The Effect of Slice Thickness between 1 and 5mm with 3D fast-FLAIR on MRI Lesion Detection and Quantification in Multiple Sclerosis

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Introduction
The serial quantification of total MRI brain lesion load has become an established outcome measure in definitive trials of new multiple sclerosis (MS) therapies [1]. However, volume averaging at a standard slice thickness of 5mm may lead to smaller, low contrast lesions going undetected and produce inconsistent delineation of lesion boundaries. This study has used a 3D fast fluid attenuated inversion recovery sequence (fast-FLAIR) developed in our Unit [2] to obtain axial brain images at slice thicknesses of 5, 3 and 1mm. The aims were to investigate the impact of slice thickness on lesion load and measurement precision.

Methods
Eight patients with MS were studied, three with relapsing-remitting and five with secondary progressive disease. Patients were scanned at two sessions separated by an interval of 5 minutes. A 1.5T Signa GE machine was used to acquire the images with contiguous interleaved axial slabs/slices. During the first session, 3D f-FLAIR images were obtained with pure axial slices in decreasing slice thickness order (5, 3 and 1mm). The following parameters were used at all slice thicknesses: TI 1740, TR 4600, TE 140, ETI 24, FOV 25cm, 256×192 matrix. The patient was removed from the scanner and then after repositioning according to our standardised protocol [3], a further set of 3D fast-FLAIR images was obtained at each slice thickness.

Lesions were identified on the hardcopy of each sequence in isolation by two of us (PM, NT) and then quantified by a single observer using a semi-automated technique based on local thresholding [4]. Finally, the images were assessed together to identify lesions not visible at all slice thicknesses. Statistical comparisons between sequences were assessed with Wilcoxon's signed ranks test and two way ANOVA where appropriate.

Results
Lesion volumes and scan rescan agreement for each sequence are given in Table 1. The mean of the scan and rescan volumes have been used, to reduce the effects of measurement error. Reducing the slice thickness from 5mm to 3mm significantly increased derived lesion loads for all but one patient (p < 0.05), with an average gain of 8.1% (range, -2.9-19.2%). In contrast, further reducing the slice thickness from 3mm to 1mm did not yield an additional increase in total lesion load (p = 0.9).

Comparing the 5mm and 3mm sequences side by side, 170 lesions were identified on only the 3mm sequence, (mean individual lesion volume:0.13cm³). When only lesions seen at both 5mm and 3mm slice thickness were included in the lesion load, the mean lesion volumes at 5mm and 3mm were 23.0cm³ and 23.1cm³ respectively (p = 0.7). A similar side by side comparison of the 3mm and 1mm sequences revealed that 185 lesions were seen only on the 1mm sequence (mean individual lesion volume: 0.027cm³). Considering only those lesions identified on both 3mm and 1mm sequences, lesion volumes were 25.3cm³ and 24.7cm³ respectively and this difference approached statistical significance (p = 0.07).

Operator times (Table 1) to perform the quantification showed significant differences between slice thicknesses (p< 0.001).

Discussion
A gain in derived lesion load of 8% was produced by reducing the slice thickness from 5mm to 3mm and this supports a previous study showing an increase of 9% with such a reduction [5]. The authors of that study postulated a linear relationship between slice thickness and MRI visible lesion load, estimating that further reduction in slice thickness might produce up to a 20% increase in the MR detectable lesion volume. However, we found that further reducing the slice thickness from 3mm to 1mm did not increase the overall lesion load, despite the improved detection of small, generally low contrast lesions, because their contribution to overall lesion volume was minimal.

Furthermore, considering only those lesions identified at both 3mm and 1mm slice thicknesses, the derived lesion volumes at 1mm slice thickness were generally smaller, and this effect offset the small contribution of the additional lesions detected only at 1mm. This may in part reflect the fact that several lesions that appeared as confluent areas at 3mm could be seen to comprise several smaller, discrete lesions with the 1mm slice acquisition. Differences in volume averaging may also have contributed to this finding. For lesions of similar diameter to the slice thickness, volume averaging will tend to cause an overestimation of volume [5], while at smaller thicknesses this effect would diminish. The impact of this will depend on the size distribution of lesions for an individual patient, but this averaging may have been more apparent with the 3mm slice acquisition.

In summary, this study shows that although reducing slice thickness improves the detection of very small small lesions and improves reproducibility, this is at the expense of increasing operator time. More work is needed to define whether these modest gains lead to better MRI/clinical correlations or reduce sample size requirements for MS treatment trials. If the very small gains in sensitivity and precision do not achieve these goals, the continuation of 3mm slice thickness as the gold standard will be confirmed.

Table 1.

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Lesion Volume (cm³)</th>
<th>Mean Scan-Rescan Agreement (%)</th>
<th>Mean Operator time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5mm f-FLAIR</td>
<td>23.4 (14.0)</td>
<td>91</td>
<td>31</td>
</tr>
<tr>
<td>3mm f-FLAIR</td>
<td>25.3 (16.1)</td>
<td>95</td>
<td>58</td>
</tr>
<tr>
<td>1mm f-FLAIR</td>
<td>25.1 (22.6)</td>
<td>98</td>
<td>154</td>
</tr>
</tbody>
</table>

References

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