Prediction of Contrast Bolus Shape Using Test-Bolus Measurements

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Introduction: CE-MRA utilizes the contrast media (CM) related signal enhancement during the first pass of a contrast media bolus. It is therefore essential to coordinate the contrast bolus with data acquisition. Techniques like "test-bolus" measurements or "fluoroscopic" triggering serve for that purpose. The shape of the bolus depend on the injection protocol (flow rate, volume, saline flash), on cardiac output, on the anatomical location and on other patho-physiological parameters. As CM concentration varies during acquisition of k-space data a more or less pronounced filter effect results additionally [1,2]. The development of programmable power injectors enables the application of sophisticated injection protocols which could optimize the bolus shape by individually adapted injection protocols. Such an approach should stabilize and improve the image quality of CE-MRA. To optimize an individual injection protocol the relation between contrast media administration and bolus kinetics must be analyzed. For that purpose it was investigated if linear system theory can be applied to find the transfer function of the cardio-vascular system and predict the measurement bolus using the data of a test-bolus.

Material and Methods: The CM administration (single or double dose) of routine clinical investigation was subdivided into a test bolus (TB) and a subsequent measurement bolus (MB). During the injection the arterial contrast media concentration was determined by special sequence optimized for measuring the arterial input function [3]. With additional proton density images (gradient echo, TR=100ms, TE=1.6ms, al=5°) the CM-concentration was calculated from $\Delta R1$ for the time series [4]. Measurements were performed with 58 patients (female=33, male=25) after informed consent. Injection rates of 2ml/s and 1ml/s were used. The total injected volume of the TB and the MB was kept constant (e.g. single dose: MB=16ml CM + 20ml NaCl, TB 2ml CM + 34ml NaCl). To predict the shape of the measurement bolus by convolution of the impulse residue function of a individual patient and the defined injection function a program was implemented in IDL (RSI, Bolder Colorado). This program calculates also the system impulse residue function by deconvolution (SVD) from theTB or the MB using the related infusion rate and infusion duration.

Results: The measurements show the large variation of the MB for a specific injection protocol and a specific anatomical location among different individuals (Fig.1). A large range of characteristic values (time to peak, width of half maximum) of the measurement bolus could be extracted. The scans also exactly documented the temporal correlation between TB and MB (Fig.2 left). For TB measurements without artifacts and a sufficient high contrast to noise ratio linear system theory allowed a good estimation of the decisive MB (Fig. 2).

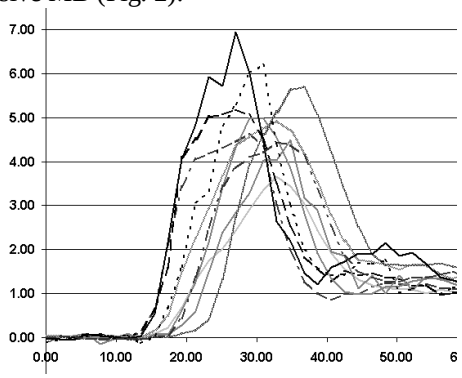

Fig. 1. Carotis, single dose, 1ml/s, 20ml NaCl

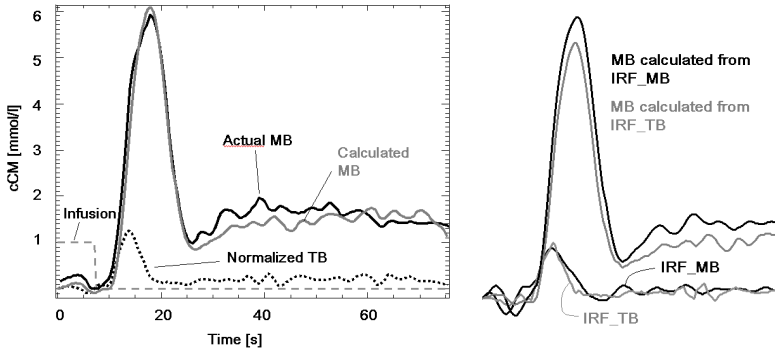

Fig.2. (left) Actual MB and calculated MB from the normalized TB. (right) The impulse residue functions calculated from TB and MB. The normalized TB equals almost the IRF_TB.

Discussion: Although many complex factors contribute to the transfer-function of the cardio-vascular system it was found that linear system theory is applicable for the prediction of a MB using a TB-measurement. However it is essential to use a sequence which suppress any inflow enhancement and result in a sufficient CNR of the TB-measurement. Optimised TB dosage can reduce uncertainties from TB measurement. In principle the performed study promises that individually optimised injection protocols for CE-MRA can be developed and implemented. This would be a logical advancement of current implemented multiphase injection protocols[5]. Additionally, the results of the study are useful for a better synchronisation of contrast bolus and data acquisition using TB measurements.

References:

[1] Boos M, Lentschig M, Scheffler K, Bongartz GM, Steinbrich W. Invest Radiol. 1998; 33(9):538-46.
[2] Svensson J, Petersson JS, Stahlberg F, Larsson EM, Leander P, Olsson LE, J Magn Reson Imaging. 1999 Dec;10(6):919-28.
[3] Stollberger R, Raith H, Payer F, et al. Proc. Intl. Soc. Mag. Reson. Med. 8:743 (2000)
[4] K. Hittmair, G. Gomischek, et al., Magn Reson Med 31:567-571 (1994).
[5] Schoenberg SO, Londy FJ, Licato P, Williams DM, Wakefield T, Chenevert TL. Invest Radiol. 2001 May;36(5):283-91.

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