Absolute Quantification of Cerebral Perfusion Parameters: Volunteers Examined by Dynamic Susceptibility Contrast MRI and SPECT During Normal Breathing and Hyperventilation

R. Wirestam[1], E. Ryding[2], P. Reinstrup[3], T. Ohlsson[4], F. Ståhlberg[1,5], S. Holtås[5]

[1]Dept. of Medical Radiation Physics, Lund University, Lund, Sweden, [2]Dept. of Clinical Neurophysiology, Lund University Hospital, Lund, Sweden, [3]Dept. of Anaesthesiology, Lund University Hospital, Lund, Sweden, [4]Radiation Physics, Lund University Hospital, Lund, Sweden, [5]Dept. of Radiology, Lund University, Lund, Sweden

Introduction

The use of dynamic susceptibility contrast (DSC) MRI for absolute quantification of perfusion-related parameters is promising (1, 2), but the concept is still controversial and far from well established. Accurate registration of the arterial input function (AIF) is hampered by partial-volume effects (3), signal saturation (4) and local geometrical distortion (5). Furthermore, the relaxation effects at a given contrast agent concentration are, most likely, different in arteries and capillaries (6). To further validate the DSC-MRI concept, cerebral blood volume (CBV) estimates obtained by DSC-MRI were compared with the corresponding results obtained by single photon emission computed tomography (SPECT) in normal volunteers examined during normal breathing and hyperventilation.

Methods

Eight volunteers were examined by DSC-MRI as well as by SPECT during normal breathing and hyperventilation. DSC-MRI was performed using GRE-EPI with TE=54 ms, 10 slices and a temporal resolution of 1.65 s (Siemens Magnetom Vision 1.5 T). Maps of CBV and cerebral blood flow (CBF) were calculated according to previously described theory (2), employing deconvolution based on singular value decomposition (SVD) (7). The AIF area, i.e. the time integral of the arterial concentration $C_{art}(t)$, was determined from the same arterial location in both the normal and the hyperventilation case. A correction for signal-saturation effects in the large arteries was introduced, somewhat similar to the suggestion by Ellinger et al. (4); the current method was, however, based on the combined concentration-time information from a large artery (showing distorted shape due to signal saturation) and a smaller artery (showing reasonable shape but suffering from partial-volume effects and a subsequently underestimated area). The SPECT investigation was based on Tc-99m-labelled red blood cells. Whole-brain CBV estimates, in absolute terms, from DSC-MRI and SPECT were obtained and compared. The DSC-MRI investigation also allowed for assessment of absolute CBF during normal breathing and hyperventilation.

Results

In all 8 volunteers, DSC-MRI-based as well as SPECT-based blood-volume estimates (denoted CBV_{MRI} and CBV_{SPECT}, respectively) decreased when the subject was hyperventilating. Figure 1 shows CBV_{MRI} versus CBV_{SPECT}, including data from normal breathing as well as hyperventilation. The DSC-MRI-based blood-flow values (CBF_{MRI}) also showed a decrease during hyperventilation in all subjects. Average whole-brain CBV_{MRI}, CBV_{SPECT} and CBF_{MRI} estimates are given in Table 1 (mean±SD, n=8). The results indicate that CBV_{MRI} as well as CBV_{SPECT} decreased by 19% during hyperventilation, while the corresponding CBF_{MRI} decrease was 29%.

Discussion

It is indeed encouraging that a decrease in CBV_{MRI} and CBF_{MRI} during hyperventilation was detected in all volunteers. Furthermore, the observed correlation between CBV_{MRI} and CBV_{SPECT} was reasonable (r=0.69). The perhaps most interesting observation is that the relative CBV decrease, caused by hyperventilation, was very similar for DSC-MRI and SPECT. However, the DSC-MRI-based absolute perfusion values were high, in accordance with previous experimental DSC-MRI investigations (1, 2) and theoretical predictions (6). If a relationship of proportionality between the DSC-MRI-based and SPECT-based CBV results is assumed, i.e. $CBV_{MRI}=k \cdot CBV_{SPECT}$, the present data indicates that k=1.8. A preliminary re-evaluation of CBF data from a previous study comparing DSC-MRI (employing a simultaneous dual FLASH pulse sequence) and Xe-133 SPECT (2), indicates a very similar proportionality constant (unpublished result). Finally, in spite of the applied correction, accurate determination of $C_{art}(t)$ was difficult in some cases, and the larger standard deviation seen in the DSC-MRI results, as compared with SPECT, might be a reflection of this difficulty.

References

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Table 1

	CBV_{MRI} [ml/(100g)]	CBV_{SPECT} [ml/(100g)]	CBF_{MRI} [ml/(min 100g)]
Normal breathing	7.5±1.5	4.1±0.28	73±19
Hyperventilation	6.0±1.1	3.3±0.30	52±7.9

Figure 1