ACCURACY THE SPATIAL POSITION OF GOLD MARKERS IN MR IMAGES

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Background

Modern external radiotherapy of prostate cancer relies on high spatial treatment accuracy. The trend is to move toward higher doses delivered to the prostate gland, combined with reduced treatment margins. To enable a high treatment precision, gold markers are often used as internal reference points as they are visible on both the CT study, used to define the treatment, and on X-ray imaging, used to position the patient. The gold makers are visible also on MR where they appear as a signal loss[1]. With gradient-echo sequences a relatively large volume is affected, while the volume of the signal loss on spin-echo based sequences are comparable to the physical volume of the marker. The visualization of the marker in MR could serve two purposes; to be used as a basis for landmark based registration between MR and CT, or to serve directly as internal reference points used for patient positioning. For both alternatives the accuracy of the apparent marker positions is highly important as errors will affect all treatment fractions systematically.

In the present study we evaluated the reliability apparent marker position, i.e. how the depiction of the markers was affected by changes in bandwidth, frequency encoding and slice selection directions, and orientation of the markers relative the main magnetic field.

Material and methods

5 cylindrical gold markers of different dimensions and of different brands were positioned in a phantom made of gelatin (Table 1). The phantom was scanned with the markers positioned along, perpendicular or at 45 degree angle to the main magnetic field (Figure 1). Two sequences was used; 2D TSE sequence: TR 3000ms, TE 14ms, Flip angle 150 degrees, BW 70 – 280 Hz/Px, Turbo factor 16; 3D TSE sequence: TR 3000ms, TE 24ms, Flip angle 150 degrees, BW 507Hz/Px, Turbo factor 37, Slice turbo factor 3, Slab selective excitation. The position of the markers in the phantom was calculated using a dedicated Matlab® script, and compared between the different sequence settings.

#	Vendor	Type	Cross section	Length
1	Civco	24h Gold	∅1.6mm	3mm
2	In-house	18h Gold	∅1.5mm	3mm
3	Civco	24h Gold	∅1.2mm	3mm
4	Beampoint	24h Gold	∅1.0mm	3mm
5	Visicoil	24h Gold	∅0.75mm	3mm

***Table 1**. Gold markers used in phantom study*

Result

Figure 2 exemplifies how the markers appear in the MR images depending on orientation and bandwidth. The apparent marker position within the image plane was independent of sequence, bandwidth, and frequency encoding direction. The position in the slice direction was; however; dependent on if the 2D or 3D sequence was used, with deviations of up to 1.3mm for marker number 4. Three markers had circular cross sections (1-3), for these the volume of the "hole" was directly dependent on the size of the marker. The image artifact was more pronounced for marker number 4, which had a star shaped cross section. Marker number 5 was spiral shaped, giving a hole with a volume equivalent to the expectations based on the diameter.

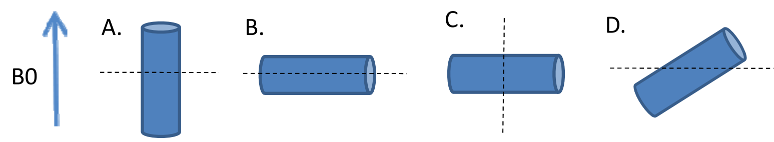

***Figure 1** Orientation of the markers relative B0. Image planes are visualized as dotted lines.*

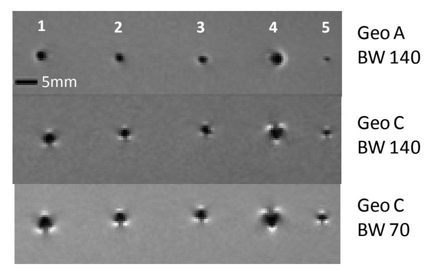

***Figure 2**. Gold markers visualized*

Discussion

The magnetic susceptibility of Gold differs with 25ppm compared to water. For a sequence with BW of 140Hz/Px on a 1.5T scanner this corresponds to an error in the depiction of the signal with 11 pixels. However, as the gold markers do not contribute with any signal, we only see a "hole" at the correct position of the marker. Therefore the apparent position of the marker is independent of the BW and direction of frequency encoding. However, local distortion of the main magnetic field caused by the marker will corrupt the slice selection, introducing a small error in the apparent marker position[2]. This effect can be avoided using a 3D sequence, as phase encoding directions are insensitive to susceptibility effects.

An interesting consequence of the mechanism behind the MR depiction of the markers is that the geometrical accuracy is directly dependent on the properties of the media/tissue hosting the marker. If the markers are positioned in fat, the apparent marker position will be shifted with the fat shift.

Conclusion

The error in the apparent marker position is small when the marker is positioned in water-like tissue. Usage of 2D sequences introduces small errors in the apparent position in the slice encoding direction. The distortions around the marker, and the error in the slice direction with 2D sequences, are dependent on both the marker size and the marker shape. Star shaped cross-sections introduced significantly larger artifacts compared to circular or spiral cross-sections.

References

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2. Schenck, J. F. (1996). "The role of magnetic susceptibility in magnetic resonance imaging: MRI magnetic compatibility of the first and second kinds." Med Phys 23(6): 815-50.