# Time-Efficient Artery and Vein Imaging in 3D TOF MRA of the Neck

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**Introduction:** Comprehensive imaging of both the arterial and venous vascular systems is a useful diagnostic tool. However, without contrast agent, exclusive imaging of both arteries (A) and veins (V) is a time consuming process since two distinct acquisitions, one suppressing arteries and one suppressing veins are required through the application of spatial saturation pulses (1). Alternative approaches for AV separation include exploiting first-pass dynamics in contrast enhancement (2) or using susceptibility-weighted phase for AV distinction (3). Limitations of the susceptibility approach include the long echo time needed at low field to achieve venous phase evolution, while contrast agent methods are preferably avoided due to occasional, although rare, incidences of contrast reaction. In this work, we return to the use of saturation pulses for preferential vessel saturation, but demonstrate that the time overhead can be dramatically reduced to obtain both arterial and venous images of the same image section. We apply this method to imaging the carotid arteries and jugular veins in normal volunteers using 3D time-of-flight MR angiography.

**Methods:** This method relies on first collecting a complete unsaturated scan that will contain all the information and contrast for both veins and arteries. Noting the fact that most of the contrast in an image resides closer to the center of k-space, a second saturated scan can be obtained of only a small fraction of the center of k-space in the phase encoding plane. By replacing the central portion of the unsaturated scan with the saturated scan, one obtains a method to easily remove arteries or veins from the complete data set. This leads to significant reduction in scanning time as well as less RF power deposition which is an important factor at higher fields.
To validate this method, and determine acceptable degrees of reduction, two scans were acquired on each normal volunteer with venous saturation applied to one scan and no saturation for the other. The experiments were run on a 1.5T Siemens magnet using a 3D-TOF sequence with 62.5% partial fourier read-out, flow compensation on read-out and slice selection, 25º excitation, FOV= 20x163x3.2 cm, acquisition matrix = 1024x208x32, SW=82.6 kHz TR/TE 36/6.9 ms.
The two k-space data sets were then combined as shown in figure (1) where different percentages from both phase encoding directions were incorporated into the (no-saturation) image and the resulting images were evaluated with ROI's for each vessel in the original unsaturated image.

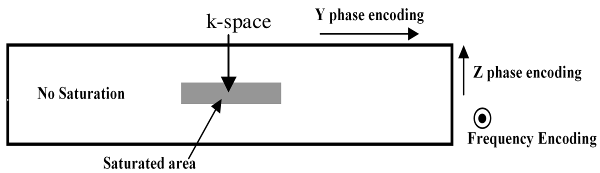



**Fig 1 (left):** Schematic showing a section of k-space perpendicular to the frequency encoding direction with the gray shaded area showing the area imported from a partially venous-saturated scan. A 5% segment at each edge of the shaded area was modulated by a hanning window with fall off towards the outside of the shaded area for saturated data and the reverse of the same modulation for the unsaturated data.

**Results:** Figure 2 shows images from both unsaturated and fully saturated scans as well as two other combined images with partially saturated k-space ratio of 25% and 11% respectively. 25% saturation (ie: 50% in each phase encode direction) led to all veins being suppressed down to the background level while the 11% case led to some of the smaller veins being slightly above the background level. This method can be used to get separate venous images either by processing the images shown so far or by running another partial scan with arterial saturation. The graphs in Fig. 3 show that less saturated K-space is needed to suppress a larger vein. It also shows that increasing Y saturation is more effective than increasing Z saturation (slice select direction). The lack of improvement with wider saturation in the Z direction after 25-30% width might be due to the anatomy of the neck having veins traversing the imaging slab in a somewhat vertical manner (along the Z direction) which implies that most of the information pertaining to these veins reside in the low spatial frequency zone.

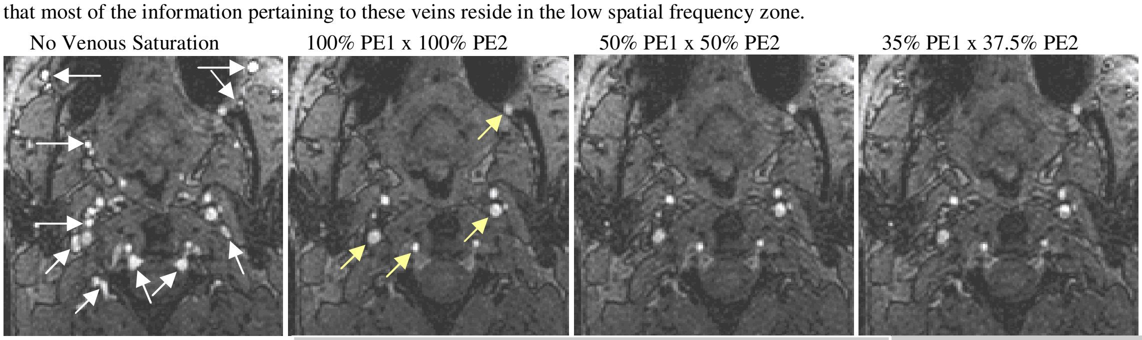
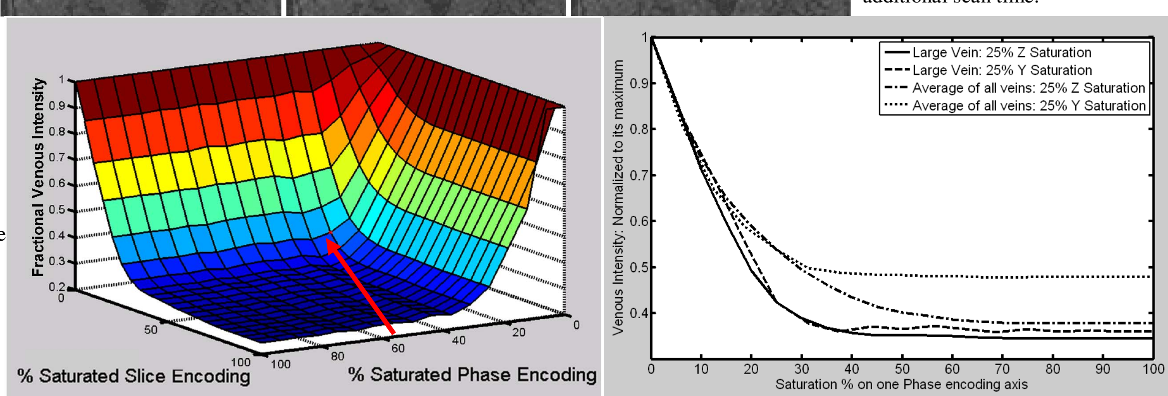



**Fig 2 (left):** Neck source images showing different saturation extents. White arrows on the left point to veins while yellow arrows show arteries in the second image. The image at far right illustrates that only ~1/3rd of k-space in each phase encode dimension was necessary to achieve venous suppression requiring only 13% additional scan time.

**Fig. 3 (right):** Experimental data illustrating progressive venous saturation. The red arrow is at 25% PE1 x 31.25% PE2, and achieves 82% venous suppression. This translates to only 8% scan time for the venous saturation portion of the combined scan. At far right, the venous intensity is illustrated for various degrees of saturation, and for all veins or a single large vein.




**Conclusions:** Using only an extra 11% of scan time, it was possible to obtain separate arterial and venous images of the neck vasculature, by utilizing the proposed method of full k-space scanning without saturation followed by limited central k-space scanning with select saturation.

**References:**

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3- Y. Wang, Y. Yu, D. Li, K.T. Bae, J.J. Brown, W. Lin and E.M. Haacke. JMRI 12:661–670 (2000).