Correlation of CT scan versus plain radiography for measuring urinary stone dimensions

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Objectives: *To correlate the measured dimensions of urinary stones from spiral non-contrast computerized tomography (CT) with that of plain radiography (KUB).*
Methods: *The transverse diameter as reported on CT was compared to the measured transverse diameter on KUB for 61 stones. The transverse and craniocaudal dimensions on CT were then re-measured for 30 urinary stones and again compared to the re-measured values for KUB. The craniocaudal dimension on CT was determined by measuring the stone on reconstructed coronal CT images. Measurements between imaging modalities were blinded and performed consecutively by a dedicated investigator.*
Results: *The mean transverse size of the stones on the initial CT report was 6.0 mm +/- 2.8 mm versus 5.6 mm +/- 2.3 mm on KUB (paired t-test, p = 0.05, 95% CI difference between the means -1.3 to 0.5). The stones were categorized in transverse size ranges of 1.0 mm to 5.0 mm, > 5.0 mm to 10.0 mm, and > 10.0 mm. A total of 14 stones failed to be put into the same size categories by the two methods. The largest difference in measurements was 5 mm. In the second analysis, where the CT dimensions were re-measured, the mean transverse dimension on CT was 4.5 mm +/- 2.1 mm versus 4.7 mm +/- 2.0 mm on plain radiography (paired t-test, p = 0.06, 95% CI difference between the means - 0.02 to 0.6). Mean craniocaudal dimension of the stones on CT was 7.4 mm +/- 3.2 mm versus 6.0 mm +/- 2.7 mm on plain radiography (paired t-test, p = 0.0001, 95% CI between the means -2.0 to -0.9). When the stones were categorized in transverse size ranges of 1.0 mm to 5.0 mm, >5.0mm to 10.0mm, and >10.0mm, CT and KUB agreed for 30/30 stones.*
Conclusions: *In this study, the initially reported CT transverse values were found to be significantly different from measured KUB values; moreover, large differences of up to 5 mm were found between the measurements. With fastidious measurement of stone dimensions on both CT and KUB, we found that the transverse dimension of stones measured by the two imaging modalities were similar. The craniocaudal measurements of the stones were found to be significantly different on CT versus KUB, with CT measurement being 1.4 mm larger on average.*

Key Words: ureteral stones, measurement, imaging

Introduction

Much of the management of urinary calculi is affected by stone size and location.[1-4] Stone width is an important size variable as those stones greater than 5 mm or 6 mm are unlikely to pass spontaneously.[2,5] Smaller ureteral stones can be safely managed on an ambulatory basis[2] if it is the expectation that the stone will pass spontaneously within a few weeks.[1] Similarly, small renal stones can be followed conservatively, although roughly half will become symptomatic within 5 years.[4] The management of larger renal stones is often predicated on size with ESWL being reserved for stones less than 2 cm.[1,6,7] Lam et al determined staghorn surface area with computerized image analysis[6,7] and found this to be

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extremely valuable in making recommendations for treatment based on stone burden.

Since size is such an important parameter in determining the approach to treatment, the accurate measurement of stones with radiological imaging is crucial information for the urologist. The correlation of ureteric stone size with spontaneous passage has historically been based on plain radiography to evaluate size, but more recently helical CT measurements have been correlated to spontaneous stone passage as well.[1,4,8] There are several problematic issues in the available literature regarding stone measurement. One is lack of a standardized technique to measure stones on plain radiograph. A literature review by Coll et al[8] revealed that no standard has been used for past reports, and that size (with regard to ureteral orientation) has been measured parallel, perpendicular or obliquely.

In general, plain radiographs tend to overestimate stone size. Coll et al suggest that an error just below 10% is expected.[8] Others have shown that the majority of radiographic measurements are within +/- 25% of the true measurement.[9] Similarly, Narepalem et al[9] examined 58 stones >/= 3 mm from 39 patients. The CT craniocaudal measurements were based on collimation thickness, the reconstruction interval and the number of images in which the stone was seen. They found that CT overestimated the craniocaudal dimension by 0.8 mm on average, and that no significant difference existed between transverse measurements.

Based on this literature and our own experience with variation of stone sizing on reported imaging modalities, we wanted to review the correlation of urinary stone dimensions from spiral non-contrast CT with that of KUB.

Materials and methods

A retrospective chart review identified 46 patients with a total of 61 urinary calculi managed in a single centre. Patients were included in this review only if they had both non-contrast spiral CT (CT) and plain radiography (KUB) within a similar time period (within several weeks) and the urinary stones were clearly demonstrated on both modalities. Any stones that were felt by the investigators to have a radiolucent component were excluded. Stones that were originally identified as measuring less than 1 cm were included in this study as these stone measurements would be clinically relevant with respect to interventional management decisions regarding ureteral stones. Forty-three of the 46 CT images were obtained with 5 mm collimation, while three were obtained with 3 mm collimation. They were retrospectively evaluated by a designated investigator to confirm the presence of a urinary calculus. The reported stone dimensions from these CT images were subsequently correlated to the KUB image. All KUB craniocaudal and transverse dimensions were measured using calipers and a graded ruler. In addition to the actual stone measurements, the stones were categorized according to transverse size ranges of 1.0 mm to 5.0 mm, > 5.0 mm to 10.0 mm, and > 10.0 mm.

We next wanted to identify if there were variations in the reported measurements on the CT images and those from fastidiously re-measured CT images, and determine if this affected the correlation between CT and KUB measures. For this subsequent analysis between re-measured dimensions, 30 stones from 19 patients were randomly identified from the previous cohort. Measurements were obtained on a PACS monitor using electronic calipers and the craniocaudal dimensions were obtained on reconstructed coronal images by dedicated investigators. Transverse dimensions were obtained from reconstructed transverse images. This dimension was taken by measuring the transverse distance between parallel lines drawn antero-posteriorly from the medial and lateral aspects of the stone.

The means +/- standard deviation (SD) was calculated for transverse and craniocaudal dimensions measured on both KUB and CT. Subsequently, the difference between the means (DBM) +/- SD with 95% confidence limits was calculated for the transverse measurements and the craniocaudal measurements. The paired t-test was applied for each DBM to determine if a significant difference existed. Interobserver differences were calculated for transverse stone dimensions measured on plain radiography. For the second analysis comparing re-measured CT and KUB, a sample size calculation determined that 30 events were needed to achieve 90% power to detect a difference of 1.0 mm between the means with an estimated SD of 2.0 mm and with a significance level of 0.05 using a two-sided one-sample t-test. Data were analyzed using Statistical Analysis Software (SAS Institution Inc., Cary, NC, USA).

Results

The reported CT transverse measurements were compared to KUB transverse measurements for 61 stones from 46 patients. Transverse size ranges were 2.0 mm - 9.5 mm versus 2.0 mm - 9.3 mm for KUB versus CT respectively. Mean transverse size on CT

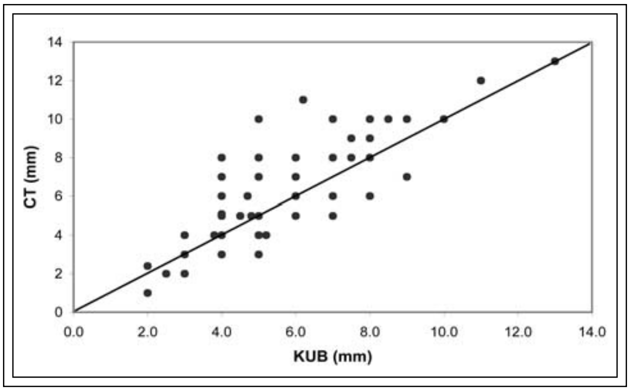

Figure 1. Reported transverse CT dimension versus measured KUB.

was 6.0 mm +/- 2.8 mm versus 5.6 mm +/- 2.3 mm on KUB, Figure 1, (paired t-test, p = 0.05, 95% CI difference between the means -1.3 to 0.5). The stones were further categorized in transverse size ranges of 1.0 mm to 5.0 mm, > 5.0 mm to 10.0 mm, and > 10.0 mm. A total of 14 stones failed to be put into the same size categories by the two methods. The largest difference in measurements was 5 mm.

In the second analysis of re-measured transverse and craniocaudal dimensions on CT and KUB, 30 stones from 19 patients previously identified were evaluated. Inter-observer error was found to not be significant between two investigators measuring dimensions on KUB. The transverse dimensions ranged from 2.0 mm to 9.5 mm, while the craniocaudal dimensions ranged from 2.3 mm to 11.8 mm on KUB. Mean transverse dimension of the stones plus or minus standard deviation on CT was 4.5 mm +/- 2.1 mm versus 4.7 mm +/- 2.0 mm on KUB, Figure 2, (paired t-test, p = 0.06, 95% CI difference between the means -0.02 to 0.6). Mean craniocaudal dimension of the stones on CT was 7.4 mm +/- 3.2 mm versus 6.0 mm +/- 2.7mm

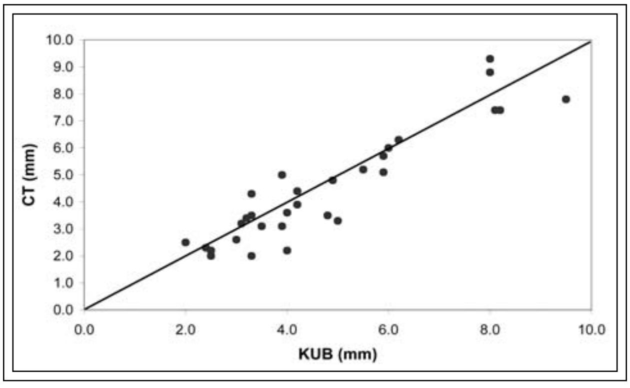

Figure 2. Transverse measurements: CT versus KUB.

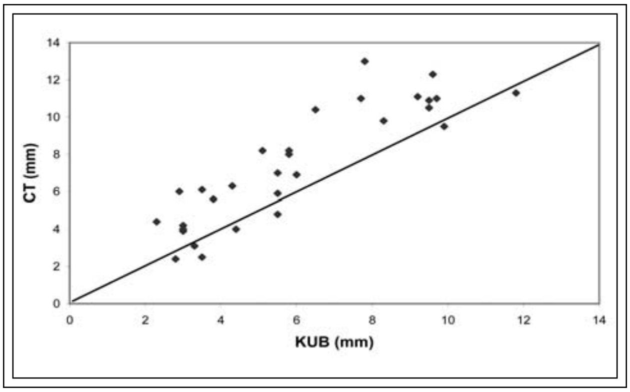

Figure 3. Craniocaudal CT versus KUB measurements.

on plain radiography, Figure 3, (paired t-test, p = 0.0001, 95% CI between the means -2.0 to -0.9). When the stones were categorized in transverse size ranges of 1.0 mm to 5.0 mm, > 5.0 mm to 10.0 mm, and > 10.0 mm, CT and KUB agreed for 30/30 stones.

Discussion

The results of this study suggest that with fastidious measurements of urinary stones, transverse dimensions on both CT and KUB are similar. The craniocaudal measurements of the stones, however, were found to be significantly different on CT versus KUB, with CT measurement being 1.4 mm larger on average. Furthermore, the originally reported CT transverse values were found to be significantly different from measured KUB values; moreover, large differences of up to 5 mm were found between these measurements.

There appears to be controversy in the literature regarding the correlation of size measurements between CT and KUB.[10,11] Dundee et al[11] recently reported that CT underestimates renal stone size by up to 12% compared to KUB; however, these stones included in this report were much larger (up to 46 mm) than our series and were measured only in one dimension introducing further sources of error other than image acquisition, including estimation of greatest diameter. Our series investigated those stones less than 10 mm, which were felt to be more clinically relevant in terms of spontaneous stone passage. Similar to our results, Narepalem[10] reported that CT overestimated craniocaudal dimension due to collimation length, reconstruction interval, and volume averaging. Smaller collimation and reconstruction interval would likely lead to more accurate measurements.

The +1.4 mm average difference that we found on CT for craniocaudal dimension could have been even larger if not due to "best guess estimation" of this dimension for several renal stones that had a "breathing artifact". Diaphragmatic movement of the kidney presumably creates this during the CT. Measurements in those cases did not include the entire opacity but would include roughly half of each of the less opaque pole extremities. This type of artifact may still have contributed to the higher CT measurement for the craniocaudal dimension.

It is possible that stone orientation could affect craniocaudal measurement. For instance, a stone that appeared perfectly centered vertically on an antero-posterior view could have its true longitudinal axis angled away from vertical in the antero-posterior axis. Our measurement methods on CT and KUB in this theoretical situation would have the craniocaudal dimension appear shorter on CT and KUB than the true dimension along the longitudinal axis of the stone. Perhaps three-dimensional reconstructed CT images with small collimation and reconstruction intervals could give a more accurate length value overall.

Our analysis of reported CT transverse dimension versus measured KUB transverse dimension found them to be statistically different, although the average difference of 0.4 mm is not likely to be clinically significant. However, significant outliers existed, with some reported CT measurements being up to 5 mm larger than KUB measurements. This also resulted in 14/61 stones being placed into different clinically relevant size categories, which had the potential to alter management strategies based on size. Recent reports of strategies to increase the spontaneous passage rate of ureteral stones may significantly change the management of some patients and we feel that results of this study underscore the importance of accurate reporting of stone measurements and should be taken into account in future reports of conservative management of ureteral stones.

Conclusions

A significant difference exists between non-contrast spiral CT and KUB in measuring the craniocaudal dimension of urinary calculi, when using 5 mm collimation cuts and measuring on reconstructed coronal images. A more accurate measurement of the craniocaudal dimension or length could perhaps be obtained from measurements from three-dimensional stone reconstruction done on CT imaging with a smaller collimation length. We found that no significant difference existed in the transverse dimensions of the stones between the two imaging modalities with fastidious measurements. Interobserver error of stone size found on CT reports may overestimate stone burden and possibly influence the management decisions for urinary calculi. □

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