Breast cancer is the most common cancer affecting women in Europe (1). It has become an increasingly treatable disease with a 10-year survival rate exceeding 80%. It is usually treated with surgery, often in conjunction with radiotherapy and systemic treatments. Two types of surgery are available:

- breast-conserving surgery (also known as lumpectomy) or
- mastectomy (i.e. the partial or complete removal of the breast).

However, even breast-conserving surgery can affect the appearance of the breast, a prospect that can cause a great deal of stress. Therefore, a good aesthetic outcome is an important consideration in breast cancer therapies and is closely linked to the patient’s psychological recovery and self-image after treatment. Yet for an estimated 30% of women treated with breast-conserving surgery, the result is less than ideal aesthetically (2). Unfortunately, to date there is no objective way to assess or predict the aesthetic outcome of breast cancer treatment.

In this paper, we report on the work of the project Patient Information Combined for the Assessment of Specific Surgical Outcomes in Breast Cancer (PICTURE), which is funded by the European Community’s Seventh Framework Programme. The goal of the project is to create, validate, and demonstrate a system for the patient-specific planning, evaluation, prediction, and quantification of the outcome of breast-conserving surgery. This system, the PICTURE demonstrator, supports the complete clinical workflow needed to plan and predict the appearance of the patient’s breast after therapy. The PICTURE demonstrator thus supports surgeons in surgical planning prior to the operation. It is also designed to aid patient-clinician communication by visualizing the foreseen outcome, and thereby empowers patients to take an active role in a Shared Decision Making process.

Figure 1: Processing chain of the PICTURE demonstrator.

Since the demonstrator should support visualisation of the shape and appearance of the breast in an upright position, it is essential that not only the shape of the breast is captured, but also skin texture and skin colour. For this purpose, we use low-cost and easy to use equipment such as standard digital cameras to capture views of the patient from multiple directions, or off-the-shelf depth sensors as developed by the gaming industry (e.g. Microsoft Kinect). The result of this acquisition is a 3D surface shape of the patient’s torso with colourised skin texture (3).
In clinical routine, medical images are acquired as part of the diagnostic process. Typically X-ray mammograms of the compressed breast in cranio-caudal (CC) and medio-lateral oblique direction (MLO) are acquired. Depending on the diagnostic need, breast MRI (Magnetic Resonance Imaging) may be acquired as well. Since X-ray mammography produces projection images only, the size and position of the tumour may be determined with sufficient accuracy, but the individual breast morphology, a pre-requisite for a personalised simulation, cannot be determined. However, MRI allows for a spatially resolved 3D classification of breast tissue into different tissue types (skin, adipose tissue, glandular tissue, pectoralis muscle, etc.).

An essential input parameter for the biomechanical modelling and outcome simulation is a spatially resolved elasticity map of the breast. Such a map can be created e.g. by Magnetic Resonance Elastography (MRE), which is a non-invasive imaging modality providing in-vivo data about the biomechanical properties of tissue. The general concept of this method is to send low-frequency mechanical waves into the object and image those waves via MR-motion sensitised sequences. This allows solving locally for the stress-strain relationship yielding the complex-valued shear modulus (4).

From the point of view of modelling, extensive medical imaging should ideally be done prior to starting the simulation. MRE is not currently used in clinical routine and even MRI is not used on every patient. Therefore, many input parameters of the outcome simulation are not known from patient-individual measurements.

We have developed a strategy to compensate for this missing data. The PICTURE project has started a clinical study with breast cancer patients, which undergo diagnostic MRI as well as surface scans. Based on this surface and MRI data, we develop a generic breast shape model describing the breast morphology. In addition, we plan to acquire MRE on a limited number of volunteers in order to study the variation of breast tissue elasticities.

All this data, both patient-individual and parameters derived from population studies, is then combined in a coherent representation of the patient, the Digital Breast Surgery Patient.

Before starting the outcome simulation, surgical planning is an essential step. The surgeon uses the available information and interacts with the Digital Breast Surgery Patient on a computer in order to define the details of the surgical procedure, e.g. tumour position, resection margins, surgical technique. Once a surgical plan consisting of a spatial representation of planned cuts and sutures has been defined, possible outcome(s) of the operation is (are) simulated and presented. If necessary, the surgeon can adapt the surgical plan interactively in order to modify the predicted result (5).

Outcome simulation using biophysical models is at the technical core of the PICTURE project. These models potentially will enable the shape of the breast of patient-specific cases, at a time point after breast-conserving surgery, to be predicted. Finite element analysis tools are developed and utilised to evaluate breast shape in an upright or supine position (6-8).

We are also developing tools to enable the patient's aesthetic appearance after treatment to be objectively evaluated (9). Current techniques use subjective methods, such as assessment by an expert panel, or computer analysis of two-dimensional photography to estimate, for instance, breast asymmetry. By adopting recent developments in low cost three-dimensional photography and depth sensing technology, we are developing a standardised, reproducible analysis tool which bases the aesthetic outcome evaluation on both the three-dimensional shape of the reconstructed breast and its volume. This will establish standardised quality assurance and evaluation procedures, enabling institutions across Europe to be compared and factors that have a positive or negative impact on surgical outcome to be identified.
Summary

The demonstrator created by the PICTURE project will integrate models of surgical techniques and treatment schemes, clinical patient data, multi-modal imaging and individualised models of patient anatomy to build a *Digital Breast Surgery Patient*. This will be used as an aid to surgical planning, via simulation of the cosmetic effects of breast conserving surgery, as a decision support tool to communicate the available options to the patient and to enable standardised evaluation and a safe outcome of the procedure. The project strives to demonstrate the ability of the Virtual Physiological Human concept to empower patients and have a direct impact on the quality of care and the quality of life.

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References