MRI-Only 3D Spine Reconstruction with Artificial Intelligence

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INTRODUCTION

MRI is preferred for paediatric spine imaging due to its radiation-free nature and strong soft-tissue visualisation, making it ideal for Adolescent Idiopathic Scoliosis (AIS) imaging.

Limitation — Routine clinical MRI lacks the 3D resolution needed for accurate vertebral (bony) reconstruction.

Clinical need — High-quality 3D spine models are increasingly essential for deformity assessment, surgical planning and navigation.

Key challenge — Large, labelled 3D MRI datasets for scoliosis do not exist due to the time-intensive nature of manual vertebral segmentation.

Opportunity — Historical CT datasets contain highly detailed labelled vertebrae but cannot be directly used due to CT–MRI domain differences.

Our solution — Develop an AI framework that converts CT into MRI-like "pseudo-MRI" while preserving accurate vertebral anatomy.

Innovation — Enables reuse of existing CT labels to train MRI-based segmentation models despite cross-modality differences.

OBJECTIVE

To implement an AI-driven, MRI-only 3D spine reconstruction tool that improves clinical decision-making and supports radiation-free, more patient-centred surgical planning and surgical navigation for AIS.

OUTCOMES

AI-generated "synthetic MRI" accurately reproduced thoracolumbar bone detail without paired thoracolumbar MRI information.

Improved segmentation accuracy (Dice score 87.34% vs 86.1%) with the synthetic MRI dataset compared to an existing research dataset of thoracic-only 3D MRI model.

Achieved full thoracolumbar 3D spine reconstruction without CT scans, supporting scalable and radiation-free 3D spinal evaluation for AIS.

Provides clinicians, including in regional and rural centres, with clearer, more accessible 3D models for planning AIS surgery, for surgical navigation, and integration into spinal navigation robots, all of which currently rely on CT.

METHODS & RESULTS

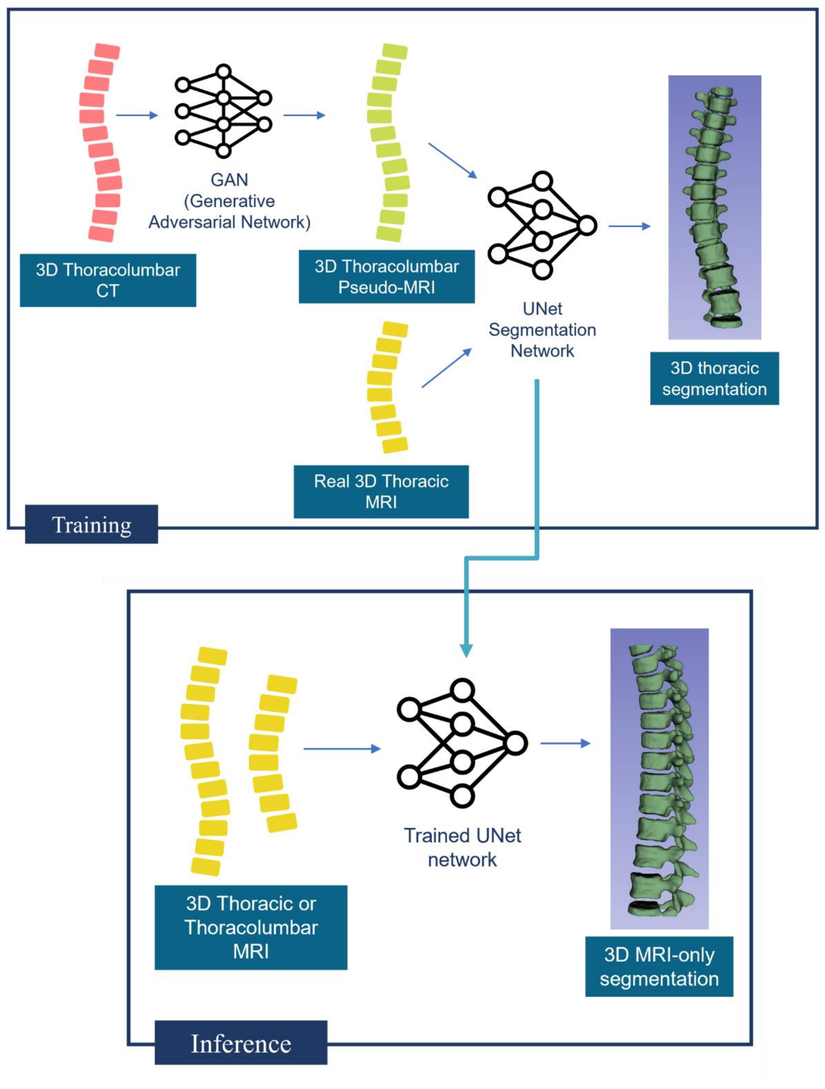
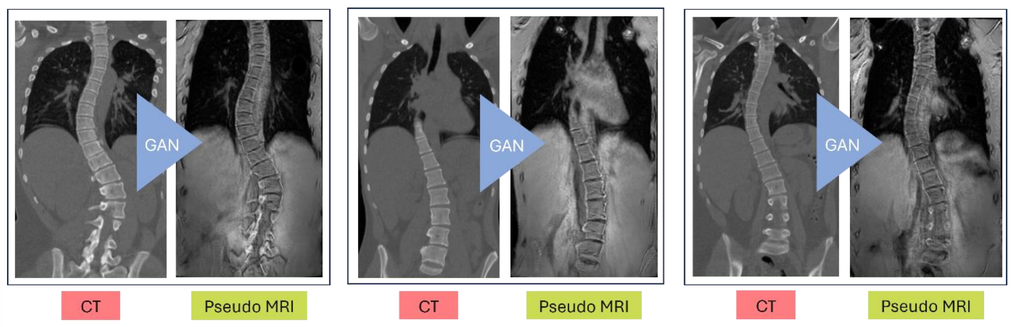


Figure 1: Overview of the proposed AI framework for MRI based spine segmentation.

Figure 2: Example coronal CT images of AIS spines and their corresponding pseudo-MRI translations



CT → pseudo-MRI generation: Trained a GAN to convert labelled thoracolumbar CT scans (T1–L5) into MRI-like volumes while preserving vertebral anatomy.

Unpaired MRI guidance: Used an existing research dataset of thoracic-only 3D MRI data to guide GAN training for realistic MRI contrast and soft-tissue appearance.

Dataset creation: Produced a full thoracolumbar pseudo-MRI dataset with accurate CT-derived vertebral labels.

Data fusion: Combined pseudo-MRI (full spine coverage) with existing dataset of real thoracic-only 3D MRI (authentic MRI signal and deformity patterns).

Segmentation model: Trained a U-Net–based deep learning (AI) algorithm for full thoracolumbar MRI-only bony segmentation in adolescent idiopathic scoliosis.

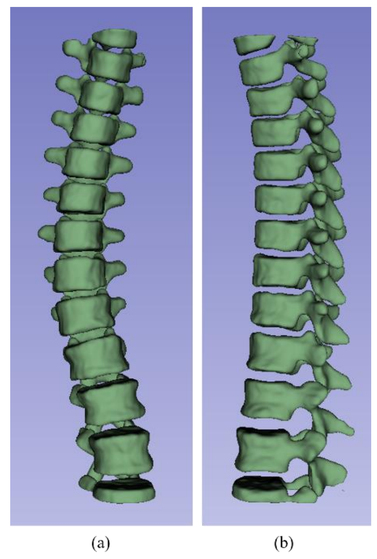


Figure 3: An example of the (a) coronal, and (b) sagittal views of the thoracic region of an AIS spine segmented and reconstructed in 3D using the enhanced AI segmentation model

Synthetic MRI-enhanced algorithm vs thoracic-MRI-only algorithm

Improved segmentation accuracy (Dice score 87.34% vs 86.1%)

drastically reduced processing time (~1 hour vs <1 minute)

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