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Forecasting Postoperative Pain Following Knee Arthroplasty: Anticipating Adverse Outcomes and Managing Expectations

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Abstract

Early identification and prediction of chronic pain in patients after total knee arthroplasty can significantly impact treatment strategies and improve patient satisfaction. This study introduces an innovative artificial intelligence model that predicts pain levels and pain evolution after TKA, empowering surgeons with insights for personalized patient care.

The pain intensity was measured with a visual analog scale on a mobile application, from 1650 knee arthroplasty patients from one week before surgery and up to 12 weeks after surgery. A training set was first used to identify patterns in the data that could best approximate pain trajectories. Out-of-sample pain trajectories were predicted by estimating pattern weights and reconstructing the remaining timepoints. Confidence intervals were calculated to determine prediction accuracy.

The model's accuracy was evaluated based on the percentage of predictions falling within 10 % of the true pain values. With an observation time of up to week 2, the model achieved 67% accuracy in forecasting pain levels for the next 4 weeks, and 61% accuracy for the next 10 weeks. By extending the observation time to week 4, the accuracy improved to 84% and 69% respectively.

The artificial intelligence model showed promising results in predicting pain evolution. By utilizing this model, surgeon teams can manage patient expectations and tailor pain management strategies. The model's predictions facilitate efficient tele-monitoring, enabling remote patient monitoring of patient with less good evolution prediction, reducing the need for frequent clinic visits. Incorporating this technology into surgical practice can enhance surgical outcomes and patient satisfaction.

1 Introduction

Despite the implementation of multimodal pain management techniques, the postoperative phase following total knee arthroplasty (TKA) frequently results in significant pain for patients. This often leads to adverse patient outcomes, including dissatisfaction, prolonged hospitalization, diminished quality of life, and non-adherence to rehabilitation protocols [1]. Identifying and predicting chronic pain early in patients may significantly improve treatment strategies and enhance patient satisfaction.
The past decade has seen the advent of digital health technologies enabling the continuous collection of perioperative data [2–5], including pain scores [6]. This development allowed the study of pain trajectories, which is distinct from the traditional approach of assessing pain at discrete time points [7]. Pain does not follow a linear progression over the 90 days following surgery; instead, it tends to follow a distinct pattern [8].

This study examines the use of a novel model to predict pain levels following a TKA.

2 Methods

2.1 Data source

Pain intensity was measured for 1650 patients who underwent TKA using a visual analog scale (VAS). Pain levels were collected starting one week before surgery and up to 12 weeks after surgery using a monitoring application.

All data collection was facilitated via the moveUP® application (moveUP®, Brussels, Belgium), which is registered as a medical device. This application operates on a smart virtual platform designed for digital monitoring, utilizing both objective and subjective patient data. The platform consists of two main components: a patient-facing mobile application and a web-based dashboard utilized by the care provider.

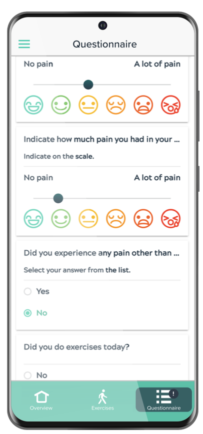

Figure 1: Patient application

2.2 Model training and assessment

Machine learning could predict the evolution of pain after surgery and define recovery trajectories. But pain trajectories are often sparse with missing values. A great tool to overcome sparsity is Functional Principal Component Analysis through conditional expectation.

A training set was first used to identify patterns in the data that could best approximate pain trajectories. Pain trajectories were predicted by estimating pattern weights and reconstructing the remaining time points. Confidence intervals were calculated to determine prediction accuracy. The model's accuracy was evaluated based on the percentage of predictions falling within 10 % of the true pain values.

3 Results

Adherence rate to pain level collection was 80%. When calculating prediction accuracy for pain rating using the first 2 weeks following surgery the model was able to achieve a 67% accuracy for the next 4 weeks, and a 61% accuracy for the next ten weeks. When the calculation was based on pain ratings collected for the first four weeks, the accuracy improved to 84% and 69%, retrospectively.

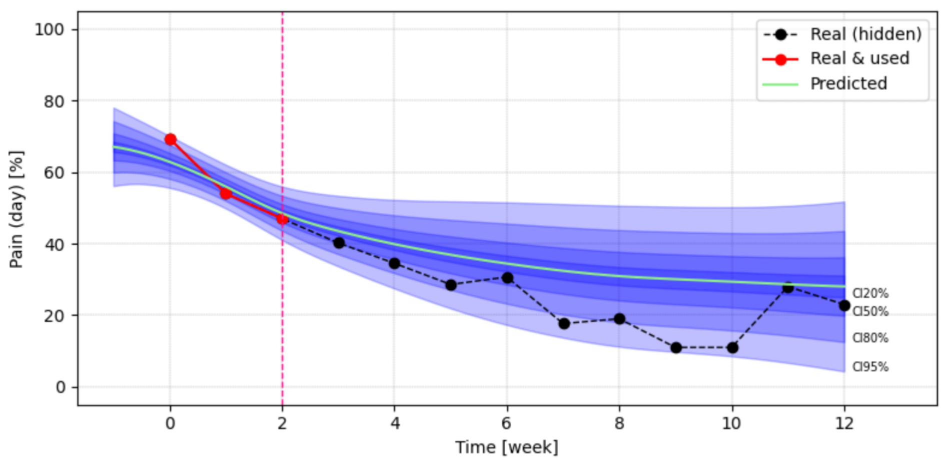

Figure 2: Pain prediction at week 2 for one typical patient

4 Discussion

This pain prediction model showed promising results in predicting pain evolution for the first months after a TKA. Previous studies investigated evolution of pain after TKA during the acute phase[9], but few investigated prediction ability of models [10]. The more data are given to the model (number of weeks), the most accurate becomes the prediction.

This model allows physical therapists to manage patient expectations and proactively tailor the care plan in the virtual platform. For example, it can be used to customize messages sent to the patient through the chat feature available in the monitoring app. These messages provide patients with both feedback and realistic pain expectations after a TKA. Such predictive insights may also be used to trigger alerts that warn physical therapists when one of their patients is not recovering as expected. The model's predictions could facilitate efficient telemonitoring, enabling remote monitoring of a patient with a poorer evolution prediction. Incorporating this technology into clinical practice could enhance patient outcomes and satisfaction.

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