Orbital MRI: What is the best coil configuration?

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Purpose

Magnetic resonance imaging (MRI) of the orbit is currently used to diagnose various pathologies occurring within the eyeball or the orbit. Ocular and orbital MRI is recommended to be performed by the use of small surface coils. Previous studies indicated that the use of the appropriate coil is decisive for successful orbital MRI [1] and the use of a high-resolution microscopy coil improves image resolution dramatically and makes a detailed depiction of the orbital and globe structures possible [2].

In our study we systematically investigated the signal-to-noise ratio (SNR) by comparing the different coils and coil combinations which can be used for MRI of the orbital space. In particular, the additional use of the head coil was evaluated.

The purpose of this phantom study was to determine the coil configuration that provides the highest SNR in orbital MRI at 1.5 Tesla.
Methods and Materials

The eyeball and the orbital fat were simulated by a phantom which was built with a lime drowned in a butter dish. The position of the lime within the butter dish was chosen to reflect the anatomic position of the globe within the orbital fat (Fig. 1). MRI scans were acquired on a 1.5-Tesla system (MAGNETOM Avanto, Siemens Health Care Sector, Erlangen, Germany). After acquisition of a localizer scan, a T1-weighted spin echo (SE) sequence with 4-mm slice thickness was acquired in axial orientation using the following parameters: TR 500 ms, TE 11 ms, matrix 256 x 256, FOV 120 x 120 mm, NEX 1. This sequence was acquired twice for each coil (coil combination, respectively) to generate subtraction images for noise calculations.

Coils and coil combinations

The following coils were investigated:

- A small loop surface coil of 4 cm diameter 'Small loop coil'
- A pair of medium loop surface coils of 6 cm diameter 'Medium loop coil' and 'Double loop array coil' (this coil is sold by the vendor as temporomandibular-joint coil)
- An 8-channel, circular-polarised head coil 'CP head array coil'

In the 'Double loop array coil' setup the two 'Medium loop coils' were placed perpendicular to each other (Fig. 4). In case of using multiple coils, separate images were reconstructed from each coil element in addition to an image using all coils. The 'Double loop array coils' are not compatible with the head coil. Therefore the following coil setups and combinations were technically possible and used for the phantom measurements:

First test arrangement: 'Small loop coil' and 'CP head array coil' (Fig. 2)

1. 'Small loop coil' and 'CP head array coil': Only the farther head element read
2. 'Small loop coil' and 'CP head array coil': Only the closer head element read
3. 'Small loop coil' and 'CP head array coil': Only the small loop element read
4. 'Small loop coil' and 'CP head array coil': All elements read

Second test arrangement: 'Small loop coil' (Fig. 3)

5. 'Small loop coil': Small loop element read
Third test arrangement: 'Double loop array coil' (Fig. 4)

6. 'Double loop array coil': Only the superior element read
7. 'Double loop array coil': Only the temporal element read
8. 'Double loop array coil': Both elements read
9. 'Double loop array coil': Both elements read and adaptive combine was used

Fourth test arrangement: 'Medium loop coil' (Fig. 5)

10. 'Medium loop coil': Medium loop element read

Adaptive combine is a test algorithm which takes particular consideration of the signal received from regions within the FOV.

Quantitative image analysis

To determine the coil configuration that provides the best image quality, the SNR was calculated. Four regions of interest (ROI; superficial mesial, superficial temporal, deep mesial and deep temporal) were placed in the lime on the central slice of each sequence (Fig. 1). The distances from the centre of each ROI to the superior and temporal surface were chosen to cover most of the orbital content. Each ROI had the same size, measuring 1.5 cm³.

The signal intensity (SI) was determined in each ROI for each measurement and a mean SI value was calculated of both measurements. The SI of the noise (standard deviation, respectively) was assessed on the subtraction images using the same four anatomical ROI positions and size that were used to calculate the SI on the unsubtracted images.

The SNR was calculated according to the formula:

\[
\text{SNR} = \frac{\text{Mean SI}}{\text{Standard deviation of the noise}}
\]

Mean SNR of the four ROIs was calculated for each measurement with each coil or coil combination.
Fig. 1: T1-weighted spin echo (SE) sequence of the phantom which was built with a lime drowned in a butter dish (medium loop coil applied superior).

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Fig. 2: Coil configuration for the first test arrangement (1.-4.). The box represents the butter dish. The circle represents the lime. Four ROIs were placed in the lime on the central slice of each sequence.

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Fig. 3: Coil configuration for the second test arrangement (5.).
Fig. 4: Coil configuration for the third test arrangement (6.-9.).

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**Fig. 5:** Coil configuration for the fourth test arrangement (10).

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Results

The calculated SNRs for each ROI for each test arrangement are given in a table (Tab. 1).

If the medium loop coil was placed on the superior surface (10.) the highest mean SNR (27.52) was reached, even higher than with the small loop coil (Fig. 6). The combination of a pair of the double loop array coil arranged perpendicular to each other (8. and 9.) revealed a mean SNR of (21.65 and 21.51 with adaptive combine).

For the deep temporal region the highest SNR was achieved with the pair of the double loop array coil arranged perpendicular to each other (28.15). In superficial regions (mesial and temporal) the small loop coil (5.) showed a higher SNR (27.97 and 33.82) than the double loop array coil combination (8.; SNR = 17.25 and 28.28).

Additional use of the head coil (3. and 4.) decreased the mean SNR to 15.95 and 10.36 (Fig. 7). However, if the head coil and small loop coil were used together (4.) the SNR was similar in all 4 ROIs (superficial mesial 9.80, superficial temporal 10.54, deep mesial 10.73, deep temporal 10.38).

The lowest mean SNR was measured by one element of the head coil only (1. and 2.; SNR = 5.68 and 6.9).
Table 1: SNR calculated in each ROI for each test arrangement.

<table>
<thead>
<tr>
<th>ROI</th>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
<th>Test 4</th>
<th>Test 5</th>
<th>Test 6</th>
<th>Test 7</th>
<th>Test 8</th>
<th>Test 9</th>
<th>Test 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial mesial</td>
<td>5.95</td>
<td>6.11</td>
<td>20.57</td>
<td>9.80</td>
<td>27.97</td>
<td>14.94</td>
<td>10.82</td>
<td>17.25</td>
<td>18.18</td>
<td>33.63</td>
</tr>
<tr>
<td>Superficial temporal</td>
<td>6.94</td>
<td>6.03</td>
<td>24.98</td>
<td>10.54</td>
<td>33.82</td>
<td>21.00</td>
<td>21.00</td>
<td>28.28</td>
<td>29.39</td>
<td>45.45</td>
</tr>
</tbody>
</table>

Mean        | 5.68   | 6.90   | 15.95  | 10.36  | 20.95  | 14.13  | 16.52  | 21.65  | 21.51  | 27.52   |

1. ‘Small loop coil’ and ‘CP head array coil’: Only the farther head element read
2. ‘Small loop coil’ and ‘CP head array coil’: Only the closer head element read
3. ‘Small loop coil’ and ‘CP head array coil’: Only the small loop element read
4. ‘Small loop coil’ and ‘CP head array coil’: All elements read
5. ‘Small loop coil’: Small loop element read
6. ‘Double loop array coil’: Only the superior element read
7. ‘Double loop array coil’: Only the temporal element read
8. ‘Double loop array coil’: Both elements read
9. ‘Double loop array coil’: Both elements read and adaptive combine was used
10. ‘Medium loop coil’: Medium loop element read
**Fig. 6:** The medium loop coil (diameter 6 cm) achieved higher SNR values than the small loop coil (diameter 4 cm).

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Fig. 7: The single use of the small loop coil achieved higher SNR values in all ROIs than used with the head coil together.
Conclusion

The main finding of this study is that the medium loop coil (diameter 6 cm) revealed the highest mean SNR, followed by the combination of a pair of double loop array coils (each diameter 6 cm) arranged perpendicular to each other, which achieved the highest SNR in the deep temporal region.

Additional use of the head coil decreased the SNR considerably. This suggests that the head coil must be turned off when images of the eye are acquired by small surface coils, e.g. in children with retinoblastoma when the head coil is necessary in order to depict trilateral retinoblastoma [3].

The lowest SNR was measured by the head coil only, suggesting acquiring images of the eye and orbit unilaterally by the head coil only can no longer be recommended. However, the SNR remained similar in all measured ROIs, suggesting a constant image quality can be achieved throughout the image. Certainly, the head coil is useful in acquiring images of both orbits for the comparison.

In conclusion this quantitative analysis suggests that orbital MRI is best achieved by the use of a loop surface coil of 6 cm diameter. For deep regions (particular deep temporal) we recommend the combination of two 6 cm loop coils arranged perpendicular to each other. Additional use of the head coil seems to spoil the image quality by an increase of noise.
References

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