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Presumed circle area ratio of the prostate in a community-based group of men

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Abstract

OBJECTIVE—To determine the normal values for the presumed circle area ratio (PCAR) in a group of community-based men, and to determine whether PCAR is associated with specific urological outcomes.

PATIENTS AND METHODS—The study was a cross-sectional analysis among 328 Caucasian men (94% participation) residing in Olmsted County, Minnesota, USA. The PCAR was measured during prostatic ultrasonography. Lower urinary tract symptoms (LUTS) were measured using the American Urologic Association Symptom Index. The peak urinary flow rate was measured by a uroflowmeter, and the postvoid residual volume (PVR) was assessed using the BladderScan™ BVM 6500 (Verathon, Bothell, WA, USA). Correlations between PCAR and presence of LUTS, peak urinary flow rate, and PVR were determined using Spearman correlation coefficients. Unadjusted and adjusted odds ratios (ORs) were calculated using logistic regression to determine the associations between PCAR thresholds and categorical urological outcomes.

RESULTS—The median (interquartile range) PCAR was 0.85 (0.81–0.88). After adjusting for age and total prostate volume, men who had PCARs of >0.90 were more likely to have elevated overall and obstructive symptom scores (OR 2.95, 95% confidence interval 1.39–6.25, and 3.47, 1.63–7.39, respectively).

CONCLUSION—PCAR might add further information beyond total prostate volume when predicting the development of obstructive LUTS.

Keywords

presumed circle area ratio; prostate; lower urinary tract symptoms

INTRODUCTION

BPH is a common problem in ageing men, affecting half of men aged 50–60 years [1]. As the prostate enlarges it can impinge on the urethra, causing lower urinary tract symptoms (LUTS), but correlations between overall prostatic growth and the development of LUTS are modest [2,3]. Watanabe [4] therefore proposed that it is not just prostate growth alone that is responsible for the development of LUTS, but rather how well the prostate approximates a circle as it grows. The rationale behind this hypothesis suggests that as the prostate grows it exerts pressure on the surrounding surgical capsule. The capsule also encloses the prostate, so as the prostate grows, the capsule reaches a point at which it does not stretch any further, and the prostate begins to approximate a circle. Once circularity is reached, the maximum pressure on both the capsule and the urethra is attained, and urinary disturbances can then be significant [4]. If this hypothesis is correct, the presumed circle area ratio (PCAR) of the prostate, or how well the prostate approximates a circle, might be a more significant predictor of LUTS than the total volume of the prostate.

In support of this theory, associations between PCAR and LUTS were moderate in a Japanese urological referral population [5], while associations between PCAR and LUTS were more modest in a Japanese population being mass-screened for prostate diseases [6]. However, it is not clear whether the PCAR is more strongly associated with urological outcomes than are standard measures of total prostate volume or transition zone volume (TZV). In a urological referral population, Kurita *et al.* [5] found that the TZV was more strongly associated with LUTS than was the PCAR, while Taneike *et al.* [7] found that in a community-based Japanese population, the PCAR was more strongly associated with LUTS than the TZV.

There are currently no data on the associations between PCAR and urological outcomes in Caucasian men residing in the USA. Also, as Japanese men have smaller prostates, and smaller age-related changes in prostate volume, than men in the present study population [8], it is not clear whether PCAR might be a useful predictor of LUTS or other urological outcomes in non-Japanese populations. Therefore, to address this question, we measured the PCAR in a population-based group of men residing in Olmsted County, Minnesota, USA, and examined correlations between PCAR and LUTS, postvoid residual urine volume (PVR) and peak urinary flow rate ($Q_{\max}$).

PATIENTS AND METHODS

The details of the present cohort study were published previously [9,10]. Briefly, a cohort of Caucasian men (aged 40–79 years) was randomly sampled from the Olmsted County general population. After excluding men with a history of prostate or bladder surgery, urethral surgery or stricture, or medical or other neurological conditions that could affect normal urinary function, 3874 men were asked to join the study, and 2115 (55%) agreed to participate and completed a previously validated baseline questionnaire. A 25% random subsample participated in an intensive in-clinic examination which included an ultrasonographic measurement of prostatic volume and PVR, measurement of PSA levels, and of $Q_{\max}$ and voided volume.

The cohort was actively followed biennially for 16 years using a similar protocol to the initial examination. During the second and third round of visits, men who did not participate in the follow-up were replaced by men randomly selected from the community, after being screened for the exclusion criteria used at baseline (332 men). Of the replacement men, 100 and 58 were added to the in-clinic subset in the second and third rounds, respectively. The study has been maintained as a closed cohort since then. However, in the eighth round, a random sample of 133 men who had previously been receiving questionnaires were added to the in-clinic subset.

During the in-clinic examination, total prostate volume was measured using transrectal ultrasound (TRUS) with a 7.5-MHz biplanar endorectal transducer. In addition to assessing the echogenic pattern of the prostate, three measurements were made to calculate the total prostatic volume. Anteroposterior and transverse diameters were measured at the maximum dimensions, and the superior-inferior diameter was measured at the maximum length from the base to the apex of the midline sagittal plane [11,12]. During this examination, similar methods were also used to determine the TZV [13].

Measurements of the PCAR were incorporated into the in-clinic examination during the ninth round of the study (2006). The PCAR was derived from images of the prostate obtained from TRUS (described above). In the transverse image, where the cross-section is greatest, an image was ‘frozen’ and printed. The circumference of that image was then measured based on a tracing (L) and the area was calculated. The presumed circle area was then calculated as $\pi(L/2\pi)^2$, as was the ratio of the measured area to the PCA; a PCAR of 1.0 indicated the prostate had formed a perfect circle.

The 25th and 75th PCAR percentiles (0.81 and 0.88, respectively) were rounded to the nearest decimal place (to 0.80 and 0.90, respectively), and these thresholds were examined as predictor variables in logistic regression models (described below). These thresholds were chosen rather than the 0.70 and 0.75 thresholds examined previously in Japanese populations, because only three (1%) and 17 (5%) of the men in the present study population had PCARs of <0.70 and <0.75, respectively.

A slightly modified version of the American Urologic Association (AUA) Symptom Index (AUA-SI) [14] was used to assess overall LUTS severity, as well as presence of irritative and obstructive symptoms [10]. $Q_{\max}$ was measured with a uroflowmeter (model 1000, Dantec Medical, Santa Clara, CA, USA). The PVR of the bladder was assessed using the BladderScan™ BVM 6500 (Verathon, Bothell, WA, USA).

Spearman rank correlation coefficients were used to describe the relationships of PCAR with LUTS, $Q_{\max}$ and PVR. Partial correlations were calculated controlling for age; age-stratified correlations were also calculated with men classified as aged 50–59, 60–69 and ≥ 70 years.

Logistic regression models were used to assess the cross-sectional associations between PCAR and urological measures, the latter categorized using standard thresholds, and outcomes were defined as follows: AUA-SI >7, irritative symptom score >3, obstructive symptom score >4, $Q_{\max}$ <12 mL/s and PVR >50 mL. Multivariable logistic regression models were used to adjust for age, total prostate volume and TZV.

RESULTS

PCAR measures were available for 328 (94%) of the men who participated in round nine (2006) of the study. All the men in the study were Caucasian, with a median (interquartile range, IQR) age of 65.5 (60.4–71.0 years; Table 1). The median (IQR) PCAR was 0.85 (0.81–0.88). The PCAR was positively correlated with age ($r_s = 0.20$), total prostate volume ($r_s = 0.45$), TZV ($r_s = 0.54$) and PSA level ($r_s = 0.37$, all $P < 0.001$; Table 2). The PCAR was also modestly correlated with the AUA-SI and PVR, but not with $Q_{\max}$ (Table 2). Correlations between the PCAR and prostate volume, TZV and PSA levels tended to be stronger among older men, while those between PCAR and AUA-SI and $Q_{\max}$ were stronger among younger men (Table 3).

When we examined associations between PCAR thresholds and the urological outcomes, only a PCAR >0.90 was significantly associated with elevated symptom scores (Table 4). Also, men with a PCAR of >0.90 were almost 3.5 times more likely to have an obstructive symptom score of >4 (age-adjusted odds ratio, OR, 3.47; 95% confidence interval (CI) 1.63–7.39). While

attenuated, the age-adjusted ORs between PCAR and overall symptom score and obstructive symptom score remained marginally significant after adjusting for total prostate volume (OR 2.25, 95% CI 0.99–5.11 and 2.40, 1.06–5.44, respectively). The age-adjusted ORs were further attenuated and no longer statistically significant after adjusting for TZV (Table 4).

DISCUSSION

In the present study there was a substantially larger PCAR in this Caucasian population of primarily European descent than in Japanese men, in whom most studies on PCAR have previously been done. We also found that men who had PCARs in the upper 25th percentile (>0.90) were more likely to have elevated overall and obstructive symptom scores, even after adjusting for age and total prostate volume, suggesting that the PCAR might be a better predictor of more severe LUTS than total prostate volume.

Our results are consistent with those of previous studies which describe modest correlations between the PCAR and presence of LUTS. In a group of Japanese men participating in a mass screening programme for urological disease, Kojima *et al.* [6] found that the PCAR was correlated with LUTS, with correlation coefficients of <0.001 –0.17, depending on the specific urinary symptom. The correlations between PCAR and all the urological outcomes examined in the present study are similar (ranging from $r_s = -0.07$ to 0.14). Also, the same group found that the PCAR was associated with presence of urinary symptoms even after adjusting for total prostate volume and TZV [7]. In the present study, the age-adjusted odds of increased LUTS in men with a PCAR of >0.90 were also still significant after adjusting for total prostate volume.

By contrast with the previous study by Taneike *et al.* [7], the associations between the PCAR and symptoms were no longer significant after adjusting for TZV. We have not previously found significant associations between TZV and any urological outcomes of interest (either cross-sectionally or longitudinally) in our larger study population [13,15]. However, in the present study, where TZV and PCAR were measured on only a small sample of the larger community-based cohort, the PCAR was significantly associated with urological symptoms (data not shown).

The men in this cohort are ageing, and increasing TZV is associated with increasing age. It is possible that the TZV might become a contributor to urological symptoms, but primarily in older groups. If such an effect is not apparent until ≥ 50 years old we might have missed such effects in earlier studies because a significant proportion of the study population was aged <50 years. In the present study, adjusting for TZV substantially attenuated the association between PCAR and overall and obstructive symptoms. Therefore, while the PCAR might add further information beyond total prostate volume in understanding the origin of urological symptoms, the PCAR might not add much further information beyond TZV.

The present study population also had substantially higher PCAR values than the screening populations of Taneike *et al.* and Kojima *et al.* The mean (range) PCAR in the Japanese population was 0.73 (0.57–0.93), compared to a mean PCAR of 0.84 (0.57–0.96) in the present population [7]. Watanabe [4] previously recommended a PCAR threshold of 0.75 as being the most predictive of having a PVR of ≥ 30 mL, while Taneike *et al.* [7] found that PCARs of ≥ 0.70 were significantly associated with increased AUA symptom scores. However, in the present study, only three (0.91%) men had a PCAR of <0.70 , and only 17 (5.2%) had a PCAR of <0.75 . We also found that only PCARs of >0.90 were significantly associated with increased LUTS. These results might be explained by previous findings of consistently smaller prostate volumes among Japanese men than in men residing in Olmsted County [8].

Finally, we found that men with a PCAR of >0.90 were over twice as likely to have greater overall and obstructive urinary symptoms than men with a PCAR of <0.80 , even after adjusting

for age and total prostate volume. Adjusting for age and TZV attenuated these associations, and results were no longer statistically significant; however, the adjusted ORs indicated that men with a PCAR of >0.90 were still 1.7–1.8 times more likely to also have greater LUTS. Watanabe [4] hypothesized that the degree of urethral pressure from the prostate will depend on the physical properties of the prostatic capsule. Therefore, some men might have elastic capsules which grow with the prostate, and do not force the prostate into a circle, increasing urethral pressure. Other men might have inelastic capsules, so as the prostate grows, the subsequent circularity of the prostate results in maximum pressure on the urethra [4]. Our results support this hypothesis, as the PCAR added information beyond that of total prostate volume when predicting the presence of increased obstructive LUTS.

The strengths of our study included our ability to measure PCAR in a population-based group of men, providing baseline reference data for this measure in Caucasian men, and allowing for comparisons with Japanese populations. Potential limitations include PCAR values made only at one point in time; therefore it was not possible to determine whether increases in PCAR over time preceded the development of obstructive LUTS, or whether increases in PCAR and increases in LUTS occurred coincidentally. It is also possible that an elongated, spherical shape could be just as obstructive as a circle, and the results described above do not reflect that possibility.

In conclusion, these population-based data on PCAR values in Caucasian men of primarily Northern European descent provide referent data for future studies that examine this measure in similar populations. Also, our data suggest that the PCAR might add further information beyond total prostate volume when predicting the development of obstructive LUTS.

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Abbreviations

PCAR	presumed circle area ratio
TZV	transition zone volume
PVR	postvoid residual urine volume
Q _{max}	peak urinary flow rate
TRUS	transrectal ultrasound
AUA	American Urologic Association
OR	odds ratio
SI	Symptom Index

TABLE 1

The characteristics of the Olmsted County study population

Characteristic	Median (IQR)
Age, years	65.46 (60.43–71.04)
PCAR	0.85 (0.81–0.88)
Total prostate volume, mL	31.25 (26.05–43.15)
TZV, mL	13.70 (9.75–21.20)
PSA level, ng/mL	1.22 (0.69–2.20)
Symptom score	8.0 (4.0–12.0)
Irritative	4.0 (2.0–6.0)
Obstructive	4.0 (1.0–7.0)
Q _{max} , mL/s	16.4 (11.3–22.9)
PVR, mL	39.5 (19.0–103.0)

TABLE 2

Spearman correlations between the PCAR and other characteristics of the Olmsted County study population

Outcome	r_s, P	
	Unadjusted	Age-adjusted
Age	0.20; <0.001	–
Total prostate volume	0.45; <0.001	0.41; <0.001
TZV	0.54; <0.001	0.51; <0.001
PSA level	0.37; <0.001	0.34; <0.001
Symptom core	0.12; 0.03	0.10; 0.08
Irritative	0.10; 0.08	0.07; 0.20
Obstructive	0.11; 0.05	0.09; 0.12
$Q_{\max}$	–0.07; 0.23	–0.03; 0.62
PVR	0.14; 0.01	0.12; 0.03

TABLE 3

Spearman correlations between PCAR and other characteristics of the Olmsted County Study population stratified by age

Outcome	<i>r</i> , <i>P</i> with age		
	50–59	60–69	≥70
No. of men	70	162	96
Total prostate vol.	0.20, 0.10	0.45, <0.001	0.50, <0.001
TZV	0.37, 0.002	0.57, <0.001	0.55, <0.001
PSA level	0.19, 0.12	0.38, <0.001	0.42, <0.001
Symptom score	0.24, 0.04	0.13, 0.10	0.04, 0.73
Irritative	0.20, 0.10	0.04, 0.60	0.10, 0.34
Obstructive	0.19, 0.11	0.15, 0.06	−0.01, 0.93
<i>Q</i> _{max}	0.20, 0.10	−0.19, 0.02	0.01, 0.95
PVR	0.11, 0.38	0.13, 0.10	0.01, 0.95

TABLE 4

Associations between PCAR thresholds and categorical urological outcomes

		OR (95% CI) for PCAR			
Outcome		<0.80	0.80–0.85	>0.85–0.90	>0.90
Age-adjusted					
Symptom score >7	ref		1.66 (0.89–3.09)	1.37 (0.73–2.58)	2.95 (1.39–6.25)
Irritative >3	ref		1.51 (0.81–2.79)	0.93 (0.50–1.73)	1.37 (0.67–2.80)
Obstructive >4	ref		1.08 (0.58–2.00)	1.03 (0.55–1.93)	3.47 (1.63–7.39)
Q _{max} <12 mL/s	ref		1.04 (0.51–2.10)	1.14 (0.56–2.32)	1.27 (0.57–2.85)
PVR >50 mL	ref		1.40 (0.73–2.70)	1.37 (0.70–2.65)	1.74 (0.82–3.67)
Age- and prostate volume-adjusted					
Symptom score >7	ref		1.62 (0.86–3.02)	1.26 (0.66–2.39)	2.25 (0.99–5.11)
Irritative >3	ref		1.48 (0.80–2.73)	0.87 (0.46–1.63)	1.10 (0.50–2.40)
Obstructive >4	ref		1.03 (0.55–1.92)	0.90 (0.47–1.72)	2.40 (1.06–5.44)
Q _{max} <12 mL/s	ref		1.01 (0.50–2.05)	1.05 (0.51–2.17)	0.96 (0.39–2.37)
PVR >50 mL	ref		1.37 (0.71–2.65)	1.27 (0.65–2.49)	1.36 (0.60–3.11)
Age- and TZV-adjusted					
Symptom score >7	ref		1.57 (0.84–2.94)	1.10 (0.57–2.13)	1.73 (0.75–4.02)
Irritative >3	ref		1.45 (0.78–2.69)	0.80 (0.42–1.52)	0.91 (0.41–2.05)
Obstructive >4	ref		1.00 (0.53–1.86)	0.77 (0.39–1.49)	1.81 (0.78–4.21)
Q _{max} <12 mL/s	ref		1.01 (0.50–2.04)	1.01 (0.49–2.10)	0.88 (0.35–2.22)
PVR >50 mL	ref		1.37 (0.71–2.64)	1.23 (0.62–2.42)	1.28 (0.55–2.98)