DTI AND TRACTOGRAPHY OF THE KIDNEY IN CHILDREN: FEASIBILITY AND CORRELATION WITH FUNCTIONAL MR UROGRAPHY

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Introduction: Indicators of both the structure and function of the pediatric kidney are necessary to differentiate pelvicalyceal dilatations requiring surgery from cases that do not. MR urography (MRU) incorporating contrast-enhanced dynamic imaging provides morphologic and functional information in the pediatric kidney [1]. However, MRU is often not sufficient to choose a treatment plan because it does not provide information on the microstructure or architecture of dilated renal tissue. DTI has previously been utilized to examine kidney structure [2]. This study evaluates the feasibility of DTI assessment of normal and abnormal pediatric kidney structure and determines the correlation of these structural DTI parameters with functional MRU.

Methods: Nine children (6 boys, 3 girls) with a mean age of 4.3 years (range 0.5-14.8 years) were prospectively enrolled. All subjects were scanned at 3.0 T (Trio or Verio, Siemens) and DTI was acquired with an echo-planar sequence, TR/TE=2300/69msec, b=300 s/mm^2, 12 non-collinear gradient directions, 3.1x3.1mm in the coronal plane, 3mm slice thickness, parallel acceleration of 2, and 3 signal averages. Respiratory triggering was used and DTI acquisition ranged from 4 to 7 minutes. Fiber tracking was performed using a deterministic streamline tracking algorithm (trackvis.org) with a fractional anisotropy (FA) threshold of 0.1 and an angle threshold of 55°. Tractography was launched from a region of interest (ROI) placed within the entire renal parenchyma. Diffusion metrics were measured in regions of interest drawn in the medulla and cortex. For analysis, the left and right kidneys as well as each moiety of a duplicated kidney were considered as separate units. All subjects had contrast-enhanced functional MRU (fMRU) and results were used to classify the kidneys as normal or abnormal (presence of dilatation or abnormal function). The fMRU incorporates pre-contrast series including a 3D-T2 weighted sequence and a post-contrast coronal T1-weighted dynamic sequence. The functional analysis is performed using the custom-made freeware "chop-fmru" which segments the contrasted part of the renal parenchyma [1].

Results: A total of 19 renal units (kidneys/moieties) were analyzed with 13 normal and 6 abnormal units. One subject had unilateral renal agenesis and two subjects had unilateral duplications. In abnormal moieties there was insufficient corticomedullary differentiation to place separate ROIs. Fiber tracking of normal renal units showed numerous tracts with a radial arrangement and convergence into pyramids. Abnormal ones did not show these features and had tracts that were loosely arranged and left hollow spaces (Figure 1). Fiber track volume correlated with MRU parenchymal volume (normal: r^2=0.93, p<0.01; abnormal: r^2=0.93, p<0.05, Figure 2). Subject age also correlated with the fiber track volume (normal: r^2=0.96, p<0.01; abnormal: r^2=0.8, p<0.01). In normal kidneys/moieties, the medulla had higher FA (0.401 +/-0.05) than the cortex (0.183 +/- 0.03) (p<0.01). FA in these regions did not significantly change with age (cortex: r^2= 0.037, p>0.1; medulla: r^2= 0.018, p>0.1). There were no observed differences in ADC between the cortex and medulla (p>0.05). We observed a trend of increasing ADC with age in the cortex and medulla (cortex: r^2=0.21, p>0.1; medulla: r^2=0.135, p>0.1).

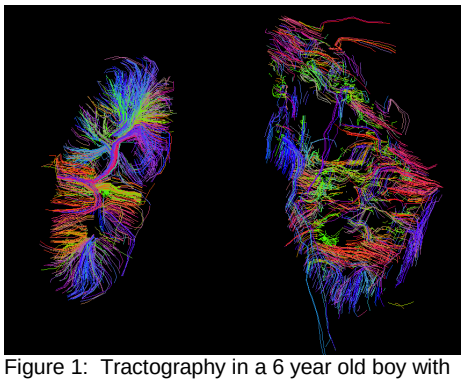

Figure 1: Tractography in a 6 year old boy with an unobstructed (left) and obstructed (right) kidney. Hollow spaces correlate with location of dilated collecting system. Superior-inferior trajectories are blue, left-right are red, and anterior-posterior are green.

Discussion/Conclusions:

Renal DTI with tractography is feasible in children and may be combined with MRU. DTI and tractography metrics were observed to correlate with parenchyma region and kidney function, suggesting the potential use of tractography as a clinical tool. Parenchymal tractography volumes were always greater than those obtained from MRU. MRU can underestimate parenchymal volume if passage of contrast is reduced. DTI can detect parenchyma without the passage of contrast agent, but is susceptible to overestimating parenchymal volume because of poor resolution and spurious trajectories. DTI and tractography provide additional information on tissue microstructure and architecture that is not demonstrated on conventional MRI or MRU.

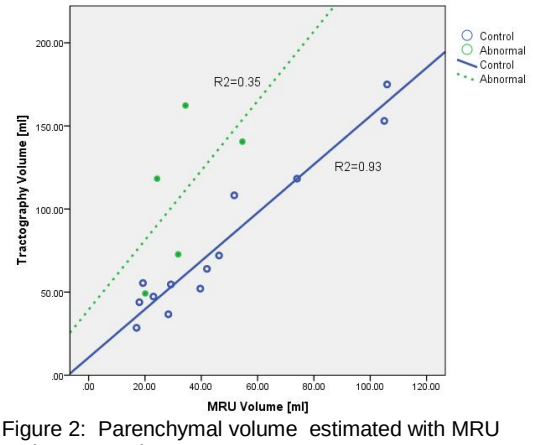

Figure 2: Parenchymal volume estimated with MRU and tractography.

References:

1) Khrichenko D, et al. Functional analysis in MR urography - made simple. Pediatr Radiol 40:182-199. 2010.

2) Notohamiprodjo M, et. al. Diffusion tensor imaging (DTI) of the kidney at 3 tesla-feasibility, protocol evaluation and comparison to 1.5 Tesla. Invest Radiol 45:245-254. 2010.