Assessing Patient Motion In Spine SBRT: Implications for VMAT Planning and Margin Selection

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Motivation

- In spine SBRT, small changes in position can lead to significant deviations in the delivered dose to the tumour and nearby healthy tissues
- It is suggested [1] that patients receiving these treatments be treated in a near rigid, full body immobilization system such as the Elekta BodyFIX with an actively evacuated top sheet (wrap) as shown in Figure 1a
- Such systems can be time consuming to setup, more costly and more uncomfortable for patients compared to other less rigid systems such as body cushions alone (no wrap) and thermoplastic masks (Figure 1b and c)
- On VMAT with only pre- or mid-treatment imaging, the treatment delivery time is short (~15 minutes) but the setup of the BodyFIX with wrap increases the overall treatment time
- The impact of using less rigid immobilization systems on VMAT where only a single mid-treatment CBCT is used to monitor patient position is unknown

INTRODUCTION

Figure 1: (a) the BodyFIX immobilization system with evacuated top sheet (wrap) (b) cushion without wrap and (c) U-frame thermoplastic head mask

Aim

- Determine if less rigid immobilization systems (BodyFIX without wrap and U-frame thermoplastic mask) provide equivalent immobilization to the BodyFIX with wrap under the conditions of a VMAT treatment
- Estimate the PTV margins required for each immobilization system to ensure that the target volume receives the prescribed dose
- Inform the need for near-rigid immobilization for spine SBRT to support more efficient resource use and increase patient capacity to accommodate an expected increase in treatments [2]

METHODS

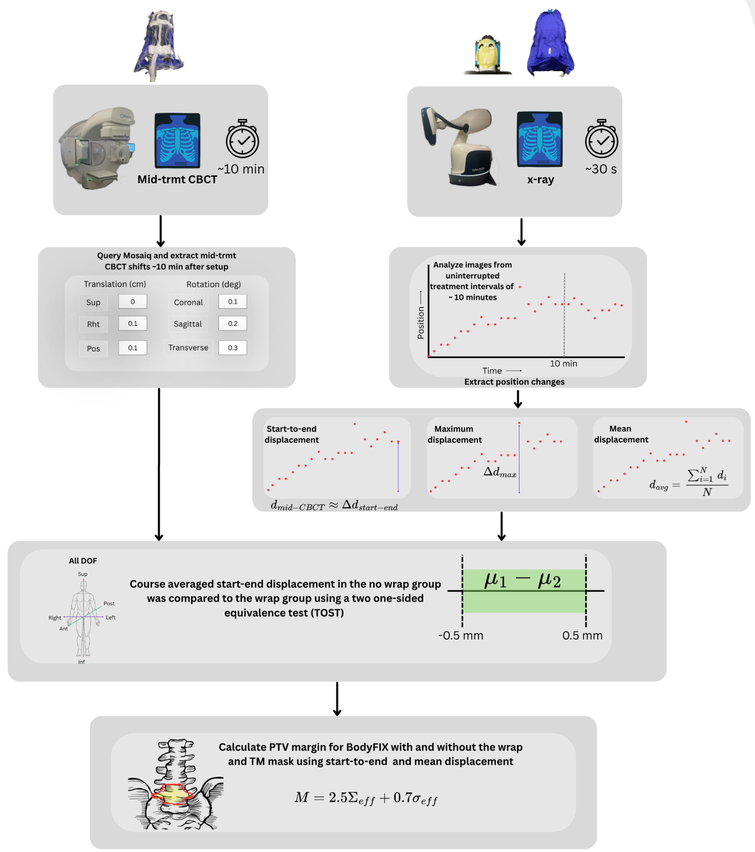

Figure 2: Summary of intrafraction motion analysis. Mid-trmt CBCT data was collected from VMAT treatments and for CK treatments, motion from 10-minute treatment intervals were analyzed to emulate what would occur during a conventional delivery. A two one-sided test (TOST) was used to compare the motion from the different immobilization groups, and PTV margins were calculated using a modified Van Herk formula which ensures that 95% of the target volume is covered by the prescribed dose in 90% of the patient population.

- Margins were estimated using the Van Herk margin formula [3] modified to account for a finite number of fractions [4] as well as incorporation of intra-fraction target motion [5]
- End-to-end errors (typically ≤ 1 mm), which are a measure of geometric accuracy in the treatment planning and delivery system are included in the systematic component, Σ, of the margin calculation

RESULTS

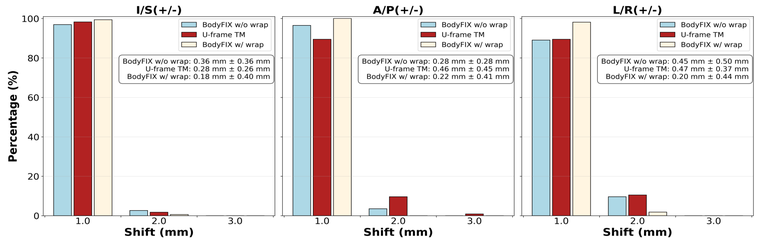

Figure 3: Distribution of the differences in initial and final translations for patients immobilized using the BodyFIX without wrap and U-frame TM compared to mid-treatment CBCT differences for the BodyFIX with wrap group. Mean and standard deviations of the absolute values across the cohort are inset. Both the mask and no wrap shift data were statistically equivalent to the data for the wrap.

- 228 and 114 uninterrupted intervals were extracted from CyberKnife log files for the BodyFIX without wrap group and U-frame mask groups respectively. 163 mid-trmt shifts were collected from VMAT patients immobilized in the BodyFIX with wrap
- Using the TOST test, both the U-frame mask and the BodyFIX without wrap groups were found to be equivalent (p-values ranged from 1.4×10^{-2} to 3.0×10^{-15}) to the shifts determined from mid-treatment CBCT observed for the BodyFIX with wrap group, for each translational DOF

	Margin		
Immobilization	**I/S (mm)**	**L/R(mm)**	**A/P(mm)**
BodyFIX without wrap (n=228)	2.4†, 1.8‡	2.9†, 2.3‡	2.2†, 1.8‡
U-frame Thermoplastic Mask (n=114)	2.0†, 1.7‡	2.6†, 2.0‡	2.8†, 2.2‡
BodyFIX with wrap (n=163)	2.3†	2.4†	2.2†

Margins marked † were calculated using start-to-end interval displacements or mid-treatment CBCT shifts, values marked ‡ were calculated using the more frequent intra-fraction motion data available from CyberKnife.

CONCLUSIONS

- Intrafraction motion for patients immobilized with and without the BodyFIX wrap were statistically equivalent within +- 0.5 mm.
- Mean motion in any translational DOF exceeding 2 mm was rare amongst all groups suggesting that less rigid immobilization may be suitable for VMAT spine SBRT if suitable image guidance and repositioning is performed at approximately 10-minute intervals.
- The margins calculated for the BodyFIX with and without wrap, using the start-end displacement approach 3 mm but assumes patient is shifted the whole treatment which is likely an over-estimate of motion
- Margins using full intra-fraction motion are near the 2 mm margin used currently at our center
- Dose reconstructions including the combined effect of rotations and translations are currently being performed to assess the full impact of intrafraction motion.

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