

Investigating the effects of simulated prosthetic loading on lymphatic activity of healthy lower limb tissues

Bramley, J.L.¹, Dickinson, A.S.¹, Bostan, L.², Bader, D.L.², Worsley, P.R.²

¹ Faculty of Engineering & the Environment, University of Southampton, UK

² Faculty of Health Sciences, University of Southampton, UK

Introduction: After amputation, the soft tissue of the residual limb forms a critical loaded interface with the prosthesis. This generates pressure and shear at the skin-device interface, which can result in discomfort and soft tissue breakdown. One of the breakdown mechanisms involves occlusion of the lymphatic vessels, impairing removal of metabolic waste products and toxins¹. Lymphoscintigraphy has been used in a canine model to determine onset of impaired lymphatic clearance². Recently researchers have used near infra-red (NIR) imaging to detect a fluorescent agent injected into human volunteers to characterise the lymphatic activity under pressure^{1,3}. This motivated the present study designed to develop a test protocol for assessing the lymphatic response of soft tissues to loads representing prosthesis use.

Methods: Approval was given to recruit non-amputee participants (ERGO29696). Indocyanine Green (ICG, 0.5mL, 0.05%w/v) was injected sub-dermally between the toes. Pressures of between 20-60mmHg, each for 10 minutes in 10mmHg increments, were applied to the calf using a sphygmamometer representing an inflatable temporary prosthesis used during early rehabilitation. Lymphatic activity was recorded by a NIR camera (Fluobeam® 800, Fluoptics) during the final 5 minutes of each inflation increment, followed by a 30 minute refractory period, in the most distinct lymphatic vessel (Fig1A,B). Lymphatic activity was quantified using droplet morphometry and velocimetry tracking^{1,3}. Lymph packets were identified, and transient events analysed to determine frequency, displacement and velocity.

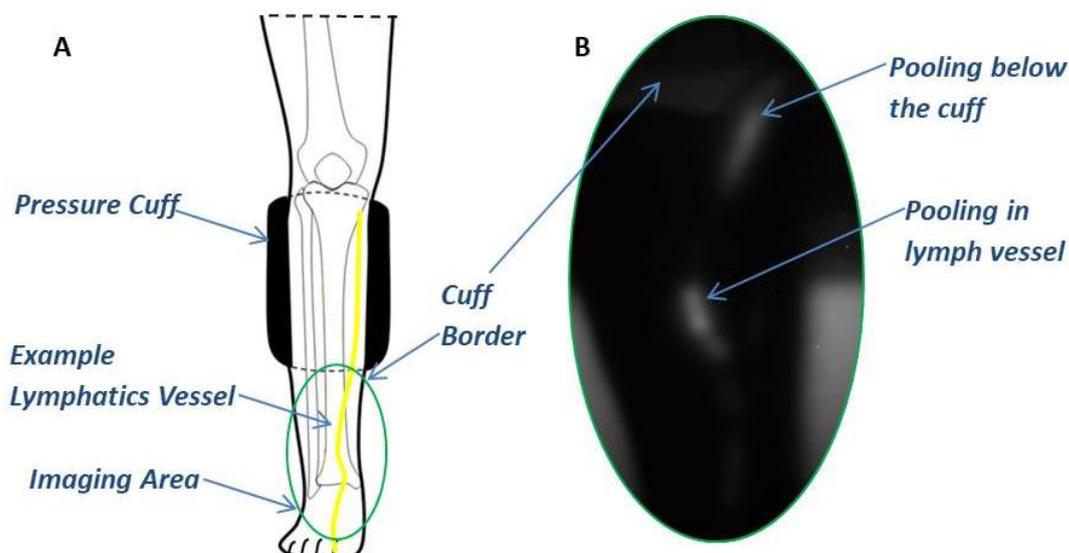


Figure 1 (A) Lymphatic Imaging set up, (B) Fluobeam imaging frame with pressure cuff inflated at 60mmHg

Results: Data are presented for four participants. Compared with baseline activity, packet frequency decreased by at least 50% at 60mmHg (Fig2). Individual variation was evident, for example, participant 1 displayed only two small packet movements throughout the pressure application. At 50-60mmHg, pooling at the cuff and backflow events were observed, but in two participants (2 & 4) there was sufficient accumulation to overcome occlusion, with high packet velocity. After pressure release, activity increased, returning to baseline after the refractory period.

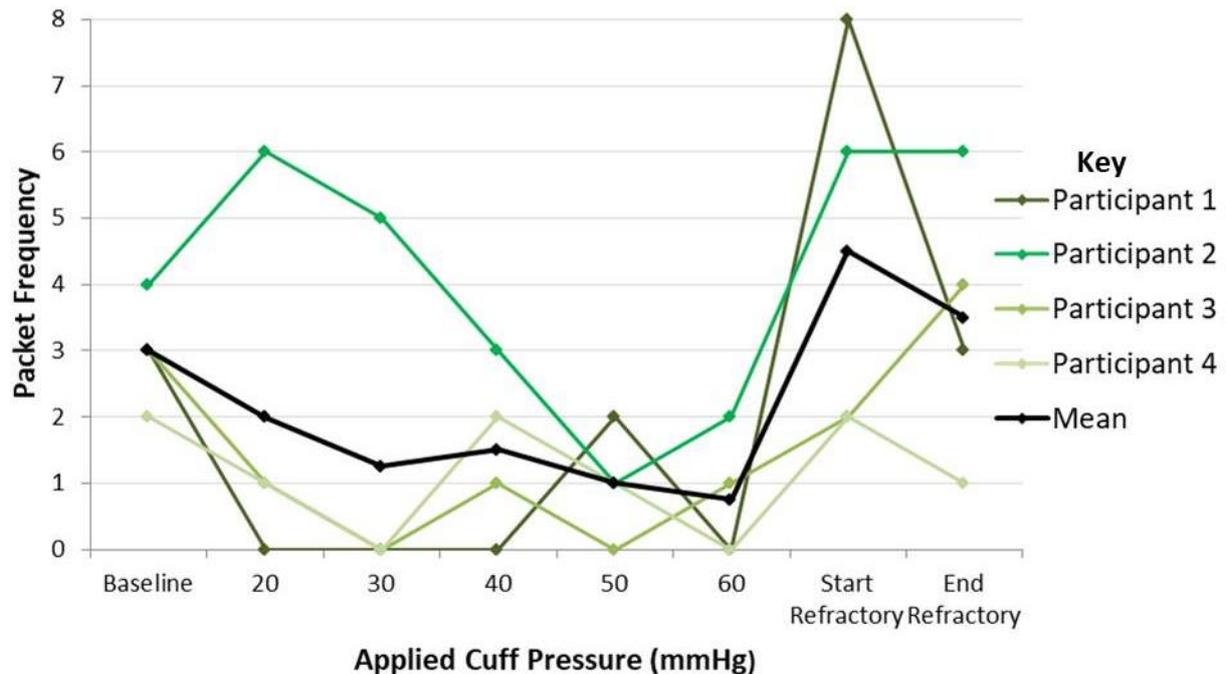


Figure 2 Lymph packet frequency during different pressure cuff conditions for four participants

Conclusions: Loads characteristic of temporary prosthesis use during early rehabilitation were shown to impair lymphatic activity in healthy individuals, at pressures as low as 20mmHg. However, some participants maintained lymphatic activity at 50-60mmHg. As further participant results are analysed, lymphatic activity trends and thresholds will be determined. The test protocol will be translated for prosthesis users, to enhance knowledge of soft tissue adaptation following lower limb amputation.

We acknowledge EPSRC/NIHR (EPN5097471, EPN02723X1), IfLS and RAEng (RF130).

References:

- [1] Gray 2016, J. Tissue Viability.
- [2] Miller 1981, Lymphology.
- [3] Lopera 2017, Lymphat.Res.Biol.