# Large Slice FOV Non-Contrast MR Angiography with Variable Slice Resolution 3D Time-of-Flight

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**Target Audience:** Clinicians and researchers with interest in efficient head-neck large FOV non-contrast MR Angiography.

**Purpose:** In practice, slow but robust 3D time-of-flight sequence with MOTSA (TOF) [1] MR Angiography is limited to smaller slice FOV coverage. The recent developments in MRI acceleration with the sparse undersampling & iterative reconstruction [2] on TOF (e.g. TOF with sparse undersampling (TOFu) [3]) may finally solve this practical issue. Not only for larger slice FOV coverage, time savings from the acceleration can be reinvested for the higher slice resolution. The current study introduces variable slice resolution TOF, a novel concept that adjusts slice resolution according to anatomical needs for the optimal large FOV coverage TOF within clinically acceptable scan time.

**Methods:** In a conventional TOF, multiple overlapped slabs in axial inplane orientation with identical voxel sizes are merged into one large volume. For the axial inplane view, the resolution must be kept through the entire merged volume for consistency in MPR source image format. Slice direction, on the other hand, is utilized only in the MIPs, and by interpolation, variable slice resolution still suffices the merging requirement in the slice voxel size. By default, every slab in TOF is a slice-shifted copy of itself with identical parameters. With larger slice FOV coverage, not every location within the FOV has the same slice resolution needs, and this can be further exploited with the variable slice resolution in each slab. In head-neck application (Fig.1), superior TOF slabs can take advantage of high slice resolution to delineate smaller vessels, while inferior slabs can be acquired with lower slice resolution since intended vessels are large and are well-defined.

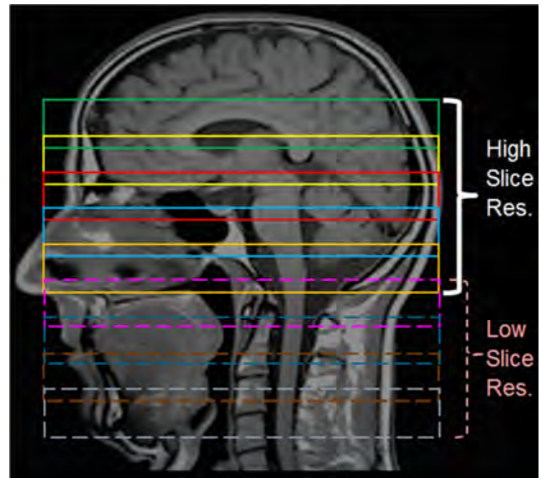


Fig.1: Schematic diagram of large slice FOV variable slice resolution TOF, prescribed for brain-neck application. Based on anatomical needs, superior 5 slabs are acquired with high slice resolution and inferior 4 slabs are acquired with low slice resolution.

The prototype sequence was implemented on 3T scanner (Magnetom Skyra, Siemens Healthcare, Erlangen, Germany). The technique was validated with healthy volunteers (n=5) under a local IRB approved protocol. Two sets of sparse sampled TOF data were acquired: 1) the standard low slice resolution for all 9 slabs, and 2) the proposed variable slice resolution (5 high slice res and 4 low slice res., as shown in Fig.1). The common protocols were as follows; FOV 220mm; 9 axial slabs, 40 slices each with 10% overlapped; voxel size = 0.6 x 0.6 x 0.5 $mm^3$; flip angle = 18°; TR/TE = 21.0/3.46 msec; BW 200 Hz/pixel; Sparse undersampling acceleration factor of 5.5. For the high slice res slabs, each slab had 100% slice resolution for scan time of 1:15min per slab, and for the low slice res slabs, each slab had 50% slice resolution and scan time was reduced to 45 seconds per slab. The resulting variable slice resolution TOF had total scan time of 9:15minutes, while all low slice resolution TOF was acquired in 6:45 minutes. The resulting MRA data sets were compared for overall image quality consistency after the merging and for delineation of vessel details.

**Results:** Variable slice resolution slabs were seamlessly merged into one data set (Fig. 2d-f), matched in the overall quality to that of the standard slice resolution TOF (Fig.2a-c). We can appreciate the high slice resolution from clearly delineated intracranial arteries (as highlighted with green arrows in Fig. 2c and with red arrows in Fig.2f).

**Discussion:** Note that slice resolution reduction by the factor of 2 (from 100% to 50%) did not reflect the same way on the slab scan time (from 1:15 min. to 45 sec.) due to Poisson disk sparse undersampling. Variable slice resolution strategy has an immense potential of optimizing all of the 3D TOF sequences. The current study is a proof-of-concept preliminary work, and further protocol optimization is needed.

**Conclusion:** We have successfully demonstrated that variable slab resolution TOF can achieve a high quality large FOV coverage TOF data set within a clinically acceptable scan time (<10 min). Further clinical evaluations are warranted.

**References:** [1] Parker DL et al. MRM 17:434-451(1991) [2] Lustig M et al. MRM 58:1182–95(2007) [3] Natsuaki Y et al. Proc. ISMRM (2014)

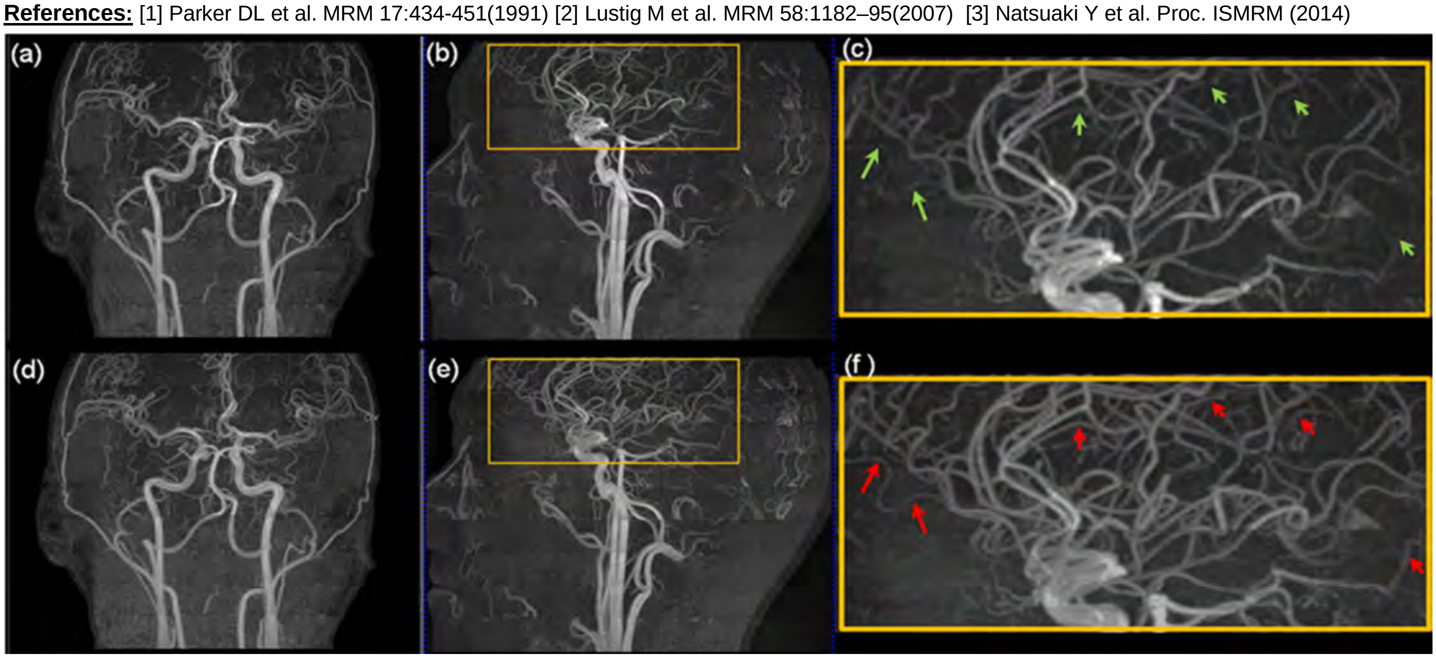


Fig.2: Representative MIPs (coronal (a) (d), sagittal (b) (e), and zoomed sagittal (c) (f)) of the large FOV TOF data sets. Upper row represents standard low slice resolution TOF ((a) – (c)) and the lower row depicts the proposed variable slice resolution TOF ((d) – (e)). For the variable slice resolution TOF, top 5 slabs are acquired with high slice resolution (100%) to better delineate smaller vessels (red arrows on (f) vs green arrows on (c)), while bottom 4 slabs are acquired with lower slice resolution (50%) since intended vessel in carotids are well-defined.