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e-Visits For Early Post-operative Visits Following Orthopaedic Surgery Can They Add Efficiency Without Sacrificing Effectiveness

William G. Jeffery
The University of Western Ontario

Supervisor
Dr. Dianne Bryant
The University of Western Ontario Co-Supervisor
Dr. J Robert Giffin
The University of Western Ontario

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Abstract

We asked 217 sport surgery and 133 total knee arthroplasty (TKA) patients to complete a questionnaire (e-Visit) before attending their two and six-week post-operative appointment. Our primary objective was to use the questions asked of patients prior to their appointment to develop a model that could be used as web-based e-Visit to predict early post-operative adverse events. Gold standard comparison was the surgeon's opinion as to the presence or absence of an event at follow-up. Secondary objective was evaluation of a simplified model. We found good area under the curve (AUC) statistics (0.76 (95% CI 0.69 - 0.84) and 0.80 (95% CI .74 - .85)) and good sensitivity (0.70, 0.83) and specificity (0.70, 0.80) for the two-week model and for the six-week model respectively. The simplified models and raw-data models were similar. Future work should improve the web-based interface, include educational content, and be validated using a large multicenter RCT.

Keywords

Keywords: Electronic, Web-based, e-Visit, Total Knee Arthroplasty, Arthroscopy, Anterior Cruciate Ligament Reconstruction, High Tibial Osteotomy, Adverse Events, Follow-up, Diagnostic Validity

Co-Authorship Statement

With the assistance of Drs. Bryant, and Giffin, we designed a prospective cohort study. We collaborated in the creation of the e-Visit, demographic, and surgeon's data forms. I was responsible for identifying, recruiting eligible patients and conducting follow-up visits. I wrote the original draft of this thesis and Drs. Bryant and Giffin made comments and suggestions that contributed to improve the final document.

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Glossary

1. Superficial Infection – Bacterial invasion and growth within the skin or subcutaneous tissue. Characterized by erythema, wound dehiscence, tenderness and sickness. Diagnosed by patient assessment, blood tests, and microbial analysis. Treatment is usually as an outpatient with oral antibiotics.

2. Deep Infection – Bacterial invasion and growth within the joint or muscle. Characterized by purulent discharge, wound dehiscence, pain, and sickness. Treatment is usually as an inpatient with revision surgery (debride/lavage + antibiotic spacer for knee replacements) and intravenous antibiotics.

3. Deep Vein Thrombosis (DVT) – Blood clot formation in distal veins due to decreased venous return with prolonged periods of inactivity during post-operative recovery. Usually treated as an outpatient with an anticoagulant (low molecular weight heparin) and monitored. At-risk patients are identified pre-operatively and are given anti-coagulant prophylaxis.

4. Pulmonary Embolism (PE) – DVT clot breaks from venous wall and travels to the lungs, impairing blood circulation and gas exchange, increasing the risk of mortality. Clinical presentation includes chest pain, coughing blood, dizziness, rapid breathing, rapid heartbeat and shortness of breath. Usually treated as an inpatient immediately with a long-term anticoagulant and surgery if necessary. Can be treated as an outpatient with anticoagulation and monitoring therapeutic anticoagulation levels in a low-risk population (PESI).

5. Limited Flexion – Decreased flexion range of motion (<110° of flexion). May be a result of mechanical blockage (components or scar tissue), muscle imbalance, or lack of pre-operative flexion. Usually treated non-operatively with outpatient physiotherapy first, then surgically with a manipulation under anesthesia (MUA) or revision (if primary TKA or MUA failed)

6. Limited Extension – Decreased extension range of motion characterized by a bent knee unable to fully straighten (>5° of flexion). May be a result of mechanical blockage (components or scar tissue), muscle imbalance, or lack of pre-operative extension.

Usually treated non-operatively with outpatient physiotherapy first, then surgically with a MUA or revision (if primary TKA or MUA failed)

7. Delayed/Non-Union – Improper bone healing within (delayed) and after (non-union) six-months post-operative classified as either hypertrophic (extensive callus formation) or atrophic (lacking callus formation). Delayed union is usually monitored up to a year, or when the surgeon deems it non-union. Non-union is usually treated operatively by revision with or without re-plating and bone grafts, or a TKA.

Chapter 1

1 Introduction

Early adverse events following elective orthopaedic surgery are rare, and early post-operative appointments are often unremarkable with no change in clinical management[1,2,3,4]. A review of 222,684 total knee arthroplasty (TKA) patients showed 90-day complication rates of 0.53%, 0.71%, 0.41% for death, infection, and pulmonary embolism respectively[5]. Likewise, a review of 12,271 knee arthroscopy patients showed 30-day complication rates of 1.96%, 1.01%, and 0.95% for any complication, major morbidity, and minor morbidity respectively[6]. Furthermore, 90-day deep vein thrombosis (DVT), pulmonary embolism (PE), and all-cause mortality rates following knee arthroscopy are 0.12%, 0.08%, and 0.02%[7]. Early complications following medial opening wedge (MOW) high tibial osteotomy (HTO) are less certain and somewhat rare. Overall complication rates of 6.35% and 14% have been reported within the first three-months post-operative[2,8]. Specifically, these studies reported 3.17% and 5.33% as rates of infection requiring surgery[2,8]. Moreover, a systematic review found clinical and radiographic delayed union rates of 4.6%, 2.6%, and 1.3% for 787 bone allograft, 895 bone autograft, and 526 no osseous filling HTO cases using a non-locking plate[9]. Delayed union was found in 12.3% and 1.4% of 89 bone allograft and 419 no osseous filling HTO cases using a locking plate[9]. Lastly, early complications not requiring surgical treatment are estimated to be 2.8% (hematoma), 5.6% (delayed wound healing), and 9.6% (cellulitis)[10]. Rates of 30-day overall complications and hospital re-admittance post anterior cruciate ligament (ACL) reconstruction are 1.34%, and 1.36%[11]. Of the patients readmitted, 41.2% had a wound complication. Lastly, rate of 90-day hospital re-admittance post ACL reconstruction is 2.3%[12]. Of the patients readmitted, 95% were readmitted because of medical issues related to the surgery (ie. infection or stiffness) and 5% because of medical issues unrelated to the surgery (ie. acute appendicitis). Given low adverse event rates, our current practice of multiple early post-operative visits may be inefficient from a cost perspective.

Advancement in e-health technology may allow surgeons to maximize their efficiency by conducting follow-up assessments remotely via the internet. In 2011, Wood et al. randomized 40 primary hip and knee arthroplasty patients who underwent surgery between 2005 and 2010 to complete a web-based visit before their regular outpatient appointment or complete the web-based visit after their appointment. The web-based group completed radiography at their closest community hospital to assess costs. They reported that 95% of their patients stated the web-based assessment was more convenient and would prefer it over future outpatient assessments[13]. They also found that the web-based group spent approximately 52 minutes (min) completing the visit whereas the regular outpatient group spent 115 min[13].

Between March 2010 and March 2011 Marsh et al. randomized 229 patients at least one year post-operative from a knee replacement to participate in a web-based visit (n=118) or the usual in-person visit (n=111). Patients randomized to the web-based visit completed the visit online, the results of which were sent to the surgeon for review. Depending on the surgeon's interpretation of the patient's online visit, patients were seen in-person either immediately, within one month, or within six months of the web-based appointment. This in-person appointment was used to determine the accuracy of the web-based appointment at alerting the surgeon to any adverse events. The authors reported that the e-Visit detected all adverse events and patient satisfaction was high, suggesting patients are receptive to this type of tool[14]. Further, the observed average assessment time for the e-Visit was 121.7 min vs 228.7 min for the group randomized to see their surgeon in-person[14]. In addition, Marsh et al showed a cost savings of $64 (95% CI $48 – $79) per appointment for patients who participated in the e-Visit group by reducing gas usage, time missed from work, and other resources associated with coming into the clinic[15]. Additionally, they showed that from the healthcare payer perspective, an e-Visit reduced costs by an estimated $27 (95% CI $25 – $29) per appointment[15]. Marsh et al. concluded that an e-Visit following total hip/knee arthroplasty is a feasible, cost-effective alternative compared to standard in-person follow-ups at 1-year post-operative or later.

In summary, because adverse events immediately following common orthopaedic procedures are relatively rare, if we can demonstrate that an e-Visit is effective at

detecting early adverse events, then it may be cost-effective to implement as an option for post-operative care.

Chapter 2

2 Literature Review

2.1 Early adverse events following orthopaedic surgery

Collection of adverse event data is critical to improving patient outcomes after surgery. A deeper understanding of how surgical procedures affect patients informs future innovation. In the literature, adverse event data is produced through prospective research, voluntary and prompted reporting, chart review, patient interviews, and electronic tools that search the patient's administrative information, medication history, and clinical narrative[16,17,18]. There is no current consensus on the best way to accurately track and report adverse event data. However, the gold standard has traditionally been voluntary reporting by physicians using their perception, interpretation and clinical decision skills[16]. Variability in voluntary reporting was shown in a study by Welsh et al. that altered the frequency of reminders sent to medical residents to report hospital adverse events. When residents received more reminders, they reported more adverse events than the hospital surveillance system. Conversely, when they received less reminders, they reported less adverse events than the hospital system[19]. Diagnosed adverse event data from voluntary reporting or post-operative electronic surveillance tools are then formatted into databases such as the National Surgical Quality Improvement Program (NSQIP) or the Canadian Institute for Health Information's (CIHI) Canadian Joint Replacement Registry (CJRR) to inform policy decision makers on patient safety and procedure efficacy.

2.2 Risks of early adverse events in orthopaedics

A retrospective review of adverse event data in the NSQIP from 101,862 patients who underwent one of the top 30 orthopaedic procedures between 2005 and 2011 across 462 global hospitals found 5368 complications, a general rate of 5% within 30-days post-operative[4]. The rate of minor complications was 3.1% (3174) and major complications was 2.8% (2880)[4]. The most frequent minor adverse event was UTI (1534) and the most frequent major adverse event was death (850)[4]. For this study, complications were

described as minor if they were localized to the surgical area or did not pose an immediate systemic threat such as: superficial wound infection (excluding stitch abscess), pneumonia, and urinary tract infection (UTI)[4]. Complications were considered major if they posed a risk of mortality or damage to an organ such as: deep wound infection, cardiopulmonary complication, DVT/PE, cerebrovascular complication, neurologic deficit, sepsis, revision, and death[4]. In terms of validity and reliability, NSQIP data have been validated by routine audits (50% of participating institutions are audited annually), and standardized procedures for identifying and reporting adverse events[20]. Each site had two nurses rigorously trained as surgical clinical reviewers to collect data from the patient's medical record, communication with the surgeon, and patient phone calls, leading to interrater disagreement of less than 1.8%[20].

2.2.1 Risks of early adverse events following TKA

A review of 11,814 patients within the NSQIP who underwent elective primary TKA between January 1st 2011 and December 31st 2011 reported reasons for readmission within 30-days post-operative[21]. The 30-day readmission rate was 4.6%, with 21.5% of those patients undergoing revision surgery[21]. Of the 4.6% readmitted, 34% were due to a major complication (ie. revision, deep infection, sepsis, and myocardial infarction) and 40% were due to a minor complication (ie. superficial infection, pneumonia, UTI, and DVT)[21]. A 1.1% mortality rate was observed. Further, they found age greater than 45, male gender, chronic obstructive pulmonary disorder status, chronic congestive heart failure status, hypertensive status, diabetic status, presence of metastatic cancer, peripheral vascular disease, dialysis, and presence of a bleeding disorder were associated with a statistically significant higher rate of readmittance ($p < 0.05$)[21].

A review of 17,784 patients within the Mayo Clinic Total Joint Registry (MCTRJ)[i] who underwent TKA between 1981 and 2004 found a 30-day superficial wound-healing complication rate requiring surgical intervention of 0.33% (95% CI 0.25-0.43)[22]. Further,

[i] The MCTJR has been collecting pre and post-operative data on total joint replacement patients since 1969[55]. Since 1993, pre-operative data are recorded by surgeons using a standardized collection form and post-operative data are collected from chart review, surgeon communication, and patient reported questionnaires using an electronic database[55]. Trained staff ensure the completeness of all data.

these patients had an increased risk of major surgical intervention by five years (5.3%) compared to patients without wound-healing problems within 30-days post-operative (0.9%). However, they did not include patients with less severe wound problems that were treated non-operatively. The MCTJR was also used to evaluate 5714 TKAs between 1997 and 2003[23]. They found MUA was required in 399 patients (6.9%), indicating the rate of stiffness after TKA[23].

In addition, a retrospective chart review of an institutional readmission database in St. Louis tracked readmission rate within 90-days post-operative in 2221 TKAs performed between January 2005 and January 2010[24]. A fellowship-trained orthopaedic surgeon blinded to patient follow-up found 121 readmissions (5.4%). 54 (45%) of the readmissions were for medical complications unrelated to the procedure, 22 (18.2%) for limited ROM, 17 (14%) for non-infectious wound complications, 12 (9.9%) for deep infection, 12 (9.9%) for bleeding complications, and four (3.3%) for DVT/PE[24].

2.2.2 Risks of early adverse events following arthroscopy

A retrospective chart review of 12,271 knee arthroscopy patients who underwent surgery between January 1st 2005 and December 31st 2010 had 30-day minor morbidity, major morbidity, and mortality data collected by the NSQIP[6]. They found 30-day complication rates of 116 (0.95%), 123 (1.01%), and 1 (0.01%) for minor morbidity, major morbidity, and mortality respectively[6]. Minor morbidity was described as a complication localized to the surgical area or not posing an immediate systemic threat such as: superficial wound infection (excluding stitch abscess), pneumonia, and urinary tract infection (UTI). Major morbidity was described as major if they posed a risk of mortality or damage to an organ such as: deep wound infection, cardiopulmonary complication, DVT/PE, cerebrovascular complication, neurologic deficit, sepsis, revision, and death.

A study reviewed the English National Health Service (NHS) which collected data from the administrative hospital admissions database containing data from every NHS patient who underwent knee arthroscopy between March 2005 and August 2010[7]. The 30-day readmission rate of 0.55% (1662) for 301,701 knee arthroscopies identified using codes comprised of wound complications 0.26% (677), unplanned re-operations 0.34% (1033),

and DVTs 0.12% (369)[7]. Arthroscopy was defined as any endoscopic knee surgery with therapeutic intent including ligament reconstruction (5.5%) and meniscal surgery (35.4%)[7]. A patient was classified as having an unplanned re-operation if they did not have an International Statistical Classification of Diseases (ICD) – 10 code designating surgical leg, or underwent another arthroscopic surgery on the same knee within 30 days[7]. They also found 90-day DVT/PE, and all-cause mortality rates in this population to be 0.19% (580), and 0.02% (47)[7].

2.2.3 Risks of early adverse events following ACL reconstruction

In a review of 13,941 ACL reconstructions performed between March 2008 and February 2010 and recorded by the English NHS found the 30-day re-admission rate was 1.36% (190) and the wound complication rate was 0.75% (104)[11]. Thirty-five patients with a wound complication received an additional surgery to wash out the joint, classifying them as having a deep infection[11].

A review by Cvetanovich et al. using the NSQIP database, of 4933 ACL reconstructions that took place between 2005 and 2013 found an overall complication rate of 1.34% (66), broken down into 0.55% (27) and 0.87% (43) for major and minor complications respectively. They defined DVT as a minor complication, in contrast to previous studies utilizing the NSQIP database[3]. The most common major complications they found were deep infection 0.14% (7), PE 0.12% (6), and re-operation 0.36% (18)[3]. Minor complications included DVT requiring treatment 0.55% (27), superficial infection 0.2% (10), and UTI 0.06% (3)[3].

2.2.4 Risks of early adverse events in HTO

Early adverse event data in MOW HTO patients are limited, but a retrospective study of 138 MOW HTO patients performed between 2002 and 2008 using T-plate fixation and autologous bone graft had 20 complications (14%) within three-months post-operative[2]. The categories of complications were developed during chart review and they were infection 2.16% (3), loss of correction 4.34% (6), broken screw 2.16% (3), joint fluid leak 2.89% (4), iliac bone fracture 2.16% (3) and pseudoaneurysm 0.72% (1)[2].

A study by Birmingham et al. used an observational cohort study design to prospectively follow 126 patients who underwent MOW HTO with a non-locking plate (Arthrex) between November 2002 and December 2007. They found three patients with delayed union, four with an infection (requiring surgical treatment), and one with a hematoma (requiring surgical treatment) for an overall early adverse event rate of 6.35% (8/126).

A systematic review of MOW HTO screened 1,383 articles to find 56 articles describing delayed union rates when utilizing non-locking or locking plates, and allograft, autograft, or no osseous filling[9]. They searched Medline, Embase, PubMed, and The Cochrane Library up to January 1st 2014. They found delayed union rates of 4.6%, 2.6%, and 1.3% for 787 bone allograft, 895 bone autograft, and 526 no osseous filling HTO cases using a non-locking plate[9]. Delayed union was found in 12.3% and 1.4% of 89 bone allograft and 419 no osseous filling HTO cases using a locking plate[9]. However, the weakness of this study was the high number of case-series studies (43) and low number of comparative studies (1), most of the studies were level IV evidence[9]. Furthermore, using the Methodological Index for Non-Randomized Studies (MINORs), the case-series studies scored 10/16 and the comparative study scored 19/24 indicating "fair" quality[9].

A study by Martin et al. retrospectively reviewed 323 MOW HTO procedures from September 2005 to August 2009 for adverse events. Medical records, radiographs, and laboratory tests were reviewed by an orthopaedic surgeon unrelated to patient care. Wound issues (infection/delayed healing), hematoma, surgical complications (tibial plateau/lateral hinge fracture), compartment syndrome, and general complications (UTI) were observed in the first six-weeks post-operative. DVT, stiffness, CRPS, and delayed union were assessed using data from the first six-months post-operative. Lastly, non-union, hardware failure, and infection were reviewed using data from a minimum of 12-months post-operative. They found complication rates of 39.6% for complications not requiring additional treatment, 29.5% requiring short-term non-operative treatment, and 7.2% requiring an additional surgery or long-term non-operative treatment[10]. Complications in the first group were increased tibial slope >10° (1%), positive culture for cancellous bone allograft (2%), undisplaced lateral tibial plateau fracture (2.8%), hematoma (2.8%), delayed wound healing (5.6%), displaced lateral hinge fracture

(5.6%), and undisplaced lateral hinge fracture (19.8%)[10]. Complications in the second group were stiffness (1.3%), DVT (1.3%), CRPS type 1 (1.3%), limited hardware failure (4%), cellulitis (9.6%), and delayed union (12%)[10]. Complications in the third group were hardware failure with loss of correction (1%), CRPS type 2 (1.3%), deep infection (1.7%), and non-union (3.2%)[10]. Furthermore, they reported 4% (12/300) of their cases were readmitted to the hospital due to complications for deep infection (5), non-union (3), and MUA for stiffness (4)[10].

2.3 Digital Health

Digital health is a broad term for supplying healthcare at a distance through telecommunication, or the internet using personal computers or smartphones[25–27]. This form of healthcare delivery came about to increase access to healthcare for individuals in remote areas or those who cannot readily travel to receive healthcare. Its uses are in consultation, specialty referral, providing patient/physician education, booking appointments, viewing historical patient information, and monitoring patient-reported information[25–28]. The Canadian Internet Registration Authorities (CIRA) annual internet tracking study surveyed 1,200 adult Canadian internet users, and 350 small and medium sized enterprise decision-makers. They reported 88.5% of Canadians had access to digital health resources through the internet in 2015[29]. Furthermore, the internet tracking study found in 2015, Canadians spent on average 36.7 hours per month (most in the world) viewing an average of 3,238 unique web pages, making Canadians large and diverse consumers of the internet[29]. The National Physician Survey (NPS) in Canada invited 63,817 physicians to complete the survey in 2014 and received 10,191 responses, for a rate of 16%[30]. According to the 2014 NPS, 72% of Canadian primary care physicians have referred patients to web-pages for information about their healthcare[30]. Furthermore, CIRA state 30% of Canadians use the internet to look for health and medical information[29].

Catalyst Canada surveyed 1,000 Canadian smartphone owners over 18 years of age online in December 2015[31]. They then surveyed 1,000 adults in April 2016 where smartphone ownership was not a prerequisite. They stated demographic breakdown

between the two surveys was similar, but did not show the data. Despite demographically matching their samples to the Canadian census for generalizability, they did not release respondent rates or their recruitment methods[31]. These surveys found that Canadian smartphone ownership is 76%, an increase of 38% from their survey in 2014[31]. Further, 30% of those surveyed had one or two health related smartphone applications (app) compared to 25% in 2013 and millennials were more likely to have a health app than someone over 35[31].

In 2012, the Canadian Medical Association (CMA) reviewed physician smart device utilization by surveying 22,000 randomly selected CMA members[32]. Of those surveyed, 2,140 responded; 68% of responding physicians use their smartphone and/or a a tablet (29%) to aid them in their practice[32].

A review by Kulendran et al. of the App Store for iPhone iOS conducted on March 11, 2013, found 500 apps across multiple specialties that were designed for physicians and patients [33]. The breakdown of apps by specialty was 38% general surgery, 24% plastic surgery, 16% orthopaedic surgery, 10% urology, 7% cardiac surgery, and 5% neurosurgery[33]. These apps utilized unique features of smartphones such as the camera, GPS, internet connectivity and touch screen to either provide information to patients/clinicians, or record and send information from patients/clinicians. Of the 79 apps focused on orthopaedic surgery, 61 were intended for clinician users and 18 toward patient users[33]. The content of the apps span clinical training, clinician networking, student education, patient education, textbooks, classification systems, general orthopaedics, radiology, research, measurement tools, and anatomy[33].

Electronic surveillance systems have the potential to have a large impact on the healthcare system in terms of cost and patient experience. These surveillance systems allow patients with chronic conditions such as diabetes or congestive heart disease to monitor themselves by entering data about their symptoms using a smart device[27]. Furthermore, electronic surveillance systems may be used for acute post-operative monitoring of patient's symptoms to establish presence of an adverse event. This method of digital health is called "store-and-forward", where patient reported data is inputted,

then sent to an intermediate. Clinicians can access the data from the intermediate at a time to assess their patient's well-being, eliminating the need for numerous post-operative visits to the clinician. Examples of data that have been collected remotely by smartphone using store-and-forward technology include communicating symptoms via text messaging, completing validated questionnaires with patient important questions centered around symptoms of adverse events, photographs of surgical sites, ROM, blood pressure or oxygen saturation through wearable devices[27,34].

2.3.1 e-Visits in outpatient clinics

Prospective post-operative electronic surveillance for post-operative patients using the store-and-forward method has shown promise as a tool for future patients [27]. In 2011 in a study by Wood et al., 40 patients who had a primary hip or knee arthroplasty and who were between a year and five years post-operative were asked to have radiography completed at their closest community hospital to recreate true travel time and costs associated with a web-based assessment. The web-based assessment consisted of the group's standard clinical questionnaires including the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and Short Form 12 (SF12) Health Survey. In terms of feasibility, all patients required a reminder to complete the web-based assessment, 97.5% of patients stated the instructions were clear, 95% stated they found the web-based assessment more convenient and would prefer it over future outpatient assessments[13]. However, 30% of their patients stated they had issues logging into the system and there were 20 data points missing, identifying some of the barriers to seamless function[13]. In terms of average patient time commitment, the web-based assessment group spent 52 min attending to their follow-up visit including travel time, web evaluation, and time to complete the radiograph, whereas the regular outpatient group spent 115 min[13]. The group did not find any adverse events, limiting their assessment of the sensitivity and specificity of the web-based assessment to accurately identify adverse events, but they concluded that their pilot study supports the practicality of web-based assessment for arthroplasty patients.

Another prospective RCT led by Marsh et al. found similar results in a cohort of 229 knee and hip arthroplasty patients who were at least a year post-operative[14]. The patients were recruited between March 2010 and March 2011 and randomized to either regular outpatient follow-up (n=111) or web-based follow-up (n=118). The web-based follow-up consisted of standard of care questionnaires, radiography at a facility with online accessibility for the surgeon, and two questions indicative of what their surgeons ask their patients: 1) "Do you have any pain or symptoms in your replaced joint?" and 2) "Do you have any problems in the other hip or knee?". When these were completed, the surgeon was notified by the web-based system to review the x-ray and questions. If the patient selected yes to either of the two questions, or if the surgeon deemed there were issues on the radiographs, then the system sent the administrative assistant an email to book an in-person appointment for the patient (including triaged timeframe for the appointment either immediately, within one month, or within six months depending on the surgeons' opinion of the urgency)[14]. The system also sent an email to the patient letting them know the results of the web-based assessment and whether or not an in-person appointment was required. If there were no issues, then the patient was scheduled for their next appointment a year later. In terms of feasibility, the group had 410 eligible patients and got 256 to participate. "Lack of computer/internet" was the most frequent reason for non-consent (24%) followed by "having significant problems or pain (10%), followed by "preference to see the surgeon in person" (14%)[14].

In terms of adverse events, 25 patients reported pain or problems, and of those 25, 16 also had radiographic issues identified by the surgeon[14]. When subsequently seen in clinic, eight of the 25 patients were identified as having a significant issue; three patients had pain in the operative joint and five had osteoarthritis in the contralateral joint[14]. The group reported that 83 of the 95 remaining web-based patients were seen in clinic a year later and none of them had an issue that was missed by the web-based system.

In terms of patient time commitment, web-based patients spent 121.7min per appointment compared to 228.7min for the regular outpatient group and their caregivers spent 44.1min compared to 127.2min for the web-based group and regular outpatient group respectively[14]. Also, Marsh et al. administered satisfaction questionnaires to the

web-based cohort and found that 44% of patients preferred the web-based assessment, 36% preferred usual care, and 16% were indifferent[35]. Furthermore, 92% of usual care patients were satisfied with their care compared to 73.9% in the web-based group[35]. An additional economic analysis was done by Marsh et al. for this cohort and found societal cost saving was $64 (95% CI $48 – $79) per appointment for patients who participated in the e-Visit group and healthcare payer cost saving was estimated $27 (95% CI $25 – $29) per appointment[15]. Societal costs were cut by reducing time missed from work, travel, accommodation and food costs. and other resources associated with coming into the clinic[15]. Healthcare payer costs included emergency room visits, inpatient hospitalization, primary care physician visits, specialist visit, imaging, medical tests, and medications[15]. They assumed the software licensing fee ($15 per patient for practice with 100 patients per year), and the billing fee for a web-based assessment ($24 per appointment)[15]. Patients filled out the cost information every three months for a year to limit recall bias.

A group from Sweden developed and prospectively evaluated the Swedish Web-version of Quality of Recovery (SwQoR) questionnaire to assess post-operative recovery in outpatient surgery[36]. The questionnaire contained 31 questions that used an 11-point VAS. The final question asked: “Would you like to be contacted by a nurse?”, the patient had the option of selecting “yes” or “no”. If they selected “yes”, they could type their issue into the app and the nurse would respond in kind. The group asked 69 patients with smartphones to complete the SwQoR each day for seven days post-discharge, at which point they were called by a member of the research team and were asked satisfaction questions. This feasibility study reinforced the idea that patients need reminders to complete the forms online. Furthermore, through their satisfaction questionnaire, they showed positive attitude towards using the app with median score of 69 (IQR 66-73, range 45-77) where the minimum score was 11 and the maximum possible score was 77[36].

The study by Semple et al. evaluated feasibility and satisfaction of a daily electronic surveillance system using a validated quality of recovery scale (QoR-9) and photographs of the surgical site for 30 days post-operative. The study began in October 2011 and they asked sixty-five patients (33 breast reconstruction, 32 orthopaedic surgery) to complete

the questionnaire and take photographs daily[37]. This data was reviewed daily by their surgeon to assess their recovery. They found that on average, patients responded more in the first 14 days than in the last 15 to 30 days for both breast reconstruction (mean log-in frequency 13.4 vs 10.5 $p<0.001$) and orthopaedic patients (mean log-in frequency 13.4 vs 6.0 $p<0.001$)[37]. With daily data, the surgeons could observe complications in real-time, before the regular outpatient appointment. Of importance is that none of the patients presented to the outpatient clinics with complications that were not first observed in the system. In terms of satisfaction, breast reconstruction patients scored 3.9/4 and orthopaedic patients scored 3.7/4, indicating high satisfaction[37]. Furthermore, the surgeons reported that the design was easy to navigate, they enjoyed the portability and flexibility, they appreciated the ability of the system to increase time efficiency, and they would feel comfortable decreasing the number of outpatient appointments if daily monitoring were used[37].

Kingsbury et al. retrospectively evaluated if a paper questionnaire and radiograph were accurate in determining TKA/THA follow-up classification. They included patients who attended an arthroplasty care practitioner (ACP)-led outpatient follow-up appointment for primary TKA/THA between October 2011 and September 2013. At the outpatient clinic, ACPs assessed 401 THA and 198 TKA patients using the paper questionnaire, radiographs, and a physical exam to produce a follow-up classification[38]. The ACP and a senior orthopaedic surgeon independently reviewed each case at the end of each clinic day and each provided a classification for each patient of either; immediate review by surgeon, annual monitoring, long-term follow-up (two to five years), and discharge[38]. The questionnaire used included dichotomous questions about problems with their joint, pain status, pain medication status, gait aid status, if the operation helped function in daily activities, and satisfaction of their outcomes. A blinded senior surgeon then reviewed the radiographs and questionnaires separately, then together, producing a follow-up classification for each scenario. The agreement (kappa) between the ACP and the blinded senior surgeon for TKA was 0.81 (95% CI 0.74-0.88) and for THA was 0.69 (95% CI 0.62-0.76)[38]. However, both showed high percent exact agreement with 88% for TKA and 79% for THA[38]. Furthermore, kappa was high for both TKA (0.90) and THA (0.84) because the ACP selected few patients to be seen urgently (TKA=16, THA=34),

increasing the likelihood the ACP and senior surgeon would agree by chance[38]. Both TKA and THA showed higher percentage agreement for the discharge (TKA=94.3%, THA=85.7%) and long-term follow-up classifications (TKA=90.2%, THA=88.5%) compared to immediate review (TKA=73.2%, THA=53.5%) and annual monitoring (TKA=37.5%, THA=47.9%)[38]. The blinded senior surgeon reviewing the questionnaire and radiographs did not miss any patients in need of increased observation when reviewing both aspects together. However, for TKA when radiographs and questionnaire were reviewed separately, they caught only 8% (2) and 66% (16) of the patients requiring urgent review[38]. Lastly, they randomly selected radiographs and questionnaires 12 months after initial review from 45 THA patients to assess intra-rater reliability and found identical decisions made by the senior surgeon 98% of the time[38].

2.4 Summary

Early adverse events following orthopaedic surgery are often rare, but when present, may be devastating if treatment is delayed. Early adverse events include infection, DVT, PE, delayed union, stiffness and complex pain syndrome. Often, signs and symptoms of these adverse events display themselves recognizably to patients, which allows accurate answers to subjective questions pertaining to adverse events. Greater patient education may increase a patient's ability to answer subjective questions about adverse events. Diagnostic imaging and patient related risk factors for adverse events are also important in determining the likelihood of an adverse event.

The number of orthopaedic operations in Canada are increasing every year and surgeons are being put under more pressure to decrease their wait lists without substantial funding increases[39,40]. As early adverse events are often rare and early orthopaedic outpatient follow-ups for routine operations are often unremarkable, this area of clinical care may be optimized using web-based technologies. With increasing technological capabilities and technological savvy amongst Canadian patients and physicians, methods of patient-reported data collection such as smartphones have come to the forefront. These methods have been shown to be feasible and decrease time requirements for patients and physicians. One of the objectives of this research study will be to develop a diagnostic

tool (e-Visit) and associated algorithm to predict the likelihood of an early adverse event following orthopaedic surgery.

Chapter 3

3 Objectives

The primary objective of this study was to develop a model to predict an early adverse event following orthopaedic surgery compared to the gold standard of in-person assessments and to evaluate its accuracy. Secondary objective includes a similar evaluation of a simplified model.

Chapter 4

4 Methodology

4.1 Study Design

This was a single-center prospective cohort diagnostic validity study using a consecutive sample of patients who underwent elective orthopaedic sport surgery or arthroplasty. The study coordinator assisted the patient in creating an account on a secure web-based data management system (EmPower Health Research, Inc, www.empowerhealthresearch.ca). Patients were provided with a unique username and password, allowing them to remotely log in and access the e-Visit, and demographic forms as per their standard post-operative visit schedule (Appendix A). If patients did not complete the forms prior to their appointment, they had an option to use iPads (Apple) in the clinic, or their own device. In situations where iPads were not feasible, patients completed the questions using paper forms. Paper copies were then inputted into the database.

During the patient's follow-up visit, the surgeon completed a form detailing whether they felt that the patient needed to be seen in clinic that day. The criteria for classifying a patient as needing to be seen was any abnormal sign, symptom, or disease shown by the patient. The study took place from September 2016 to April 2017 at the London Health Sciences Center, Rorabeck Bourne Joint Replacement Clinic and Fowler Kennedy Sport Medicine Clinic, London Ontario. The study was approved by the institutional Health Sciences Research Ethics Board (Appendix B).

4.2 Eligibility Criteria

Patients 15 years of age or older who underwent a TKA, HTO, ACL reconstruction, MPFL reconstruction, meniscal surgery or knee arthroscopy by an orthopaedic surgeon at London Health Sciences Center University Hospital were eligible for the study. Patients were ineligible if they were unable to speak English or if cognitive impairments rendered them unable to complete the forms.

4.3 Patient Recruitment

Patients were screened by the study coordinator prior to their first post-operative appointment. The study coordinator described the study, presented the Letter of Information (Appendix C), and answered any questions regarding participation. Upon agreeing to participate, the patient signed the consent form and completed the e-Visit. Patients could complete the e-Visit online up to three days before their in-person appointment, until they met with their surgeon.

4.4 Descriptive and Predictive (Independent variables):

4.4.1 Demographic Information

We collected sex, age, BMI and eight known risk factors for adverse events. These included the presence or absence of diabetes (type I, II), rheumatoid arthritis, autoimmune disorder, hemophilia, organ transplant, previous post-operative infection requiring surgical intervention, previous surgery on the index knee, and any previous surgery.

4.4.2 e-Visit Questionnaire

We created the e-Visit questionnaire (Appendix D) to represent the flow of a clinical assessment. The questions were designed to elucidate for the surgeon whether a patient had an adverse event and what the adverse event may be, without having the patient come in for a clinical assessment. We also included questions that may offer the surgeon a larger picture of their patient's recovery, aiding them in making clinical decisions. For example, "Do you have any concerns that you would like to share with your surgeon?".

The e-Visit questionnaire had 21 questions; including 11 questions with skip logic, covering eight domains of post-operative recovery and questions as to whether the patient felt they needed or wanted to be seen. The questionnaire was developed by two orthopaedic surgeons with greater than 15 years' experience each, one with expertise in sport medicine and the other in arthroplasty. Each reviewed the signs and symptoms of early adverse events and proposing questions that reveal the signs and symptoms to

clinicians for review. After clinician review, questions were added, removed, or altered based upon clinician perceived importance.

4.5 Outcome (Dependent variable): Surgeon's Data Form

The surgeon's data form (Appendix E) was completed by the surgeon after the clinical examination. First, the form asked the surgeon if they felt the patient needed to be seen in clinic. If the surgeon selected no, then the patient could have continued their recovery without the examination. If the surgeon selected yes, then there was an option for the surgeon to indicate the aspect(s) of the patient's recovery that warranted the appointment. Categories of issues included pain, incision, discharge, knee effusion, swelling, joint stability, ROM, constitutional symptoms, and re-injury. The surgeon selected the "other" box and added comments if the checklist did not encompass the patient's identified issue. Changes in management of the patient (ie. prescription) were recorded if any changes occurred. Surgery performed, and surgical characteristics were completed by the surgeon. Finally, the time at which the patient finished their clinical examination was recorded.

4.6 Estimation of Sample Size

We assessed our sample size required for this pilot study based on the number of knee surgeries performed by sport and arthroplasty orthopaedic surgeons at University Hospital during the allocated time for degree completion (approximately 11 months remaining from REB approval). As adverse event rates following knee orthopaedic surgery are low, it was not feasible to recruit a sample size based upon event rates. Thus, we recruited a convenience sample of 350 patients.

4.7 Plan for Statistical Analyses

4.7.1 Descriptive Statistics

Statistics were calculated using IBM SPSS Statistics version 22 (IBM Corp., Armonk, NY). We used descriptive statistics (mean/median, minimum, maximum, standard deviation) to summarize continuous data and proportions for categorical data.

4.7.2 Diagnostic Validity of e-Visit

We constructed two logistic regression models where the dependent variables were the necessity to come into clinic for an in-person appointment 1) at two and 2) six weeks and the independent variables included questions from the e-Visit questionnaire and individual patient risk factors.

4.7.2.1 Model Construction

1. *Raw data models:* We constructed our logistic regression models using the backward method to pick relevant predictors and compute their model coefficients and ORs[41]. We used an exclusion threshold of greater than 0.1. Variables with anecdotal clinical relevance that were removed during logistic regression were added back into the model using an enter method.
2. *Simplified models:* We then developed a simplified model such that each continuous predictor was dichotomized for ease of use and interpretability. To dichotomize the continuous predictors, we generated receiver operator characteristic (ROC) curves to establish the most efficient cut-point for each predictor. Cut-points were assessed as the value with the highest positive likelihood ratio. We ran backwards logistic regression using the new dichotomized predictors and a threshold of 0.1 to generate the simplified model.
3. We calculated tolerance, Studentized residual, leverage, and dbeta for the two and six-week raw data and simplified models[42] to ensure the data met the assumptions of the model. Further, we used the Hosmer and Lemeshow test and Nagelkerke R^2 to assess goodness-of-fit.
4. Using each model's predictive probabilities computed during logistic regression as the test variable and surgeon's recommendation as the state variable, we calculated ROC-AUC. We hypothesized the difference in AUC between raw data and simplified models would be less than 0.05[43]. We then assessed each model's sensitivity and specificity.
5. Further, we used the model's prediction as to whether the patient needed to be seen and the surgeon's opinion (gold standard) to determine agreement using

Cohen's kappa. Since we expected a low event rate, we planned to use an adjusted Kappa. Low-event rates cause marginals of the 2 x 2 classification table to become unbalanced, creating a paradox of low Kappa with a high percentage of correctly predicted outcomes[44–46]. A prevalence and bias adjusted Kappa (PABAK) using the proportion of overall observed agreement, as well as bias (BI) and prevalence indices (PI) with unadjusted Kappa scores have been proposed to circumvent this paradox. PI (difference in overall proportion of positive results and overall proportion of negative results) range from negative one to one and a negative sign denotes a higher proportion of "No" selections than "Yes". A positive sign denotes the opposite. BI (difference in proportion of positive results between raters) range from negative one to one and a negative sign denotes a higher proportion of gold-standard classified positive results. A positive sign denotes the opposite. PI and BI values close to zero have little effect on Kappa.

Chapter 5

5 Results

5.1 Patient Demographics

Three-hundred and fifty unique patients completed the e-Visit questionnaire at one or both of a two and six-week post-operative appointment (Sports=217; Arthroplasty=133). Baseline demographic characteristics are presented in Table 1 and a breakdown of participation flow during the study is presented in Figure 1.

Table 1: Patient Demographics

Characteristic	**Recruited (350)**	**Sport Surgery (217)**	**Arthroplasty (133)**
Sex (male, %)	187 (53.3)	133 (61.3)	54 (40.6)
Age (mean, SD)	48.3 (18.6)	37.3 (14.1)	66.1 (8.3)
BMI (mean, SD)	28.9 (6.2)	27.1 (4.8)	31.9 (7.1)
All previous surgeries (mean, SD)	2.6 (2.9)	1.63 (2.1)	4.3 (3.4)

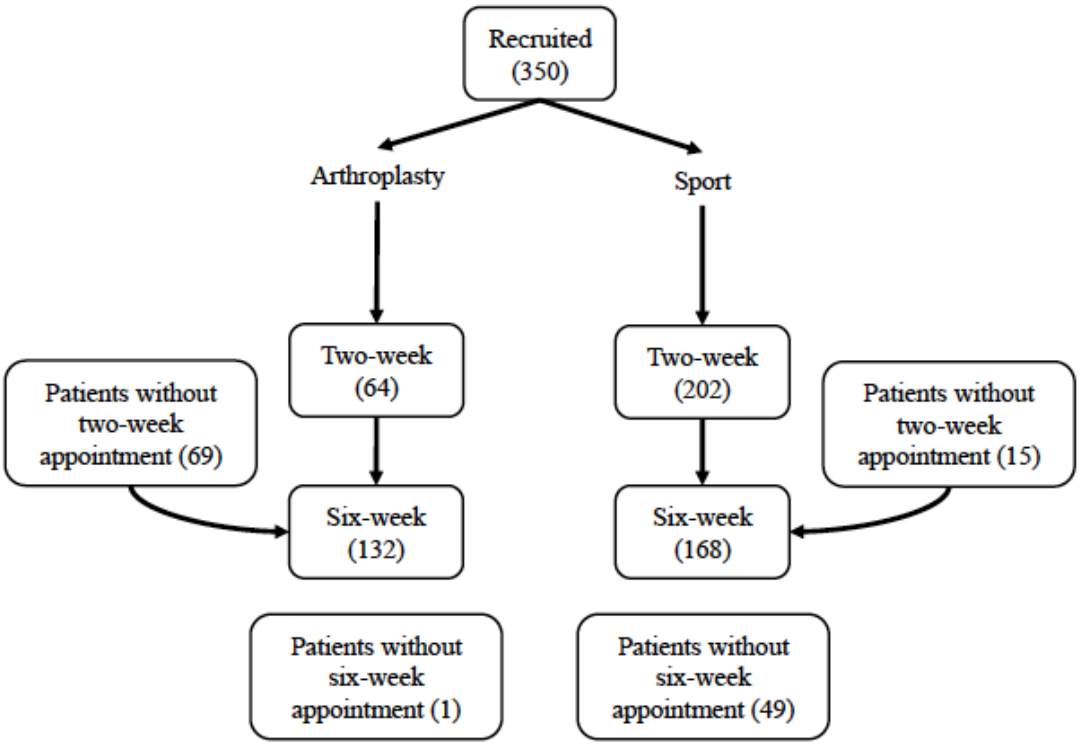

Figure 1: Participant Flow

5.2 Appropriate Appointments

At the two and six-week time-points, 65 (24.3%) and 97 (32.4%) patients were classified as needing to be seen for their clinic appointment. At two-weeks 40 (20%) sport and 25 (40%) arthroplasty patients were classified as needing to be seen. Furthermore, at six-weeks 38 (22.6%) sport and 57 (43.2%) arthroplasty patients were classified as needing to be seen. Table 2 provides a breakdown of reasons the clinician felt the patient needed to be seen. For some patients, the clinician gave multiple reasons for needing to be seen (for example, unexpected extension and flexion deficits), which is why the total proportion is greater than 100%. “Other” reasons for needing to be seen at two weeks were non-compliance with post-operative rehabilitation protocol (n = 1), to discuss further surgical options (n = 2), and general reassurance (n=3) and at six weeks “Other” reasons included a hardware issue (n = 1), general reassurance (n = 6), a nervous system issue (n = 1), and non-compliance with post-operative rehabilitation protocol (n = 2).

Table 2: Surgeon's reasons for patients to be seen

Reason (%)	**Two-week Appointment 65 (24.3)**	**Six-week appointment 97 (32.4)**
Pain	17	21
Wound	16	13
Effusion/Swelling	21	15
Function	1	5
Extension Loss	22	42
Flexion Loss	14	29
Constitutional	1	2
Re-injury	1	1
Other	6	10
Total	**99**	**138**

5.3 Model Diagnostics

There was no evidence of multicollinearlity as tolerance for the predictors in each model were greater than the recommended cut-off of 0.2[42]. The Studentized residual statistic was within negative three and positive three, indicating that the cases fit the models[42]. Three cases exceeded "multiple times" the expected leverage and had a Cook's D of greater than one or less than negative one. These cases were deemed to influence the regression coefficients too heavily and were therefore taken out of the two-week raw data model[42]. Expected leverage was calculated by $((k+1)/n)$[42]. The other three models included all cases because there were no excessive outliers or cases identified as influential. The Hosmer and Lemeshow test for goodness of fit showed non-significance

for all models, indicating that the models fit their data (Table 3)[47]. However, Nagelkerke R^2 values were low, representing a weak relationship between the predictors and the dependent variable of surgeon's recommendation[47].

Table 3: Goodness of Fit

Model	**Hosmer and Lemeshow** χ^2_{8df} **(*p*-value)**	**Nagelkerke R^2 (range = 0 – 1)**	**R^2 (range = 0 – 1)**
2-Week Raw Data Model	5.5 (0.70)	0.30	0.19
2-Week Simplified Model	10.1 (0.25)	0.32	0.19
6-Week Raw Data Model	4.72 (0.78)	0.30	0.25
6-Week Simplified Model	6.15 (0.63)	0.31	0.25

5.4 Predictor Contribution

The ORs with 95% CI and p-values for the two and six-week raw data models are presented in Tables 4 and 5 below. In the two and six-week raw data models, the predictors with the highest OR were questions 7a and 20, respectively. Patients who reported their wound looking red and infected were about four times more likely to be classified as needed to be seen than patients who did not. Likewise, patients who stated they were not content with their recovery were about three times more likely to be classified as needed to be seen. Conversely, when patients responded at six-weeks that they felt clicking or locking in their knee and that they were attending physiotherapy, they were 40% and 60% less likely to be classified as needed to be seen.

Table 4: 2-Week Raw Data Model

		95% CI		
Predictor	**Odds Ratio**	**(Lower)**	**(Upper)**	**P-Value**
2b. Is the pain localized to your knee or whole leg?	1.17	0.79	1.73	0.44
2h. Does taking medication lessen your pain?	1.20	0.62	2.32	0.59
7a. Do any of your incisions have redness/ red streaks indicative of infection?	23.05	2.12	250.84	0.01
8. Have you had any fluid leak from your incisions and/or arthroscopy portals in the last week?	3.81	1.34	10.82	0.01
9. Check the box next to the image that best represents how straight you can make your surgical leg.	1.18	0.78	1.78	0.44
10. Check the box next to the image that best represents how bent you can make your surgical leg.	1.30	1.02	1.66	0.03
17. Emergency (hospital)	2.65	0.69	10.08	0.15
20. Are you content with your overall progress after surgery?	3.83	1.72	8.52	0.00

R8. How many surgeries have you had in the past, not including this past knee surgery?	1.10	0.95	1.27	0.21
R2. Do you have diabetes?	17.71	1.71	183.36	0.02

Table 5: 6-Week Raw Data Model

		95% CI		
Predictor	**Odds Ratio**	**(Lower)**	**(Upper)**	**P-Value**
2b. Is the pain localized to your knee or whole leg?	1.35	1.00	1.80	0.04
6. Have you experienced any clicking or locking sensations in your knee since your surgery?	0.61	0.34	1.10	0.10
9. Check the box next to the image that best represents how straight you can make your surgical leg.	2.12	1.42	3.18	0.00
10. Check the box next to the image that best represents how bent you can make your surgical leg.	1.21	0.94	1.55	0.12
15. Are you going to physiotherapy or doing exercises on your own?	0.41	0.17	0.96	0.04
17. Emergency (hospital)	2.05	0.65	6.43	0.21

19. Do you have any concerns that you would like to share with your surgeon?	1.91	1.05	3.47	0.03
20. Are you content with your overall progress after surgery?	2.91	1.33	6.36	0.00
R8. How many surgeries have you had in the past, not including this past knee surgery?	1.04	0.95	1.14	0.32
Sex	1.51	0.85	2.69	0.15

5.5 Agreement

The two-week model had a Cohen's kappa of 0.39 (95% CI 0.25 - 0.53), representing fair strength of agreement between the model's predicted group allocation and the gold standard surgeon recommendation. PI, BI, PABAK, and percent of observed agreements were -0.64, -0.10, 0.62, and 81%. The six-week model performed similarly with a Cohen's kappa of 0.38 (95% CI 0.27 - 0.49) representing fair strength of agreement. PI, BI, PABAK, and percent of observed agreements were -.47, -.05, 0.52, and 76%.

5.6 ROC – AUC and Accuracy

The ROC curves calculated for the two and six-week raw data models are presented in Figures 2 and 3. The AUC for the two-week model was 0.76 (95% CI 0.69 - 0.84) and the AUC for the six-week model was 0.80 (95% CI 0.74 - 0.85). From these scores, both models are in the "good" range of diagnostic accuracy[48].

The accuracy of the two-week raw data model was good with a sensitivity of 0.70 and the specificity of 0.83. The accuracy of the six-week raw data model was also good with a sensitivity of 0.70 and a specificity of 0.80.

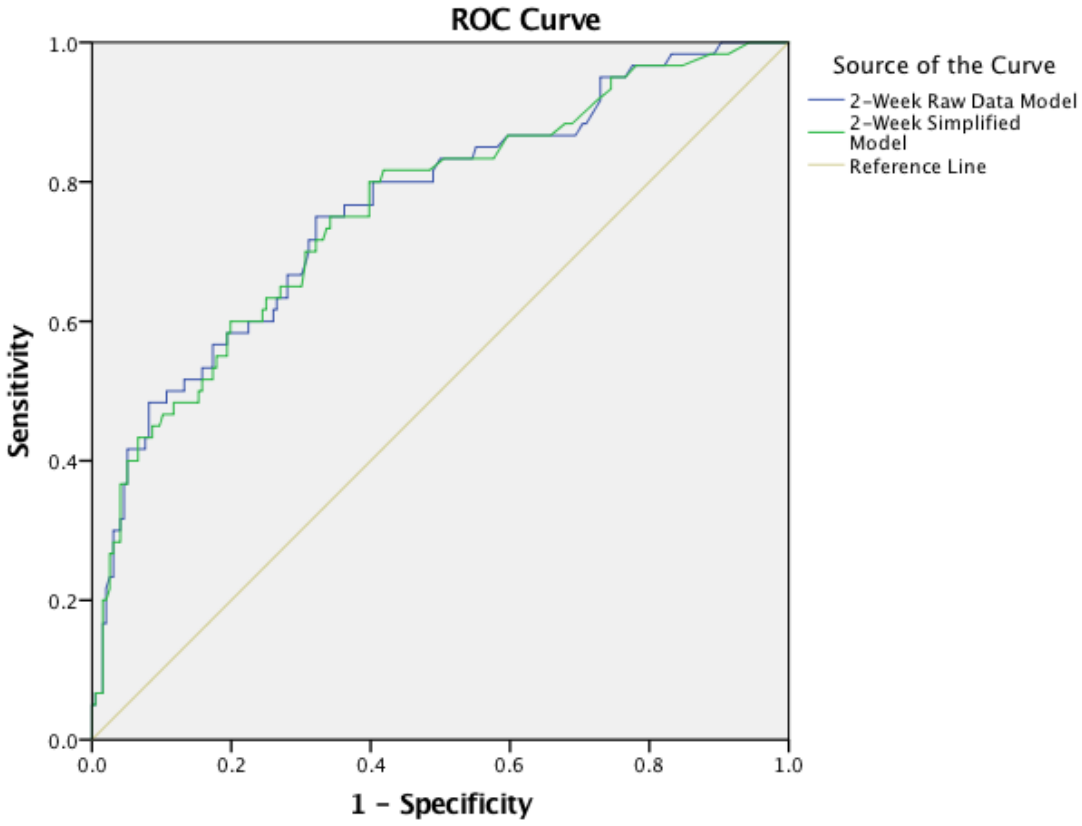

Figure 2: Two-week Raw Data and Simplified Models ROC-AUC

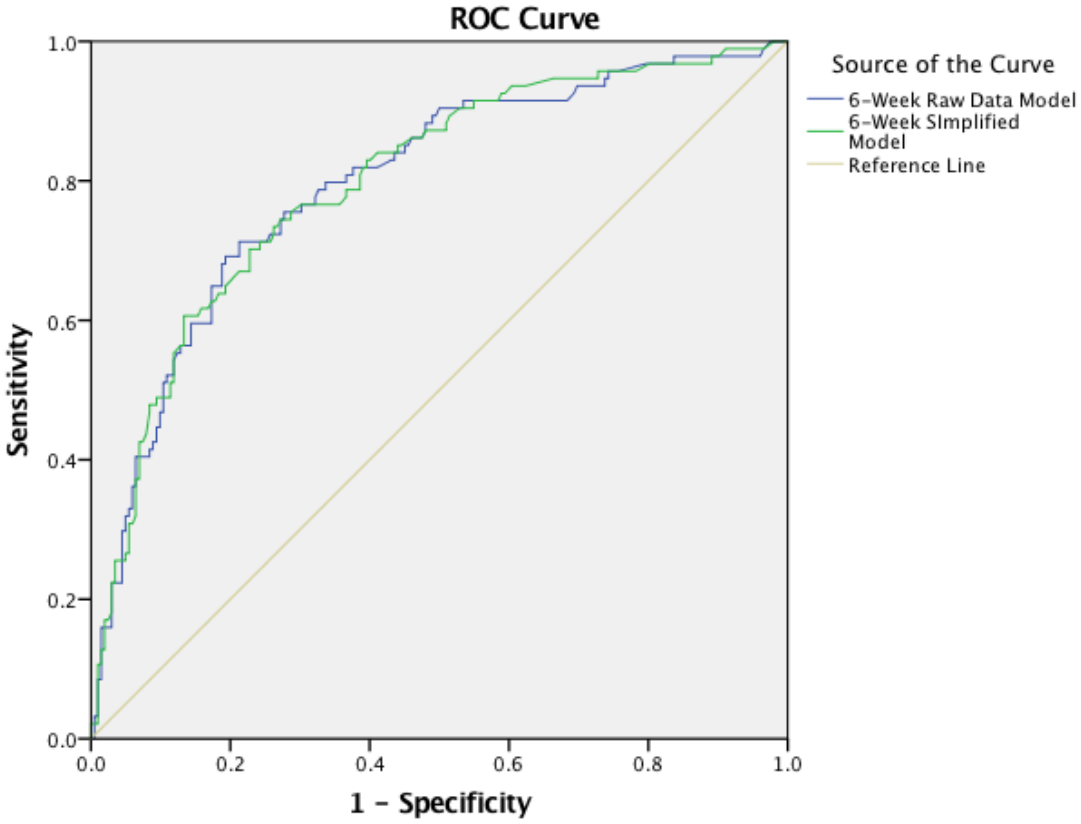

Figure 3: Six-week Raw Data and Simplified Models ROC-AUC

5.7 Simplified Models

Predictive variables were plotted against the surgeon's recommendation in an ROC curve to assess the cut-point that would maximize positive likelihood ratio, and Youden's index[48]. The ORs with 95% CI and p-values for the two and six-week simplified models are presented in Tables 6 and 7 below. Tolerance was above 0.2, Studentized residuals were within negative three and positive three, and values did not exceed the limits for both Cook's D and leverage. The simplified models based on maximizing positive likelihood ratio had better ROC-AUC values than the models that maximized Youden's index. The ROC curves for the two and six-week simplified models are presented in Figures 2 and 3. The two-week simplified model had an AUC of 0.76 (95% CI 0.69 – 0.83) and the six-week simplified model had an AUC of 0.80 (95% CI 0.74 - 0.85). The difference in AUC values between raw data and simplified models was less than 0.05, validating the simplified models[43]. The two-week simplified model had a Cohen's kappa of 0.41 (0.27 - 0.54), representing moderate strength of agreement. PI, BI, PABAK, and percent of observed agreements were -0.63, -0.10, 0.64, and 82% The six-week simplified model had a Cohen's kappa of 0.40 (0.29 - 0.51), representing moderate strength of agreement. PI, BI, PABAK, and percent of observed agreements were -0.45, -0.08, 0.52, and 76%.

Table 6: 2-Week Simplified Model

		95% CI		
Predictor	**Odds Ratio**	**(Lower)**	**(Upper)**	**P-Value**
2b. Is the pain localized to your knee or whole leg?	1.19	0.80	1.75	0.37
2h. Does taking medication lessen your pain?	1.16	0.60	2.25	0.65

7a. Do any of your incisions have redness/ red streaks indicative of infection?	21.87	1.95	244.61	0.01
8. Have you had any fluid leak from your incisions and/or arthroscopy portals in the last week?	3.62	1.28	10.23	0.01
9. Check the box next to the image that best represents how straight you can make your surgical leg.	1.20	0.79	1.81	0.38
10. Check the box next to the image that best represents how bent you can make your surgical leg.	1.29	1.01	1.64	0.04
17. Emergency (hospital)	3.00	0.80	11.12	0.10
20. Are you content with your overall progress after surgery?	3.79	1.70	8.44	0.00
R8. How many surgeries have you had in the past, not including this past knee surgery?	1.51	0.74	3.08	0.25
R2. Do you have diabetes?	16.25	1.57	167.59	0.01

Table 7: 6-Week Simplified Model

		95% CI		
Predictor	**Odds Ratio**	**(Lower)**	**(Upper)**	**P-Value**

2b. Is the pain localized to your knee or whole leg?	1.36	1.02	1.83	0.03
6. Have you experienced any clicking or locking sensations in your knee since your surgery?	0.64	0.35	1.17	0.15
9. Check the box next to the image that best represents how straight you can make your surgical leg.	2.12	1.42	3.17	0.00
10. Check the box next to the image that best represents how bent you can make your surgical leg.	1.23	0.96	1.58	0.09
15. Are you going to physiotherapy or doing exercises on your own?	0.43	0.18	1.02	0.05
17. Emergency (hospital)	2.28	0.72	7.16	0.15
19. Do you have any concerns that you would like to share with your surgeon?	1.94	1.06	3.54	0.03
20. Are you content with your overall progress after surgery?	2.80	1.28	6.11	0.00
R8. How many surgeries have you had in the past, not including this past knee surgery?	4.54	0.25	80.69	0.30
Sex	1.55	0.86	2.77	0.13

Chapter 6

6 Discussion

The purpose of this study was to administer a patient-reported e-Visit questionnaire, at two and six-weeks post-operative, and use the data collected to build a statistical model to estimate the likelihood that an adverse event was present; making a recommendation as to whether the patient should be seen by their surgeon in-person. We found that when surgeons rated the necessity of the two-week in-person follow-up, they felt that only 24.3% of patients actually needed the appointment. For patients who returned for an in-person follow up six-weeks post-operative, only 31.6% of patients actually needed the appointment. Furthermore, an additional 20% of the in-person post-operative visits were rated as unnecessary when the patient had undergone a procedure by a sport medicine orthopaedic surgeon (e.g. an ACL reconstruction, HTO or arthroscopy) than an arthroplasty surgeon, likely related to the age and concomitant comorbidities of the joint replacement patients. These results suggest a current inefficiency in healthcare delivery following common orthopaedic procedures.

In our study, 65 patients had 99 reasons to be seen at two-weeks and 97 patients had 138 reasons to be seen at six-weeks. Extension loss was the most frequent reason for needing to be seen at both two and six weeks, indicating the importance the surgeons at our sites place on gaining terminal extension. Restoration of terminal extension after knee orthopaedic surgery has been shown to be essential in maintaining full extension later in recovery, reducing joint pain and regaining full quadriceps strength[49,50]. However, slow extension and flexion range of motion gains in early post-operative rehabilitation are not true adverse events, but are an educational issue. Patients may not fully understand the parameters and goals in achieving early range of motion, and it is mostly education that patients require from their surgeon at two and six-weeks, rather than medical treatment. Persistent extension and flexion loss 12 weeks post-operative will usually require medical treatment. Hence, the importance of pre and post-operative education and patient adherence to rehabilitation in reducing unremarkable appointments.

We found fair agreement between the models' ability to predict whether the patient should be seen in-person and the gold standard defined by the surgeon's recommendation. The models made a correct prediction for 81% of patients seen at two weeks and 76% of patients seen at six weeks post-operatively. PI was further from zero than BI for both two and six-week models, suggesting that Kappa was biased more by large differences between true positive and true negative rates rather than different frequencies of the observed condition between the questionnaire and gold standard[46]. Adjusting for PI and BI, we found the PABAK statistic was increased from 0.39 to 0.62 and 0.38 to 0.52 at two and six-weeks. This makes sense as absolute PI was further from zero at two weeks (-0.64) than six weeks (-0.47), resulting in a larger adjustment. An assumption is made that an increase in disease prevalence will increase the agreement when calculating the PABAK.

In the literature, rare events have proven difficult to explain and predict using logistic regression, as logit coefficients are biased when events are rare[51]. Even if a study has 2000 patients, but a low event rate, the estimated event probabilities will be deceptively low[51]. This means that if prevalence between settings change, a diagnostic test will have different predictive accuracy in each setting (spectrum bias)[51,52]. Spectrum bias may be thought of as samples of patients with varying degrees of disease severity and comorbidities which makes diagnosis more difficult[52]. Increasing the event rate will increase validity of the model by decreasing the variance within the logit coefficient equation, due to an event having a value of one as opposed to zero[52]. Logit coefficient calculation was achieved through maximum likelihood estimation, which estimates and selects values of the model parameters that maximize the likelihood function[41]. Not to be confused with the likelihood function are positive and negative likelihood ratios used in diagnostic testing and are calculated by sensitivity and specificity[53]. We observed moderate/high sensitivities of (.70, .70) and specificities of (.83, .80) in our raw data models. With predictive models, sensitivity and therefore positive likelihood ratio have a greater importance as we would rather accept a patient misclassified as needing an appointment than risk rejecting a patient who truly needs to be seen by their surgeon[53]. Therefore, diagnostic models with large sensitivity values are better at ruling out a

disease (truly needing to be seen); therefore prior to use in a clinical setting it will be important to adjust the model to increase the sensitivity.

To increase the diagnostic ability of the raw data models, we used ROC curves to introduce cut-points to continuous variables, maximizing their positive LR or sensitivity and specificity. The simplified models that maximized positive LR performed slightly better than the models maximizing both sensitivity and specificity. The simplified models differed from the raw data models only in Hosmer and Lemeshow chi-square values. This is not of concern considering the bias inherent in the statistic[47]. Simplifying the model will allow surgeons to quickly understand which predictor is contributing to the model in the absence of a computer. Observing presence of a predictor would increase the likelihood that an adverse event was present, and the patient should be seen in-clinic. Given similarities between the raw data and simplified models, we suggest future research should also employ cut-points to continuous variables to simplify models.

In theory, the e-Visit questionnaire and associated prediction algorithm could help to improve wait times for first consult by reducing the number of uneventful appointments. Furthermore, the e-Visit questionnaire can include patient education modules regarding signs and symptoms of complications and when to be concerned. The current e-Visit tool is constructed so that surgeons may review each patient's question responses and comments and receive a score from the associated model recommending whether the patient should be seen in-person. This construction serves to retain the surgeon's autonomy.

One of the limitations of this study is its small sample size (i.e. low event rate). For this thesis, we recruited a sample of convenience based on the time allocated for degree completion as recruiting the required sample size would not have been feasible given the low adverse events rate. Given our observed adverse event rates in this study of 24.3% at two-weeks post-operative and 32.4% at six-weeks post-operative, we can estimate sample sizes needed for future studies. Specifically, we would need 784 and 653 patients at the two and six-week visit for an expected sensitivity of 0.85 with a marginal error of 0.05[54]. Further, if we wanted to have 95% confidence in our AUC values given a marginal error

rate of 0.03, we would have needed 1080 and 1020 patients at two and six-week visits respectively[54]. Lastly, for a future study to compare our AUC values with theirs in a different sample of patients, they would need 1370 patients to detect a difference in the AUC of 0.05 with 95% confidence and 80% power[54].

Further limitations of this study could be the technological savvy of the patients. In our study, 24.6% of the patients who underwent arthroplasty and 21.1% of patients who underwent a sport medicine surgery refused to participate for reasons including perceived length of time to participate, uninterested in research, research burn out, and incompetence with web-based technology. The average age of patients in our sport orthopaedic surgical sample was 37.3 years, much lower than the arthroplasty sample of 66.1 years of age.

Finally, although only anecdotal, we felt that the phrasing of some questions may require revision before the e-Visit questionnaire becomes part of clinical practice. Therefore, we suggest performing a talk-aloud with patients from diverse backgrounds to increase the clarity of each question perhaps adding brief (<2 minute) patient education videos would further increase patient comprehension of question content, for example with more difficult topics like wound infection.

Strengths of the study include the prospective nature of patient selection, the sample size collected, the method of model construction, and the study location (ie. high volume).

Results of this pilot study are promising. Next steps will be to perform a randomized controlled trial, where patients will be randomized to receive early post-operative care by an e-Visit questionnaire, or in the clinic and should involve a full cost-effectiveness analysis.

Chapter 7

7 Conclusion

A web-based e-Visit completed by the patient can predict early adverse events in an orthopaedic population. Future work should concentrate on improving web-based interface and content and should involve large-scale surveillance (ideally through a multicenter RCT) to confidently estimate its ability to identify early adverse events.

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Appendices

Appendix A: Post-operative Visit Schedule

TKA

- Dr. Howard: 2 week (staple removal) + 6 week (x-ray)
- Dr. Lanting: 2 week (staple removal) + 6 week (x-ray)
- Dr. MacDonald: 6 week (x-ray)
- Dr. Naudie: 6 week (x-ray)
- Dr. Vasarhelyi: 2 week (staple removal) + 6 week (x-ray)

HTO

- Dr. Giffin: 2 week (x-ray) + 6 week (x-ray)
- Dr. Getgood: 2 week (x-ray) + 6 week (x-ray)
- Dr. Willits: 2 week (x-ray) + 6 week (x-ray)

ACL

- Dr. Giffin: 2 week (stitch removal) + 6 week
- Dr. Getgood: 2 week (stitch removal) + 6 week
- Dr. Willits: 2 week (stitch removal) + 6 week

Arthroscopy

- Dr. Giffin: 2 week + 6 week (sometimes just 4 week)
- Dr. Getgood: 2 week + 6 week (sometimes just 4 week)
- Dr. Willits: 2 week + 6 week (sometimes just 4 week)

Arthroscopy with Meniscal Repair

- Dr. Giffin: 2 week + 6 week
- Dr. Getgood: 2 week + 6 week
- Dr. Willits: 2 week + 6 week

Appendix B: Institutional REB Approval

Western Research

Research Ethics

Western University Health Science Research Ethics Board
HSREB Delegated Initial Approval Notice

Principal Investigator: Dr. Robert Giffin
Department & Institution: Schulich School of Medicine and Dentisty\Surgery,Western University

Review Type: Delegated
HSREB File Number: 107975
Study Title: E-Visit for Early Postoperative Follow Ups Post Elective Orthopaedic Surgery
Sponsor:

HSREB Initial Approval Date: August 22, 2016
HSREB Expiry Date: August 22, 2017

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Data Collection Form/Case Report Form	Demographic Information (Received 13Apr16)	
Data Collection Form/Case Report Form	e-Visit Questionnaire (Received 13Apr16)	
Data Collection Form/Case Report Form	In-Person Appointment Costs (Received 13Apr16)	
Data Collection Form/Case Report Form	Surgeon's Data Form (Received 13Apr16)	
Western University Protocol	Received 9Aug16	
Letter of Information & Consent		2016/08/18

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above named study, as of the HSREB Initial Approval Date noted above.

HSREB approval for this study remains valid until the HSREB Expiry Date noted above, conditional to timely submission and acceptance of HSREB Continuing Ethics Review.

The Western University HSREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use Guideline for Good Clinical Practice Practices (ICH E6 R1), the Ontario Personal Health Information Protection Act (PHIPA, 2004), Part 4 of the Natural Health Product Regulations, Health Canada Medical Device Regulations and Part C, Division 5, of the Food and Drug Regulations of Health Canada.

Members of the HSREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Ethics Officer, on behalf of Dr. Joseph Gilbert, HSREB Chair

Ethics Officer: Erika Basile __ Nicole Kaniki __ Grace Kelly __ Katelyn Harris __ Vikki Tr[illegible] __ Karen Gopaul __

Appendix C: Letter of Information

London Health Sciences Centre

FOWLER KENNEDY SPORT MEDICINE CLINIC

LETTER OF INFORMATION

Title of Research:

e-Visits for early post-operative appointments following orthopaedic surgery: Can they add efficiency without sacrificing effectiveness?

Lead Researchers:

Dr. Robert Giffin Fowler Kennedy Sport Medicine Clinic, Western University London, Ontario,

Dr. Steven MacDonald London Health Sciences Centre, University Hospital London, Ontario,

Dr. Dianne Bryant Elborn College, Western University London, Ontario

Information:

You (the patient) are being invited to participate in a research study because your surgeon has determined that you are a candidate for the study. The purpose of this letter is to provide you with information required for you to make an informed decision regarding participation in this research.

The purpose of this study is to evaluate the accuracy of an e-Visit to detect the likelihood of an early adverse event following orthopaedic surgery compared to usual care in-person assessments. Adverse events include infection, deep vein thrombosis (blood clot formation), and stiffness. An e-Visit is a potential diagnostic tool in the form of a patient reported questionnaire. The rate of adverse events within the first 3 months following orthopaedic surgery is low. For example, the overall incidence of infection was found to be 0.5%, 1.4%, and 5% for arthroscopic anterior cruciate ligament (ACL) reconstruction, hip and knee replacement, and high tibial osteotomy (HTO), respectively. Arthroscopic ACL reconstruction differs from open ACL reconstruction as scopes act as "sights" into the knee, making the procedure less invasive. An HTO is a surgical technique where bone is cut out or added to the lower limb in an attempt to correct loading forces through the knee in osteoarthritis patients. Despite low adverse event rates, it is common practice for the surgeon to schedule an in-person follow-up with the patient at least once, but up to three times, within the first three months following surgery. Given the low incidence of early adverse events, if we can demonstrate that an e-Visit can accurately detect early adverse events, then we can support reducing the proportion of patients attending in-person follow-up visits, which may translate to reduced costs to the healthcare system, society and to you, the patient. Seven hundred (700) patients will be recruited for this study.

Eligibility:

To participate in this study you must be over 15 years of age. We will include all patients who undergo an orthopaedic surgery by a sports orthopaedic surgeon or arthroplasty surgeon at London Health Sciences Center University Hospital.

Explanation of the Study Procedures:

The study will be coordinated by a MSc candidate, William Jeffery. If you decide to participate in

this study, you will complete questions querying your age, sex, and surgical procedure. At your next appointment, you will be asked to complete the e-Visit containing 21 questions querying signs, and symptoms of an adverse event. We will also ask you to comment on your surgical incision and range of motion using images indicative of adverse events. This set of questionnaires will be completed at every scheduled visit with your surgeon until 3 months postoperative (1-3 visits as determined by your surgeon's usual follow-up schedule). This study will determine whether the computer can use your responses to predict whether you are at a higher risk of developing an early adverse event and should therefore be seen in-person with your surgeon.

Because we are still in the development phase of using the e-visit, you will see your surgeon for your usual in-person check-up. To determine whether the e-Visit can accurately determine the likelihood of an early adverse event, we will compare the computer's prediction to the surgeon's findings during their assessment. To keep track of resource use we will ask you to complete a questionnaire that contains questions inquiring the cost/time/distance associated with coming into the clinic for an in-person follow-up. You will also be asked to record time missed from work (if applicable) and a caregiver's time missed from work (if applicable). Lastly, you will be asked if you accessed any other healthcare resources in lieu of your surgeon.

Risks:

There are no known health risks associated with this study.

Benefits:

There are no direct benefits to you for participating in this study; however if we show that the e-Visit is accurate at predicting early adverse events following orthopaedic surgery, we may be able to reduce the number of in-person visits with the surgeon while still maintaining the same level of care. The decrease in travel may save time and money for patients, society and healthcare payers.

Cost/Compensation:

There are no additional costs to you for participating in this study. There is no compensation for participating in this study. The assessments for this study will coincide with your routine follow-ups with your surgeon.

Voluntary Participation:

Participation in this study is completely voluntary. You may refuse to answer any questions you do not want to answer and remain in the study. You are free to withdraw at any time without affecting the quality of the care you receive at this institution, and by signing this form you do not waive your legal rights. When you withdraw your permission, no new health information will be gathered after that date. Information that has already been gathered may still be used. If you would like to withdraw from this study, you will need to provide written or verbal confirmation to the study coordinator: William Jeffery Participation in this study does not prevent you from participating in any other research studies at the present time or future. If you are participating in another research study, we ask that you please inform us of your participation.

Request for Study Results:

Should you decide to participate and want to receive a copy of the study results, please provide your contact information on a separate piece of paper. Once the study has been published, a copy will be mailed to you. Should your mailing information change, please let us know.

Confidentiality:

Any personal health information collected or other information related to you will be coded by a unique number to ensure that persons outside of the study will not be able to identify you. In any publication, presentation or report, your name will not be used and any information that discloses your identity will not be released or published unless required by law. Despite these protections being in place, there is always a risk of unintentional release of information. The study personnel will protect your records and keep all the information in your study file confidential to the greatest extent possible. The chance that this information will be accidentally released is small.

The data that is collected from you is managed by a company called EmPower Health Research. Any information provided by you is protected by a username and password. It travels in a scrambled format to a server (storage computer) that is located in Montreal, Canada. Your email address and your date of birth are part of this database. The database will send automatic reminder emails to you if you are required to login and answer questions. Instructions for logging into the database will be provided by the research assistant. The company that houses the database is a professional company with extremely high standards of physical and virtual security. We want to let you know however, that even with this high level of security, there is always a remote chance that your information could be accessed or "hacked" by someone who is not supposed to have your information. If we became aware that this had happened, we would inform you immediately. We wish to make you aware that Dr. Bryant, who is one of this study's investigators, is the Director of EmPower Health Research. However, Dr. Bryant is not paid a salary by EmPower.

Study data will be kept for fifteen years. Representatives of the University of Western Ontario Health Sciences Research Ethics Board may require access to your study-related records or follow-up with you to monitor the conduct of this research. Representatives of Lawson Quality Assurance (QA) Education Program may look at study data for QA purposes.

Questions:

If you have questions about the conduct of the study or your rights as a research participant, you may contact Dr. David Hill, Scientific Director, Lawson Health Research Institute

If you have questions or concerns about your surgery or physiotherapy, please contact your orthopaedic surgeon. If you have any questions about this research, please contact William Jeffery or your orthopaedic surgeon.

This letter is yours to keep.

Sincerely,

Dr. Robert Giffin, MD	Dr. Jacquelyn Marsh, PhD
Dr. Dianne Bryant, PhD	Laura Churchill, PhD |can.|
Dr. Steven MacDonald, MD	William Jeffery, MSc |can.|

CONSENT FORM

Title of Research:

e-Visits for early post-operative appointments following orthopaedic surgery: Can they add efficiency without sacrificing effectiveness?

I have read the letter of information, have had the nature of the study explained to me, and I agree to participate in the study. All questions have been answered to my satisfaction. I will receive a copy of the Letter of Information and this signed consent form.

Printed Name of the Participant	Signature of the Participant	Date
Printed Name of the Parent or Legally Authorized Representative (if required)	Signature of the Parent or Legally Authorized Representative (if required)	Date
Printed Name of the Person Responsible for Obtaining Informed Consent	Signature of the Person Responsible for Obtaining Informed Consent	Date

☐ I would like to receive a copy of the results of this study. Please mail to:

_____
_____
_____

Appendix D: e-Visit

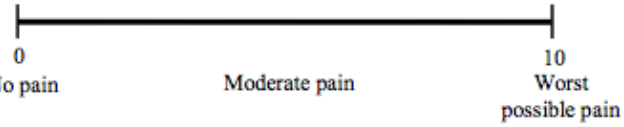
Date: _____/ ____ / ____
YYYY MM DD

e-Visit

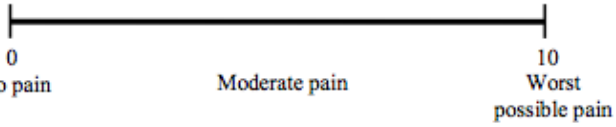
1. **What time are you starting the e-Visit at?** ☐ AM ☐ PM

2. **Are you presently having pain in your knee or leg?**
   - ◯ No, skip to question 3
   - ◯ Yes, answer questions below

a. Is the pain constant or intermittent? ☐ Constant ☐ Intermittent
b. Is the pain localised to your knee or whole leg? ☐ Knee ☐ Leg ☐ Both
c. What does the pain feel like? Select all that apply ☐ Sharp ☐ Dull ☐ Throbbing ☐ Stabbing
d. When do you primarily experience pain? ☐ Day ☐ Evening ☐ Overnight
e. How much pain do you feel? Pain scale below (place a single vertical line between 0 and 10)



f. Has the pain gotten better or worse over the last week? ☐ Better ☐ Worse
g. Are you still taking pain medication? ☐ Yes ☐ No
h. Does taking medication lessen your pain? ☐ Yes ☐ No
i. Indicate using the pain scale below how much pain you feel after taking medication



Version Date: 21/09/2016

j. Which pain medications have you taken? Select all that apply

- ☐ Tylenol Regular Strength
- ☐ Tylenol Extra Strength
- ☐ Tylenol 3
- ☐ Percocet
- ☐ Other: ____
- ☐ Tramacet
- ☐ Hydromorphone (Dilaudid)
- ☐ Gabapentin
- ☐ Lyrica

k. Are you taking more or less pain medication each day (ie. increasing or decreasing dosage)? ☐ More ☐ Less ☐ Constant

l. Have you switched from narcotics (Tylenol #3/Percocet) to over the counter medications such as Tylenol or NSAIDS? ☐ Yes ☐ No ☐ Never took narcotics

3. Have you experienced any issues with swelling in your knee or leg since your surgery?

- ○ No, skip to question 4
- ○ Yes, answer questions below

a. Is the swelling constant or is it intermittent? ☐ Constant ☐ Intermittent

b. Is the swelling localised to your knee or whole leg? ☐ Knee ☐ Leg ☐ Both

c. When do you primarily experience swelling? ☐ Day ☐ Evening ☐ Overnight

d. Has the swelling gotten better or worse over the last week? ☐ Better ☐ Worse

4. **Have you experienced any issues with numbness in your knee or leg since your surgery?**

   ◯ No, skip to question 5

   ◯ Yes, answer questions below

a. Is the numbness constant or is it intermittent? ☐ Constant ☐ Intermittent

b. Is the numbness localised around your incisions or is it diffuse across your whole leg? ☐ Localised ☐ Diffuse

c. What does the numbness feel like? Select all that apply ☐ Pin-pricks ☐ Burning ☐ Completely numb (no sensation)

d. When do you primarily experience numbness? ☐ Day ☐ Evening ☐ Overnight

e. Has the numbness gotten better or worse over the last week? ☐ Better ☐ Worse

5. **Have you experienced any episodes of "bucking" or "giving way" of your knee since your surgery?**

   ☐ Yes | ☐ No

6. **Have you experienced any clicking or locking sensations in your knee since your surgery?**

   ☐ Yes | ☐ No

7. **Use the associated images to assess your surgical incisions and arthroscopy portals and answer the following questions**

a. Do any of your incisions have redness/red streaks indicative of infection? ☐ Yes ☐ No

b. Are your incisions/area around the incisions warm or hot to the touch? ☐ Yes ☐ No

c. Have your incisions fully closed (ie. healed with no drainage)? ☐ Yes ☐ No ☐ Unsure

8. **Have you had any fluid leak from your incisions and/or arthroscopy portals in the last week?**

   ◯ No, skip to question 9

   ◯ Yes, answer questions below

a. Does the fluid look… (select one) ☐ Clear ☐ Cloudy ☐ Blood tinged ☐ Pus (yellow/white)

b. Is the drainage increasing or decreasing? ☐ Increasing ☐ Decreasing

c. Are you increasing or decreasing your frequency of bandage replacement? ☐ Increasing ☐ Decreasing

9. **Make your surgical leg as straight as you can. Tell us how straight you can get your leg by comparing your leg to the model in the associated images. In these images, the model's front (left) leg represents the leg that did NOT have surgery. It is straight. The model's right (back) leg represents the leg that had surgery. In the first image, both legs are straight. In the subsequent images, the right leg is less straight. Check the box next to the image that best represents how straight you can make your surgical leg.**

   ☐ Image A

   ☐ Image B

   ☐ Image C

   ☐ Image D

   ☐ I cannot straighten my leg even as much as Image D

10. Bend your leg as much as possible by bringing your heel as close to your bottom as you can. Now look at the associated images. In each image, the model's front (left) leg is bent to an ideal position and is meant to represent the leg that did NOT have surgery. The model's back (right) leg is bent more with each image and is meant to represent the leg that had surgery. Tell us how much you can bend your leg by looking at the images below and comparing your leg to the model's right (back) leg. Check the box next to the image that best represents how far you can bend your surgical leg.

- ☐ I cannot bend my leg even as much as Image A
- ☐ Image A
- ☐ Image B
- ☐ Image C
- ☐ Image D
- ☐ I can bend my leg further than Image D

11. Are you experiencing any illness (ie. fever or shaking chills), or have you experienced illness in the last three/four days?

- ○ No, skip to question 12
- ○ Yes, answer questions below

a. Did you have a temperature over 38°C (100°F)?	☐ Yes ☐ No ☐ Unsure
b. Do you have shaking chills (ie. shivering)?	☐ Yes ☐ No
c. Do you have nausea?	☐ Yes ☐ No
d. Do you have dizzy spells?	☐ Yes ☐ No
e. How long have you felt unwell?	☐ >3 days ☐ <3 days
f. Are you eating more or less than usual?	☐ More ☐ Less ☐ Normal

12. Can you contract your quadriceps muscle? (Select the most accurate)

☐ Yes | ☐ Yes, but weak | ☐ Yes, but painful | ☐ No

13. Are you able to walk? (Select the most accurate)

☐ Yes, with crutches | ☐ Yes, without crutches | ☐ No

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14. Are you concerned you may have re-injured your knee or had any significant slips or falls?

- ◯ No, skip to question 15
- ◯ Yes, answer questions below

a.	How did you re-injure yourself? (Select all that apply)	☐ Fall ☐ Doing exercises ☐ Twist knee ☐ Other:
b.	Was the potential re-injury painful?	☐ Yes ☐ No
c.	Did you hear anything in your knee when you potentially re-injured yourself?	☐ Yes ☐ No
d.	Did you feel anything in your knee when you potentially re-injured yourself?	☐ Yes ☐ No
e.	Did your knee swell when you potentially re-injured yourself?	☐ Yes ☐ No

15. Are you going to physiotherapy or just doing exercises on your own?

- ◯ Physiotherapy, answer questions below
- ◯ Home exercises, answer questions below

a.	Are you or your physiotherapist concerned with your range of motion?	☐ Yes ☐ No ☐ Unsure
b.	Are you or your physiotherapist concerned with your incision?	☐ Yes ☐ No ☐ Unsure
c.	Are you or your physiotherapist concerned with re-injury?	☐ Yes ☐ No ☐ Unsure
d.	Are you or your physiotherapist concerned with your muscle activation?	☐ Yes ☐ No ☐ Unsure

16. Have you taken any other regularly prescribed medications since your surgery?

◯ No, skip to question 17

◯ Yes, fill out the chart and answer questions below

Medication	Dose (mcg, mg, g, other)	Doses/day	How long? (Years/months)

a. If you are diabetic, have you had any unexplained blood sugar issues since your surgery? ☐ Yes ☐ No ☐ Not diabetic

b. If you are diabetic, has your blood sugar been controlled by medication since your surgery? ☐ Yes ☐ No ☐ Not diabetic

17. Have you sought other medical help or assistance in (check all that apply)?

☐ Walk-in clinic | ☐ Doctor's office | ☐ Emergency (hospital)

18. Have you consumed tobacco/alcohol/marijuana recreationally or to alleviate pain since your surgery? (Your answers will not be released, these questions are designed to gain as much information as possible regarding your condition)

- ◯ No, skip to question 19
- ◯ Yes, answer questions below

a. Select all that apply
- ☐ Tobacco (answer b)
- ☐ Alcohol (answer c)
- ☐ Marijuana (answer d)

b. Have you increased smoking tobacco since your surgery? ☐ Yes ☐ No

c. Have you increased drinking since your surgery? ☐ Yes ☐ No

d. Have you increased smoking marijuana since your surgery? ☐ Yes ☐ No

19. Do you have any concerns that you would like to share with your surgeon?

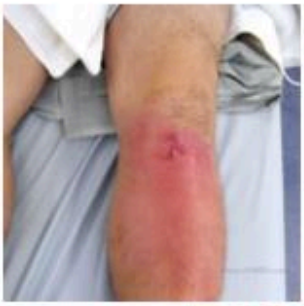
- ◯ No, skip to question 20
- ◯ Yes, enter your concerns below

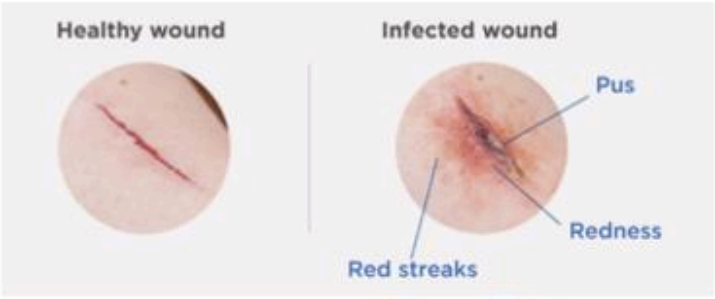
20. Are you content with your overall progress after surgery?

- ◯ No. Check all that apply.
- ◯ Yes, skip to question 21

- ☐ Pain
- ☐ Illness
- ☐ Reliance on mobility aid
- ☐ Stiffness
- ☐ Dependent on others
- ☐ Dependence on pain medication
- ☐ Other, please explain:

21. What time are you finishing the e-Visit at? ☐ AM ☐ PM




Healthy wound
Infected wound
Pus
Redness
Red streaks

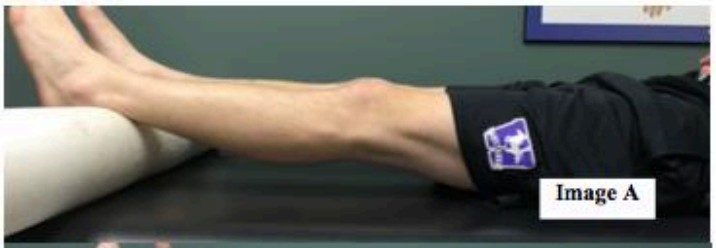
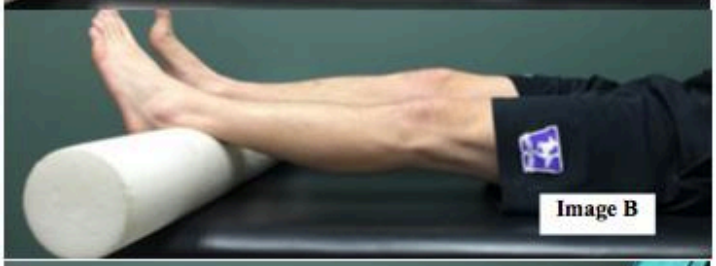


Image A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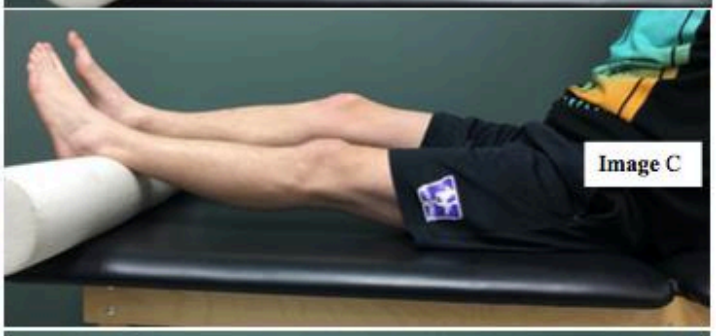
Image C


Image D


Image A
Image B
Image C
Image D

Appendix E: Surgeon's Data Form

Date: _____ / ____ / ____
YYYY MM DD

Surgeon's Data Form

Did this patient need to be seen in clinic?

☐ Yes ☐ No

What aspect of their condition lead you to this conclusion? Check all that apply

Pain:	☐ Persistent pain
	☐ Pain poorly controlled with medication (requiring ongoing medication)
	☐ Pain uncontrolled with medication
Incision:	☐ Healing poorly
	☐ Not healing
Discharge:	☐ Mild
	☐ Moderate
	☐ Severe
Knee Effusion:	☐ Persistent effusion
	☐ Effusion uncontrolled by modalities
Leg Swelling:	☐ Swelling uncontrolled by modalities
	☐ Swollen area discolored
	☐ Swollen area warm/hot
Stability:	☐ Unable to weight bear
	☐ Locking with PROM
ROM:	☐ Limited flexion
	☐ Limited extension
Constitutional	☐ Fever
Symptoms:	☐ Rigors
	☐ Nausea
	☐ Dizzy spells
Re-injury:	☐ Risk of re-injury
	☐ Suspected re-injury

Other: Please explain

Is there a change in management for this patient? Please explain

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☐ Check this box if the patient required a note to return to work (full or graduated duties) BUT the timing for return-to-work has not changed

☐ Check this box if the patient required a note to return to work (full or graduated duties) BECAUSE the timing for return-to-work has changed related to recovery time

Operation Performed (select all that apply):

☐ ACL Reconstruction
☐ Knee Replacement
☐ Hip Replacement
☐ Shoulder Replacement
☐ Osteochrondroma Excision
☐ Osteochondral Autograft Transfer System (OATS procedure)
☐ Fasciotomy
☐ Distal Femoral Varus Osteotomy
☐ Bankart Repair
☐ PCL Reconstruction
☐ MCL Reconstruction
☐ Open Reduction Internal Fixation (ORIF)
☐ High Tibial Osteotomy
☐ Knee/Hip/Shoulder/Ankle Scope
☐ Trochleoplasty
☐ Meniscal Transplant
☐ Meniscal Debridement/Menisectomy
☐ Medial Patellofemoral Ligament Reconstruction
☐ Broström Operation
☐ RC Repair
☐ Latarjet Operation
☐ Joint Arthrotomy
☐ Birmingham Hip Resurfacing
☐ Tibial Tubercle Osteotomy

Graft (select all that apply):

☐ Hamstring
☐ Quadriceps Tendon
☐ Single-Bundle
☐ Contralateral Leg
☐ Patellar Tendon
☐ Allograft
☐ Double-Bundle
☐ Ipsilateral Leg

What time did the patient leave the orthopaedic clinic? ☐ AM ☐ PM

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Curriculum Vitae

Name:	William Jeffery
Post-secondary Education and Degrees:	Western University London, Ontario, Canada 2011-2015 B.Sc. Kinesiology Western University London, Ontario, Canada 2015-2017 M.Sc. (In progress)
Honours and Awards:	Western Graduate Research Scholarship 2015-2017 University of Western Ontario Scholarship of Excellence Valued at $2000 2011 Dean's Honour Roll: Faculty of Health Sciences 2011-2015
Related Work Experience	Fowler Kennedy Sport Medicine Clinic/Rorabeck Bourne Joint Replacement Clinic Western University 2015-2017 Research Student Teaching Assistant Western University 2015-2017 KIN 2230 Introductory Exercise Physiology Professor: Dr. Glen Belfry KIN 2241 Biomechanics Professor: Dr. Tom Jenkyn KIN 3353 Biomechanical Analysis of Human Locomotion Professor: Dr. Volker Nolte

Presentations:

Oral Presentation: e-Visits for early post-operative visits following orthopaedic surgery: Can they add efficiency without sacrificing effectiveness?
Fowler Kennedy Sport Medicine Day Symposium, London ON, 2016

Oral Presentation: e-Visits for early post-operative visits following orthopaedic surgery: Can they add efficiency without sacrificing effectiveness?
Fowler Kennedy Research Rounds, London ON, 2016

Poster Presentation: e-Visits for early post-operative visits following orthopaedic surgery: Can they add efficiency without sacrificing effectiveness?
Canadian Bone and Joint Conference, London ON, 2016