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Case Report

Delayed Recovery Following Total Knee Arthroplasty Identified by Remote Monitoring With Tibial Extension Sensors

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ABSTRACT

Remote monitoring of patient activity following total knee arthroplasty has grown in popularity over the past decade. Recent technological advances have allowed for implantation of accelerometry devices within the tibial stem for remote monitoring of mobility postoperatively. Remote monitoring is suggested to allow for intervention in the case of events that may occur outside of regular follow-up appointments or traditional patient questionnaires. This report details the ability of an implanted tibial sensor to continuously collect objective mobility data allowing the orthopaedic surgeon to intervene beyond the standard 90-day episode of care.

Introduction

Historically, the success of total knee arthroplasty (TKA) has been measured by patient-reported outcome measures that have been validated for use in this population [1]. Postoperatively, the burden associated with their administration limits the ability of providers to obtain these questionnaires with frequency. In many cases, patient-reported outcome measures are collected during standard in-person follow-up appointments, leaving orthopaedic surgeons unapprised of their patients' recovery and functional status between visits. After the standard 90-day episode of care, surgeons may be unaware of a patient's status unless a related incident occurs, with no opportunity for intervention.

Remote patient monitoring, particularly following total joint arthroplasty, has gained popularity with the increased adoption of technology over the past several years [2,3]. The use of fitness trackers and mobile devices has allowed surgeons the ability to review objective data regarding recovery of mobility postoperatively, though patient adherence to these technologies has been criticized as a potential limitation. Recently, a tibial stem extension containing sensors for collected objective kinematic data has been approved for use by the US Food and Drug Administration. The implanted sensors allow for continuous passive collection of step count data during a sampling day, with additional gait metric information during discrete periods of movement throughout the day [4,5]. Remote monitoring of this data has been suggested as a potential solution for identification of slow recovery or significant postoperative events where traditional methods of assessing patient function may not occur or signal a need for intervention.

We present the case of a patient who underwent TKA with a knee implant including a tibial stem extension containing accelerometers and gyroscopes for remote data collection via a smartphone-based care management platform. Surveillance of the mobility data transmitted by the implant by the orthopaedic surgeon prompted contact with the patient and treatment to help improve rehabilitation efforts.

The patient provided written informed consent for the publication of the data concerning this case.

Case history

The patient is a 53-year-old female homemaker with a significant medical history of anxiety, depression, thyroid disease, sleep apnea, falls, and previous ischemic stroke. She reported a 20-pack-year history of smoking, having quit more than 1 year prior to the procedure. The patient denied any alcohol or illicit drug use and

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indicated no current exercise program or any significant traumatic injury related to her knee pathology. Family history of cancer and cerebrovascular accidents were also reported. The patient was diagnosed with bilateral knee osteoarthritis in 2019; x-rays in 2020 revealed grade IV advanced medial and patellofemoral osteoarthritis with joint space narrowing, osteophyte formation, and subchondral sclerosis, which was more pronounced in the right knee. The patient went on to primary right TKA approximately 6 weeks following radiologic assessment, with no intra- or postoperative complications.

The patient presented again to the clinic 22 months following the right TKA to undergo replacement of the left knee. The procedure was performed using the Persona IQ (Zimmer Biomet, Warsaw, IN), a personalized implant with a novel tibial stem extension incorporating an embedded inertial measurement unit and sensor pairing accelerometers and gyroscopes for passive gait data collection, including step counts, gait speed, stride length, and cadence. Imbedded sensors collect 10-second bursts of data during 3 predefined five-hour periods each day. The implant is paired with the mymobility smartphone-based care management platform (Zimmer Biomet, Warsaw, IN); objective kinematic data is provided for physician and patient review during postoperative care to supplement in-person assessments.

On preoperative examination, the patient presented with 90° of active flexion and 10° of extension in the left knee and ambulated with the assistance of a four-wheel walking device. A left primary knee replacement was performed on an outpatient basis without incident, and the patient was discharged home. She was prescribed in-person outpatient physical therapy 3 times per week for a total of 6 weeks. The patient progressed well following arthroplasty and returned at 2 weeks postoperative, at which time she was fully weight bearing, continuing to ambulate with a walker assistive device, and had achieved 95° of active flexion on range of motion assessment. At the 2-week postoperative period, her daily average step count remained low, with 15-day rolling average gait speed of 0.3 m/s. She continued to recover uneventfully and presented again at 6 weeks postoperatively, at which time she had achieved 128° of flexion. Daily step counts began to increase modestly, with an average daily gait speed of 0.4 m/s.

Approximately 5 months later, the patient began to experience an unrelated decline in health status and was admitted to the hospital for 4 days due to acute respiratory failure with hypoxia and bilateral pneumonia. Prior to this, the patient's daily step count had been increasing and was averaging 104 steps logged per day. The hospitalization led to an almost 88% decrease in average daily steps from the week previous, as shown in Figure 1. The surgeon performed a remote therapeutic visit for the patient at 6 months postoperatively and was concerned for the lack of improvement by this time and the low data values, prompting a phone call to the patient. She described her recent hospitalization and associated immobilization at this time. She had no complaints of pain or any decrease in range of motion of the operative knee at the time of the visit. The surgeon prescribed an additional 6 weeks of physical therapy, 3 times per week to aid in achieving improved daily step counts and gait speed. In the 10 weeks following the start of additional physical therapy, average daily step counts increased to approximately 573 steps per day, average total distance walked per day increased by 0.224 km, and average gait speed increased by 0.17 m/s.

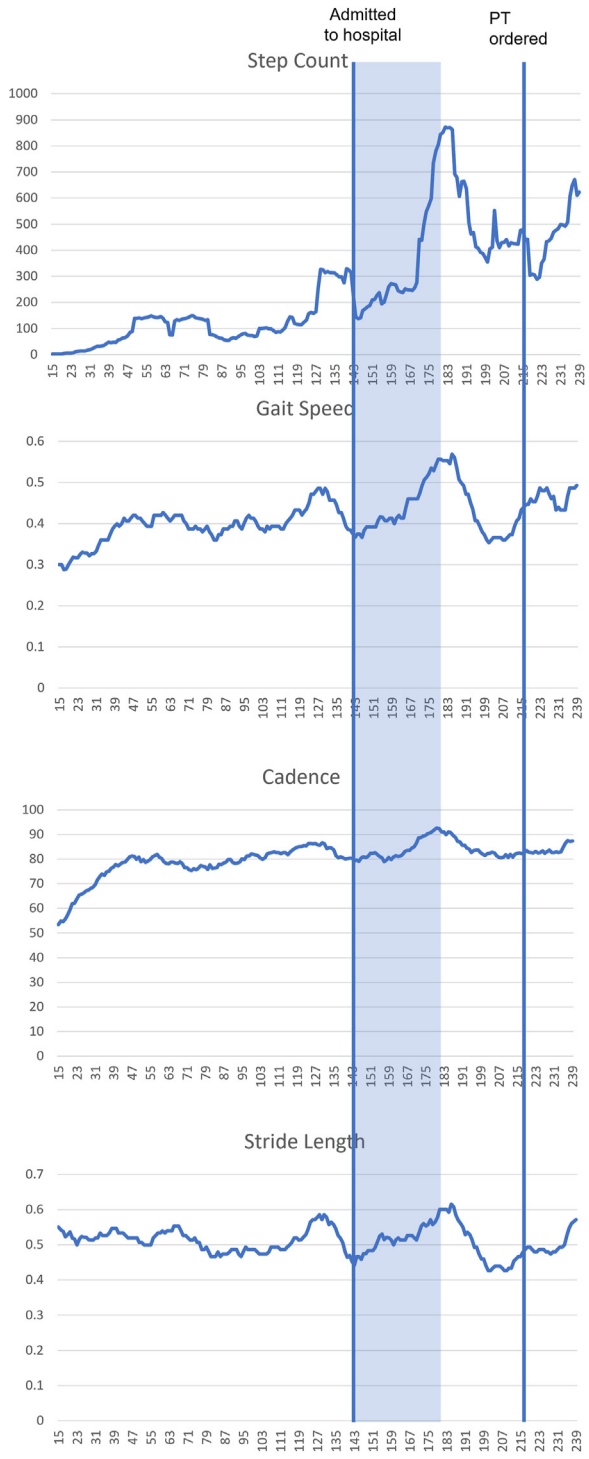

Figure 1. Gait metrics obtained from the smart implant postoperatively are plotted as 5-day rolling averages for each metric. Hospitalization occurred on postoperative day 141; this date and physical therapy prescription (postoperative day 216) are indicated by solid lines; the period of metrics reviewed during remote monitoring visit are indicated by shaded area.

Discussion

Though remote patient monitoring has been growing in prevalence over the past several years and has become particularly appealing with the onset of COVID-19 pandemic, few investigations into its ability to identify adverse events have been published. Some of the earliest remote patient monitoring has been possible in the field of cardiology, particularly with regards to implanted sensors such as pacemakers and cardioverter defibrillators [6]. The utility of the data collected initially centered on the health and settings of the device, with little patient information available to clinicians. However, a recent report has shown the ability of remote

monitoring with these types of devices to improve early diagnosis of new events and reduce hospital readmissions [7].

In the field of orthopaedics, remote monitoring has been most common in patients with spinal pathology, with cases recently reporting identification of patient status deterioration using wearable technology [8,9]. Of particular interest is the fact that these cases detail the ability to track gait metrics including step counts and gait speed over extended periods of time, which guided clinical decision-making for surgical intervention due to the observed loss of mobility [8]. The use of remote monitoring of mobility metrics in lower limb arthroplasty has been widely explored in recent years; however, much of the research has focused on establishment of postoperative recovery curves and identification of baseline characteristics impacting patients' ability to achieve preoperative activity levels. To our knowledge, this is the first case to report the ability to correlate mobility data gathered remotely via implanted tibial stem technology to an unplanned readmission of a patient following TKA. Continued tracking of recovery following a remote therapeutic monitoring visit allowed the orthopaedic surgeon to intervene and prescribe additional physical therapy, with observed improvements in daily step counts and gait speed.

This case presents a patient with low baseline mobility, likely related to the patient's medical history, which included previous incidence of ischemic stroke where use of an assistive device was necessary prior to the arthroplasty procedure. In such cases, it is possible that steps may not be registered by accelerometry devices as slow walking speed and little change in gait speed (shuffling) may not be registered, which may have contributed to the very low step counts observed both pre- and post-operatively in this case. However, previous studies of accelerometry to monitor mobility in populations of stroke survivors have indicated use of accelerometry devices and mobile phone applications is feasible, with relatively high reliability and validity of step count data [10]. Moreover, Fini et al. observed similar step counts and gait speeds in patients classified as limited or household ambulators in their study of activity in stroke survivors, suggesting the low daily step counts presented here are likely an accurate depiction of the subject's walking behaviors [11]. Nonetheless, the gait recovery curves presented clearly indicate trends that correlate with known medical events in this patient.

Research suggests the rate of hospitalization within a year of undergoing TKA may increase by over 50% compared to the year prior to surgery [12]. Admissions occurring more than 30 days after the index procedure are more commonly due to medically rather than surgically related causes [13]. These types of medical events, though potentially unrelated to the index procedure and outside of the Comprehensive Care for Joint Replacement model's defined episode of care, can significantly impact arthroplasty recovery. The ability to remotely monitor patients' mobility beyond the 90-day episode of care provides a unique opportunity for surgeons to ensure that rehabilitation continues to progress and identify the occurrence of events that can derail recovery. Implantation with a tibial stem sensor in this case provided additional confidence that variations in mobility data were not due to changes in patient adherence to the use of associated technology. Continued experience with the objective data made available to healthcare professionals by implanted and worn technology will improve our ability to detect changes in patient mobility and may help guide decisions to provide additional treatment to affect outcomes in arthroplasty patients.

Summary

Readmission due to nonsurgical medical events is not uncommon in the first year following TKA. When associated with prolonged immobilization, such events have the potential to negatively impact return to mobility; however, surgical teams are unlikely to be made aware of the patient's status or need for additional physical therapy for rehabilitation. Remote monitoring combining wearable technology for mobility tracking may be a useful tool to assist in identifying patients in need of intervention. The implantation of a tibial sensor has the potential to provide additional information regarding mobility with added confidence in the observed mobility trends.

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Conflicts of interest

J. Yergler receives research support from Zimmer Biomet, is a paid speaker for Zimmer Biomet, and is a paid consultant for Zimmer Biomet and Canary Medical. R. Redfern is an employee of Zimmer Biomet with stock options; the other author declares no potential conflicts of interest.

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Informed patient consent

The author(s) confirm that written informed consent has been obtained from the involved patient(s) or if appropriate from the parent, guardian, power of attorney of the involved patient(s); and, they have given approval for this information to be published in this case report (series).

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