Exploring LET Prediction with Multimodal Deep Learning

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OBJECTIVE

The decision to perform lateral extra-articular tenodesis (LET) in addition to anterior cruciate ligament (ACL) reconstruction is lacks objective reasons [1]. Current risk assessment includes anatomical and clinical factors which demonstrate poor reliability [2]. This study aimed to develop an AI-based approach to understand LET decision-making patterns and identify anatomical features that influence surgical choices beyond conventional risk factors.

METHODS

A retrospective dataset of 191 knee MRI scans from patients undergoing ACL reconstruction was analysed. Femur and Tibia were segmented from T1 scans using nnUnet [3] and converted to point clouds with 4096 points on the contours (Fig. 1).

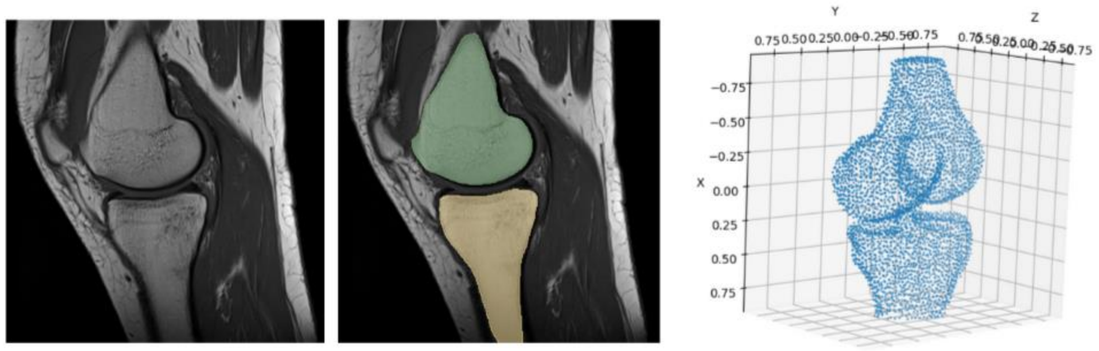

Fig. 1: Automatic bone segmentation and point cloud generation.

The model combined three volumetric MRI sequences with 3D bone morphology represented as point clouds. Multi-head attention mechanisms fused volumetric features (Fig. 2). The architecture was trained to predict the actual LET surgical decisions, gender and posterior tibial slope (PTS) classification. Integrated gradients [4] were used to interpret the model's decisions.

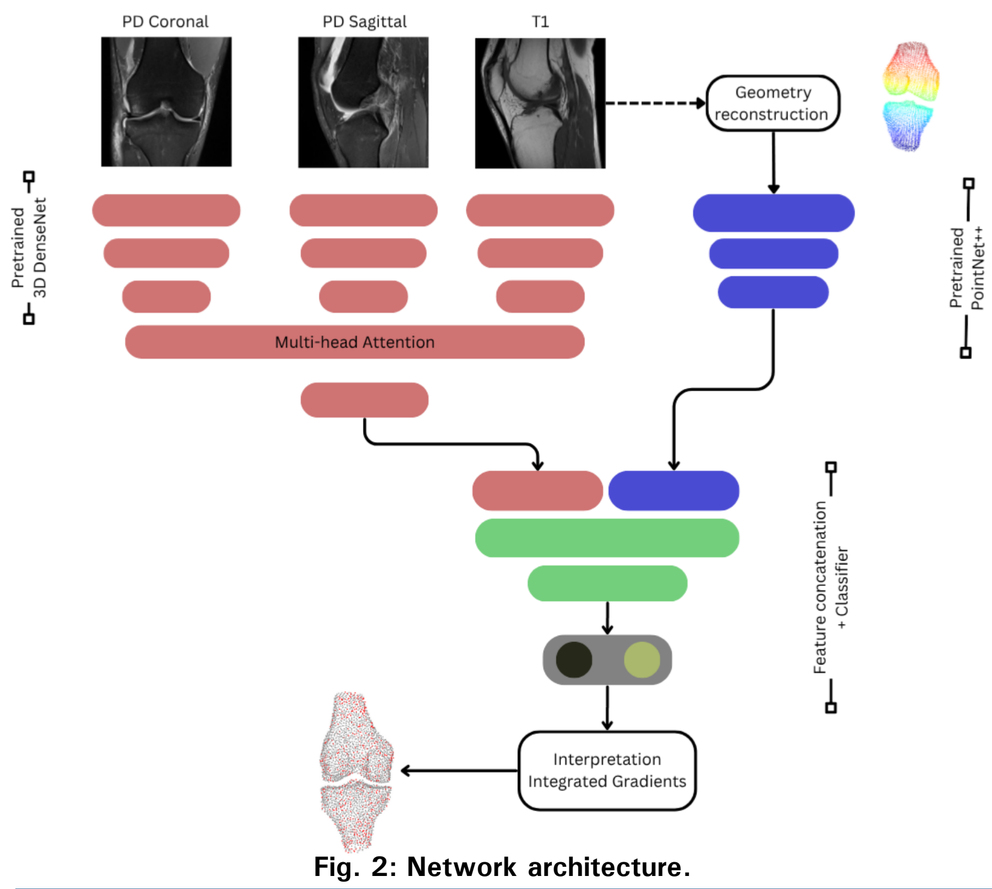

Fig. 2: Network architecture.

RESULTS

Poor performance on LET decision prediction (Fig. 3), suggested limited ability of MRI-based anatomical features alone to explain clinical decision-making (Fig. 3). In contrast, the model showed high performance in sex classification and moderate success in binary PTS classification (Table 1). Attribution analysis highlighted point clouds and T1-weighted sequences as the most influential inputs. Interpretability methods revealed anatomically plausible activation for sex classification [5] (Fig. 4), but inconsistent patterns for clinical decision prediction [6].

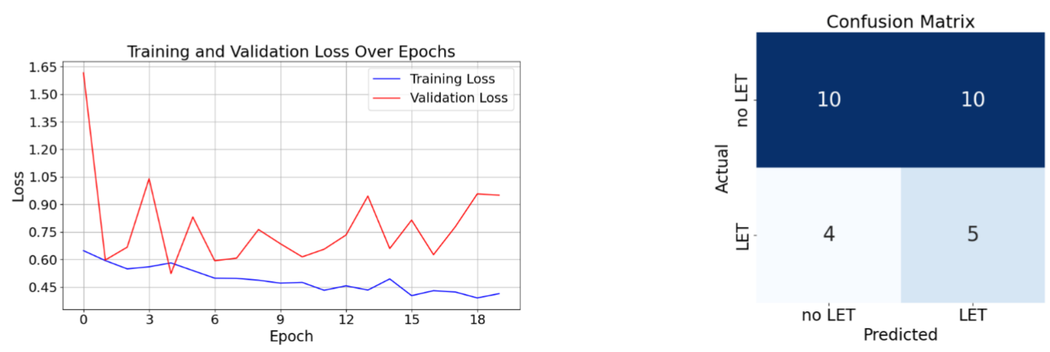

Fig. 3: Training history and confusion matrix for LET classification

Model	LET			Sex			Slope > 12°		
	Acc (%)	Pre (%)	Rec (%)	Acc (%)	Pre (%)	Rec (%)	Acc (%)	Pre (%)	Rec (%)
Multimodal model	51.7	33.3	55.6	**89.6**	**94.1**	**91.0**	**65.5**	**58.3**	58.3
Pointnet++	–	–	–	86.2	88.8	88.8	59.1	53.2	62.1
DenseNet3D	–	–	–	51.5	83.8	57.9	31.5	34.9	**75.1**

Table 1: Performance metrics for different models across classification targets on the test set. For precision and recall calculation the classes Sex–male and the risk classes Slope < 12◦, LET were evaluated.

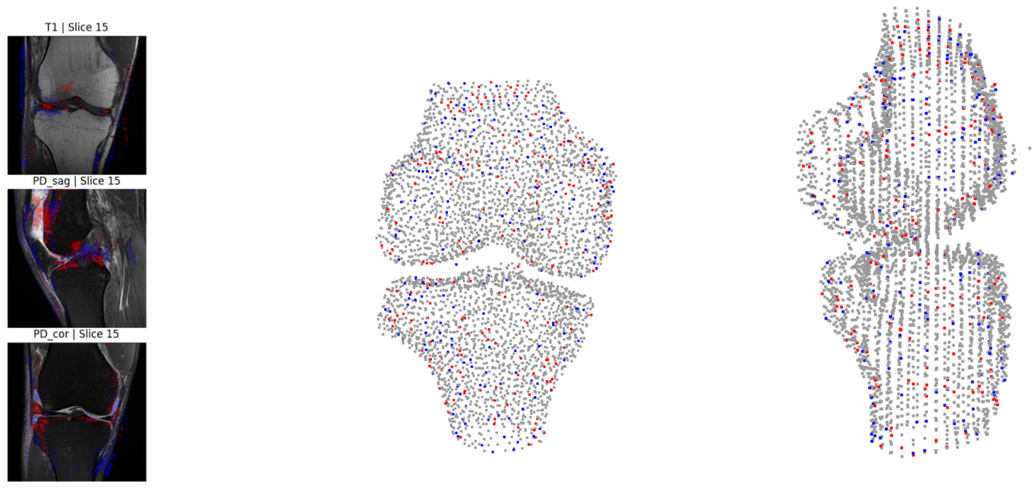

Fig. 4: Attribution scores overlaid on the point cloud for sex prediction. Red regions indicate evidence supporting the "male" class, while blue regions support the "female"class. This sample was labeled as male.

CONCLUSION

These findings suggest that while deep learning models can capture morphological variation in knee anatomy, surgical decisions regarding LET are mostly influenced by additional clinical, functional, and contextual factors not present in static MRI. Future studies should incorporate larger datasets, detailed clinical information, and objective outcomes such as rerupture rates to improve predictive performance and clinical relevance.

References: [1] D. C. Lewis et al., "Age and surgical volume impact likelihood and technique of lateral extra-articular augmentation during primary anterior cruciate ligament reconstruction," 2023[2] J. Zabrzynski et al., "Indications for lateral extra-articular tenodesis in anterior cruciate ligament reconstruction: A systematic review," The American Journal of Sports Medicine, Feb. 2025. [3] F. Isensee et al., "nnu-net: a self-configuring method for deep learning-based biomedical image segmentation," 2020. [4] M. Sundararajan et al.,"Axiomatic attribution for deep networks," 2017 [5] S. Conley et al., "The female knee: Anatomic variations," 2007. [6] S. Yao et al., "Enhanced reliability and time efficiency of deep learning-based posterior tibial slope measurement over manual techniques," 2024.