Modified Coronal Plane Alignment of the Knee Classification: Population-Level Analysis using Deep Learning

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INTRODUCTION: Accurate assessment of knee phenotype is crucial for successful surgical planning in total knee arthroplasty (TKA). The Coronal Plane Alignment of the Knee (CPAK) classification proposes nine phenotypes based on constitutional limb alignment and joint line obliquity (JLO). However, there is considerable confusion and variability in defining the categories. A simple modified CPAK system that eliminates reliance on JLO would improve accuracy and facilitate surgical decision making. Herein, we applied deep learning (DL) methods to automate knee phenotyping and subsequently analyzed modified CPAK distributions in a large patient cohort.

METHODS: Patients with full-limb radiographs from the Osteoarthritis Initiative national database were retrospectively analyzed. A previously validated deep learning model was used to automate modified CPAK knee alignment parameters including the lateral distal femoral angle (LDFA), medial proximal tibial angle (MPTA), and arithmetic hip-knee-ankle (aHKA) angle. The aHKA angle was calculated (aHKA = LDFA–MPTA). Neutral alignment was 90 ± 0.5 degrees with varus aHKA less than $-0.5°$, while a valgus aHKA is greater than $+0.5°$. The distribution of modified CPAK was compared based on patient sex and whether they underwent TKA within 10 years.

RESULTS: A total of 972 patients (1,944 healthy and arthritic knees) were included for analysis (mean age 61.4 years, 51% female). Some 44.5% of knees were varus, 12.6% of knees were neutral, and 43.0% of knees were valgus based on the aHKA. Female patients were more valgus than male patients ($p < .05$). A valgus femur with varus tibia was found to be the most prominent alignment combination across all patients (65.9%), as well as across all alignments. Overall valgus knees were primarily driven by valgus femurs (96.7% of valgus knees had femurs in valgus alignment), while varus knees were driven by varus tibias (97.4% of varus knees had tibias in varus alignment).

DISCUSSION AND CONCLUSION: We applied a previously validated deep learning algorithm on a large patient cohort to determine knee phenotypes in a newly proposed modified CPAK classification system. By eliminating joint line obliquity and relying only on the coronal alignment of the femur and tibia, this adapted system offers a more objective, practical, and accurate evaluation of knee alignment, and enhances surgical decision making. Further validation and clinical implementation of this novel approach are warranted to fully evaluate its impact on surgical practice.

	Femur		
	Valgus	Neutral (0)	Varus
Varus	-Valgus -Varus -Neutral	Only Varus	Only Varus
Neutral (0)	Only Valgus	Neutral	Only Varus
Valgus	Only Valgus	Only Valgus	-Varus -Valgus -Neutral