MECHANICAL CHARACTERISATION OF LOWER LIMB VASCULATURE IN DETERMINING AUTOGRAFT SUITABILITY FOR PERIPHERAL ARTERIAL DISEASE BYPASS SURGERIES

McCarthy, Clíona M.(1,2,3), McKevitt, Kevin L.(3,4), McGourty, Kieran D.(1,3), Leahy, Fiona C. (4), Kavanagh, Eamon G.(4), Moloney, Michael A. (4), Walsh, Michael T.(1,2,3) and Mulvihill, John J.E.(1,2,3)

1. Bernal Institute, University of Limerick, Limerick, Ireland. 2. School of Engineering, University of Limerick, Limerick, Ireland. 3. Health Research Institute, University of Limerick, Limerick Ireland, 4. University Hospital Limerick, Limerick, Ireland

email: (cliona.mccarthy@ul.ie)

Introduction

The estimated prevalence of peripheral arterial disease (PAD) is over 240 million people globally [1]. PAD is caused by atherosclerosis resulting in a narrowing of the arterial lumen. In advanced cases, this restricts blood flow, leading to a number of complications for the patient such as reduced or limited mobility, pain, tissue loss and ulceration, and possibly gangrene. A bypass graft may be required to restore blood flow [2, 3].

While other graft choices available, such as xenografts (bovine pericardium) and synthetic grafts (PTFE & Dacron), the use of autografts (venous conduit) remain the gold standard. However, depending on the extent of PAD, an arterial conduit may not be an option. Veins such as the great saphenous vein (GSV) are often used alternatively as optimal venous conduits. Unfortunately, approximately 40% of patients do not have the required length or lumen diameter of GSV available [4]. For example, if varicose veins are present within the vein it will not be used as a graft, despite a lack of studies determining the suitability of varicose veins as a graft option. This study aims to mechanically and structurally characterise lower limb vasculature to determine the suitability as a bypass graft option.

Methods

Human GSV and varicose veins (VV) and healthy margins (HM) were sourced from the University Hospital Limerick, Ireland. To prepare the tissue for microscale mechanical testing, transverse sections of the embedded fresh human tissue were sectioned to 400 µm thickness with liquid agarose and gelatin in a petri dish. The tissue was kept hydrated in 1X PBS at 4 °C before microscale testing to maintain tissue viability [5]. The Chiaro Nanoindenter was used to perform the microscale mechanical testing in this study (Figure 1). The displacement was detected by the optical fibre in the probe. The resulting load displacement graph is used to calculate the effective elastic modulus (E_{eff}) from the loading curve using the Hertz Contact Model. An automated 5x5 matrix scan, in 100 µm increments, was performed which provided a surface area heatmap of the E_{eff} (Figure 1).

Results

Preliminary results from this study are displayed in Figure 1. The data showed a significant difference between the E_{eff} of GSV 1.39[0.72-3.58] kPa and VV 0.09[0.04-0.27] kPa and between the E_{eff} of GSV 1.39 [0.72-3.58] kPa and HM 0.42[0.22-1.18] kPa. No significance was observed between the VV 0.09[0.04-0.27] kPa and HM 0.42[0.22-1.18] kPa. Further, the E_{eff} heatmap generated during microscale testing demonstrates the heterogeneity of vascular at the microscale. This is an important observation to consider when determining the suitability of a vessel as a bypass graft.

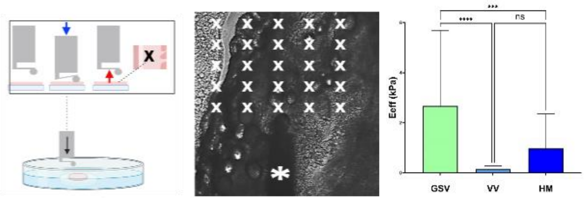

Figure 1: Microscale mechanical testing of vascular tissue. (left) Chiaro Nanoindenter probe tip coming into contact with tissue sample. (middle) Example area tested during testing. (right) Preliminary results showing a significant difference between the E_{eff} of GSV and VV and between the E_{eff} of GSV and HM.

Discussion

Initial results indicate that VV are not a suitable alternative for bypass grafts, although sparse, this is in keeping with current literature. However, biological heterogeneity within and between samples needs to be considered and further testing is required to develop bypass graft inclusion parameters for the optimal E_{eff}. Combining this micromechanical data with histological staining e.g. H&E would allow more robust tissue characterisation through visualisation of the microanatomy and tissue components like collagen and elastin which gives tissue its mechanical properties.

References

1. L. Horváth et al, Life (Basel), vol. 12, no. 7, 2022,
2. L. Pascarella et al, J Laparoendosc Adv Surg Tech A, vol. 28, no. 5, pp. 562-568, 2018
3. D. J. Adam et al, Lancet, vol. 366, no. 9501, pp. 1925-34, 2005
4. L. M. Taylor, et al, The American Journal of Surgery, vol. 153, no. 5, pp. 505-510, 1987
5. C. M. McCarthy et al, Journal of the Mechanical Behavior of Biomedical Materials, vol. 138, p. 105599, 2023