Rapid tracking of soft palate motion during speech using pencil beam and turbo navigators

Andrew David Scott[1], Redha Boubertakh[2], Malcolm Birch[1], Marie Pinkstone[3], and Marc Eric Miquel[1,2]

[1]Clinical Physics, Barts Health NHS Trust, London, United Kingdom, [2]NHLI Cardiovascular BRU, Barts Health NHS Trust, London, United Kingdom, [3]Cleft Lip and Palate Team, Great Ormond Street Hospital for Children, London, United Kingdom

Target Audience: Speech therapists; physicists and engineers developing MRI techniques for rapid motion tracking.

Purpose: Articulatory timing is crucial in producing accurate speech, but apraxia or dysartharia can cause errors.[1] The motion of the tongue, lips and velum is rapid and the temporal resolution of current real-time 2D MR techniques (2-33[2,3] frames s^{-1}) is insufficient to precisely evaluate timing. However, the timing of velopharyngeal closure could be observed by tracking a relevant section of the velum in one dimension. Navigator echoes are used to track respiratory motion in 1D, but respiratory motion is relatively slow and the temporal resolution of navigators is typically low.[4] In this work we demonstrate the evaluation of velar motion using a gradient echo navigator with a 2D RF pulse (pencil beam navigator) and a novel turbo spin echo navigator (turbo navigator) which collects multiple spin echoes for every excitation.

Methods: Imaging was performed with a 1.5T Philips Achieva using a 16 channel neurovascular coil while subjects performed test phrases including sustained vowels and counting. 2D real-time images were acquired in the mid sagittal plane with a balanced steady-state free precession sequence (1.9×1.9×10mm^3 spatial and 101ms temporal resolution, 2.4× SENSE, 5/8$^{\text{ths}}$ partial Fourier, field of view 277×255mm, flip angle 30°) as a reference. The pencil beam navigator used a spiral RF excitation with 8 turns and a block shaped RF pulse. The pencil beam had 12mm diameter, 27ms TR, 25° flip angle and used the body coil for reception. The turbo navigator was implemented by removing the phase encode gradients and moving the slice selection gradient of the refocusing pulse to the phase encode axis in a standard turbo spin echo sequence with driven equilibrium.[5] This resulted in a cuboid shaped imaging volume with a square cross section and edge length equal to the specified slice thickness. A 10mm slice thickness was used with an echo spacing of 10ms and an echo train length of 8. The average spacing between echoes, accounting for the gap between echo trains was 16ms.

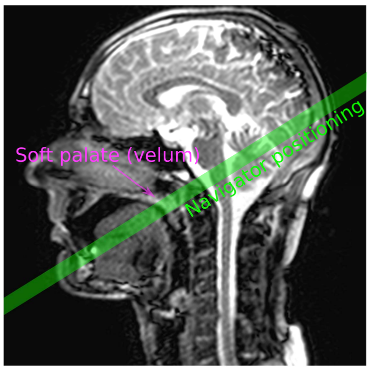

***Figure 1:** The position of the navigators (green) shown on a 2D mid-sagittal image.*

The navigators were positioned through the soft palate in the mid-sagittal plane, along the primary direction of palatal motion through the position of velopharyngeal closure (see figure 1). Simultaneous audio was recorded using a fibre optic microphone system with noise cancellation. The navigator data were reconstructed offline using Matlab (R2011b, The Mathworks, Natick, MA) and the ReconFrame library (Gyrotools, Zurich, Switzerland) and synchronised with the recorded audio. By stacking the navigator lines horizontally a 1D + time image of palatal motion was generated. The turbo navigator images were noisy and T2 decay during the echo train caused severe intensity variations. The data was filtered in the readout direction, noise thresholded and corrected for intensity variations based on the stationary soft tissue. To account for the time gaps between echo trains, the data was linearly interpolated to an equispaced time base of 10ms.

For comparison, a simulated navigator acquisition was derived from the 2D real-time images by defining a line on a reference image in the same orientation and position as the navigators used.

Results: Figure 2 shows short segments of data for each of the techniques while the subject counts from eight to ten. Similar patterns of palate motion are seen with each technique. In a second subject the contrast was poor and the velum could not be delineated reliably throughout the speech sample in the navigator images. This is thought due to the curvature of the posterior pharyngeal wall.

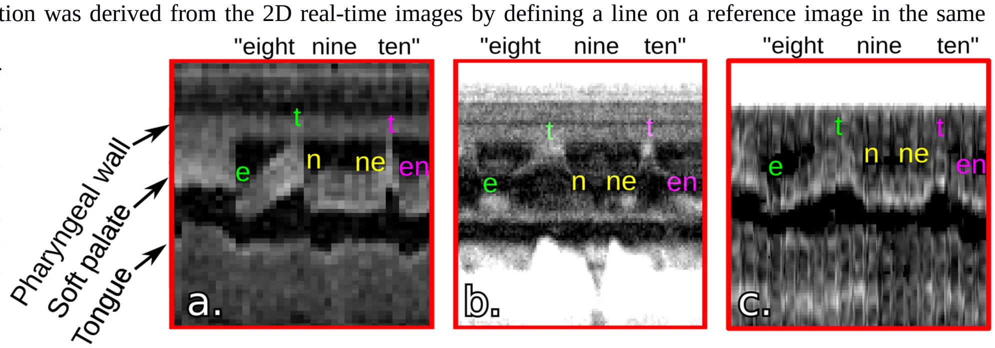

***Figure 2:** 1D intensity profiles through the soft palate plotted with time (horizontal axis). Shown for (a) simulated navigator, (b) pencil beam navigator and (c) turbo navigator.*

Palatal closure during the word "ten" takes around 300ms (measured on the turbo navigator image shown), corresponding to 3 frames in the bSSFP acquisition, 11 lines of the pencil beam navigator and an average of 19 lines of the turbo navigator acquisition.

Discussion: This work presents the first demonstration of rapid tracking of soft palate motion using navigators. Pencil beam navigators achieved 37 lines s^{-1} and a novel turbo navigator technique, 62 lines s^{-1}, which both exceed current maximum 2D real-time imaging frame rates.[4] Further work, particularly regarding navigator diameter and placement is required to address the limitations of the technique in subjects with curved posterior pharyngeal walls.

Conclusion: The additional temporal fidelity provided by the navigator techniques should permit precise assessments of the timing of velopharyngeal closure and could aid in discerning apraxia or dysartharia from inadequate closure of the velopharyngeal port.

References:

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