Automatic Acetabular Fracture Classification from CT using Deep Learning Techniques

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Introduction

Acetabular fractures (AFs) are rare and complex injuries, making their diagnosis challenging for clinicians. Diagnosis typically relies on the Letournel and Judet classification system, which is based on plain radiographs [1]. While this system has been the reference standard for decades, it is limited by low inter- and intra-observer reliability, a steep learning curve, and fails to account for increasingly heterogeneous fracture patterns emerging from changes in trauma mechanisms, and patient demographics. Recent studies have shown the feasibility of deep learning for hip and acetabular fracture detection, primarly using radiographs or 2D CT projections. However, most models address only binary classification, and true 3D multiclass approaches remain limited due to data and computational constraints. This study explores the potential of 3D deep learning for automated multiclass AF classification using CT scans, with the goal of improving diagnostic consistency, reducing inter-observer variability, and accelerating surgical decision-making.

Materials and Methods

This study investigates whether a 3D CNN trained on CT data will achieve diagnostic accuracy and inter-observer agreement comparable to or exceeding that of less experienced surgeons. To evaluate this, we leverage Med3D [2], a family of pre-trained 3D ResNet models trained on 3D medical datasets. By using transfer learning and data augmentation techniques, a multi-class model focused on three of the most common fracture types: ABC, AC, and ACPHT, was developed.

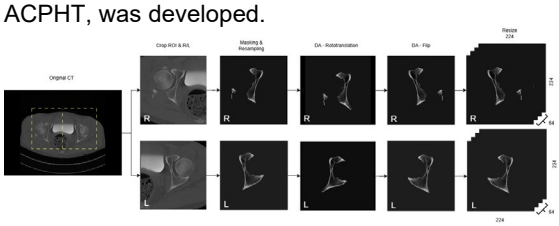

Fig. 1 Data preprocessing pipeline included cropping of ROI and R&L hips, masking, resampling, augmentations: rototranslations and flips, and finally resizing.

This study used 183 CT scans with confirmed AF collected from Inselspital (KEK, 2022-00213). Careful data preprocessing and augmentation were applied (see Figure 1). Labeling was performed independently by two orthopedic surgeons, with the annotations from the more experienced surgeon considered as the ground truth.

Results

The model achieved an overall accuracy of 78%, comparable to the 81% accuracy obtained by the less experienced surgeon. Inter-observer reliability, assessed using Cohen's kappa, indicated a moderate level of agreement between the AI model and the experienced surgeon ($\kappa = 0.64$) and lower agreement with the less experienced surgeon ($\kappa = 0.51$). In addition, Grad-CAM visualizations revealed that the model focused on regions surrounding the acetabular dome and column structures, where fracture lines are most apparent.

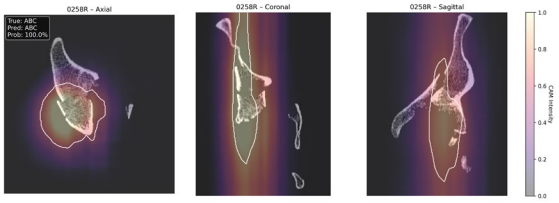

Fig. 2 Grad-CAM visualization showing model attention across the axial, coronal, and sagittal planes. The white contour outlines the top 10% CAM intensity. Text box reports ground truth, model prediction, and predicted probability.

Discussion

This work demonstrates that 3D convolutional neural networks pre-trained on medical imaging datasets can be effectively adapted for the classification of acetabular fractures using CT data. The results confirm that the exploitation of full 3D spatial information from CT volumes, together with transfer learning and realistic data augmentation, contributes meaningfully to model learning and interpretability. Moreover, AI could assist in the consistent classification of acetabular fractures and support future data-driven updates to classification systems as new fracture patterns are recognized. Future work will extend the dataset and compare 3D with 2D models based on synthetic radiographs.

References

[1] R. Judet, J. Judet, and E. Letournel, "Fractures of the acetabulum: classification and surgical approaches for open reduction: preliminary report," JBJS, vol. 46, no. 8, pp. 1615–1675, 1964.
[2] S. Chen, K. Ma, and Y. Zheng, "Med3d: Transfer learning for 3d medical image analysis," arXiv preprint arXiv:1904.00625, 2019.

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