

A Semi-empirical Predictor for Visceral Fat Fraction from 3D Dual Echo Dixon Technique

K. B. Krishnan¹, U. Patil¹, R. Mullick¹, and P. Hervo²

¹Imaging Technologies Lab, GE Global Research, Bangalore, Karnataka, India, ²GE Healthcare, Buc, France

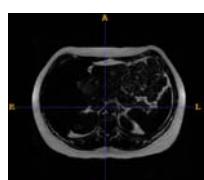
Introduction: Central obesity with high abdominal visceral fat is known to be an indicator of metabolic syndrome [1]. A multi-echo acquisition with 2-point Dixon reconstruction with decomposition of aqua/lipid (MEDAL) simultaneously provides a set of four images per slices – in-phase, out-phase, fat-only and water-only images [2]. A threshold based on MEDAL acquisition parameters applied to fat-only images can be used to evaluate visceral fat present within the peritoneal cavity to within a fraction of 0.1 of a manually assisted method in which visceral mask drawn on water-only image is used to demarcate the visceral region in the fat-only image [3]. In this study, we demonstrate that the application of the threshold to an anatomical region ranging from T12 to iliac crest corresponding to the lower end of the L4 vertebral body permits a simple correction term to be used as a predictor to automatically assess the visceral fat fraction (VFF).

Methods: In a retrospective study, we apply the threshold [3] to a representative set of N=7 fat-only datasets from a study in which patients were imaged on a 1.5T whole body scanner (Signa HDX, GE Healthcare, Waukesha, WI) with MEDAL (TR = 7 ms, TE=4.8 ms, flip angle = 12 deg) [4] in an anatomical region ranging from T12 vertebral body to the iliac crest corresponding to the lower end of the L4 vertebral body chosen by an experienced radiologist. Selection of T12 as upper limit excludes the lungs. Inclusion of the lung bases could tend to reduce the visceral-parietal fat fraction. In the subjects, where the lung bases are seen at T12 level, L1 vertebral level is used as the upper limit. Selection of the region from T12 to Iliac crest permits linear reproducibility in the same subject and comparable evaluation across different subjects. The threshold provides both the total count of fat pixels (TF) and the number of parietal or subcutaneous fat (SF) pixels; the difference being a measure of visceral fat (VF). In an alternate approach, the radiologist manually delineates the visceral mask on the corresponding water-only image slices [5] using ITK-Snap [6]. We place these masks on the thresholded fat-only images to demarcate the visceral region. The pixel count inside the mask gives an independent measure of VF. Visceral Fat Fraction (VFF) is defined as VF/TF.

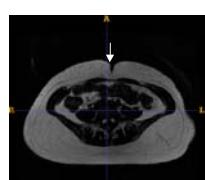
We assume that the manually delineated visceral mask is a true depiction of the anatomical site and calculate the difference in VFF between the two methods as: VFF (manual) – VFF (automatic) as ‘error’. Since the automated algorithm includes the fat in the parietal wall muscle plane in the VF computation [3], it always provides a higher VFF and the ‘error’ is always negative. An Anderson-Darling normality test [7] with 95% confidence level performed on the error is found to be normal (p-value = 0.06). We perform a more stringent test of normality by removing one data point at a time and find that except for one dataset that gives an error value close to a pivot point (close to the mean error), the error distribution remains normal for a sample size of N=6 also. The normality of the error distribution verifies the representative nature of the datasets and the relevance of the chosen anatomical volume. It also allows the proposition of a simple estimate for VFF based on the mean and standard deviation of the error values. Based on these values evaluated for N=7, we propose the existence of a predictor given by: VFF (estimated) = VFF (automatic) – (0.046 ± 0.02). In a prospective study, we then apply the predictor to calculate VFF for N=3 fat-only MEDAL datasets from the same study [4].

Results: Application of the VFF predictor provides most likely estimates within $\pm 10\%$ of the visceral fat computed from manually drawn visceral mask in the three prospective cases. Estimates with bounds that are derived from the standard deviation of the error distribution for all datasets overlap with 5% margin from the manually assisted method. Automatically computed VF/SF values from our algorithm are 0.26, 0.20 and 0.53 and lie within the range of VF/SF ratios reported in literature [8].

Conclusions: We have proposed a novel acquisition and anatomy based VFF predictor that could be useful in (i) the assessment of response to therapeutic measures in treatment of obesity (ii) obesity research by rapid evaluation of patterns of fat accumulation in community studies.



(a)



(b)



(c)

Fig. 1 (a) Axial slice at T12 (b) Axial slice at L4 (c) Sagittal view showing umbilicus

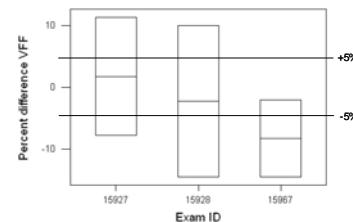


Fig. 2 VFF estimates with bounds

References: [1] S. Klein, J Clin Invest. 113(11): 1530–1532, 2004. [2] J. Ma, MRM 52: 415-419, 2004. [3] K.B. Krishnan et al. Proc. Intl. Soc. Mag. Reson. Med. 1516, 2008. [4] R. Low et al. Proc. Intl. Soc. Mag. Reson. Med. 726, 2007. [5] K. Miller et al, The Lancet 351: 871-875, 1998. [6] ITK-Snap Version 1.6.0.1 www.itksnap.org [7] Minitab Release 12 for Microsoft Windows [8] T. Gomi et al. Rad. Med. 23(8): 584 – 587, 2005.