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The value of detecting Hounsfield density of renal papillae in kidney stone formers patients compared with non-stone formers by CT study

Abeer.S.Abbas[2], M.M.Khalil[1] and M.A.Tawfik[2]
[1]Urology, Dept., Faculty of Medicine, Benha Univ., Benha, Egypt
[2]Radio-Diagnosis, Dept., Faculty of Medicine, Benha Univ., Benha, Egypt
E-mail: Dr.abeersamy@yahoo.com

Abstract

In order to properly diagnose kidney stones and determine which therapeutic approach should be used for treatment, imaging is an essential initial step. Radiography, ultrasound, computed tomography, and magnetic resonance imaging are all viable options for these individuals. Evaluation of nephrolithiasis patients is best done using CT of the abdomen and pelvis because of its high degree of accuracy. The purpose of this research is to better comprehend the pathophysiology of stone formation by comparing the renal papillary density of stone formers of all prevalent stone subtypes to that of non-stone formers. Renal papillary density was compared between calyces in the kidney with a stone, calyces in the kidney without a stone, and calyces in the control group. Moreover, the density of the papillary structures in the kidneys was compared between kidneys where the stones were located. Methods: Fifty people participated in the trial, 25 of whom had unilateral renal stones and 25 of whom were healthy controls. Study participants were seen in the outpatient clinics of both Sheikh Zayed and the International Hospital for Urology and Nephrology. Results: The major findings of the research showed that the mean density of the upper, middle, and lower calyces of the renal papillae varied significantly across the study groups, with the greatest mean density found in the stone-bearing kidneys and the lowest density found in the normal group. This study's findings that individuals with renal stones had a higher papillary density compared to normal participants have implications for the diagnosis and follow-up of these patients. Renal stones of all types are radiographically characterised by increased renal papillary Hounsfield density. The involvement of papillary plaques and concretions in stone formation is supported by these radiography findings.

Key words: stone formation, future risk, Imaging of renal stones.

1. Introduction

Urinary tract stones originated from two primary occurrences. The first phenomenon is a urinary system that is supersaturated with stone-forming elements such uric acid, calcium, and oxalate. Crystals or other foreign substances may serve as nidi, allowing supersaturated urine to precipitate ions into minute crystalline formations. Stone material deposition on a renal papillary calcium phosphate nidus, generally a Randall plaque, is the second phenomenon (which always consists of calcium phosphate). In the renal papilla, calcium phosphate first forms deposits in the basement membrane of the narrow loops of Henle, then destroying into the interstitium and eventually building up in the subepithelial area. Randall plaques, now called as subepithelial deposits, used to erode through the papillary urothelium. Urinary calculi form when stone matrix, calcium oxalate, and calcium phosphate accumulate slowly on a substrate (1).

Renal stone imaging is an important diagnostic technique and the first step in determining a treatment strategy. Plain radiography, ultrasonography, computed tomography, and magnetic resonance imaging are all useful for these individuals. Plain film radiography of the kidney, ureter, and bladder (KUB) is less beneficial in the context of acute stones but more useful in investigating interval stone development in individuals with established stone disease. Although MRI offers the possibility of 3D imaging without exposing patients to radiation, the procedure is expensive, and it is still difficult to see stones with the naked eye. Due to its superior specificity and sensitivity compared to ultrasonography, non-contrast CT of the abdomen and pelvis is often regarded as the most comprehensive diagnostic technique in the examination of nephrolithiasis patients (2).

In addition, CT scans may be utilised to determine the relative stone composition and density, both of which can help guide treatment decisions. Shockwave lithotripsy is more effective on low-density stones, but ureteroscopy could be necessary for higher-density stones (1).

Patients with kidney stones of any composition had the same radiographic feature, an increase in renal papillary Hounsfield density. This was the same for all renal calyces and all kidneys in stone-formers with a single renal calyceal stone. These imaging findings support a pathophysiological function for renal papillary plaques or deposits in stone production (3).

This study set out to compare patients who already have stones versus those who have never had one before in an effort to establish a baseline for predicting who could get stones in the future.

2.Patients and Methods

Technical design:

2.1The study type: Prospective study.

Study setting: The study was performed in Urology outpatient clinic at EL- Sheikh Zayed specialized hospital, Faculty of medicine, Cairo University and International hospital for urology and nephrology and it was approved by the ethics committee at the Faculty of Medicine, Banha University

2.2Study subjects:

The target patients for this study were determined patients who came to Urology outpatient clinics at the study hospitals and are fulfilling the inclusion and exclusion criteria

2.3Inclusion criteria:

1. Age 18 years and above.
2. Renal stone in one kidney & no stones in the contralateral kidney
3. Healthy controls.
4. Both genders.

2.4Exclusion criteria:

1. Bilateral renal stones.
2. Age below 17.
3. Radiolucent renal stones.
4. Pregnancy

The study included 50 adult patients (comprised of 25 stone formers patients with unilateral renal stones and 25 healthy controls with no history of stone formation).

2.5Operational design:

1. The study started from October 2021 and finished in November 2022 once the requested approval of the corresponding authorities was obtained.

- Urology and Radiology department outpatient and hospital documentation were studied to detect patients with nephrolithiasis
- Study included three groups.
- First group: The normal group.
- Second group: Stone forming kidney in stone formers.
- Third group: Non-stone forming kidney in the stone formers.
- CT was performed before stone management and CT slides were assessed by 2 experienced radiologists in the abdominal imaging, who were had no knowledge about patient clinical details
- Renal papillary Hounsfield density was estimated at 5x magnification by placing regions of interest with a mean size of 0.2 cm2 in the region of the renal papillae. Mean attenuation values were measured in HU. The Hounsfield density of a single papillae in the upper, middle and lower kidney calyces were documented.
- Comparisons were done among non-stone bearing calyces in the kidney with stone, calyces in the non-stone bearing kidney and calyces in the controls.

2.6Considerable Ethics:

- Study protocol received approval from institutional Review Board (IRB) - Faculty of Medicine
- Administrative approval and permissions were obtained from the heads of radiology departments prior to data collection

2.7Data analysis:

1. The collected data was reviewed, coded, processed and analyzed using SPSS program (Statistical Package for Social Science) for windows version 25 ***(SPSS Inc., Chicago, IL, USA)***
2. The data were demonstrated as number and percentages for the qualitative data, mean, standard deviations, median, minimum and maximum for the quantitative data and using frequency (count) and relative frequency (percentage) for categorical data
3. The appropriately significance tests were conducted. ***Chi-square test*** was used in the comparison between groups with qualitative data and ***Fisher exact test*** was used instead of the Chi-square test when the expected count in any cell found less than 5. ***One Way ANOVA test*** was used in the comparison between quantitative data and groups.
4. The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the significance of p-value was considered as follows:
   - P > 0.05: non-significant
   - P < 0.05: significant
   - P < 0.01: highly significant
   - P < 0.001: very highly significant

3. Results

Table (1) Age distribution in the study groups

	Normal group Group 1 (No=25)		**Stone bearing kidney group Group 2 (No=25)**		**Non stone bearing kidney group Group 3 (No=25)**		**One way ANOVA**	
	Mean	SD	Mean	SD	Mean	SD	t	p value
Age	40.80	11.59	37.52	12.46	37.52	12.46	0.604	0.549

Table (1): The mean age in the first group was 40.8 ±11.59 years. The mean age in the second group was 37.52±12.46 years. The mean age in the third group was 37.52±12.46 years. Showing that there was no significantly statistical significant differences among the study groups as regards age.

Table (2) Gender distribution in the study groups

		Normal group Group1 (No=25)		Stone-bearing kidney group Group2 (No=25)		Non-stone-Bearing kidney group Group3 (No=25)		Chi square test	
		No	**%**	**No**	**%**	**No**	**%**	x^2	**p value**
Gender	Female	6	20.0%	9	40.0%	9	40.0%	1.103	0.576
	Male	19	80.0%	16	60.0%	16	60.0%		

Table (2): The mean gender in the first group was 20% females and 80% males. The mean gender in the second group was 40% females and 60% males. The mean gender in the third group was 40% females and 60% males. Showing that there was no significantly statistical differences among the study groups as regards gender.

Table (3) Renal papillae HU density of upper calyx in the study groups

	Normal group Group1 (No=25)		Stone-bearing kidney group Group2 (No=25)		Non-stone-bearing kidney group Group3 (No=25)		One way ANOVA	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**f**	**p value**
Renal papillae HU density of upper calyx	12.80	2.84	38.16	4.90	34.48	4.96	248.609	<0.001

Table (3): The mean Renal papillae HU density of upper calyx in the first group was 12.8±2.84. the mean Renal papillae HU density of upper calyx in the second group was 38.16±4.9. the mean Renal papillae HU density of upper calyx in the third group was 34.48±4.96. Showing that highly statistically significant differences were detected among the study groups as regards renal papillae HU density of upper calyx with the highest mean density being detected in the stone bearing kidneys (Group2) and the lowest density in the normal group (Group1). Additionally, pairwise comparisons between the normal group and stone bearing or non-stone bearing showed highly statistically significant differences as regards renal papillae HU density of upper calyx.

Table (4) Renal papillae HU density of middle calyx in the study groups

	Normal group Group1 (No=25)		Stone-bearing kidney group Group2 (No=25)		Non-stone-bearing kidney group Group3 (No=25)		One way ANOVA	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**f**	**p value**
Renal papillae HU density of middle calyx	13.12	2.71	39.72	6.38	35.28	5.48	194.963	<0.001

Table (4): The mean Renal papillae HU density of middle calyx in the first group was 13.12±2.71. the mean Renal papillae HU density of middle calyx in the second group was 39.72±6.38. the mean Renal papillae HU density of middle calyx in the third group was 35.28±5.48. Revealing that highly statistically significant differences were detected among the study groups as regards renal papillae HU density of middle calyx with the highest mean density being found in the stone bearing kidneys (Group 2) and the lowest density in the normal group (Group 1). In addition, pairwise comparisons between the normal group and stone bearing or non-stone bearing showed highly statistically significant differences as regards renal papillae HU density of middle calyx.

Table (5) Renal papillae HU density of lower calyx in the study groups

	Normal group Group1 (No=25)		Stone-bearing kidney group Group2 (No=25)		Non-stone-bearing kidney group Group3 (No=25)		One way ANOVA	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**f**	**P value**
Renal papillae HU density of lower calyx	13.00	2.66	46.24	13.29	35.68	4.83	104.474	<0.001

Table (5): The mean Renal papillae HU density of lower calyx in the first group was 13±2.66. the mean Renal papillae HU density of lower calyx in the second group was 46.24±13.29. the mean Renal papillae HU density of lower calyx in the third group was 35.68±4.83. Showing that highly significantly statistical differences were detected among the study groups as regards renal papillae HU density of lower calyx with the highest mean density being detected in the stone bearing kidneys and the lowest density in the normal group. Additionally, pairwise comparisons between the normal group and stone bearing or non-stone bearing demonstrated highly significantly statistical differences as regards renal papillae HU density of lower calyx.

4.Illustrative Cases

History:

A 37-years old male with history of loin and pelvic pain.

Abdomen-pelvic CT Findings:

A stone in right lower calyx

Density of papillae	Stone-bearing kidney	Non-stone-bearing kidney
Upper calyx	51.5	29
Middle calyx	48	22.5
Lower calyx	47.7	22

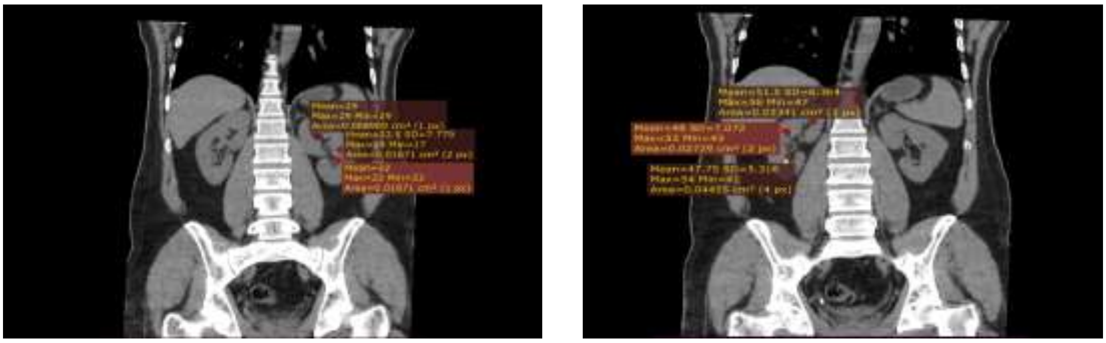

Fig. (1) (A) coronal cut of CT abdomen & pelvis show right lower calyx stone

5. Discussion

Hounsfield papillary density in the kidney was also examined among stones of different locations. The present research's comparison of the gender distribution of the study groups demonstrated that there were no statistically significant differences between the study groups with respect to gender. There were also no statistically significant variations in age between the groups in this investigation.

This uniformity in the research groups' starting points allows for fair comparisons between them (4).

Patients were classified as stone formers or non-stone formers in our research. Patients with nephrolithiasis had a greater papillary density in all calyces compared to controls, regardless of stone subtype.

High levels of statistical significance (p0.001) were found between the groups with the greatest and lowest mean renal papillae density in the present investigation.

This is in line with prior research showing a positive link between papillary hyper-density and kidney stone disease, in which stone formers had much higher Hounsfield densities in their kidneys compared to those who did not develop stones.

The results of this research suggest that a CT scan may be used to assess the likelihood of future stone development. In addition, a higher papillary density can predict the likelihood of a recurrence of renal stones in patients who have already experienced a first stone episode, allowing for the identification of high-risk patients and the prediction of the development of new stones in patients without known renal stone disease (5). Because of this, CT KUB is useful not only for diagnosis in stone formers but also for counting and localising stones and evaluating their kind.

These findings are consistent with those of previous research, such as that conducted by Deshmukh et al. (6), who aimed to further highlight the pathophysiology of stone formation by examining renal papillae Hounsfield density in stone formers with all prevalent stone subtypes. Stone-bearing calyces, non-stone-bearing calyces in the afflicted kidney, and calyces in the contralateral non-stone-bearing kidney were all shown to have considerably higher Hounsfield densities in patients with stones than in controls. They conclude that the presence of renal papillary plaques or deposits contributes to the pathophysiology of stone development based on this radiography result.

These results are consistent with those found by Shavit et al. (7), who compared 57 patients with kidney stones to 54 healthy controls to determine if patients who form kidney stones repeatedly have higher papillary density than controls and to look for a link between renal papillary density and hypercalciuria. Results showed that kidney stone formers had considerably greater papillary density, but no correlation with hypercalciuria. They concluded that CT-estimated papillary density is a useful non-invasive approach for distinguishing between those prone to developing kidney stones and healthy controls.

In conclusion, we think CT might be utilised as a screening tool for future nephrolithiasis since CT's slices showed useful information on the possible future risk of stone illness. Recent advances in iterative reconstruction of CT images have permitted considerable reductions in radiation supplied to humans, which may justify ongoing widespread use of CT for abdominal imaging despite public concerns about radiation exposure. Finally, a high under- lying risk for kidney stone disease should be suspected when an elevated papillary density is seen during a non-contrast CT scan.

6. Conclusion

This study's findings that people with renal stones had higher papillary densities than healthy people may inform the diagnosis and follow-up of these individuals. Renal stones of all types are radiographically characterised by increased renal papillary Hounsfield density. The involvement of papillary plaques and concretions in stone formation is supported by these radiography findings.

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