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Fetal Radiotherapy Dose Reduction with Lead Aprons In Pregnancy Associated H3-K28M Diffuse Midline Glioma of the Brainstem

George Ibrahim, MS[1]; Zohaib Sherwani, MD[1] ;Taoran Cui, PhD[1]; Imraan Jan, MD[1], Ning J. Yue, PhD[1],
Rutgers Cancer Institute of New Jersey, New Brunswick, NJ

ABSTRACT

Purpose: To quantify the impact of lead aprons on reducing out-of-field fetal dose during external beam photon intracranial treatments.

Methods: A 34-year-old female at 19 weeks gestation underwent intracranial photon radiotherapy. An anthropomorphic phantom was used to measure fetal dose. Reference measurements evaluated the effects of beam energy and field size. Patient-specific measurements were performed using the clinical treatment plan, with a solid water insert representing the uterus and absolute dose measured using a calibrated Farmer-type ionization chamber. Measurements were acquired with no shielding, one to three anterior lead aprons, and combined anterior/posterior shielding. Dose was measured at the phantom surface, upper uterus, and mid-uterus.

Results: Reference measurements showed that 6 MV photons and smaller field sizes produced the lowest out-of-field fetal dose. For the 30-fraction treatment, cumulative fetal dose without shielding exceeded 2 cGy at the phantom surface (2.09 cGy) and upper uterus (2.13 cGy). Increasing anterior shielding produced progressive dose reductions at all locations. Two or more anterior aprons reduced upper uterine dose below 2 cGy (≤1.96 cGy), while mid-uterine dose remained below 2 cGy for all configurations. The lowest doses were achieved with three anterior aprons (upper: 1.94 cGy; mid: 1.72 cGy).

Conclusions: Lead apron shielding effectively reduced fetal dose during intracranial radiotherapy. Posterior aprons provided no additional benefit. Lower beam energy and smaller field sizes further minimized fetal dose and should be considered during treatment planning for pregnant patients.

CONTACT

George Ibrahim
Rutgers Cancer Institute of New Jersey,
New Brunswick, NJ
gmi25@cinj.Rutgers.edu
(+1) 657-272-4491

INTRODUCTION

Radiation therapy during pregnancy presents a clinical challenge due to potential fetal radiation exposure and associated stochastic risks.

In cases of intracranial irradiation, the fetus lies well outside the primary treatment fields, and fetal dose arises predominantly from out-of-field radiation, including head leakage and patient scatter.

Treatment planning systems are not optimized for accurate estimation of peripheral dose at large distances from the field edge, leading to significant uncertainty in fetal dose assessment.

AAPM Task Group 36 recommends phantom-based measurements as the most reliable method for evaluating fetal dose in pregnant patients.

The current recommendation from AAPM Task Group 36 is to use a custom-made lead shield. However, a lot of clinics do not readily have access to this. However standard x-ray lead aprons are readily available in most clinics.

This study describes phantom-based and in vivo dosimetric methods used to estimate fetal dose and assess the effectiveness of lead apron shielding in a pregnant patient undergoing intracranial radiotherapy.

METHODS AND MATERIALS

Reference Phantom Measurements

All measurements were performed using an anthropomorphic phantom with a solid water uterine insert and an ionization chamber positioned at the simulated fetal location.

Reference measurements were performed to characterize out-of-field fetal dose as a function of beam energy and field size.

Beam energies and field sizes were systematically varied, and all measurements were acquired without lead apron shielding to establish baseline peripheral dose trends.

Patient-Specific Phantom Measurements

Using the same phantom setup, the clinically delivered two-arc 6 MV VMAT plan was delivered to evaluate fetal dose with no shielding, one to three anterior lead aprons, and combined anterior/posterior configurations.

To account for positional uncertainty, dose was measured at three locations (1) the midpoint of the uterine volume, (2) a more superior location representing a conservative position closer to the treatment field, and (3) the phantom surface in the uterine region.

Figure 1. Anthropomorphic Phantom with ionization chamber setup.

Figure 2. Anthropomorphic phantom with ionization chamber and lead Configuration. This figure includes 1 anterior + 1 posterior lead apron

RESULTS

Reference measurements illustrated in Fig 3. demonstrated that 6 MV and 6 FFF photons along with smaller field sizes produced the lowest out-of-field fetal dose.

For the patient-specific plan, cumulative fetal dose without shielding exceeded 2 cGy at the phantom surface and upper uterine position, while the mid-uterine measurement remained below 2 cGy.

Increasing anterior lead apron shielding produced a stepwise reduction in dose at all measurement locations. With one anterior apron, dose remained above 2 cGy at the upper uterine position (2.035 cGy).

Use of two anterior aprons reduced upper uterine dose below 2 cGy (1.958 cGy), while mid-uterine dose remained below 2 cGy for all configurations.

The lowest measured doses were observed with three anterior aprons, yielding 1.939 cGy at the upper uterine position and 1.722 cGy at the mid-uterine position; surface dose was not measured for this configuration.

Relative to no shielding, anterior lead apron configurations reduced dose by approximately 9% at the upper uterine position and 7% at the mid-uterine position. The addition of posterior lead aprons offered little to not further dose reduction.

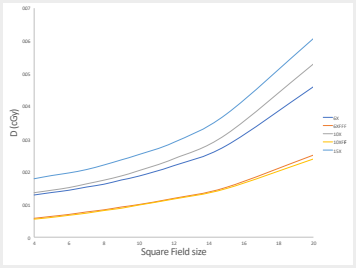

Figure 3. Measured fetal dose (cGy per fraction) as a function of field size for multiple photon beam energies,obtained using an anthropomorphic phantom without shielding. Dose was measured at the mid-uterine position using a solid water insert representing the fetal volume.

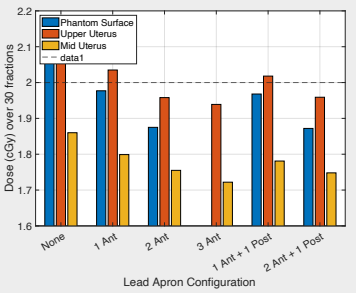

Figure 4. Cumulative fetal dose (cGy) over 30 fractions as a function of lead apron configuration.

Conclusion

Lead apron shielding effectively reduced fetal dose during intracranial radiotherapy.

Combined anterior and posterior apron configurations provided no meaningful additional dose reduction compared with anterior shielding alone.

Lower beam energy and reduced field size further minimizes fetal dose and should be considered during treatment planning for pregnant patients.

This study showed that for clinics without access to custom designed lead shields for pregnant patients: the use of readily available x-ray lead aprons can be an effective tool used for fetal dose reduction.

REFERENCES

1. Smeets, G.M., Vogt, I., Wolters, H. *et al.* Analysis of fetal dose exposure by modern radiation therapy in pregnant patients with supradiaphragmatic Hodgkin lymphoma—a phantom-based simulation. *Strahlenther Onkol* **201**, 1279–1288 (2025).