

# Arterial input function correction and its impact on quantitative DCE-MRI: a comparison with DCE-CT

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**Introduction** Accurate quantitative DCE-MRI analysis ideally requires the use of arterial input functions (AIFs) measured in the individual subject [1]. However, it is well known that it is difficult to make accurate measurements of MR AIFs due to issues such as partial volume effects and inflow [2]. Such errors in MR AIFs may affect the results of DCE-MRI analysis by inducing a bias in the calculated tracer kinetic parameters [3]. Both Yang et al [4] and Zhang et al [5] have recently suggested the use of cardiac output (Q) measurements to correct MR AIFs. In this work, we applied two methods of Q-based MR AIF correction, using DCE-CT AIFs and tracer kinetic parameter estimates as a “gold standard” for assessing the impact of the AIF corrections on DCE-MRI.

**Methods** Ten male patients aged between 53 and 80 years old (mean, 68 years) with primary bladder cancer (stage T2 to T4) underwent DCE-CT followed by DCE-MRI within 1 week. DCE-CT was performed on a GE Lightspeed Plus scanner at 1 s temporal resolution for the first 60 s, and then 30 s temporal resolution for a further 4 min (5 min total scan time). 100 ml of iohexol (Omnipaque 300) was injected at a rate of 5 ml/s immediately before the start of CT scanning; a calibration factor of 42 HU/mg/ml was used to convert signal to contrast agent concentration. Images were acquired with an in-plane spatial

resolution of 0.68 mm. DCE-MRI was performed on a Philips Intera 1.5 T system using a 3D T1-weighted RF spoiled gradient echo sequence at 5 s temporal resolution for 6 minutes. Images were acquired with an in-plane spatial resolution of 2.9 mm. A power injector was used to inject 0.1 mmol/kg Gd-DTPA-BMA (Omniscan) at 2 ml/s shortly after the start of scanning; a relaxivity of 4.5 /mM/s was used to convert from signal intensity to concentration.

**Analysis** AIFs were derived from manually drawn regions in the external iliacs. Cardiac output for both MR and CT was estimated by applying the Stewart Hamilton equation to the first pass of these AIFs [4]. The MR AIFs were then corrected using two schemes: using CT measurements of cardiac output to adjust the baseline MR signal using the method outlined in [5] and scaling the MR AIF using a ratio of MR/CT cardiac output. Each of these AIFs were used to perform quantitative tracer kinetic analysis using a two compartment exchange model (2CXM) [6]. This model was fitted directly to the baseline subtracted CT data and to the MR signal intensity data using a standard fast water exchange limit approximation [7]. Tracer kinetic analysis provided estimates of tissue perfusion ( $F_p$ ), plasma volume ( $v_p$ ), interstitial volume ( $v_e$ ) and microvessel permeability-surface area product (PS). One-sided paired t-tests were performed to assess whether the corrected parameter estimates were closer to CT than the uncorrected estimates. One-sided squared ranks tests of variance were used to determine whether the corrections reduced the variance in the results.

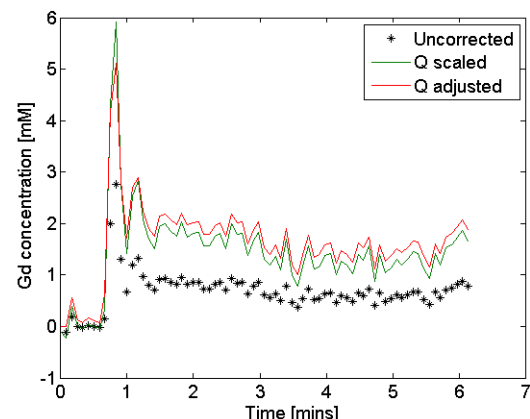
**Results** The cardiac output-based corrections give improved estimates of tracer kinetic parameters (figure 2). Both using the CT cardiac output to adjust the MR AIF, and scaling the MR AIF by the ratio of cardiac output resulted in MR parameters which were significantly closer to CT ( $p < 0.05$  for  $F_p$  and  $v_p$ ). These methods also resulted in significant reductions in the variance of PS,  $v_p$ , and  $F_p$  ( $p < 0.05$ ).

**Discussion** DCE-CT provided a valuable reference point for assessing DCE-MRI; our comparisons with CT suggest that artefacts affecting AIFs have significant effects on DCE-MRI analysis which can be corrected using measurements of cardiac output. The artefacts affecting the uncorrected DCE-MRI data appear to include a combination of partial volume and inflow. A partial volume correction is expected to be a linear scaling. As shown in figure 1, this type of linear scaling is an important effect (seen in both correction techniques). The non-linear corrections seen in the Q adjustment technique are less dramatic but still important (as shown in the difference between the red and green curves, figure 1). The Q scaling technique is simpler to implement and provides a comparable level of correction to the Q adjustment technique (figure 2). Our results suggest that the MR FXL parameter estimates are in reasonable agreement with the DCE-CT parameters for these data, and can be brought into better agreement by using Q-based AIF corrections. The use of cardiac output to correct individually measured AIFs could be of significant benefit in DCE-MRI analysis and should be further investigated.

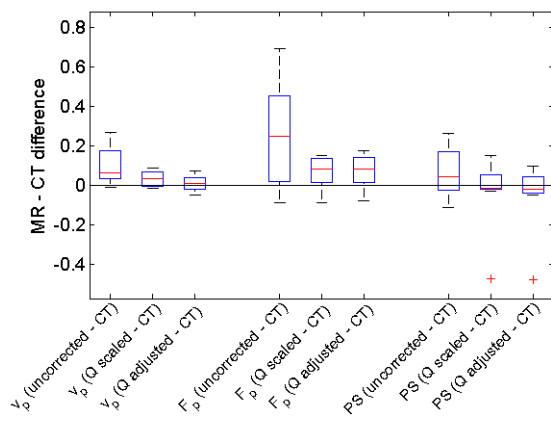
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**Figure 1** Example of an uncorrected (black) and corrected (green, red) MR AIF



**Figure 2** The difference between MR and CT parameter estimates before and after AIF correction.  $F_p$  and PS are in units of ml/min/ml