Feasibility and Repeatability of Human Brown Adipose Tissue Volume and Perfusion Activity Using MRI

Weiying Dai[1], Lauren S. Weiner[2], David C. Alsop[1], and Aaron M. Cypess[2]

[1]*Radiology, Beth Israel Deaconess Medical Center & Harvard Medical School, Boston, MA, United States,* [2]*2Section of Integrative Physiology and Metabolism, Joslin Diabetes Center, Boston, MA, United States*

Introduction: Brown adipose tissue (BAT), also known as brown fat, consumes fat calories by generating heat in response to cold expenditure and may be a new and effective tool to help treat obesity and metabolic dysfunction. The volume and activity of BAT have been measured using a combination of ^{18}F-FDG PET and CT (1, 2). FDG PET/CT uses ionizing radiation and may not detect all of the BAT (2) since it only shows the activated tissue that is avidly involved in glucose uptake. MR imaging is thus appealing because it has the potential to distinguish BAT and white adipose tissue (WAT) based on two independent, physiologic factors: BAT has a higher water-to-fat ratio than WAT, and BAT has a higher density of mitochondria to blood vessels. In this study, we demonstrated the feasibility and repeatability of using MR water/fat imaging and perfusion MRI to assess BAT volume and BAT responses to mild cold stimulation in the cervical areas of adult humans.

Methods: 10 healthy lean young subjects (30.3 ± 4.6 years old) were scanned on a GE 3 Tesla scanner. Each subject was scanned on three study days: one study day was temperature neutral day (room temperature approximately 23ºC) to examine BAT mass and activity without environmental stimulation. On two study days, the subject wore cooling vests set to 57-61ºF (room temperature approximately 19-20ºC) to stimulate BAT. Magnetic resonance images were started approximately 75 minutes after initial exposure to cold/neutral temperature. Each scan followed the same protocol. After acquiring localizer images, 3D multislice fast spin echo IDEAL(3) fat/water images (FOV:40cm, matrix size:350×350, slice thickness: 2mm, flip angle:5^0) were acquired to cover spinal locations from C7 to T3 using the Dixon method (4). After the Dixon method, single-slice perfusion images in a 2cm slab were acquired using single shot fast spin echo (SSFSE). The perfusion imaging slice (FOV: 40cm, matrix size: 128×128, slice thickness: 2mm) was centered on the slice location with maximum fat volume in the cervical areas based on the Dixon method. Pseudo-continuous arterial spin labeling (PCASL) (5) was used for perfusion labeling (labeling duration: 1.5s, post-labeling delay:1.5s). Two labeling locations were used: immediately below the aortic arch, and between aortic root and arch. Vessel suppression by gradient dephasing was applied along the inferior-posterior direction.

Water-to-fat ratio image was calculated from the water and fat images. The ratio image was first thresholded between 10% to 50% and then masked with the fat image to assess the BAT mass. Despite similar coverage relative to the spine, the BAT coverage may vary across scan days depending on whether the shoulders were relaxed or tilted. For each subject, we chose the day of scan where the shoulders were most symmetrically positioned as the reference day, and registered the other two Dixon water images to it and transformed the water-to-fat ratio images accordingly. The BAT mass was measured for all 3 days of each subject in the 2cm slab where perfusion was measured on the reference day.

Results & Discussion: Example BAT volume segmentations are shown in fig 1a-c. The BAT volume within the 2cm-thick volume was 14.88 ± 6.94mL averaged across the subjects. The measurement error or repeatability (within-subject standard deviation) was 2.04mL, which may have been due in part to changes in BAT volume over the duration of each subject's 3 studies (mean 30.1 ± 7.1 d). We observed increased perfusion activity of 86% ± 32% with the BAT for the two cold days compared with the thermoneutral day (Fig. 1d, 1e and 1f) for four of the subjects. The averaged perfusion on the BAT are 9.76 ± 1.86 ml/100g.min and 5.15 ± 0.66 ml/100g.min (6) for the cold day and neutral day respectively. However, for the other six subjects, the perfusion images on the BAT areas were heavily contaminated with large vessels and therefore the perfusion values within the BAT were not reliable. An example is shown in Fig. 2. The bright signals are located either on or adjacent to the vessels. Without suppressing the nearby vessel signals of the BAT, we cannot reliably assess the perfusion activity within the BAT areas. This indicates that suppressing the vessels along the anterior-posterior direction is a prerequisite for measuring the BAT perfusion accurately.

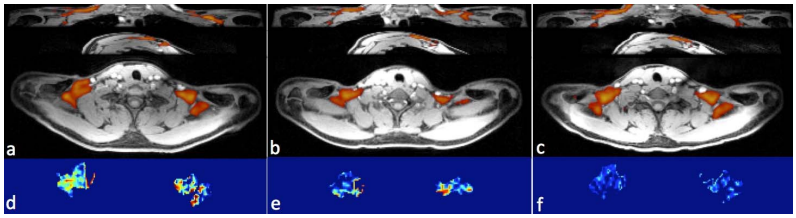

Fig. 1 The orthogonal (Coronal, Sagittal and Axial) views of water-to-fat ratio images overlaid on the water image using the Dixon method and the perfusion images centered on the axial slice using the PCASL method on the (a)(d) cold day 1, (b)(e) cold day 2 and (c)(f) neutral day. The BAT volumes are similar on three study days. The perfusion images on the cold days showed increased signal compared to the neutral day.

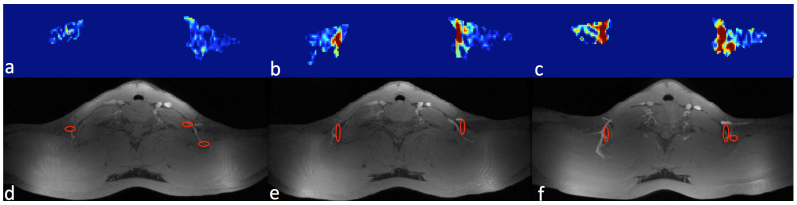

Fig. 2 The perfusion images of a subject obtained on the (a) cold day 1, (b) cold day 2 and (c) thermoneutral day. Maximum signal intensity projection images from the Dixon water images (d)(e)(f) are shown to visualize the large vessels on the perfusion slice corresponding to (a)(b)(c). Red ovals are used to mark the corresponding locations for bright signals in the perfusion images. Clearly, the bright signals on the perfusion images are either on or adjacent to the vessels.

Conclusions: The Dixon method can provide a quantitative measurement of the BAT mass in the cervical areas. ASL shows great promise for measuring perfusion activity within the BAT and can be successful if the vessel signals near the BAT are well suppressed.

References: 1. Ouellet et al, J Clin Invest 2012;122:545-552. 2. Cypess et al, Proc Natl Acad Sci USA. 2012; 109(25): 10001–10005. 3. Reeder SB, et al. Magn Reson Med. 2005 54:636-44. 4. Dixon et al, Radiology 1984; 153:189-194. 5. Dai et al, Magn Reson Med 2008;60(6):1488-97. 6. Hamilton et al, Journal of Magn Reson Imaging 2011;34: 468-473.