Rate of Myocardial Contrast Enhancement with Extracellular Contrast Agent and Relationship to Perfusion Reserve

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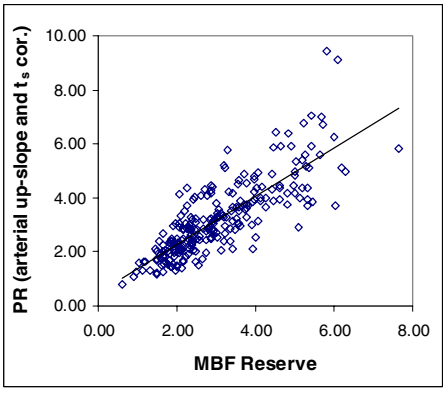
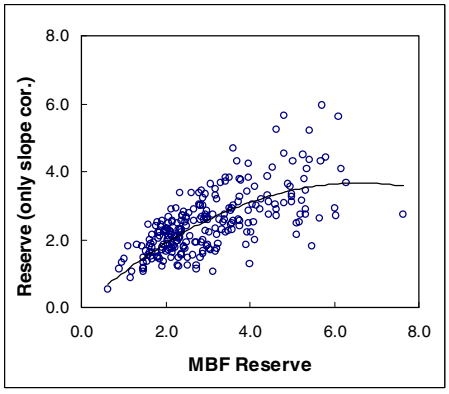
Introduction: The myocardial perfusion reserve (PR) defined in analogy to the coronary flow reserve, as the ratio of hyperemic and basal myocardial blood flow, is used to determine the hemodynamic severity of epicardial lesions. For MRI, the myocardial rate of contrast enhancement (CE), normalized by the rate of contrast enhancement in the blood pool, measured for rest and vasodilation, respectively, has been widely used to estimate the myocardial PR. Nevertheless the values for this PR index obtained with MRI in normal, healthy controls fell considerably below perfusion reserves measured with other well-established modalities[1]. In this study we investigated the relationship between the myocardial rate of CE with an extra-cellular contrast agent, and myocardial blood flow (MBF), to arrive at a better estimate of the PR.

Methods: 17 volunteers underwent first pass perfusion studies at rest and during vasodilation with adenosine (0.14 mg/min per kg BW) in a 1.5 Tesla clinical MR scanner, using a flexible 4-element phased array coil. Perfusion images during the first pass of a contrast bolus (Magnevist, Berlex; dosage of 0.04 mmol per kg of body weight) were acquired with a T1-weighted gradient echo pulse sequence, with a non-slice-selective saturation recovery magnetization preparation (TR/TE/TI/ flip = 2.2/1.2/90 ms/ 18˚, 256 x 152 matrix, receiver bandwidth of 31 kHz, FOV: 280-340 mm by 300 mm), both at baseline and during maximal vasodilation (iv adenosine 0.14 mg/kg/min for > 3 minutes). Starting with the central volume principle[2], the rate of change of the myocardial residue response, $q(t)$, in response to a constant rate arterial input $i(t) = a_1 \cdot t$, was approximated by the following proportionality relationship between maximum up-slope (dq/dt) measured at time t_s, the slope of the arterial input (a_1), and myocardial blood flow F: $dq/dt \propto a_1 \cdot t_s \cdot F$. The following assumptions were made: the contrast injection is rapid, the arterial input before the first pass peak can be approximated as a constant rate input, and the time t_s for reaching the maximum up-slope is short in comparison to the myocardial mean transit time. The quantities a_1, t_s, and dq/dt were measured from signal intensity versus time curves to estimate the perfusion reserve. Absolute MBF was calculated by deconvolution, a method validated against measurements with microspheres, albeit more complex and technically demanding than measurements of the rate of CE.

Results: The perfusion reserve index based on the myocardial rate of CE ("up-slope"), corrected by the slope of the arterial input and the time t_s, correlated more closely with the ratio of hyperemic MBF divided by baseline MBF (r=0.82), than a perfusion reserve ratio calculated from the myocardial "up-slope", normalized only by the arterial "up-slope" (r=0.68). Linear regression analysis showed that the perfusion reserve corrected only by the arterial "up-slope" had a significant negative quadratic dependence on the MBF ratio. The 95% limits of agreement from Bland Altman analysis for the perfusion reserve corrected by arterial "up-slope" and MBF ratio (95% limits of agreement: -2.4 – 1.29; mean difference: -0.6; $p<0.05$) were larger than for the perfusion reserve corrected by both arterial "up-slope" and t_s (95% limits of agreement: -1.8 – 1.5; mean difference: 0.17, n.s.)

Discussion: Simulations and theory predict that the myocardial rate of CE increases approximately linearly with time in response to a constant rate arterial input. This implies that the slope ratio, normalized by both the "up-slope" of the arterial input, and the time (t_s) at which the rate of myocardial CE reaches a maximum, should be in better agreement with the ratio of MBF's measured during hyperemia and rest, than a myocardial "up-slope" ratio that is only normalized by the arterial "up-slope". While the "up-slope" ratio used in previous studies appears to have been derived empirically, the new algorithm used in this study is based on the central volume principle of Zierler[2].





References:

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