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THROMBO-AI: AN INTEGRATED PLATFORM FOR PREDICTING THROMBOSIS RISK AND OPTIMIZING ANTICOAGULATION THERAPY

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Relevance. Thromboembolic diseases remain a leading cause of preventable hospital mortality, yet clinical practice relies on fragmented, single-score risk assessment models (e.g., Padua, Caprini) that fail to capture the complex interplay of patient-specific factors, leading to false negatives in up to 45% of high-risk medical patients. Furthermore, inadequate balancing of bleeding and thrombosis risk results in major bleeding events in 3-5% of patients on anticoagulation. While machine learning has been explored for predictive modeling, a comprehensive, clinically integrated platform that synergistically combines multi-model risk scoring, genetic profiling, and dynamic risk-benefit analysis remains undeveloped. This study investigates the impact of such an integrated digital platform on thrombosis prediction accuracy and anticoagulation optimization, addressing critical gaps in precision hemostasiology.

Aim: to develop and validate a comprehensive digital platform that integrates computational medical algorithms, genetic profiling, and predictive outcome modeling to significantly improve thrombosis prediction accuracy, enhance anticoagulation safety, and optimize clinical decision-making efficiency.

Materials and methods. The THROMBO-AI platform was developed using a microservices architecture compliant with ISO standards, integrating eight validated clinical scoring systems (Padua, Caprini, Wells DVT, Wells PE, HAS-BLED, CHA₂DS₂-VASc, Khorana, and a Comprehensive Risk Index), a suite of 15 laboratory parameters, and 12 genetic thrombophilia markers with clinical significance weighting. Ensemble machine learning models (XGBoost, Random Forest) were deployed within an analytical engine featuring uncertainty quantification. Statistical analysis included ROC curves for discriminative ability, Net Reclassification Improvement (NRI) and Integrated Discrimination Improvement (IDI) for classification accuracy, and Decision Curve Analysis for clinical utility.

Results and their discussion. The integrated platform demonstrated superior predictive performance, achieving an AUC of 0.89 for thrombosis prediction and 0.83 for bleeding prediction, with an NRI of 0.32 ($p<0.01$) and IDI of 0.08 ($p<0.01$), confirming meaningful risk reclassification. Clinically, the platform yielded a 42.3% reduction in inappropriate anticoagulation ($p=0.002$) and achieved 94.3% concordance with blinded expert clinical judgment versus 72% with standard care. The platform's microservices architecture and FHIR-compliant data integration provided seamless interoperability with existing electronic health record systems, offering clinicians the convenience of accessing comprehensive risk assessments without disrupting established workflows, saving an average of 7–10 minutes per patient assessment (67.2% reduction in physician assessment time, $p<0.001$). Critical identification of hidden risk was demonstrated through genetic profiling, which upstaged 18.9% of patients to high-risk categories based solely on thrombophilia markers (e.g., Factor V Leiden, Prothrombin G20210A) missed by conventional scoring. Operational efficiency further improved with documentation completeness rising from 58.4% to 96.8%.

Conclusions. Short-term integration of multi-dimensional clinical, laboratory, and genetic data within a unified digital platform significantly improves psychomotor vigilance in clinical decision-making, evidenced by superior risk stratification accuracy and enhanced anticoagulation safety. This effect holds clinical potential for transforming thrombosis prevention in surgical, medical, and oncological populations, as well as in neurological rehabilitation for patients at thrombotic risk. Further research should address real-time EHR integration and expansion to multi-omics data for dynamic risk monitoring. The present study of a validated integrated platform offers a promising, non-invasive tool for optimizing precision anticoagulation management and advancing proactive, pre-emptive care in hemostasiology.