DETECTION AND MEASUREMENT OF DATA LOSS DUE TO MRI INTERLEAVE POSITIONING ERRORS

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Introduction

To obtain sufficient slices for full anatomical coverage, most MRI sequences require several "passes" (other synonymous terms used by scanner vendors include "acquisitions", "packages", and "concatenations") to produce a single scan set. For example, a scanner may acquire the odd slices in the first pass, and the even slices in the second pass. We refer to such scans as "interleaved" scans. With current MRI technology, scans with two to four or more acquisitions are routinely used. One common problem with interleaved scans is the potential of patient movement that can result in misregistration between acquisitions. In the two pass example, if the patient moves between the odd and even acquisitions, the odd and even slices would be misaligned with each other. This can result in overlapping coverage in parts of the volume, but incomplete coverage in others, with up to 50% data loss in extreme cases. **Figure 1** illustrates an example of how much data can be lost in a brain scan even with a small amount of patient movement. In this case, a nodding motion causes a five degree misalignment between the even and odd acquisitions of 3mm slices, resulting in large areas of overlap between consecutive slices (red areas in the left set of images), and a 24% loss of data (black stripes in the right image).

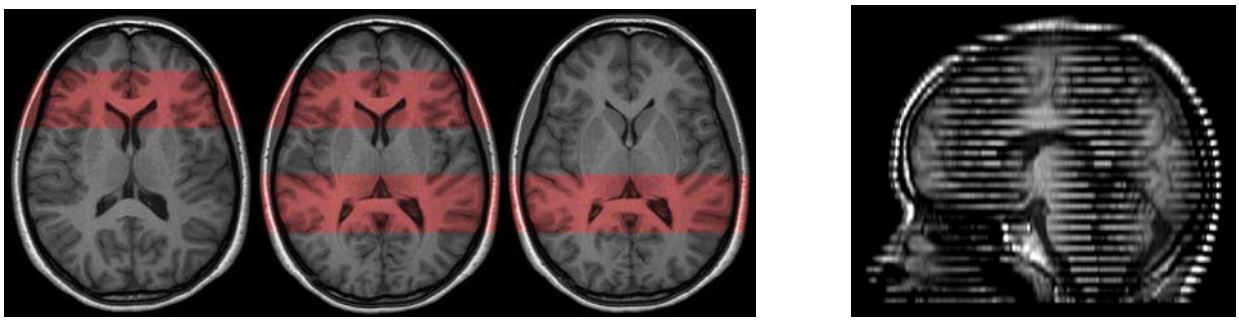

Figure 1. The left panel shows the overlapping coverage (red areas) as a result of the mispositioning of the middle slice. The areas that would normally be covered by the red regions in the middle slice are now missing. Blacking out these regions gives an idea of the extent of the missing data (right panel).

Methods

We have developed two methods to assess interleave positioning errors; one to detect the problem and the other to measure the amount of data loss. The first tool checks for the presence of misalignment by first measuring the similarity between regions in adjacent slices, then searches for a repeating pattern in the maxima and minima of similarity through the slice stack. The rationale is that a misaligned slice most likely overlaps in anatomical coverage with an adjacent slice, resulting in an unusually high similarity value on one side and a lower value on the other. **Figure 2** shows two examples of results of applying our detector to 3mm thick axial scans that have had one of their acquisitions shifted perpendicularly to the slice direction by 1/3 of a slice, which is an amount shown by our experiments to be extremely difficult to detect, even by radiologists who are visually checking for anatomical progression through the slice stack. In contrast, the regular patterns in the plots make the problem very apparent.

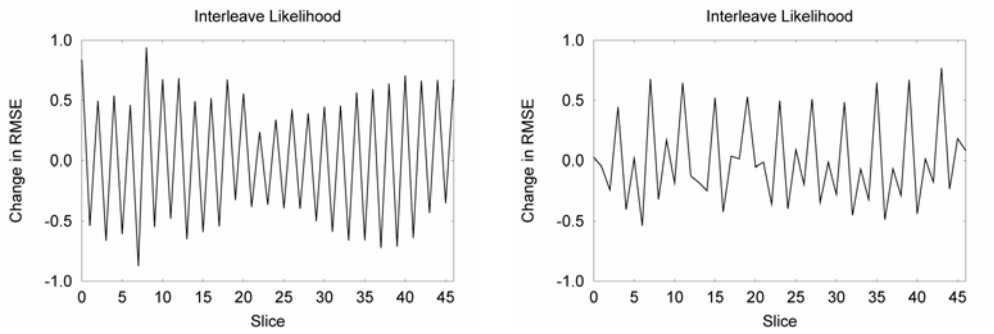

Figure 2. Output from the interleave positioning error detection tool. Large peaks or valleys at regular intervals indicate a misalignment. The left image shows a two-acquisition case (alternating peaks and valleys), and the right image shows a four-acquisition case (large peak at every fourth slice).

The second tool estimates the amount of data lost due to positioning error by using rigid registration. For each scan, a high resolution (1mm^3 voxel spacing) 3D MRI of the same patient is used as a positional reference. 3D scans are not acquired in a slice-by-slice manner, so motion errors are averaged, and coverage is usually not compromised. For a two-acquisition scan, the odd and even slices are independently registered to the 3D scan to find the difference in their positions. The procedure is similar for greater numbers of acquisitions, although the higher the number, the less accurate registration is likely to be. After the slice positions are determined, the data loss is estimated by computing the volume not covered by the slices.

To estimate the prevalence of the problem and the amount of data that could be lost in a clinical trial setting, we applied our tools to the scans of 125 randomly selected patients from a recent multiple sclerosis (MS) treatment trial. As is normally done in MS trials, straps were used to restrain the head and minimize motion during scanning, and all images were collected using a standardized protocol. One T1-weighted and one T2-weighted scan, both acquired axially with 3mm slice thickness, of each patient were processed (250 scans total). Only scans with two acquisitions were used to maximize registration accuracy.

Results

The results are summarized in **Table 1**. The figures show that, despite efforts to minimize motion, 12% of the T1 scans and over 16% of the T2 scans had at least 10% data loss.

	Data Loss		
	0-9%	10-19%	20+%
T1	110/125 (88.0%)	10/125 (8.0%)	5/125 (4.0%)
T2	104/125 (83.2%)	12/125 (9.6%)	9/125 (7.2%)

Table 1. Data loss statistics for MS clinical trial data.

Conclusions

We have determined that patient motion in multi-acquisition interleaved MRIs can result in significant loss of data. We have developed tools to detect and measure these positioning errors. The application of these tools to a MS clinical trial data set shows that the effect is potentially large enough to be a confounding factor in quantitative analysis.