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POST BREAST CONSERVING SURGERY FINITE ELEMENT SIMULATIONS OF WOUND HEALING: A PRELIMINARY STUDY TOWARDS COSMESIS

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Breast cancer is currently the most prevalent form of cancer affecting women worldwide. In this regard, surgical treatments for early-stage breast carcinoma are primarily reconstructive oncologic interventions. The challenge of tumorectomy is complete removal of the lesion whilst preserving the cosmetic appearance of the breast. Currently, surgical planning is limited to photographic and anthropometric studies of patient's breast. Thus, there is a clear need for an accurate and efficient numerical tool that could be used for pre-operative planning, which could also guarantee the final result of such surgical operations. Nonetheless, to date, there have been very few attempts to model the complex process of oncoplastic breast surgery towards cosmetic outcome assessment. This is due to the necessity of the mathematical model to account for both the biological processes of wound healing, the biomechanical behaviour of living tissues and the corresponding wound contraction on the breast.

In this work, we propose a multiscale numerical procedure that is based on the finite element (FE) method for simulating the coupled problem of biochemical and biomechanical processes associated with breast tissue' healing after oncoplastic surgical interventions. In the biochemical part, a mathematical model that describes the dependence of tissue regeneration on oxygen level and the growth of capillaries in the wound, the production of chemical growth factors, and fibroblasts proliferation is presented. The model incorporates diffusion equations that describe the biochemical aspects of wound healing [1] and angiogenesis [2], coupled together in order to take into account the influnce of mechanical signalling on cellular behaviour. Furthermore, the biomechanical model assumes that tissues are a composite material comprising of the extracellular matrix and cells, in which fibroblasts are expected to actively contribute to wound contraction [3]. The skin is modelled as a hyperelastic membrane [4], whereas adipose and fibroglandular tissues are described by an isotropic polynomial constitutive law [5].

We investigate the effect of wound healing and wound contraction of a lesion on a patient-specific breast after tumorectomy (see Fig. 1). An arbitrarily sized wound approximately equal to 2.5% of the breast volume is defined. The breast geometry was acquired through MR imaging with the patient in the prone position, and comprised 73% adipose and 27% fibroglandular tissues. Then, the reference (or gravity-free) configuration of the breast was obtained numerically [6]. At this point the wound healing FE solver was initiated to simulate a 3-month period, while estimations of the deformed shape of the breast were obtained by re-applying the gravity load (with the patient in upright position) and the final breast shape is assessed. The numerical results demonstrate that the volume of the wounded tissues reduced by 13% after one month (initially 15.8cm^3), and approximately 15% in both of the subsequent second and third months. However, the final breast shape did not alter significantly during the wound healing/contraction process, and the total volume of the breast didn't change by more than 0.2%. This is due to the the fact that the size of the wound was very small and that living tissues are incompressible. Nevertheless, we expect for larger lesions (more than 10-20% the breast volume) to significantly change the final shape of the breast due to wound healing.

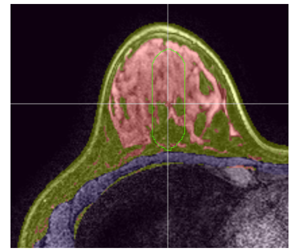

Figure 1: MR image of patient-specific breast (fat in yellow, fibroglandular tisses in red and lime outline for excised tissues).

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