EVALUATION OF DYNAMIC DCE-MRI OF THE TEMPOROMANDIBULAR JOINT

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Synopsis

The feasibility of DCE-MRI as a tool to investigate perfusion of temporomandibular joints (TMJs) in case of Juvenile Idiopathic Arthritis (JIA) in children is investigated. The hypothesis in this current study is that inflammation is associated with increased vascularity and is the origin of experienced pain. Contrary to previous studies, high temporal resolution ($\approx 4\,$s) dynamic DCE-MRI using advanced pharmacokinetic models are for the first time applied when imaging the TMJ in JIA children aged 6-15. Results of deconvolution show that there is a difference in perfusion parameters between affected and unaffected patients, especially when permeability-surface area product (PS) and blood plasma flow (F_p) parameters are combined.

Introduction

- Juvenile Idiopathic Arthritis (JIA) is a heterogeneous condition including all forms of chronic arthritis of unknown origin and affects around 1-2 children in 1000 under the age of 16. There is increasing evidence that many, if not most, children with JIA will have a chronic disease with ongoing activity into adulthood, and that the temporomandibular joints (TMJs) are more frequently involved than previously believed.
- The reported incidences are highly inconsistent - difference in methodologies cause hampering the effective use of therapeutic interventions in early childhood.
- Hypothesis: inflammation is associated with increased vascularity and an origin of pain.
- High temporal resolution ($\approx 4\,$s) is used here (contrary to previous studies).
- Dynamic DCE-MRI, first time applied when imaging the TMJ in JIA children aged 6-15.
- Characterization of lateral differences, comparison with clinical information .
- Four different pharmacokinetic models are compared to validate the proposed method of characterization of lateral differences.

Methods

An extended imaging protocol in accordance with ethical guidelines was performed using Siemens Skyra 3 T, (64-channel head coil) system with following parameters:

- dynamic T1-weighted DCE-MRI seq. FLASH-3D, TR/TE/FA/=4 ms/1 ms/9°,
- image matrix 160x160x16, 60 volumes in time,
- Dotarem contrast-agent, power injector (inj. speed 5 mL/s, 10 s after start of acquisition).

A 3D volumes of interest (VOI) covering synovial TMJ were drawn to identify the right (R) and left joint (L) with: (Figure 1):

- polygons based on consensus between three radiologists, and always on the 5.th pre-contrast volume,
- voxels completely within the VOIs were averaged and relative enhancements curves, i.e. (signal-baseline)/baseline, were estimated.
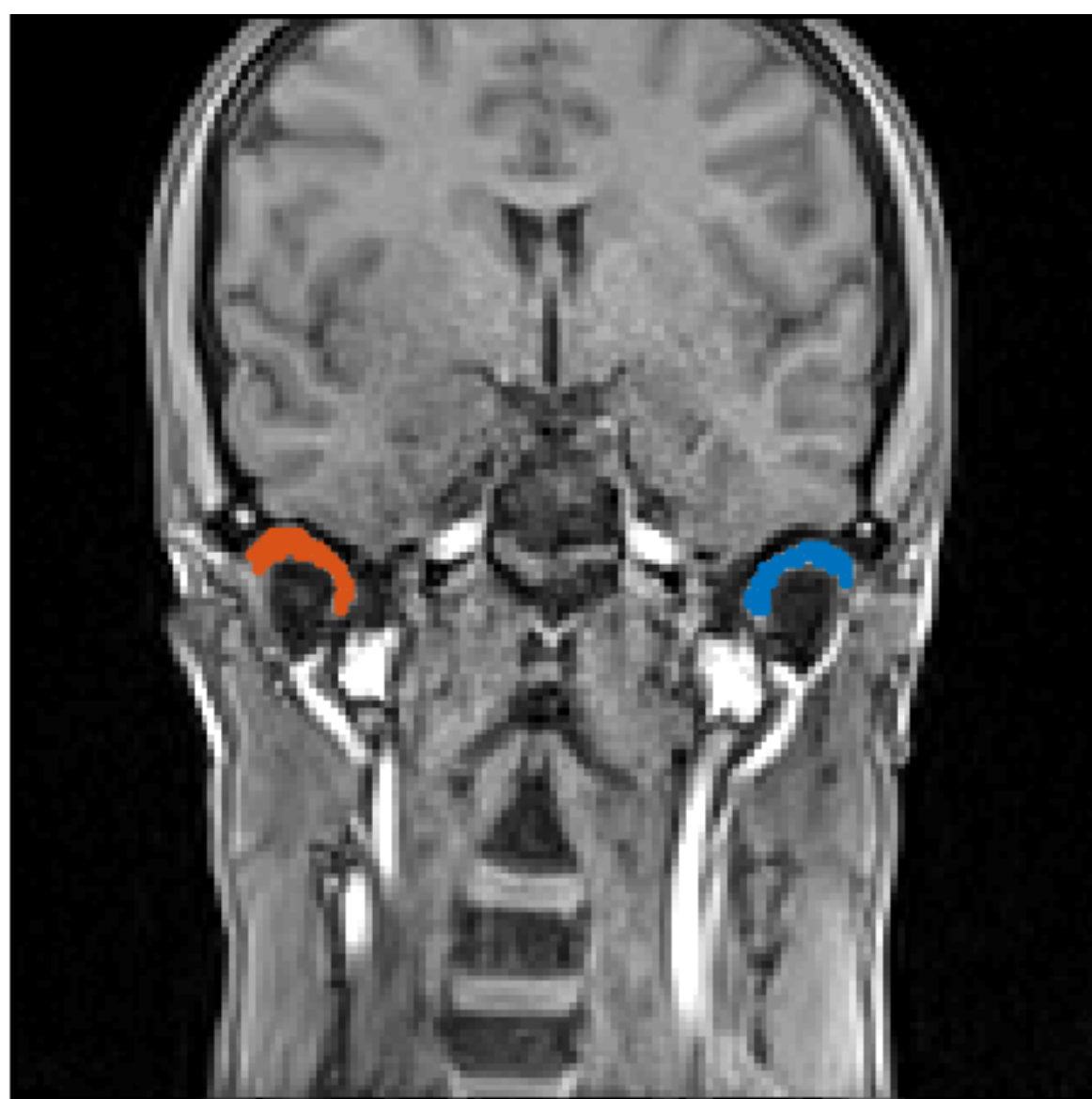

Figure 1:Placement of ROI for L side (blue) and right side of TMJ (red).

Arterial input functions (AIFs) were selected semi-automatically:

- searching regions were constrained by hand-drawn region including the large brain feeding arteries,
- voxel with the highest signal peak in region was selected.

Methods cont.

Deconvolution was performed using models with vascular phase (ability to estimate a full set of parameters - Table 1) i.e. **aaTH**, **DCATH**, **GCTT** and **2CXM** implemented as constrained GCTT. Patient datasets were split into **two groups**: **Unaffected** (4 females, 3 males, age 9-15) and **Affected** (4 females, age 6-14)

Table 1:Perfusion parameters. Primary (free) parameters of advanced models are shown in bold

Parameter	Units	Description
F_p	mL/mL min	Blood plasma flow
E	–	initial extraction ratio
v_e	mL/mL	Volume of extravascular extracellular space (EES)
T_c	min	Mean capillary transit time
BAT	min	Bolus arrival time
K^{trans}	1/min	Transfer constant between blood plasma and EES
k_{ep}	1/min	Rate constant (between EES and blood plasma)
v_p	mL/mL	Blood plasma volume
PS	mL/mL min	Permeability-surface area product
σ (DCATH only)	min	Standard deviation in transit time
α^{-1} (GCTT only)	–	Width of the distribution of capillary transit times

Characterization of lateral differences:

- Boxplots showing relative differences were constructed for all parameters, models and each group
- F_p and PS were put together to improve robustness and boxplots were tested by Wilcoxon's test (median difference, median of unaffected gr. is lower compared to affected group). Model providing the lowest p-value was selected with respect to number of free parameters

Results

- All models interpolated the measured data with no substantial residue Fig. 2
- Relative differences of affected children compared to unaffected children were systematically higher for F_p, PS and samples combining F_p and PS together (Fig. 3).
- Medians of relative differences were tested using the Wilcoxon's signed rank test (Tab. 2). Test confirmed lower medians of relative differences in unaffected group compared to Affected group. Lowest p-value was observed using GCTT model
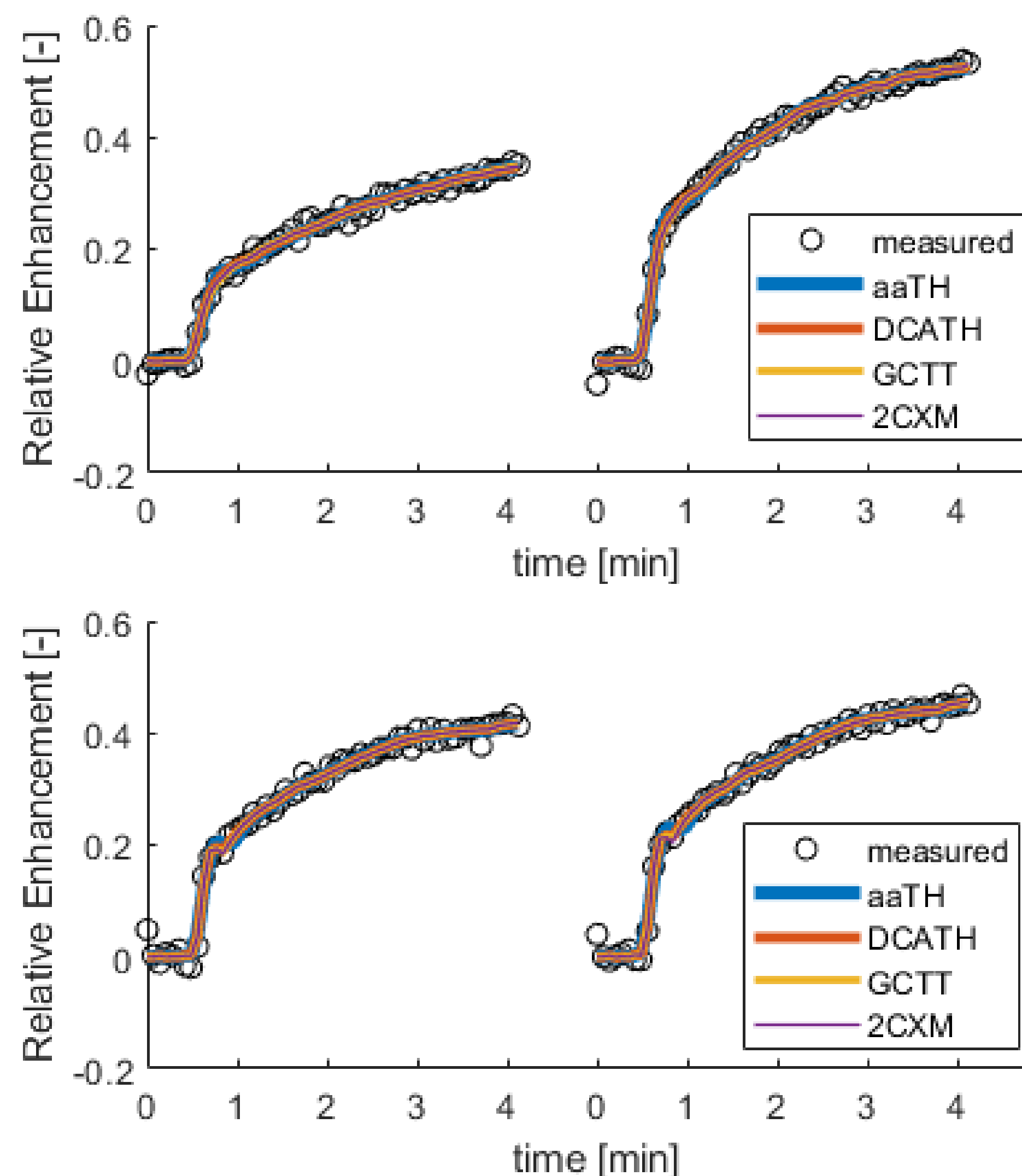

Figure 2:Plots of left (L) and right (R) side of contrast-enhanced TMJ curve for two patients - example of R side affected subject is on top row, unaffected subject enhancement curves are on bottom row. Different colours denote different pharmacokinetic models.
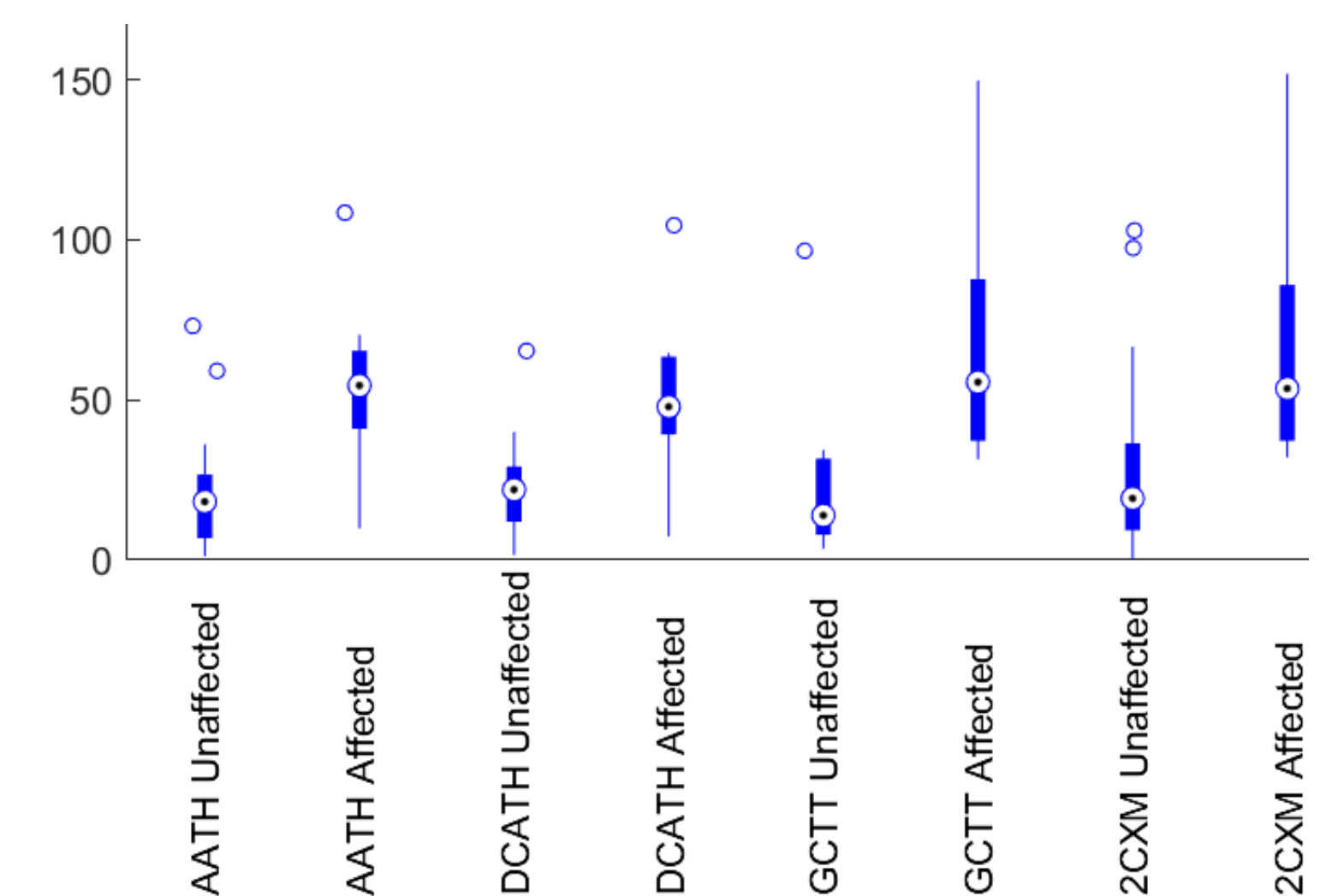
Results cont.

Figure 3:Boxplots of relative differences between left (L) and right (R) joint for F_p and PS

Table 2:Results of the Wilcoxon's signed rank test

Model	Abbreviation	p-value
adiabatic approx. tissue homogeneity	aaTH	0.0077
distributed capillary adiab. tiss. homog.	DCATH	0.0077
gamma capillary transit time	GCTT	0.0043
two-compartment exchange	2CXM	0.0111

Discussion

The proposed approach to evaluate affection of TMJ is feasible using DCE-MRI. The affected group had higher variance and higher medians indicative of increase uptake (flow) as indicative inflammation. Boxplots show that relative differences in perfusion parameters are higher in case of disease, however this can also be caused by uncertainties of fitting algorithm. Thus, GCTT and DCATH should not be preferred, because they have one additional free parameter compared to aaTH, 2CXM and are probably more susceptible to noise. From two remaining models i.e. aaTH and 2CXM, the aaTH performed better compared to 2CXM, because of lower p-value 0.0077 and much narrower boxplots indicating higher numeric stability.

Conclusion

Results show that **DCE-MRI of TMJ is feasible**. In following stage all of 100 patients will be included. With more dataset in database it would be possible to reveal pattern how disease affects perfusion parameters. Adding reference region will make it possible to localize affected side of TMJ and uncover both side inflammation, which is not possible at this stage. Deconvolution using the **aaTH model will be preferred**.

Acknowledgements

References

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