3D dose verification with polymer gel detectors of brain-spine match line for proton pencil beam cranio-spinal: A preliminary study

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Abstract. This paper is intended as a preliminary study to demonstrate the quality assurance benefits from polymer gel detectors for proton pencil beam cranio-spinal treatments. A stable gel type was selected for protons to suppress the LET dependence at the end of the Bragg peak. The depth dose distributions in the gels were examined with regard of its dose dependences and compared to baseline measurements. The preliminary experimental results indicate polymer gel detectors may be able to verify dose in three dimensions along match line for proton therapy treatments.

1. Introduction
The purpose of our study is to examine the dose due to match lines using polymer gel detectors for quality assurance of proton pencil beam cranio-spinal treatment plans. An advantage of gels is that you have the ability to verify dose in three dimensions. The uses of polymer gel detectors as a tool for radiation dosimetry have been well investigated in the literature [1]. The Council on Ionizing Radiation Measurements and Standards reported in October 2011 that there’s an urgent need for the introduction of high-resolution 3D methods of dosimetry, quality assurance and treatment verification [2]. Some of the advantages of gel dosimeter include potential applications of high linear energy transfer (LET) particles and proton therapy [3-5]. To improve quality assurance of particle therapy treatment of cancer and other diseases by the introduction of fast, accurate, high-resolution, three-dimensional dosimetry based on laser CT of soft-tissue-equivalent polymer dosimeters whose local optical density changes in proportion to local dose. This technology could be used in quality assurance (QA), and in patient-specific pre-treatment verification. Particle therapy is on the rise, but it lacks adequate dosimetry and QA tools. The promise of clinical benefits of particle therapy, which is characterized by superior tumor/normal tissue dose ratio, sharp range definition, enhanced relative biological effectiveness (RBE), and reduced oxygen sensitization effect in normal tissues, will materialize only to the extent that the accuracy of treatment delivery, both dosimetric and spatial, can be assured. The technology will become stagnate if new quality assurance methods are not developed.

In the study we generate a cranio-spinal plan and deliver it to a polymer gel phantom to interpret experimental results on the dose response of the gel from the irradiation of protons.
2. Materials and Methods

If a patient has a tumor that has spread along the covering of the spinal cord (meninges) or into the surrounding cerebrospinal fluid, then radiation may be given to the whole brain and spinal cord. Tumors such as medulloblastomas are more likely to spread this way and often require cranio-spinal radiation [6]. We prepared a treatment plan using the Varian Eclipse treatment planning system. Field matching is achieved by matching the edges of the abutting fields. For example, the inferior edges of the field for the brain are aligned with the superior edge of the superior spine field. For the match line study using proton, all gels were irradiated with pencil beam line option at the Roberts Proton Therapy Center which is housed in the department of Radiation Oncology at the University of Pennsylvania Medical Center.

![Figure 1](image1.png)

**Figure 1.** (a) Colorwash of dose distribution for cranio-spinal plan with pencil beam protons. (b) Setup of polymer gel phantom for treatment position in proton room.

Figure 1 shows the patient plan and the polymer gel phantom setup in the treatment room. We used BBs the setup the phantom at isocenter. We first delivered the brain field then shifted the table to deliver the spine field.

![Figure 2](image2.png)

**Figure 2.** (a) Axial view of dose plane with right and left lateral fields from brain plan Combined with PA field from spine plan. (b) Lateral view of brain-spine interface.

To determine the correct position of the matchline a verification plan was calculated using the CT study of polymer gel detector. Figure 2 shows the axial and lateral view of the dose distribution. The figure clearly shows the dose for the matchline is inside the polymer gel phantom.
Experimental measurements were scanned with OCTOPUS laser CT and compared to the treatment plan. Figure 3 shows the 3D overlay between the plan and measurements – initial results indicate good agreement of the gel dosimeter with the calculated plan.

Examining the profiles at the maximum dose point indicated the largest disparity in the anterior-posterior direction. This behaviour is expected due to the high LET dependence at the end of the Bragg peak. In figure 3 we see ~30% difference due to the end if range effects.

Stability studies of the polymer determine the best detector for measurements of proton beams. Figure 5 illustrates the improvement of the profiles – especially in the anterior-posterior direction where we saw the biggest effect due to LET dependence.

3. Results and Discussion
We determined a stable polymer gel detector could possibly be used for quality assurance of cranio-spinal fields from proton pencil beam plans Figure 6 shows the 30, 50 and 90% isodose planes for the coronal and axial views. From the analysis of the optical scans using our MATLAB code we were able to calculate a dose comparison from the proton irradiation. This study will allow serve as a baseline for dose to be calculated for future plans with proton beams.
4. Conclusions
In this initial study, we demonstrated a method to verify the brain-spine matching using pencil beam proton beams. We developed a consistent method for preparing a stable gel and developing a procedure the compare with the treatment plan. The results indicate that the gels have the potential of measuring the dose response from proton beams. Further work is needed in this study to examine the characteristics of the dose response before we use them clinically; especially in match line for pencil beam proton plans. We also want to develop the system to be used routinely in the clinic with minimal workload on the part of the hospital physicist.

5. Conflicts of Interest
One co-author (M J Maryanski) is the founder and owner of MGS Research Inc. All other co-authors report no actual or potential conflicts of interest.

6. References
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