Brain Atrophy Following Temporal Lobe Epilepsy Surgery

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Introduction

Current understanding of the secondary effects of brain surgery, both conventional and irradiative, is largely limited to clinical observations. Studies of post-operative imaging data have mainly concentrated on brain atrophy following radiotherapy and/or chemotherapy [1,2].

We have investigated the effect of conventional surgery on the unresected brain tissue based on the comparison of MR images acquired pre- and post-operatively in subjects with a history of mesio-temporal epilepsy. Matching of the pre- and post-op scans allows improved visualization of the morphological changes resulting from surgery, as shown in figure 1. This example illustrates an enlargement of the ventricules, indicating possible atrophy of the unresected tissue.

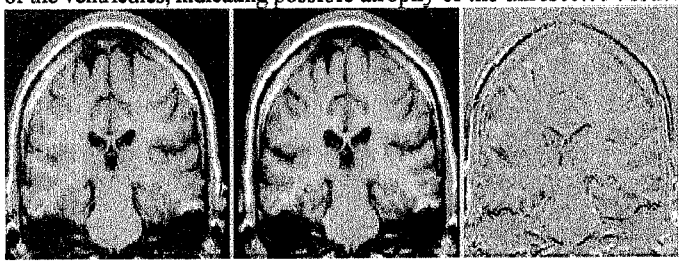

Figure 1. Left: Pre-operative scan; middle: post-operative scan, co-registered and intensity matched to the pre-op scan; right: difference image in a plane posterior to the resection, showing a pattern of 'shadows' typical of brain atrophy [1].

We have sought to quantify this effect. Our approach is based on the combination of semi-automatic brain segmentation to measure the total brain volume, pre- and post-operatively, and of manual drawing to measure the volume of the resected tissue. We have previously shown that scan matching improves the repeatibility of volumetric analysis in serial scans [3]. Therefore, the pre- and post-op scans were matched prior to volumetric analysis.

Methods

Data

Eight normal subjects were scanned prior to (pre-op or 'PR', mean interval: 4 months) and following unilateral mesio-temporal surgery (post-op or 'PO', mean interval: 3 months) using a 'Fast IRSPGR' T1-weighted gradient echo volume sequence (1.5mm thickness in the coronal plane) on a Signa 1.5T Echospeed MR imager (GE Medical Systems, Milwaukee, USA). Prior to further processing nonuniformity correction (NUC) was performed using a nonparametric method [4]. The PR and PO scans were co-registered (9-parameter rigid-body transformation) and intensity matched using our software, *MRreg* [5].

Volumetry

The total brain volume, *TBV*, in the matched PR and PO scans was estimated by seeding, thresholding and region-growing in every fifth slice (starting at the most anterior slice in which the brain is visible); a unique threshold level was used for all slices in the PR and PO scans for a given subject. The *TBV* was obtained by multiplying the sum of the volume in each slice by five. The measurements were performed twice, by different observers. The total volume loss, *TVL*, was defined as:

$$TVL = TBV_{PR} - TBV_{PO}$$

Two methods were used to estimate the resection volume, *RV*. First, RV was estimated by manual drawing in every fifth slice in the matched PO scans (direct method). However, 'sagging' of the unresected tissue into the resection cavity could result in an underestimate of *RV*. Therefore, a second drawing method was used that relies on anatomical landmarks, by manual drawing in the PR and PO scans of a set, or atlas, of anatomically defined sub-structures of the temporal lobe [3]. The second estimate of *RV* was then obtained by calculating the difference between the total volume of the substructures in the PR and PO images (atlas method).

The atrophy volume, *AV*, in the PO scans was calculated as the difference between the total volume loss and the resection volume:

$$AV = TVL - RV$$

Results and Discussion

The mean *TVL* was 34.6cm^3. The mean and standard deviation of the difference between repeated measuremsnts were -1.0cm^3 and 5.4cm^3, respectively. The mean of *VR* was 12.3cm^3 and 15.9cm^3 (mean and standard deviation of difference: -3.6cm^3 and 2.4cm^3), for the direct and atlas methods, respectively, which represents a significant difference (two-tailed, $p<0.005$); This is in agreement with our espectation of larger, and presumably more accurate, *VR* estimates from the atlas method. The correlation coefficient between the two sets of VR values was 0.90. We take the measurement error on *AV* to be the sum of *twice* the standard deviations of the repeated measurements for *TVL* and *RV*, which is 15.6cm^3.

The values of *TVL* (mean of two measurements), *RV* (atlas method) and *AV* are given in the table below. It demonstrates a significant atrophy in four cases (subjects #2-5). The amounts of atrophy represent changes of the order of 2-3% of the brain volume. In the other cases, the atrophy volume was less than the measurement error. In one case the result indicates an enlargement of the un-resected brain tissue, however, the amount is within the measurement error.

Subject #	*TVL* (cm^3)	*RV* (cm^3)	*AV* (cm^3)
1	24.8	12.6	12.2
2	52.3	19.0	33.3
3	59.3	17.9	41.4
4	40.8	24.1	16.7
5	48.8	15.8	33.0
6	14.8	12.2	2.6
7	10.7	13.9	-3.2
8	17.0	11.5	5.5

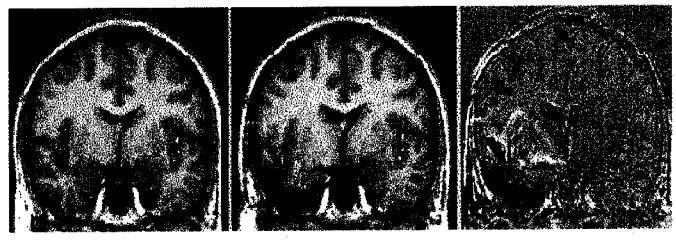

Figure 2. Subject #3. Left: Pre-operative scan; middle: post-operative scan, co-registered and intensity matched to the pre-op scan; right: difference image in a plane through the resection, showing the sagging of the structures superior to the resection into the resection cavity. These images also show clearly an enlargment of the ventricles.

Conclusions

We have demonstrated for the first time a significant degree of atrophy of the un-resected brain tissue in four out of eight patients who underwent surgery for chronic epilepsy. The causes and significance of this phenomenon are unknown. This must investigated further as it may be an important factor in surgical outcome.

References

1. Jager H.R. et al. *AJNR* **17**: 1275-1282 (1996).
2. Reddick W. E. et al. *Magn. Reson. Imaging* **16**: 413-421 (1998).
3. Moran N.M et al. *Epilepsia* (in press).
4. Sled J.G. et al, *IEEE Trans. Med. Imag.* **17**: 87-97 (1998).
5. Lemieux L. and Barker G.J., *Med. Phys.* **25**: 1049-1054 (1998).