Use of normoxic polymer gel dosimeters for measuring diagnostic doses on CT scanners

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1. Introduction

X-ray CT has been used to evaluate polymer gel dosimeters for dose response in the therapeutic dose range [1,2]. This method of polymer gel dosimeter evaluation has been shown to be useful for instance in the comparison of complex stereotactic field distributions with treatment plans [3]. Image averaging and subtraction techniques are used for noise reduction in polymer gel dosimeters [1,2] resulting in the delivery of several CT slices across the polymer gel dosimeters.

It was a logical progression to evaluate normoxic polymer gel dosimeters [5,6] with optimized CT scanning protocols [4]. During these investigations it was found that unirradiated regions in irradiated normoxic polymer gel dosimetry phantoms polymerised possibly as a result of the evaluation using CT. This prompted an investigation of the CT diagnostic dose response of the normoxic polymer gel dosimeter in order to determine the dose contribution when evaluated using a CT scanner.

Having established that there was an effect on the normoxic polymer gel dosimeter when evaluating with a CT scanner the suitability of these gels in the determination of CT diagnostic dose measurement was further investigated.

2. Materials and methods

A Philips AcQSim spiral CT scanner (Philips Medical Systems, NL) was used for all CT measurements. Three CT phantoms were used: head (diam. 15 cm), body (diam. 30 cm) and a cylindrical water phantom (diam. 25 cm). The CT dose was measured with a 100 mm ion chamber for the protocol; 8 mm slice width, 140 kV and 400 mAs for a single axial slice. This measurement was repeated for 250 single slices to determine linearity of dose for this protocol.
The MAGIC polymer gel dosimeter was manufactured following previously described methods [5,6]. Figure 1a shows the two types of bottles (390 and 1500 ml) MAGIC gel was poured into following manufacture. All bottles were positioned centrally in the CT scanner within the water phantom as shown for example in figure 1b. Six 390 ml bottles were used to measure R2-dose response as a result of the number of slices delivered to each bottle. 25 slices were delivered to an axial plane on the central part of a 390 ml bottle ensuring the bottle remained in the same position throughout following the same protocol as delivered to the ion chamber. This was repeated for 50, 75, 100, 125 and 150 slices for individual 390 ml bottles. The R2-dose response as a function dose (Figure 2) was calculated from ion chamber dose as a function of number of slices and MAGIC R2-dose response as a result of the number of slices. 50 slices were delivered to another four 390 ml bottles with varying slice thickness of 5, 4, 3 and 2 mm for the same protocol. CT dose index (CTDI) was calculated from both ion chamber and MAGIC polymer gel dosimeter measurements.

25 slices of 8 mm slice thickness, 120 kVp, 400 mAs were delivered to an axial plane on the central part of a 1500 ml bottle. A spiral protocol of 8 mm slice width, 120 kVp, 400 mAs and pitch of 2.0 was delivered to 100 mm on a second 1500 ml bottle 25 times. All bottles were scanned in a Siemens Vision 1.5T MRI whole body scanner using the head coil. T2 weighted base images were acquired using a 64 multiple slice multiple spin-echo pulse sequence and an R2 was subsequently calculated (figure 1c) [6].

3. Results

Figure 2 shows the R2-dose response of MAGIC polymer gel dosimeter as a function of dose and as a function of number of slices. Figure 3 shows the R2-dose response of MAGIC polymer gel dosimeter coronal profile as a function of distance. The R2 response is shown on the left axis and the dose is shown on the right y-axis. This plot may be considered a dose profile for an 8 mm nominal slice width.
Figure 2. R2-dose response of the MAGIC gel dosimeter.

Figure 3. Dose profile for 8 mm slice width.

Table 1 is a summary of comparative results for nominal slice widths 2, 3, 4, 5 and 8 mm as measured with the 100 mm ion chamber and MAGIC polymer gel dosimeter in the water phantom. Figure 4 shows the corresponding R2-dose response of MAGIC polymer gel dosimeter coronal profile as a function of distance for the protocol, 8 mm slice width, 120 kVp, 400mAs, pitch 2 over 100 mm.

| Nominal slice width | MAGIC measurement (mGy) | Ion chamber measurement (mGy) |
|---------------------|-------------------------|-----------------------------|
| 2                   | 6.70                    | 10.76                       |
| 3                   | 15.88                   | 15.98                       |
| 4                   | 18.36                   | 18.42                       |
| 5                   | 21.30                   | 22.05                       |
| 8                   | 28.46                   | 28.78                       |

Figure 4. Dose profile for 100 mm spiral scan.
4. Discussion and conclusions

Measurements were performed with the MAGIC polymer gel dosimeter to demonstrate that diagnostic CT doses can be determined. Figure 2 demonstrates that the dose response from CT on an un-irradiated gel can be significant when multiple slices are used to evaluate the polymer gel dosimeter indicating that CT scanners used to evaluate polymer gel dosimeters can affect the dose evaluation. The contribution from the CT evaluation may be subtracted given that it is linear and reasonably uniform for larger slice widths.

The role of polymer gel dosimeters in the measurement of diagnostic CT dose was shown to be complimentary to conventional methods of measuring diagnostic CT doses. It has recently been suggested that the CTDI is an exponential function of the phantom diameter [7] and thus an important issue in determining optimal pediatric CT protocols. Polymer gel dosimeters offer an alternative to TLD in any size soft tissue equivalent phantom [8,9]. Additionally there is an issue of 100 mm ion chambers limiting the accuracy of CT dose measurements due to insufficient length in determining dose in multi-slice CT scanners [10]. The use of polymer gel dosimeters may overcome this as gel measurements can account for long scatter tails in a single axial slice or for direct measurements over an entire scan length (figures 3 and 4). Polymer gel dosimeters provide dose profile information in 3D previously not achieved with any single measurement device used for measuring diagnostic doses on CT scanners. Phantoms can be manufactured and used in any combination of cylindrical phantom size or more importantly, anthropomorphic phantoms.

Generally polymer gel dosimeters have the potential for use in acceptance testing of CT scanners in diagnostic radiology which compliment existing methods. A potentially wider application may be as a specialized tool for comparative dose investigations of several types of protocol on single or multiple CT scanners.

References

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