Prediction of Coronal Alignment in Robotic-Assisted Total Knee Arthroplasty with Artificial Intelligence

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INTRODUCTION:

Robotic-assisted technologies provide the ability to avoid soft tissue release in a majority of cases utilizing more accurate bony cuts during total knee arthroplasty (TKA). However, the ideal limb alignment is not yet established. The aim of this study was to predict postoperative Coronal Plane Alignment of the Knee (CPAK) using corresponding native bony measurements.

METHODS:

This study analyzed a retrospective cohort of 530 primary robotic-assisted TKAs (Mako, Stryker) performed from November 2022 to December 2023. Medial proximal tibial angle (MPTA) and lateral distal femoral angle (LDFA) measurements were determined from the robotic system. We utilized machine learning to predict appropriate target LDFA and MPTA values from preoperative LDFA and MPTA measurements. In the preprocessing stage, the dataset was split into input and target sets using the preoperative and planned LDFA and MPTA values, then split again into testing, training, and validation sets of sizes 30%, 66.5%, and 3.5%, respectively. Normalization of LDFA and MPTA alignments was performed using the min-max scaler operation on the training set with feature range [-1, 1] and repeated separately for the input and target distributions. A neural network of hidden dimensions (16, 8, 4) (Figure 1) was trained via supervised learning to predict planned LDFA and MPTA values from preoperative LDFA and MPTA measurements.

RESULTS:

The model converged after 104 epochs and batch size 4 (Figure 2) with mean squared error ±1.82°. The model's regression agrees with the hypothesized change in preoperative to planned coronal alignment: valgus measurements (x-axis, right) are translated to neutral/aligned targets (y-axis, middle) while varus alignments (x-axis, left) are translated to varus alignment of lesser severity (y-axis, bottom) (Figure 3). Evaluative statistics demonstrate this method for planning knee morphologies is significantly more accurate than making predictions about the mean (RMSE 1.440; R-squared 0.444; Nash Sutcliffe 0.579).

DISCUSSION AND CONCLUSION:

This study's model provides accurate predictions for target knee alignment morphologies. Future work is warranted to evaluate this method's usefulness for planning robotic TKA.

Figure 1. Neural Network Model Architecture

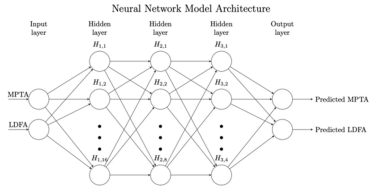

Figure 3. Prediction of Planned aHKA from Preoperative aHKA

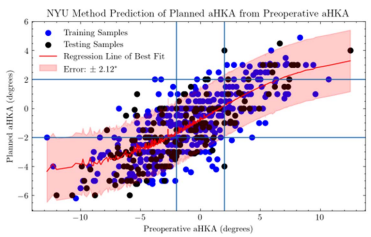

Figure 2. MLP Regressor Loss Curve