

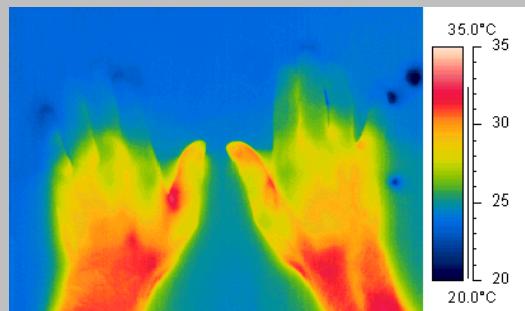


# On the *Vascular Optics* spectrum with Thermal Imaging. Wider opportunities for clinical measurements and research

Prof. John Allen

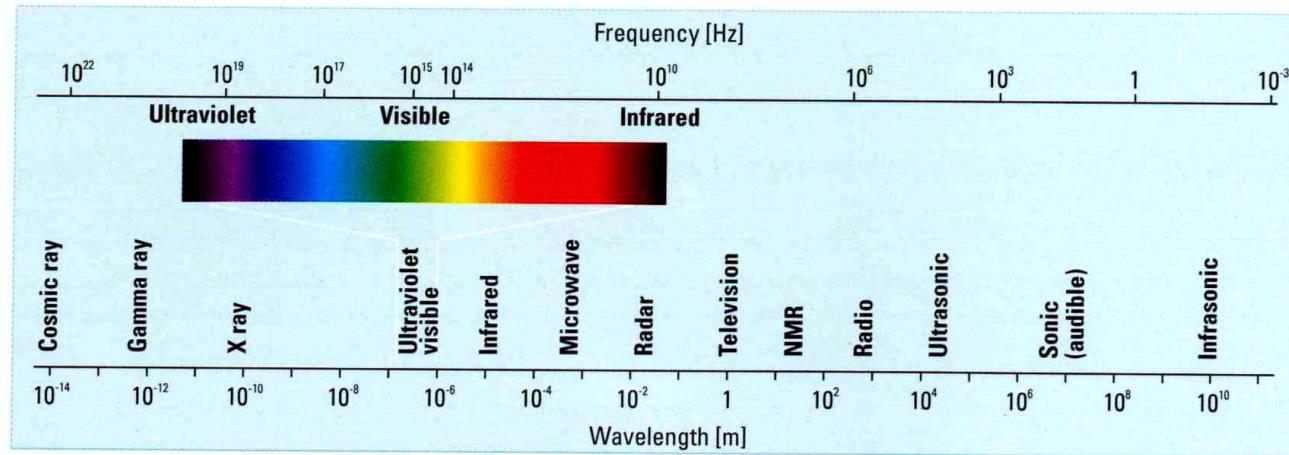
Centre for Intelligent Healthcare, Coventry University, UK.

*Honorary Reader in Microcirculation, Newcastle University, UK.*



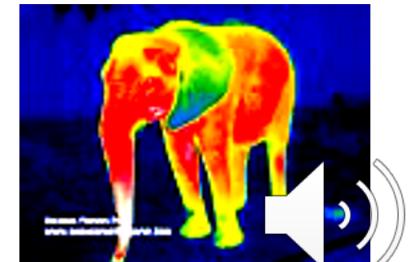


# “LIGHT”



**Figure 1**  
The electromagnetic spectrum

# “Wavelength is very important”



# Context and successes going forward

- *Vascular Optics* theme - small blood vessels.
- Significant medicine component. Imaging and non-imaging assessments.
- Founder of Newcastle Microvascular Facility,  
~2000+
- Device and Novel Measurements R&D: 2014+  
CI/Co-I >£3M R&D funding with collaborators.
- Collaborative links with industry.
- JA now setting up a *Vascular Optics* Facility /  
new R&D team at Coventry University in UK.

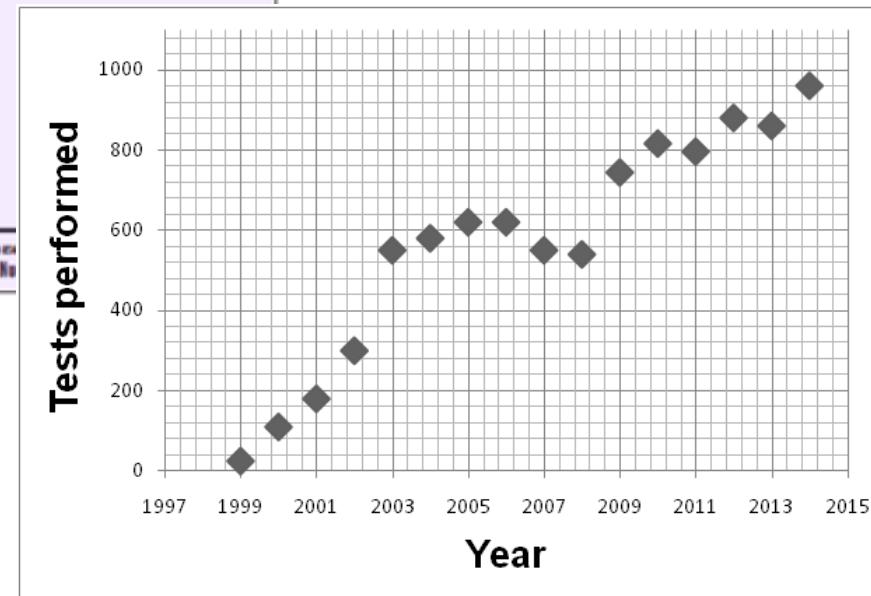


# Portfolio / tests – “Vascular Optics”

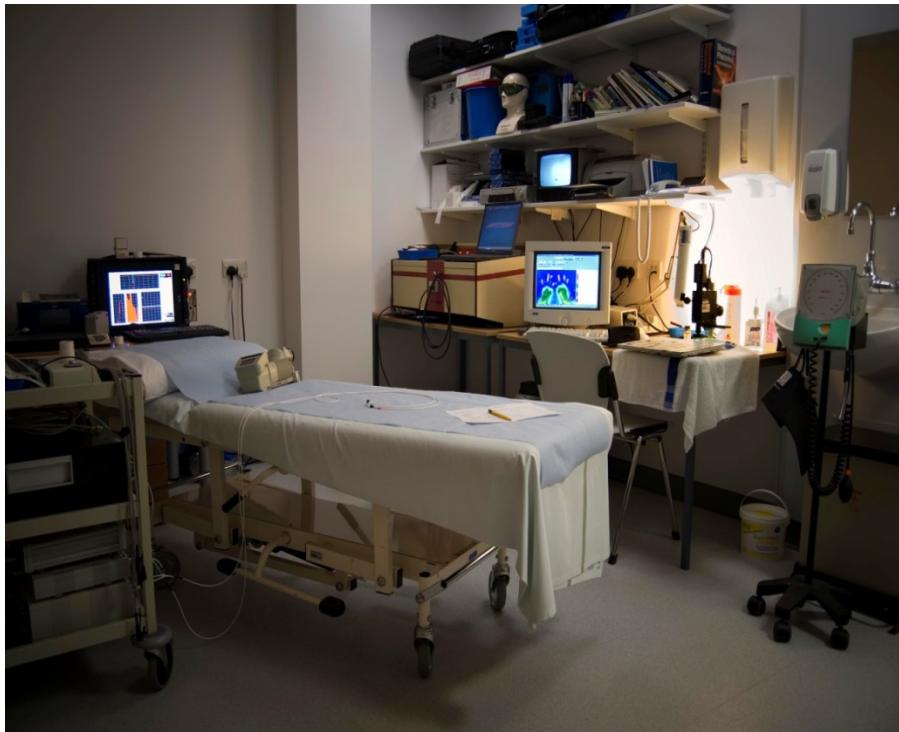
**NHS** MICROVASCULAR BLOOD FLOW STUDIES

After patient identification label below or complete details

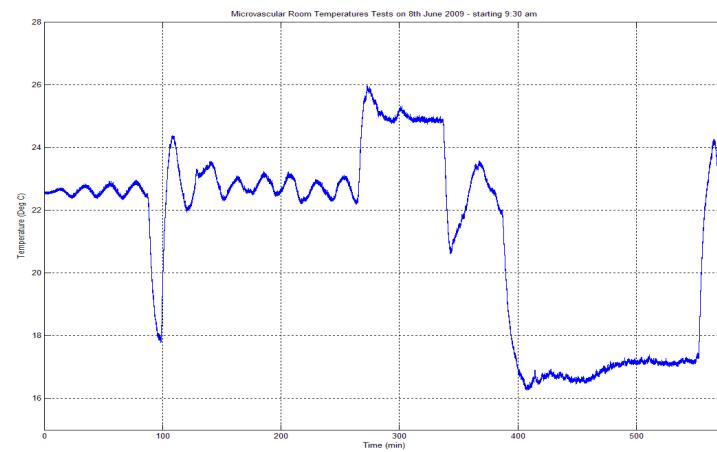
Sex:	Patient L.I. No.:	M / F	Age:
Female	1113		
Address:	115 Br.	Hospital	
Sec.	Male / Female	Consultant	
Details		Patient Telephone No.:	
Consultant Name/Department's ?		Walking <input type="checkbox"/> Chair <input type="checkbox"/> Bed <input type="checkbox"/> Ambulance <input type="checkbox"/>	
Catheterisation _____		DNACNA _____	
Therapy with cold therapy _____		Category: _____	
Invasive Studies, e.g. Angiogram _____		Notes: _____	
<b>Specialist Link Studies:</b>			
Angiogram Link _____			
Tissue Viability Studies _____			
Muscle Compartments _____			
Venous Physiology _____			
<b>Cervico/Breast studies:</b>			
Blood Physiology/Biochemistry _____			
Lower Limb Venosity _____			
Pheophytinography _____			
Doppler Venosity _____			
Optical Tissue Fluorescence _____			
Blow/Drawn Study _____			
DOCTOR'S SIGNATURE: _____		PRINTED SIGNATURE: _____	
REF ID: _____		REF ID: _____	
INCORRECTLY COMPLETED FORMS WILL BE RETURNED FOR AMENDING BEFORE AN APPOINTMENT IS MADE			



# Clinical Vascular Optics Facility

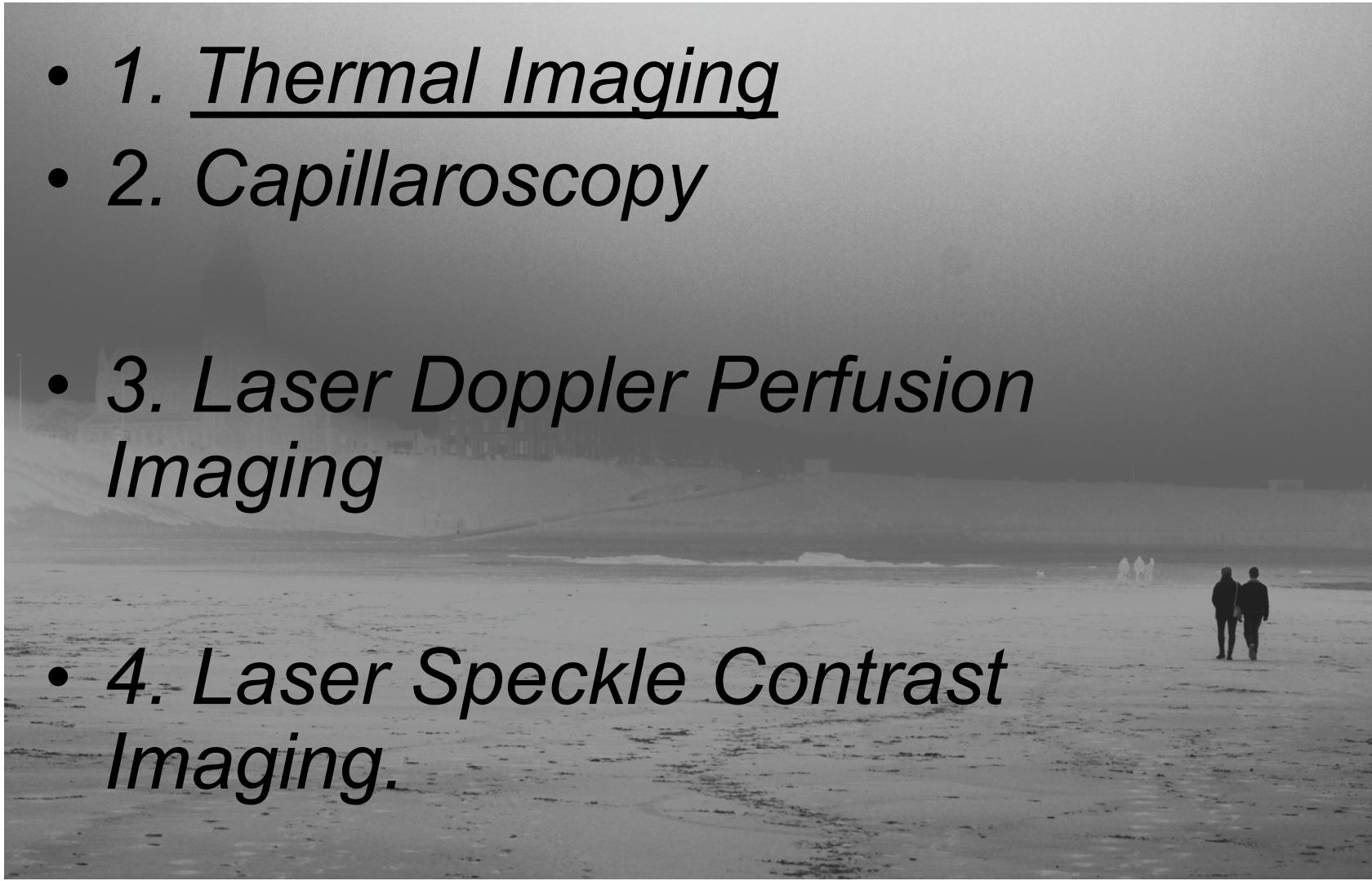


- Tightly controlled temperature and humidity ( $23\text{ }^{\circ}\text{C}$ ,  $\sim 40\%$  RH).
- Minimal circulating draughts.
- Operating range  $15$  to  $32\text{ }^{\circ}\text{C}$ .
- Transition attainable  $0.5\text{ }^{\circ}\text{C}/\text{min}$ .
- Designed for medical thermography.

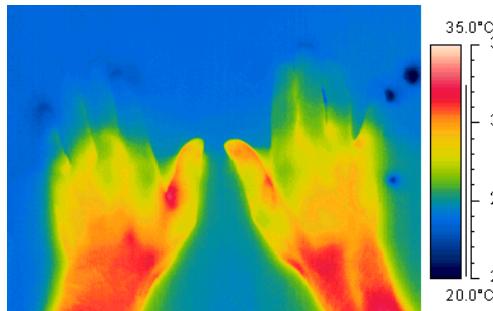


# Typical imaging modalities used

- 1. Thermal Imaging
- 2. Capillaroscopy
- 3. *Laser Doppler Perfusion Imaging*
- 4. *Laser Speckle Contrast Imaging.*



# Paper: Microvascular Imaging : Techniques and opportunities for clinical physiological measurements



John Allen and Kevin Howell

Topical Review paper for the Physiological Measurement journal. 2014. Nine techniques overviewed.

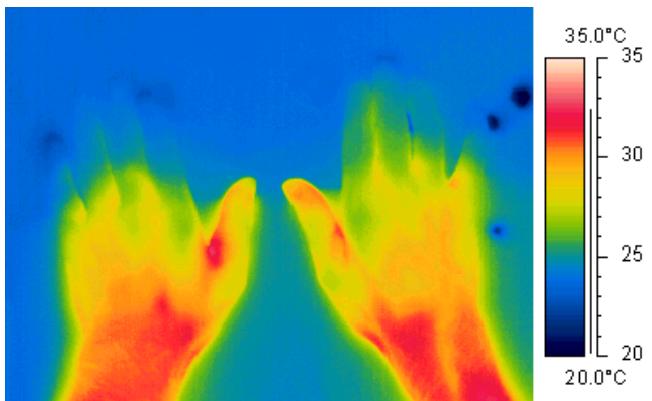
= Thermal Imaging, Capillaroscopy, LDPI, Laser Speckle, Hyperspectral, iPPG, TVI, SO<sub>2</sub>, + OCT



# 1. Medical thermal imaging



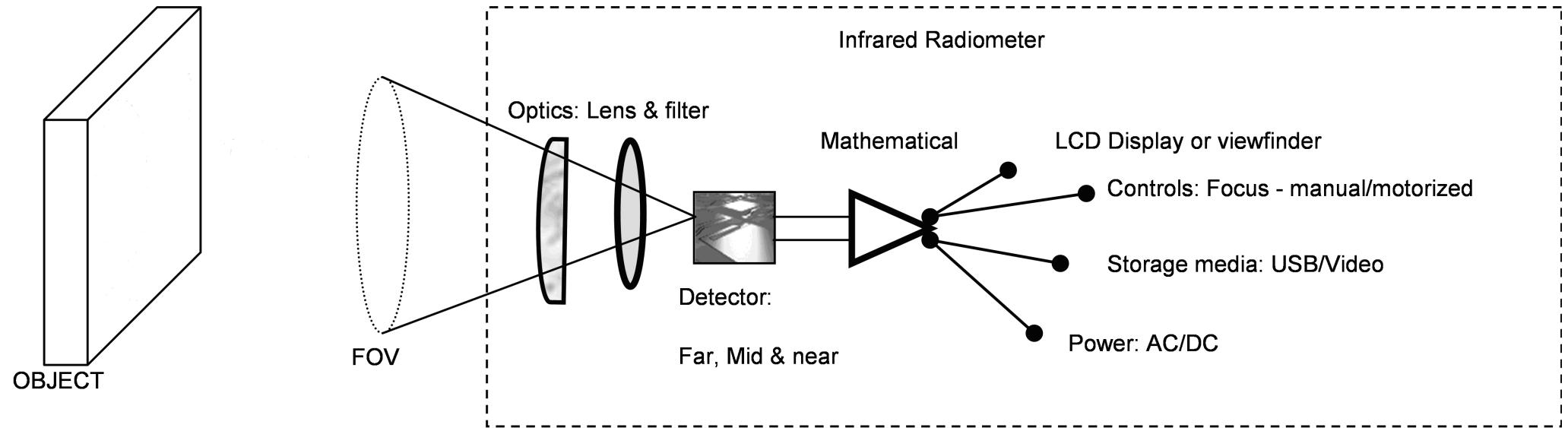
FLIR A655sc  
camera



Land P80P thermal black body reference

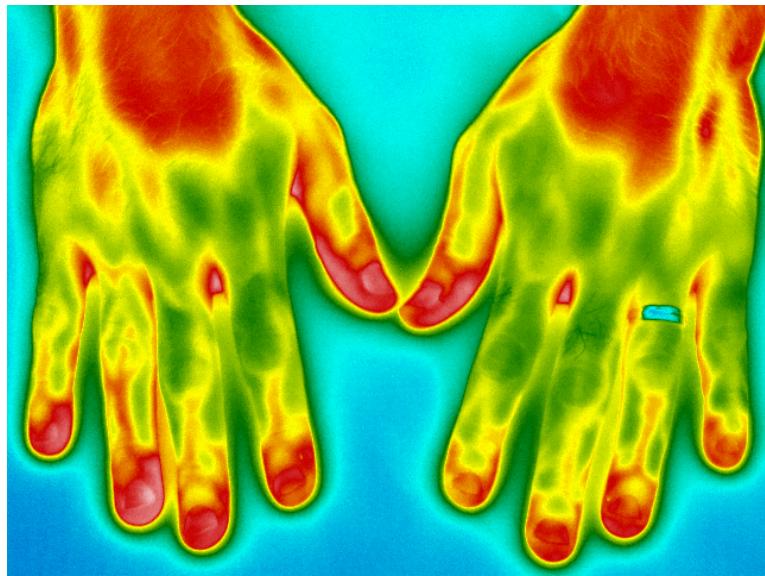


# Schematic of a modern thermal imaging system ...

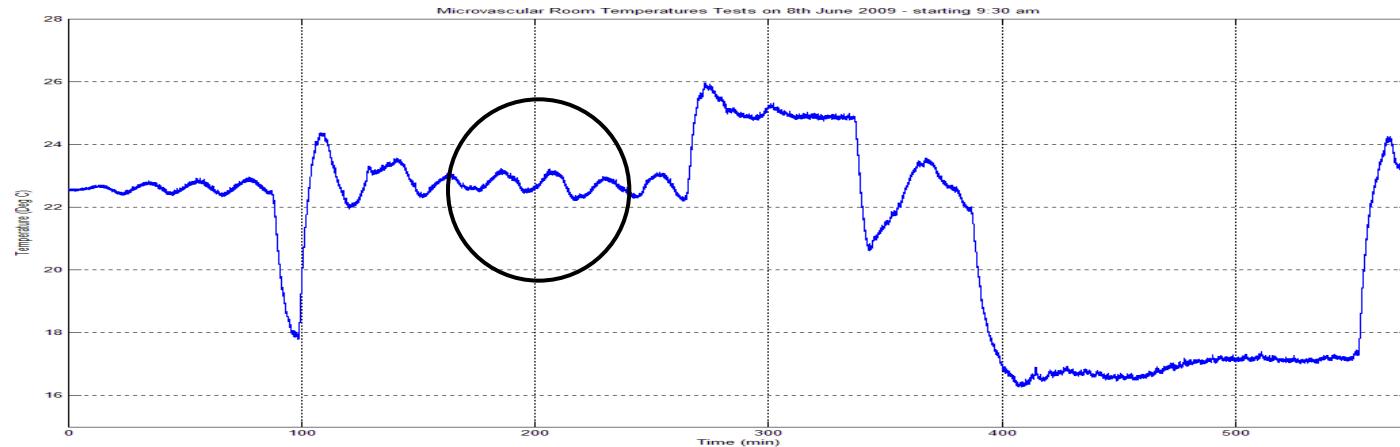


# Need reliable imaging

## Need to know characteristics of thermal imager

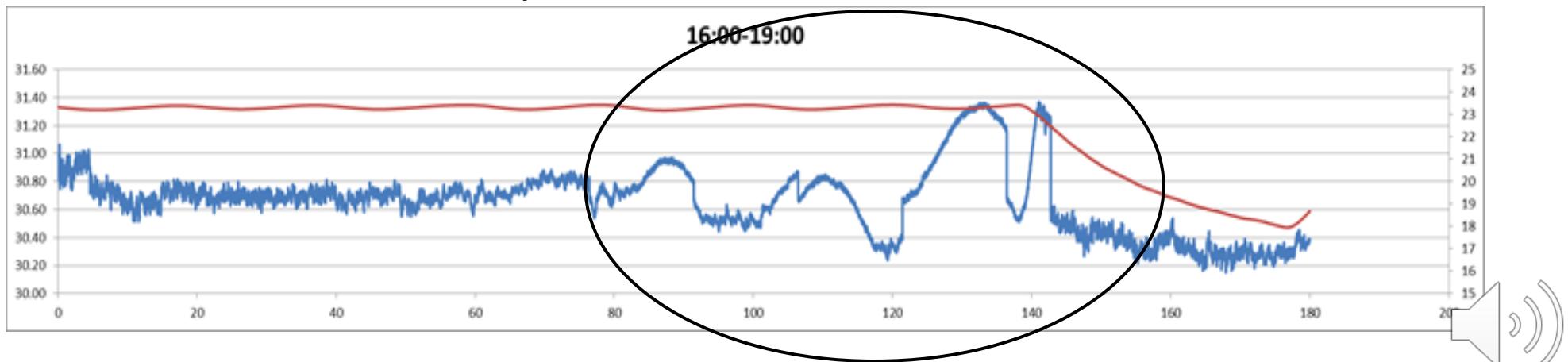


# Calibration / QA / testing vital!

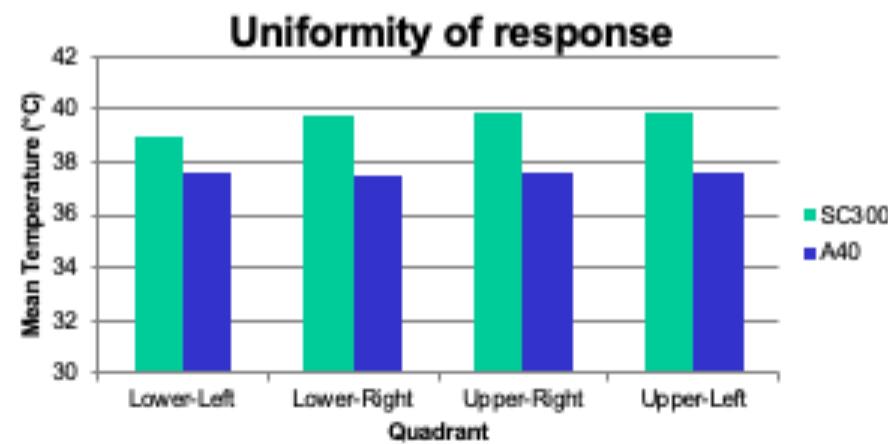
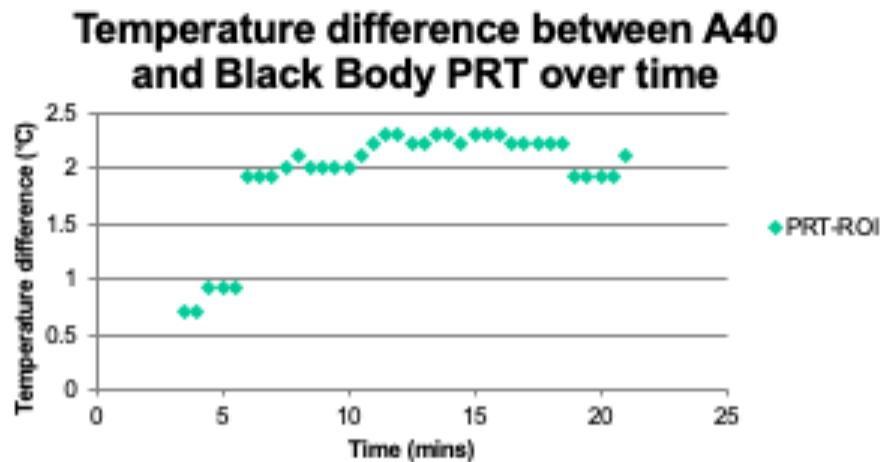


It is essential to have QA procedures ...

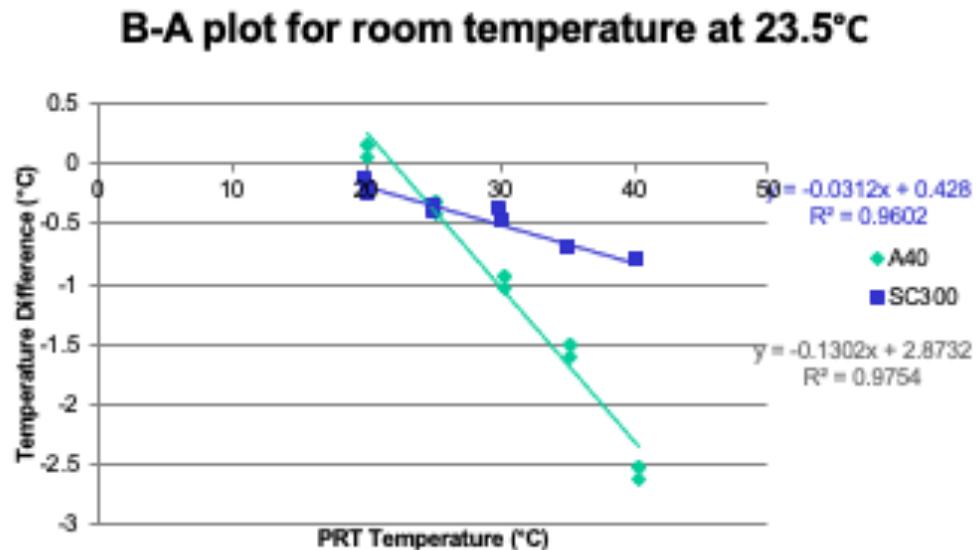
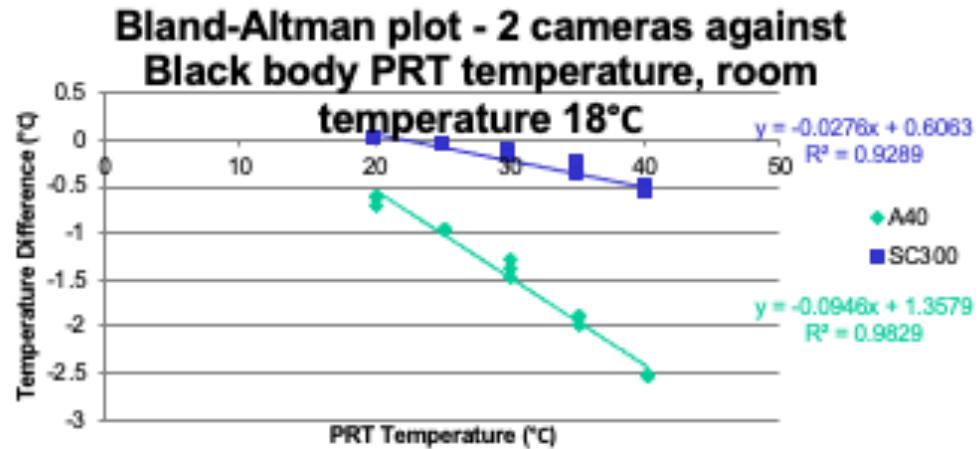
New thermal camera in service



# QA Camera tests 1



# QA Camera tests 2



# **Fundamentals: de-risking**

**Training in measurements +  
reporting**

**Risk Assessment  
Quality Assurance / Calibration  
Quality Management System  
External Audit**



# Key application: Raynaud's Phenomenon (RP)

- Skin vasospasm - cold exposure / emotional stress.
- Female predilection (F:M, 4:1).
- Fingers and toes.
- Colour changes: “White”, “Blue”, “Red”.
- Numbness.

Primary incidence ~3-10%. Also, ~10% of apparent RP patients who seek medical help eventually develop a secondary disorder (Spencer-Green).



# Key application: Systemic Sclerosis (SSc), a Connective Tissue Disease (CTD)

- Varied presentation:
- Fibrosis of skin & internal organs
- Thickening, hardening and tightening of skin
- Extent of skin involvement allows classification
- **Usually Raynaud's...**



# Examples of abnormal thermograms (?secondary Raynaud's – CTD)

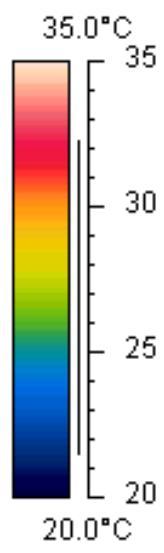
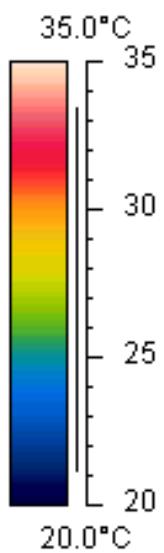
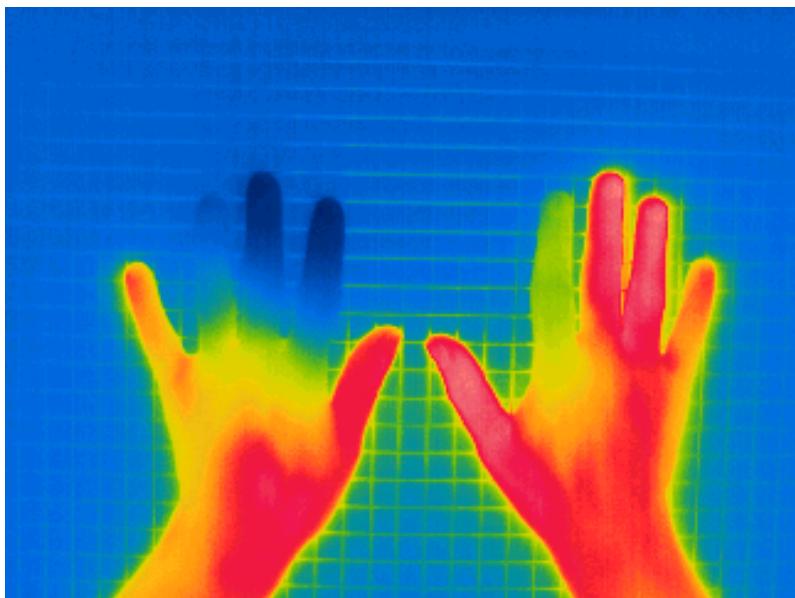


Image interpretation needs medical history /  
knowledge of neurophysiology and immunology



# Cold challenge provocation ...

- Temperature response to mild cold challenge
- Assess degree of vasospasm in the peripheral circulation to cold
- Post-challenge expect healthy subjects to have rapid symmetrical re-warming of fingertips. Fingers of Raynaud's patients greatly delayed ...
- Measurement protocol important. No standardization as yet, however.



# **Suggested pre-test protocol notes:**

Don't run a marathon before your test!

Don't smoke cigarettes. Don't drink coffee / cola / tea.

Wear sensible clothing on way to testing.

Don't use skin creams / talc on target measurement sites.

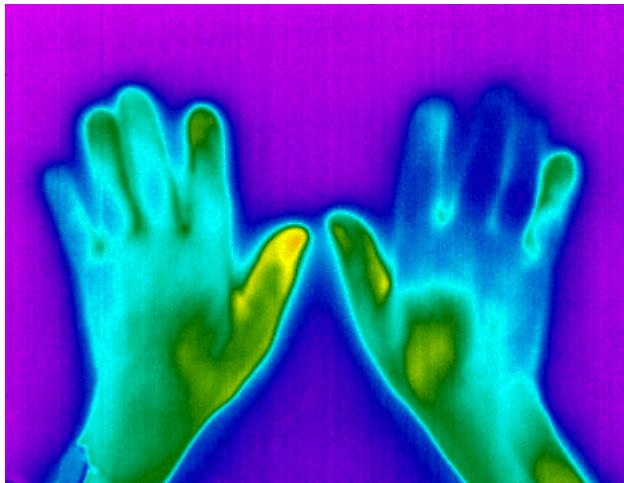
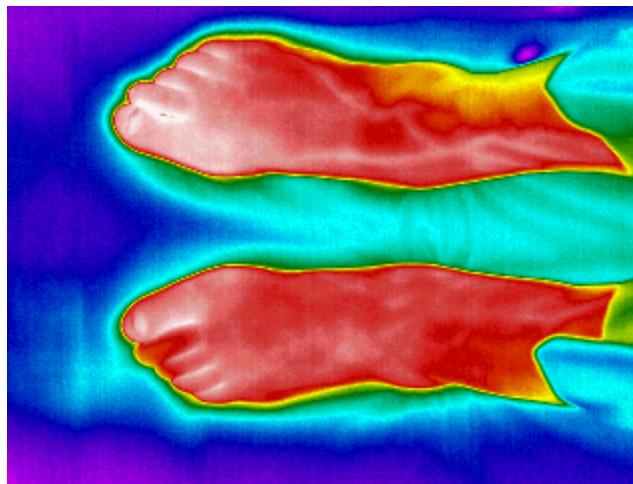
%

Arrive in good time for test. Patients to acclimatize at least 30 mins before imaging commences.

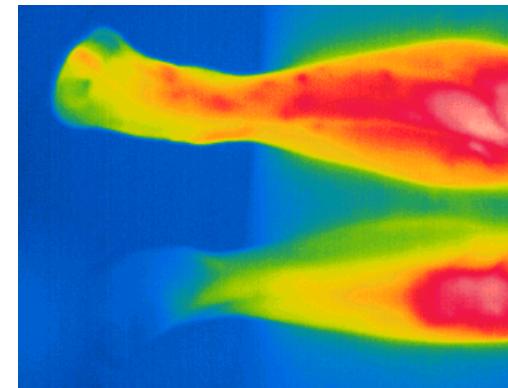


# Feet? : Other conditions ...

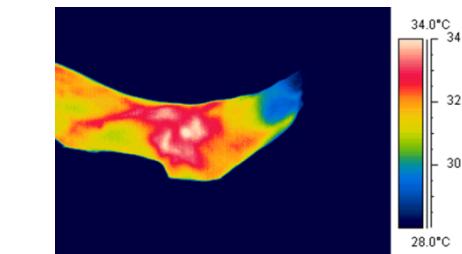
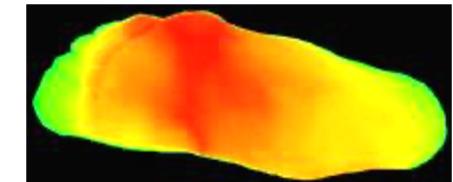
Erythromelalgia



Complex Regional Pain Syndrome



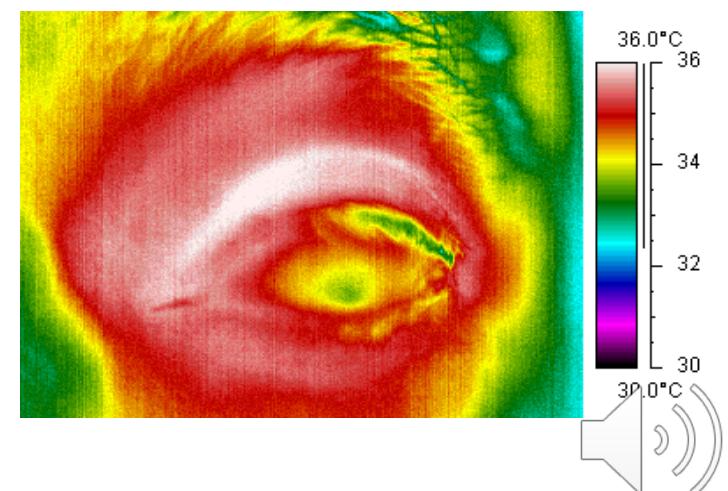
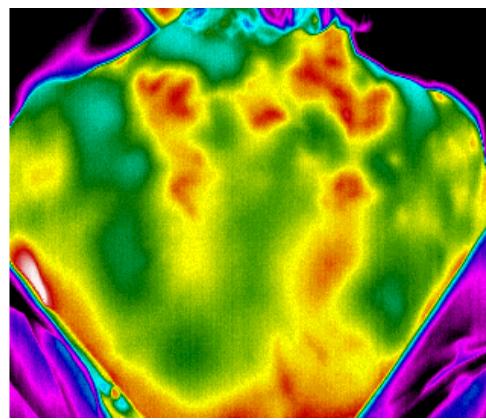
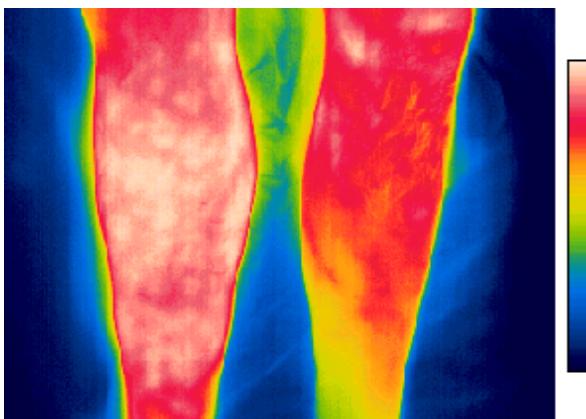
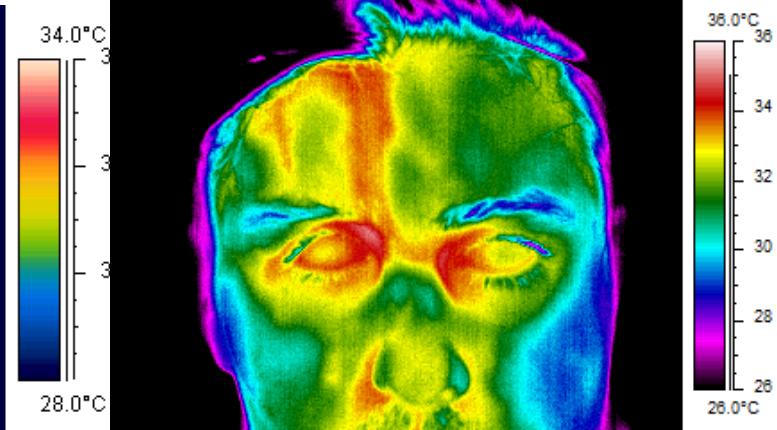
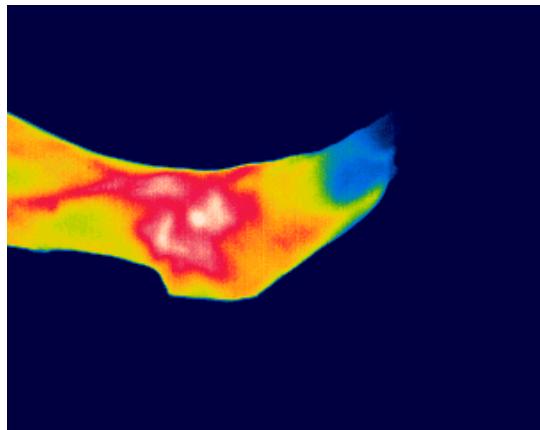
Diabetes



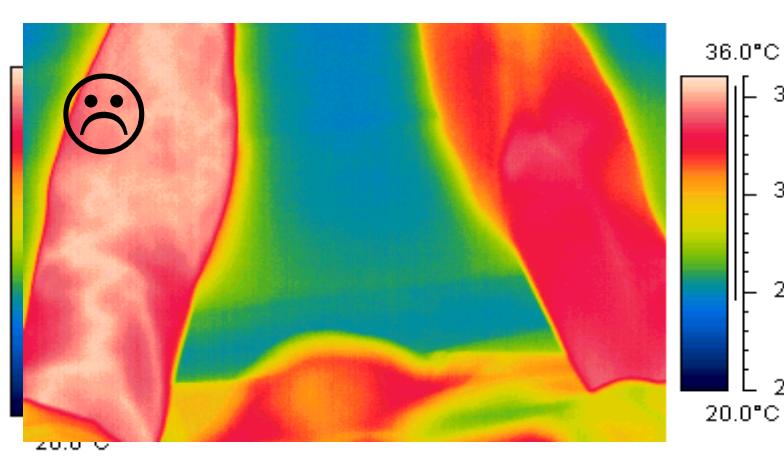
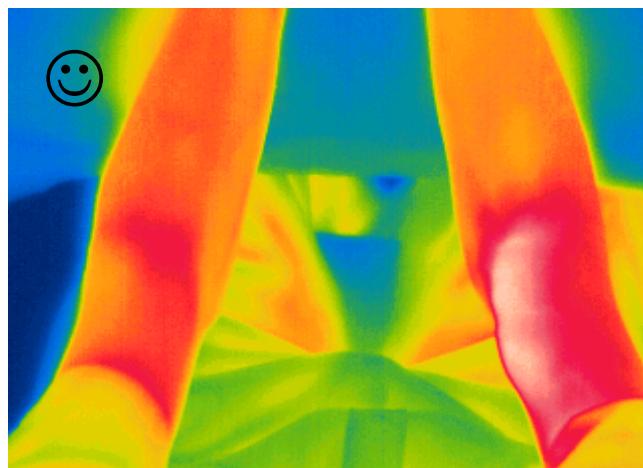
Non freezing cold injury



# Inflammation assessments



# Renal Fistula Assessment (steal and patency)



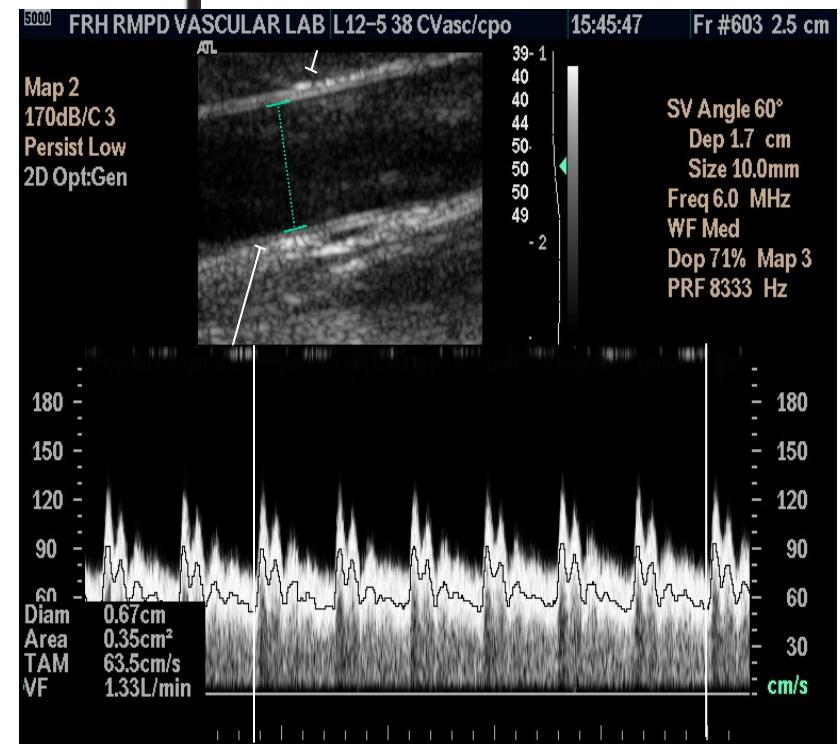
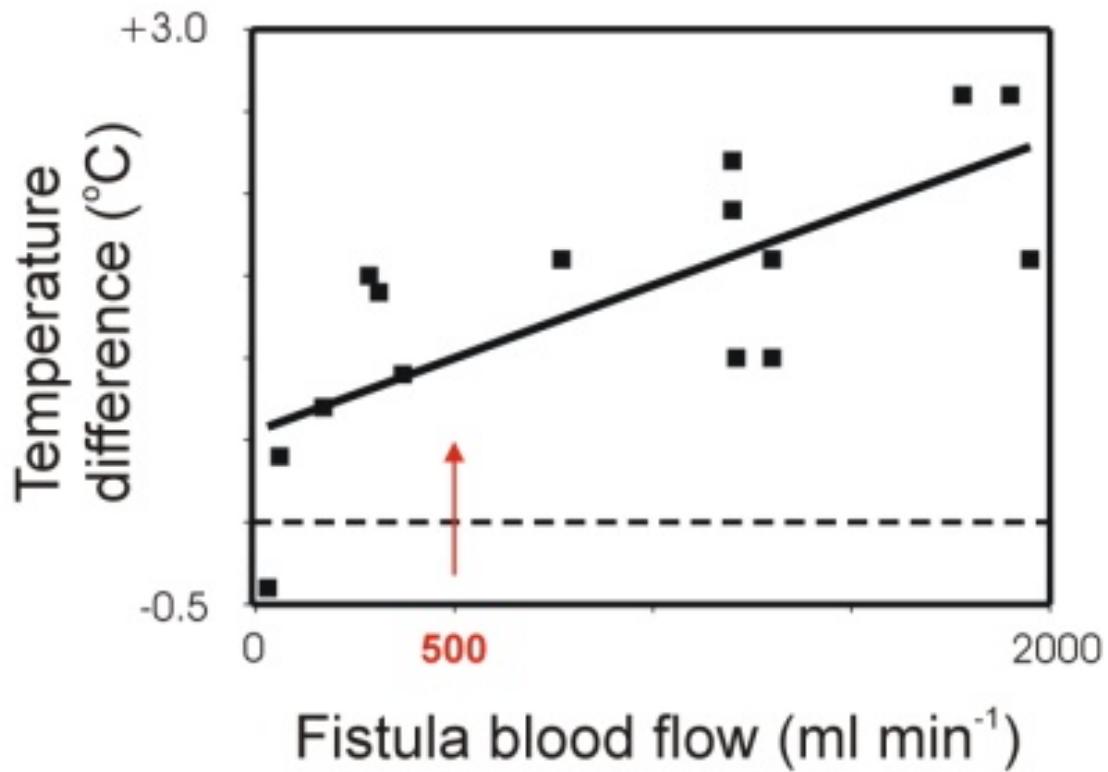
Brachial fistulas

Allen *et al* Physiol Meas 2006

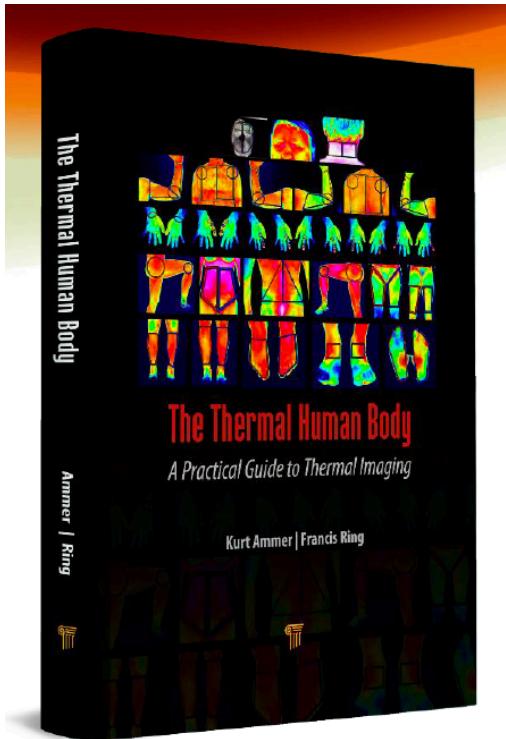


# Renal Fistula Assessment – great scope for TI

MAX Fistula - Non-Fistula region ( $R=0.76$ ,  $p<0.01$ )

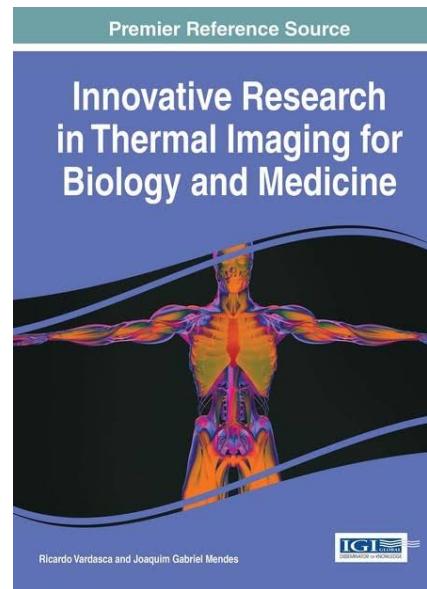
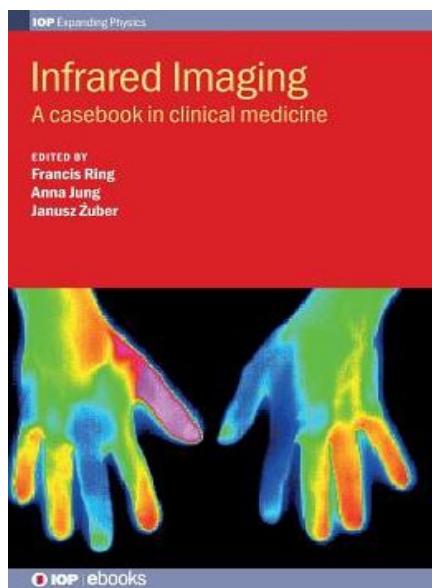


# Evidence base / Guidelines



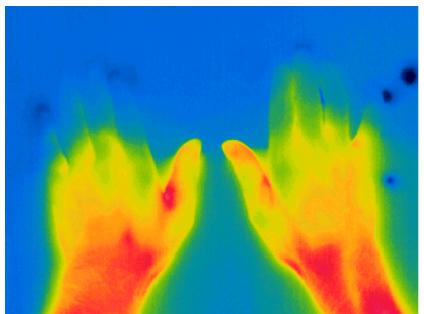
978-981-4745-82-6 (Hardback)  
978-0-429-01998-2 (eBook)

2019



# **Chapter: Development of a clinical thermal imaging and *vascular* *optics* measurement facility – the Newcastle upon Tyne experience**

In: Innovative Research in Thermal Imaging  
for Biology and Medicine, 2017

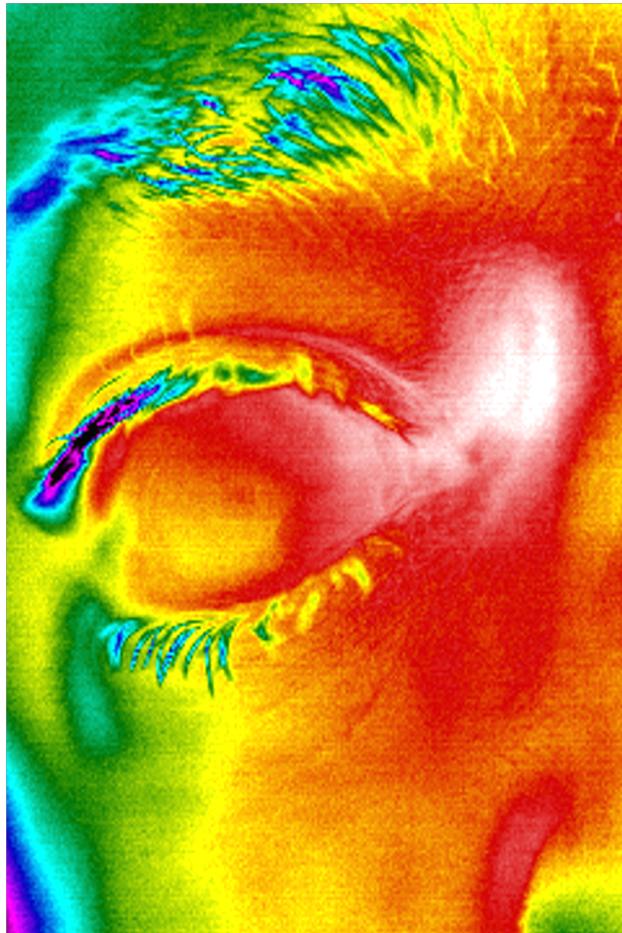


**John Allen**

**Overview article – development of facilities, measurement services, associated R&D, quality and training considerations**



# **Knowing the indirect symptom(s) of a disease ...**



**= Thyroid [eye] disease**



# TI cannot be used blindly...

## What is this?



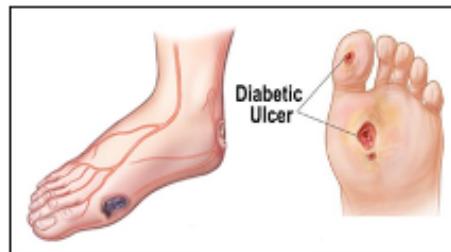
3

1

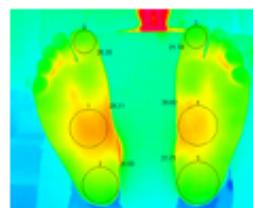


# Device development - Innovative diabetic foot ulcer prediction

**UK Consortium : NIHR i4i ~£1.2M Awarded NPL industry led project. UKCRN Portfolio**



- Knowing what is normal?
- Knowing optical imaging technology
- Calibration
- Develop robust image analysis method
- Testing effectiveness in clinic



Diabetic Med 2020 Jan;37(1):95-104.  
Doi: 10.1111/dme.14152. Epub 2019 Nov 13

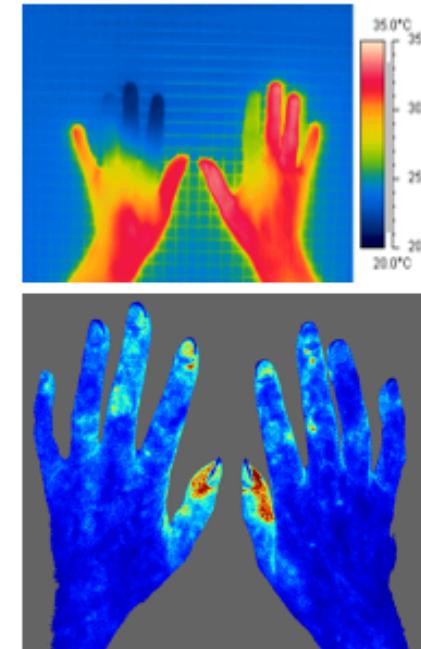


This slide is from independent research funded by the National Institute for Health Research Invention for Innovation (i4i) programme, "Innovative photoplethysmography technology for rapid non-invasive assessment of peripheral arterial disease in primary care", II-C1-0412-20003. The views expressed in this presentation are those of the author(s) and not necessarily those of the NHS, the National Institute for Health Research or the Department of Health.



# Scleroderma Imaging Research (UKCRN Portfolio)

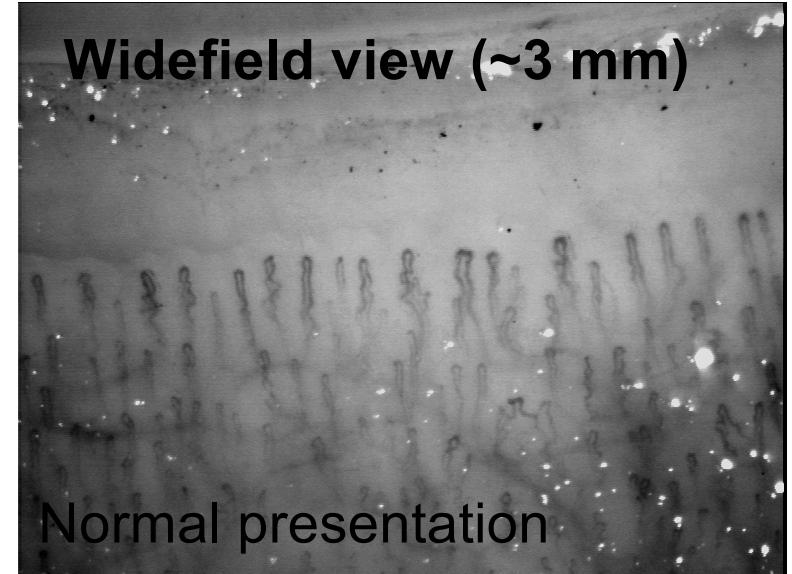
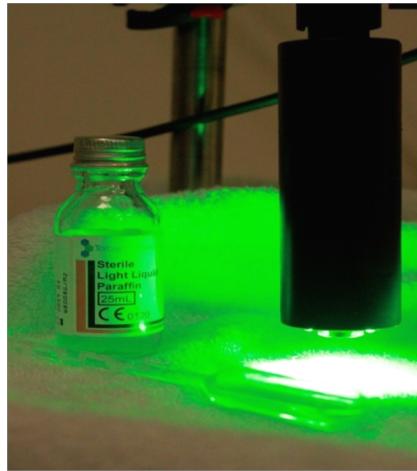
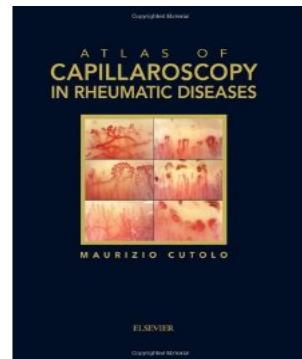
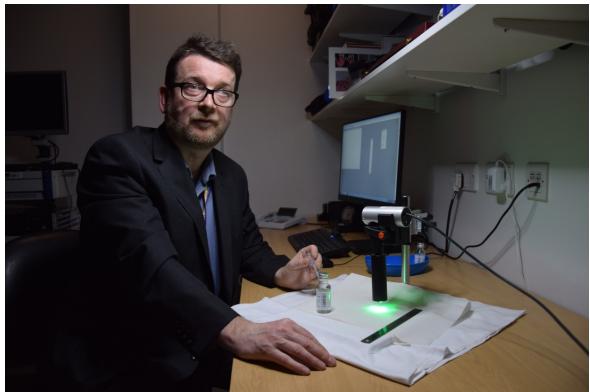
**~£200k Grant application to Arthritis Research UK  
Manchester University lead – 7 centres in UK  
John Allen Co-I Newcastle Upon Tyne**



Arthritis Rheumatol 2018 June;70(6):903-911.  
Doi:10.1002/art.40457 Epub 2018 Apr 23.

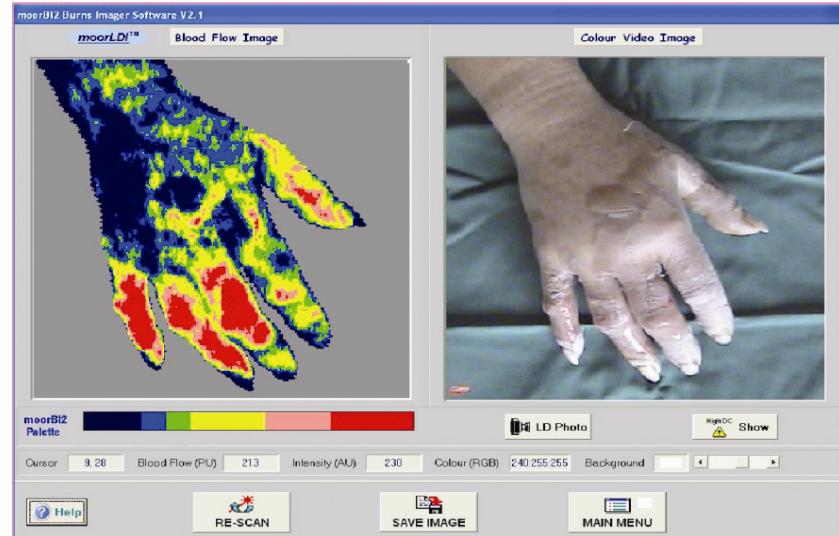
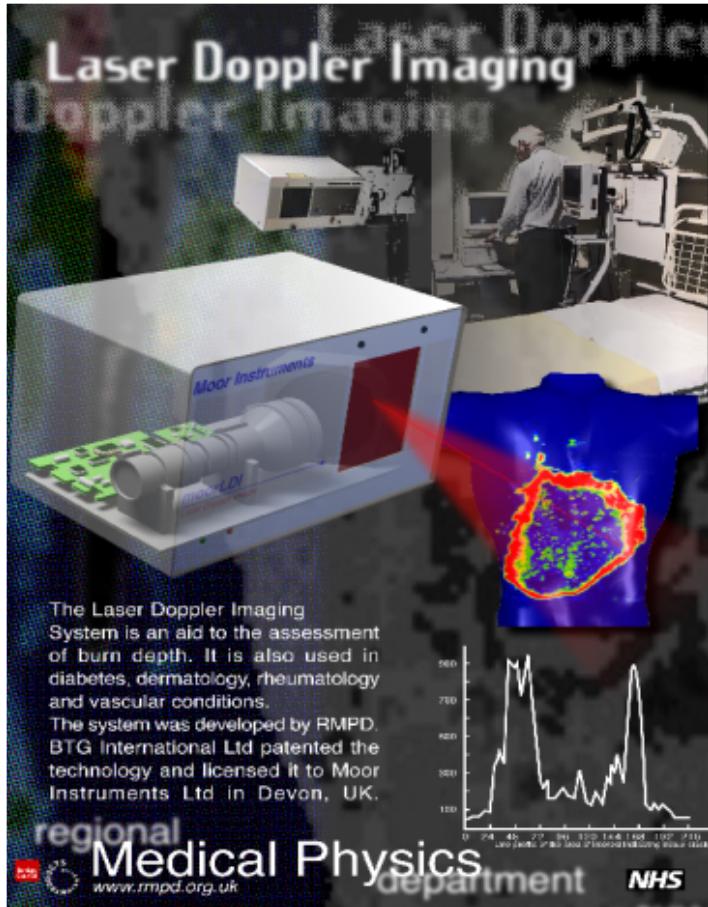


# 2. Nailfold Capillaroscopy (NFC)



From Allen and Howell 2014 (Physiologic Measurement)

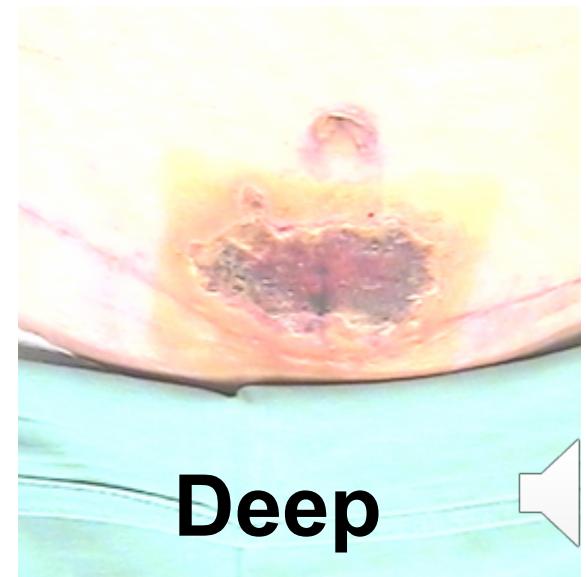
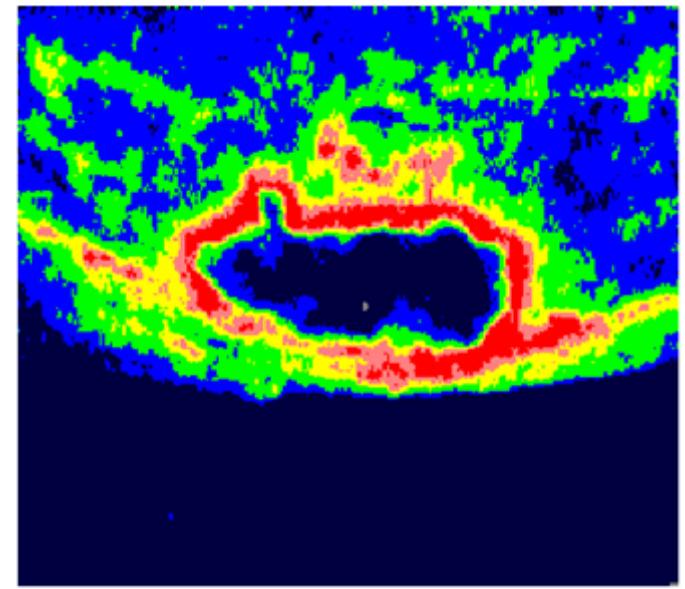
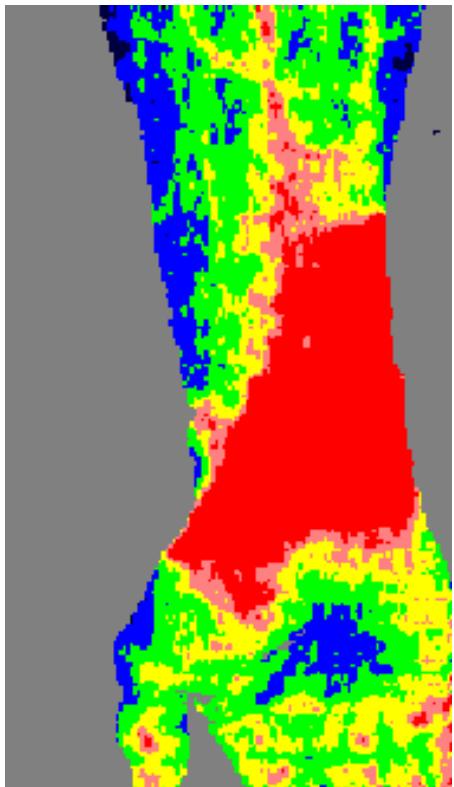
# 3. Laser Doppler Perfusion Imaging (LDPI)



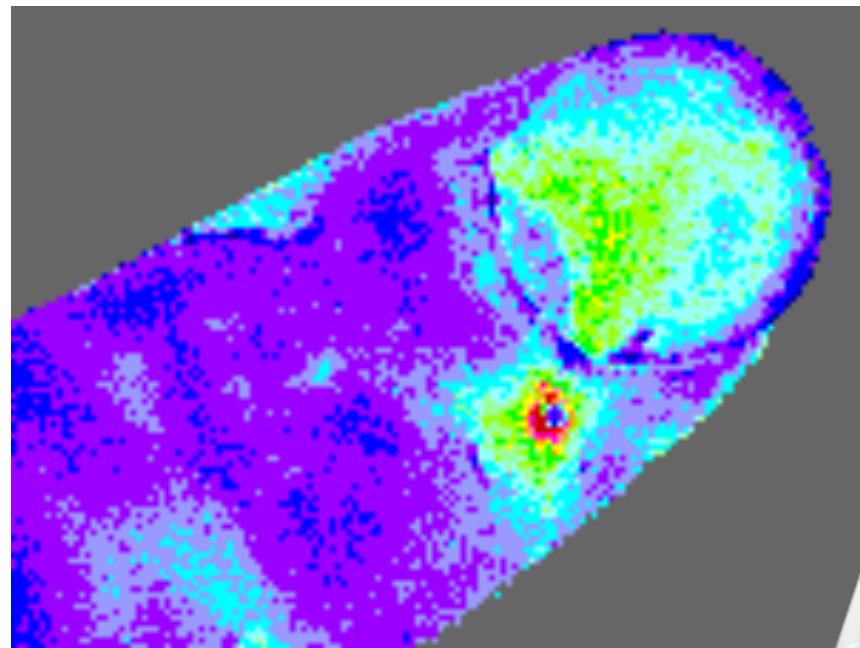
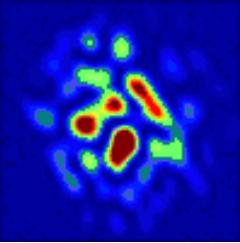
## Microvascular (skin) blood flow images



# LDI: Burn depth (NICE Approved):



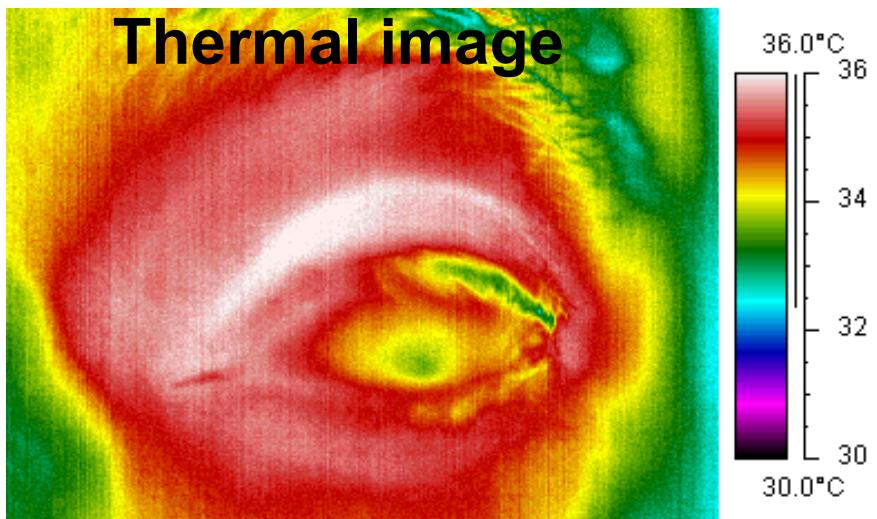
# 4. Laser speckle imaging (Moor Instruments)



- Full field imaging (25 fps)
- Indirect measure of fluctuations
- Reduction in spatial resolution, spatial averaging

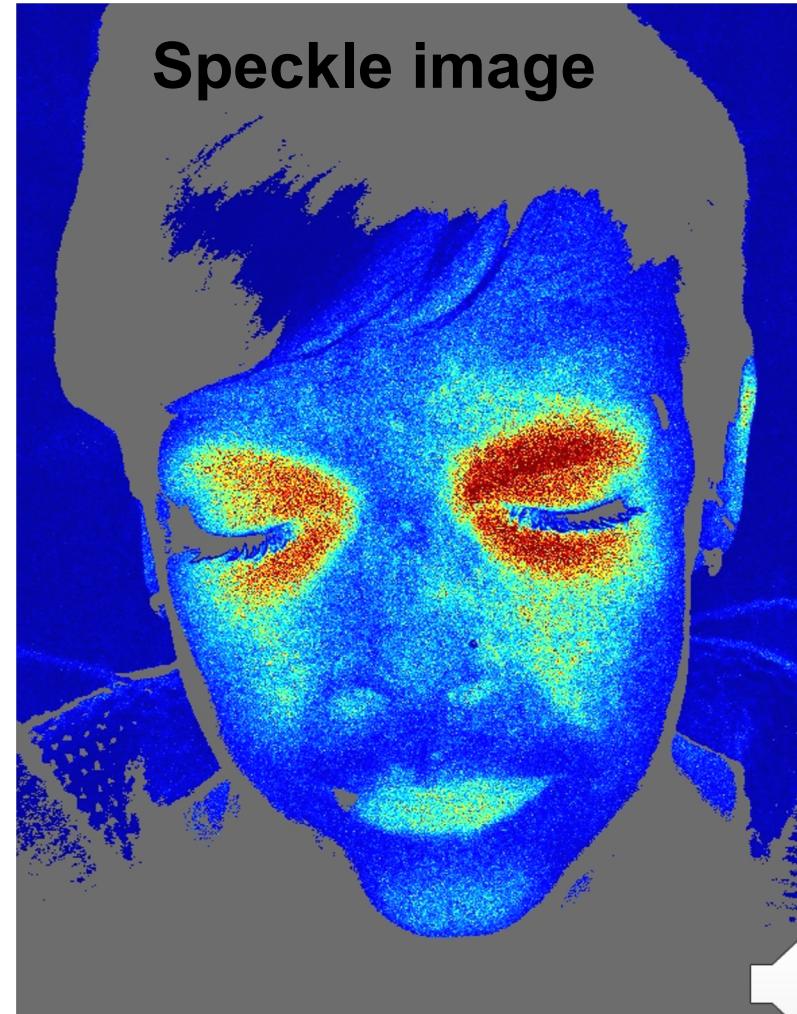


# Laser speckle imaging of tissue viability: Thyroid eye disease (TED) – Active inflammation



TED and TI :

Di Maria *et al* J Clin Endocr Metab 2014



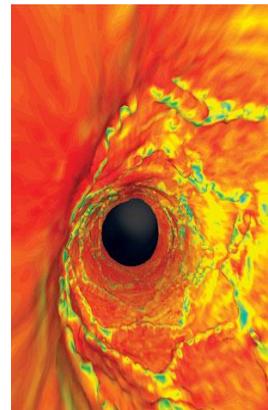
# Potential of *Vascular Optics*:

**Other optical techniques  
with capability for  
microvascular assessment**

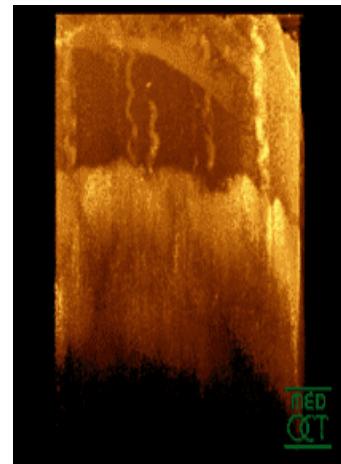


# Optical coherence tomography (OCT)

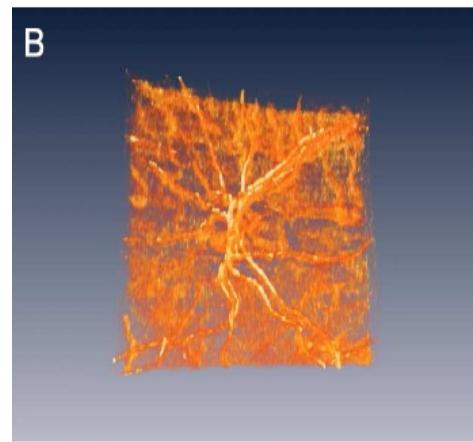
- Typically uses infrared light. *Interferometry*.
- High resolution.
- Tissue discontinuities / micro-structures.



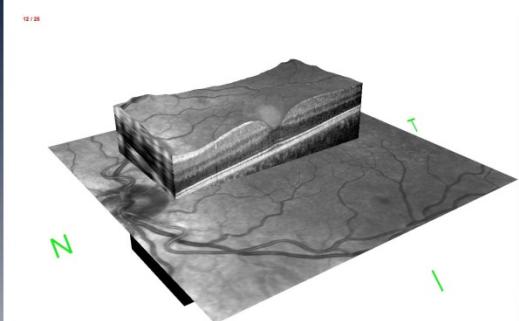
Coronary Artery  
wall composition



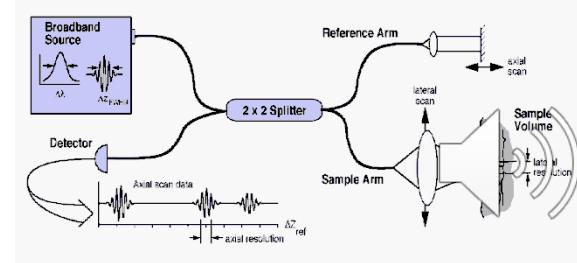
3D skin ( $\sim\text{mm}^3$ )



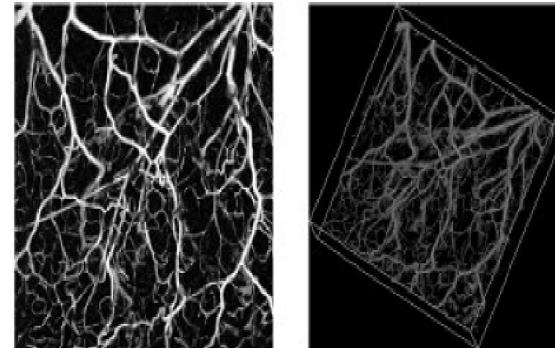
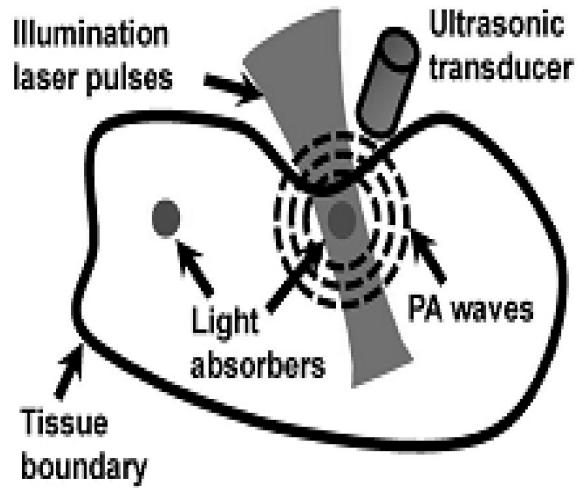
OCT Doppler blood flow



Eye

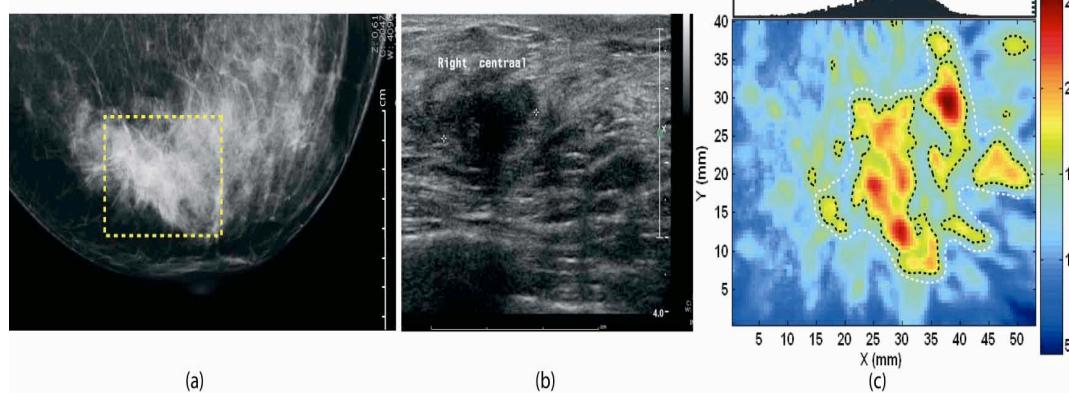


# Photo-Acoustic Tomography (PAT)



Skin

(b)



Breast  
cancer

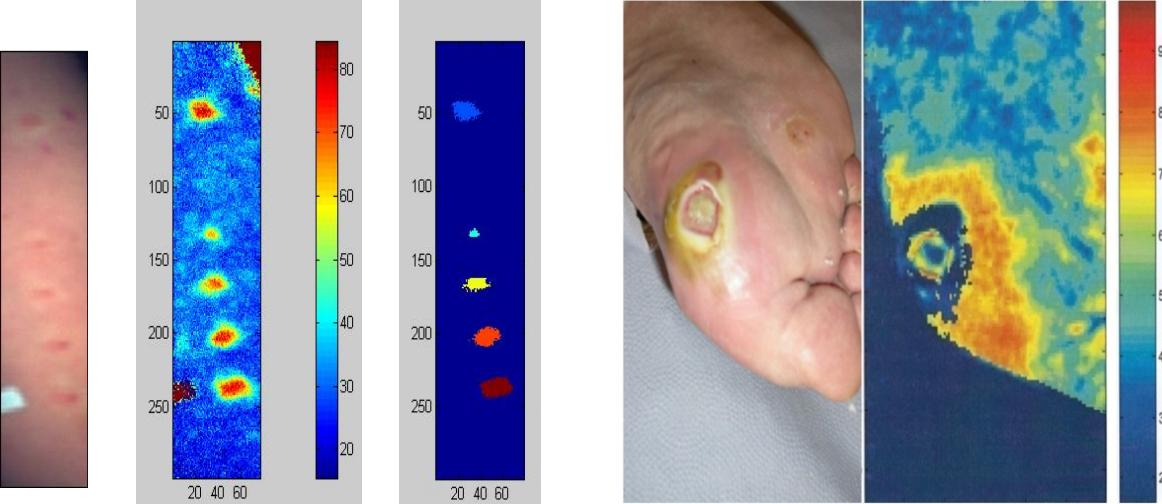
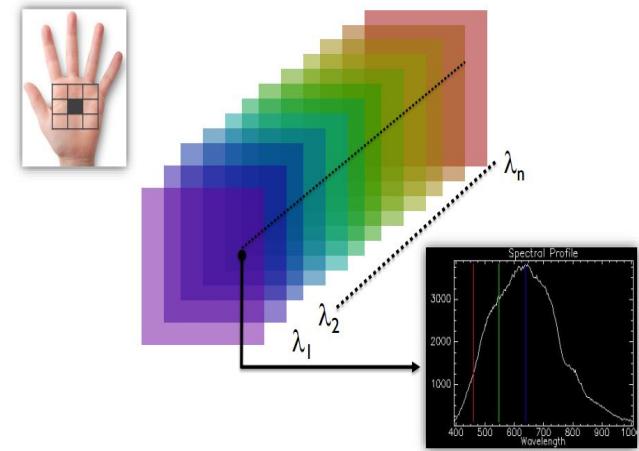
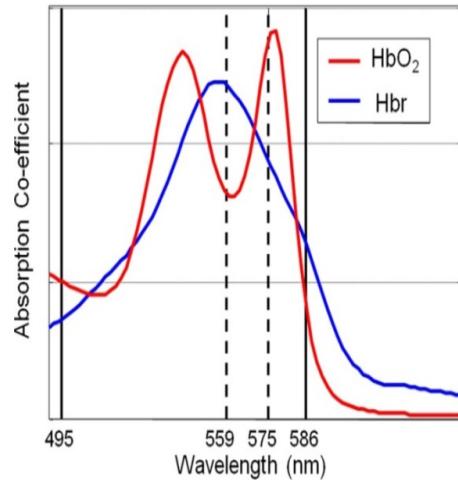


# Hyperspectral Imaging

## Tissue oxygen mapping

### HYPER SPECTRAL IMAGING

Improves vision and discrimination power by using spectral signature information of surface material / object being captured



Skin inflammation / reaction      Diabetic foot ulcers



The Newcastle upon Tyne Hospitals **NHS**  
NHS Foundation Trust



## The *PulsePad* device for rapid assessment of peripheral arterial disease (PAD) in primary care



North of England  
Commissioning Support Unit



- **Problem:** PAD is a killer disease. Clinical need for patients to get accessible diagnostics in primary care.
- **Solution:** Develop *PulsePad* device + build case for adoption + commercialisation.
- **Design:** Automated, easy-to-use, quick, digital, informed ergonomics and aesthetics, production, scalability, IP.
- **Accuracy:** comparable with current PAD diagnostics i.e. the ABPI.
- **NIHR i4i Cardiovascular Challenge** funded ~£1.3M. Project 2014-17. NuTH / Medical Physics led by Dr John Allen and a multi-disciplinary team including Dr A. Sims, Dr J Wightman and Professor G. Stansby.
- A journey to “game changer” impact.

### *PulsePad* device with innovative pulse wave analysis to detect PAD



Pulses damped &  
delayed in PAD

Uses our patented photoplethysmography (PPG)  
finger / toe pulse sensor design

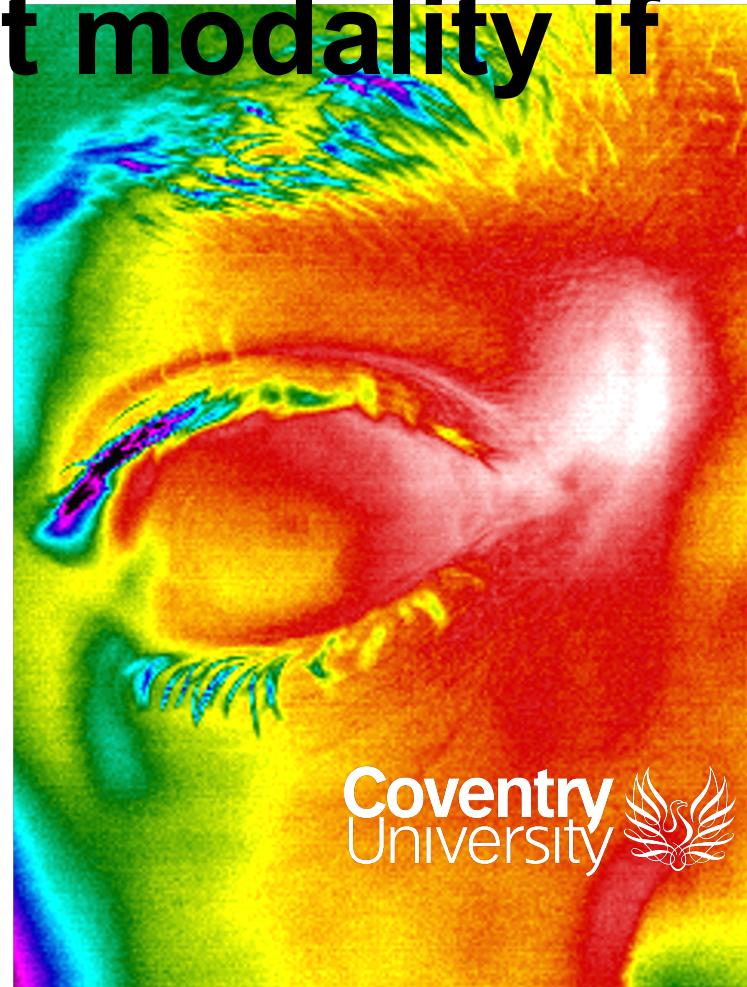


This slide is non-independent research funded by the National Institute for Health Research Inventive for Innovation (I4i) programme, “Innovative photoplethysmography technology for rapid non-invasive assessment of peripheral arterial disease in primary care”, II-D1-0412-20003. The views expressed in this presentation are those of the author(s) and not necessarily those of the NHS, the National Institute for Health Research or the Department of Health.



Allen *Physiol Meas* 2007

Many opportunities in  
*Vascular Optics* but Thermal  
Imaging is a great modality if  
used carefully.



# Summary

- Service potential overviewed.
- Microvascular FOCUS. Thermal Imaging and Capillaroscopy main technologies.
- ... many other measurements possible.
- Overviewed - linked R&D potential.
- Challenges = protocols and standardization, training for resilience, equipment resources, evidence base, QMS and service accreditation.
- **New Facility / Research team at Coventry, UK.**
- ... New focus on Digital Healthcare / accessible Dx.
- Bottom-line: Vascular Optics has great potential.

# Thank you



IMAGING  
SCIENTIST  
ASIS FRPS

- <https://pureportal.coventry.ac.uk/en/persons/john-allen>
- [ad5325@coventry.ac.uk](mailto:ad5325@coventry.ac.uk)
- Health Technology and Innovation (HTI) group,  
Research Centre for Intelligent Healthcare (CIH),  
Coventry University, Coventry UK.

