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Advancement in keratoconus detection using machine learning and pachymetric progression index

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The novel index termed the "Thickness Speed Progression Index" (TSPI) was introduced to enhance the early detection of keratoconus—particularly relevant for individuals being considered for refractive surgery—and to address current challenges in identifying subclinical and asymmetric presentations of the condition.

The study titled "Thickness Speed Progression Index: Machine Learning Approach for Keratoconus Detection" is a retrospective observational investigation focused on the development and validation of the TSPI. This index is noteworthy for relying solely on pachymetric data. By emphasizing localized biomechanical changes—which are believed to precede the structural alterations typically captured by other diagnostic markers—the study demonstrated notably high diagnostic accuracy.

Data acquisition was conducted using the GALILEI Dual Scheimpflug–Placido system. From this, parameters quantifying the rate of corneal thickness change at multiple angular positions and radical distances from the cornea's thinnest point were calculated. Six specific parameters were identified: ATS1.0, ATS2.0, ATS4.0, DTS1.0, DTS2.0, and DTS4.0. The TSPI was subsequently validated through machine learning techniques, with the Random Forest algorithm selected as the optimal model following random hyperparameter optimization and cross-validation procedures.

The study evaluated 349 eyes from 349 patients, categorized as follows: 133 normal eyes, 141 eyes with established keratoconus (KC), and 75 suspected KC (KCS) eyes. The KCS group was further divided two subcategories based on the topographic and tomographic appearance of the fellow eye in patients with asymmetric keratoconus: 34 eyes with normal findings (TNF) and 41 eyes with borderline features (TBF). Three experimental analyses were performed: (1) comparison between normal and KC eyes, (2) inclusion of KCS eyes, and (3) evaluation involving the TNF and TBF subgroups. In the first experiment, the model achieved perfect accuracy with an AUROC of 1.00. In the second experiment, the model yielded 91% accuracy, with AUROCs of 0.93 for normal eyes, 0.83 for KCS eyes, and 0.99 for KC eyes. In the third experiment, accuracy dropped to 87%, with AUROCs of 0.91(normal), 0.60 (TNF), 0.77 (TBF), and 0.94 (KC).

TSPI demonstrated strong performance in detecting KC, including its earliest forms, and outperformed conventional indices such as ART and PPI in the conducted evaluations. It was also able to detect corneal asymmetries that went unnoticed with other indices, reinforcing its potential value in identifying eyes at elevated risk for ectasia. Unlike indices that rely on concentric or meridional averaging—which may obscure localized anomalies—TSPI's localized pachymetric assessment helps preserve critical diagnostic detail.

A key limitation of the study was the relatively small sample size within the TNF and TBF subgroups. Additionally, the study excluded postoperative corneas. The authors suggest future studies could involve applying the index to stratified corneal layers and exploring correlations between TSPI and other diagnostic parameters.

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