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Uncertainties in the Assessment of Cortical Flow by Perfusion-Weighted MRI in Acute Stroke

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In a study of 145 acute ischemic stroke patients, Galinovic et al. [1] analyzed the validity of various parameters in perfusion-weighted magnetic resonance imaging (PW-MRI) to predict the extent of final infarction. They conclude that: (1) volumes of perfusion deficit overestimate the final lesion size, (2) volumes of calculated critical perfusion values were significantly different between programs for calculating the same map and threshold, and (3) on a patient-to-patient basis, a rater significantly under- or overestimated the final lesion size. Based on these data, the authors concluded that no combination of software, map and threshold was able to give a reliable estimate of tissue fate for all patients, thereby severely questioning the wide acceptance of the application of MRI procedures to assess the 'penumbra' or to predict the final lesion size.

After the first reports of the use of perfusion-weighted MRI (PW-MRI) in critically perfused tissue to predict the extent of final infarctions [2, 3] and assess reperfusion after recanalization [4], several studies proved that the values for critically perfused tissue were dependant on the methods used for its calculation [5–7]. Due to intrinsic characteristics of these methods, PW-MRI was considered to be an unreliable tool to derive absolute values for cerebral blood flow [8], an assumption supported by a low correspondence of flow values determined by PW-MRI to those from quantitative measurements with positron emission tomography with ^{15}O -labeled water in healthy volunteers [9] and patients after stroke [10, 11].

Two different limitations of PW-MRI might be responsible for the inaccuracies in the assessment of reliable flow values: the difficulties in accurately measuring the delay in tracer arrival, dispersion and transit in pathologically perfused tissue, and the difficulties in determining the arterial input function for the respective tissue volume. In most studies, the delay of tracer transit in the critical area is compared to the contralateral side using different procedures of analysis for the delay in bolus arrival [12]; after some corrections, these estimates may show some correlations to quantitative flow values [11, 13–15], and arrival delay has successfully been applied to predict outcome based on tissue at risk and response to reperfusion [16].

However, whereas non-deconvolved methods to assess the delay are useful to demonstrate effects of reperfusion due to recana-

lization, they have limited value in assessing changes in blood flow due to improved collateral perfusion. This means that patients with regional hemodynamic delay due to occlusion or stenosis of the supplying arteries will have time-to-peak abnormalities due to the delay in arterial input, and changes in the perfusion within these areas usually cannot be detected accurately by determination of the delay in tracer input, which might not be affected in the territory around an occluded vessel, despite the fact that blood flow in the collaterals might actually be increased.

Deconvolution methods of the tracer transit including input functions may be a better option in these patients [5], but T_{max} will mainly show the delay, so probably suffers from the same restrictions as, for example, time-to-peak – i.e. from the long way the blood has to take before reaching the regions around the territory around the occluded vessel. Non-time-domain parameters, applying delay-insensitive deconvolution methods [17], might be better suited to assess critical hypoperfusion in patients with large arterial occlusion [18], even though these measures are probably most commonly affected by the increased bolus dispersion taking place in the collaterals. However, these methods suffer from uncertainty in defining a reliable input function, which is often obtained from the neck or from the contralateral side [7]. These vessels yield an imprecise definition of the input function to determine collateral flow, which is important for the survival of tissue in the area surrounding an ischemic infarct, predicting the response to endovascular therapy [19], and is the target of treatment strategies beyond revascularization procedures. Since collateral blood supply is believed to be a key prognostic factor in acute stroke, existing methods for perfusion-weighted imaging map calculation and mismatch definition have to be optimized to improve the detection of penumbral collateral supply in the future.

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