Improvement of positive contrast dUTE using susceptibility-weighted phase image information applied to iron-labelled cells

Lindsey A Crowe[1], Sophie Borot[2], Sonia Nielles-Vallespin[3], Christian Toso[2], Domenico Bosco[2], Thierry Berney[2], and Jean-Paul Vallée[1]

[1]Faculty of Medicine/Department of Radiology, University of Geneva, Geneva, Switzerland, [2]Islet Isolation and Transplantation Center, Visceral Surgery Department, Geneva University Hospital, Geneva, Switzerland, [3]Royal Brompton Hospital, London, United Kingdom

Introduction

An image analysis improvement for serial MR examination of iron labeled islet cells transplanted into the liver is proposed. Rats with varying types of graft and numbers of transplanted cells were imaged using 3D radial ultrashort echo time (UTE) imaging. The images produce quantifiable positive contrast from the iron labeled cells. The reproducibility in stable syngeneic grafts using this method has been reported previously. A UTE image will include all of the species, including the very short T2* islet cells. A second echo image is subtracted from this (when the short T2* species have decayed) resulting in positive contrast from the iron containing cells and nulled background liver signal (d-UTE). dUTE positive contrast MRI images can be further improved using susceptibility-weighting information form the long echo phase image to enhance contrast and further suppress background to homogeneous near-zero values for the UTE-TE(2) difference image (SWI-dUTE). In-vivo MR imaging of iron-labelled iron cells in the liver are used to illustrate the technique.

Methods

Scanning was carried out on a Siemens MAGNETOM Trio, a Tim system, 3T clinical scanner (Siemens AG, Erlangen, Germany) using the system 4 wrist coil. Rats were transplanted with syngeneic (Lewis in Lewis), allogeneic (Norway Brown in Lewis) or xenogeneic (Human in Lewis) islet grafts. Number of islet equivalents (IEQ) varied, with labeling using incubation with ferucarbotran Resovist® UTE image parameters are a 3D isotropic resolution matrix of 320 and a 12cm FOV, with 35000 radial projections. TE(1)/TE(2)/echo spacing/FA = 0.07ms/5.7ms/9.6ms (x 70-110 segments)/10°. Respiratory triggering, pausing imaging during the short inhale/exhale period, used a pressure pad and external trigger input system (SA Instruments Inc. Stony Brook NY, USA) with a trigger delay of around 150ms to ensure imaging is at a constant respiratory position over the 6 minute scan time. Both magnitude and phase reconstructed images were used and exported to Matlab (Mathworks Inc.) for processing. dUTE images are enhanced using a smoothed phase mask reconstructed from the central raw data of the second echo which multiplies high phase iron regions by a higher factor than zero phase background. This is achieved using a multiplication factor of 1 + phase to a power 4.

Results

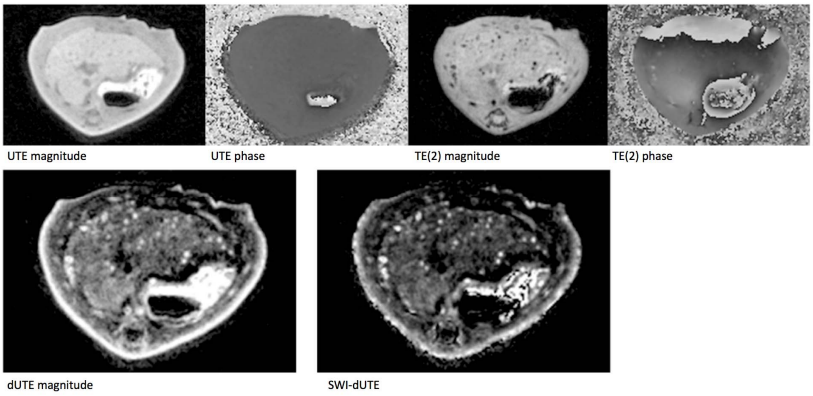

Figure 1 *UTE, TE(2), (magnitude and phase) Visual improvement from dUTE to SWI-dUTE images of labeled islet cells*

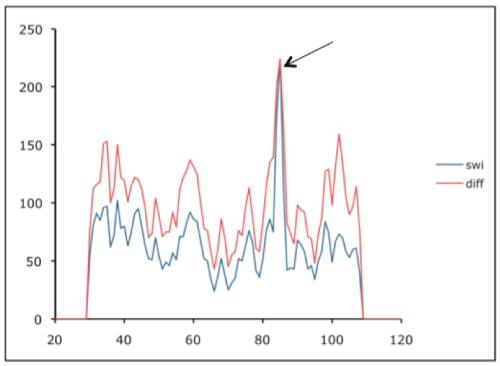

Figure 2 *Profile through an islet cell – islet remain the same, background drops*

An example of the observed improvement is shown in the liver images of Figure 1. Figure 2 shows that while the intensity of the islet cell is preserved the level and variation in the liver background is reduced by SWI treatment.

A control liver was analyzed and showed that with the same analysis, for the simple difference image dUTE there are 0.28% false positive pixels and for the SWI-dUTE there were only 0.10% high intensity pixels. For a liver containing around 200,000 pixels, this leads to approximately 560 and 200 pixels respectively. With grafted animals giving labeled pixel numbers on the order of thousands, this improvement significantly reduces any baseline signal. In this control animal, both the mean liver signal is greater (theoretical =0) and the standard deviation 50% larger, making threshold choice more difficult. This means the situation with islets means a lower threshold above the mean signal needs to be set for the difference image and that there will be even more false pixels (up to 0.9%). To illustrate the pre-clinical utility of these results we present the change in signal in the differently rejecting models. A 40% loss in signal can be compared to increase in glycemia in the diabetic allogeneic model and the loss of human c peptide measurement in the xenogeneic model (figure 3). The syngeneic model only drops by <20% in 2 weeks and 100% is around 7000 pixels at the initial timepoint.

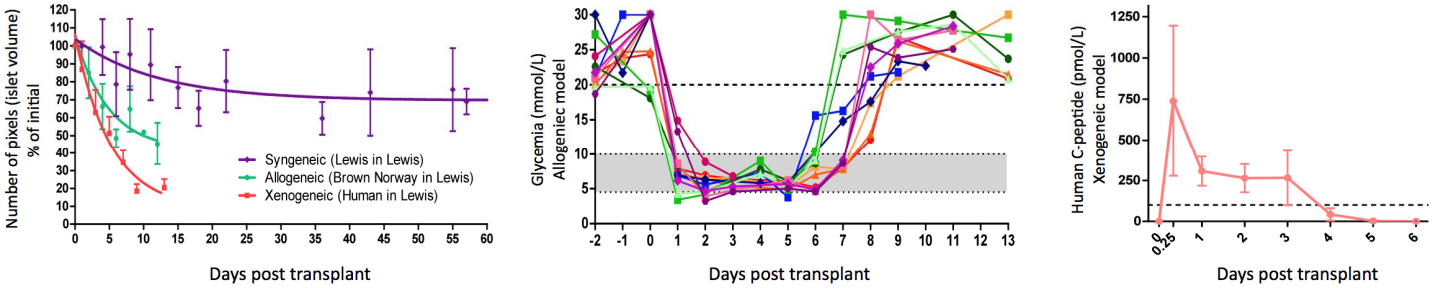

Figure 2 *Pixel number decay curves, glycemia changes in the allogeneic model and c peptide levels for the xenogeneic.*

Conclusion

Use of the longer echo phase information can be used to further enhance the background suppression in dUTE images of iron oxide contrast agents in the SWI-dUTE method proposed. Easier thresholding assists quantification of iron content and islet volume.

References

Crowe LA, Ris F, Nielles-Vallespin S, et al. Am J Transplant. 2011;11(6):1158.
Robson MD, Gatehouse PD, BydderM, et al. J Comput Assist Tomogr 2003;27(6):825.
Nielles-Vallespin S, Weber MA, Bock M, et al. Magn Reson Med 2007;57(1):74.
Toso C, Vallee JP, Morel P, et al. Am J Transplant 2008;8(3):701.
Gatehouse PD, Bydder GM. Clin Radiol 2003;58(1):1.
Larson PZ, Gurney PT, Nishimura DG. IEEE Trans Med Imaging 2008;27(1):47.