HEMODYNAMIC EFFECTS OF FUROSEMIDE ON RENAL PERFUSION AS EVALUATED BY NONINVASIVE ASL-MRI

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Introduction

Furosemide, a powerful diuretic acting on the thick ascending limb of the loop of Henle to promote the renal excretion of both water and solutes from the body, is commonly used in patients with congestive heart failure and edema, or in some patients with oliguric acute renal failure (ARF) (1, 2). The existed studies on the renal hemodynamic effect of furosemide, mostly performed in anesthetized animals or by invasive facilities, are conflicting and difficult to reconcile (3, 4). In this study, we aimed to monitor the renal perfusion in response to the furosemide administration in healthy young human subjects by using noninvasive ASL technique (5). This MR technique was hypothesized to be sensitive to changes in renal hemodynamics following loop diuretics injection.

Materials and Methods

Total eleven healthy young human subjects (6 men, 5 women, 22-39 years) participated in this study. Experiments were conducted on a 3T GE MR scanner with a commercial TORSOPA coil. With regard to RBF measurement, the FAIR-ASL was combined with a single-shot fast spin-echo (SSFSE) sequence. An single oblique coronal plane through the center of both kidneys was determined with the following imaging parameters: TR= 3500ms, flip angle = 90 degrees, 5mm slice thickness, an inversion slice thickness of 20 mm , an inversion time (TI) of 1500ms. The subjects were trained to hold breath during examination (20-30s) to avoid motion artifacts. Twenty milligrams of furosemide were injected intravenously. Post-furosemide FAIR-ASL images were acquired following administration to measure the hemodynamic responses. The T1 values for the cortex, the medulla and the global kidney were set at 1142ms, 1545ms and 1194ms (6). The quantitative RBF maps were calculated by using an established equation on Matlab. Pixels with high perfusion of more than 600 ml/100g/min in the cortex or more than 250 ml/100g/min in medulla were excluded. ROI RBF was measured using 80-100 mm^2 area in the kidney of cortex and medulla (fig. 1). To determine the differences and changes of RBF between the cortex and medulla for pre and post administration of furosemide, a two-tailed paired t test was used.

Results

The ASL images used for RBF evaluation revealed enough spatial information of the kidney, in which renal cortex and medulla were easily recognized. Fig. 2 revealed a representative baseline ASL image obtained in a single subject at 3T. The baseline RBF were estimated as 386.04±76.67 ml/100g/min in renal cortex, 96.47±23.97 ml/100g/min in medulla and 248.66±51.75 ml/100g/min for the whole kidney (P<0.00). No statistically significant difference of RBF was found between male and female subjects or between the right and left kidneys (P>0.05). Post-injection ASL scans showed the cortical RBF in the total subjects increased from 386.04±76.67 to 412.06 ± 90.28 ml/100g/min (P=0.15). The medullar RBF in the total subjects decreased from 96.47 ± 23.97 ml/100g/min at baseline to 84.47 ± 24.40 ml/100g/min (P=0.01). For the global kidney, the RBF in the total subjects was changed from 248.66±51.75 to 252.08 ± 47.55 ml/100g/min (P=0.74). The mean and inter-subject RBF deviation pre and post furosemide administration were shown in fig. 3-5. It revealed that furosemide increased cortical RBF with a range of 2.57-53.24% in six subjects (3 males, 3 females), while decreased cortical RBF with a range of 2.69 -15.89% in the other five subjects. Medullar RBF was decreased by 7.48-30.40% in nine subjects (4 males, 5 females), while increased by 12.51-14.40% in two male subjects.

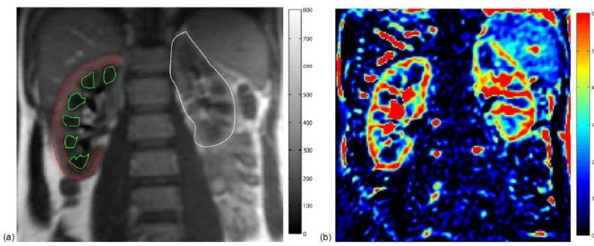

Figure 1: Illustration of ROI selection. (a) section-selective image providing an excellent tissue contrast between the cortex and medulla, where the ROI of the cortex (red line), medulla (green line) and global kidney (white line) were drawn respectively. (b) The obtained RBF map.

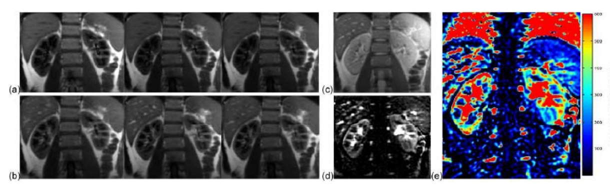

Figure 2: representative renal ASL images obtained in a single volunteer (a) three magnitude images with global inversion and, (b) corresponding magnitude images with section-selective inversion; (c) one of M0 images in the same coronal section; (d) delta M map from the averaged magnitude images and, (e) corresponding RBF map cover the entire length of the kidney.

Discussion and Conclusion

In recent years, it revealed an appreciable progress in ASL-MRI of the kidneys (7). But to our knowledge, it is rare to evaluate renal perfusion under the treatment of loop diuretics by this noninvasive technique. According to an in vivo study in eleven young volunteers, we reveal that it is feasible to monitor the hemodynamics effects of a loop diuretic, furosemide on the human renal function based on a sequential FAIR-ASL. Furosemide administration is associated with a prominent decrease in the medullar blood perfusion, but its hemodynamic effects on the kidney of cortex need further reevaluation. In conclusion, our present study using ASL technique serves a noninvasive way for the renal functional estimate. Combined with in-vivo human study, double-sided effects of furosemide on the renal hemodynamics were investigated.

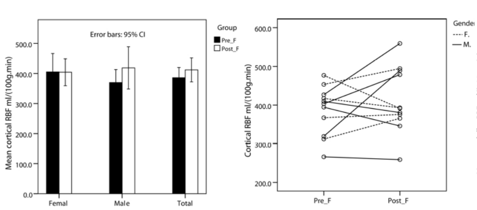

Figure 3: the mean and individual cortical RBF pre- and post-furosemide administration.

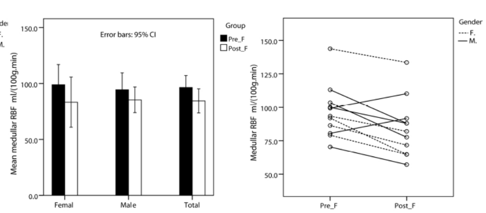

Figure 4: the mean and individual medullar RBF pre- and post-furosemide administration.

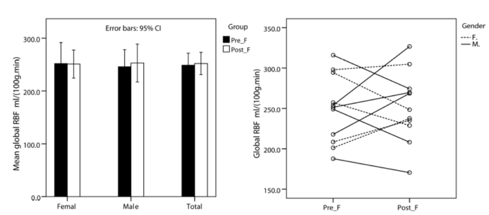

Figure 5: the mean and individual global RBF pre- and post-furosemide administration.

References

1. Ho KM, et al. Anaesthesia 2010;65:283-293. 2. New Engl J Med 1994;331:1416-1420. 3. Gerber JG, et al. Kidney Int 1980;18:454-459. 4. Dobrowolski L, et al. Exp Physiol 2000;85:783-789. 5. Roberts DA, et al. Radiology 1995;196:281-286. 6. de Bazelaire CMJ, et al. Radiology 2004;230:652-659. 7. Robson PM, et al. Magnet Reson Med 2009;61:1374-1387.