Quantification of Renal Volume and length in Normal Subjects by Magnetic Resonance Imaging

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Introduction: There is limited information in the literature regarding renal dimensions, such as kidney length and volume obtained by MRI.[1] In routine clinical practice, the bean shaped kidney is approximated by an ellipsoid to compute the renal volume. The ellipsoid formula uses the dimensions of the principal axes of the kidney measured using US (*Volume = π/6 x (length x width x thickness)*.[2-3] However, tomographic imaging can estimate renal volumes directly without such an approximation. The purpose of this study is two-fold. Firstly, to evaluate the accuracy of the ellipsoid approximation of the kidney using an excised porcine kidney model, and secondly, to report the reference values for kidney lengths and volumes in patients without intrinsic kidney disease using MRI.

Methods: *Phantom Study:* A freshly excised porcine kidney was imaged using a T_1 weighted gradient echo sequence at 1.5 T. A quadrature head coil was used for signal reception. The specific acquisition parameters were as follows: repetition time (msec)/echo time (msec), 315/6.3; flip angle, 80°; sensitivity encoding factor of 2. The contribution of partial volume effect to the kidney volume was studied by imaging the kidney at increasingly finer spatial resolutions: ***A***: 1.6 x 2.7 x7 mm^3; ***B***: 2 x 2 x 4 mm^3; ***C***: 2 x 2 x 2 mm^3; and ***D***: 1 x 1 x 1 mm^3. To study the effect of the double oblique orientation of the kidney within the human body on the volumetric measurements, the imaging plane was rotated about the right-to-left axis, as well as the anterior-posterior axis, from 0^o to 40^o at 10^o increments. This resulted in a total of 36 imaging volumes of the kidney (4 methods, 9 angulations). The porcine kidney volume was also obtained by using the water displacement method.
Human Study: In the human study, 130 patients (60 men) with no history of intrinsic renal disease were identified retrospectively from the MR database who have undergone MRI / MR angiography of the abdomen. The acquisition parameters are identical as the phantom study with spatial resolution of 1.6 x 2.7 x 7 mm^3. All patients were imaged using a 4-channel phased-array coil for signal reception. All the data was transferred and analyzed in a remote workstation. An expert observer drew contours that circumscribed the kidney, but excluded the renal pelvis and renal vasculature. From these contours, the renal volume was computed by the disc summation method. The renal length was measured by aligning the kidneys in their long-axis by multi-planar reformation. Twenty patients were also selected randomly from the study group and their renal volume was re-calculated using the ellipsoid formula used by US (*Volume = π/6 x (length x width x thickness)*.

Results: The renal volume result from the phantom study is shown in Figure 1. MRI underestimates the volume by 4-5% when compared to water displacement method, whereas the ellipsoid formula underestimated the kidney volume by 21%. In the 20 patients, the ellipsoid formula consistently underestimated the kidney volume by 17-20%, compared to the volumes obtained by the disc summation method (157 ± 34 cc *vs.* 178 ± 32 cc for the right kidneys, $p < 0.05$; 158 ± 36 cc *vs.* 180 ± 31 cc for the left kidneys, $p < 0.05$) [Figure 2]. Different spatial resolutions do not appear to have an appreciable effect on the mean kidney volume measured. As expected, the highest spatial resolution scan (D) has the smallest standard deviation, suggesting that it is not affected by orientation of the kidney within the imaging volume. The kidney cranio-caudal length as well as the kidney volume obtained in this MRI study *(volume*: 203 ± 38 cc for male and 155 ± 31 cc for female; *length*: 12.4 ± 1 for female and 11.6 ± 1 cm for female) are considerably higher than the reference values commonly quoted from US (*length*: 10 to 12 cm; and *volume*: 90 to 190 cc).

Conclusion

In summary, our *ex-vivo*, and *in-vivo* results suggest that kidney volumes are underestimated by the ellipsoid approximation. MRI estimation of kidney volume does not require any geometric assumptions, and our *ex-vivo* data closely approximates that obtained by water displacement method. In addition, neither different spatial resolutions used in this study nor the orientation of the kidney with respect to the imaging volume affects the estimation of renal volume significantly. This suggests the MRI techniques routinely employed in clinical practice are adequate for the estimation of kidney volumes. The mean kidney length and volumes estimated using MRI in 130 patients with no intrinsic kidney disease are greater than the hitherto reported reference values obtained using US.

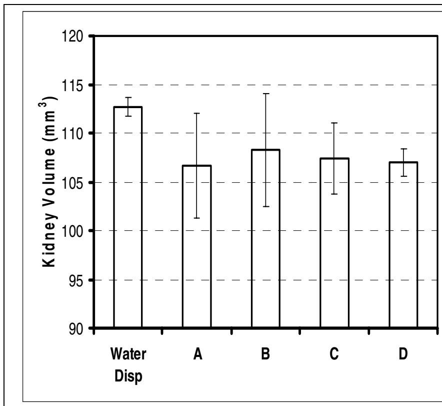

Figure 1: Renal volume of ex-vivo kidney imaged at four spatial resolutions (A-D), and the water displacement method.

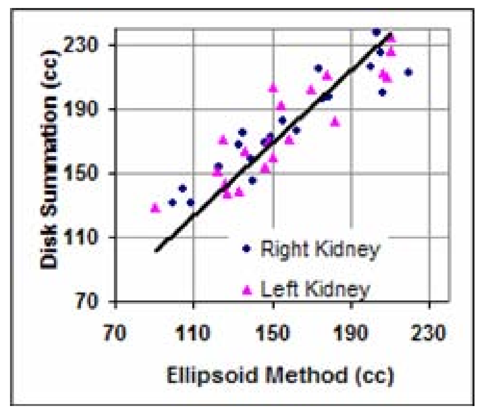

Figure 2: Comparison of methods for computing renal volumes. (n = 20)

References

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