Advanced methods for quality assurance and dose distribution improvement for high dose rate brachytherapy

Valorization

Brachytherapy has been under continuous development since its origin, as it has been proven an effective technique for cancer treatment. Efforts have been made to improve precision and accuracy of treatment delivery, including several steps on the treatment workflow, from applicators design to treatment delivery verification and in vivo dosimetry, as mentioned in Figure 1.1. This thesis focus on advanced methods as part of an effort to overcome these technical challenges aiming to provide tools that will help move towards more accurate dose delivery.

The studies in this thesis were performed in collaboration between 2 countries, Brazil and the Netherlands, with a strong input from a multidisciplinary team including engineers, medical doctors, physicists and radiotherapy technologist, always having the quality improvement of patient care as the main goal.

This thesis can be divided into 3 main novel subjects:

Brachytherapy source tracking using an imaging panel
Imaging panels are commonly used for treatment verification in external beam radiotherapy, however, their use in brachytherapy is still incipient. Studies in this thesis showed that an imaging panel is not only capable of 3D tracking a brachytherapy source in real time, but also detect errors (such as wrong dwell time or dwell position) that would be unnoticed in standard practice. Moreover, it was shown that imaging panels can be also used as a precise and accurate method for brachytherapy applicators commissioning, measuring not only source dwell positions and dwell times, but comparing them with reference treatment plans to detect errors.

Development of a rectal applicator for contact brachytherapy
The standard care of treatment for rectal cancer includes surgery, which may have undesirable side effects. In some cases, surgery can be omitted in treatments including contact x-ray brachytherapy techniques, however, such techniques are not often adopted because of the lack of planning tools and the relative high cost of the aforementioned devices. The development of a rectal applicator able to generate a dose distribution similar to those of CBX devices using HDR ^{192}Ir sources, holds the potential to reduce the number of patients having surgery during a rectal cancer treatment, therefore improving patient quality of life.

Evaluation of an afterloader treatment limitations and transit time

The afterloader is an essential part of HDR brachytherapy. Its precision and accuracy for dwell times and dwell positions directly impacts the resulting dose distribution and, consequently, treatment outcome. A thorough evaluation of the new Bravos afterloader released by Varian Medical Systems also shows how precise and accurate it can be during treatment delivery. Moreover, the transit time measured with a high-speed camera allows a precise transit dose simulation using the instantaneous source speed instead of average source speed profiles, which are especially relevant for treatments using multiple channels such as HDR prostate treatments.

Clinical relevance

Patient safety and quality of life are of the uttermost importance for any healthcare center. Therefore, medical research centers are always working to improve their treatment workflow and installations aiming to provide the best experience possible for the patients.

Nevertheless, brachytherapy is a treatment modality prone to human errors and it lacks the treatment verification tools to detect them in case a mistake happens during the treatment. Efforts have been made towards in vivo dosimetry and real time treatment verification, but there is no solution commercially available yet.

For this reason, a proper system commissioning is paramount to a successful treatment delivery. The work on the pretreatment verification system is a first step moving towards real time treatment verification.

The IrIS system has a friendly interface and allows the user to perform several quality assurance measurements in a fraction of the time that would be required if radiochromic films were used, allowing a better applicator evaluation.

The MAASTRO applicator holds the potential to be a cost-effective alternative to contact x-ray brachytherapy devices since it does not require any extra tool other than those that an oncology center that works with brachytherapy already has. Moreover, the possibility to control the shape of the dose distribution using a treatment planning system is an advantage of the MAASTRO applicator when compared to CBX devices.

Societal relevance

The patient is the first to benefit from a more precise and accurate radiotherapy treatment. All studies presented in this thesis aim to improve brachytherapy precision and accuracy, which will reflect on the quality of the treatment received by the patient.

The MAASTRO applicator, which is the main subject of this thesis, should provide one more treatment modality for rectal cancer patients, potentially reducing the number of surgeries and, consequently, improving quality of life. Moreover, due to its expected low cost, the MAASTRO applicator may be especially societal relevant in developing countries.

Commercial relevance

The MAASTRO applicator was co-developed with Varian Medical Systems and will become a commercially available product in the coming years. The first clinical trials are expected to start in 2021.