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Original Research

Advancements in Gel Dosimetry and Its Comparative Analysis with Conventional Dosimeters in Radiotherapy: A Comprehensive Review

Sujan Mahamud[1]*, Md. Mokhlesur Rahman[2], Prof. Dr. Golam Abu Zakaria[3]
[1]Lecturer, Department of Medical Physics and Biomedical Engineering, Gono Bishwabidyalay, Savar, Dhaka 1344.
[2]Assistant Professor, Department of Medical Physics and Biomedical Engineering, Gono Bishwabidyalay, Savar, Dhaka 1344.
[3]Chairman and Chief Medical Physicist at the Department of Medical Radiation Physics,
Gummersbach Teaching Hospital, Germany.

*** Corresponding Author:** Sujan Mahamud; Email: sujan.mpbme@gmail.com; Mobile: +8801921467076.
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Abstract

Purpose: *A major challenge in radiotherapy treatment is to deliver precise dose of radiation to the tumor with minimum dose to the healthy normal tissues. Recently, gel dosimetry has emerged as a powerful tool to measure 3D dimensional dose distribution for complex delivery verification and quality assurance. The dosimeters act both as a phantom and detector. The aim of the study is to know the application of gel dosimeters in radiotherapy and find out the comparison with 1D and 2D dimensional dosimeters.*

Methods and Materials: *The study is found from gel dosimeter literature's. Secondary data and images have been collected from different sources such as different guidelines, books, and internet etc.*

Result: *Analyzing, verifying, and comparing data from TPS is determined that gel dosimeter is a very powerful tool to measure 3D dimensional dose distribution. TPS calculated data were in good agreement with the dose distribution measured by the ferrous gel. The overall uncertainty in the ferrous-gel dose determination was reduced using an optimized MRI acquisition protocol and a new MRI scanner. The method developed for comparing measuring gel data with calculated treatment plans, the gel dosimetry method was proven to be a useful for radiation treatment planning verification. In 1D and 2D film the depth dose and lateral for RMSD are 1.8% and 2% and (Di-Dj)max is 2.5% and 8%. Other side 2D+ (3D) film gel and plan gel for RMSDstruct and RMSDstoch are 2.3% & 3.6% and 1% & 1%, and system deviation are -0.6% and 2.5%. The result is confirmed that 2D+ (3D) film dosimeter is better than the 1D and 2D dosimeter.*

Discussion: *Gel dosimeters is a quality control and quality assurance tool which will be used as the future clinical application.*

Keywords: *Gel dosimeters, 1D and 2D dosimeters, QC, detector & phantom, RMSD*

Introduction

Gore introduced gel dosimetry, which could be performed with magnetic resonance rather than spectrophotometer. The Fricke solution was stabilized with gelatin or agarose, and MRI imaging showed spatial dose information in 3D dimensions. T1 relaxation variable was proportional to the dose. Ferric ions produced by absorption of radiation diffuse readily through the gel or agarose matrix, causing a decrease in signal intensity. Dosimetry detail must be preserved within 2 hours of irradiation without serious degradation. A poly vinyl alcohol matrix had been replaced with a gelatin matrix which is less porous to the ferric ions. Delay diffusion had been reduced, although imaging must still be performed after irradiation [1]. Free radical interactions caused monomers to cross link into polymer chains in polymer gels. Water protons are tightly bonded to polymer chains; hence their paramagnetic properties change [3]. This can be attributed to dose-dependent optical density in some compositions. Polymer chains changed the density of the gel to measure the change in attenuation coefficient, and x-ray transmission. Polymerization causes changes in elasticity and vibrational spectroscopy can demonstrate the conversion of monomers to polymers [4].

Methodology

Advantages/ importance of gel dosimeter:The gel dosimetry method may be developed further as the gel can be mound in any desired shape and in homogeneities can be placed within the phantom. Compared with conventional dosimeters the advantages of gel dosimetry are –

1. Independence on radiation direction radiation quality and dose rate for conventional clinical beams.
2. Absorbed dose integration in the dosimeter & evaluation of a complete volume.
3. Potential for true 3D dimensional dosimetry utilizing a high spatial resolution.
4. Possibility to measure in a phantom that is equivalent to anatomical soft tissue [9,13].

Uncertainty estimations:Uncertainty is divided into two categories –

i) Type A is determined by statistical methods.
ii) Type B is obtained from a calibration certificate.

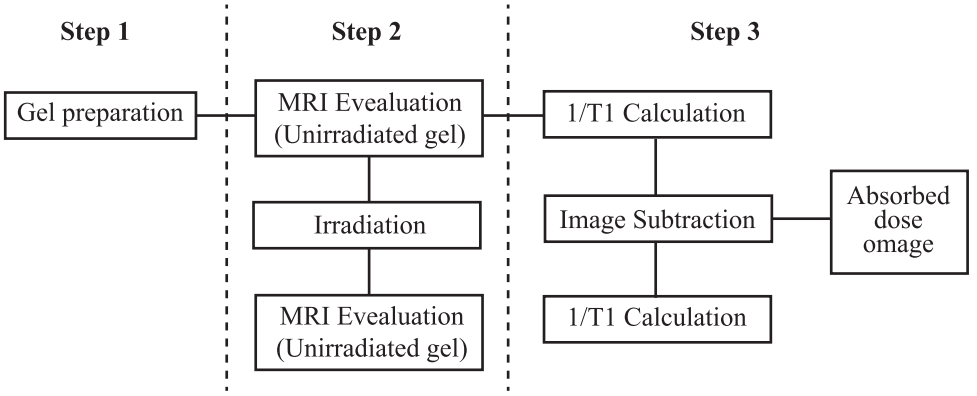


Figure 2: A schematic description of the procedure used for the Fe-Gel system, including the background subtraction.

The gel is prepared in Step 1, where the uncertainty is considered negligible. Type A standard uncertainty is estimated from Steps 2 and 3 at zero dose. To simulate dose variations within an irradiated phantom, standard samples with varying T1 (and T2) relaxation times are analyzed using the same method. Type B standard uncertainty is derived from profile measurements after background subtraction [11,12].

These uncertainties are then combined to calculate the expanded uncertainty across different dose levels. At a 95% confidence level, the expanded uncertainty is found to be less than 3.3% for low doses and 1.6% for high doses. It is noted that background subtraction is necessary to ensure accurate results, even though it may increase the Type A uncertainty.For Po-Gel dosimetry, the uncertainty in measured absorbed dose is estimated to be approximately 3% at high doses and up to 10% at low doses. These estimates are obtained using a standard MRI acquisition protocol. Evidence suggests that background subtraction is essential for obtaining reliable measurements with Po-Gel [10].

Comparison with other dosimeters: The relative accuracy, volumetric nature, inherent 3D dimensionality, high resolution, and lack of energy are the common characteristics of gel dosimeter. Today gels are still time-consuming and relatively expensive. The availability of optical CT scanning and other imaging techniques are likely to drive down the cost of gel analysis [9].

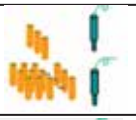
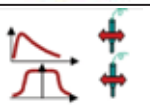
O-D	**2_{OD}/D**	**max{D_i-D_j}**			
Intra-batch	1.6%	2.6%			
Intra-batch	15%	25%			
I-D	**RMSD**	**max{D_i-D_j}**			
Depth-dose	1.8%	2.5%			
Lateral	2%	8%			
(2-D)+	**$RMSD_{Stoch}$**	**$RMSD_{Stoch}$**	**Sys. Dev.**	**d (N>50%)**	**d (N>95%)**
Film-Gel	2.3%	1%	-0.6%	<1.5 mm	<4 mm
Plan-Gel	3.6%	1%	2.5%	<2 mm	<5 mm

Figure 3: Comparisons of gel dosimetry with other gel dosimeters with different spatial dimensions.

Treatment Planning System:Two clinical treatments were investigated using the Fe-Gel system. The first technique was a simulated bladder cancer treatment and the second simulated breast cancer treatment. The difference between the TPS and Fe-Gel in a simulated target was +0.6% [16].

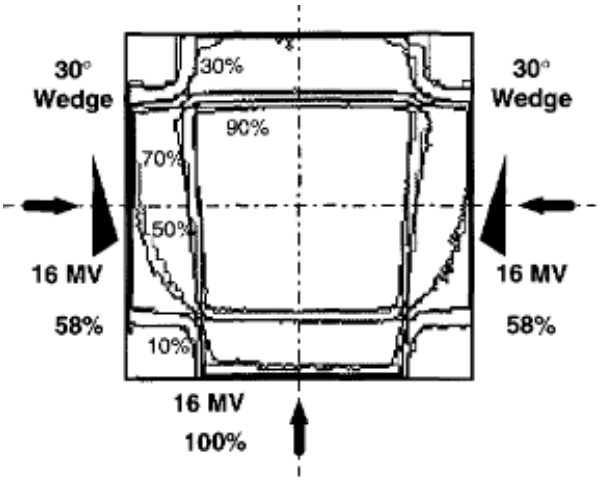


Figure 4: Normalized isodose curves (90, 70, 50, 30 and 10%) from the TPS calculations (grey) and Fe-Gel measurements (black) for a simulated urinary bladder cancer treatment.

Result

The dose distribution calculated by the Treatment Planning System (TPS) showed good agreement with the measurements obtained using Fe-Gel dosimetry. However, in beam abutment regions, larger dose discrepancies were observed. These differences may be attributed to beam alignment errors and a slight underestimation by the TPS of the lateral scatter outside the primary electron beam.

The overall uncertainty in Fe-Gel dose measurements was significantly reduced through the use of an optimized MRI acquisition protocol and a newer MRI scanner. The relative dose uncertainty was found to be better than 3.3% across all dose levels, with a 95% confidence level [14,16].

By applying the developed method for comparing gel-measured data with TPS-calculated plans, Fe-Gel dosimetry was demonstrated to be an effective tool for verifying radiation treatment plans.

Discussion

The accurate delivery of the prescribed dose depends on procedures involving dosimetry systems. Gel dosimetry offers the promise of accurate and convenient dosimetry under a variety of circumstances. Gel dosimeters offer several advantages over conventional dosimeters. Advantages include tissue-equivalence, high spatial accuracy, good dose precision, and reasonable convenience. However, gel dosimetry continues to experience little acceptance in the clinic, largely because some aspects of promise have not been achieved, and because of a perceived lack of convenience. Members of the radiation physics community are apparently not convinced that the benefits of gels sufficiently outweigh conventional dosimeters such as film and TLD. It is incumbent on those of us working with gels to encourage.

Conclusion

Gel dosimetry offers the promise of precise and appropriate 3D dose measurement over conventional dosimeters. A lot of work has been done to make these gels less toxic and user friendly. These gels offer advantages such as tissue equivalence, measurement of precise dose and high spatial resolution. Polymer gels are affected by O2 contamination and concentration of cross linkers. CT scanning emerged as an alternative to MRI for imaging in phantom dose measurements in radiotherapy treatment because of their availability and cost effectiveness. Although many advances have been made in this field, but because of perceived inconvenience it finds little acceptance in clinic. It is incumbent for the key members working in this field to encourage wider use of gels.

Authors Contributions

Sujan Mahamud performed the literature review and drafted the manuscript. Md. Mokhlesur Rahman provided academic guidance and critical review. Prof. Dr. Golam Abu Zakaria supervised the study and approved the final manuscript.

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Conflict of interest
The authors declare that they do not have any conflict of interest.

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