REDUCED ORDER MODEL FOR DRAINAGE COMPUTATION IN LOWER LIMB LYMPHEDEMA

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Abstract

The lymphatic system is formed by a series of vessels and glands that collect and filter excess fluid, proteins and toxins (lymph) from cells and tissues, next, return them to the bloodstream. When the lymphatic system is damaged, the body is unable to drain it and the lymph tends to accumulate (1). Lymphedema is usually treated with compression therapy through compression stockings. Compression therapy raises the interstitial fluid pressure, which increases the pumping capacity of the lymphatic vessels. The aim of the treatment is to regress to an edema-free stage or at least to decrease swelling.
Patient-specific compression stocking applies personalized pressure over the lower-limb increasing the effectiveness of the treatment. Computer-aided approach can model the behaviour of lower-limb lymphedema and it supposes a digital replica to try different compression pressure. The behaviour of soft-tissues is usually simplified and it is modeled as an elastic or hyperplastic material (2). However, the fluid phase plays an important role regarding the interstitial fluid pressure. Soft-tissues are modeled as a poroelastic material to consider the interstitial pressure due to the lymph.

The digital-twin of the lower lymph (poro-elastic model) is built to model the impaired fluid drainage. The proposed digital-twin is based on reduced order model (ROM) (3). In this study non-intrusive ROM are applied to compute the drainage effect in the lower-limb. The ROM is carried out through the solution computed by several finite element (FE) model or high-fidelity model defined by a set of patient-specific parameters. This is carried out through Proper Orthogonal Decomposition (POD), which decomposes the high-fidelity solution in a linear combination of a set of coefficients and modes. In order to reconstruct the approximated solution, the POD coefficients should be predicted using surrogate models. This method is known as Proper Orthogonal Decomposition with Interpolation (PODI). The proposed algorithm reduces the computational cost and enables to estimate the desired features to evaluate the effects of the compression therapy in real time such as lymph velocity, drained volume, morphology etc.

The digital-twin of the lower-limb enables to foresee the effects of the applied compression therapy. It will suppose a step forward in the treatment of lymphedema moving from

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off-the-shelf stocking to patient-specific compression stocking.

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