Serial changes in Apparent Diffusion Coefficient in Acute Ischemic Stroke

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Target audience: Stroke physicians and scientists working in the field of diffusion-weighted imaging

Purpose

Regions of restricted water diffusion identified on diffusion-weighted imaging (DWI) have been used to identify core infarct in patients with acute ischemic stroke, although there has been much discussion about whether such lesions really represent irreversibly damaged tissue and what mechanisms underlie restricted diffusion.[1] Restricted diffusion lesions are commonly defined by visual inspection of a b1000 image rather than the absolute apparent diffusion coefficient (ADC), and serial imaging, co-registration and appropriate final infarct definitions are rarely used.[1] An ADC threshold of 620mm^2/s has recently been suggested to be both sensitive and specific for infarct core.[2] In this cohort of patients with acute ischemic stroke we used this threshold to create a tool to objectively define infarct core in serial DWI. These objectively defined masks were used to interrogate the data for early, sustained and late reversal of lesions.

Methods

Patients with ischemic stroke (<6hours from symptom onset) were recruited into an observational cohort study following informed consent or agreement from a representative, according to the protocol agreed by the UK National Research Ethics Service committee (ref:12/SC/0292). Serial MRI scans were performed (at presentation, 2 hours, 1 day, 1 week and 1 month). A 3.0T Siemens Verio scanner was used and scanning protocol included DWI (b=1000 and b=0s/mm^2, 1.8x1.8x2mm, 3 directions, TR=9000ms, TE=98ms) with automated ADC calculation, T1-weighted imaging and fluid attenuated inversion recovery (FLAIR) imaging at 1 month. Analysis was restricted to patients with lesions greater than 5mm axial diameter. Final infarct was defined manually using the 1-month FLAIR image. Final infarct was co-registered to each diffusion scan to quantify the serial ADC changes. Infarction before 1 month was objectively defined using an ADC threshold of 620mm^2/s and cluster-based analysis derived from FMRIB software library tools.[3-5] All scans were registered to the presenting scan to determine early, sustained and late lesion reversibility, which was defined objectively using the masks generated at each time point in a voxel-wise manner. A clinician confirmed regions of lesion reversal by visual inspection to exclude any errors of registration that might lead to erroneous results.

Results

Data from 17 eligible patients were analyzed, of which 13 had a 1-month scan. Serial ADC values within the co-registered final infarct can be seen in Figure 1. Voxel-wise analysis of the objectively defined lesion masks demonstrated that by volume 36% of lesions reverse in the first 2 hours after presentation with 17% reversed at 1 day (Figure 2). Although only 3% of this early reversal was sustained at 1 month, a total of 15% of the original ADC lesion had reversed in other regions (late reversal). Despite this late reversal in some regions, in other areas there were increases in lesion volume of 188% from presentation to 1 month. Sensitivity and specificity were 35.0% and 99.8% respectively for the presenting ADC lesion in determining final infarction. Sensitivity of the ADC lesion at 24 hours improved to 60%. Despite regions of lesion growth and reversal there was a good correlation between automated ADC lesion at 24 hours and final infarct at 1 month (Figure 3).

Discussion

Using objectively defined ADC lesions it appears that although early ADC lesion reversal is common, sustained lesion reversal is rare. Delayed reversal was also observed, although the magnitude of this change by volume is much less than average lesion growth. The transient nature of early ADC reversal compared to the sustained late changes suggests that discrete underlying pathophysiological processes are occurring, which are not differentiated by DWI. Although 24-hour ADC lesion and follow up FLAIR lesion volumes correlate, they are not necessarily representing the same regions of tissue.

Conclusion

The observation that lesion reversal during different time points has different tissue consequences supports the hypothesis of a poorly understood, dynamic and complex interplay of injury and repair following ischemic stroke.[6] Changes in the diffusivity of water may occur for different reasons at different time points, representing different pathological processes.

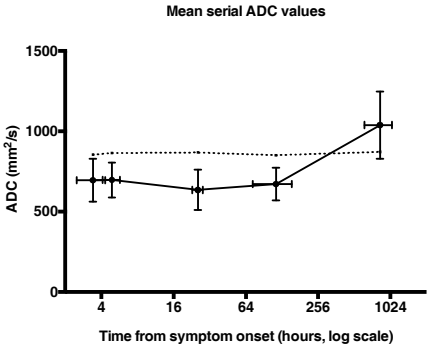

Figure 1 - Serial ADC values within the final infarct volume. Error bars represent standard deviation. Dashed line represents contralateral mean ADC.

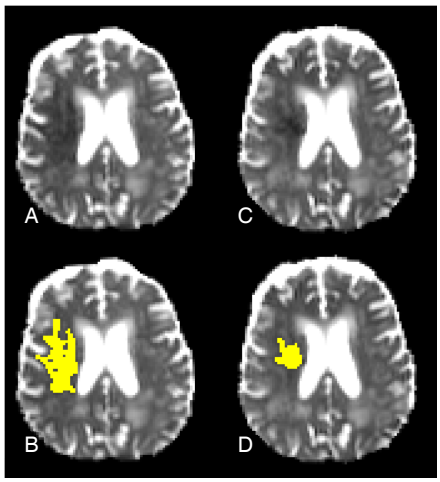

Figure 2 - Example of ADC lesion reversal at presentation (A,B) and 24 hours (C,D) with (lower) and without (upper) the objectively defined lesion mask (yellow)

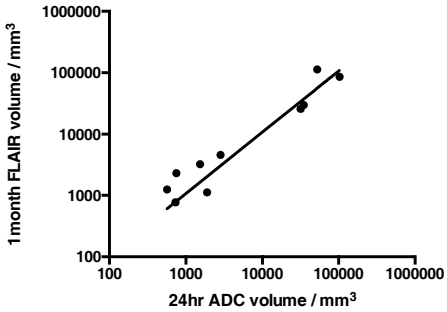

Figure 3 – Lesion volumes at 24 hours correlate with, but are not equal to, final infarct volume. Log scale. R^2=0.73, p=0.0015

References

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