Unique Considerations When Delivering Radiation Therapy Treatment to a Pregnant Patient: Inadvisable Delivery of Noncoplanar Beams

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BACKGROUND

Radiotherapy treatments of pregnant patients should be avoided whenever possible, but there are rare cases where the targeted cancer is so aggressive or otherwise life-threatening that radiotherapy becomes a justifiable necessity [1,2]. The brain and head-and-neck regions are common sites for these urgent and unavoidable treatments [1].

With reductions in the number of MU required to deliver VMAT treatments compared to IMRT or wedged treatments, and the increasing availability of flattening-filter-free (FFF) beams which avoid flattening-filter scatter, it is becoming common to deliver cranial radiotherapy treatments to pregnant patients using a VMAT technique [3,4]. For cranial radiotherapy, the conformity already achievable using the VMAT technique can be enhanced (while spreading and minimising the low-dose bath to the healthy brain) by adding non-coplanar beams to the treatment plan [5].

Non-coplanar beams through the patient in the superior-inferior direction from ≈90° couch angles, while common in cranial VMAT, are clearly unacceptable for treating pregnant patients. However, evaluation of potential effects of smaller couch rotations, including beams though the patient in the inferior-superior direction remains crucial.

This study provides an example of the effect on estimated foetal dose from delivering part of a pregnant cranial radiotherapy patient's treatment using noncoplanar VMAT arcs, even when those beams are oriented towards the superior direction.

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INTRODUCTION

A 23.3 Gy 10 fraction cranial radiotherapy boost treatment was planned for a pregnant patient, with two of four FFF VMAT arcs to be delivered with a 45-degree couch (aka. table/floor) rotation that oriented the beam from the inferior towards the superior direction. These noncoplanar beams brought the linac head closer to the patient's body, raising concerns about incident head leakage [8]. Phantom measurements were performed to obtain a foetal dose estimate after the first treatment fraction, leading to immediate replanning of the treatment using two coplanar FFF VMAT arcs only. The new coplanar treatment was used for all subsequent fractions.

METHODS AND MATERIALS

The systematic investigation was undertaken using test beams: Head, neck and thorax sections of an Alderson RANDO phantom (1974 model) were set up with slabs of water-equivalent plastic positioned to allow calibrated ionisation chamber measurements 50 cm inferior of isocentre. A static 6 MV FFF radiation beam with geometry derived from average cranial VMAT beam characteristics (3x3 cm^2 MLC aperture inside 6x6 cm^2 jaw field, identified using Crowe et al's TADA software [6]) was directed to a hypothetical cranial target from various gantry and couch angles. Three collimator angles were tested at each gantry angle. All irradiations used a Varian Edge linac – usually optimal for cranial VMAT but with a reduced MLC bank width compared to Varian TrueBeam.

The case study measurements were completed using clinical treatment plans: Based on the patient geometry, the RANDO phantom was again combined with water-equivalent plastic blocks and positioned to allow calibrated ionisation chambers to be placed on the surface and at 10 cm depth (as in previous work [7]), 47 cm from the inferior edge of the treatment target, to obtain estimates of the foetal dose and the expected in vivo surface dose from each treatment plan.

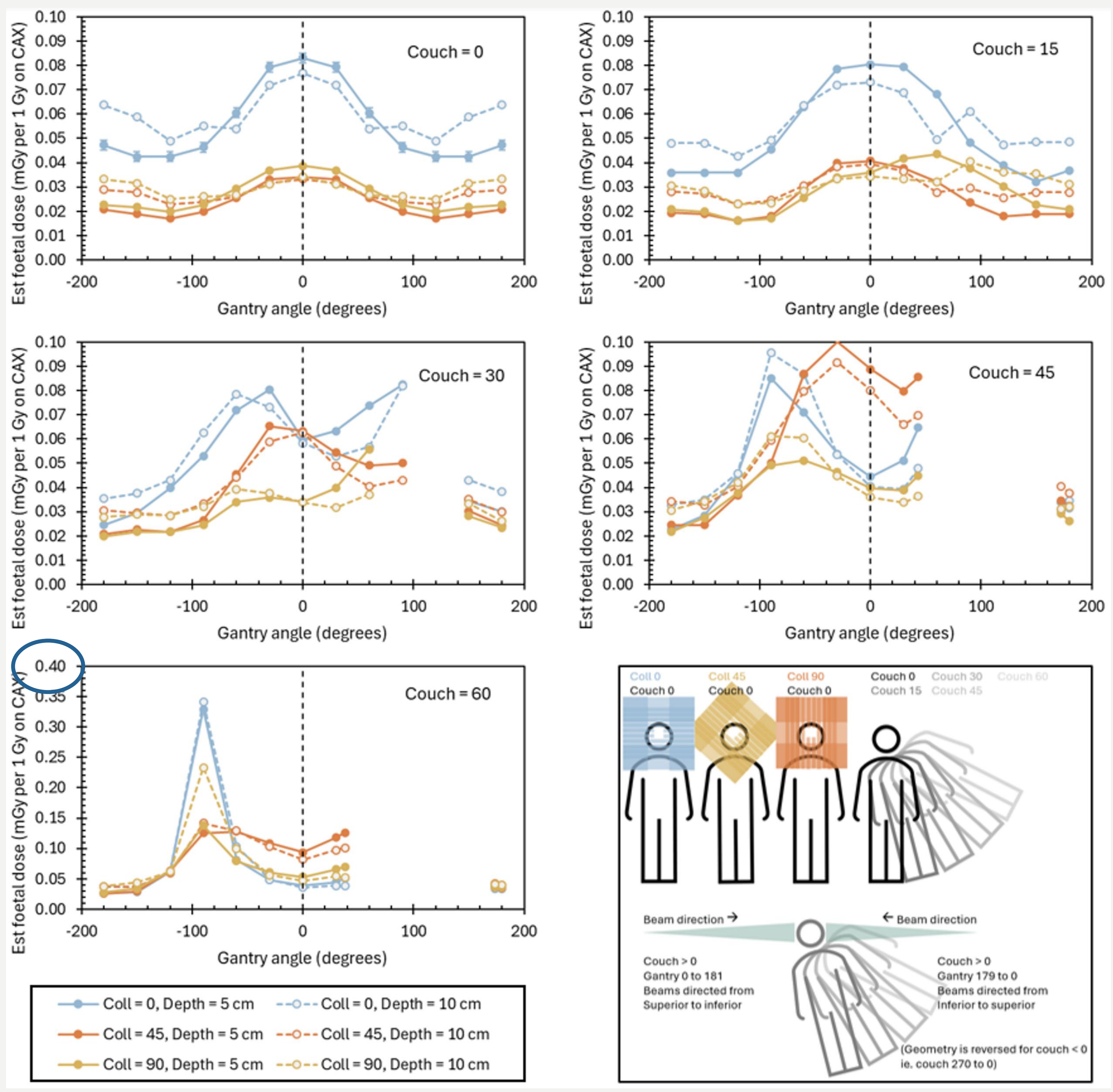

Figure 1. Out-of-field results relative to central axis (CAX) for test beams including measurements at 5 and 10 cm depth, and diagram (not to scale) of measurement geometry. Note:
- "Couch angle" is the term used here to refer to the angle sometimes called "table angle" or "floor angle" elsewhere.
- All angles listed in the figure above (gantry, collimator, couch) are given in degrees(°).
- The depths listed above are measured relative to the anterior surface of the phantom, and obviously vary with gantry angle if considered in relation to the incident beam.
- Gaps in data for 30, 45 and 60° couch rotations resulted from insufficient gantry clearance to permit measurement.
- Results for the 60° couch rotation are plotted on a courser scale (circled) due to substantially increased out-of-field dose from this arrangement.

Table 1. Case study treatment plan features and results: Measured dose values are for the whole 10 fraction treatment, "surface" dose was measured (on phantom and *in vivo*) beneath a 2 cm bolus sheet to filter low-energy component from anterior arc sections and thereby provide a consistent ratio for estimating foetal dose from *in vivo* surface measurements.

Treatment plan	Gantry angle range	Couch angle	Monitor Units	Foetal dose (mSv)	Surface dose (mSv)
Initial plan, 1st arc	181-179° (358°)	0°	339	1.6	1.8
Initial plan, 2nd arc	179-181° (358°)	0°	338	1.6	1.8
Initial plan, 3rd arc	181-0° (179°)	45°	147	1.6	2.1
Initial plan, 4th arc	120-179° (59°)	315°	41	0.5	0.6
Total				**5.3**	**6.4**
Replan, 1st arc	181-179° (358°)	0°	421	2.2	2.4
Replan, 2nd arc	179-181° (358°)	0°	378	1.8	1.9
Total				**3.9**	**4.5**
Replan *in vivo*				**3.6 (est)**	**4.0**

RESULTS – TEST BEAMS

Generally, beams that were directed into the phantom from the superior towards the inferior due to the rotated couch showed a trend of increasing dose to the foetal region with increasing couch angle, a clear effect of internal patient scatter [2,7].

Beams directed in the opposite direction also showed increasing dose to the foetal region with increasing couch angle, with leakage dose increasing dramatically as the linac head moved closer to the phantom [8].

For non-coplanar beams, the inherent shielding provided by the HD-MLC and orthogonal jaws varied substantially with couch rotation.

RESULTS – CASE STUDY

The coplanar method produced a clinically acceptable treatment plan while achieving substantial reductions in measured dose at the approximate foetal location (19.4% at surface and 29.3% at depth), compared to the noncoplanar treatment plan.

The measured foetal dose estimate of 3.9 mSv for the noncoplanar boost treatment enabled a conservative estimate of 10 mSv to be provided to the radiation oncologist, for risk communication to the patient.

CONCLUSIONS

There is an obvious logic in avoiding noncoplanar beams oriented towards the inferior direction (ie. towards the foetus) in the rare cases when cranial radiotherapy treatments of pregnant patients are justified. The results of this unusual case study highlight the additional disadvantages of orienting noncoplanar beams towards the superior direction.

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