Evaluation of motion sensitivity of a 4-port ^{23}Na body coil

Anna Fischer[1],Tanja Platt[1], Armin M Nagel[1,2], Peter Bachert[1], Mark E Ladd[1], Nicolas G R Behl[1]
[1]Medical Physics in Radiology, German Cancer Research Center (DKFZ), Heidelberg, Germany; [2]Institute of Radiology, University Hospital Erlangen, Erlangen, Germany

Purpose

^{23}Na MRI has been proposed for the assessment of pathologies in the human lung[1,2,3,4]. However, respiratory motion remains a challenge that leads to additional blurring. In this study we used a water-filled body phantom containing a moveable cylinder[5] filled with saline solution to assess the motion sensitivity of a 4-port ^{23}Na body coil[6]. The results are then used to optimize volunteer positioning for the separation of motion states in ^{23}Na lung MRI.

Methods

The moveable cylinder inside the phantom was filled with 0.9% saline solution. Motion of the cylinder was manually induced, the exact position was recorded by an incremental encoder and consequently used as a ground truth for the evaluation of the motion signal obtained from k-space center.
Phantom and in-vivo (healthy volunteer, male, 30 y/o) ^{23}Na measurements were performed on a 7T whole-body MR scanner (MAGNETOM 7T, Siemens Healthcare, Erlangen, Germany) using a 4-port ^{23}Na body coil. A 3D density adapted radial sampling scheme[7] and a golden angle distribution of projections[8] were used to acquire the images.

Measurement parameters: phantom/in-vivo: TE=0.8ms/0.9ms, TR=20ms/20ms, resolution=$(4mm)^3/(5mm)^3$, FA=44°/44°, projections=9100/14000, radial samples=384/384, short-term averages=1/5, t_{ACQ}=3min 2sec/23min 20sec, reconstructed FOV=$(400mm)^3/(500mm)^3$.

Measurements at 5 different positions with regard to the center of the coil were performed with the phantom. For the first measurement, the lower edge of the cylinder was placed in the center of the coil, while for further measurements it was shifted in head direction by 5cm in every step. For the in-vivo measurements, the diaphragm was placed according to the position of the first and third phantom measurement.

In phantom measurements the internal motion signal acquired based on k-space center was compared to the data from the incremental encoder for the 5 different positions.
The motion signal was used to separate the data set into inhaled subset ($S(t) < 0$ since less ^{23}Na containing tissue is located near the center of the coil) and exhaled subset ($S(t) \geq 0$ vice versa). The resulting data subsets as well as the full dataset were reconstructed with a Nonuniform Fast Fourier Transform (NUFFT)[9].
Intensity profiles in z-direction were used to evaluate motion blurring at the edge of the cylinder for phantom measurements and at the liver/lung boundary for in-vivo measurements.
The full in-vivo dataset was additionally divided into 5 motion states, which partially overlap to ensure a minimum number of projections (high/low sensitivity: 4100/4030) in each state.

Results

<u>Phantom measurement:</u>
The comparison of signals obtained from k-space center and external data from the incremental encoder for different positions of the phantom in the body coil indicates, that the field of view can be divided into regions of high or low motion sensitivity. Fig. 1 exemplarily shows this comparison for measurements 1 and 3 at a region of low and high motion sensitivity respectively.
At regions of high sensitivity, circa 90% of the projections were assigned to the same motion state based on internal and external signal, whereas for regions of low sensitivity, this value was circa 70-80%. Furthermore, the variation in the signal intensity at k-space center is higher compared to a measurement in a region of low sensitivity.
This is confirmed by the motion-separated images and the intensity profiles, resulting in sharper edges of the cylinder for a measurement in a region of high motion sensitivity (Fig. 2).

<u>In-vivo measurement:</u>
Fig. 3 displays the motion-separated images and the intensity profiles for a measurement in which the volunteer's diaphragm was positioned in a region of high motion sensitivity. In this case, the movement of the liver/lung boundary is clearly visible, whereas for a measurement in a region of low sensitivity motion blurring is still visible.
When more than two motion states are to be separated, correct positioning is of even more importance.

Discussion & Conclusion

In this study we showed that the field of view of the 4-port ^{23}Na body coil used here can be divided into regions of different motion sensitivity. The optimized volunteer positioning within a region of high motion sensitivity leads to a better separation based on the signal obtained from k-space center, which consequently results in reduced motion blurring and possibly improves quantitative ^{23}Na body imaging.

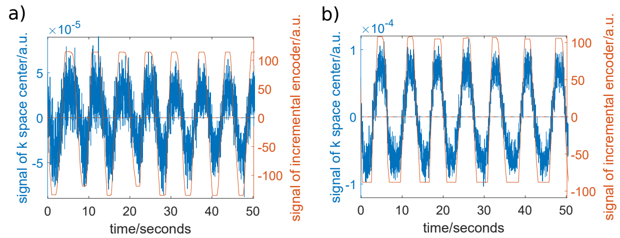

Fig. 1: Respiratory signal of k-space center (blue) and external signal from incremental encoder (orange) for phantom measurement 1 in a region of low motion sensitivity (a) and for measurement 3 in a region of high sensitivity (b). Measurement 1 shows higher noise in the internal signal, which leads to less distinct separation compared to measurement 3.

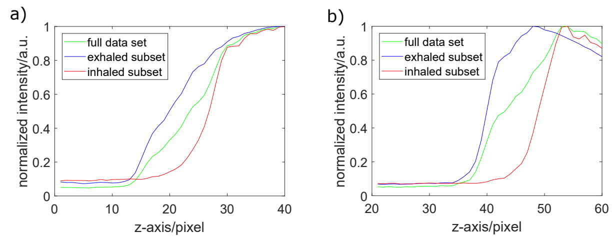

Fig. 2: Intensity profile in z-direction at the edge of the cylinder for phantom measurement 1 in a region of low motion sensitivity (a) and for measurement 3 in a region of high sensitivity (b). For measurement 3, the separation into two motion states clearly reduced the motion blurring at the edge of the cylinder when compared to measurement 1.

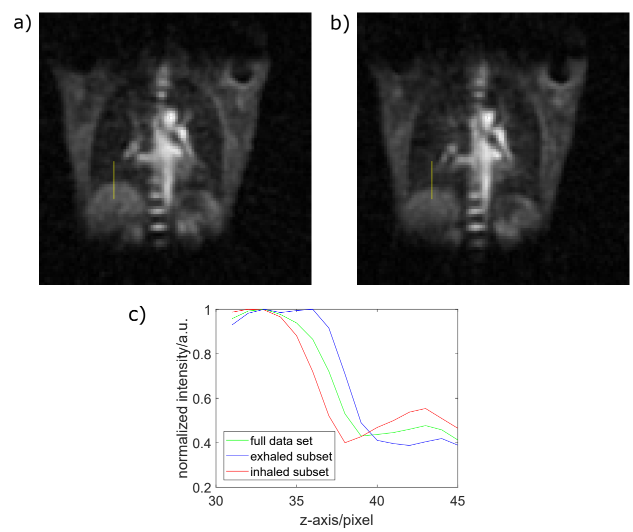

Fig. 3: Motion-separated images of exhaled (a) and inhaled (b) state for a measurement in a region of high motion sensitivity. In the exhaled state, the diaphragm is located further in head direction compared to the inhaled state. The intensity profile (c) along the yellow line within those images shows this movement as well as the reduction of motion blurring for separated reconstruction.

References

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