

Compte rendu de congrès

## Quantification methods Techniques de quantification

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### Abstract

Ultrasound contrast agents can be assimilated to intravascular flow tracers opening the field of myocardial blood flow (MBF) quantification. However, tracer theories are invalidated because of microbubble unstable structure and peripheral injection. In order to overcome these limitations, new models have been developed as destruction/refilling sequences allowing MBF assessment. © 2002 Éditions scientifiques et médicales Elsevier SAS. All rights reserved.

### Résumé

Les agents de contraste ultrasonore assimilés à des traceurs intravasculaires ouvrent les portes de la quantification de la perfusion myocardique. Cependant, en raison de leurs propriétés, les théories des traceurs sont invalidées. De nouvelles approches ont été développées comme les séquences de destruction/remplissage qui permettent une évaluation quantitative des débits myocardiques. © 2002 Éditions scientifiques et médicales Elsevier SAS. Tous droits réservés.

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The microbubbles contained in the echocardiographic contrast agents remain entirely within the intravascular space and can be assimilated to intravascular flow tracers. Accordingly, several studies have been performed to quantify blood flow by contrast echocardiography based on tracer theory. In this field the most ambitious end point is the quantification of myocardial blood flow, which is more difficult than the quantification of flow in other organs because of the movements of the muscle during cardiac imaging and of the complexity of coronary microcirculation.

Approaching the quantification of myocardial blood flow by contrast echocardiography, two main situations should be considered as to the site and the modality of contrast

administration. The contrast agent can be injected at the inlet of the coronary circulation (central injection) or in a peripheral vein (remote injection).

In the central injection model the agent is administered directly into the coronary arteries or in the left ventricular cavity to facilitate its mixing with blood. The important issue for quantification is that the agent is administered as a bolus, ideally in an instantaneous way. In this model the parameters related to the appearance of contrast in the myocardium allow blood flow quantification with difficulty as myocardial appearance is very short. Conversely, several experimental studies have demonstrated that coronary blood flow can be quantified by the analysis of the transit times of the agent through the myocardial microcirculation. Attempts to mimic a central injection have been made by a mathematical deconvolution of the curves obtained by a peripheral contrast administration. However, deconvolution algorithms introduce a huge amount of noise, and these attempts have been abandoned. Thus, a bolus central injection

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tion of the agent strictly at present requires an invasive approach.

If a contrast agent is injected as a bolus in a peripheral vein, its input function is instantaneous in the vein but becomes heavily dispersed in the left side heart. This is due to the mixing of the agent with the blood inside the vessels and the cardiac cavities, and to its passage through the lungs, where the agent crosses circuits of different length. In the model of peripheral, remote injection-independently of the modality of contrast administration-the input function in the coronary circulation is so dispersed that coronary blood flow can hardly be quantified by the analysis of myocardial transit times; in this scenario the comparison of myocardial appearance time in different areas provides an information on relative perfusion of the different myocardial walls.

To overcome the limitations of the models above, a peripheral venous infusion of the contrast agent has been utilized together with new technologies (as pulse inversion, power modulation or coherent contrast imaging) which allow myocardial contrast refilling to be evaluated after the destruction of microbubbles by high energy ultrasound [1,2]. In this model the agent is infused intravenously to obtain a constant concentration, and the destruction of microbubbles by high energy ultrasound is assumed to be instantaneous, occurring within a few frames. Thus, such a model mimics a central injection of the agent and guarantees an adequate mixing and a constant concentration of the agent because of its infusion. Using this approach, myocardial refilling follows the equation  $y = A(1 - e^{-bt}) + C$ , where  $A$  is myocardial plateau intensity (which reflects myocardial vascularity),  $e$  is the base of natural logarithms,  $b$  is signal intensity rise (reflecting blood flow velocity),  $t$  is time after

microbubble destruction and  $C$  is offset of intensity. The product of  $A$  and  $b$  provides quantitative information on myocardial blood flow as demonstrated in several experimental studies and initially validated in man. However, both the parameters  $A$  and  $b$  are affected by several factors, including examination variables.

For several years, contrast echocardiographic images were recorded on video tapes and digitized off-line using computer boards. Image storage on video tapes, however, is accompanied by a significant image degradation, so that a fall in image content can be predicted using this approach. More recently new scanners have been produced which allow to generate, store, retrieve and analyze the images in a digital format. Several reasons let us believe that this is the winning trend in technology. In both digital and digitized images, the analysis can be performed on the entire image or, more commonly, in regions of interest. The parameters measured inside these regions include signal intensity, time intervals derived from the analysis of several images, or statistical parameters. Finally, functional images can be generated to facilitate image display and qualitative interpretation.

## References

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