



Machine-Learning Prediction of Blood Transfusion Risk after Total Knee Arthroplasty

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DESCRIPTION

Total knee Arthroplasty is a widely performed procedure for people with advanced knee degeneration, particularly when pain and functional limitations substantially affect daily activities. Although improvements in surgical techniques and blood-management protocols have reduced perioperative blood loss, postoperative anaemia and the need for blood transfusion remain important considerations. Identifying patients who are more likely to require transfusion before surgery could help clinicians prepare individualized blood-management strategies and determine which postoperative laboratory assessments are most appropriate. Machine learning offers a practical approach to this problem because transfusion risk is influenced by multiple patient and treatment characteristics rather than by a single measurement. Conventional prediction methods may have difficulty capturing interactions among demographic characteristics, body composition, laboratory values and perioperative interventions. A machine-learning algorithm can process several variables simultaneously and identify combinations that are associated with a higher or lower probability of postoperative transfusion.

A published model addressing this issue used data from 774 total knee arthroplasties performed between January 2020 and March 2023. Among these procedures, 100 patients, corresponding to 12.9%, received postoperative blood transfusion. The model initially considered 25 preoperative variables and subsequently used recursive feature elimination to identify the characteristics that contributed most strongly to prediction. A gradient-boosting machine was then developed from the selected variables. Five variables ultimately formed the prediction model: age, body mass index, administration of Tranexamic acid, preoperative haemoglobin concentration and preoperative platelet count. These variables represent several complementary dimensions of transfusion risk. Age can reflect differences in physiological reserve and the prevalence of

associated conditions, while body mass index may be related to surgical characteristics and blood-volume considerations. Haemoglobin provides direct information about the patient's preoperative capacity to tolerate blood loss, whereas platelet concentration is relevant to normal clot formation. Tranexamic acid is particularly interesting because its administration is associated with strategies intended to reduce bleeding during and after surgery.

The reported predictive performance was strong. The model achieved an area under the receiver operating characteristic curve of 0.97, with a 95% confidence interval of 0.921 to 1.00. Sensitivity was reported as 94.4%, while specificity reached 85.4%. These values indicate that the algorithm was able to distinguish patients with different levels of transfusion probability within the evaluated population. Nevertheless, high performance in one clinical dataset does not automatically guarantee equivalent performance in other hospitals or healthcare systems. The potential clinical value of such a tool extends beyond predicting whether transfusion will occur. A preoperative risk estimate could help clinicians identify patients who may benefit from additional attention to anaemia management before surgery. It could also support decisions about postoperative monitoring. Patients categorized as having a low predicted risk might not require the same intensity of routine laboratory testing as individuals with substantially higher predicted risk, provided that clinical circumstances remain stable.

This approach fits within the broader concept of patient blood management, which aims to reduce avoidable blood loss, recognize and correct anaemia when appropriate and use transfusion carefully. Tranexamic acid, optimization of haemoglobin before surgery and individualized postoperative monitoring are examples of measures that can contribute to this objective. A predictive model can complement these measures by identifying patients who may require greater attention rather

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than applying an identical monitoring strategy to everyone. The use of machine learning also introduces several considerations. Algorithms can be influenced by the characteristics of the population from which their training data originate. Differences in surgical techniques, transfusion thresholds, patient demographics, anesthesia protocols, blood-management practices and laboratory procedures may affect performance when the model is transferred to another setting. External validation across different hospitals and populations is therefore important before a prediction tool is incorporated broadly into routine clinical decision-making.

Interpretability is another important requirement. Clinicians need to understand which characteristics contribute to an

estimated risk rather than receiving an unexplained numerical result. The five-variable structure of this model offers an advantage because the inputs are routinely recognizable clinical measurements. A relatively compact model can also be easier to integrate into electronic medical records or preoperative assessment systems. If reliable prediction allows monitoring intensity to be adjusted according to individual risk, unnecessary testing may potentially be reduced while maintaining closer observation of patients who are more vulnerable to postoperative blood loss.