Redefining caliceal anatomy in axial plane: selective overlapping of the appropriate contiguous sections on delayed post-contrast CT

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Abstract

Developments in endourology, percutaneous nephrostolithotomy and nephrostomy with newer advances in radiological imaging of the pelvicaliceal system have rekindled interest in the axial anatomy of the collecting system. The objective of this study was to evaluate the placement of the posterior calyx in relation to the coronal plane of the body viz., the corporo-caliceal angle. A simple, but less cumbersome measurement was utilized than the previously defined methods to assess the relationship of the posterior calices in relation to the frontal plane of the body. Data from 32 right kidneys and 31 left kidneys from 41 patients who underwent delayed CT pyelogram in supine or prone position was examined over a year. The angles subtended by the posterior calices in supine and prone position for the right and left kidneys were 61 and 63 degrees and 52 and 64.3 degrees, respectively. The variations in the orientation of the posterior calices on either side ($p < 0.05$) and in supine or prone position ($p < 0.05$) were statistically not significant. The calices were seen to vary considerably in position, shape and number with only a few falling into the classical Brodel and Hodson's type. There was no significant change in the intrarenal anatomy with change in position. Hence, the data obtained from a supine study can be extrapolated to a procedure done in prone position.

INTRODUCTION

Choice of an ideal end-on posterior interpolar calyx located along the avascular plane of the Brodel is essential to safely perform endourological procedures. Until now, the information available on caliceal anatomy is primarily from 3D corrosion cast pyelograms and excretory urograms [1]. Excretory urograms clearly depict the position of the anterior and the posterior calices but do not provide data regarding axial caliceal orientation. The latter is essential for planning the posterior caliceal puncture in fluoroscopy guided endourological procedures, particularly in malrotated kidneys [1, 2]. Two studies in literature have evaluated axial anatomy of the calices but both have used relatively cumbersome measurement techniques and one study was done prior to the advent of helical CT [2, 3].

The current study depicts a simple, yet accurate method to assess the relationship of the posterior calices in relation to the frontal plane of the body on axial CT sections. The angle measurement tools available on a picture archival and communication system (PACS) workstation along with the aid of selective overlapping technique on delayed CT pyelogram can delineate the posterior caliceal orientation. Prior to difficult endourological procedures especially in patients with malrotated kidneys or in whom pre-procedural imaging has been done, the on-table patient obliquity can be determined based on the corporo - caliceal angle.

MATERIAL AND METHODS

Analysis of the angle subtended by a definable posterior interpole calyx with the frontal / mid-coronal plane of the body was done from 41 voluntary kidney donors who were randomly allocated to be scanned in either the supine or prone positions. The patient cohort was obtained over a period of one year. Patients with a definable posterior interpolar calyx either on a single section or post super-imposed axial sections were included in the study, whereas patients with incidental space occupying lesions, motion artifacts or those with complex anatomy were excluded. Using these criteria, 32 right kidneys and 31 left kidneys from 41 patients examined over a year were included in the study. The axial CT sections were evaluated with the aid of workstation tools like magnification, inversion of gray scale, angle measurement and also utilizing the post-processing

superimposition technique available in the CT console. The corporo-caliceal angles of all definable posterior calices in both right and left kidneys in relation to the mid coronal plane of the body were measured.

SUPERIMPOSITION OF AXIAL IMAGES – POST-PROCESSING TECHNIQUE

In the event of a partially imaged posterior calyx on a single axial CT section, a post –processing technique available on the CT workstation was used to superimpose successive axial sections of the posterior calyx. The resultant image, a sum of two or three successive axial sections, defined the posterior interpolar calyx in its entirety (Fig2).

IMAGING PROTOCOL

All CT examinations were performed using helical CT (Siemens Emotion, Erlangen, Germany). A CT pyelogram was obtained with a delay of fifteen minutes in the supine or prone position following injection of 100 ml of intravenous contrast (Ultravist 300, Schering AG, Allemagne). Contiguous slices of 5mm thickness with single breath hold technique were obtained through the kidneys. Images were archived to PACS, subsequently, interpretation and angle measurements were done on the workstation using high resolution monitors (BARCO, Belgium).

DEFINITIONS

Frontal / mid coronal plane of the body – plane passing longitudinally through the body from side to side at right angles to the median plane, dividing the body into anterior and posterior halves [$_2$].

Frontal plane of the kidney – plane passing through the most convex point of the lateral renal margin and the mid renal hilus and projected medially to intersect the frontal plane of the body [$_2$].

Caliceal angle – angle the posterior calyx makes with the frontal plane of the kidney and the coronal plane of the body [$_2$].

Corporo - Caliceal angle – angle subtended by a line drawn from the tip of a posterior calyx through the infundibulum and a line parallel to the coronal plane of the body (Fig3).

INTERPRETATION

The kidneys with a definable posterior interpolar calyx were selected for angle measurement (Fig1).

Figure 1

Figure 1:Delayed axial CT pyelogram: Classical axial sections that outline the caliceal anatomy with a well defined mid hilar point.

In the event of a poorly defined posterior calyx, super-imposition of successive axial sections was done on a workstation to obtain a definable posterior interpolar calyx (Fig2). Using the tools available at the workstation, the Corporo-caliceal angle was measured as depicted in Fig3a and 3b.

Figure 2

Figure 2: Delayed axial CT pyelogram: Partially imaged posterior calyx [first two axial sections], selectively overlapped utilizing the superimposition technique available at the CT console, with a resultant well defined posterior calyx [third axial section].

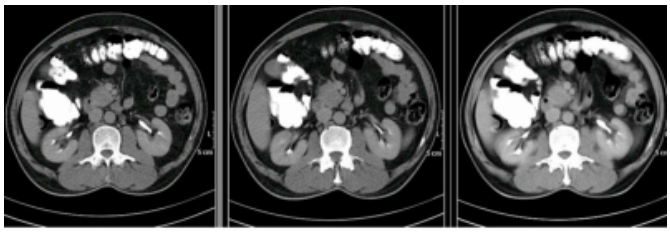


Figure 3

Figure 3a:Schematic representation: Mathematical derivation of the corporo-caliceal angle from the formerly described caliceal angle by Kaye and Reinke.

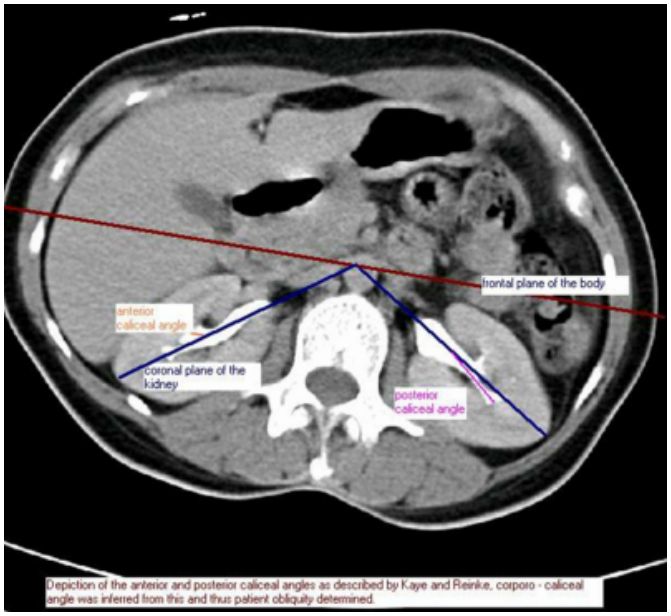
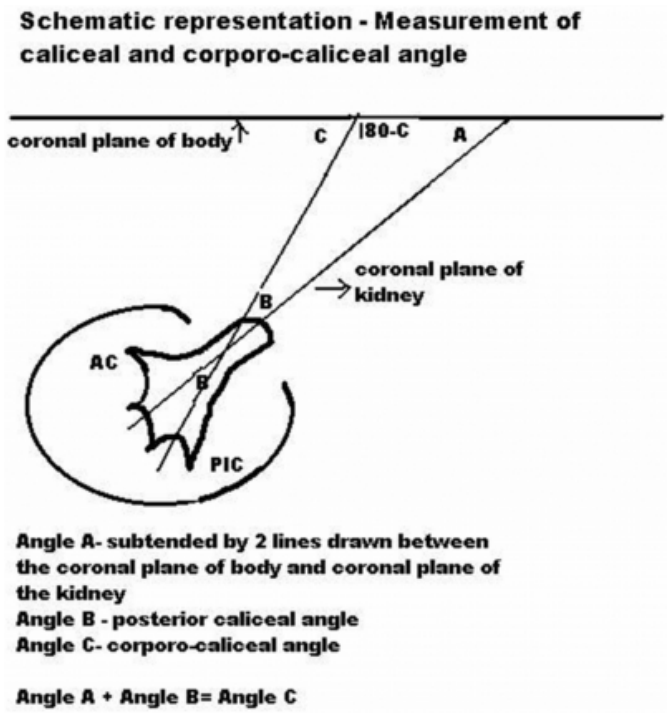


Figure 4

Figure 3b:Measurement of the Corporo-caliceal angle: Magnification and inversion of the gray scale with angle measurement tools available at the PACS workstation.



RESULTS

Results of the current study were compared using Levene's Test for equality of variances. On an average, the posterior calices projected 61o on the right and 63o on left in supine position and 52o on the right and 64.3o on the left in prone position. Of the 32 right kidneys and 31 left kidneys studied, 16 were excluded due to complex anatomy, 2 due to incidental space occupying lesions, 1 due to hydronephrosis and 1 due to chronic pyelonephritis. Of the 63 kidneys, 22 kidneys [26%] required post-processing super-imposition to obtain a definable posterior interpolar calyx for angle measurement.

Statistical evaluation was done using student's t test of significance as shown in tables 1 to 4, the p value obtained was not statistically significant ($p < 0.05$).

Figure 5

Table 1: Right and left kidneys in supine position

	Right	Left
Total kidneys (32)	17	15
Average Corporo-Caliceal angle (degrees)	61.3	62.9
Range (degrees)	17 - 97	34 - 84
Average ±- SE (degrees)	61.3 ± 4.1	62.9 ± 3.6

p value compared to the right kidney – 0.77

Figure 6

Table 2: Right and Left kidneys in prone position

	Right	Left
Total kidneys (29)	14	15
Average Corporo-Caliceal angle (degrees)	51.8	64.3
Range (degrees)	15 - 78	41 - 78
Average ± SE (degrees)	51.8 ± 4.9	64.3 ± 3.5

p value compared to the right kidney – 0.05

Figure 7

Table 3: Comparing the angles of the right kidney (Supine and Prone position on the right

	Right (supine)	Right (prone)
Total kidneys	24	16
Average Corporo-Caliceal angle (degrees)	61.3	51.8

p value compared to the right kidney – 0.15

Figure 8

Table 4: Comparing the angles on the left kidney (Supine and prone position on the left

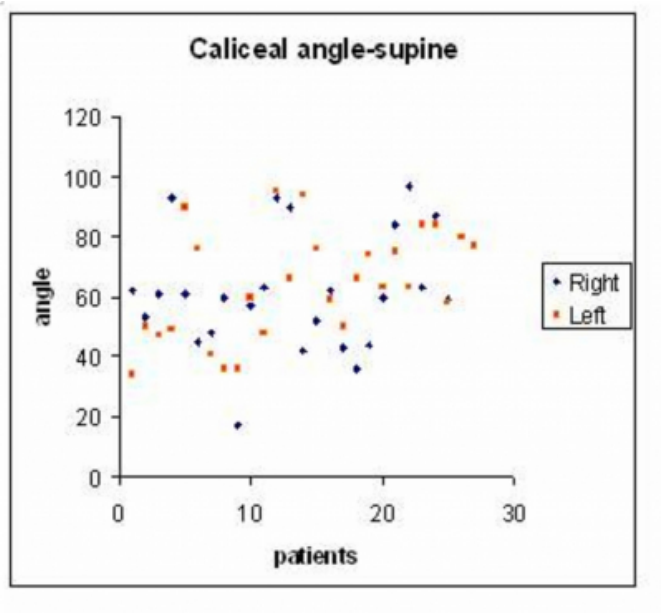
	Left (supine)	Left (prone)
Total kidneys (29)	25	16
Average Corporo-Caliceal angle (degrees)	62.9	64.3

p value compared to the right kidney – 0.8

The supine or prone positions of the patient had no effect on the orientation of the kidneys. The mean caliceal angle changing from 61.3o in supine position to 51.8o in prone position was not statistically significant [3]. There was a wide variation in the number, size, shape and orientation of the calices with very few actually falling into the classical Brodel and Hodson's type [5]. The scatter graphs are shown in Fig4a and 4b.

Figure 9

Figure 4a & 4b:Scatter graphs obtained plotting the angles obtained in supine and prone position.



DISCUSSION

The principal segmental arteries lie relatively deep within the kidney, running close to the infundibula within the hilar region. Distally as the calices are approached along the avascular plane of Brodel, the arteries are fewer and smaller in caliber. Renal puncture and subsequent tract dilatation for fluoroscopy guided endourological procedures is planned along the avascular plane of Brodel to avoid transection of a large artery [4, 5]. The collecting system is entered at the tip of a lower or middle posterior row calyx via the avascular plane of Brodel after the patient is given the desired obliquity to ensure an end-on posterior calyx [2]. The anterior and the posterior calices though seen on an excretory pyelogram fail to provide the necessary axial orientation of the calices. Perfect understanding of this is essential to infer the degree of on-table patient obliquity required to ensure an end-on calyx for posterior caliceal punctures particularly in malrotated kidneys. The CT best demonstrates the axial anatomy of the renal pelvis and the calices and hence could be used to guide punctures more accurately, the limiting factor being cost and time [2, 3].

Studies reported in literature describing caliceal orientation are based on 3D-corrosion pyelogram casts and excretory urography [1]. Two studies have described the axial orientation of the calices [2, 3]. Kaye and Reinke, described the caliceal orientation and estimated the incidence of Brodel

and Hodson's type of kidneys. In their study, the Brodel's type (longer posterior calyx) was found to be more frequent on the right and Hodson's (longer anterior calyx) on the left. They also suggested the degree of on-table patient obliquity required to ensure an end-on posterior calyx. However, the caliceal angles estimated by them showed wide variation [4,6]. Limitations of their study were the lack of a prone subset which was subsequently evaluated by Sengupta et al, who described caliceal orientation in relation to change in position by subjecting the same patient subset to both prone and supine position. In their subset of patient's evaluated, there was no significant variation in the intrarenal anatomy [3]. The angle measuring techniques in both the former studies were cumbersome and not user friendly with regard to on-table application.

In the current study, a simple, user-friendly angle measuring technique was used to assess the Corporo-caliceal angle (Fig3a, 3b). This angle is derived from the previously described caliceal angle. The mathematical derivation of the same is depicted in Fig 3a. The supine and prone subsets were different and were randomly allocated. The contiguous 5 mm axial sections obtained clearly defined the caliceal anatomy for 60% of cases. Additional image manipulation features in the PACS and recent advances in CT can bring about better definition of caliceal anatomy. Results from this study give additional data in comparison to those reported earlier.

CONCLUSION

The Corporo-caliceal angle described in our study refers to the angle subtended by the posterior calyx to the frontal plane of the body. By evaluating this angle, the degree of patient obliquity required to ensure an end – on calyx can be inferred. Calices are seen to vary considerably in position, shape and number with only a few falling into the classical Brodel and Hodson's type [5]. Hence, generalization of the obliquity required to ensure an end-on calyx in the prone oblique position prior to the caliceal puncture may not be appropriate. In patient's with malrotated kidneys or in whom pre-procedure imaging has been performed, this angle can be measured and could be used to guide posterior caliceal punctures.

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