CT Perfusion Mismatch in Subacute Stroke: Oligemia or Luxury Perfusion? Response to Persistent Benign Oligemia Causes CT Perfusion Mismatch in Patients with Intracranial Large Artery Occlusive Disease during Subacute Stroke

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We read with great interest the study of Li et al. [1] which demonstrates the existence of a mismatched area with similar characteristics to penumbra in patients with intracranial large artery occlusive disease (ICAD) during the subacute phase of stroke. The authors suggest that this area may be the result of benign oligemia rather than penumbra. CBV ratio was significantly higher in the ICAD versus the acute stroke group, and there was a trend toward higher CBF values in the ICAD group as well. MTT values were >145% in both groups. However, the authors did not consider the possibility that these data may be the result of postischemic hyperperfusion (PH) rather than oligemia. PH refers to restoration of perfusion in a cerebrovascular territory affected by prior severe ischemia due to either spontaneous or therapeutic recanalization of the occluded vessels. This phenomenon has been termed “luxury perfusion” and may or may not progress to infarction. Luxury perfusion refers to a condition where CBF is in excess of oxygen demand. Luxury perfusion thus represents nonnutritive flow to infarcted tissue, resulting from a loss of cerebrovascular autoregulation. Luxury perfusion is reported to occur in up to one-third of patients by 48 h after ischemic stroke [2]. With functional imaging (PET/SPECT) [2] in animal and human studies, the pattern of luxury perfusion is characterized by a near-normal or slight increase in CBV and CBF; however, limited data are available on this topic with respect to CT perfusion (CTP) imaging.

Nagar et al. [3] reported elevated CBV, MTT, and variable CBF in patients with subacute infarcts, ascribing these changes to the reperfusion phenomenon masking acute/subacute hypoperfusion.

The appearance of CTP data in the subacute stage of ischemic stroke can lead to misinterpretation of tissue as normal or simply oligemic [4]. However, in this setting, the neurologist or radiologist should already suspect infarction either clinically, from areas of low attenuation on unenhanced CT images, or from similar findings on the source imaging data from the CT-angiography/CTP. Thus, careful patient history and physical examination as well as critical assessment of unenhanced CT and dynamic CT source data are critical prior to CTP interpretation.

Software applications from different vendors also do not generate equivalent quantitative perfusion results. Caution should thus be exercised when interpreting quantitative CTP measures because these values may vary considerably depending on the postprocessing software. In the work of Li et al. [1], important methodological details concerning the CTP postprocessing data are missing. The major mathematical technique utilized for calculation of perfusion parameters is the deconvolution approach. Deconvolution can be performed by several methods. The classic deconvolution method is termed “standard singular value decomposition” (ssVD). This technique is robust and independent of the underlying vascular anatomy (i.e., intra/extracranial stenoses and/or leptomeningeal collaterals). However, the technique is sensitive to delayed arrival of contrast media. When such delays occur, MTT is overestimated and CBF is underestimated. The use of abnormal CBF/MTT values may lead to overestimation of the ischemic penumbra by including nonischemic brain regions with delayed contrast agent arrival into calculations. To overcome

these difficulties, new deconvolution methods have been developed to minimize the effects of bolus delay and dispersion, including delay-corrected deconvolution (dSVD) and delay-insensitive technique named block-circulant deconvolution (bSVD) algorithms. As a general rule, the use of a delay-insensitive method is recommended when dealing with stroke patients, a population in whom arterial stenoses are common, because dSVD and bSVD methods yield more stable results than sSVD regardless of contrast agent delay.

Kamalian et al. [5] reported that MTT maps optimally distinguish benign oligemia from true “at-risk” ischemic penumbra, but that thresholds vary depending upon the postprocessing technique (sSVD or dSVD). In light of these considerations to correctly interpret the work of Li et al., we must know which method the authors used. It is critical for radiologists using PCT for stroke imaging to be familiar with the postprocessing soft-

ware used at their institution, including its advantages and limitations. This can be helpful to avoid misinterpretation of perfusion maps and to define the infarct core and penumbra more accurately. Also in the presence of MTT prolongation and near-normal CBV and CBF values, it is important to keep in mind the possibility of PH, although the presence of PH must be supported by findings on unenhanced CT, dynamic source data, and/or clinical data.

The concepts of the penumbra, oligemia, and PH have not yet been fully resolved, and further studies must be performed to better understand the hemodynamic phenomena that occur in the acute and subacute phases of ischemic stroke.

Conflict of Interest

The authors declare no conflict of interest.

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