Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: http://www.elsevier.com/locate/rpor

Original research article

Pretreatment verification of dose calculation and delivery by means of measurements with PLEXITOM™ phantom

Paweł Wołowiec[a,*], *Paweł Kukołowicz*[a,b], *Krzysztof Lis*[a]

[a] *Medical Physics Department, Holycross Cancer Centre, Kielce, Poland*
[b] *The Jan Kochanowski University of Humanities and Sciences, Kielce, Poland*

ARTICLE INFO

Article history:
Received 20 March 2012
Received in revised form
24 September 2012
Accepted 30 December 2012

Keywords:
Radiotherapy
Quality control
Treatment plan verification
PLEXITOM™

ABSTRACT

Aim: To validate a pretreatment verification method of dose calculation and dose delivery based on measurements with Metaplex PTW phantom.

Background: The dose-response relationships for local tumor control and radiosensitive tissue complications are strong. It is widely accepted that an accuracy of dose delivery of about 3.5% (one standard deviation) is required in modern radiotherapy. This goal is difficult to achieve. This paper describes our experience with the control of dose delivery and calculations at the ICRU reference point.

Materials and methods: The calculations of dose at the ICRU reference point performed with the treatment planning system CMS XiO were checked by measurements carried out in the PLEXITOM™ phantom.

All measurements were performed with the ion chamber positioned in the phantom, at the central axis of the beam, at depth equivalent to the radiological depth (at gantry zero position). The source-to-phantom surface distance was always set to keep the source-to-detector distance equal to the reference point depth defined in the ICRU Report 50 (generally, 100 cm). The dose was measured according to IAEA TRS 398 report for measurements in solid phantoms. The measurement results were corrected with the actual accelerator's output factor and for the non-full scatter conditions. Measurements were made for 111 patients and 327 fields.

Results: The average differences between measurements and calculations were 0.03% (SD = 1.4%), 0.3% (SD = 1.0%), 0.1% (SD = 1.1%), 0.6% (SD = 1.8%), 0.3% (SD = 1.5%) for all measurements, for total dose, for pelvis, thorax and H&N patients, respectively. Only in 15 cases (4.6%), the difference between the measured and the calculated dose was greater than 3%. For these fields, a detailed analysis was undertaken.

Conclusion: The verification method provides an instantaneous verification of dose calculations before the beginning of a patient's treatment. It allows to detect differences smaller than 3.5%.

* *Corresponding author at*: Medical Physics Department, Holycross Cancer Centre, ul. Artwińskiego 3, 25-734 Kielce, Poland. Tel.: +48 41 367 4416; fax: +48 41 3674 090.
E-mail address: pawel.wolowiec@gmail.com (P. Wołowiec).

1507-1367/$ – see front matter © 2013 Greater Poland Cancer Centre. Published by Elsevier Urban & Partner Sp. z o.o. All rights reserved.
http://dx.doi.org/10.1016/j.rpor.2012.12.007

1. Background

The dose–response relationships for local tumour control and radiosensitive tissue complications are strong. It is widely accepted that the accuracy of dose delivery of about 3.5% (one standard deviation) is required in modern radiotherapy.[18] This goal is difficult to achieve.[7,8] Many measures are necessary to minimize the uncertainty in dose delivery during patient treatments.[25] The sources of uncertainties may be divided into four areas: geometrical errors, dosimetry errors, human error (that may lead to both geometrical and dosimetry errors) and, finally, errors that arise directly from equipment.[19,21,23] To minimize geometrical errors, sophisticated measurements of reproducibility of the patient set-up combined with correction strategies are employed.[1,4] Typical human errors include irradiation of an incorrect patient or an incorrect site.[20] These errors are more likely to occur in very busy radiotherapy departments. A good example of an error linked to improper equipment operation is the Saragossa accident.[24] In many accidents human error plays an important role.[22] The uncertainty in dose delivery may be analyzed by reviewing the sequence of steps in the dose delivery chain.[2,17] Alternatively, it may be assessed during treatment using in vivo dosimetry.[5,16]

Systematic and random errors occur in treatment delivery. For many years, "manual" treatments rendered radiotherapy very open to random human errors, such as miss-read or miss-set parameters. Many of these were never noticed or recorded. The number of random treatment error rates decreased considerably when record and verification systems (R&V systems) were introduced.[20] However, even with sophisticated R&V systems, some systemic errors still occur.[6] For example at the Princess Margaret Hospital in Toronto from January 1, 1997, to December 31, 2002 there were 555 errors among 28,136 patient treatments. Eighty-seven errors were directly attributed to incorrect programming of the R&V system.[10] Likewise, at the University of Utah during a 1-year period, 38 errors out of 22,542 external beam treatments administered under their R&V were identified.[20] Most of them arose from incorrect manual transcription of radiotherapy treatment parameters from the planning system to the R&V system. Ideally, all systemic errors should be detected before the start of treatment. The correctness of dose calculations at the prescription point performed with sophisticated treatment planning systems (TPS) is often performed using an independent monitor units (MUs) calculation programme.[15] Calandrino published data from the implementation of an independent control of MU and distribution calculation, together with a check of data reported in the treatment chart.[3] He showed that their system, which was relatively effective in detecting systemic errors before starting the treatment, still missed a quarter to one third of errors. Furthermore, Calandrino's experience confirms the utility of in vivo dosimetry in detecting previously unnoticed systemic errors. This paper details our experience with the control of dose delivery and calculations at the ICRU reference point. The method relies on dose measurements, performed at the prescription point before the start of treatment, using a PLEXITOM^{TM} phantom. We present results for the 111 patients treated with photon beams in our centre.

2. Aim

To validate a pretreatment verification method of dose calculation and dose delivery based on measurements with Metaplex PTW phantom.

3. Materials and methods

The calculations of dose at the ICRU reference point ($ICRU_{Ref}$) performed with the treatment planning system XiO (CMS XiO – Release V4.40.00) were checked by measurements carried out in the PLEXITOM^{TM} phantom (PTW – Freiburg). The calculation algorithm used by TPS was generally FFT (fast Fourier transform) Convolution. Only in the case of the thorax region the calculation algorithm was superposition. The phantom (see Fig. 1) contains two eccentrically mounted rotary acrylic cylinders inside a solid acrylic block. The double rotation provides for quick and precise positioning of a detector along the central beam axis, as well as for the off-axis measurement within a perimeter of 12.2. The phantom is powered by two stepper motors remotely controlled by the TBA CONTROL UNIT (PTW – Freiburg) and by the MEPHYSTO software. The movement control allows for the positioning of an ion chamber with the accuracy of 0.5 mm. The size of the phantom top surface is 19.0 × 11.5 cm. The chamber may be positioned at depths ranging from 1.0 cm to 12.2 cm.

3.1. *Method of dose measurement at the ICRU reference point*

The dose was measured separately for each treatment field. All measurements were performed with the ion chamber ("0.125 ccm flex.", Type/Ser. – No. M31002 – 0594, Manufacturer: PTW – Freiburg, Germany) positioned at the central axis of the beam at the radiological depth and with the UNIDOS electrometer. The radiological depths were obtained from the treatment plan protocols. The phantom density differs from the density of water; therefore, the radiological depth was converted into an equivalent depth in the phantom according to the scaling factor recommended by the manufacturer of the PLEXITOM^{TM} phantom. The source-to-phantom surface distance was always set to keep the source-to-detector distance

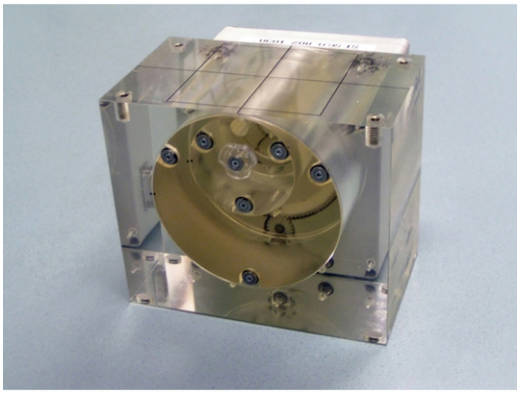

Fig. 1 – PLEXITOM^{TM} phantom.