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Diagnosis and clinical significance of prostate calcification using computed tomography

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This study aimed to assess the exact location, size, and clinical significance of prostatic calcification using computed tomography (CT). We retrospectively analyzed data from 5,492 patients who underwent CT at the Department of Urology in our hospital between January 2010 and December 2020. After applying exclusion criteria (prostate cancer, post-prostatectomy, indwelling urethral catheter, severe artifacts, and software errors), 4,805 patients were included in the final analysis. Patient age, medical history, laboratory findings, and the International Prostate Symptom Score (IPSS) were collected, with linear regression used to identify predictors of IPSS. Of the 4,805 patients, 1,525 had no calcification, 285 had calcification with a Hounsfield unit (HU) < 100, and 2,995 had calcification with HU ≥ 100. The average age of patients with calcification was significantly higher than that of patients without calcification. Total IPSS scores were significantly elevated in the calcification group, particularly in those with calcifications of HU ≥ 100. The majority of calcifications were located in the central zone (79.3%), followed by the periurethral (48.6%) and transitional zones (42.0%). Only a small number of calcifications were observed in the peripheral zone (0.9%). Multivariate analysis revealed that both age and prostate calcification were significant predictors of urinary symptoms. CT can be effectively utilized to accurately assess the exact location, size, and number of prostate calcifications. Prostate calcification increases with age and is associated with worsened lower urinary tract symptoms.

Keywords Prostate, Calcification, Computed tomography, Lower urinary tract symptoms

As the global population ages, interest in urological conditions has grown, leading to an increased utilization of transrectal ultrasonography (TRUS) in health promotion centers and urology departments. This rise in the application of TRUS has correspondingly increased the diagnosis of prostate calcifications, which are reported in 7.4–76.6% of cases, depending on the patient's age[1–3]. Prostate calcifications are commonly associated with benign prostatic hyperplasia (BPH) and prostate cancer, although their precise etiology remains unclear[4,5]. Chemical analyses of prostatic calcifications have identified calcium phosphate—distinct from the calcium oxalate typically found in urinary stones—as the predominant component[6,7]. This finding supports hypotheses suggesting that stasis of prostatic secretions or dilation of prostatic ducts are key mechanisms in the formation of prostatic calcifications. Most calcifications are localized at the junction where the urethra meets the ejaculatory duct[2,8,9].

Despite advancements in imaging techniques, most studies on prostate calcifications have been limited by technical challenges. Small calcifications often become indistinguishable within ultrasound noise, and accurate measurements are hindered by acoustic shadows cast behind the calcifications. Furthermore, prior research has analyzed prostate calcifications without precise classification methods, leading to inaccuracies. The assessment of calcification burden has also been insufficient, as many studies only documented the presence or absence of calcifications without quantifying their extent. In studies that attempted to evaluate the calcification burden using transrectal ultrasound, reliance on the longest axis of the calcifications introduced significant limitations. This method often failed to provide an accurate representation of the true burden, further complicating efforts to establish reliable quantitative measurements.

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Unlike ultrasound, computed tomography (CT) is unaffected by ultrasound noise and provides imaging quality comparable to magnetic resonance imaging (MRI), the gold standard for prostate imaging in the diagnosis of prostatic calcifications[10]. CT not only allows precise identification of the calcification's location within the prostate but also facilitates accurate measurement of its size. This study aims to leverage the advantages of CT imaging to determine the exact location and size of prostatic calcifications. Additionally, it seeks to assess the clinical significance of various factors associated with prostate calcifications, offering insights into their diagnostic and prognostic implications.

Methods

Study participants

This retrospective study analyzed data from 5,492 male patients aged ≥ 18 years (range: 18–93 years) who underwent both enhanced and non-enhanced abdominal pelvic computed tomography (APCT) at the Department of Urology in our hospital between January 2010 and December 2020. Patients were excluded if they had a history of prostate cancer, previous prostatectomy, indwelling urethral catheter, severe imaging artifacts, or errors in imaging software. After applying these exclusion criteria, a total of 4,805 patients were included in the final analysis (Fig. 1).

Protocol for assessment of prostate calcification on APCT

Prostate calcifications were evaluated using multiple CT scanners (Brilliance iCT 256, Somatom Definition AS+, Somatom Definition Flash, and Somatom Force) with imaging parameters set to 100–120 kVp and slice thicknesses ranging from 2 to 3 mm. Calcifications were identified and measured in non-contrast abdominal pelvic computed tomography (APCT) axial images using a threshold value of ≥ 100 Hounsfield units (HU) through three-dimensional reconstruction with imaging software (SyngoVia, Siemens Healthineers, Germany)[11,12]. Only highlighted pixels within the prostate boundary were selected for analysis. Lesions with HU values < 100 were not classified as calcifications; however, these lesions were identified and classified separately if their boundaries were distinct from surrounding tissues. The locations of prostate calcifications were categorized into periurethral, central, transitional, and peripheral zones. Non-contrast APCT was utilized to determine the presence and volume of calcifications, while contrast-enhanced APCT was used to differentiate the transitional and peripheral zones for precise localization. To ensure diagnostic accuracy, two experienced specialists—a urologist (S. C. Kim) and a radiologist (T. Y. Lee)—independently reviewed the images. Diagnoses were made through cross-reading of another observer's interpretations and double-reading of their own, performed under strict blinding to prior results. In cases of discrepancies, reexaminations were conducted to achieve consensus. The prostate calcification locations are illustrated in Fig. 2.

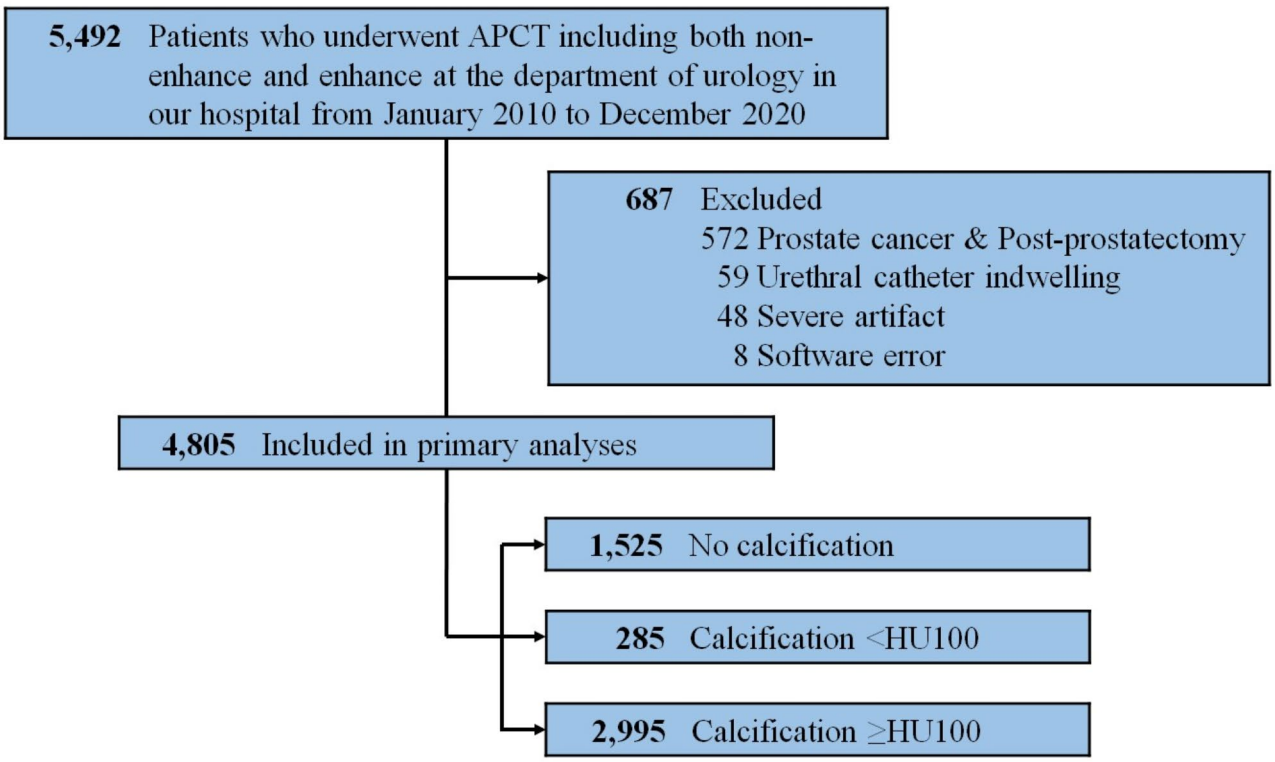

Fig. 1. Overview of patients.

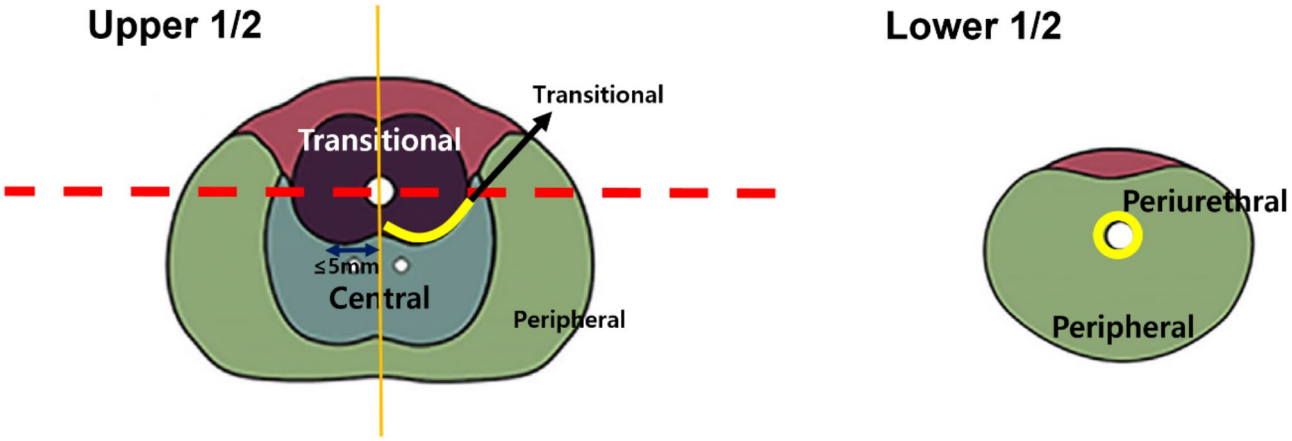

Fig. 2. Zone classification for prostatic calcifications.

Clinical and laboratory measurements

Patient demographics, including age, medical history, and laboratory findings, were recorded. Urinary symptoms were assessed using the International Prostate Symptom Score (IPSS), which incorporates a quality-of-life (QoL) component to evaluate the impact of symptoms on patients' daily lives. Prostate size was measured using TRUS. Prostatic calcifications were measured using a Picture Archiving and Communication System (PACS) measurement tool. Dimensions were reported in millimeters to one decimal place. The maximum anteroposterior diameter was measured on axial images, while the length and width were obtained from midsagittal images. Stone volume was calculated using the prolate ellipsoid formula (0.524 × height × width × length).[13]

Statistical analysis

Nominal variables were summarized as frequencies and percentages, while continuous variables were presented as mean values and interquartile ranges. The frequency of calcifications by location was illustrated using a Venn diagram. Differences based on calcification location and number were analyzed using either analysis of variance (ANOVA) or the Kruskal–Wallis test for continuous variables, depending on data distribution. Predictors of the IPSS were evaluated using linear regression analysis. Variables with a p-value < 0.2 in univariate analysis were included in the multivariate analysis to adjust for potential confounders. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using SPSS software (version 25.0; IBM Corp., Armonk, NY, USA).

Ethics statement

This retrospective observational study was approved by the Institutional Review Board (IRB) of Ulsan University Hospital (approval number: 2021-07-0732) and adhered to the principles outlined in the Declaration of Helsinki. Due to the retrospective nature of the study and the anonymization of included data, the IRB waived the requirement for informed consent.

Results

Participants

Among the 4,805 patients included in the analysis, 1,525 had no calcifications, 285 had calcifications with a Hounsfield unit (HU) < 100, and 2,995 had calcifications with HU ≥ 100. Table 1 presents the differences in age and clinical characteristics based on the presence or absence of prostate calcifications as observed on CT imaging. Patients with calcifications were, on average, older than those without calcifications. Notably, the group with calcifications of HU ≥ 100 had the highest mean age at 60.5 years ($p < 0.001$). No significant differences were observed in prostate-specific antigen (PSA) levels or prostate size among the groups. However, total, storage, and voiding scores on the International Prostate Symptom Score (IPSS) were significantly higher in patients with calcifications, with the highest scores recorded in the HU ≥ 100 group.

Characteristics of prostate calcification

The majority of calcifications, including duplicates, were located in the central zone ($N = 2,375$; 79.3%). The periurethral ($N = 1,475$; 48.6%) and transitional zones ($N = 1,257$; 42.0%) followed as the most frequently observed sites, while a small number were found in the peripheral zone ($N = 28$; 0.9%) (Fig. 3). One calcification was the most common, observed in 1,366 patients (45.6%), followed by two calcifications in 1,137 patients (38.0%), and three calcifications in 491 patients (16.4%). The average HU for calcifications was 172 ± 75.7, and the average calcification size was 187.6 mm^2 (Table 2).

When calcifications were located in the peripheral zone, the mean age of patients was the highest, but the HU value was the lowest. Additionally, while calcifications in the peripheral zone had the largest size, there was no significant difference in the International Prostate Symptom Score (IPSS), suggesting that urinary symptoms are not influenced by the calcification location. As the number of calcifications increased, the mean age, HU,

Variable	No calcification	Calcification < HU100	Calcification ≥ HU100	*p*-value
No.	1,525	285	2,995	
Mean age ± SD, year	52.3 ± 15.9	57.8 ± 13.9	60.5 ± 13.6	< 0.001
Current use of urologic medication, n (%)[a]	102 (6.7)	18 (6.3)	213 (7.1)	0.355
Diabetes, n (%)	362 (23.7)	67 (23.5)	763 (25.4)	0.663
Hypertension, n (%)	178 (11.7)	34 (11.9)	380 (12.7)	0.326
Mean body mass index ± SD, kg/m^2	24.1 ± 2.8	23.6 ± 2.8	23.9 ± 2.9	0.449
Mean PSA ± SD, ng/ml	1.68 ± 1.7	1.63 ± 1.8	1.81 ± 2.0	0.109
Mean Prostate volume on TRUS ± SD, ml	24.4 ± 6.9	24.3 ± 7.1	25.3 ± 6.8	0.112
Mean serum uric acid level ± SD, mg/dl	5.8 ± 1.5	5.4 ± 1.4	5.7 ± 1.5	0.067
Mean total cholesterol ± SD, mg/dl	172.6 ± 38.1	171.3 ± 36.9	169.7 ± 34.6	0.078
Mean IPSS total ± SD	11.7 ± 8.6	13.0 ± 10.0	13.9 ± 9.2	< 0.001
Mean IPSS storage ± SD	5.0 ± 4.5	5.6 ± 5.2	5.8 ± 4.8	0.013
Mean IPSS voiding ± SD	6.7 ± 4.9	7.5 ± 5.6	8.0 ± 5.3	< 0.001
Mean IPSS Quality of life ± SD	2.6 ± 1.7	2.9 ± 1.7	3.0 ± 1.7	0.001

Table 1. Patients characteristics. [a]Current use of urological medications affecting voiding conditions, such as alpha blockers, 5-alpha reductase inhibitors, and antimuscarinics. SD, Standard deviation; PSA, Prostate specific antigen; TRUS, Transrectal Ultrasonography; IPSS, International Prostate Symptom Score.

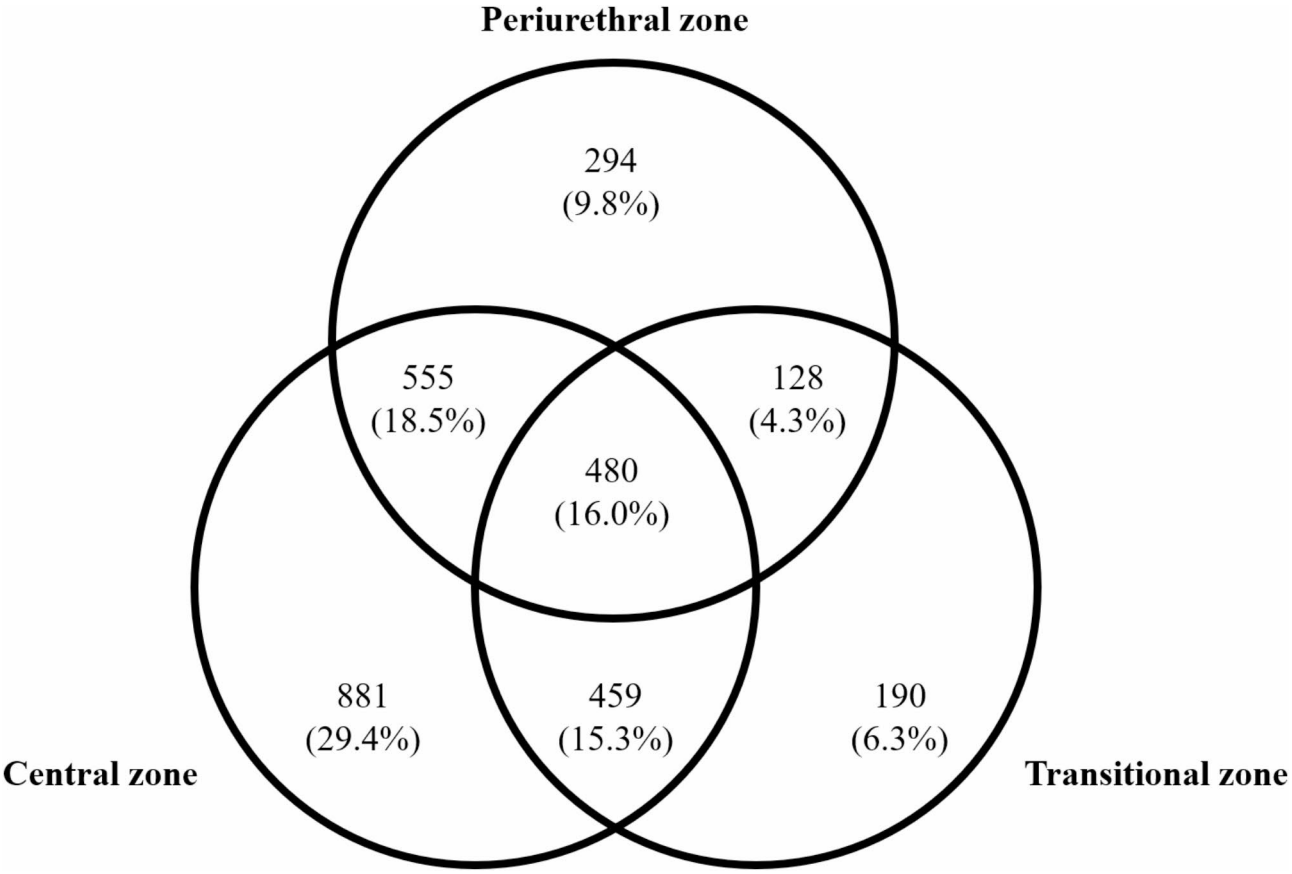

Fig. 3. Venn diagram showing proportions by location of calcifications.

and calcification size showed a significant increase. However, there was no corresponding change in IPSS scores (Table 3).

Clinical significance of prostate calcification

Total International Prostate Symptom Score (IPSS) was significantly higher with increasing age and the presence of prostate calcifications. In the univariate analysis, Storage lower urinary tract symptoms (LUTS) also showed

Variable	*N*	Percentage (%)
Locations		
Periurethral zone	1,475	48.6
Central zone	2,375	79.3
Transitional zone	1,257	42.0
Peripheral zone	28	0.9
No of lesion		
1	1,366	45.6
2	1,137	38.0
3	491	16.4
4	1	0.0
Mean HU of calcification ± SD	172.3 ± 75.7	
Mean Size of calcification ± SD, mm^3	187.6 ± 368.7	

Table 2. The description of prostate calcification. HU, Hounsfield unit; SD, Standard deviation.

Variable	Number of calcifications			*p*-value
	1	2	3	
Mean age ± SD, year	58.6 ± 13.8	61.2 ± 13.2	64.2 ± 13.0	0.001
Mean HU of calcification ± SD	157.7 ± 68.6	176.2 ± 74.9	203.6 ± 85.2	< 0.001
Mean size of calcification ± SD, mm^3	76.9 ± 182.7	197.7 ± 309.6	471.8 ± 632.2	< 0.001
Mean IPSS total ± SD	13.8 ± 9.4	13.5 ± 9.1	14.6 ± 9.0	0.491

Table 3. Clinical features according to prostate calcification. SD, Standard deviation; HU, Hounsfield unit; IPSS, International Prostate Symptom Score.

a significant increase with both age and calcifications. However, in the multivariate analysis, only age emerged as a significant factor influencing Storage LUTS. Voiding LUTS, on the other hand, significantly increased with both age and calcification in both the univariate and multivariate analyses. Therefore, both age and prostate calcification were identified as significant factors influencing urinary symptoms (Table 4).

Discussion

Prostate calcification is a common finding in middle-aged and older men, with incidence rates ranging from 7 to 70%, largely depending on the age of the study population[3,14,15]. In our study, the mean age of participants was 59 years, and approximately two-thirds of the cohort exhibited prostate calcifications. Notably, both the size and number of calcifications increased with age, which aligns with findings from previous studies[9,16,17]. Prostate calcification is most commonly associated with benign prostatic hyperplasia or chronic inflammation. The relationship between calcification and LUTS has been well-documented, though the underlying mechanism remains incompletely understood. One possible explanation is an inflammatory response. Histopathological studies often reveal lymphocytic and histiocytic infiltration of the prostate acinar glands in areas of calcification, which may create a microenvironment that perpetuates further inflammatory changes[18,19]. Prostate calcification causes inflammation by blocking the intraprostatic ducts, and this chronic inflammation is ultimately associated with calcification in the surrounding tissues. This can cause fibrosis, leading to tissue stiffness and LUTS[19,20]. In the multivariate analysis, age and calcification were significant factors affecting urinary symptoms.

Numerous studies have reported that the presence of prostate calcifications and their characteristics can influence urinary symptoms. In particular, calcifications located around the prostatic urethra can cause tissue stiffness, which exacerbates urinary symptoms[8]. Additionally, increasing calcification size has been shown to correlate with worsening urinary symptoms[5]. In our analysis, both the HU value and size of the calcifications varied according to their location within the prostate. However, no significant correlation was found between these characteristics and the IPSS. As age increased, there was a higher incidence of multiple calcifications, and the size of the calcifications also increased. Despite this, no correlation between the number or size of the calcifications and urinary symptoms was observed. This lack of correlation is likely due to the fact that not all participants in the study presented with urinary symptoms, leading to a smaller variation in IPSS scores, which made it difficult to detect significant differences. Similarly, it was difficult to identify a relationship between prostate volume and IPSS, likely because not all participants had benign prostatic hyperplasia or LUTS, resulting in minimal differences in prostate volume.

To date, most studies on prostate calcification have relied on TRUS for diagnosis[8,9,16,21]. However, TRUS is operator-dependent and may be limited in its ability to accurately diagnose and localize calcifications due to the noise generated behind them. In contrast, this study employed CT, which offers a standardized imaging modality that is independent of the operator. CT enables precise evaluation of not only the location, size, and number of

Variable	Univariate analysis				Multivariable analysis*			
	Beta	95% CI		*p* value	Beta	95% CI		*p* value
IPSS total								
Age	0.134	0.099	0.168	0.001	0.126	0.077	0.175	0.001
Calcification (Yes)	1.072	0.557	1.586	0.001	0.725	0.209	1.241	0.006
HU of calcification	0.006	− 0.002	0.013	0.144	− 0.001	− 0.010	0.009	0.893
Size of calcification	0.001	0.001	0.002	0.068	0.001	− 0.001	0.002	0.371
Location of calcification	− 0.129	− 1.053	0.795	0.784				
No. calcification	0.273	− 0.505	1.051	0.491				
Prostate volume on TRUS	0.002	− 0.003	0.023	0.580				
IPSS storage								
Age	0.051	0.034	0.071	0.001	0.045	0.019	0.071	0.001
Calcification (Yes)	0.403	0.134	0.673	0.003	0.267	− 0.005	0.540	0.054
HU of calcification	0.003	− 0.001	0.007	0.204	− 0.001	− 0.005	0.005	0.992
Size of calcification	0.001	− 0.001	0.001	0.109	0.001	− 0.001	0.001	0.397
Location of calcification	0.058	− 0.426	0.541	0.815				
No. calcification	0.039	− 0.368	0.446	0.851				
Prostate volume on TRUS	0.001	− 0.001	0.014	0.348				
IPSS voiding								
Age	0.081	0.062	0.101	0.001	0.081	0.053	0.108	0.001
Calcification (Yes)	0.668	0.376	0.961	0.001	0.458	0.165	0.751	0.001
HU of calcification	0.003	− 0.001	0.008	0.163	− 0.001	− 0.006	0.005	0.820
Size of calcification	0.001	0.001	0.002	0.083	0.001	− 0.001	0.001	0.431
Location of calcification	− 0.187	− 0.714	0.340	0.486				
No. calcification	0.234	− 0.210	0.678	0.301				
Prostate volume on TRUS	0.001	− 0.002	0.011	0.433				

Table 4. Factors predictive of IPSS. HU, Hounsfield unit; IPSS, International Prostate Symptom Score; TRUS, Transrectal Ultrasonography. * Linear regression model.

calcifications but also the HU, which provides valuable information regarding the density of the lesions. MRI has limitations in detecting intraprostatic calcifications due to its sensitivity to variations in signal intensity and the small size of the lesions. Given these constraints, CT may offer a distinct advantage over MRI in identifying prostate calcifications, providing clearer, more accurate imaging for both diagnostic and clinical purposes[10,22].

This study has several limitations. First, it was retrospective in nature, which inherently restricts the ability to establish causality and may introduce selection bias. Second, while we used the IPSS to assess the clinical significance of prostate calcification, it is important to note that calcifications can have varying clinical implications. LUTS can be caused by factors other than calcifications, which may have confounded our findings. Third, the study exclusively included patients who underwent CT scans in the urology department, regardless of their reason for seeking care. This limited our ability to detect significant differences in urinary symptoms, as the patient population may not have been fully representative of the broader group with prostate calcifications. Finally, we were unable to perform pathological evaluations to assess fibrosis or tissue stiffness surrounding the calcifications, which we hypothesize to be a major contributor to the worsening of LUTS in our study participants. Despite these limitations, our study provides valuable insights as one of the few to use CT for the assessment of prostate calcification. It represents a significant advancement in the accurate evaluation of prostate calcifications. Future large-scale, prospective studies are essential to further investigate the potential for preventing calcification by controlling the underlying inflammation, as well as to assess the efficacy of treatments aimed at removing calcifications.

Conclusions

CT can be effectively utilized to accurately assess the exact location, size, and number of prostate calcifications. Our findings indicate that the prevalence of prostate calcifications increases with age and that these calcifications are associated with worsening LUTS. However, further prospective studies are needed to validate the effectiveness of preventive strategies and treatment options for prostate calcification, particularly in alleviating associated symptoms.

Data availability

The data that support the findings of this study are available from the authors, but restrictions apply to the availability of these data, which were used under license from the Ulsan University Hospital for the current study, and so are not publicly available. Data are, however, available from the authors upon reasonable request and with permission from the Ulsan University Hospital. If necessary, please contact the corresponding author by email (Taekmin Kwon; tmkwon@uuh.ulsan.kr).

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Author contributions

Research conception and design: Seong Cheol Kim and Taekmin Kwon. Data acquisition: Ji Hyung Yoon, Sungchan Park, Kyung Hyun Moon, and Sang Hyeon Cheon. Statistical analysis: Tae Young Lee, Seong Cheol Kim and Taekmin Kwon. Data analysis and interpretation: Seong Cheol Kim and Tae Young Lee Drafting of the manuscript: Seong Cheol Kim and Taekmin Kwon. Critical revision of the manuscript: Seong Cheol Kim and Taekmin Kwon Administrative, technical, or material support: Woocheol Kang, Hoyoung Bae Supervision: Tae Young Lee and Taekmin Kwon. All authors reviewed the manuscript Approval of the final manuscript: Seong Cheol Kim and Taekmin Kwon.

Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

The requirement for informed consent was waived by the Institutional Review Board of Ulsan University Hospital given the retrospective study design and the anonymization of the data included in the study.

Additional information

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-025-88320-w.

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