# A quantitative comparison of dynamic contrast enhanced MR perfusion imaging of the prostate with dynamic contrast enhanced CT.

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## Introduction

Dynamic Contrast-Enhanced (DCE) MRI is a promising tool for characterizing the location and extent of tumors in the prostate. Three dimensional mapping of physiological parameters such as blood flow and vessel permeability is possible by analyzing the enhancement curves on a voxel-to-voxel basis. Unfortunately, the quantification of the concentration of contrast agent is complicated by several effects. Spatial variations in flip angle and non-ideal RF pulse shapes can result in deviations in contrast concentration throughout the image. Inflow effects particularly complicate the quantification of the arterial input function (AIF). The combination of these effects may lead to systematic deviations of the physiological parameters.

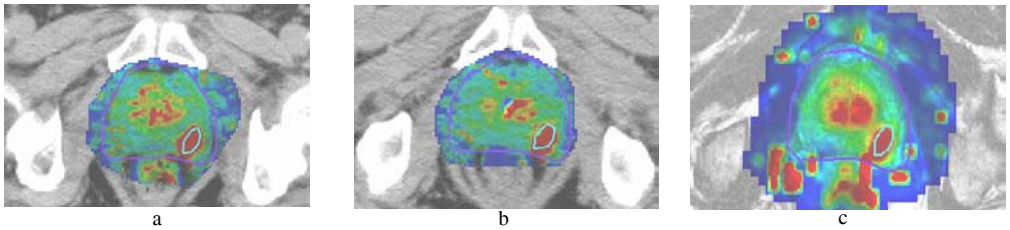
In DCE-CT the quantification is relatively simple due to the linear relation between CT signal and contrast concentration. However, this advantage is sharply contrasted by the relatively high radiation burden and the toxicity of iodine contrast agents, limiting its use for diagnostic purposes. Therefore, the use of MRI in a diagnostic setting is preferred. In order to evaluate the quantification of DCE-MRI, we performed a quantitative comparison of DCE-MRI with DCE-CT using data of 12 patients, scheduled for radiotherapy, that underwent two DCE-CT and one DCE-MRI exams.

## Methods

All patients had biopsy proven prostate cancer and were scheduled for radiation treatment. Written informed consent was received from all patients. Approval for the study was obtained by the local ethics committee. Each patient underwent two DCE multi-slice and one DCE MRI T1-weighed exams within one week. The DCE-CT exam was performed on a 40 slice CT scanner (Phillips, MX 8000 IDT, 120 kV, 200 mAs) and involved 24 acquisitions with a time interval of 2.4 s followed by 10+6 acquisitions with a temporal resolution of 10 and 20 s respectively. The 40 slices were reconstructed to 8 slices (resolution 0.7x0.7x5mm$^3$). After administration of the iodine contrast agent (60 ml, 6 ml/s Schering, Ultravist 300), image acquisition started. To determine the optimal delay between start of contrast administration and start of the acquisition, a 10 ml test bolus was injected first and the enhancement in the aorta was monitored.

The DCE-MRI dynamic protocol consisted of a 3D spoiled gradient echo sequence (TR/TE=4.0/2.1 ms, flip angle 16$^o$) using a 3 T MR scanner (Achieva, Philips Medical Systems, Best, NL) with a 2 element circular surface coil as receive coil. A total of 120 acquisitions were acquired every 2.4 s. A single acquisition consisted of 10 axial slices that were reconstructed on a grid with 1x1x5 mm$^3$ resolution. After three acquisitions, 8 ml gadolinium DTPA (0.1 M) was administered with an injection rate of 0.8 ml/s. This was also followed by a saline flush. Signal intensity variations were converted to changes in contrast agent concentration by using estimates of the pre-contrast T1 relaxation time, which was mapped before administration using the variable multi flip angle method (flip angles: 4.5$^o$, 8$^o$, 12$^o$, 16$^o$).

The arterial input function (AIF) was determined in the DCE-CT and MRI by monitoring the signal enhancement in a central region of the femoral artery. The adiabatic approximation of the tissue homogeneity model [1,2] was fitted to the enhancement data resulting in three dimensional parameter maps of blood flow, transit time (Tc), extraction fraction (E), extravascular extracelluar volume (Vextra) and delay time. To ascertain a fair comparison between the parameters maps from the second CT session and the MRI session were registered to the scan of the first CT using a rigid, mutual information-based matching procedure followed by a resampling procedure to the grid of the parameter maps from the first CT scan.



a b c

Figure 1: Example of an axial blood flow map in the prostate based on two DCE-CT (a,b) and one DCE MRI (c) exams superimposed on anatomy. Color scales from 0 to 40 ml/100gr/min. For every patient a region with elevated flow is drawn on the flow map from first DCE-CT

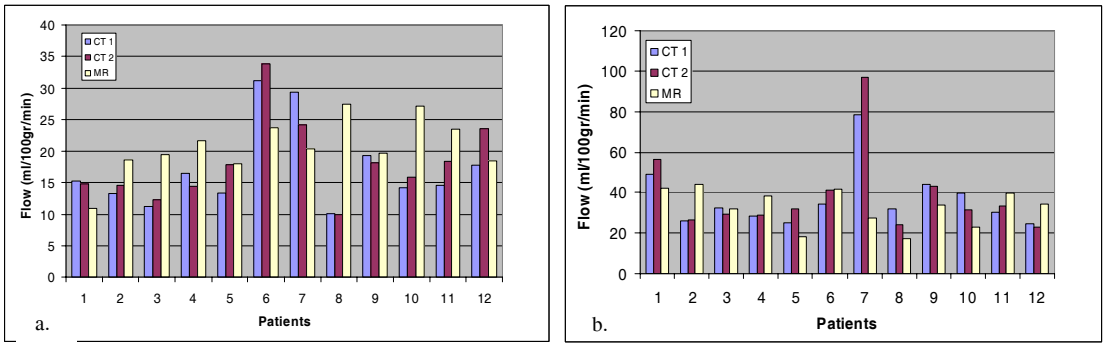



Figure 2: Overview of mean prostate blood flow (a) and mean blood flow in a region with elevated blood flow for 12 patients.

## Results and Discussion

As demonstrated by Figure 1 and 2, DCE-CT and MR result in similar quantitative blood flow maps of the prostate, although the CT-MR variance is somewhat larger than the CT-CT variance. While the analysis of the DCE-CT proved to be relatively straightforward, the analysis of the DCE-MRI requires more precaution. We observed that in DCE-MRI the susceptibility of the AIF to inflow effects can lead to a large under-estimation of blood flow values. In this study we minimized this effect by including only AIFs from the most caudal axial slices. The high reproducibility of subsequent DCE-CT exams indicates that the day-to-day variations in prostatic blood flow are limited.

## Conclusions

In this study we demonstrate that quantitative blood flow mapping with DCE-MR can compete on a quantitative level with DCE-CT. However, the complex relation between signal intensity changes and contrast agent concentration in DCE-MRI necessitates precaution, especially with respect to a reliable determination of the AIF.

## References

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