

Tissue oxygen saturation in healthy volunteers with varying degrees of occlusion to their peripheral circulation

Helping to understand the risk factors involved in PU formation?

Miss Emma Scott

Vascular Research Fellow and Specialty Trainee

Prof Gerard Stansby

Professor of Vascular Surgery

Dr John Allen

Lead Medical Physicist



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Pressure ulcers

- Localised injury to the skin and/or underlying tissue usually over a bony prominence, as a result of pressure or of pressure in combination with shear
- Pressure ulcers are common, debilitating and potentially avoidable.
- Managing patients with pressure ulcers costs the NHS an estimated **£3.8million per day**.
- Currently scoring systems and skin checks by nursing staff form the risk assessment carried out for patients.
- Despite this, in our NHS Trust over **100 new Pressure Ulcers** develop in hospital **inpatients every month**.

Secondary Perception	1. Completely limited	2. Very limited	3. Slightly limited	4. No impairment
Moisture	1. Completely moist	2. Moist	3. Occasionally moist	4. Dryly moist
Activity	1. Bedridden	2. Limited	3. Partially ambulatory	4. Mobile
Healthy	1. Completely healthy	2. Very limited	3. Slightly limited	4. Not limited
Nutrition	1. Very Good	2. Probably inadequate	3. Inadequate	4. Inadequate
Infection and other	1. Problem	2. Potential Problem	3. No Apparent Problem	4. No Apparent Problem

Superficial



EPUAP - Category/Grade 1

- Non-blanchable erythema of intact skin; persistent redness in lightly pigmented skin.
- Discolouration of the skin: observe for a change of colour as compared to surrounding skin. In darker skin, the ulcer may be blue or purple.
- Warmth, oedema, induration or hardness as compared to adjacent tissue may also be used as indicators, particularly on individuals with darker skin.
- May include sensation (pain, itching).

EPUAP System - Category/Grade 2

- Partial thickness skin loss involving epidermis, dermis or both.
- Presents clinically as an abrasion or clear blister.
- Ulcer is superficial without bruising*
- Check for moisture lesion.

*Bruising appearance and blood filled blister would indicate deep tissue injury.

Deep



EPUAP - Category/Grade 3

- Full thickness skin loss. Subcutaneous fat may be visible but bone, tendon and muscle are not exposed.
- May include undermining and tunneling.
- The depth varies by anatomical location (ridge of the nose, ear, occiput and malleoli do not have adipose) subcutaneous tissue and grade 3 ulcers can be shallow.
- In contract areas of significant adiposity can develop extremely deep grade 3 pressure ulcers.
- Ischaemia is not visible or directly palpable.

Phases: Unclassified/PU - now Grade 3

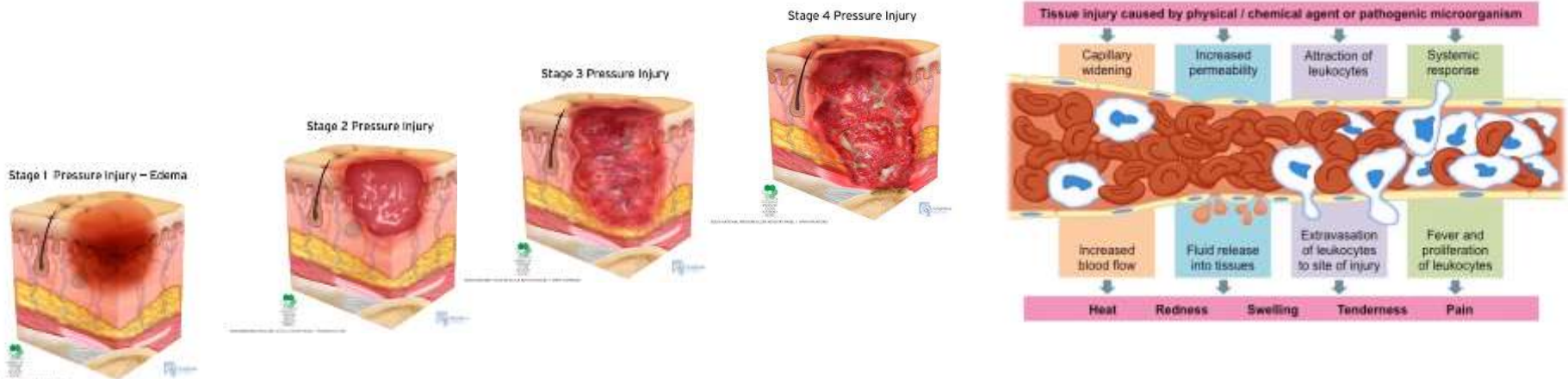
- Full thickness tissue loss in which actual depth of the ulcer is completely obscured by slough (yellow, tan, grey, green, brown, black, eschar) in the wound bed. (until enough slough is removed to expose the base of the wound), the true depth cannot be determined, but it will be either grade 3 or 4.
- Stable eschar (dry, adherent, intact without erythema or fluctuance) on the heel can be the body's natural biological cover and should not be removed.
- Should be documented as grade 3 until proven otherwise.

EPUAP - Category/Grade 4

- Full thickness tissue loss with exposed bone (or directly palpable), tendon.
- Often include undermining and tunneling.
- The depth varies by anatomical location (ridge of the nose, ear, occiput and malleoli do not have adipose) subcutaneous tissue and grade 4 ulcers can be shallow.
- Grade 4 ulcers can extend into the muscle and/or supporting structures (eg fascia, tendon or joint capsule).

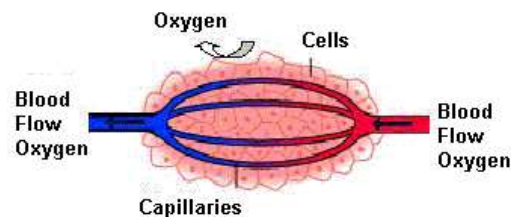
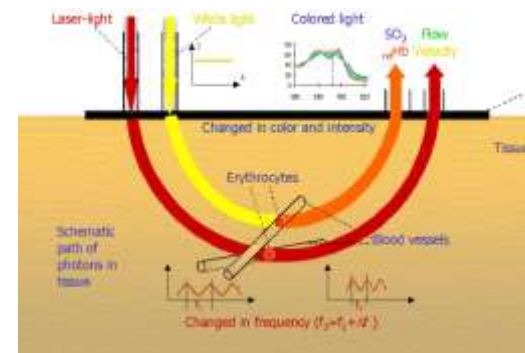
Tissue Injury

- When tissue damage occurs, local inflammatory responses cause inflammation and swelling.
 - This can lead to necrosis and ulceration.
- One risk factor for pressure ulcer is peripheral vascular disease.
- In order for inflammation and healing to occur, an adequate circulation is required.



Spectrometry

- Visible light spectrometry ($\lambda=500-620\text{nm}$)
- Blood changes colour with level of oxygen bound to haemoglobin.
 - Arterial blood=light red
 - Venous blood=light blue
- Light shone onto skin, detected by probe
- Measures capillary-venous part of vascular tree
 - sensitive to hypoxia
 - Microcirculation, end organs (rather than pulse ox)



Tissue oxygen saturation

- Visible (white light) spectrometry can be used to evaluate tissue oxygen saturations on the surface of the skin.
- Near infra-red spectrometry is a technique which can estimate tissue oxygen saturation levels of tissues up to 25mm in depth with certain probe configurations and for specific tissue areas

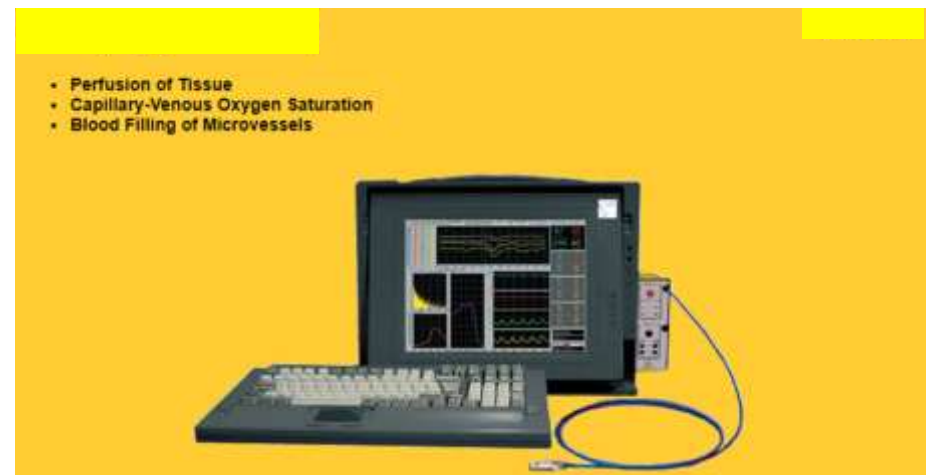
Aim

- The aim of this pilot study was to

assess **tissue perfusion changes** under
simulated vascular impairment with
objective measurements derived
using **tissue oxygen saturations**

Method

- Twelve adult healthy volunteers were studied in a temperature and light controlled room.
- Brachial BP measurement taken.
- Offloading
- After 10 minutes of acclimatisation, baseline TOS measurements were taken from their right heel.



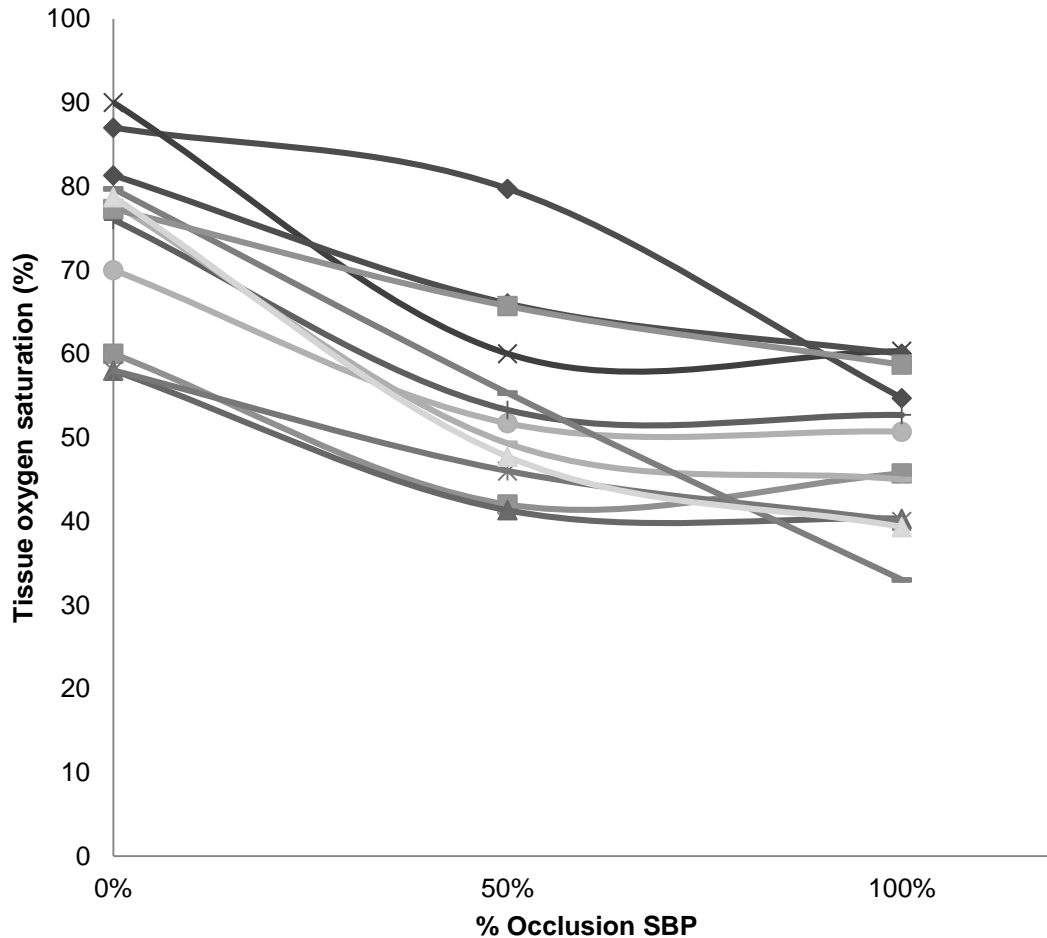
- A manual sphygmomanometer was positioned around their study ankle.
- TOS measurements were taken
 - at rest
 - after cuff inflation to 50% SBP
 - after cuff inflation to 100% SBPfor 1 minute (with 1 minute rest periods).
- TOS measurements were repeated 3 times and the mean values used.



Results

- 12 healthy volunteers
 - 6 male and 6 female
- Age range 23 to 62 years
- For all healthy volunteers
 - The baseline saturation values were variable (58.0 to 90.0%).
 - The saturation values dropped following occlusions of the peripheral circulation.

Tissue oxygen saturation levels for varying % occlusion

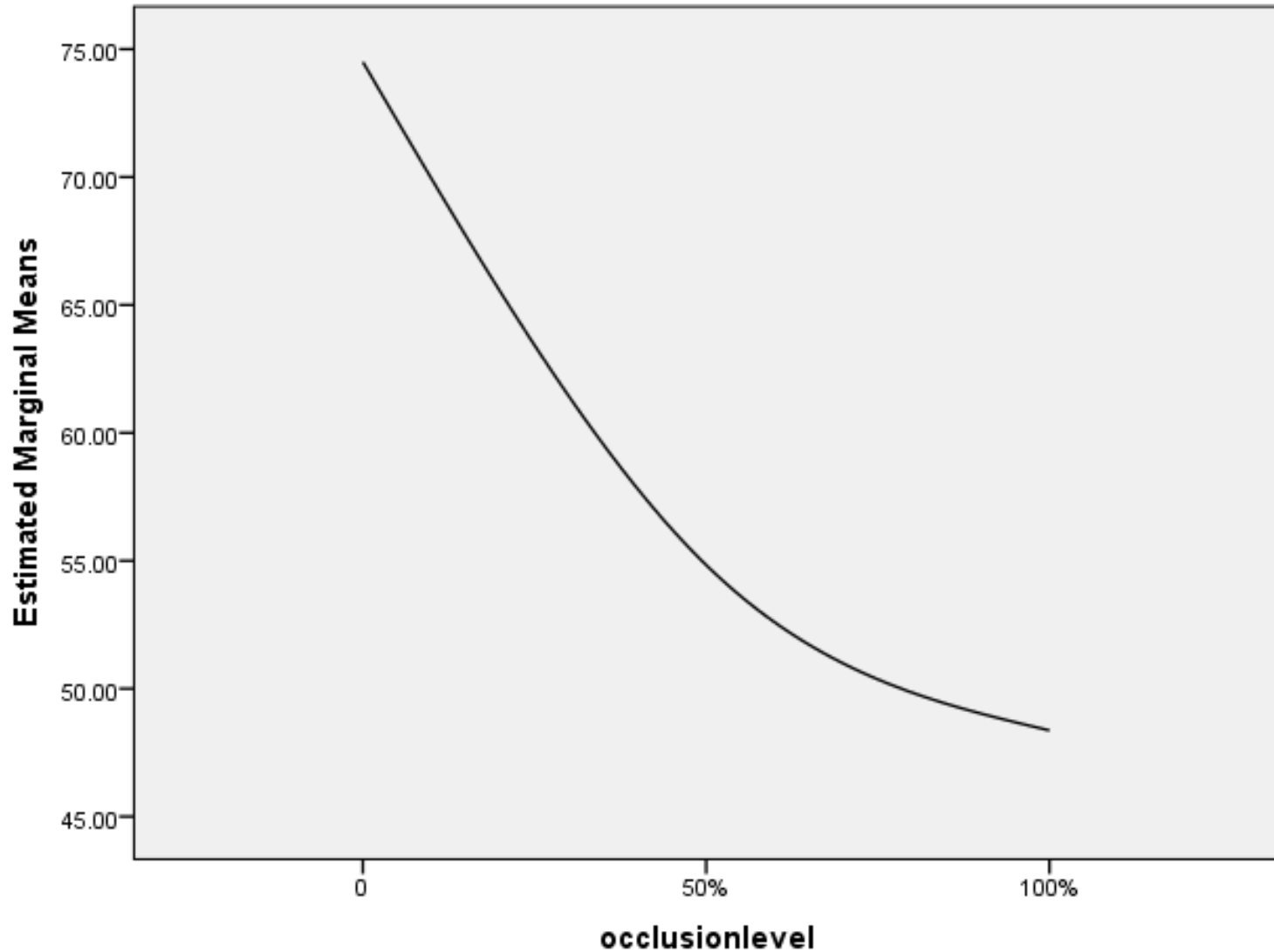


- Occlusion by 50% SBP reduced the saturation levels in all volunteers (mean 25.2%) $p < 0.05$

- Increasing from 50 to 100% SBP only dropped the saturation levels by a further 8.2% $p > 0.05$



Estimated Marginal Means of TOS



Discussion

- The relationship between degree of vascular occlusion and tissue oxygen saturation appears to be non-linear.
- The presence of even mild peripheral vascular disease or a state of reduced perfusion (i.e. any cause of shock) may significantly reduce the tissue saturation and thus healing potential, increasing the risk of ulcer formation.
- Should we be even more aggressive in our assessment and management of BP and vascular disease in patients with pressure related damage and ulceration?
- Is there a role for combination of patient risk factors and tissue quality measurements in the management of PUs?

Limitations

- Limited number of participants
- Superficial measurements
 - Melanin content
 - Dry skin/Callous
- Low frequency variations



Further work

- Measurements in patients
 - at risk of PUs
 - confirmed Category I PUs
- Other techniques to assess tissue properties
- Low frequency variation analysis
- Time to recover

References

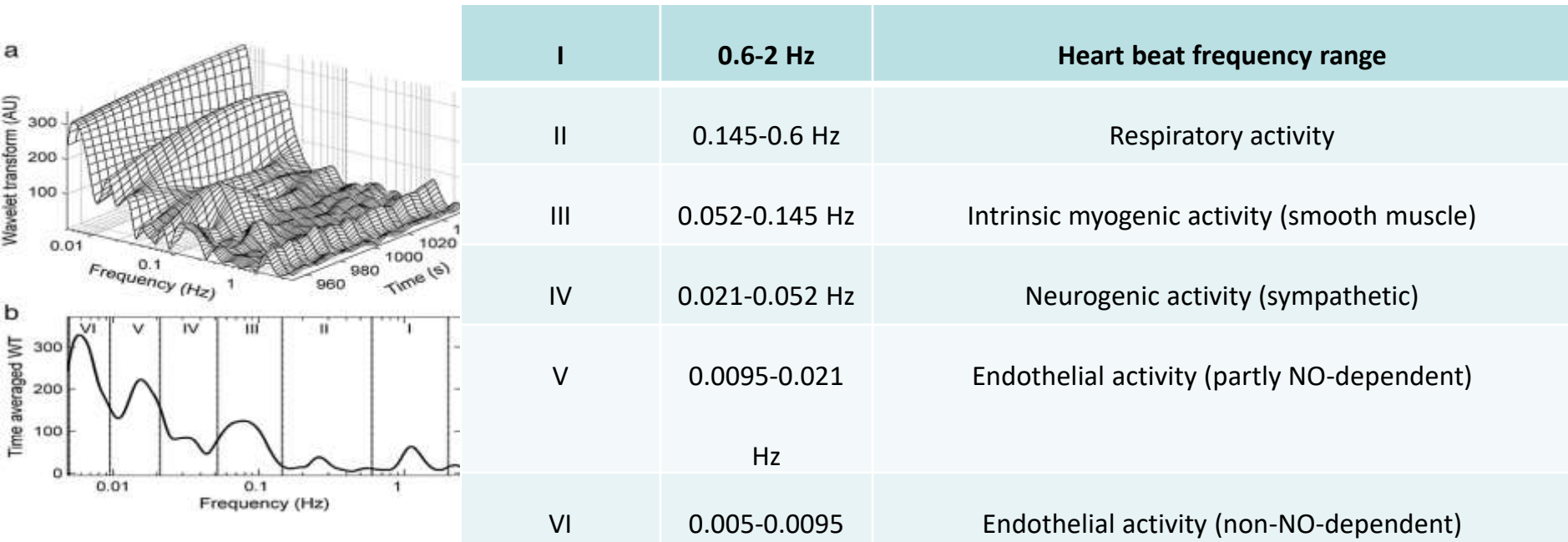
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Thank you

Low frequency

- Beat to beat timescale.
- Low frequency (2-0.005 Hz) changes in tissue perfusion and oxygenation occur.
- May be clinically important.
- Stefanovska et al: may give an indication of intrinsic and autonomic functions which can be crucial in tissue healing.



Stats

Pairwise Comparisons

Measure: TOS

(I) occlusionlevel	(J) occlusionlevel	Mean Difference (I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
					Lower Bound	Upper Bound
1	2	19.667 [*]	2.232	.000	13.372	25.962
	3	26.133 [*]	2.899	.000	17.959	34.307
2	1	-19.667 [*]	2.232	.000	-25.962	-13.372
	3	6.467	2.533	.081	-.675	13.609
3	1	-26.133 [*]	2.899	.000	-34.307	-17.959
	2	-6.467	2.533	.081	-13.609	.675

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

General linear modelling,
test of sphericity-sphericity assumed



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