



Review paper

Radiomics in radiooncology – Challenging the medical physicist

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ABSTRACT

Purpose: Noticing the fast growing translation of artificial intelligence (AI) technologies to medical image analysis this paper emphasizes the future role of the medical physicist in this evolving field. Specific challenges are addressed when implementing big data concepts with high-throughput image data processing like radiomics and machine learning in a radiooncology environment to support clinical decisions.

Methods: Based on the experience of our interdisciplinary radiomics working group, techniques for processing minable data, extracting radiomics features and associating this information with clinical, physical and biological data for the development of prediction models are described. A special emphasis was placed on the potential clinical significance of such an approach.

Results: Clinical studies demonstrate the role of radiomics analysis as an additional independent source of information with the potential to influence the radiooncology practice, i.e. to predict patient prognosis, treatment response and underlying genetic changes. Extending the radiomics approach to integrate imaging, clinical, genetic and dosimetric data ('panomics') challenges the medical physicist as member of the radiooncology team. **Conclusions:** The new field of big data processing in radiooncology offers opportunities to support clinical decisions, to improve predicting treatment outcome and to stimulate fundamental research on radiation response both of tumor and normal tissue. The integration of physical data (e.g. treatment planning, dosimetric, image guidance data) demands an involvement of the medical physicist in the radiomics approach of radiooncology. To cope with this challenge national and international organizations for medical physics should organize more training opportunities in artificial intelligence technologies in radiooncology.

1. Introduction

Evolution of radiooncology towards an individualized patient treatment approach benefitted strongly from the increasing implementation of imaging technology in the radiotherapy process. From the beginning, medical physicists initiated and significantly contributed to this development. Aiming to integrate patient imaging in all phases of radiotherapy, medical physicists took over responsibilities in bridging over informatics and computer science with radiooncology. In this role, medical physicists were challenged to look more and more beyond the borders of their domains in dosimetry, treatment planning and delivery, quality assurance and radiation protection. In the attempt to

optimize the treatment for each individual patient, yet long before the flag of *personalized medicine* was raised, medical physicists contributed most significantly by incorporating individual patient image data into the treatment process. Two major breakthroughs in this development can be identified so far: (i) CT-based treatment planning and (ii) image guided radiation therapy (IGRT) [1].

Following the adjustment of anatomical cross sections from standard atlases, shortly after the invention of computer tomography (CT) with its revolutionary role in radiology, the first step in the individualization of radiotherapy was the introduction of CT-based treatment planning [2]. Meanwhile, CT-based treatment planning has expanded towards multimodality-based treatment planning by

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integrating other imaging modalities, such as Magnetic Resonance Imaging (MRI) and/or Positron Emission Tomography (PET), aiming to further improve the definition of target volumes and critical organs [3].

Another breakthrough in the integration of imaging into the radiotherapy process was the image control of the treatment delivery at the treatment unit, known as IGRT [1]. From the beginning with the verification of the patient set-up on the treatment couch with film, up to the most recent technology of combined MR-linac systems, medical physicists were increasingly driving the integration of imaging into radiotherapy [4].

Now, we are facing a fascinating new field, so to say as the third breakthrough, where however medical physicists are not widely engaged yet, but certainly have to find their role in the future: quantitative image analysis or in short “radiomics” [5,6]. Radiomics can be considered a two-step process with (1) extraction of relevant static and dynamic imaging features, and (2) incorporating these features into a mathematical model to predict treatment outcome as discussed in the following subsections [7]. Radiomics is designed to assist the radiooncologist in the decision on the individual treatment of a patient, and to assess prediction and prognosis of the disease.

In institutions dealing with radiomics techniques, it is most important to establish an interdisciplinary team where medical physicists interact closely with clinicians, computer scientists and biologists. Applying quantitative image analysis combined with specific radiotherapy data as an individual radiooncomics signature for each treated patient requires fundamental knowledge of AI techniques, big data processing, medical imaging analysis methods, and the clinical and molecular biological basics relevant for performing radiomics and radiogenomics studies.

Mainly from the medical physicists view, this review addresses four questions: what radiomics is about, what are the methods used, what is the impact expected for radiooncology, and what is the particular challenge to medical physicists.

2. Radiomics in radiooncology – goals and workflow

Radiomics is a higher order data-driven concept, which initially has been used in radiology to support the detection of abnormal findings in the large sets of CT data. Due to modern computer technology in conjunction with efficient data mining, it became possible to extract large amounts of imaging features which associated with medical, biological and physical information may be clinically relevant, for instance for prediction of treatment outcome [8–10]. The previous mainly qualitative interpretation of images is now complemented by quantitative image analysis based on techniques of artificial intelligence (AI), including ML techniques such as deep learning (DL).

Expanding the radiomics concept to include molecular biology data (e.g. genomic, proteomic, metabolomic), also designated “radiogenomics”, has broken new ground to generally characterize diseases, identify genetic variations and to predict treatment response by evaluating multidimensional imaging feature signatures. Translation of radiomics to radiooncology has been investigated with encouraging results over the recent years. An interesting aspect has been emphasized by authors from the QUANTEC group (Quantitative Analyses of Normal Tissue Effects in the Clinic) expecting more valid predictors for clinical outcome when combining traditional dose-volume quantities, endogenous biological biomarkers and radiomics features [11–13]. As proposed recently, an even more comprehensive collection of input data for radiooncology information analysis may be considered [11,14]. Such a “pan-omics” or “radio-oncomics” concept may for instance integrate all diagnostic and treatment data, specifically treatment planning images, image based 3D-/4D dose distribution, treatment verification and image-guidance data.

To implement the radiomics concept in radiooncology, it is recommended to establish a special interdisciplinary working group, which covers the related clinical, biological, physical, mathematical

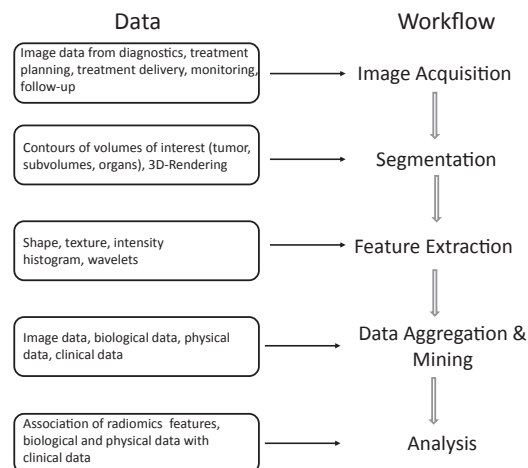


Fig. 1. Workflow of the radiomics concept in radiooncology.

and most importantly computer science skills. In order to assure an effective interaction and critical evaluation of the results, all members of such a group should at least have some fundamental knowledge on each mutual field of expertise. A typical radiomics workflow in clinical practice comprises the data acquisition, data processing and clinical testing of radiomics signature (Fig. 1).

3. Radiomics concepts and methods

3.1. Image acquisition, reconstruction, segmentation

Different modalities (CT, MRI, PET) have been explored as a potential basis for radiomics, where the choice of modality mostly hinges on the region of interest. In lung as well as head and neck cancer for example, CT (and PET) scans are considered standard of care, and most studies in these areas therefore focus on these modalities [15,16]. In gliomas on the other hand, MRI is dominantly used. A challenge in MR-based radiomics remains that the typically obtained anatomic MR images rely on visual interpretation of tissue contrast resulting from experimental pulse sequence parameters, and do not directly measure the underlying tissue properties. Recent advances in the field of quantitative MR imaging however have enabled to directly quantify properties like T1 and T2 relaxation times [17]. In addition, extending MR imaging beyond pure visualization of anatomy has further benefitted the field of radiomics. By visualizing key oncogenic features, such as angiogenesis or hypoxia, MR sequences, like diffusion or perfusion imaging, capture oncogenic processes and make them available for radiomics. In parallel, post-processing techniques have matured to a point where derived metrics, such as cerebral blood volume (from perfusion imaging) and tensor indices (from diffusion imaging) can be reliably assessed [18,19].

For most modalities and diseases, (semi-)automatic segmentation algorithms have been developed to supersede the time-consuming and often unreliable process of manual segmentation, as segmentation quality is critical for the subsequent analyses. In many fields, challenges have been designed to compare and benchmark these algorithms against each other, such as the Liver Tumor Segmentation Challenge (<http://www.lits-challenge.com>) or the Brain Tumor Segmentation Challenge (<http://braintumorsegmentation.org>). Furthermore, such a central evaluation of algorithms enables the synthesis of “meta-algorithms”, which consider and weigh segmentation information from multiple algorithms to synthesize a substantially improved final segmentation. Such approaches may encompass simple strategies, such as majority voting or more complex algorithms such as STAPLE (Simultaneous truth and performance level estimation) [20,21].

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