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Review article

Place of modern imaging in brachytherapy planning

Place de l'imagerie moderne dans la planification de la curiethérapie

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ABSTRACT

Imaging has probably been the most important driving force for the development of brachytherapy treatments the last 20 years. Due to implementation of three-dimensional imaging, brachytherapy is nowadays a highly accurate and reliable treatment option for many cancer patients. To be able to optimize the dose distribution in brachytherapy the anatomy and the applicator(s) or sources should be correctly localised in the images. For computed tomography (CT) the later criteria is easily fulfilled for most brachytherapy sites. However, for many sites, like cervix and prostate, CT is not optimal for delineation since soft tissue is not adequately visualized and the tumor is not well discriminated. For cervical cancer treatment planning based on magnetic resonance imaging (MRI) is recommended. Some centres also use MRI for postimplant dosimetry of permanent prostate seed implant and high dose rate prostate brachytherapy. Moreover, in so called focal brachytherapy where only a part of the prostate is treated, multiparametric MRI is an excellent tool that can assist in defining the target volume. Applicator or source localization is challenging using MRI, but tolls exist to assist this process. Also, geometrical distortions should be corrected or accounted for. Transrectal ultrasound is considered to be the gold standard for high dose rate prostate brachytherapy and transrectal ultrasound -based brachytherapy procedure offers a method for interactive treatment planning. Reconstruction of the needles is sometimes challenging, especially to identify the needle tip. The accuracy of the reconstruction could be improved by measuring the residuals needle length and by using a bi-planar transducer. The last decade several groups worldwide have explored the use of transrectal and transabdominal ultrasound for cervical cancer brachytherapy. Since ultrasonography is widely available, offers fast image acquisition and is a rather inexpensive modality such development is interesting. However, more work is needed to establish this as an adequate alternative for all phases of the treatment planning process. Studies using positron emission tomography imaging in combination with brachytherapy treatment planning are limited. However, development of new tracers may offer new treatment approaches for brachytherapy in the future. Combination of several image modalities will be the optimal solution in many situations, either during the same session or for different fractions. When several image modalities are combined so called image registration procedures are used and it is important to understand the principles and limitations of such procedures.

Mots clés :
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RÉSUMÉ

L'imagerie a été probablement un des éléments moteurs du développement de la curiethérapie au cours des 20 dernières années. Grâce à l'implémentation de l'imagerie tridimensionnelle (3D), la curiethérapie est actuellement une option thérapeutique hautement précise et fiable pour de nombreux patients pris en charge pour un cancer. Pour pouvoir réaliser une optimisation de la dose en curiethérapie, il faut être capable de visualiser correctement sur les images l'anatomie et les applicateurs ou sources. Pour l'imagerie scanographique, ce dernier critère est facilement rempli pour la plupart des localisations

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traitées. Cependant, pour plusieurs indications, comme la curiethérapie des cancers du col utérin ou de la prostate, l'imagerie scanographique n'est pas optimale pour la délinéation puisque les tissus mous ne sont pas visualisés de manière adéquate et la discrimination de la tumeur n'est pas satisfaisante. Pour le traitement des cancers du col utérin, une planification du traitement basée sur l'imagerie par résonance magnétique (IRM) est recommandée. Certains centres utilisent également l'IRM pour la dosimétrie après l'implantation dans le cadre de la réalisation d'implants permanents de prostate, ainsi que pour la curiethérapie de prostate de haut débit de dose. Par ailleurs, pour la réalisation d'une curiethérapie dite focale, où seule une part de la prostate est traitée, l'IRM multiparamétrique est un excellent outil, qui permet d'aider à la définition du volume cible. La localisation de l'applicateur ou de la source est difficile avec l'utilisation de l'IRM, mais il existe des outils pour aider à ce processus. Il faut également corriger les distorsions géométriques ou en tenir compte. L'échographie transrectale est considérée comme l'examen de référence pour la curiethérapie de prostate de haut débit de dose et la curiethérapie de haut débit de dose guidée par échographie transrectale repose sur une méthode interactive de planification thérapeutique. La reconstruction des aiguilles est parfois délicate, en particulier pour identifier leur extrémité supérieure. La précision de la reconstruction pourrait être améliorée par une mesure de la longueur résiduelle des aiguilles et par l'utilisation d'un transducteur bi-planaire. Au cours de la dernière décennie, plusieurs groupes de par le monde ont tenté d'évaluer l'utilisation de l'échographie transrectale et de l'échographie transabdominale pour la curiethérapie des cancers du col utérin. Puisque l'échographie est largement disponible, qu'elle permet une acquisition rapide des images et qu'elle représente une modalité d'imagerie relativement peu chère, de telles évaluations sont intéressantes. Cependant, davantage de travaux sont encore nécessaires pour établir que c'est une alternative adéquate pour toutes les phases de la planification. De rares études ont utilisé la tomographie par émission de positons-scanographie en association à la planification de la curiethérapie. Cependant, le développement de nouveaux traceurs pourrait permettre des approches innovantes pour la curiethérapie à l'avenir. L'association de différentes modalités d'imagerie sera une solution optimale dans de nombreuses situations, soit au cours du même traitement, soit pour différentes fractions. Lorsque diverses modalités d'imagerie sont combinées, des procédures d'acquisition d'images sont utilisées et il est important de comprendre les principes et les limites de ces procédures.

1. Introduction

Imaging has probably been the most important driving force for the development of brachytherapy treatments the last 20 years. Due to implementation of three-dimensional (3D) imaging, brachytherapy is nowadays a highly accurate and reliable treatment option for many cancer patients. To be able to optimise the dose distribution in brachytherapy the anatomy and the applicator(s) or sources should be correctly localised in the images. If the image modality does not enables both of these criteria the dose delivered the patient may be calculated incorrectly. In traditional brachytherapy radiographic films (x-ray imaging) has often been used for treatment planning. However, even if this image modality usually visualizes the applicator/sources very well, it does not provide any soft tissue contrast. Thus, it will not be possible to define the target volume and organs at risk and surrogate means, like defined points, have to be used. Additionally, a pair of x-ray images will not give the 3D information that is needed to create a dose distribution highly tailored to the target volume and avoiding too high dose to organs at risk. To have such 3D information computed tomography (CT), ultrasonography and/or magnetic resonance imaging (MRI) are needed. The optimal image modality for brachytherapy treatment planning is depending on the site to be treated as well as the geometry and the material of the applicator. Nowadays an imaging procedure is often performed prior to each application (or for each treatment) and individual treatment plans are made for each fraction. This means that brachytherapy treatment planning can be a time-consuming procedure and availability of the imaging devices a key issue.

2. CT imaging

CT is a highly available image modality. Moreover, the applicators, sources and source path are easy to recognize in the images [1,2]. In a French multicentre non-randomized prospective study Charra-Brunaud et al. showed that CT based brachytherapy improved the outcome for cervical cancer patients compared to traditional bidimensional based technique [3]. More than 700 patients from twenty centres were analysed and they found improved local control as well as decreased toxicity. Compared to conventional x-ray based brachytherapy CT-based treatment planning for cervical cancer allows for the detection of uterine perforation, which is a well-known complication [4]. CT is of limited use for image guided assessment of the boundaries of the tumor versus the cervix and the uterus and of parametrial invasion [5]. Viswanathan et al. showed that delineations based on CT can significantly overestimate the tumor width compared to MRI. They found, on the other hand, that CT is useful for the contouring of organs at risk in cervical cancer brachytherapy [6].

CT is the most frequently used image modality for postimplant dosimetry of permanent prostate seed implants. The seeds can be easily identified, often with a computerized algorithm. In a small study, seven observers reconstructed the seed positions on CT and MR images from three patients and found that the interobserver variability in seed detection resulted in a standard deviation for the dose delivered to 90% of the target (D90) of 1.5% and 6.6% for CT and MRI, respectively [2]. However, an essential disadvantage of postimplant CT is that the delineation of the prostate is challenging and a tendency of overestimation is seen compared to MRI [7].

In multicatheter interstitial brachytherapy for partial breast irradiation, CT is the recommended image modality for target delineation [8,9]. It is also feasible to reconstruct the catheter on the CT images with an acceptable accuracy by using 3 mm slice thickness or less. Plastic catheter could be identified merely by the air inside with proper windowing of the images, i.e. no special markers are needed [10]. A large phase 3, multicentre trial patients with stage 0, I and IIA breast cancer who underwent breast-conserving treatment were randomized to either whole-breast irradiation using external beam radiotherapy or accelerated partial breast irradiation using CT based multicatheter interstitial brachytherapy. Five years results showed that the accelerated partial breast

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