Influence of the Fit-Function on Myocardial Perfusion Measurements

A. Karg[1], K. Oberholzer[1], N. Abegunewardene[2], B. Romaneehsen[1], D. Becker[2], M. Vosseler[2], N. Hoffmann[1], G. Horstick[2], K. F. Kreitner[1], W. G. Schreiber[1]

[1]Department of Radiology, Johannes Gutenberg-University, Mainz, Rheinland-Pfalz, Germany, [2]2nd medical Clinic, Johannes Gutenberg-University, Mainz, Rheinland-Pfalz, Germany

Abstract

Influences on myocardial perfusion reserve (MPR) determination by a linear fit, a gamma-variate fit and numerical calculation of the steepest slope were examined. Variations between the linear and both other methods were large ((-4.5 ± 29.3)% for linear vs. gamma-variate and (-4.5 ± 28.9)% for linear vs. numerical evaluation). Variations between gamma-variate and numerical calculation were smaller (-0.01 ± 1.8)%. If the fit range was expanded by two time-points, variations were largest for linear fit function ((0.41 ± 19.5)%) and smaller for the gamma-variate fit ((1.0 ± 12)%). The numerical calculation is not influenced by a change of the evaluation-range.

Introduction

For semiquantitative analysis of myocardial perfusion the steepest up-slope may be used as a surrogate marker for myocardial blood flow [1]. The up-slope may be used by fitting with different mathematical functions. In recent studies a linear function [1] and a gamma-variate-function [2] have been described. They were chosen because of stability of fit [1, 2] or hemodynamic considerations [3]. It was the aim of this study to determine the influence of the choice of the fit-function to the semi quantitative determination of the MPR and to compare results to calculation of the steepest up-slope by numerical differentiation of the measurement-points.

Materials and Methods

Measurements were performed on a Magnetom Sonata (Siemens, Germany) under resting- and under stress-conditions (Adenosine infusion (140µg/kg BW/min). A SSFP-sequence with a non-selective saturation pulse and TR/TI/TE: 356ms/1.16ms/187ms, α: 50°, FoV: 350mm x 350mm, Matrix: 128 x 128, bandwidth: 1400 Hz/Px was used [4]. During each heartbeat, 1-2 slices with a thickness of 8mm were acquired in the short axis before, during and after application of 0.04ml Gadolinium per kg BW.

In each image-series, regions of interest (ROIs) were drawn according to a six segment-model. The arterial input function (AIF) was determined from the left ventricular cavity. Signal intensity values were normalized to their precontrast signal intensity. The up-slope of the signal intensity in each curve was fitted by a linear (Eq. 1) and a gamma-variate-function (Eq. 2) using an in-house-software, developed under PV-Wave (Visual Numerics, Boulder, Co). The steepest up-slope was calculated from the fit parameters.

$$NSI(t) = at + b \qquad \text{Fit-parameters: a, b} \qquad \text{Eq. 1}$$

$$NSI(t) = at^b \cdot e^{-\frac{t}{c}} + d \qquad \text{Fit-Parameters: a, b, c, d} \qquad \text{Eq. 2}$$

For numerical differentiation, the difference between two adjacent signal intensities was calculated relatively to their time displacement and maximum value was acquired (Eq. 3).

$$\max\left(\frac{SI(t_n) - SI(t_{n-1})}{t_n - t_{n-1}}\right) \qquad \text{Eq. 3}$$

Subsequently, the MPR was calculated using Eq. 4.

$$MPR = \frac{slope^{myo}{}_{stress} \,/\, slope^{AIF}{}_{stress}}{slope^{myo}{}_{rest} \,/\, slope^{AIF}{}_{rest}} \qquad \text{Eq. 4}$$

The procedure was repeated with an expanded (one time point more on each side) fit range (Fig. 1). The quality of the fit was described by an F-test. Different fit-functions and different fit-ranges were compared by Box-Plots and Bland-Altman-plots.

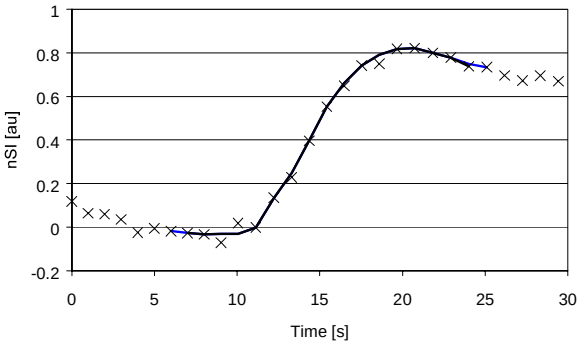

Fig. 1: *normal (black) and by one time point on each side expanded fit-range (blue)*

Results

42 MPR-values were calculated from 84 Segments. The variation between two fits was minimal for comparison of numerical differentiation and gamma-variate ((-0.02 ± 1.8)%) and maximal for comparison of linear fit to numerical differentiation and gamma-variate with (-4.5 ± 29)% and (-4.5 ± 29.3)% respectively (Fig. 2). When different fit-ranges were used, variations were (0.41 ± 19.5)% for the linear fit and (1.0 ± 12)% for gamma-variate (Fig. 3).

The F-test gave significant p-values for both firt-forms (0.06 ±0,188 for linear fit and 0.01 ± 0.011 for gamma-variate fit).

Discussion

Results show that MPR-values obtained using a linear function differed significantly from MPR-values obtained using the two other methods. Moreover, MPR-values varied more than gamma-variate if fit-range was expanded. This may be considered an indication for an elevated intraobserver-variability. Numerical differentiation is not influenced by variations of the fit range but could by less accurate if noise is superposed to the signal intensity-curves. For accurate results, gamma-variate and numerical differentiation appear to be more consistent.

Acknowledgement

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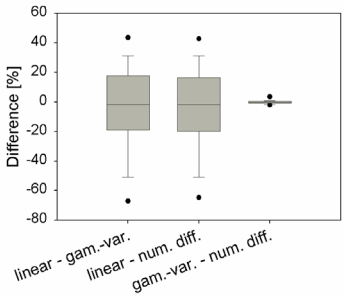

Fig. 2: *Differences in MPR between different methods*

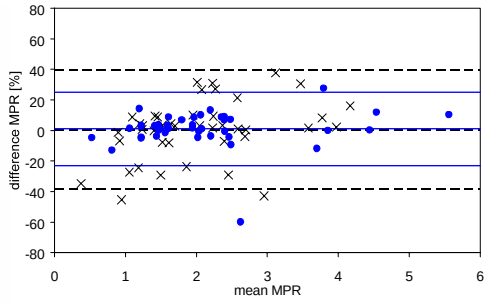

Fig. 3: Expandet fit-range: higher variations for linear fit (- - -×- - -), lower for gamma-variate (—●—)

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