AI-Based Vertebral Body Auto-Contouring for Secondary Verification of Spine CBCT Registration

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ABSTRACT

Purpose: Automatic intensity-based CBCT registration for initial spine treatment setup is challenging due to the similar appearance of vertebral bodies (VBs), which can lead to misalignment. This study evaluated the feasibility of using AI-based VB auto-contouring as a secondary check to detect and alert clinical teams of potential setup errors.

INTRODUCTION

Innovation/Impact: This study applies a new methodology to support accurate spinal target identification during radiotherapy treatment setup. Rather than relying solely on conventional image intensity-based registration, we evaluate an AI-driven, vertebral body recognition approach to guide alignment in challenging clinical scenarios. This method has the potential to improve robustness in cases where intensity-based algorithms can fail.

METHODS AND MATERIALS

Nineteen spine cases with target VBs between C3 and L2 were retrospectively analyzed. Limbus v1.8 software auto-generated individual VB contours on each patient's helical planning CT (HCT). Contour accuracy was reviewed, and the target VB and/or two adjacent VBs were selected. For each CBCT acquired on an Elekta XVI system, a synthetic CT (sCT) was generated by Elekta Admire software and then further imported into Limbus software for VB auto-contouring. The center of mass (COM) of selected VB ROIs was calculated relative to the treatment isocenter. The difference between COM positions from the HCT and sCT datasets was computed as the table shift for that registration and compared to clinical XVI registrations.

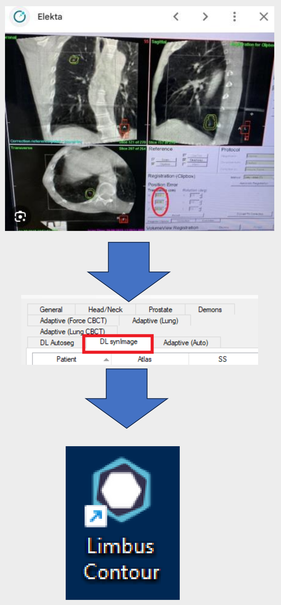

Figure 1. Data Flow

RESULTS

The secondary alignment check took about 2.5 minutes to complete because currently the cbct data need be communicated among three vendors' computers. Four patients were excluded because Limbus software failed to generate VB auto-contours on sCT. For the remaining 15 patients, superior-inferior shift discrepancies were <10 mm, with a mean difference between the clinical shift and the secondary check of −0.7 ± 3.0 mm (range: −1.8 to 7.0 mm). Review of auto-contoured VBs indicated discrepancies were primarily due to uncertainties in generating VB contours on the sCT as shown in figure-2. In three out of the 15 cases, initial shifts showed larger discrepancies(−20.4, 34.7, and 27.7mm in the superior-inferior direction), triggering alerts for clinicians.

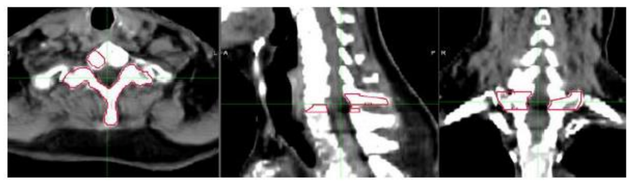

Figure 2. An Example of AI-generated auto-contour of vertebral bone C6 on sCT

DISCUSSION

1.Limitation of Intensity-Based Image Registration

Current vendor alignment tools rely on intensity-based registration algorithms. Because adjacent vertebrae share similar bony anatomy, these methods are vulnerable to single-vertebra misalignment, particularly when large initial setup errors are present.

In three cases with substantial initial misalignment, we exported the reference planning HCT and treatment CBCT to an independent, widely used system (MIM Software) for comparison. MIM produced similar vertebral misalignments, indicating that this issue is algorithmic and not vendor-specific. These findings underscore a systematic limitation inherent to intensity-driven registration methods.

DISCUSSION (cont.)

In contrast, AI-based auto-contouring methods explicitly identify individual vertebral bodies, offering a fundamentally different—and potentially more reliable—approach for guiding clinicians toward the correct anatomical alignment.

2.Evaluation of the Robustness of AI-based Alignment Approach

The proposed AI-assisted secondary check showed good agreement with the clinical intensity-based registration, even when the AI algorithm exhibited minor uncertainties in auto-contouring individual vertebral bodies on the synthetic CT. Because Limbus software trains its AI model on HCT data, contour accuracy on sCT may be reduced. In some cases, contours for a single vertebra extended slightly into adjacent levels (Figure 2).

To mitigate this uncertainty, incorporating two neighboring vertebral bodies into the shift-calculation algorithm significantly improved the stability of the final positional correction. This demonstrates that the AI-based method remains robust when appropriate multi-level anatomical context is included.

CONCLUSIONS

AI-based VB auto-contouring on HCT and sCT is a feasible method for detecting potential spine mis-registrations. Based on auto-contouring uncertainties on sCT, a 10mm table shift discrepancy threshold appears appropriate for flagging possible spine misalignment.

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