Absorbed dose measurements in the build-up region of flattened versus unflattened megavoltage photon beams

Annemieke De Puysseleyr [1,*], Wolfgang Lechner [2,3], Wilfried De Neve [1], Dietmar Georg [2,3], Carlos De Wagter [1]

[1] Department of Radiation Oncology and Experimental Cancer Research, Ghent University, Ghent, Belgium
[2] Department of Radiation Oncology, Medical University of Vienna/AKH Wien, Vienna, Austria
[3] Christian Doppler Laboratory for Medical Radiation Research for Radiation Oncology, Medical University of Vienna, Vienna, Austria

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Abstract

This study evaluated absorbed dose measurements in the build-up region of conventional (FF) versus flattening filter-free (FFF) photon beams. The absorbed dose in the build-up region of static 6 and 10 MV FF and FFF beams was measured using radiochromic film and extrapolation chamber dosimetry for single beams with a variety of field sizes, shapes and positions relative to the central axis. Removing the flattening filter generally resulted in slightly higher relative build-up doses. No considerable impact on the depth of maximum dose was found.

Keywords: Flattening filter-free, build-up dose, surface dose

Dosisberechnungsgenauigkeit im Aufbaubereich konventioneller und ausgleichsfilterfreier MV-Photonenstrahlen

Zusammenfassung

In dieser Studie wurde die Energiedosis im Aufbaubereich konventioneller Photonenstrahlung (FF) und ausgleichsfilterfreier Photonenstrahlung (FFF) untersucht. Die Messung der Dosis in der Aufbauregion wurde mittels einer Extrapolationskammer und radiochromatischen Filmen in statischen Feldern verschiedener Größe, Form und Position relativ zur Zentralachse durchgeführt. Dabei wurden 6 und 10 MV hochenergetische Photonenstrahlen sowohl im FF- als auch im FFF-Modus verwendet. Das Entfernen des Ausgleichsfilters führte zu einer leichten Erhöhung der relativen Dosis in der Aufbauregion. Die Position des Dosismaximums blieb davon jedoch relativ unbeeinflusst.

Schlüsselwörter: Ausgleichsfilterfreie Photonenstrahlung, Dosis in der Aufbauregion

1 Introduction

As modern intensity modulated radiation techniques (IMRT) do not require a uniform photon fluence across the beam, multiple authors have investigated the advantages when operating linear accelerators without a flattening filter. In literature, the main rationale behind the removal of the flattening filter concerns an increase in dose rate [1–5] and an important reduction of the head scatter and its variation with field size [2,4,6]. As a result, the use of flattening filter-free (FFF) photon beams in IMRT has been shown to reduce out-of-field dose [5,7,8] and delivery times while maintaining treatment plan quality [9].

However, as the flattening filter is generally considered to be the main source of electron contamination and strongly influences the low-energy contributions of the beam spectrum

*Corresponding author: Annemieke De Puysseleyr, Department of Radiation Oncology and Experimental Cancer Research, Ghent University, De Pintelaan 185 0P7, 9000 Gent, Belgium.
E-mail: Annemieke.DePuysseleyr@UGent.be (A. De Puysseleyr).

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[3,10,11], flattening filter removal is also expected to affect the absorbed dose in the build-up region of megavoltage photon beams. In literature, however, no detailed study on the build-up dose in conventional (FF) versus flattening filter-free beams is available. While some authors shortly addressed build-up dose when investigating the advantages of FFF beams, these studies remained limited to the central axis and mostly included centrally positioned fields [2,4,6,12,13]. Additionally, most of these data rely on fixed separation plane-parallel chamber measurements. When used in the build-up region, these chambers suffer from multiple limitations, such as the finite entrance window thickness, possible polarity effects and uncertainties regarding the stopping-power ratio [14]. Within these limitations, the studies reported FFF surface dose to be slightly higher for small fields [2,4,6,12,13], but similar or lower for large fields [2,6]. For the older generation of FFF accelerators without multileaf collimator (MLC), Sixel et al. [15] reported the depth of dose maximum for large FFF beams to be constant with field size, while a gradual decrease with field size was observed for FF beams. In this respect, the first part of this study aims at quantifying the absorbed dose in the build-up region for a broad range of investigated depths and measurement positions within each field, for a variety of field sizes and field positions relative to the central axis. To cope with the mentioned measurement uncertainties, a combination of radiochromic film and extrapolation chamber dosimetry was used.

2 Materials and methods

The absorbed dose in the build-up region was evaluated for 6 and 10 MV FF versus FFF beams. All beams were provided by an Elekta Precise linear accelerator equipped with an Elekta MLC*i* multileaf collimator (Elekta, Crawley, West-Sussex, UK). In FFF mode, a 2 mm steel disk is standardly positioned in the filter carousel and inserted in the beam line in order to guarantee the normal operation of the monitor chamber and beam steering.

The 6 MV beams provided by this accelerator were energy-matched ($TPR_{20/10}$: 0.686 (FF) and 0.684 (FFF)). The investigated 10 MV FF and FFF beams, however, were not energy-matched, but employed the same electron energy incident on the target ($TPR_{20/10}$: 0.735 (FF) and 0.714 (FFF)) [6]. Measurements were performed for 5×5, 10×10, 15×15, 20×5 and $20 \times 10\,cm^2$ fields positioned symmetrically on, 5 and 10 cm off the central axis in the leaf travel direction. The longest field dimension of the elongated fields was perpendicular to the leaf travel direction. The gantry and collimator angles were 90° and 0° respectively. SSD was set to 90 cm.

Measurements were conducted by radiochromic film (Gafchromic EBT2, Ashland Specialty Ingredients, USA) and extrapolation chamber (EPC, Böhm type 23392, PTW-Freiburg, Germany) dosimetry. All film and extrapolation chamber measurements were performed with a gantry angle equalling 90°. An overview of the film and EPC experimental set-up is provided in Fig. 1.

Radiochromic films were scanned prior to and 36 h after irradiation on an Epson Expression 1680 Pro flatbed scanner in transmission mode (Seiko Epson Corp., Japan). The net optical density in the red colour channel was used for film calibration. An extensive description of the film scanning protocol is provided in [16], while the precision and accuracy of the used film-digitizer system is extensively discussed in [24]. The most important aspects of the film-digitizer system and film

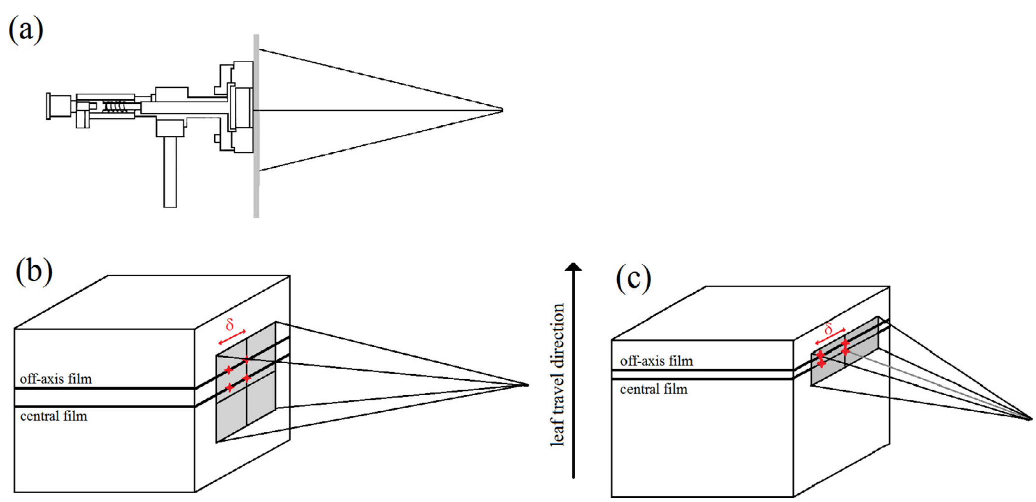

Fig. 1. Schematic representation of the extrapolation chamber (a) and film dosimetry (b and c) set-up. All measurements were performed with a gantry angle equalling 90°. Build-up dose was measured by positioning solid water slabs in front of the extrapolation chamber's entrance window, while the SSD was kept constant by lateral table readjustments (a). Two radiochromic films were mounted in parallel orientation in a Solid Water slab phantom (b and c). Subplots (b) and (c) represent the phantom set-up for a central and an elongated off-axis field respectively. The red stars mark the positions in the films where PDDs have been extracted. δ represents the distance in the latero-lateral direction between the PDDs extracted in one film.