Chapter 11
Machine Learning Applications in Cancer Therapy Assessment and Implications on Clinical Practice

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ABSTRACT

Precision medicine is an emerging medical model based on the customization of medical decisions and treatments to individuals. In personalized cancer therapy, tailored optimal therapies are selected depending on patient response to treatment rather than just using a one-size-fits-all approach. To this end, the field has witnessed significant advances in cancer response monitoring early after the start of therapy administration by using functional medical imaging modalities, particularly quantitative ultrasound (QUS) methods to monitor cell death at microscopic levels. This motivates the design of computer-assisted technologies for cancer therapy assessment, or computer-aided-theragnosis (CAT) systems. This chapter elaborates recent advances in the design and development of CAT systems based on QUS technologies in conjunction with advanced texture analysis and machine learning techniques with the aim of providing a framework for the early assessment of cancer responses that can potentially facilitate switching to more efficacious treatments in refractory patients.

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INTRODUCTION

Neoadjuvant chemotherapy is typically administered to patients with large breast tumours (> 5cm) that are inoperable and at risk of metastasis. Patients with this type of cancer, called *locally advanced breast cancer* (LABC), have a relatively poor prognosis with five-year survival rates below 50% due to variable response to chemotherapy (Yalcin, 2013). Currently, clinical tumour response to chemotherapy is determined based on changes in tumour size, using guidelines from Response Evaluation Criteria in Solid Tumours (RECIST 1.1) (Eisenhauer et al., 2009). Low survival rate is due to the late assessment of response (typically at the end of the full course of treatment, which takes several months) resulting in a missed opportunity for treatment intervention for refractory patients. Thus, there is growing interest in personalized medicine – delivering patient-tailored treatment based on their predicted response early on in the course of treatment.

In this book chapter, a review of machine learning techniques for cancer response assessment is presented. Specifically, a review of computer-aided cancer therapy assessment, referred to in this text as computer-aided-theragnosis (CAT) system, is provided, demonstrating how it can be utilized to assist physicians in making appropriate treatment decisions and improve patients' quality of life. The review begins with a survey of various imaging techniques for early cancer therapy assessment such as diffusion-weighted magnetic resonance imaging (DW-MRI), positron emission tomography (PET), diffuse optical spectroscopy (DOS), and quantitative ultrasound (QUS) methods. QUS Methods are described in conjunction with machine learning techniques for cancer therapy assessment and the design of a CAT system is presented. Examples of works in QUS–based cancer therapy assessment and CAT system design concepts can be found in (Gangeh, Tadayyon, et al., 2016; Gangeh, Hashim, Giles, Sannachi, & Czarnota, 2016; Sannachi et al., 2015; Tadayyon et al., 2016), on which this book chapter elaborates. The authors delve into the components of this system, which include data acquisition, feature extraction, feature selection, dissimilarity measurement, learning from imbalanced data, and response classification. The chapter ends with a discussion commenting on the performance of different machine learning methodologies, clinical implications, and future work.

BACKGROUND

Cancer Response Imaging

This section provides a brief overview of clinically relevant cancer response imaging techniques that can provide early indications (i.e., after one cycle of chemotherapy) of tumour response. The modalities that are described include PET, DW-MRI, DOS, and QUS. As QUS for cancer response imaging is the area of the authors' research expertise, a separate section is dedicated for this topic following the current section.

PET Imaging permits the probing of tumour metabolic activity, which can change during treatment as a sign of response. For instance, fluoro-deoxyglucose PET (FDG-PET) involves injecting the patient with FDG - a radiotracer/contrast agent - prior to imaging. Due to the preferential uptake of glucose-based molecules by tumours, the tumour region in the PET image will be enhanced and its metabolism can be tracked over the treatment period. FDG-PET has exhibited a specificity and sensitivity of near 90% for detecting primary cancers in various cancer patients (Czernin & Phelps, 2002). It has also been