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Morphological variations of the human ejaculatory ducts in relation to the prostatic urethra

Abstract

Purpose: Loss of ejaculation can ~~occur following~~ follow transurethral resection of the prostate (TURP). ~~Preservation of p~~Periverumontanal prostate tissue is ~~practiced~~ preserved in ~~ejaculation~~ ~~ejaculation~~-preserving TURP (ep-TURP). Knowledge of ejaculatory duct anatomy in relation to the prostatic urethra can ~~aid help~~ in ep-TURP. This was evaluated in ~~cross cross~~-sections of the prostate using a 3D model to determine a safe zone ~~to resect~~for resecting the prostate in ep-TURP.

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Materials and Methods: A 3D reconstruction of the ejaculatory ducts was developed ~~based~~ ~~on the basis of~~ ~~cross sections of~~ six prostate gland ~~cross-sections~~. The measurements obtained ~~on from~~ the 3D model were standardized according to the maximum width of the prostate. Simple linear regressions were used to predict the relation~~ships~~ of the ejaculatory ducts.

Results: ~~Maximum~~ ~~The maximum~~ widths of the prostates ranged from 22.60mm to 52.10mm. The ejaculatory ducts entered the prostate with a concavity directed posterolaterally. They then proceeded ~~to~~ towards the seminal colliculus in a fairly straight course, and ~~then from that point~~ ~~they~~ angulated anteromedially ~~at the seminal colliculus~~. As they opened into the prostatic urethra they diverged. Significant regression models ~~were found to predict the relations~~ ~~predicted the~~ ~~relationships~~ of the ejaculatory ducts to the prostatic urethra based on the sizes of the prostates.

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This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the [Version of record](#). Please cite this article as [doi:10.1002/ca.23036](https://doi.org/10.1002/ca.23036).

Conclusions: The 3D anatomy of ejaculatory ducts can be predicted ~~based on the basis of the~~ prostate width ~~of the prostate~~. The ejaculatory ducts can be preserved with 95% accuracy if a block of tissue 7.5 mm from the midline on either side of the seminal colliculus is preserved, up to 10mm proximal to the level of the seminal colliculus, during TURP.

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Keywords: ejaculatory ducts; prostate; ejaculation; TURP

Introduction

Bladder outlet obstruction (BOO) is a leading cause of morbidity and poor quality of life in elderly men (Dmochowski, 2005). Benign prostatic hyperplasia (BPH) is a common aetiological factor for BOO worldwide. BPH is treated by medical and surgical methods. Transurethral resection of the prostate (TURP) is one of the commonest of the surgical procedures carried out for BPH. Despite recent pharmacological and technological advances, Yu et al. (2008c) stated that TURP has accounted for 39% of surgical interventions for BPH carried out in the USA in during 2008. These rate is are likely to be much higher in a lower middle-income country such as Sri Lanka.

According to Bolt (1987) and Chuang (2016), the loss of antegrade ejaculation is a common complication of this procedure. Current evidence suggests that the incidence of loss of antegrade ejaculation following TURP is as high as 48%–80% (Rassweiler et al., 2006; Reich et al., 2008b; Chung and Woo, 2016; Pavone et al., 2015). However, the pathophysiological mechanism of this is poorly understood. Vecchis (1998) conducted a randomized controlled trial from 1994 to 1997 and concluded that preservation of a portion of supramontanal prostatic tissue during TURP could preserve antegrade ejaculation in 80% of patients, with improved sexuality and quality of life. With the emergence of As interest in ejaculation-ejaculation-preserving surgeries grew, a number of several studies were conducted over the next few decades. Talab (2013) assessed the sexual function of 160 men following the ejaculation-preserving photo-selective vaporization technique with preservation of the periverumontal region, thus preserving the ejaculatory hoods and the urinary bladder neck. It was successful in achieving a post-operative ejaculation rate of 86.6%. Roehrborn (2002) recommended “careful removal of apical tissue around the verumontanum” to minimize damage-injury to the ejaculatory ducts and reduce post-post-TURP

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ejaculatory dysfunction. Alloussi et al. (2014) conducted prostatectomies ~~y~~-preserving paracollicular prostatic tissue in 89 patients with active sexual lives. The surgical technique was described as: “apical resection utilizing the colliculus seminalis as a distal resection border and maintaining a 1cm safety area for preservation of ejaculation”. Antegrade ejaculation was preserved in 90.8%; three months after surgery.

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Kim et al. (2015) explored the effectiveness of the ejaculatory hood-preserving technique with Holmium laser enucleation of the prostate in ~~the preservation of~~preserving ejaculation. ~~Fifty~~ ~~Fifty~~-two sexually active patients with BPH were randomized into the ejaculatory ~~hood-hood~~-preserving method and ~~the~~ conventional method. In the ejaculatory ~~hood-hood~~-preserving method, paracollicular and supracollicular tissues ~~s~~ more than ~~one centimetre~~ 1cm proximal to the seminal colliculus (verumontanum) were preserved. The surgical technique was described as being “started by carving the boundary of ejaculatory hood to be spared, commencing from the bilateral borders of ~~the~~ seminal colliculus with a 2–3 mm gap bilaterally from the verumontanum (paracollicular tissue). These two incision lines were encountered transversely approximately 1 cm proximal from the verumontanum upper margin (supracollicular tissue). The whole adenoma tissue except the ejaculatory hood was completely removed up ~~to~~ the prostatic capsule layer.” Patients were followed up at 3, 6 and 12 months following surgery. The overall success rates of ejaculation preservation ~~was were~~ 46.2% in the ejaculatory ~~hood-hood~~-preserving method ~~compared to and~~ 26.9% in the conventional method.

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There is no clear anatomical evidence to recommend the distance from the seminal colliculus or the amount of periverumontal prostatic tissue that should be preserved to protect the ejaculatory ducts ~~from being damaged against injury~~ during prostatectomy. Therefore, ~~identification of it is~~ ~~very important to identify the~~ anatomical relationships of the ejaculatory ducts to the prostate,

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the prostatic urethra and seminal colliculus ~~is extremely important~~. Unfortunately, research on normal human ejaculatory duct anatomy is sparse. A study of cadaveric and surgical specimens ~~conducted~~ by Nguyen (1996) at the University of California School of Medicine, San Francisco, USA found that the thick muscle walls of the seminal vesicles are absent in the ejaculatory duct and normal duct dimensions are remarkably uniform among US men. Aboul-Azm (1979) ~~identified found~~ that the ampullary vesicular angle of the ejaculatory duct was acute and the duct had anteromedial concavity. ~~A study done by~~ Nguyen et al. (1996) ~~on studied~~ 10 cadaveric prostates and 10 prostates obtained after radical prostatectomy ~~and~~ revealed that ejaculatory ducts ~~have an oblique course~~ course obliquely towards each other as they proceed towards the seminal colliculus. ~~But-However~~ at the points where they joined the seminal colliculus, they deviated from each other and had separate openings.

~~But none of the~~ No studies have identified a clear ~~three three~~ three-dimensional structure of the ejaculatory ducts and their relationship to the prostatic urethra, which ~~can aid~~ could help in endoscopic prostate surgery. The objectives of our study were to ~~evaluate determine~~ the anatomical relationship of the ejaculatory ducts and prostatic urethra in ~~cross cross~~ sections of the prostate gland using a 3D model and to determine a safe zone ~~to resect~~ for resecting the prostate without ~~damaging injuring~~ the ejaculatory ducts.

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Materials and Methods

This descriptive ~~cross-cross~~-sectional study was carried out on self-donated cadavers. It was ~~ethically~~ approved by the Ethics Review Committee, Faculty of Medicine, Colombo and was conducted in accordance with the guidelines set forth ~~by-in~~ the Declaration of Helsinki.

Six male cadavers of Sri Lankan nationality above the age of fifty were selected using a simple random sampling method. All the cadavers were preserved using the conventional arterial injection method ~~using-with~~ formalin as the main preservative. ~~The e~~Cadavers with macroscopic abnormalities of the urinary bladder, prostate, prostatic urethra, or seminal vesicles were excluded from the study. The selected cadavers were positioned dorsal decubitus. A suprapubic curved incision was made. The prostates along with the seminal vesicles and the trigone region of the urinary bladder were harvested *en bloc*. The false capsule of the prostate along with the prostatic venous plexus was dissected out. The pair of seminal vesicles and a small segment of the vas deferens were preserved with the dissected prostate. The tissues were processed ~~according to by~~ the standard histological techniques described by Bancroft and Gamble (2008a).

Wax blocks were prepared and the processed prostates were fixed to a mould. One/two ~~millimetre-millimeter~~ segments were cut manually with a sharp knife using a single uniform force. The cut surfaces were photographed from a fixed point using a high resolution camera with and without marking the openings of the ducts. A ruler was placed alongside the specimen to measure the distances. The digital images were processed and ~~accurate~~ measurements were obtained ~~accurately~~ in the zoomed photographs. Matlab R2015a and Insight ~~segmentation~~ Segmentation and Registration Toolkit (ITK) softwares were used ~~in-the-for~~ 3D reconstruction of the ejaculatory duct pathways within the prostate. The level at which the two ejaculatory ducts drained into the prostatic urethra was identified using this model. The reference point was

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considered ~~as to be~~ the seminal colliculus. Virtual ~~cross-cross~~ sections of the prostate and the duct system were obtained at 2 mm distances proximal (superior) to the seminal colliculus (height; “a”). The angle between the two ejaculatory ducts (angle; “ θ ”) was measured from the midpoint of the prostatic urethra. The perpendicular distance (depth; “d”) from the midpoint of the prostatic urethra to a line joining the two ejaculatory ducts ~~were was~~ measured. The distance between the two ejaculatory ducts was also measured (separation; “b”). The measurements obtained in each segment are shown in Figure 1. The maximum width of the prostate was measured on the model (width; “w”).

Statistical Analysis

Standard descriptive analyses ~~were conducted to describe of~~ the measurements ~~were performed~~. Data ~~analysis was conducted~~ ~~were analyzed~~ using R-3.2.2. statistical software. The measurements were standardized by dividing each by the maximum width of the prostate. ~~A s~~Simple linear regressions ~~were was~~ conducted to predict the standardized separation (b_std) from the standardized height (a_std) and standardized depth (d_std).

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Results

Six prostates were studied. ~~Maximum~~ Their maximum widths of the prostates studied ranged from 22.60 mm to 52.10 mm. ~~Mean (mean width was~~ 33.85 ± 11.06 mm). The 3D model demonstrated that the ejaculatory ducts entered the prostate with a concavity directed posterolaterally. Then they passed towards the seminal colliculus in a fairly straight course. Distally, the ejaculatory ducts angulated anteromedially at the seminal colliculus and finally diverged as they opened into the prostatic urethra (Figure 2). ~~Their openings of the ejaculatory ducts were~~ angulated/angled downwards towards the membranous urethra rather than opening perpendicular to the prostatic urethra. The angle between the two ejaculatory ducts as measured from the centre of the prostatic urethra was plotted against the distance from the seminal colliculus proximally in Figure 3. ~~A~~ The curve was “U” shaped, ~~curve was observed in the graph depicting showing~~ that the angle ~~was larger~~ increased both proximally and distally. The distance between the two ejaculatory ducts (separation) was plotted against the depth from the centre of the prostatic urethra in Figure 4. The distance between the ducts was directly proportional to the depth proximal to the prostatic urethra (Figure 5). This linear relationship was not maintained when the depth increased.

Results of the regression analysis

A simple linear regression was conducted to predict the depth (d) to the two ejaculatory ducts from the height (a) from the seminal colliculus proximally (defined above). Preliminary analyses ~~were conducted to ensure no violation of~~ ensured that the assumptions of normality, linearity and homoscedasticity ~~were not violated~~. ~~A~~ There was a significant regression equation was ~~found~~ correlation ($F(1,114) = 170.1, p < 0.05$) between the depth (d) and height (a) with an R^2 of

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0.749. The depth of the ejaculatory ducts (mm) is equal to was ($d = 0.58 + 0.48a$ mm). The 95% confidence intervals of the predicted depths were calculated at given heights (10 mm, 20 mm and 30 mm). The results are shown in Table 2.

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It was noted that The separation between the ejaculatory ducts (b) varied at a given depth in different differed among glands. Similar variability was noted after standardization of This variability was maintained when the separation was standardized by dividing the separation distance with by the maximum width of the gland. Therefore We therefore we developed separate regression models for small (maximum width of the prostate ≤ 25 mm), medium (maximum width of the prostate from 25 mm to 40 mm) and large prostate glands (maximum width of the prostate ≥ 40 mm) prostate glands, to obtain the separation distance at a given depth. Significant There were significant correlations, regression models were found between the between (s) and (d). The regression models used to predict the separation in mm of between the ejaculatory ducts (s) from the depth (d) are given below: were;

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Small sized glands: ($s = 1.44 + 0.19d$ mm)

Medium sized glands: ($s = 0.28 + 0.72d$ mm)

Large sized glands: ($s = 3.18 + 0.52d$ mm)

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The 95% confidence intervals of the predicted separations were calculated at given depths (10 mm, 20 mm, and 30 mm) for small, medium and large sized glands separately. The results are shown in Table 3.

Similarly, we noted that the separation of the ejaculatory ducts ~~varied~~ at a given height ~~in~~ ~~different~~ ~~differed among~~ glands. ~~Similar variability was noted after standardization of~~ ~~There was~~ ~~similar variability after~~ the separation ~~was standardized~~ by dividing separation distance ~~with by~~ maximum ~~gland~~ width ~~of gland~~, therefore ~~so again~~ we developed separate regression models for small (maximum ~~width of the prostate~~ ≤ 25 mm), medium (maximum ~~width of the prostate~~ from 25 mm to 40 mm) and large (maximum ~~width of the prostate~~ ≥ 40 mm) prostate glands to obtain separation distance ~~in mm (s)~~ at a given height ~~(a)~~.

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~~Significant regression models were found~~ ~~There were significant correlations~~ between ~~the~~ (s) and (a). The regression models to predict the separation of ejaculatory ducts from the depth are given below.

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Small ~~sized~~ glands: ~~(s = 1.49 + 0.07a - mm)~~

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Medium ~~sized~~ glands: ~~(s = 0.25 + 0.32a - mm)~~

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Large ~~sized~~ glands: ~~(s = -0.74 + 0.48a - mm)~~

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The 95% confidence intervals of the predicted separations were calculated at given heights (10 mm, 20 mm, and 30 mm) for small, medium and large ~~sized~~ glands separately. The results are shown in Table 4.

Discussion

Nguyen et al. (1996) described the ejaculatory ducts as ~~having an oblique course~~ coursing ~~obliquely~~ towards each other as they pass towards the seminal colliculus, ~~and then diverting~~ away and ~~angulate~~ ing downwards as they enter the urethra. These findings ~~were are~~ consistent with our study (Figure 2). Gallizia (1972) described spastic contractions of the smooth muscles of the urinary bladder neck as an essential component of antegrade ejaculation (Gallizia, 1972). ~~But However~~, the function of the urinary bladder neck in antegrade flow of the ejaculate was de-emphasized in subsequent studies by Kim et al. (2015) and Gil-Vernet et al. (1994). Supramontal prostatic tissue, which was also known as the “ejaculatory hood”, ~~was found to be proved~~ important for the antegrade flow of seminal fluid in a dynamic endorectal ~~ultrasonographical~~ study ~~done by~~ Gil-Vernet et al. (1994). ~~So far To date~~, some ~~amount of~~ prostatic tissue ~~has been left~~ in the periverumontanal region ~~was left in~~ ~~ejaculation-ejaculation~~-preserving prostatic surgeries (Roehrborn C, Talab et al., 2013; Vecchis, 1998; Kim et al., 2015). The amount left unresected was decided subjectively. According to Chuang and Woo (2016), the objectives of ~~the~~-ep-TURP should be to remove as much prostatic tissue as possible to relieve the obstruction while ~~at the same time~~ preserving antegrade ejaculation. However, preserving periverumontanal tissue should not compromise resecting out ~~an adequate amount of enough~~ prostatic tissue ~~in order~~ to resolve the bladder outflow obstruction. To achieve this objective, we need an objective cutoff for the tissue resection margins. ~~By~~ preserving the ejaculatory ducts during TURP, ~~the~~ antegrade ejaculation ~~may can~~ be preserved.

In this study, we found that the ~~3three-dimensional-dimensional~~ relationships of ~~the~~ ejaculatory ducts and the prostatic urethra depended on the maximum width of the prostate. The safe distances to resect the prostate without ~~damaging-injuring~~ the ejaculatory ducts during an ep-

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TURP can be calculated preoperatively ~~based on~~ from the maximum width of the prostate. According to the present study, it is safe to resect ~~preserving if~~ an area of tissue measuring 7.5 mm from the midline on either side of the seminal colliculus, and up to 10 mm proximal to the level of the seminal colliculus ~~is preserved~~; a total of a 15x10 mm² area of periverumontanal prostatic tissue, since ~~in~~ 95% of ~~the time cases~~ the ejaculatory ducts lie within this range at the seminal colliculus, within a depth of 10mm from the urethral surface, irrespective of ~~the prostate~~ size ~~of the prostate~~. Proximal to this level, the ejaculatory ducts lie >10mm deep to the surface of the urethral lumen, ~~and therefore so they~~ are probably protected during ep-TURP. However, in the small glands, the ejaculatory duct lies at a mean depth of 7.83 mm (range 6.02 ~~to~~ 8.62) even at 20 mm from the seminal colliculus, and this ~~may could~~ be surgically relevant. ~~For These parameters can be refined further for differently sized glands further refinement of these parameters can be made. Therefore if~~ In a small gland, the area to be resected would be 2.5mm adjacent to the midline on either side, while in medium and large glands the dimensions would be 7.5mm on either side. Preserving these calculated amounts of the periverumontanal prostatic tissue, thus preserving the ejaculatory ducts ~~could may~~ prevent an ejaculation following prostatectomy. ~~But However~~, these results need to be clinically validated.

We identified the following limitations of the study. Since ~~this was conducted on a small sample~~ ~~the sample was small~~, population inferences ~~may not be possible~~ are dubious. The study was conducted on preserved cadavers. ~~Thus, so~~ subtle deteriorations of the anatomical relationships ~~may could~~ have interfered with the measurements. As we overlapped the prostatic urethra to develop the 3D model, we did not observe the anterior angulation of the prostatic urethra in the model. ~~But However~~, since we measured the distances with the centre of the prostatic urethra as the reference point, these relative distances necessary for the surgery were

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not affected. ~~The No~~ clinical or histopathological evidence for ~~the presence of BPH among was~~ available for the study subjects ~~was not available~~. However, in the larger prostates included in the study, ~~it is almost certain that BPH would have been present~~ was highly likely. It is necessary to assess whether the observed relationships can be reproduced ~~even~~ among patients with histologically proven BPH. ~~Carefully Carefully~~ designed clinical trials are ~~necessary required~~ to develop recommendations for ~~the~~ safe distances. The results of this study can be ~~utilized used~~ to design such trials.

Conclusions

Ejaculatory ducts run towards the seminal colliculus in a fairly straight course and divert from each other as they enter the prostatic urethra. The ~~three three~~ dimensional anatomy can be accurately predicted preoperatively ~~based on the size of the from~~ prostate size. This knowledge can be used to determine ~~the amount of how much~~ periverumontanal prostatic tissue ~~to must~~ be preserved ~~in order~~ to safeguard the ejaculatory ducts during ep-TURP. In crude terms, ejaculatory ducts can be preserved if a block of tissue 7.5 mm from the midline on either side of the seminal colliculus, up to 10 mm proximal to the level of the seminal colliculus, is preserved during TURP. Further studies are necessary to confirm the validity of these findings in a clinical setting.

Acknowledgements

The authors sincerely thank all the cadaver donors and their families.

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The authors acknowledge the kind assistance of Prof Rohan W Jayasekara in the final proofreading of this article. We also acknowledge the kind assistance of Mr Kalpa Perera in formatting the images.

Conflicts of interest: none

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Legends

Figure 1: The measurements obtained from the sections of a prostate

Figure 2: The 3D models of the prostate

Figure 3: The angle between the two ejaculatory ducts as measured from the centre of the prostatic urethra (angle, “ θ ”) against the distance from the seminal colliculus proximally (height, “a”) in four series of prostates.

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Figure 4: The perpendicular distance (depth, “d”) between the urethra and a line joining the ejaculatory ducts against the distance from the seminal colliculus proximally (height, “a”) in six series of prostates.

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Figure 5: Analysis of the first 20 mm of the perpendicular distance (depth) between the urethra and a line joining the ejaculatory ducts against the distance from the seminal colliculus upwards (proximally) in six series of prostates.

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The measurements obtained from the sections of a prostate
65x52mm (600 x 600 DPI)

Author

The 3D models of the prostate
78x29mm (600 x 600 DPI)

Author Man

The angle between the two ejaculatory ducts as measured from the centre of the prostatic urethra (angle, "θ") against the distance from the seminal colliculus proximally (height, "a") in four series of prostates.

141x95mm (600 x 600 DPI)

Author

The perpendicular distance (depth, "d") between the urethra and a line joining ejaculatory ducts against the distance from the seminal colliculusproximally (height, "a") in six series of prostates.

119x68mm (600 x 600 DPI)

Author M

Analysis of the first 20 mm of the perpendicular distance (depth) between the urethra and a line joining ejaculatory ducts against the distance from the seminal colliculus upwards (proximally) in six series of prostates.

98x45mm (600 x 600 DPI)

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Tables

Table 1: The angle between the two ejaculatory ducts as measured from the centre of the prostatic urethra in different series of prostates.

Prostate series	Angle at the proximal end	Angle at the distal end
1	61.3 ⁰	47.2 ⁰
2	86.1 ⁰	47.4 ⁰
3	37.2 ⁰	61.4 ⁰
4	46.0 ⁰	35.2 ⁰
5	68.3 ⁰	32.8 ⁰
6	96.2 ⁰	50.2 ⁰

Table 2: The predicted perpendicular distance from the midpoint of the prostatic urethra to a line joining two ejaculatory ducts (depth) from the distance of the prostatic urethra proximally from the seminal colliculus (height) with 95% confidence intervals. (Please refer to the definitions).

Given Height	Predicted Depth (in mm) (95% Confidence Intervals)
10 mm	5.42 (1.38-9.47)
20 mm	10.27 (6.22-14.32)
30 mm	11.21 (7.15-15.27)

Table 3: The separation in mm (i.e. the predicted distance between the two ejaculatory ducts) in relation to the depth of the ejaculatory ducts (i.e. the perpendicular distance from the midpoint of the prostatic urethra to a line joining two ejaculatory ducts) with 95% confidence intervals. (Please refer to the definitions).

	<i>Separation in mm (95% Confidence Intervals)</i>		
	<i>10 mm depth</i>	<i>20 mm depth</i>	<i>30 mm depth</i>
<i>Small sized gland</i>	3.37 (0.56–6.19)	5.32 (2.12–8.53)	7.27 (3.31-11.22)
<i>Medium sized gland</i>	7.51 (0.00 – 19.09)	14.75 (2.11-27.38)	21.98 (7.21-36.75)
<i>Large sized gland</i>	8.39 (0.00-22.33)	13.62 (0.00-28.75)	18.84 (0.99-36.77)

Table 4: The predicted distance between the two ejaculatory ducts (separation) from the distance of the prostatic urethra proximally from the **seminal colliculus** (height) with 95% confidence intervals. (Please refer to the definitions).

	<i>Separation in mm (95% Confidence Intervals)</i>		
	<i>10 mm height</i>	<i>20 mm height</i>	<i>30 mm height</i>
<i>Small sized gland</i>	2.19 (0.00-4.95)	2.89 (0.15-5.63)	3.59 (0.81-6.37)
<i>Medium sized gland</i>	3.46 (0.00-15.16)	6.68 (0.00-18.33)	9.89 (0.00-21.81)
<i>Large sized gland</i>	4.06 (0.00-14.43)	8.87 (0.00-19.18)	13.68 (3.23-24.12)

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Title:

Morphological variations of the human ejaculatory ducts in relation to the prostatic urethra

Date:

2018-05-01

Citation:

Malalasekera, A. P., Sivasuganthan, K., Sarangan, S., Thaneshan, K., Weerakoon, D. N., Mathangasinghe, Y., Gunasekera, C. L., Mallawaarachchi, S., Nanayakkara, N. D., Anthony, D. J. & Ediriweera, D. (2018). Morphological variations of the human ejaculatory ducts in relation to the prostatic urethra. *Clinical Anatomy*, 31 (4), pp.456-461. <https://doi.org/10.1002/ca.23036>.

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