The use of transdermal optical coherence tomography to image the superficial temporal arteries

SP Mollan^{1,2}, PA Keane^{3,4} and AK Denniston^{4,5,6}

Abstract

Purpose The diagnosis of Giant Cell Arteritis (GCA) is an area of major challenge. This is the first reported use of the directed use of transdermal optical coherence tomography (OCT) to image the superficial temporal artery (STA).

Methods This proof of concept study used a commercially available transdermal OCT instrument to identify and image the STA in eight patients (suspected GCA, confirmed GCA, and in healthy controls). Three cases are presented to demonstrate the preliminary imaging findings.

Results In all eight cases the STA was identified. Imaging findings from three cases are presented. A hyper-reflective signal was seen, which distinguishes the artery from vein. In two cases, a ratio of band thickness (BT) to arterial lumen diameter (ALD) could be calculated (BT:ALD ratio) where the whole circumference of the artery was imaged.

Discussion Using dermal OCT to image the temporal arteries is a novel concept. With ongoing advances in resolution, penetration, and blood flow detection; this non-invasive technology warrants further investigation to determine its role in Giant Cell Arteritis.

Eye (2017) 31, 157–160; doi:10.1038/eye.2016.206; published online 14 October 2016

Introduction

Giant Cell Arteritis (GCA) is a major area of clinical risk, due to a combination of the seriousness of the condition, challenges in its diagnosis, and the associated morbidity of its treatment. Admissions for investigation of suspected GCA currently shows an upward trend,¹ hence a reliable, noninvasive test is

required. Temporal artery biopsy (TAB) is specific, but surgically invasive. Using ultrasound to identify temporal artery oedema ('the halo sign'), stenosis and occlusion has gained popularity. A meta-analysis reported the sensitivity and specificity for unilateral halo sign as 68% and 91%, respectively.² Ultrasound is cheaper, noninvasive, permits longitudinal scanning for disease activity, and can be quicker to organise than TAB but requires experience.^{2,3} Magnetic resonance imaging and angiography⁴ has also been used to image the superficial temporal artery, but access and high expense has limited its widespread use.

Optical Coherence Tomography (OCT) is a noninvasive interferometric optical imaging modality.⁵ Dermal OCT devices are capable of imaging tissues *in vivo*, including distinct skin layers up to 2 mm in depth, and the acquisition time is short.⁶ Dermal OCT uses longer infrared wavelengths (1300 nm) compared with that conventionally used in ophthalmic OCT (800 nm). Both dermatological and ophthalmic OCT machines have demonstrated the ability to image arterial microvascular structures.^{7,8} To the authors' knowledge, OCT has not yet been used in GCA or health to image the superficial temporal artery (STA).

Materials and methods

We used a commercially available dermatological multi-beam, Fourier-domain, swept source OCT device (InVivoSight; Michelson Diagnostics, Kent, UK) with a wavelength of 1305 nm (HSL- 2000; Santec Corp, Komaki, Japan), an axial optical resolution of 10 µm, and lateral optical resolution of 7.5 µm. The aim was to test the hypothesis that the STA could be imaged using dermal OCT. We scanned eight individuals, all over the age of 50 years: five had a clinical diagnosis of GCA (TAB positive $n=3$; TAB negative $n=2$), and

¹Birmingham Neuro-Ophthalmology Unit, Department of Ophthalmology, University Hospitals Birmingham NHS Trust, Queen Elizabeth Hospital Birmingham, Birmingham, UK

²Neurotrauma and Neurodegeneration, School of Clinical and Experimental Medicine, College of Medical and Dental Sciences, The Medical School, The University of Birmingham, Birmingham, UK

³NIHR Biomedical Research Centre for Ophthalmology, Moorfields Eye Hospital NHS Foundation Trust, London, UK

⁴University College London, Institute of Ophthalmology, London, UK

⁵Centre for Translational Inflammation Research, School of Immunity and Infection, College of Medical and Dental Sciences, University of Birmingham, Birmingham, UK

⁶Department of Ophthalmology, University Hospitals Birmingham NHS Trust, Queen Elizabeth Hospital Birmingham, Birmingham, UK

Correspondence: SP Mollan, Birmingham Neuro-Ophthalmology Unit, Department of Ophthalmology, University Hospitals Birmingham NHS Trust, Queen Elizabeth Hospital Birmingham, Mindelsohn Way, Edgbaston, Birmingham B15 2WB, UK
Tel: +44 (0)789 301 7588;
Fax: +44 (0)121 643 2023.
E-mail: soozmollan@doctors.org.uk

Received: 16 November 2015
Accepted in revised form: 14 July 2016
Published online: 14 October 2016

three were healthy controls with no prior history of GCA symptoms or ophthalmic history (other than cataracts). Three cases are presented here to illustrate the preliminary imaging findings. Ethical approval was obtained and informed consent was taken.

Case reports

In this proof of concept case series eight individuals were scanned. In all eight (1) the STA could be localized by palpation to align the OCT tracer beam, (2) the STA could be identified on OCT 'free-run' mode, and (3) the STA could then be captured, in part, on 'multi-scan' mode to obtain the desired 6.0×6.0 mm grid of high-resolution stack of images with 0.1 mm separation between slices and 2.0 mm slice depth.

A specific limitation of the technology was found with depth of penetration at around 2 mm, therefore in some cases only the more superficial wall of the artery and lumen

were captured. A hyper-reflective band that probably corresponds to elastin within the external elastic lamina, and possibly including the internal elastic lamina, distinguished artery (Figure 1ai–aiii, bi and c) from vein (Figure 1bii). Signal drop out is seen on the images as linear artifact from skin hairs. Where the whole circumference of the artery was captured in the image, a ratio of band thickness (BT) to arterial lumen diameter (ALD) could be calculated (BT : ALD ratio) using the device software.

The following 3 cases were chosen to demonstrate the capability of the device: Case 1 and 3 illustrate the ability to calculate the BT : ALD ratio and Case 2 shows the presence and absence of the hyperreflective band.

Case 1

A 69-year-old caucasian female presented with bilateral arteritic anterior ischemic optic neuropathies. TAB was positive. Figure 1(a) images are from the contralateral side

Figure 1 Patient A, a 69-year-old female presented with bilateral arteritic anterior ischemic optic neuropathies (TAB positive). Images ai–aiii are taken from the side contralateral to the TAB site over 9 months after treatment. The arrow demonstrates a clear hyperreflective band isolating the vessel lumen, this corresponds to the thicker connective tissue wall of an artery rather than vein. Band measures $22 \mu\text{m}$, lumen $240 \mu\text{m}$ (ratio 0.092). Patient B, a 68-year-old male, diagnosed with unilateral arteritic anterior ischemic optic neuropathy (TAB positive). Images are taken 4 weeks after initial diagnosis. (bi) Demonstrates the artery proximal to the TAB site; (Bii) Observes a vessel without the hyper-reflective band likely to be a vein. Patient C, a 72-year-old male who has cataracts (control). The arrow demonstrates the clear hyper-reflective band of the artery. Band measures $21 \mu\text{m}$, lumen $213 \mu\text{m}$ (ratio 0.099).

to TAB site 9 months after diagnosis. The white arrows demonstrate a hyperreflective band isolating the vessel lumen corresponding to the thicker connective tissue wall of an artery rather than vein. BT = 22 μm , ALD = 240 μm ; BT : ALD ratio 0.092.

Case 2

A 68-year-old caucasian male diagnosed with unilateral arteritic anterior ischemic optic neuropathy. TAB was positive. Images in Figure 1(b) are taken 4 weeks post-diagnosis, and ongoing corticosteroid treatment. Figure 1 (bi) demonstrates the artery distal to TAB site; Figure 1 (bii) observes a vessel without the hyperreflective band likely to be a vein.

Case 3

A 72-year-old systemically well caucasian male was reviewed for cataracts (control). The arrow demonstrates the hyper-reflective band of the artery in Figure 1(c). BT = 21 μm , ALD = 213 μm ; BT : ALD ratio 0.099.

Discussion

We have demonstrated that transdermal OCT can identify the STA. The preliminary images presented here need further validation. We found specific limitations of the technology such as the depth of penetration; in some cases only the proximal vessel wall and lumen were captured. Also, artifact from overlying hairs masked the image data that may, in future investigations, be problematic. We did not attempt to scan the parietal branch of the STA and given its position beyond the hairline may not be possible due to hair follicle artifact. Current developments in the technology include enhanced depth imaging, which may see the image data increased by 50% greater depth. No coupling agent was used and it is probable in future investigations that this may reduce artifact.

Potentially transdermal OCT has a number of advantages over TAB as it is quick and noninvasive, and could be performed serially over time. OCT allows image acquisition by a novice, permits detailed retrospective analysis of all images with extremely high resolution enabling assessment and measurement of structural changes down to a few microns. The axial resolution of OCT images achieved here is less than 20 μm , up to 10 times higher than conventional ultrasound and magnetic resonance imaging.

As a significant number of patients with large vessel GCA do not have demonstrable temporal artery abnormalities, this could limit the development of dermal OCT for GCA as here we have only demonstrated

imaging of the STA. Additionally, current expense of the platform may hinder widespread clinical access for cranial GCA.

These cases provide a proof of concept that transdermal OCT can image parts of the STA. A large-scale validation study of this imaging modality is required to provide evidence that this technique is meaningful in the diagnosis of GCA.

Summary

What was known before

- The diagnosis of GCA is an area of major challenge to rheumatologists, internal physicians, and ophthalmologists.
- Imaging techniques for the STA that are currently being used both for diagnosis and monitoring in GCA include ultrasound and magnetic resonance imaging/magnetic resonance angiography.
- Histopathology from a temporal artery biopsy is still considered the definitive investigation for diagnosis of GCA.

What this study adds

- This is the first report that the superficial temporal artery can be identified and imaged, in part, noninvasively using a commercially available dermal OCT instrument.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

The VivoSight Scanner was kindly loaned to the department by VivoSight; Michelson Diagnostics, Kent, UK. We would also like to thank both Adam Meekings and Nikki Steadman for their expertise and helpful discussions. PAK has received a proportion of his funding from the Department of Health's NIHR Biomedical Research Centre for Ophthalmology at Moorfields Eye Hospital and UCL Institute of Ophthalmology. The views expressed in the publication are those of the author and not necessarily those of the Department of Health.

References

- 1 Mollan SP, Begaj I, Mackie S, O'Sullivan EP, Denniston AK. Increase in admissions related to giant cell arteritis and polymyalgia rheumatica in the UK, 2002-13, without a decrease in associated sight loss: potential implications for service provision. *Rheumatology* 2015; **54**: 375-377.

- 2 Arida A, Kyprianou M, Kanakis M, Sfikakis PP. The diagnostic value of ultrasonography-derived edema of the temporal artery wall in giant cell arteritis: a second meta-analysis. *BMC Musculoskelet Disord* 2010; **11**: 44.
- 3 Czihal M, Zanker S, Rademacher A, Tatò F, Kuhlencordt PJ, Schulze-Koops H *et al*. Sonographic and clinical pattern of extracranial and cranial giant cell arteritis. *Scand J Rheumatol* 2012; **41**: 231–236.
- 4 Rhéaume M, Rebello R, Pagnoux C, Carette S, Clements-Baker M, Cohen-Hallaleh V *et al*. Accuracy of high resolution mri of scalp arteries for the diagnosis of giant cell arteritis: results of a prospective study. *Arthritis Rheumatol* 2014; **66**: S390–S391.
- 5 Huang D, Swanson EA, Lin CP, Schuman JS, Stinson WG, Chang W *et al*. Optical coherence tomography. *Science* 1991; **254**: 1178–1181.
- 6 Sattler E, Käßle R, Welzel J. Optical coherence tomography in dermatology. *J Biomed Opt* 2013; **18**: 061224.
- 7 Yonetsu T, Bouma BE, Kato K, Fujimoto JG, Jang IK. Optical coherence tomography– 15 years in cardiology. *Circ J* 2013; **77**: 1933–1940.
- 8 Ouyang Y, Shao Q, Scharf D, Heussen FM. An easy method to differentiate retinal arteries from veins by spectral domain optical coherence tomography: retrospective, observational case series. *BMC Ophthalmology* 2014; **14**: 66.