Determining the Mechanical Axis of the Femur from a Standard Anteroposterior Knee Radiograph with Deep Learning

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INTRODUCTION:

Several important knee alignment measurements, including the lateral distal femoral angle (LDFA) and the hip-knee-ankle angle (HKAA), rely on localization of the center of the femoral head to assess the mechanical axis of the femur. As the femoral head is not visible on a standard anteroposterior (AP) knee view, surgeons looking to assess alignment on a patient with only an AP view must either: (i) forgo the measurement, (ii) use the less-meaningful anatomic axis, or (iii) use crude heuristics. The purpose of this study was to develop a deep learning (DL) model for predicting the correction factor between the anatomic and mechanical axis, thus unlocking long-leg image alignment measurements for AP views.

METHODS:

Data: In this single-center retrospective DL analysis, we queried our institutional image registry for patients with both a bilateral AP knee and a long leg radiograph taken within 90 days of each other (accounting for operative dates to ensure consistency of measurements). This resulted in 15,621 image pairs. We used two validated DL algorithms to measure the mechanical axis of each femur on the long-leg view and the corresponding anatomic axis from the AP view. The correction factor was defined as the difference between the two axes.

Modeling: The dataset was split into training, validation, and testing sets in a 80:10:10 ratio. Then we trained a deep learning regression model to predict the correction factor based on the AP image alone (Figure 1). We compared the mean absolute error (MAE) of our DL model against two other approaches: 1) an existing published heuristic of adding 6 degrees, and 2) an ordinary least squares regression predicting the mechanical axis from the anatomic axis.

RESULTS:

The calculators from which the mechanical and anatomic axes were derived calculate the HKAA and anatomic tibiofemoral angle to an average error of 0.7° and 1.2°, respectively. The DL approach to predicting the correction factor between anatomic and mechanical axes resulted in a MAE of 1.1° (SD: 0.8°). The ordinary least squares approach resulted in a MAE of 1.4° (SD: 1.2°), while the heuristic approach resulted in a MAE of 2.1° (SD: 1.6°). The model processes 100 images in 15 seconds.

DISCUSSION AND CONCLUSION:

We developed a DL model to predict the mechanical axis of the femur from a single AP-view radiograph. The DL model was accurate to within 1° and performed the best out of the three attempted solutions, with not only the lowest MAE but also the lowest SD of errors. This is due to the model's ability to personalize the prediction to a patient's anatomy. This model potentiates the calculation of long-leg derived measurements for new and existing AP view images with multiple research and clinical implications.
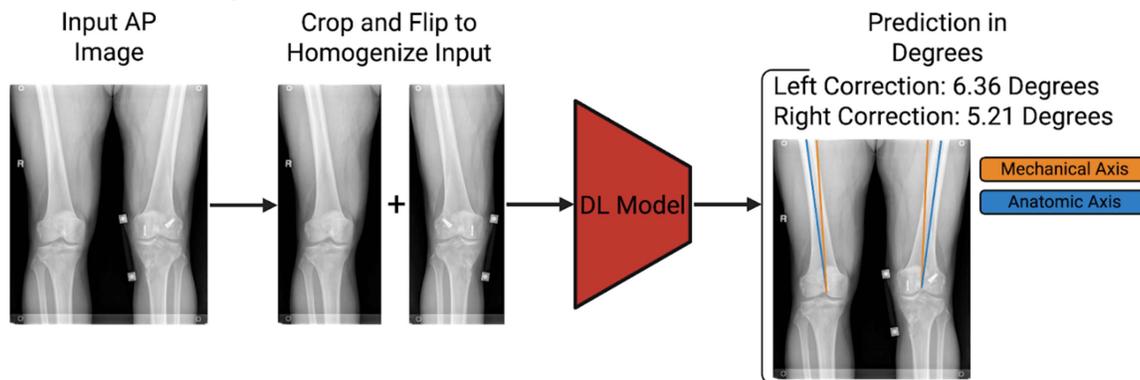

Figure 1: Diagram showing the standard operation of the deep learning model. In order to facilitate training, bilateral images were halved and mirrored so that the model only has to predict correction factors in one direction.