Physica Medica 66 (2019) 133–134

Contents lists available at ScienceDirect

Physica Medica

journal homepage: www.elsevier.com/locate/ejmp

Letter to the Editor

Impact of inertia on possible fundamental drawbacks in radiochromic film dosimetry

History of radiochromic film dosimetry

From its very inception [1] radiochromic films draw an immediate attention for its high spatial resolution and near tissue equivalence in most dosimetry applications [2]. The earlier GafChromic™ film models (MD-55, HS) were quite expensive, limiting their use to experimental dosimetry. The renaissance of radiochromic film dosimetry came about in 2005 with the introduction of the EBT film model [3] with significantly lower (10 times per square inch lower) price and readily accepted radiochromic film protocols (RFPs) using inexpensive flatbed document scanners [4]. To date, a number of RFPs have been described, using either transmission single [5] or multiple color channels [6], or reflection scanned images [7].

Possible drawbacks

Despite relatively steep development of radiochromic film dosimetry, the authors of this letter came across two significant errors in using radiochromic film dosimetry within not only reviewing phase but in the published articles in some very respectful journals. We sincerely believe the omissions in published papers came due to lack of focus by both authors and reviewers, and our intention is to simply bring to the attention of film users the two issues that may potentially lead to significant errors. The first issue is the use of non-linear response of radiochromic film (*netOD*, raw *PV*) and attributing a simple division of such response functions to relative dose. Second problem is the lack of awareness that radiochromic films exhibit a significant energy dependent response when irradiated in low energy photon beams. Such obvious, yet significant omissions could be eventually explained by inertia, as laid down by Newton, more than three centuries ago [8]. It seems that inertia does not only drive the mechanics of the Universe, but the human way of life too.

Non-linearity of response function

Radiographic film dosimetry was around for much longer than radiochromic film based one. At the time, radiographic film response to exposure was commonly expressed in terms of optical density (*OD*), a quantity derived as logarithm for base 10 of inverse transmission. Rationale for choosing this quantity was the H&D curve, which exhibited linear relation in relatively wide dose range, except at low (toe) and high (saturation) dose values. Quite possibly, the radiochromic film user's community followed (by inertia) the suit in using the very same quantity despite the fact the response of radiochromic film was non-linear in the whole dose range [9]. We can only make a hypothesis that some users tend to use ratio of optical densities (for measuring either *PDD* curves or profiles) following the practice (inertia) with ion-chambers, who (again in certain ranges of beam qualities) have linear response (measured charge) with dose. When the same methodology is used for (any) dosimeter having non-linear response, such obtained "relative values" in the case of radiochromic films will overestimate the real relative dose values [10]. Over the last decade, a few novel functional forms have been suggested that do linearize the response of radiochromic films [10,11]. However, one has to be cautious with using even these new functional forms, as they would provide accurate relative dose values by simple division of responses if and only if the film response for the given beam quality does not change over the plane in which film is used for relative dose measurements.

Radiochromic film response as a function of beam quality

The second possible drawback that may lead to inaccurate dose measurements is if one ignores the energy dependent response at low photon energies. It was well established that all the EBT film models exhibit strong energy dependence as the effective beam energy goes bellow 100 keV [12–14]. Nevertheless, one may find papers measuring relative dose distributions with films at 50 kVp beam quality and reporting relative dose by completely ignoring this effect by using calibration curve obtained at either different kVp beam quality or sometimes even using calibration at MV beam. We believe this might be yet another case of inertia, following the widely adopted prejudice that film has energy independent response based on the fact that most of the early research with films has been performed in megavoltage photon and electron beams, the range of beam qualities where radiochromic film indeed has response to dose independent of energy [15].

How to avoid the two drawbacks when performing radiochromic film dosimetry

When measuring the relative dose, user could use any function that make the film response linear with dose. This can be easily done once calibration films are scanned – data is there forever to experiment with. If, for whatever reason (existing software, existing protocols), user prefers to use response functions with non-linear response (*netOD*, raw *PV*), to obtain relative dose distribution, one has to go through the reference dosimetry protocol, where the calibration curve function will sort out the non-linear response. Once the issue with response function is solved, user has to make sure dose distribution is measured for photon beam qualities with effective energy above 100 keV. For lower photon energies, one has to determine beam quality at every measurement point within the film plane, and then apply the corresponding calibration curve for each measurement point. For this task, user clearly has to go through the reference dosimetry protocol for each measurement point irrespectively of using response function with linear or nonlinear response.

https://doi.org/10.1016/j.ejmp.2019.08.019
Received 11 May 2019; Received in revised form 23 August 2019; Accepted 25 August 2019
Available online 26 September 2019

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