Using Pattern Recognition to Assess Tumour Perfusion in High Grade Soft Tissue Sarcoma

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Introduction

- High grade soft tissue sarcomas develop metastases in approximately 50% of patients, with a poor prognosis of 3-year survival rate of approximately 50% [1].
- The efficacy of radiotherapy treatments of cancer tumours is related to tumour vasculature, as well-oxygenated tumours are more susceptible to radiation treatment.
- In Dynamic Contrast-Enhanced Magnetic Resonance Imaging (DCE-MRI), tumour and tissue perfusion can be described using temporally resolved data to understand contrast agent uptake within the tumour region [2].

Aim

The aim of our study was to describe the perfusion properties of solid tumours and produce spatial maps that characterize the heterogeneity of the perfusion distribution using a data-driven approach.

Methods

Study Population

- Patients (n=18) with high-grade soft tissue sarcoma (two datasets discarded due to data quality issues)
- Patients had 3 visits over the course of their neoadjuvant radiotherapy treatments (before, during, and after 50 Gy/25 fractions)

Imaging Protocol

- Imaging performed on 1.5 T MRI scanner (Signa, GE Healthcare)
- Dynamic T1-weighted time-series images were acquired during intravenous injection of gadobutrol using 3D Fast Spoiled Gradient Echo sequence [3].
- Each sarcoma was manually contoured by a radiation oncologist to exclude healthy tissue from the analysis
- Images were masked to exclude healthy tissue from the analysis

Blind Source Separation

- Non-negative Matrix Factorization (NMF) Algorithm [4]:
  - Alternating Nonnegative Least Squares using Block Pivot Principle (ANLS-BPP)
  - A multi-run-averaged NMF approach was used to produce the most reliable sources and weight maps for each patient.

Results

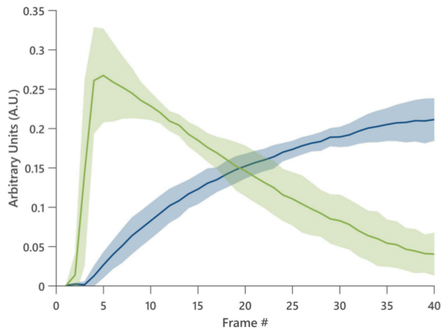

Figure 1

- Non-negative matrix factorization on DCE-MRI identifies two curves (k=2) that describe the perfusion patterns in the data. The green curve resembles a high perfusion curve and the blue curve resembles a low perfusion curve.
- The average curve (line) from 16 patients along with its standard deviation (shaded area) are shown here.

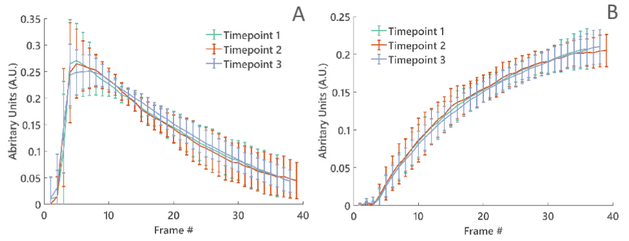

Figure 2

- These curves resemble signal enhancement curves that are comparable to perfusion curves generated from model-based approaches.
- Average normalized perfusion curves for all patients per timepoint do not change across timepoints for both high perfusion (A) and low perfusion (B) curves.
- The normalization factor for the perfusion curves is absorbed into the weight maps.

KEY POINT:
The NMF algorithm produces replicable perfusion curves, which suggests that changes over the course of treatment will be reflected in the weight maps.

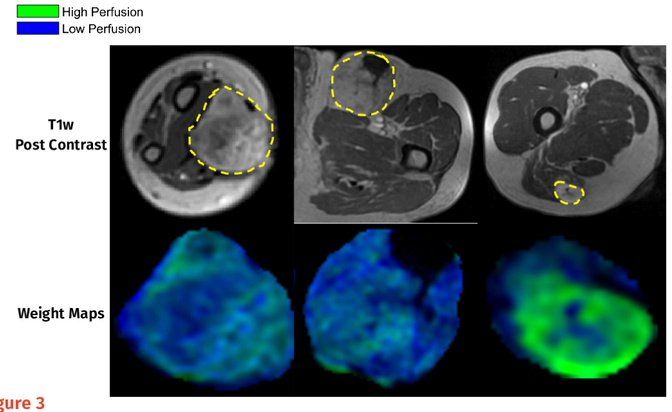

Figure 3

Perfusion weight maps for multiple slices of a volumetric high-grade soft tissue sarcoma tumour. The algorithm produces weight maps to represent each pixel's correlation to the perfusion curves. The weight maps that correspond to high perfusion (denotated as green pixels) and low perfusion (denoted as blue pixels) were superimposed in color images. Signal magnitude is absorbed into the weight maps, which may reveal changes in patients across timepoints in response to treatments.

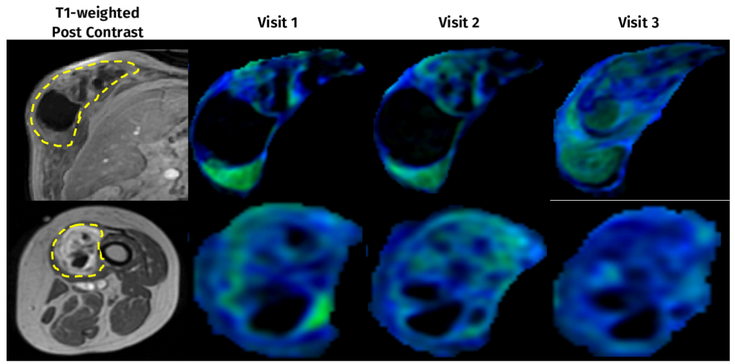

Figure 4:

Longitudinal progression of the perfusion distribution for high-grade sarcoma patients over the course of their radiotherapy treatments for two patients. The segmented tumour is represented in the T1-weighted image within the yellow dashed-lined area. The green regions represent high perfusion, blue regions represent low perfusion, and dark regions represent necrotic regions.

Discussion

- Perfusion curves produced by the NMF algorithm show consistency in the characterization of different types of perfusion properties in high-grade sarcoma tumours
- Weight maps reveal the heterogeneity of the perfusion distribution in solid tumors
- Longitudinal assessment of the perfusion distribution in weight maps show changes over the course of a radiotherapy treatment.
- Multi-run averaging approaches to reduce variability in weight maps could be a practical and robust data-driven approach to characterizing blood supply in tumours.
- This approach could be used to study tumour progression throughout the course of radiotherapy treatments.
- Correlation of NMF tumour perfusion metrics to clinical outcomes is currently underway.

References

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