in Table 2. Only the removed prostate volume was a predictor of SPL shortening at 10 days after RP on univariate analysis; the tendency to predict SPL shortening at 10 days was observed on multivariate analysis; however, the association was not statistically significant (Table 2). PDE5-Is were used twice a week regularly in 7 patients since 1 month after operation; in other 19 patients, usage tended to vary from only once after operation to once a week on demand. No predictor of SPL shortening was shown at 12 months after RP (Table 2).

Discussion

The current study is the first to focus on pelvic anatomical changes after RP, which cause chronological changes in PL. Measurement of SPL provides the closest approximation of the erect PL [16]; therefore, several studies have employed SPL as a measure of PL [4, 5, 7, 8, 10, 12, 17, 18]. To maintain measurement quality, only Y.K.

measured SPLs and was blinded to previous results. Further, only patients who completed the entire 2-year study were included in this analysis.

In the current study, SPL was shortest 10 days after RP and then gradually recovered to pre-RP levels after 12 months. Similar to the present study, SPL measurements taken 1 week after RP in past studies were reportedly the shortest [7, 19]. However, the reported chronological changes in SPL have tended to differ; some reports state the SPL kept shortening for up to 1 year after RP [7, 11], while others have shown post-RP recovery of SPL to preoperative levels 3–5 years later [8]. Another report mentioned that postoperative SPL recovered to the preoperative level after 6–12 months after surgery, which is consistent with our results [10]. Long-term follow-up studies have been affected by a substantial drop-out rates [8, 10]; however, our study was able to chronologically obtain SPL measurements from over 100 cases over the 2-year study period.

Animals studies in rats have suggested cavernosal nerve injury, hypoxia-induced structural alterations in the penis and/or sympathetic hyperinnervation as the cause of PS after RP [20]. However, these hypotheses were based on histological changes, which do not explain how the PL immediately after RP was the shortest. Comparison of pre- and postoperative MRI in the present study revealed proximal retraction of the membranous urethra and bulb of penis immediately after RP, which was found to have returned to its former position 1 year later (Fig. 3). Anatomically, the corpus spongiosum which surrounds the urethra continues as the bulb of penis on the proximal side and the glans of penis on the peripheral side, thereby integrating these structures (Fig. 1) [21]. Because the bladder is thought to be loosely fixed by vascular pedicles and connective tissues, it can be moved down towards the bottom of the pelvis after removal of the prostate, albeit with some resistance. Moreover, the proximal side of urethra can retract towards the bladder after urethrovesical anastomosis (Fig.5B).

Indeed, we observed intrapelvic retraction of the urethral stump during urethrovesical anastomosis in operation. Since the urethra pierces the urogenital diaphragm but is thought to be loosely connected, it is liable to be pulled down slightly into the pelvic. A past report posited the membranous urethra as being fixed to the urogenital diaphragm and not easily retractable into the pelvis [20]. Although the urogenital diaphragm is fixed to the pelvic bone, it is a membranomuscular structure and not very firm. Therefore, the urogenital diaphragm itself, as well as the membranous urethra, can move somewhat vertically (Fig. 5). We usually apply perineal pressure during urethrovesical anastomosis to push the urethral stump intrapelvically for easy observation during robot-assisted RP [22]. According to our MRI findings, the bulb of penis is thought to have retracted towards bladder 10 days after RP; this indicates that the membranous urethra and urogenital diaphragm were lifted proximally. Comparison of MRI findings at 10 days and 12 months post-RP revealed the bulb of penis returned to almost the same pre-RP position; therefore, the tension of the vascular pedicles and connective tissues, which pull the bladder proximally, are speculated to loosen over the course of a year (Fig. 5C). MRI revealed that the bulb of penis was lifted proximally by an average of 3.9 mm at 10 days after RP (Fig. 3) (Fig. 4).

On Pearson's correlation analysis, the correlation between SPL change at 10 days after RP and the removed prostate weight was statistically significant. However, on multivariate linear regression analysis, the correlation was not statistically significant. Excision of a large prostate is liable to leave a space at the bottom of the pelvis; therefore, bladder neck is likely to experience traction that displaces it downwards towards the bottom of the pelvis. This may exert a greater proximal pull to the point of urethrovesical anastomosis after removal of large prostate gland as compared to that in case of small prostate removal. A significant correlation was observed between IIEF-EFD and EHS ($r = 0.612$, $P < 0.001$). However, EHS was used as the predictor in multivariate analysis for predicting SPL shortening in this study as it is considered to be more suitable than IIEF-EFD to be used for a cohort, such as that of Japanese men, with low sexual activity [23]. There were no statistically significant changes between mean preoperative SPL before RP and that at 12 months after RP, and no predictive factor for SPL shortening at 12 months were found on multivariate analysis.

The present study has some limitations. The sample size was not large enough to allow definitive conclusions. With respect to penile measurement, only SPL was evaluated, and the circumferences and the rigidity of the penis was not evaluated in our study. Our results tended to differ from those of previous studies in some respects. PDE5-Is showed no association with SPL shortening in our study; however, most user of PDE5-Is used it on demand. Past reports have mostly addressed the correlation between PL changes after RP and sexual function [5, 24]. Preoperative sexual functions of our study population were very low; therefore, it is difficult to mention the correlation between PL changes after RP and sexual function in our study. Administration of PDE5-Is has been shown to effectively prevent PS [12, 13]; therefore, PDE5-Is might have a positive impact on the blood supply to the penis and influence PL long-term. Therefore, the effect of PDE5-Is to SPL shortening requires further investigation. The early use of the vacuum erection device (VED) after RP also reported to help to preserve penile length [25]; however, the VED was not used and evaluated in our study. A NS technique has been reported to be protective for PS [3], and a preserved postoperative PL has been shown to correlate well with maintenance of erectile function after NS RP [10, 24]. Thus, it is possible that patients with less PS might preserve more erectile function; however, the present study did not show any affect of NS status on PS after operation. ADT or ADT and radiation therapy reportedly shorten PL [17, 18]; therefore, testosterone would affect PL long-term. Further research is necessary to elucidate the long-term relationship between PL and erectile function.

In conclusion, this is the first report showing that slight vertical repositioning of the membranous urethra after RP causes chronological changes in SPL. Anatomically, glans and corpus spongiosum surrounding urethra is an integral structure, and proximal urethral is drawn into pelvis during urethrovesical anastomosis. Changes in PL represent one phenomena of chronological anatomical changes induced by RP and could be elucidated in short-term after RP due to the results of our study. However, further research is needed to elucidate long-term changes of PL with respect to the influence of sex hormones or changes in penile blood flow after RP. The information is useful for patients to know penile appearance changes after RP.

Conflict of Interest: None declared

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Abbreviations

RP, radical prostatectomy; PS, penile shortening; PL, penile length; NS, nerve sparing; PDE5-Is, phosphodiesterase type 5 inhibitors; MRI, magnetic resonance imaging, ADT, androgen deprivation therapy; SPL, stretched penile length; IIEF-EFD, erectile function domain of International Index of Erectile Function; EHS, erection hardness score; DMU-PO, distal end of membranous urethra to pelvic outlet.

Figure legends

Fig. 1 Mid-sagittal view of pelvic anatomy; cited from *Pernkopf Anatomy* [21]

A: bottom edge of pubic bone; B: lowest end of coccyx; C: midline of pelvic outlet (red dotted line); D: the most proximal attachment point of urethra and bulb of penis; E: perpendicular distance from “D point” to “C line” (red line with bidirectional arrowheads = distal end of membranous urethra to pelvic outlet distance: DMU-PO distance), F: thickness of subcutaneous fat at lower abdomen.

Fig. 2 Mean change in penile length

SPL, stretched penile length; RP, radical prostatectomy, SD, standard deviation.

*$P < 0.05$ versus before RP

Fig. 3 Mid-sagittal magnetic resonance imaging

The line connecting the lowest end of the pubic bone and tip of the coccyx represents the pelvic outlet; red lines with bidirectional arrowheads show the perpendicular distance from the distal end of membranous urethra to the midline of the pelvic outlet (= DMU-PO distance) (A) before, (B) 10 days after, and (C) 12 months after radical prostatectomy.

Fig. 4 (A) Mean change in SPL (n=102) and mean change in the thickness of subcutaneous fat at lower abdomen (n=88). (B) Mean change in the DMU-PO distance measured on magnetic resonance imaging (n=88). (C) Mean change in IIEF-EFD and EHS (n=102).

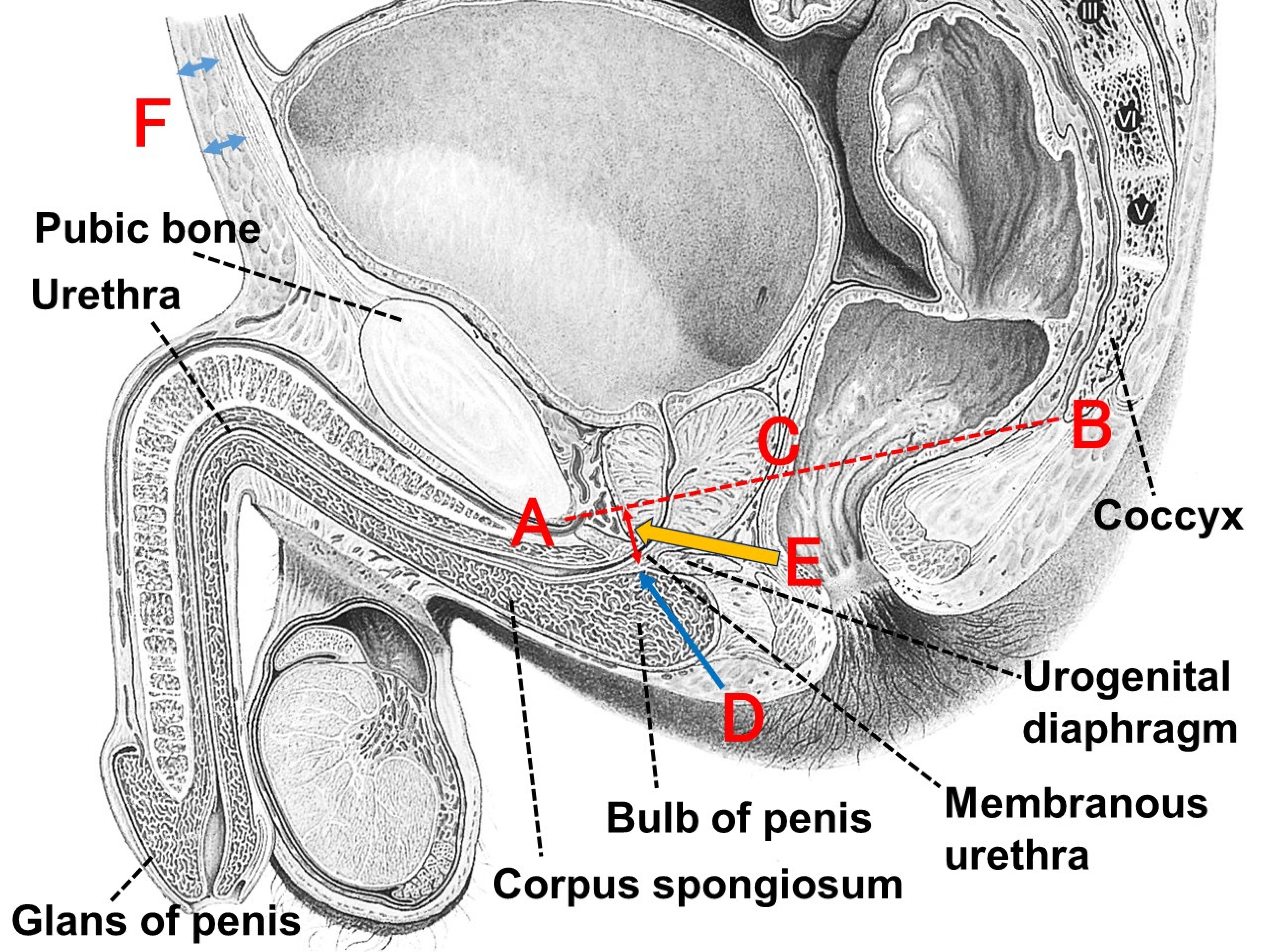
SPL, stretched penile length; DMU-PO distance, the perpendicular distance from the distal end of membranous urethra to the midline of the pelvic outlet; IIEF-EFD, erectile function domain of International Index of Erectile Function; EHS, erection hardness score; SD, standard deviation.

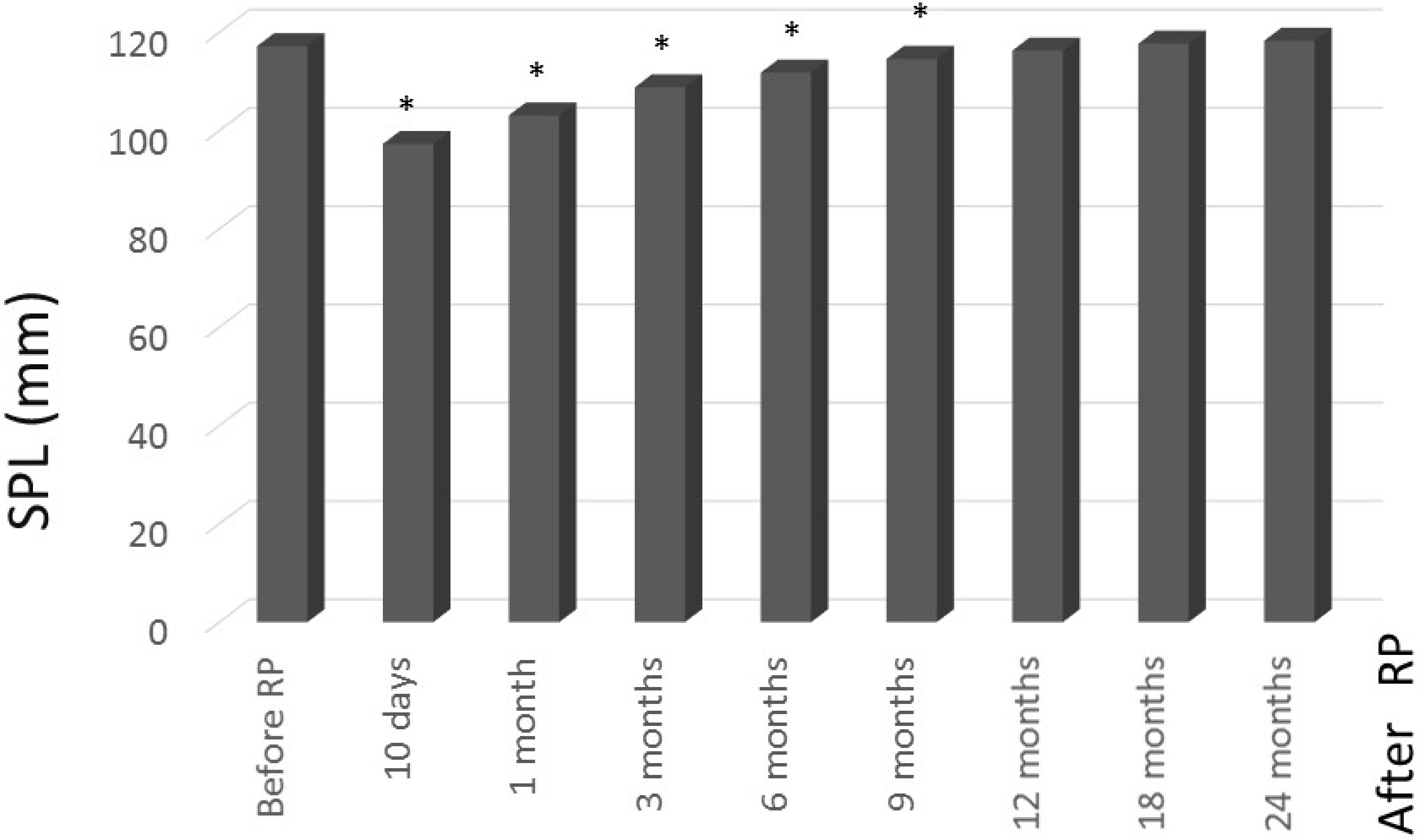
Fig. 5 Illustration of chronological changes in pelvic anatomy after radical prostatectomy

Membranous urethra is pushed proximally at 10 days post-RP, and tends to be repositioned at 12 months after radical prostatectomy.

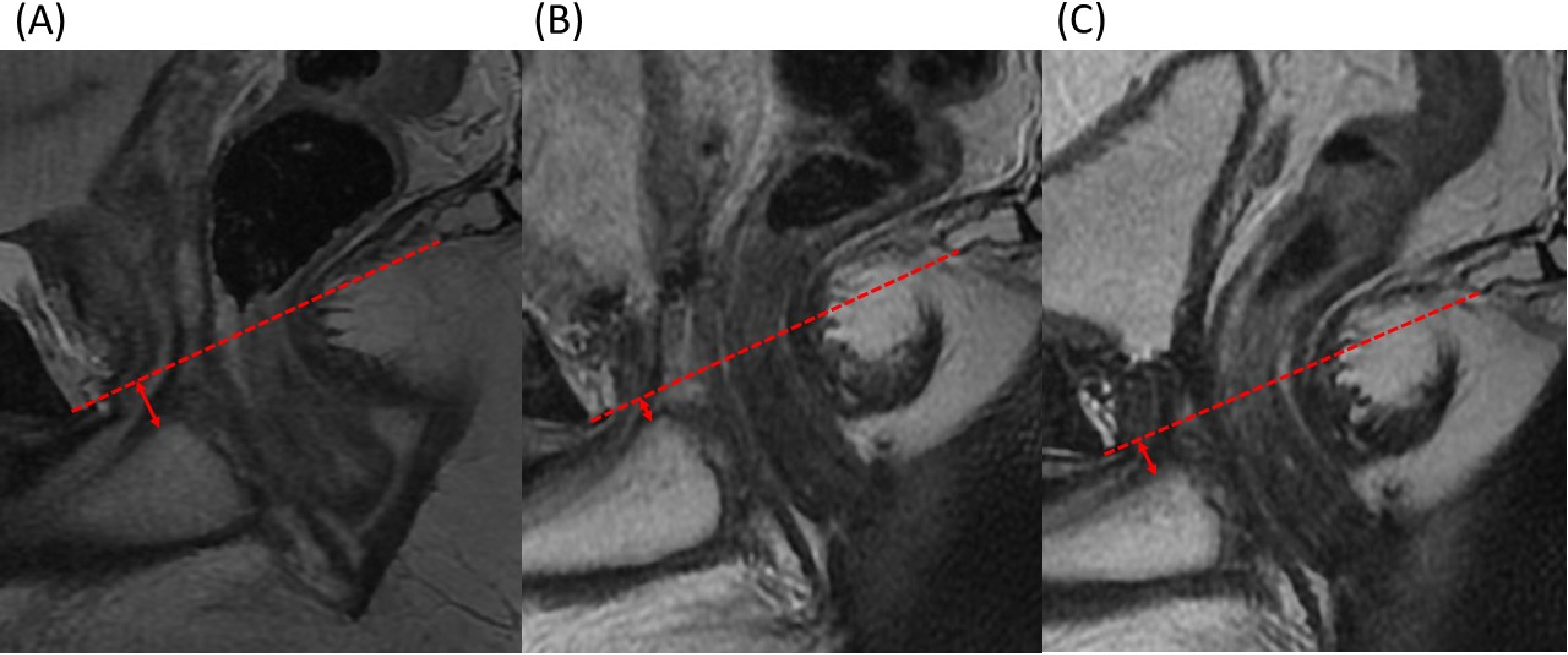
(A) preoperative; (B) 10 days after RP; and (C) 12 months after RP

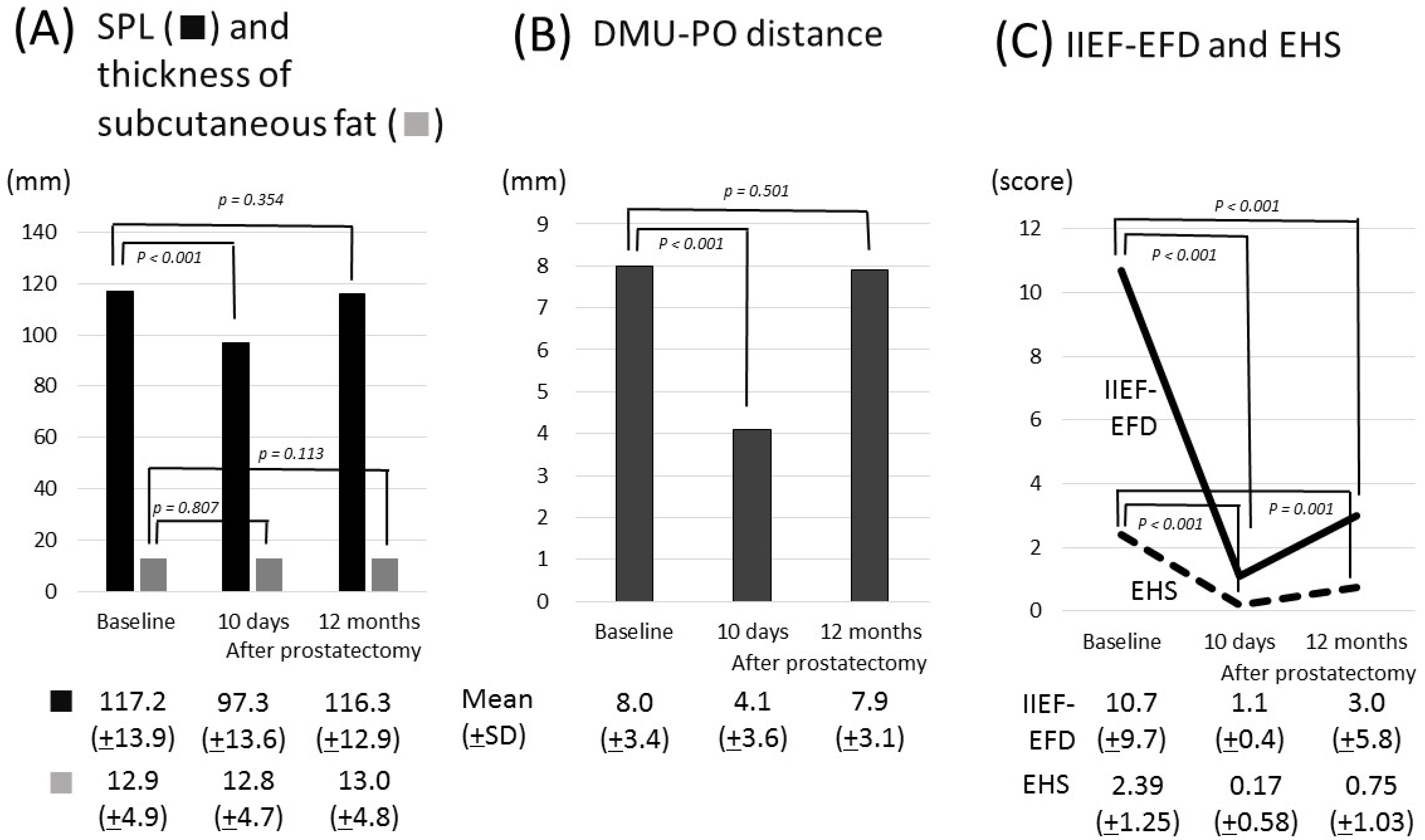
RP, radical prostatectomy


F
Pubic bone
Urethra
A
C
B
E
D
Coccyx
Urogenital
diaphragm
Membranous
urethra
Bulb of penis
Corpus spongiosum
Glans of penis
III
VI
V



SPL (mm)	117.2	97.3*	103.1*	108.8*	111.8*	114.6*	116.3	117.7	118.3
(SD)	(13.9)	(13.6)	(13.6)	(13.1)	(12.5)	(12.6)	(12.9)	(12.9)	(13.4)


(A)
(B)
(C)


(A) SPL (■) and thickness of subcutaneous fat (■)
(mm)
p = 0.354
P < 0.001
p = 0.113
p = 0.807
140
120
100
80
60
40
20
0
Baseline
10 days
12 months
After prostatectomy
■ 117.2 (±13.9) 97.3 (±13.6) 116.3 (±12.9)
■ 12.9 (±4.9) 12.8 (±4.7) 13.0 (±4.8)
(B) DMU-PO distance
(mm)
p = 0.501
P < 0.001
9
8
7
6
5
4
3
2
1
0
Baseline
10 days
12 months
After prostatectomy
Mean (±SD) 8.0 (±3.4) 4.1 (±3.6) 7.9 (±3.1)
(C) IIEF-EFD and EHS
(score)
P < 0.001
P < 0.001
P = 0.001
P < 0.001
12
10
8
6
4
2
0
IIEF-EFD
EHS
Baseline
10 days
12 months
After prostatectomy
IIEF-EFD 10.7 (±9.7) 1.1 (±0.4) 3.0 (±5.8)
EHS 2.39 (±1.25) 0.17 (±0.58) 0.75 (±1.03)

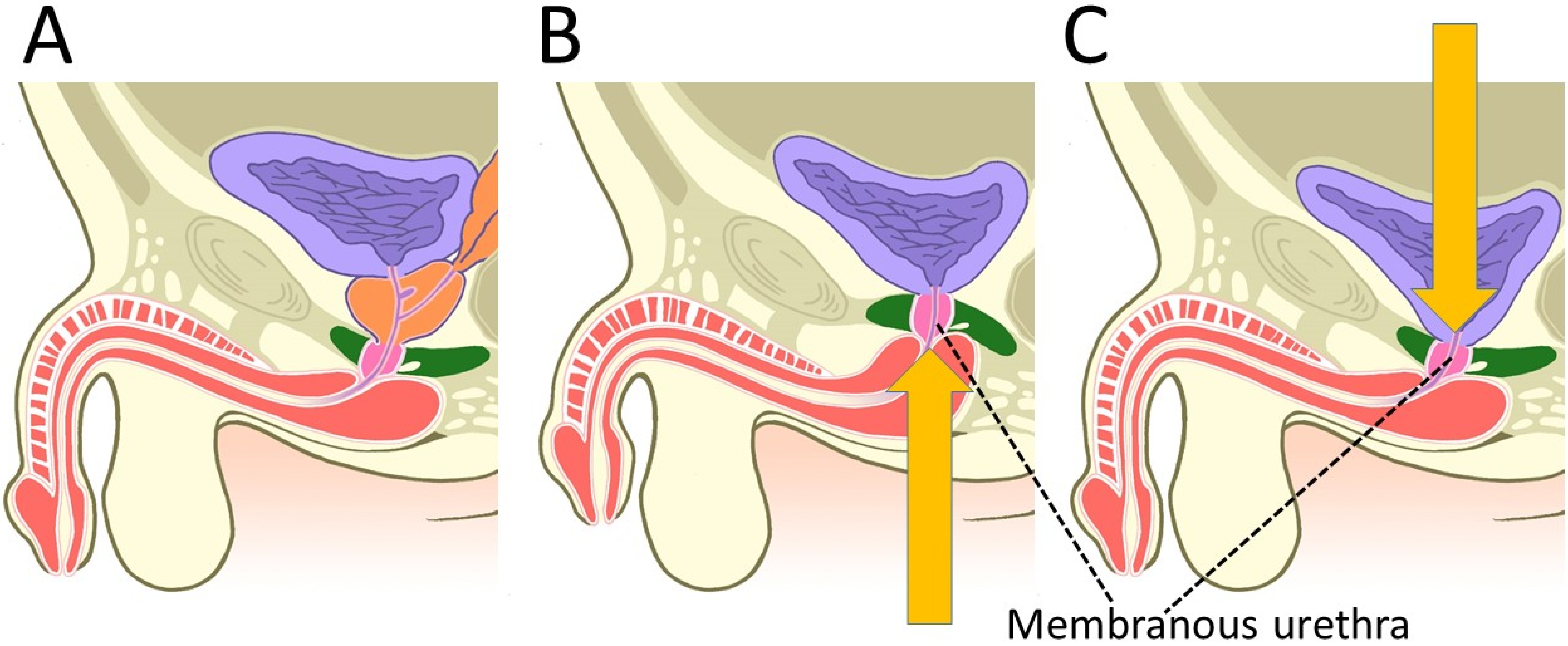

A
B
C
Membranous urethra

Table 1 Characteristics of the study population

Variable	Mean (±SD) or n (%)
Total number of patients	102
Age, years	64.4 (±5.4)
Body mass index, kg/m^2	24.0 (±2.8)
PSA, ng/mL	8.2 (±5.4)
Biopsy Gleason Score	
6	42 (41.2%)
7	44 (43.1%)
8	11 (10.8%)
9-10	5 (4.9%)
Clinical stage	
T1	21 (20.6%)
T2	72 (70.6%)
T3	9 (8.8%)
D'Amino risk group	
Low	31 (30.4%)
Intermediate	39 (38.2%)
High	32 (31.4%)
Preoperative IIEF-EFD score	10.7 (±9.7)
Preoperative EHS	2.4 (±1.3)
Nerve-sparing procedure	
Not performed	22 (21.6%)
Unilateral	56 (54.9%)
Bilateral	24 (23.5%)
Removed prostate weight, g	41.1 (±11.1)
PDE5-Is use after RP	26 (25.5%)

SD, standard deviation; PSA, prostate-specific antigen;
IIEF-EFD, Erectile function domain of International Index of Erectile Function;
EHS, Erection Hardness Score;
PDE5-Is, phosphodiesterase type 5 inhibitors;
RP, radical prostatectomy.

Table 2 Results of linear regression analysis showing predictors of SPL shortening at 10 days and 12 months after RP

	10 days after RP			12 months after RP		
	Univariate	Multivariate		Univariate	Multivariate	
	P-value	*P*-value	b (95%CI)	*P*-value	*P*-value	b (95%CI)
Age (year)	0.783	0.803	0.057 (-0.393 to 0.507)	0.992	0.866	0.033 (-0.351 to 0.417)
Body mass index (kg/m^2)	0.254	0.428	0.329 (-0.492 to 1.149)	0.902	0.860	−0.059 (-0.724 to 0.605)
Preoperative EHS (0–4)	0.529	0.545	0.585 (-1.329 to 2.500)	0.237	0.225	0.981 (-0.615 to 2.576)
Nerve spare status	0.850	0.732	-0.586 (-3.968 to 2.796)	0.786	0.610	−0.707 (-3.450 to 2.035)
(Non- = 0, Uni- = 1 Bi- = 2)						
Weight of removed prostate gland (g)	0.036	0.061	0.200 (-0.009 to 0.408)	0.311	0.328	0.084 (-0.085 to 0.253)
PDE5-Is use (no = 0, yes = 1)	-	-	-	0.763	0.952	-0.144 (-4.879 to 4.592)

SPL, stretched penile length; RP, radical prostatectomy; EHS, Erection Hardness Score;

Non-, non-nerve sparing; Uni-, unilateral-nerve sparing; Bi-, bilateral-nerve sparing;

PDE5-Is, phosphodiesterase type 5 inhibitors. CI, confidence interval.