DCE breast MRI: How fast is fast enough?

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Introduction: Dynamic contrast enhanced (DCE) MRI breast imaging has showed great promise in discriminating benign and malignant breast lesions (1-4). It is important to choose a temporal resolution that allows for a sufficient analysis of the contrast uptake mechanisms involved in the breast. However, excessive temporal resolution will come at the price of poor image resolution and/or image SNR. DCE data is traditionally analyzed by performing a non-linear least squares (NLLS) fit to the two-compartment model (2-4). The two-compartment model characterizes contrast uptake with the exchange parameter (k_{ep}). The NLLS algorithm is difficult to analyze due to its non-linearity, thus numerical simulations have been used to study k_{ep} sensitivity vs. temporal resolution (4,5). These however are often based on a specific set of "typical" DCE time series, thus it is difficult to generalize these findings. Recently we proposed a linear combination (LC) method to analyze DCE-MRI (6), we found the performance of LC to be comparable to NLLS two-compartment model fits. However being a linear method the LC method is far easier to analyze. In this work we will analyze the effect of temporal resolution on the performance of LC filters.

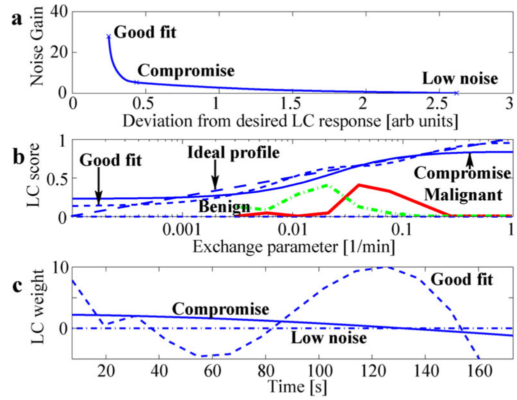

Figure 1: LC filter design tradeoffs. (a) Filter tradeoff curve, showing noise gain vs. deviation from ideal k_{ep} profile. Three filters are considered in more detail: Low noise, good fit to the ideal k_{ep} profile and a compromise between the two. (b) Filter score as a function of k_{ep} superimposed with a histogram of k_{ep} parameters obtained from a NLLS fit of 50 biopsy proven lesions (c) Filter weights used for each of the three filters.

Theory: To design a LC filter one needs to choose a temporal resolution and a desired k_{ep} range. For a specified minimum k_{ep} we choose a desired filter response of 0, and for the maximum k_{ep} a desired filter response of 1, with a log-linear k_{ep} vs. desired score profile in between (Fig. 1b). If one were to design a filter that would very closely match this specified ideal k_{ep} profile, noise gain would be excessive as for the good fit filter in fig 1. The low noise filter in fig 1, would also be diagnostically useless as the same score of zero is always returned, regardless of the DCE-curve. Using convex optimization we have developed efficient algorithms that find the LC filter that is as close as possible to our specified ideal k_{ep} profile (in the least square sense), with a specified noise gain(4). We can use this algorithm with different temporal resolutions, to evaluate how close we can get to the ideal k_{ep} profile.

Methods: Using the results of a DCE exam from 50 biopsy proven lesions (26 malignant, 24 benign), the DCE time curve was fitted to the two-compartment model using a NLLS algorithm (1-4). From the curve fit k_{ep} was estimated. Based on the histogram of k_{ep} values we specified the ideal k_{ep} profile (Fig. 1b). Depending on the temporal resolution, the noise gain was specified so that after the linear combination reconstructed images would have a noise level similar to the compromise filter in fig. 1 (7). A case of invasive ductal carcinoma was considered in more detail. An LC parameter image was constructed with the original 10.6 s temporal resolution. By averaging, the same dataset was reconstructed to a 85 s temporal resolution, and the LC parameter image was recalculated.

Results: Filter performance vs. temporal resolution is shown in fig. 2 along with the LC filtered images. The tumor has a lower LC score on the Δt = 85 s image than on the Δt = 10.6 s image.

Discussion and conclusions: As temporal resolution is increased, our calculations indicate that significant performance gains can be achieved, however improving temporal resolution beyond 10-20 s, does not seem to significantly improve calculated performance for our specified ideal k_{ep} profile. By specifying a different ideal kep profile, the effects of temporal resolution on filter performance can be studied for other regions of the body, where temporal resolution may need to be increased.

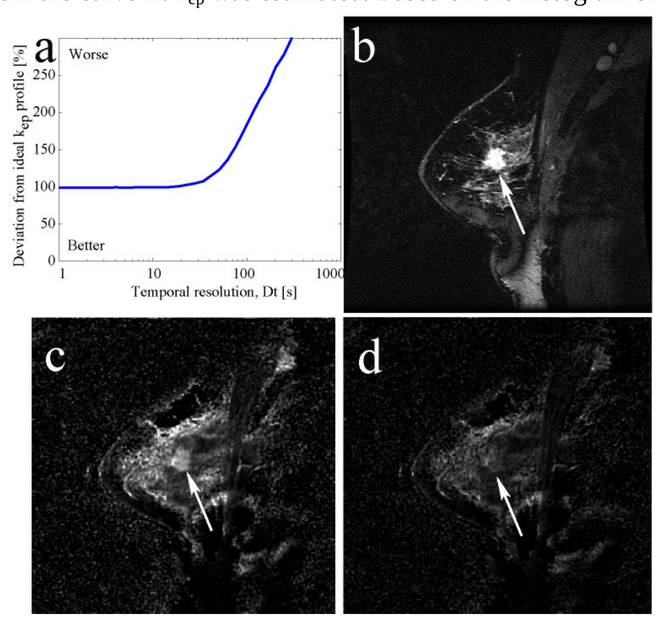

Figure 2: (a) Tradeoffs in LC performance vs. temporal resolution. (b) Anatomic image of a subject with IDC. (c,d) LC parameter map from a DCE dataset with a 10 s (b) and 85 s (d) temporal resolution (b,d) are windowed identically. As temporal resolution decreases, LC performs worse as can be seen since the lesion in (d) is not as bright as in (b).

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