

Basic contrast-enhanced measures

Dr. Steven Sourbron

Division of Medical Physics, University of Leeds, UK

Background

Contrast-enhanced measures are numbers that are extracted from contrast-enhanced images and that quantify how much or how rapidly the contrast agent is taken up or released from the tissue. Unlike a visual analysis such measures enable a direct comparison between patients, pathologies, follow-up studies or against reference values to address questions of tissue characterisation, staging, therapy planning, prognosis, assessment of treatment effects, etc..

The simplest measure that can be extracted from contrast-enhanced MR imaging is the mean signal value over a Region-Of-Interest (ROI) on a post-contrast image. As signal intensity depends on the concentration of contrast, this will provide some indication of the tissue's capacity to take up contrast agent and therefore of its underlying physiological state. It is easy to determine on standard reporting platforms and does not require any additional acquisitions or technical expertise. On the other hand, such a simple measure depends on a large number of other variables, including arbitrary scaling factors, type of scanner, sequence type and sequence parameters, injection protocol (dose and flow rate, type of contrast agent), time since injection, precontrast signal, and a combination of physiological characteristics. It is therefore poorly reproducible, cannot be interpreted in physiological terms, and does not have much practical value as a quantitative measure.

A large number of more advanced measures are commonly used in the literature. They all aim to improve reproducibility by eliminating the effect of some, or many, of these variables. When all variables except one can be eliminated, we are left with fully quantitative indices that form a direct measurement of a well-defined physiological property. On the other hand, eliminating the effect of individual variables necessarily also increases the complexity of the technique, and will require additional acquisitions and post-processing steps. This has practical implications in terms of increased measurement- and analysis time, and the need for in-house expertise. In addition, these additional steps may introduce new variables such as an inter-observer variability, sensitivity to patient motion, error propagation, loss in image quality and resolution, model- and software dependence. Unless these problems can be contained, there is no a priori guarantee that such more advanced measures do indeed improve reproducibility or diagnostic power.

There is currently no approach that is universally accepted as optimal, and measures at all levels of complexity are frequently used. In this talk we will provide a systematic overview of the most common measures, along with limitations and requirements on data acquisition and analysis. They

will be illustrated with typical examples of patient data and a simple spread-sheet based analysis tool.

Objectives

- To provide an overview of contrast-enhanced measures, notations and terminology
- To clarify the advantages, limitations and physiological interpretation of common measures
- To identify the acquisition and analysis requirements for any given measure
- To identify the suitable measures for any given data type
- To introduce some practical spread-sheet based tools for deriving basic measures

Contents

- One post-contrast image
 - ROI signal
 - Histogram analysis
 - Relaxation rates (longitudinal, transverse)
 - Normalisation to reference tissues
- Pre- and post-contrast image
 - Signal change and relative signal change
 - Change in relaxation rate, concentration
 - Steady-state indices (blood volume)
 - The use of colour-coding
- “Slow” dynamic acquisition (~ minutes)
 - Signal (change) at fixed time points
 - Curve-type classification
 - Uptake measures: maximum, area-under-the curve, ..
 - Dynamic measures: time-to-peak, first moment, wash-in/wash-out rate, ...
- “Fast” dynamic acquisition (~ seconds)
 - Intravascular and extravascular contributions
 - Semi-quantitative versus quantitative measures
 - The role of the arterial input function
 - The first pass, perfusion measures, blood flow & volume
 - The uptake phase, permeability measures, K_{trans}, Interstitial volume, extraction fraction
 - The concept of mean transit time, central-volume principle
 - Some simple algorithms: maximum slope, ratio of areas, the Patlak plot
 - Accuracy and precision: what do we know?