Comparison of DANTE- and iMSDE-based methods for subtractive NCE-MRA of the central thoracic vein

Andrew N Priest[1], Kristian H Mortensen[1], and David J Lomas[1]
[1]*Department of Radiology, Addenbrooke's Hospital and Cambridge University, Cambridge, United Kingdom*

Target audience Researchers interested in non-contrast-enhanced central venous imaging

Purpose

Patients with central venous obstruction, post-catheter strictures or occlusions, or suspected central venous thrombus may benefit from venous imaging both for identification of pathology and safe catheter routes for venous access for monitoring, drug and fluid administration. In this group of patients renal impairment and limited peripheral venous access are common making administration of contrast agents difficult. Although ultrasound is useful for imaging the axillary, subclavian and jugular veins it does not reliably image the innominate veins or the superior vena cava (SVC).

Recent work[1] adapted a non-contrast-enhanced MR angiography (NCE-MRA) method[2] for application in the thorax, combining respiratory navigator gating with a subtraction of bright- and dark-blood images, with the latter using two consecutive velocity-selective iMSDE modules[3] for flow-suppression. Best image quality was seen using a dual-inversion recovery (DIR) method giving good fat suppression even in the presence of magnetic field inhomogeneities.

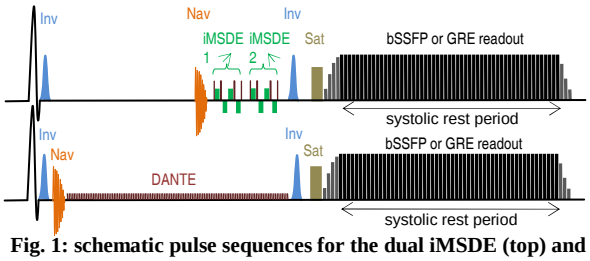

Fig. 1: schematic pulse sequences for the dual iMSDE (top) and DANTE (bottom) methods, also including 2 inversion pulses, navigator, saturation and bSSFP or GRE readout.

A recent black-blood technique uses DANTE pulse trains as an alternative flow suppression method[4]. This work aimed to investigate the use of DANTE for NCE-MRA and to compare it with the previous iMSDE approaches for imaging the central thoracic veins. Additionally, we compared image readouts using gradient echo with balanced SSFP (bSSFP) and free-breathing methods with breath-hold approaches.

Methods

Following ethical approval and informed consent, 12 healthy volunteers were imaged at 1.5 T (Discovery MR450, GE Healthcare, Waukesha, WI) using an 32-channel cardiac array coil. The 3D dark- and bright-blood coronal images were acquired sequentially, using the pulse sequence schemes in Fig. 1. Flow suppression was achieved either using two consecutive iMSDE modules[1] (gradient duration 4 ms, amplitude 6 mT/m) or using DANTE[4] (TR 1 ms, flip angle 10°, gradient 20 mT/m, ETL 150–270 pulses).

Four free-breathing and four breath-hold techniques were acquired for comparison. The free-breathing methods used either DANTE or iMSDE with two different image readouts: bSSFP (with acquisition matrix 256×256, flip angle 65°, TE/TR=1.0/2.7 ms, 10 sinusoidally increasing dummy acquisitions, segment duration 116 ms); or gradient-recalled echo (GRE, with acquisition matrix 192×192, flip angle 12°, TE/TR=1.2/3.6 ms, segment duration 115 ms). Both readouts additionally used the following parameters: FoV 40 cm, 20 slices of 4 mm, 1 Nex, ASSET factor 3, 2 segments per k-space plane, segment TR 2 heartbeats. The fat signal was suppressed using dual inversion-recovery (DIR)[1]. A respiratory navigator (without slab-tracking, acceptance window 3–4 mm, placed before flow-suppression modules) was used to compensate motion. The total acquisition time was 160 heartbeats (assuming 100% navigator efficiency).

The breath-hold techniques used either DANTE and iMSDE with either a dual acquisition (with bright- and dark-blood acquisitions on separate breath-holds) or a single breath-hold acquisition (using a segment TR of 1 heartbeat and no DIR) were acquired. The bSSFP readout was (as above, except TE/TR=1.2/2.7ms, acquisition matrix 192×192, 0.5 Nex, 10–14 slices of 7 mm, 1 segment per k-space plane).

For all imaging methods, the image readout was placed during the end-systolic rest period to avoid cardiac motion, and spatial pre-saturation was used to remove residual wrap in the slice-selection direction.

The image datasets for each individual were assessed by two experienced radiologists in consensus, blinded to the technique and in randomised order. For each image volume the SVC, left and right innominate (LIn, RIn) and left and right subclavian (LSV, RSV) veins were assessed, scoring both margin delineation and intraluminal signal homogeneity on 5-point Likert scales (1–5, 5 best, 1–2 non-diagnostic). Vessels were of diagnostic quality if both scores were 3 or greater.

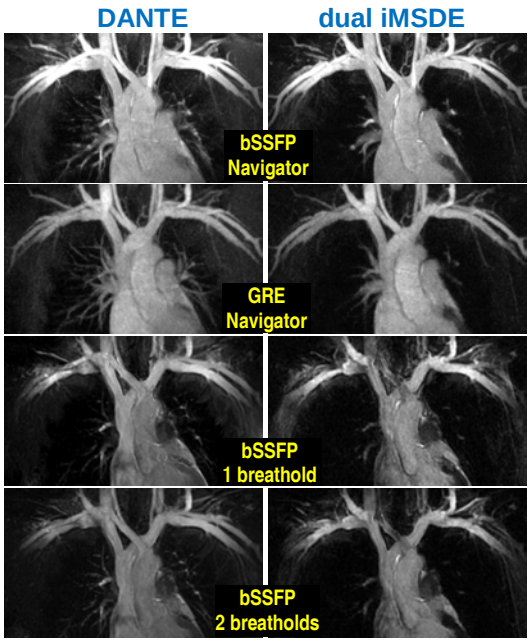

Fig. 2: Example MIPs of the subtraction angiograms with DANTE (left) or iMSDE (right). The bSSFP and GRE navigated images are in the top two rows, with the single and dual breath-holds below.

Results

Figure 2 shows example MIPs from each imaging technique for an example volunteer. Figure 3 shows box-plots of the scores for each technique and vessel.

Overall the navigated methods greatly out-performed the breath-hold techniques. In the central veins (innominate & SVC), the best methods overall were the navigated DANTE sequences which always gave diagnostic image quality (10/10 cases). The navigated iMSDE method was diagnostic in 8/10 (bSSFP) and 9/10 (GRE) cases. For comparison, the best breath-hold sequence (dual breath-hold DANTE) was diagnostic in only 6/10 cases. Subclavian veins were less well depicted: when these vessels were included, both DANTE sequences were diagnostic in 6/10 cases, and both iMSDE methods in 5/10 cases; the best breath-hold method was diagnostic in only 3/10 cases.

Discussion

In general, the new DANTE methods give more uniform venous signal with slightly higher SNR than the previous iMSDE approach. The choice of image readout must balance the greater resolution and SNR of bSSFP (compared to GRE) with its susceptibility to variations in signal homogeneity and to banding artifacts (especially in the subclavian veins). The navigator-gated technique has a longer acquisition time than the breath-holds, but gives far better image quality.

Conclusion

The 2 navigated DANTE methods allowed diagnostic quality depictions of the thoracic central veins without an exogenous contrast agent, and are well suited for future studies in patients.

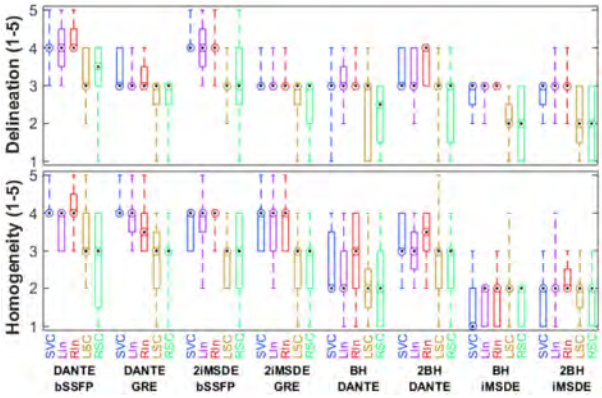

Fig. 3: Box plots showing the median, quartiles and limits of the scores awarded for each technique and vessel type. Scores of 3 or greater indicate acceptable diagnostic image quality.

References

1. Priest AN, Lowe G, Graves MJ, Lomas DJ. Non-contrast-enhanced MR angiography of the thoracic central veins. Proc Intl Soc Mag Reson Med. 2014;22:2513.
2. Priest AN, Graves MJ, Lomas DJ. Non-contrast-enhanced vascular magnetic resonance imaging using flow-dependent preparation with subtraction. Magn Reson Med. 2012;67(3):628–637.
3. Wang J, Yarnykh VL, Yuan C. Enhanced image quality in black-blood MRI using the improved motion-sensitized driven-equilibrium (iMSDE) sequence. J Magn Reson Imaging. 2010;31(5):1256–63.
4. Li L, Miller KL, Jezzard P. DANTE-prepared pulse trains: a novel approach to motion-sensitized and motion-suppressed quantitative magnetic resonance imaging. Magn Reson Med. 2012 Nov;68(5):1423–38.