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Original paper

A patient immobilization device for prone breast radiotherapy: Dosimetric effects and inclusion in the treatment planning system

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ABSTRACT

Purpose: To assess the dosimetric impact of a patient positioning device for prone breast radiotherapy and assess the accuracy of a treatment planning system (TPS) in predicting this impact.
Methods: Beam attenuation and build-up dose perturbations, quantified by ionization chamber and radiochromic film dosimetry, were evaluated for 3 components of the patient positioning device: the carbon fiber baseplate, the support cushions and the support wedge for the contralateral breast. Dose calculations were performed using the XVMC dose engine implemented in the Monaco TPS. All components were included during planning CT acquisition.
Results: Beam attenuation amounted to 7.57% (6 MV) and 5.33% (15 MV) for beams obliquely intersecting the couchtop–baseplate combination. Beams traversing large sections of the support wedge were attenuated by 12.28% (6 MV) and 9.37% (15 MV). For the support cushion foam, beam attenuation remained limited to 0.11% (6 MV) and 0.08% (15 MV) per centimeter thickness. A substantial loss of dose build-up was detected when irradiating through any of the investigated components. TPS dose calculations accurately predicted beam attenuation by the baseplate and support wedge. A manual density overwrite was needed to model attenuation by the support cushion foam. TPS dose calculations in build-up regions differed considerably from measurements for both open beams and beams traversing the device components.
Conclusions: Irradiating through the components of the positioning device resulted in a considerable degradation of skin sparing. Inclusion of the device components in the treatment planning CT allowed to accurately model the most important attenuation effect, but failed to accurately predict build-up doses.

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1. Introduction

Radiotherapy after breast-conserving surgery improves loco-regional control and survival. However, radiation induced cardiac events and cancer of the lungs and the non-treated breast are of increasing concern [1–4]. Recent studies provide evidence behind a shift to prone radiotherapy for breast cancer: less acute toxicity, less risk of radiation-induced cardiac toxicity and of lung cancer induction [5–7]. The prone set-up requires specific patient set-up devices.

One widespread device is the Orfit All-in-One Solution (AIO) patient positioning system (Orfit Industries, Wijnegem, Belgium), which combines one generic base plate with multiple sets of support cushions and accessories to be used for multiple patient set-ups. The system consists of a combination of low- and high-density components.

Although this and other devices largely consist of low-density materials, a recent report by Olch et al. [8] emphasized that their dosimetric effects can be clinically relevant, but are often underestimated or overlooked. These effects include beam attenuation, as well as skin and build-up dose perturbations. Consequently, the authors stress the importance of taking these effects into account during the treatment planning process when beams traverse device components before entering the patient.

In this respect, this study quantified the dosimetric impact of the AIO patient positioning system and assessed the accuracy of the Monaco treatment planning system in modeling these effects. Although this investigation was originally initiated for the prone breast configuration of the device, the experiment design mainly focused on the generic common components and materials (i.e. the common base plate and foam cushions). Consequently, the general conclusions remain valid for all configurations, that use the same base plate and cushion materials.

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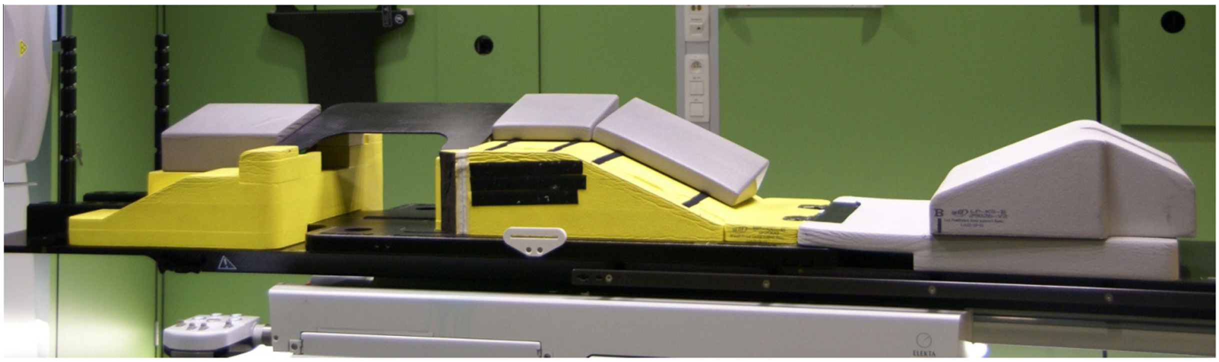

Fig. 1. The prone breast configuration of the AIO positioning device.

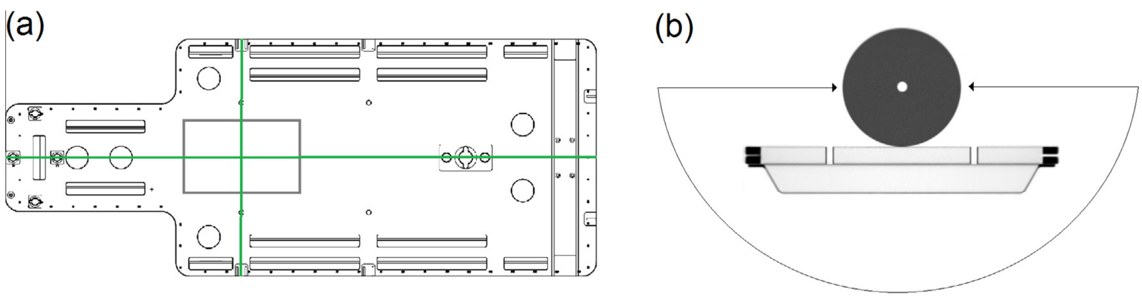

Fig. 2. A schematic overview (a) of the AIO base plate (Courtesy of Orfit Industries). The positions of the cylindrical phantom and isocenter during the attenuation measurement are indicated by the projection of the transversal and sagittal laser lines. Subplot (b) represents a transversal section through the AIO base plate and iBeam evo couchtop at the isocenter. The position of the cylindrical phantom and the gantry angle range during the attenuation measurements are equally depicted.

2. Materials and methods

2.1. The positioning device

The AIO device is an indexed patient positioning and immobilization system that combines one carbon fiber base plate with 4 sets of cushions and accessories into 4 different configurations. Each configuration is intended for a different treatment set-up. This study mainly focused on the dosimetric properties of the system's basic and generic components: the carbon fiber base plate and support cushions. For the prone breast configuration, illustrated in Fig. 1, one additional accessory (the support wedge for the contralateral breast) was also investigated. A detailed description of the prone breast configuration's use is provided in Mulliez et al. [5].

The carbon fiber base plate (type 32301) is depicted in Fig. 2(a) and consists of a polyvinyl chloride foam core (0.07 g/cm^3) sandwiched between two carbon fiber layers. The thickness of a single carbon fiber layer varies between 0.6 and 0.8 mm depending on the exact location. It also contains some areas with excisions used for cushion positioning or with higher density materials (1400 g/cm^3) used for reinforcement.

The AIO support cushions all consist of a low density polyethylene foam (PE, 0.029 g/cm^3) with a thin polyurethane coating (PU, >1000 g/cm^3). Each of the 4 configurations employs a separate set of cushions with varying shapes and thicknesses.

The investigated support wedge for the contralateral breast evenly consists of a foam core sandwiched between two carbon fiber layers. The wedge evaluated in this study is clearly depicted in Fig. 1 and in Mulliez et al. [5].

2.2. Dosimetric effects

The dosimetric effects investigated in this study comprise both beam attenuation and build-up dose perturbations when irradiating through these main components of the AIO positioning device. All investigations were conducted for both 6 and 15 MV photon beams provided by an Elekta Synergy linear accelerator equipped with an MLCi2 multileaf collimator (MLC, Elekta, Crawley, West-Sussex, UK). For both attenuation and build-up dose measurements, the recommendations regarding set-up geometry and equipment from the recent AAPM-report TG 176 [8] were adhered to.

2.2.1. Dosimetry techniques

In this study, beam attenuation was characterized as the dose decrease at 10 cm depth in a polystyrene phantom irradiated by a 10×10 cm^2 field and quantified by ionization chamber (type 30012, PTW Freiburg, Freiburg, Germany) dosimetry. Build-up dose measurements were mainly conducted by radiochromic film dosimetry and supplemented by extrapolation chamber measurements for the support foam cushions. All measurements were performed using polystyrene (ρ = 1.02 g/cm^3) slab phantoms with a varying geometry depending on the dosimetric effect and component considered.

Radiochromic films (Gafchromic EBT2, Ashland Specialty Ingredients, USA) were scanned prior to and 36 h after irradiation on an Epson Expression 10000XL flatbed scanner in transmission mode (Seiko Epson Corp., Japan). Films were scanned in portrait orientation (coating direction, paralleling the short dimension of the original film sheet, perpendicular to the scanning direction) with a resolution of 100 dpi. The Epson scanner was used with the software package "EPSON scan" in professional mode. Six warm-up scans were performed prior to data acquisition, in order to minimize the influence of its well-known light source warm-up effect [9]. All image enhancement features were turned off. Image data were stored in 48-bit RGB uncompressed TIFF-format and analyzed in Matlab version 7.10 (The Math Works, Inc., Natwick, MA, USA). The net optical density in the red color channel was used for film analysis and calibration. All radiochromic films were irradiated in a parallel orientation relative to the beam axis.

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