Non-contrast MRI perfusion angiosome in diabetic feet

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Target Audience Radiologist, vascular surgeon, physical therapist, and the professionals involved with diabetic foot care.

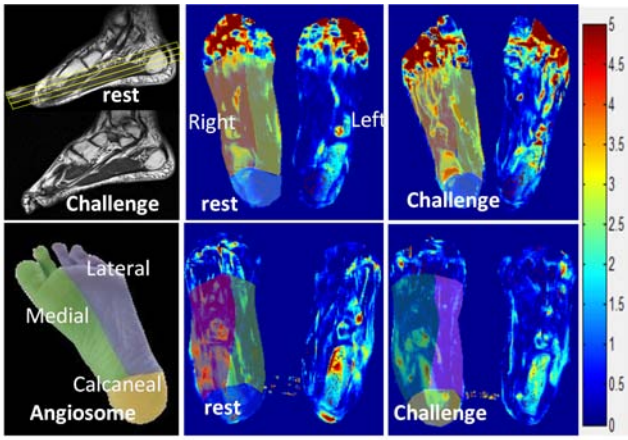

Figure 1 The examples of perfusion projection maps in a healthy volunteer (1st row) and a patient with diabetes and severe neuropathy (2nd row), at rest and during a toe crunch challenge. The first graph in 1st row shows sagittal view of a foot at rest and during the toe crunch with three slices of perfusion imaging. The first graph in the 2nd row shows three regions in angiosome map: medial plantar, lateral plantar, and calcaneal branch. The color bar for perfusion: 0 – 500 ml/100g/min

Purpose In patients with diabetes mellitus, foot ulcers are a significant complication. Approximately 85 percent of all diabetes-related lower-extremity amputations are preceded by foot ulcers [1]. While peripheral neuropathy is often a predisposing risk factor to ulceration and amputation in diabetes patients, impaired microcirculation plays an important contributing role in wound development and healing of neuroischemic diabetic feet [2]. In this project, we developed a non-contrast MRI approach to evaluate perfusion in diabetic foot based on the concept of angiosome of the foot, which links source artery with the tissue territory perfused by the artery [3].

Methods Imaging Methods: Skeletal muscle perfusion was measured using a FAIR type of arterial spin labeling (ASL) method adapted from cardiac imaging [4]. Two sets of inversion recovery images were acquired with initial TIs of 190 ms: a slice-selective inversion (SS) and nonselective inversion (NS) preparations. Perfusion was calculated using the equation:

$$Perfusion = \lambda \frac{T_{1,NS}}{T_{1,Blood}} \left(\frac{1}{T_{1,SS}} - \frac{1}{T_{1,NS}} \right) \qquad (1)$$

where λ is the constant blood-tissue coefficient of water; $T_{1,NS}$ and $T_{1,SS}$ are T_1 values of the tissue after nonselective and slice-selective inversion recovery pulse were applied. The 2D ASL sequence parameters included: single-shot gradient-echo acquisition, TR/TE = 2.8 msec/1.2 msec; 10 T1-weighted images for each T_1 measurement; flip angle = 5^o; FOV = 160 x 112 mm^2; matrix = 128 x 90; average = 3; acquisition = 50 sec. Three slices were acquired along the axial direction (***Figure 1***).

Experiments: In this ongoing study, 3 healthy volunteers (69±1y) and 3 diabetes patients (64±2y, HbA1c = 7.8±2) without history of peripheral artery disease were scanned for the measurement of foot perfusion. The volunteers lay supine on MRI table with both feet inside a head coil. A cardiac phased array coil was placed on the lower legs to acquire non-contrast MRI angiography [5]. This was used to confirm the patency of peripheral arteries in all subjects. The perfusion measurements were performed at rest and during a toe crunching challenge (***Figure 1***).

Data Analysis: Perfusion map was obtained using a T_1 algorithm reported previously [4] and Eq. (1) for each slice. A perfusion projection map was then created using the maximal intensity of 3 perfusion maps. Three regions were then segmented based on angiosome definition: medial plantar, lateral plantar, and calcaneal branch of posterior tibial artery. Perfusion data was only obtained from medial and lateral regions in this study since calcaneal branch has little muscle in the 3-slice covered area. In ***Figure 1***, projected perfusion maps of foot were demonstrated from a healthy volunteer and a diabetes patient. The transparent display of three regions represents the mean perfusion values in these regions, but transparent colors were not scaled with the perfusion values. Perfusion reserve was calculated as the ratio of perfusion at rest to the perfusion during the challenge.

Results Non-contrast MR angiography confirmed there was no apparent arterial stenosis in any of three branches of peripheral arteries. Foot perfusion maps were successfully measured in all 6 subjects. In ***Figure 1***, the patient with severe periphery neuropathy and diabetes show elevated resting perfusion and attenuated perfusion response under the toe crunch challenge. ***Figure 2*** shows comparison findings of averaged perfusion reserve values between healthy and diabetes patients. Even with small number of subjects, a significant reduction in perfusion reserve was observed in the medial plantar region of dominant right foot in diabetes.

Discussion and Conclusion Non-contrast MRI perfusion angiosome demonstrates the sensitivity to detect the alternation of perfusion in the foot muscle for the first time. Without macrocirculation obstruction, local microcirculation appears to be compromised in the dominant foot of the diabetes, even without foot ulcer. This approach may provide an objective mean to understand the complex interplay between neurogenic and neurovascular regulation and contribution of regional muscle malperfusion for developing foot ulcer.

References [1] American Diabetes Association, Diabetes Care, 1999;22:1354–1360. [2] Dinh T, et al. Curr Pharm Des 2005; 11: 2301–2309. [3] Taylor GI, et al, Br J Plast Surg. 1987;40:113-141. [4] Zhang H, et al, MRM, 2005; 53: 1135 - 1142. [5] Zhaoyang Fan, et al, MRM, 2009;62:1523-1532.

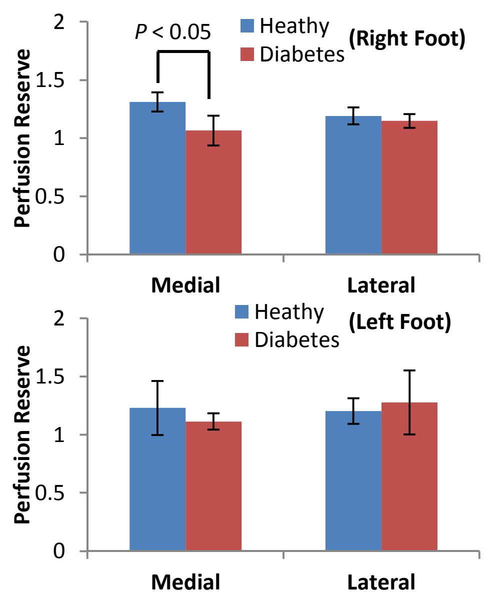

Figure 2 Comparison of perfusion reserves in foot muscle between healthy and age matched patients with diabetes and peripheral neuropathy. Using angiosome concept, significant attenuation in perfusion reserved was found in the medial plantar region of dominant feet of diabetes.