Journal of Pediatric Urology (2017) **13**, 401.e1–401.e7

Simple visual review of pre- to post-operative renal ultrasound images predicts pyeloplasty success equally as well as geometric measurements: A blinded comparison with a gold standard

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Keywords
Hydronephrosis; Kidney; Ureteropelvic junction obstruction; Ultrasonography; Image analysis

Received 1 January 2017
Accepted 6 April 2017
Available online 28 April 2017

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Summary

Background
MAG3 diuretic renal scan remains the gold standard for determination of improvement in renal drainage following pyeloplasty for ureteropelvic junction obstruction. We hypothesized that (i) a change in geometric measurements between pre-operative and post-operative renal ultrasound (RUS) images and (ii) blinded simple visual review of images both would predict pyeloplasty success.

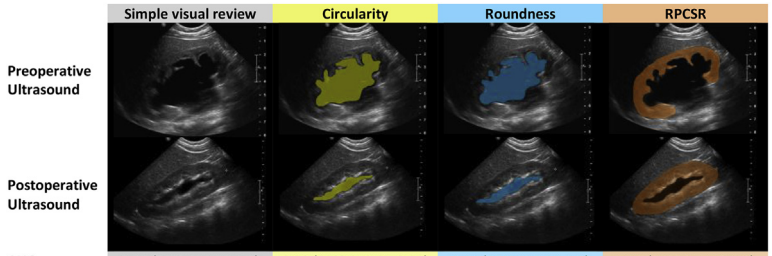
Objective
To determine if simple visual review and/or novel geometric measurement of renal ultrasounds can detect pyeloplasty failure.

Study design
This study was a retrospective, blinded comparison with a gold standard. Included were children aged ≤18 years undergoing pyeloplasty at our institution from 2009 to 2015. For each kidney, representative pre-operative and post-operative RUS images were chosen. Our standard for pyeloplasty success was improved drainage curve on MAG3 and lack of additional surgery. Measurements for collecting system circularity, roundness, and renal parenchymal to collecting system area ratio (RPCSR) were obtained by three raters (Figure), who were blinded to the outcome of the pyeloplasty. Changes in geometric measurements were analyzed as a diagnostic test for MAG3-defined pyeloplasty success using ROC curve analysis. In addition, six reviewers blinded to pyeloplasty success reviewed pre-operative and post-operative images visually for improved hydronephrosis and categorized pyeloplasty as success or failure based on simple visual review of RUS.

Results
Fifty-three repaired renal units were identified (50 children). There were five pyeloplasty failures, four of which underwent revision or nephrectomy. While all geometric measurements could discriminate pyeloplasty failure and success, the geometric measurements that discriminated best between pyeloplasty failure and success were change in collecting system roundness and change in RPCSR. Consensus opinion among six blinded reviewers using simple visual review had a sensitivity of 94% and PPV of 100% with respect to identifying pyeloplasty success (AUC 0.97 (95% CI 0.93–1.0)). This was not significantly different from AUC for change in roundness ($p = 0.09$) or change in RPCSR ($p = 0.1$).

Discussion
Change in collecting system roundness and change in RPCSR were the most accurate geometric measurements in predicting pyeloplasty success. Simple visual review of ultrasound images for pyeloplasty success performed as well or better than geometric measurements. However, geometric measurements remain useful as a research tool or to communicate findings between clinicians.

Conclusions
Complex geometric measurements of hydronephrosis or post-operative MAG3 scans are not needed if hydronephrosis is visually significantly improved, as simple visual review is highly sensitive for detecting pyeloplasty failure.



	Simple visual review	Circularity	Roundness	RPCSR
AUC	0.97 (95% CI 0.93-1.0)	0.80 (95% CI 0.67-0.92)	0.94 (95% CI 0.85-1.0)	0.93 (95% CI 0.86-1.0)
Cutoff	-	Decrease ≥ 0.05	Decrease ≥ 0.13	Increase ≥ 0.48
Sensitivity	94%	69%	81%	90%
PPV	100%	100%	100%	100%

Comparison of performance to detect pyeloplasty success between simple visual review and geometric analysis modalities, including (i) circularity, (ii) roundness and (iii) RPCSR.

Figure Test performance to determine pyeloplasty success.

http://dx.doi.org/10.1016/j.jpurol.2017.04.005

Introduction

Renal ultrasound (RUS) is the most commonly used imaging study in pediatric urological practice for diagnosis of hydronephrosis [1]. Yet, given the limits of current technology, RUS has not yet subsumed the role of gold standard functional nuclear imaging such as technetium mercaptoacetyltriglycine excretory renography (MAG3) [2]. Objective metrics on RUS which reliably correlate to MAG3 parameters have not been clearly defined. Hydronephrosis because of ureteropelvic junction obstruction (UPJO) is a typical indication for RUS, and in this setting an accurate measurement of renal function is critical; yet, MAG3 has significant associated costs, and is not available as a point-of-care test.

Currently, several hydronephrosis classifications exist, including the Society for Fetal Urology (SFU) grade [3], and the hydronephrosis severity index (HI) [4,5]. The multidisciplinary consensus on urinary tract dilation (UTD) [6], originally intended as a predictive nomogram for perinatal hydronephrosis, is now widely used as a descriptive classification. However, there is substantive disagreement as to how these measurements should be interpreted in clinical practice [7,8]. Although UTD was put forth to address these challenges, it too requires a subjective interpretation of RUS images [9]. Other investigators have described additional methods, including the PHAR score [10,11], and PI-APD measurement [12], which herald a shift toward objective interpretation of RUS based on image geometry. Cerrolaza [2] developed techniques for interpretation of two-dimensional ultrasound using machine learning, which could predict MAG3 outcomes with high reliability. However, this requires specialized resources unlikely to be unavailable to the practicing urologist.

For quantitative measurements of RUS to be useful to a practicing urologist they should be easy to obtain, objective, and simple to interpret. Significant improvement in hydronephrosis after pyeloplasty leads to the collecting system appearing decompressed and less round-appearing. RPCSR is the ratio of renal parenchymal area to collecting system area (Fig. 1). An increase in RPCSR would correspond to a decrease in hydronephrosis. The circularity and roundness of two-dimensional shapes can be mathematically defined (Fig. 2). Circularity is $4\pi^*(\text{area}/\text{perimeter}^2)$ and roundness is $(4^*\text{area})/(\pi^*(\text{major axis})^2)$. Circularity is a function of the perimeter length of the bounded shape, whereas roundness is a "best-fit" to an idealized ellipse along the major axis, meaning roundness is relatively insensitive to small changes in perimeter length compared with circularity. Circularity and roundness of an object range from 0 to 1. A perfect circle has both circularity and roundness of 1. We hypothesized that the change in collecting system circularity, collecting system roundness, and RPCSR based on RUS could predict pyeloplasty success. Because these measurements quantify a visual improvement in hydronephrosis, we also hypothesized that simple visual assessment of hydronephrosis following pyeloplasty can predict pyeloplasty success. To test our hypotheses, we performed a blinded comparison of change in collecting system circularity and roundness, change in RPCSR, and

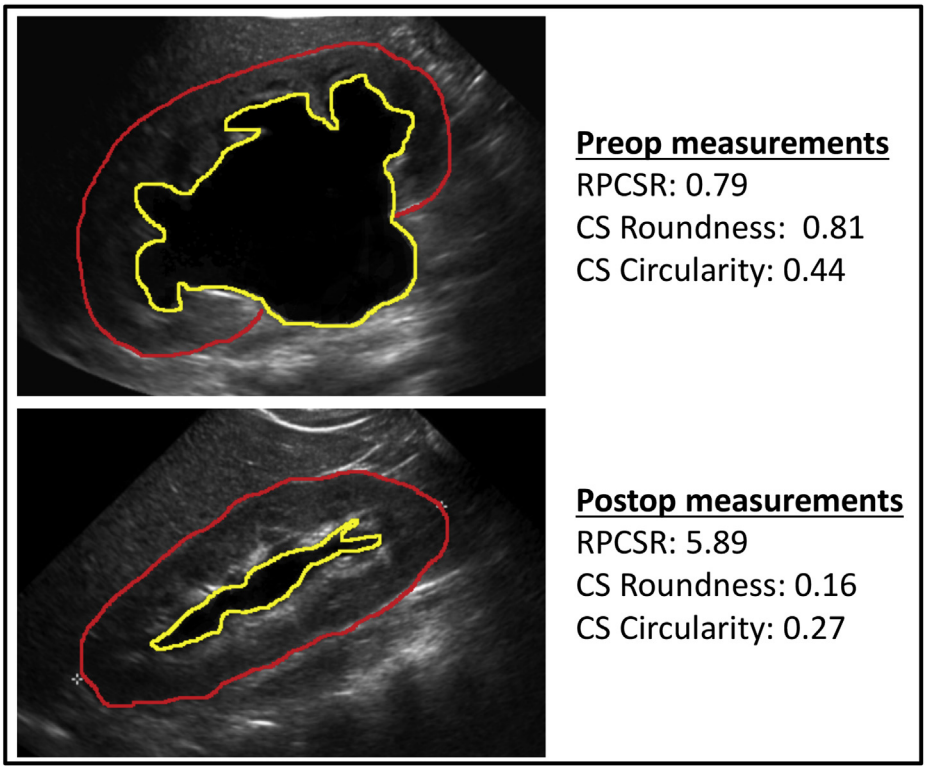


Figure 1 Imaging. Ultrasound of a single kidney undergoing successful pyeloplasty with improved post-operative MAG3 drainage curve. Pre-operative (1.) and post-operative (2.) images are depicted. Total renal area and renal collecting system area highlighted in software. Image demarcations are used as inputs to calculate RPCSR, circularity, and roundness.