# Seeing the Unseen: Deep Learning for Diagnosis of Tarsal Coalition

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INTRODUCTION:

Tarsal coalition is a rare congenital disease that most commonly manifests during adolescence and early adulthood, presenting with nonspecific symptoms such as chronic ankle pain, stiffness, or repeated sprains. These subtle clinical signs often delay diagnosis. Radiographic detection is difficult due to overlapping bones—particularly the calcaneus, talus, and navicular—which obscure key features. As a result, the disease is frequently overlooked, especially by non-specialists.

While CT and MRI offer greater diagnostic precision, they are constrained by cost, radiation exposure, and limited accessibility. In contrast, standard lateral ankle radiographs are inexpensive and widely available but require expert interpretation, which may not be present in general or emergency settings. This creates a diagnostic gap where coalition often goes unrecognized at the point of care.

Artificial intelligence (AI) offers an opportunity to support radiographic interpretation in clinical settings, particularly where expert evaluation is unavailable. Its ability to detect subtle, overlooked patterns may help address diagnostic challenges associated with tarsal coalition.

In this study, we specifically focused on talocalcaneal coalition, a common subtype of tarsal coalition, due to its distinct radiographic characteristics. Leveraging this capability, we developed a deep learning model to detect talocalcaneal coalition using only standard radiographs. Our aim was to provide a practical, scalable screening tool to support early recognition and timely referral without relying on advanced imaging or subspecialty expertise.

METHODS:

We retrospectively collected 368 lateral ankle radiographs from multiple institutions, including 50 cases of talocalcaneal coalition and 318 cases without coalition. To reflect clinical variability, radiographs obtained under both weight-bearing and non-weight-bearing conditions were included without distinction. Labeling was performed based on expert interpretation by an orthopedic surgeon.

The dataset was randomly divided into training (90%) and validation (10%) sets. A deep learning model was constructed using ResNet, a convolutional neural network with residual connections that enable stable training of deep architectures. Attention mechanisms were integrated to focus on anatomically relevant features.

As part of standard preprocessing, contrast adjustment was applied to normalize brightness and enhance clarity, and geometric augmentations such as flipping and rotation were used to simulate anatomical variability and improve model robustness and generalizability.

The model was trained to perform binary classification (coalition-positive vs. coalition-negative). Diagnostic performance was evaluated using sensitivity, specificity, accuracy, area under the receiver operating characteristic curve (AUC), F1-score, positive predictive value (PPV), and negative predictive value (NPV). Score-CAM was used to visualize and confirm the image regions contributing to the model's diagnostic decisions.

RESULTS:

The AI model achieved strong diagnostic performance on the validation set: sensitivity 1.00, specificity 0.84, accuracy 0.89, AUC 0.93, F1-score 0.84, PPV 0.72, and NPV 1.00. (Figure 1.) Score-CAM visualization confirmed that the model consistently focused on radiographic features characteristic of tarsal coalition, including the C-sign.(Figure 2.)

A board-certified orthopedic surgeon independently reviewed a subset of radiographs from the validation set. On this subset, the AI achieved sensitivity 1.00, and specificity 1.00, while the surgeon's performance showed a sensitivity of 0.75 and specificity of 1.00. This direct comparison suggests the model's potential to assist in reducing missed diagnoses in coalition cases, especially those with subtle or overlapping radiographic features.

DISCUSSION AND CONCLUSION:

This study demonstrates that deep learning can be effectively applied to lateral ankle radiographs to identify talocalcaneal coalition with high diagnostic accuracy. The model outperformed a orthopedic surgeon in detecting coalition cases under controlled conditions, showing particular promise in subtle or ambiguous cases.

Unlike CT or MRI, which offer high precision but are limited by cost and radiation, this model relies solely on widely available radiographs, making it well-suited for screening in general or emergency outpatient settings where advanced imaging may not be accessible.

While not intended as a replacement for clinical judgment, Score-CAM visualizations supported the plausibility of the model's predictions by confirming focus on clinically relevant diagnostic features, especially the C-sign.

In conclusion, this AI-based diagnostic support tool shows strong potential as a practical screening aid for talocalcaneal coalition. By facilitating earlier recognition and reducing diagnostic oversight, particularly among non-specialist clinicians, it may contribute to more efficient and accessible orthopedic evaluation. Future research should focus on expanding the dataset and validating the model across multiple institutions to further assess generalizability and clinical readiness.

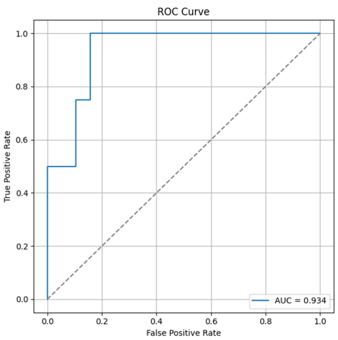
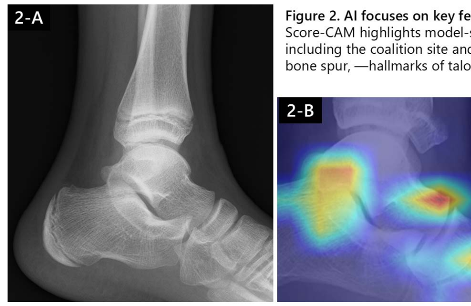



**Figure 1.**
**Diagnostic ROC curve of the AI model**

ROC curve showing the model's performance in detecting talocalcaneal coalition.

The model achieved sensitivity of 1.00, specificity of 0.84, accuracy of 0.89, and AUC of 0.93.

**Figure 2. AI focuses on key features**
Score-CAM highlights model-selected regions, including the coalition site and talonavicular bone spur, —hallmarks of talocalcaneal coalition.




2-A:
Original image
2-B:
Score-CAM image