New methods for evaluating the significance of lower extremity arterial lesions and foot perfusion using fractional flow reserve (FFR) and MRI: How they work and their value in assessing therapeutic success

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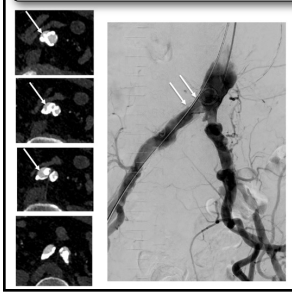
Characterisation of peripheral arterial lesions

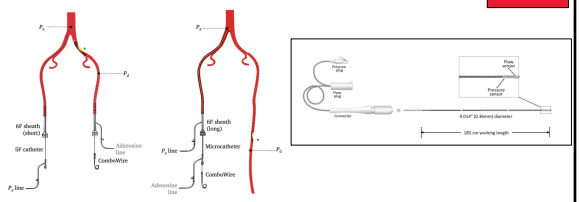


Functional flow

End organ oxygenation and / or perfusion

Intra-arterial Fractional Flow Reserve Measurements Provide an Objective Assessment of the Functional Significance of Peripheral Arterial Stenoses

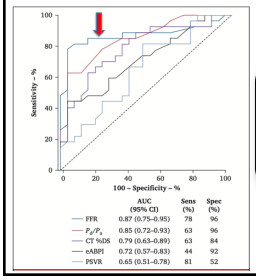
Mostafa A. Albayati [1], Ashish Patel [2], Bhavik Modi [3], Prakash Saha [2], Lawen Karim [2], Divaka Perera [3], Alberto Smith [2], Bijan Modarai [1,*], the Guy's and St Thomas' Limb Salvage Research Collaborative [1,3]



Albayati et al. EJVES 2024

Standard of care vs pressure/flow measurements

Mostafa Albayati



	AUC (95% CI)	Sens (%)	Spec (%)
FFR	0.87 (0.75–0.95)	78	96
P_d/P_a	0.85 (0.72–0.93)	63	96
CT %DS	0.79 (0.63–0.89)	63	84
eABPI	0.72 (0.57–0.83)	44	92
PSVR	0.65 (0.51–0.78)	81	52

Fractional flow reserve (FFR) is a more discriminatory measure of haemodynamic significance than visual assessment, ABPI or duplex

Albayati et al. EJVES 2024

CLINICAL PRACTICE GUIDELINES

2024 ACC/AHA/AACVPR/APMA/ABC/SCAI/SVM/SVN/SVS/SIR/VESS Guideline for the Management of Lower Extremity Peripheral Artery Disease: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines

Circulation

Recommendations for Resting ABI and Additional Physiological Testing (Continued)

COR	LOE	Recommendations
2a	B-NR	10. In patients with CLTI with nonhealing wounds or gangrene, it can be useful to use toe pressure/TBI with waveforms, $TcPO_2$, SPP, and/or other local perfusion measures to determine the likelihood of wound healing without or after revascularization.[12,14,28,29–30,38]

"....it can be useful to use local perfusion measure to determine the likelihood of wound healing"

Gornik et al. Circulation 2024

CLINICAL PRACTICE GUIDELINE DOCUMENT

Editor's Choice – European Society for Vascular Surgery (ESVS) 2024 Clinical Practice Guidelines on the Management of Asymptomatic Lower Limb Peripheral Arterial Disease and Intermittent Claudication☆

Recommendation 16

For patients with lower limb peripheral arterial disease in whom imaging is indicated, duplex ultrasound, magnetic resonance angiography, or computed tomography angiography are recommended as primary imaging modalities, at the discretion of the treating physician.

Class	Level	References	ToE
I	B	Jens *et al.* (2013)[230] Menke *et al.* (2010)[227] Met *et al.* (2009)[231] Heijenbrok-Kal *et al.* (2007)[232] Collins *et al.* (2007)[228] Sun *et al.* (2006)[233] Koelemay *et al.* (2001)[238] Nelemans *et al.* (2000)[239] Visser *et al.* (2000)[229] Verma *et al.* (2022)[146]	

"Promising methods which directly addresses muscle perfusion and therefore effectively investigate the end organ in intermittent claudication are currently under evaluation as are different deep tissue perfusion MRI protocols…."

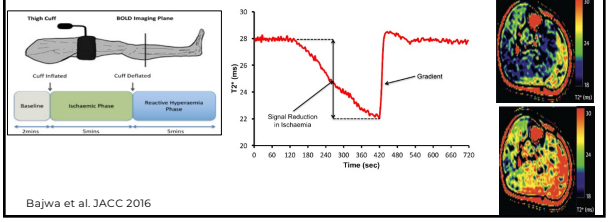
Nordanstig et al. EJVES 2024

Modalities for measuring oxygenation/perfusion

Modality	Advantages	Disadvantages
CT	• Widely available • Definition of vessels and anatomy • Fast acquisition	• Radiation exposure • Need for contrast
MRI	• Multiple sequences • Non-contrast sequences • Detailed assessment of soft tissues	• Expertise • Not widely available • Cost • Acquisition time
Ultrasound	• Widely available • Cheap • Microbubbles enhance value	• Operator dependent • Lack of anatomical definition
PET	• Validated • Available in most centres • Sensitive	• Radiation exposure • expensive

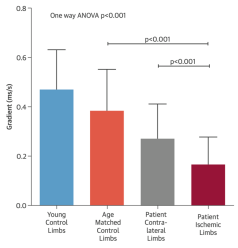
Adnan Bajwa

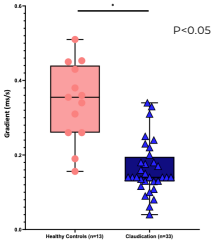
Blood Oxygenation Level-Dependent CMR-Derived Measures in Critical Limb Ischemia and Changes With Revascularization



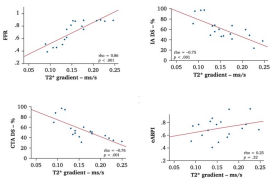
Bajwa et al. JACC 2016

MRI BOLD: Assessment of calf oxygenation





Lesion characteristics vs limb oxygenation



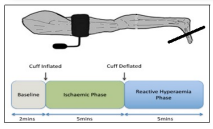
Fractional flow reserve correlates strongly with calf oxygenation

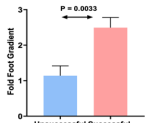
Modality	Rho	P value
Fractional flow reserve	0.86	<0.001
eABPI	0.25	0.32
Intra-arterial angiogram	-0.75	<0.001
CT angiogram	-0.76	<0.001

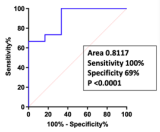
Albayati et al. EJVES 2024

BOLD assessment of foot oxygenation

Lawen Karim



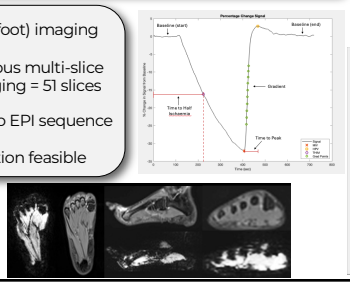




- Single slice
- Multi-echo gradient-recalled echo sequence

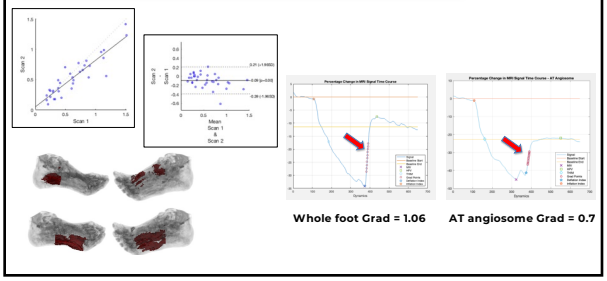
Evolving BOLD sequence for foot assessment

- 3D (whole foot) imaging
- Simultaneous multi-slice (SMS) imaging = 51 slices
- Single-echo EPI sequence
- Segmentation feasible



Trixie Yap

Preliminary segmental assessment



Whole foot Grad = 1.06

AT angiosome Grad = 0.7

Segmental foot oxygenation

- Move toward functional assessment of PAD
- FFR → haemodynamic significance of lesions
- BOLD oxygenation → end organ consequences of impaired flow
- Whole foot MRI assessment of oxygenation is feasible
- Important to develop a tool with day to day clinical utility