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Improved real-time MRI to visualise velopharyngeal motion during speech using accelerated radial through-time GRAPPA

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Purpose/Introduction:
Real-time MRI (rt-MRI) has been used to dynamically image the vocal tract during speech [1,2]. However, achieving sufficient temporal resolution while maintaining image quality is challenging. Non-Cartesian sampling and parallel imaging such as through-time GRAPPA (tt-GRAPPA) have been used to improve highly accelerated rt-MRI in cardiac [3,4] and speech [5] applications. This study investigates the use of tt-GRAPPA and accelerated radial rt-MRI to visualise velopharyngeal motion during speech.

Subjects and Methods:
Two subjects were imaged at 3T (Philips Achieva) while performing phonation: counting, non-sense vocalizations and extended phonation. A spoiled-GRE radial sequence (FOV: 190×190 mm^2, 1.9×1.9 mm^2, 10 mm single slice, TE/TR/α: 2.1/4.5/10°) was implemented at several accelerated factors resulting in temporal resolutions: 227, 91 and 45 ms. A through-time/through-k-space GRAPPA, described here [3,4], was implemented within MATLAB (The MathWorks, R2014b). tt-GRAPPA relies on the repetition of data patterns over time to estimate calibration weights. Thus, fully sampled data (R=1, 100 projections, temporal resolution:454 ms) with 200 dynamic frames was acquired for calibration. Different calibrations were investigated: 1) varying the number of calibration frames and 2) varying space segmentation. Image quality was assessed visually and with normalized mean squared error (nMSE) over a ROI in the velopharyngeal region. The proposed method was compared to established commercial protocols [6].

Results:
tt-GRAPPA was successfully implemented with accelerated radial rt-MRI to visualise velopharyngeal motion. Figure 1 shows nMSE values in accelerated radial (R=5) for different calibrations and corresponding dynamic frames. Optimal image quality was achieved a 1×1×200 calibration (readout×projection×number of frames), thus, this was used as reference data. If weight calculations are underdetermined (e.g. insufficient dynamic frames), image quality decreases as reconstruction errors are introduced (e.g. 1×1×5). However, reconstruction with a hybrid calibration (2×4×75) allowed maintaining image quality equivalent to 1×1×200 image and low nMSE (0.024). Examples of intensity-time displays of velum motion for accelerated radial R=2, 5 and 10 are shown in Fig. 2. Figure 3 compares temporal depiction of velopharyngeal motion of data acquired with clinical protocols [6] and proposed radial GRAPPA.

Discussion/Conclusion:
Accelerated radial tt-GRAPPA was successfully used in the visualisation of velopharyngeal motion. Optimal image quality was obtained with higher number of calibration frames (200). However, acquisition of multiple fully sampled calibration frames can be time consuming (≈1.66 min). Through-time/through-k-space reconstruction maintained adequate image quality with a lower number of calibration frames. Results suggest that radial tt-GRAPPA provides improved temporal sharpness and identification of velopharyngeal closures when compared to Cartesian and radial established commercial protocols.

References:

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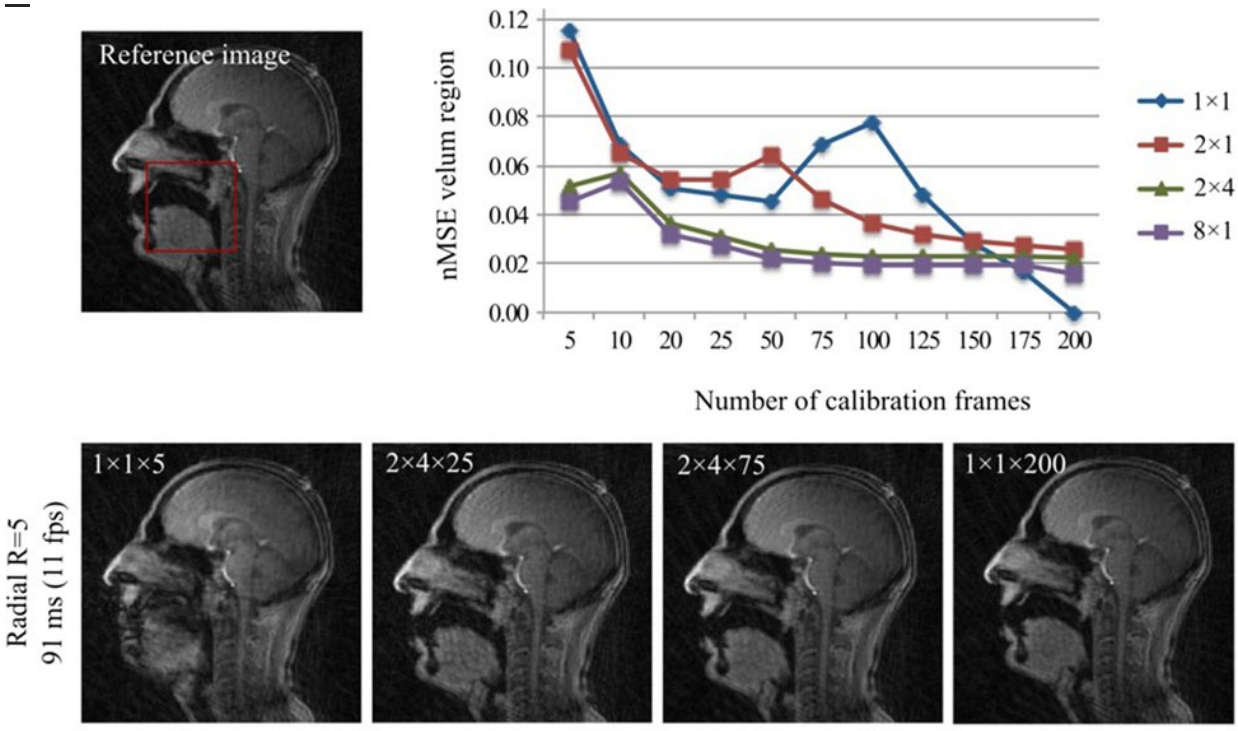

Figure 1. Average normalised MSE in a region-of-interest (ROI) selected over the velopharyngeal region (reference image) calculated from accelerated radial data (R=5) reconstructed with different calibration schemes. Accelerated data reconstructed with optimal calibration 1×1×200 was chosen as reference data. Calibration of GRAPPA weights was investigated with both through-time/through-k-space calibration scheme. Example of dynamic frames reconstructed with GRAPPA 1×1×200, 1×1×5, 2×4×25, 2×4×75 are shown to demonstrate differences in visual image quality and presence/absence of image artefacts.

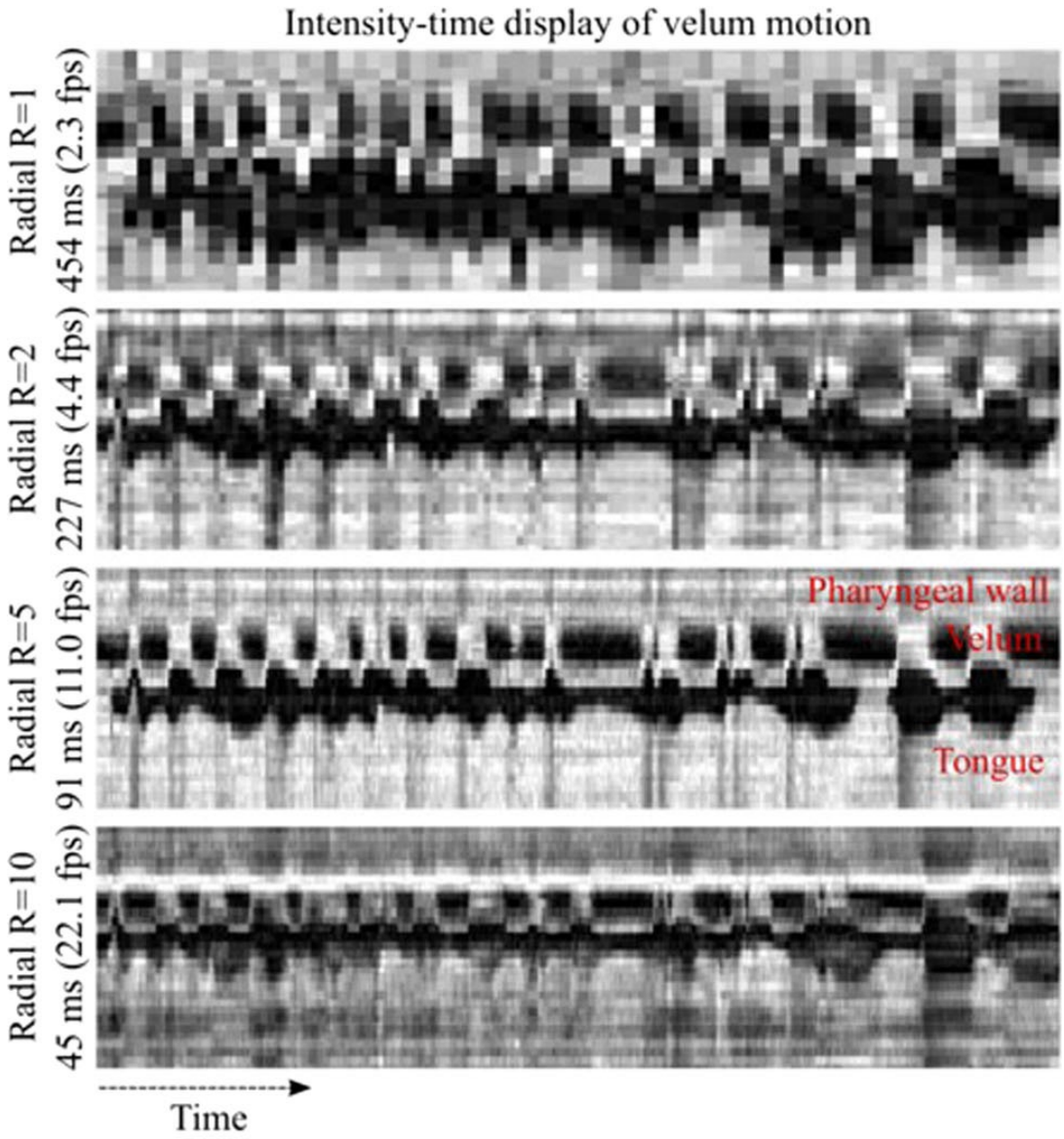

Figure 2. Examples of intensity-time displays of velum motion during speech for calibration data R=1 and data accelerated by R=2,5 and 10 with corresponding temporal resolutions of 454, 227, 91 and 45 ms. Intensity-time displays were obtained by selecting an intensity profile along the velum main direction of motion and displaying adjacent profiles side-by-side. Data was reconstructed with a through-time GRAPPA 1×1×200 calibration. At a lower sampling rate (2.3 fps), data acquisition is inadequate to accurately depict velum motion. However, data acquired at R=5 (11 fps) showed crisp representation of velum motion without temporal blurring and clear identification of contact points between the velum and the pharyngeal wall. Although highly accelerated data was acquired at 22.1 fps, final image quality was degraded due to the high acceleration factor.

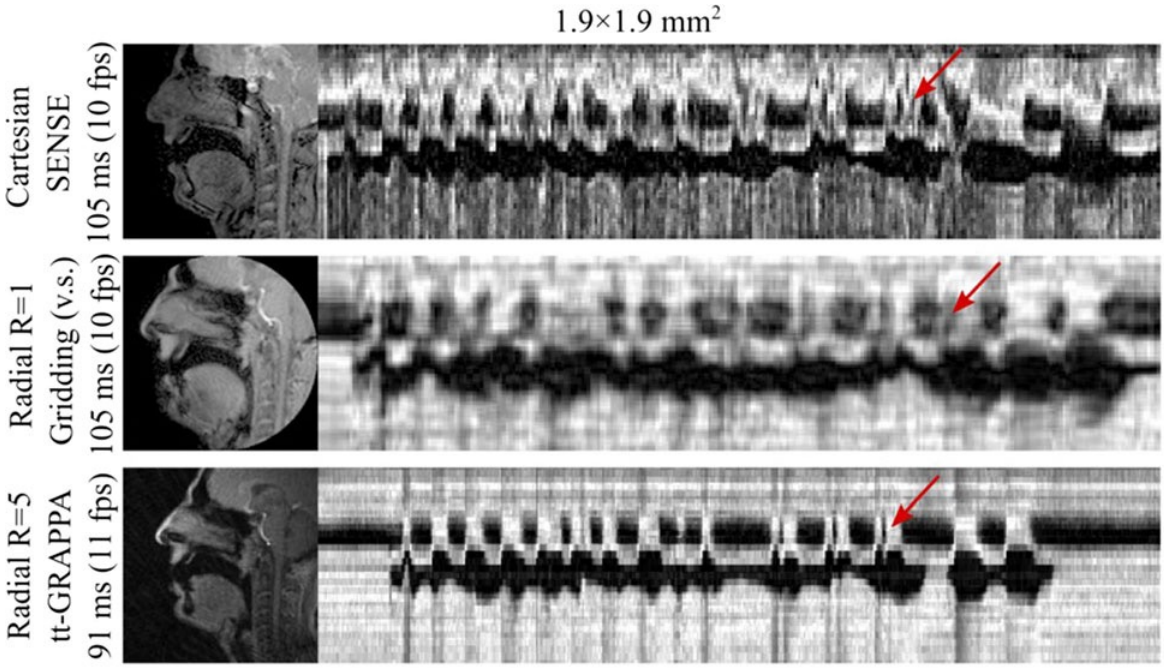

Figure 3. Intensity-time displays of velum motion from dynamic data acquired with commercial protocols Cartesian SENSE, radial gridding with view sharing and accelerated radial with offline through-time GRAPPA reconstruction. Image data was acquired at 1.9×1.9 mm^2 and 91 to 105 ms. Accelerated radial tt-GRAPPA allowed to improve visual depiction of velum's motion and for a clear identification of velopharyngeal closure events (red arrows) compared to the commercial Cartesian and radial protocol.