Qualitative and Quantitative Assessment of Osteosarcoma Treatment Response using DCE-MRA

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Introduction: DCE-MRI is widely used in clinical studies for assessing cancer drug treatment efficacy by comparing findings from images acquired before and after therapy. A DCE-MRI study generates a large 4D volume data set and it is difficult for a radiologist to read through images from several exams and make an overall assessment of tumor response. Kinetic modeling is usually used in DCE-MRI data processing (1); however, this type of processing is very complex. In this abstract, we presented the DCE-MRA method, a new way of rendering the DCE-MRI data, which greatly simplifies the process for the large volume of 4D DCE-MRI data and enables qualitative and quantitative assessment of the treatment response of osteosarcoma.

Methods: Five serial DCE-MRI exams for each OS patient were performed on the baseline day, the first day after the first bevacizumab dose, and day 7, at week 5, and week 10 just before surgery to assess the effect of neoadjuvant antiangiogenic and chemotherapy on tumor. DCE-MRI data were acquired using a fast 3D Cartesian gradient-echo pulse sequence on a 1.5 T Siemens Avanto scanner. The patient was given injections of 0.1 mmol/kg of Gd-DTPA at a rate of 1 ml/s, followed by a saline flush using a Hickman line and an infusion pump synchronized with the MRI scanner. The total acquisition time was 350 s for 50 measurements.

DCE-MRA method combines 3D DCE-MRI and time-resolved CE-MRA (2,3), resulting in great simplification of data analysis for 3D DCE-MRI studies. Qualitative DCE-MRA analysis employs maximum intensity projection (MIP) algorithm conventionally used in MRA to generate vasculature and tumor structure information for phase II, the second phase following the bolus point in one DCE-MRI exam. Phase II was selected on purpose to generate arterial phase MIP images. In quantitative analysis, the images of phase II subtracted by the baseline phase images were normalized by dividing the smoothed baseline phase images. And then sum intensity projection (SIP) algorithm is employed to generate the projection image by adding all pixels along slice direction together instead of just picking up the maximum pixel value as in MIP algorithm. Tumor ROI can easily be drawn on this SIP image, and then the mean values of the same phase in five different exams using the same tumor ROI are computed and all these mean values can be plotted as a function of time. The values of kinetic parameter K^{trans} were also computed for comparison.

Results: The results from two pediatric patients are reported here. One is a responder ($\geq$ 95% necrosis at resection) and the other a nonresponder (<95% necrosis at resection) based on the histologic grading of necrosis. Fig. 1 shows the phase II MIP images of both patients from five longitudinal DCE-MRI exams. Phase II occurs at 14 sec from the bolus point and is an arterial phase in which most of the contrast agent is still in blood vessel. The first row shows results for the responder and the second row for the nonresponder. The darker the tumor appears in these images, the more perfused the tumor is because all images are displayed in inverted grayscale. For the responder in Fig. 1a-e, the tumor perfusion on exam day 7 increased significantly, and the perfusion at week 5 dropped dramatically in comparison with that on the baseline exam. Moreover, the tumor perfusion at week 10 had almost disappeared completely in the MIP image of phase II, which is a significant signal for a responder. For the nonresponder, the tumor perfusion remained relatively unchanged.

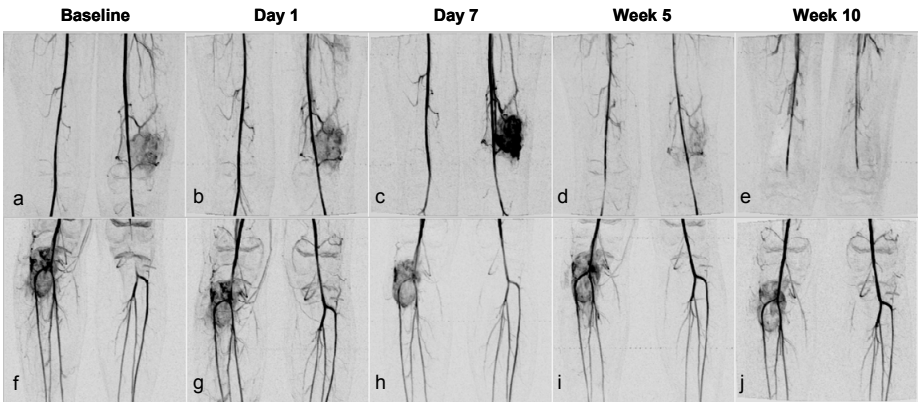

Fig.1 DCE-MRA MIP images from Phase II of the five longitudinal DCE-MRI exams for two patients (a responder: upper row; a nonresponder: bottom row). Each row is in the same gray scale.

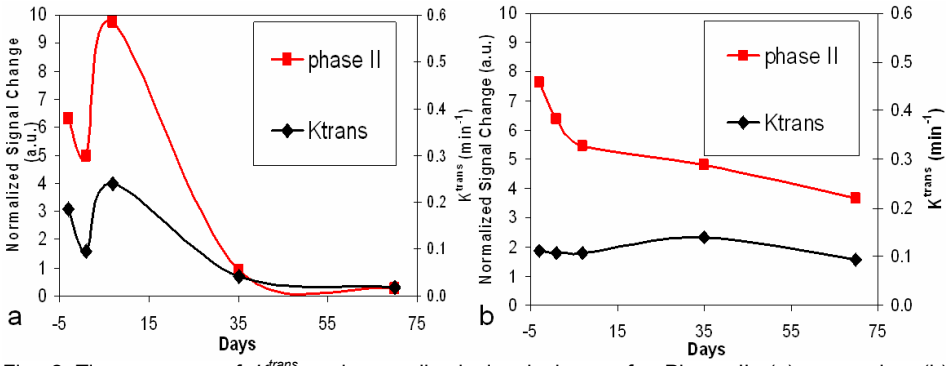

Fig. 2 Time courses of K^{trans} and normalized signal change for Phase II. (a) responder, (b) nonresponder.

Fig. 6a shows time course of mean values from phase II of the dynamic series for a responder. The normalized signal change was marked on the left y-axis. The time course of the corresponding K^{trans} values was also plotted in the same figure with the values of K^{trans} marked on the right y-axis. Even though the normalized signal change may have a different meaning than K^{trans}, the curve of the normalized signal change has shown a similar pattern as and demonstrated a high correlation with the K^{trans} curve. The correlation coefficient is 0.97. Fig. 6b shows the similar plots for the non-responder. The correlation coefficient with K^{trans} is 0.09.

Conclusion: DCE-MRA MIP images were generated for qualitative analysis of tumor treatment response. The qualitative DCE-MRA method provides a simple and quick way for a radiologist to make an overall assessment of tumor response to neoadjuvant chemotherapy. The proposed method makes it possible for a radiologist to potentially identify a likely nonresponder by comparing the DCE-MRA MIP images from the first three exams. The quantitative measures from the normalized SIP images were evaluated and the shape of plot curves of the two patients was consistent with that from direct observation of MIP images. Further investigation of this DCE-MRA method on a larger cohort of patients will be performed.

Reference:

1. Tofts PS, et. al. MRM 1991;17(2):357-367. 2. Finn JP, et. al. Radiology 2002;224(3):896-904. 3. Korosec FR, et. al. MRM 1996;36(3):345-351.