Objective Knee Functional Assessment to Document Appropriateness for Total Knee Arthroplasty

Michael Dunbar, Neila Mezghani, Youssef Ouakrim, Alex Fuentes, Hilary Susan Macdonald[1], Sara Whynot[2], Christopher Glen Richardson
[1]Nova Scotia Health Authority, [2]Dalhouise University - Orthopaedics

INTRODUCTION:

Traditional subjective patient assessment, with limited standardization, contributes to significant variation in surgery recommendations for patients with knee osteoarthritis (OA). As clinical care moves towards increased accountability in decision-making, need has arisen for objective quantifiable data to document the appropriateness for total knee arthroplasty (TKA). Knee kinematic assessment has shown the ability to identify and quantify functional changes associated with OA allowing for objective disease severity assessment, tailoring care pathways and offering opportunities to develop automatic objective methods of computer-aided diagnosis to help support clinical decisions.

The aim of this study is to assess the utility of 3D knee kinematic data to objectively classify, via a decision tree, surgical candidates (SC) and nonsurgical candidates (NSC) for TKA and validate this method based on determination of SC or NSC by standard surgeon/patient decision-for-surgery. The relevance of additionally including patient characteristics, such as gender, body mass index (BMI) and patient reported outcomes in decision tree expansion were also evaluated.

METHODS:

After ethics institutional review board approval and experienced arthroplasty surgeon assignment to SC or NSC groups, 89 participants with moderate to severe knee OA were enrolled. All participants underwent physiotherapy assessment and patient reported outcomes. Additionally, a three-dimensional (3D) knee kinematics evaluation was done to quantify flexion/extension, varus/valgus and internal/external tibial rotation while participants walked on a treadmill at a self-selected, comfortable speed.

These data were used to build a decision tree model to classify patients as SC or NSC. A first model was built integrating only 3D knee kinematic parameters. A second model was generated using combined kinematic and clinical data. Parameters with the most discriminative value were identified by incremental selection on a regression tree. These classification methods were then validated using a 10-fold cross-validation method. Effectiveness of the regression trees was further evaluated using receiver operating characteristic (ROC) curves, area under the ROC curve (AUC), sensitivity and specificity. We also performed a t-test statistical analysis to examine the general participant characteristic differences between the two groups. A P-value of 0.05 was set as the level of statistical significance.

RESULTS:

Forty-four surgical candidates and 40 non-surgical patients completed the protocol (see Table 1 for patient characteristics). Seventy biomechanical parameters of interest were extracted from 3D kinematics data as well as 4 clinical data (age, gender, BMI, Oxford Knee Score).

In the first model, using only knee kinematics to generate the decision tree, parameters with the most discriminative weight and allowing highest classification rates were one parameter in the sagittal and two parameters in the transverse plane. Area under the ROC curve reached 0.848, with sensitivity of 79.5% and specificity of 90% (see Figure1 for ROC curve and Figure 2 for the confusion matrix).

In the second model, with the addition of objective clinical data to knee kinematic data, the decision obtaining the highest classification rate was composed of one parameter in the flexion/extension movement, two in the inter/external rotation and the Oxford Knee Score. Area under the ROC curve reached 0.881 with 88.6% sensitivity and 87.5% specificity (see Figure 3 for ROC curve and Figure 4 for the confusion matrix).

DISCUSSION AND CONCLUSION:

Results show strong correlations between arthroplasty surgeon recommendation for surgery and the automated objective decision tree based on either kinematic data only, or a combination of kinematic parameters and patient reported outcomes to discriminate SC and NSC groups for TKA. Adding the Oxford knee total score improved algorithm sensitivity and classification rate. Future work will include the addition of other data sets (i.e. pain visual analog scale, functional performance tests such as Time up-and-go & Sit-to-Stand, range of motion, strength) as inputs in the decision tree to improve classification performance. Development of a clinically validated, objective assessment method has the potential to help standardize surgical decision processes, provide computer-aided recommendations and documentation of appropriateness for TKA.

Real class	Classification results: Surgical	Classification results: Nonsurgical
Surgical	39	5
Nonsurgical	5	35

Figure 4 Confusion Matrix of decision tree using 3D knee kinematic parameters and Oxford-12 total score

Real class	Classification results: Surgical	Classification results: Nonsurgical
Surgical	35	9
Nonsurgical	4	36

Figure 2 Confusion Matrix of decision tree using only 3D knee kinematic parameters

	SC group	NSC group
Age (year)	68 ± 8.0	64 ± 9.2
Height (m)	1.6 ± 0.4	1.6 ± 0.8
Weight (Kg)	93.2 ± 25.9	89.7 ± 19.9
BMI (Kg/m^2)	33.2 ± 7.5	31.2 ± 6.2
Proportion of men	27%	44%

Table 1. Patient characteristics. Student t-test revealed no statistical significant differences between groups ($p>0.05$)

Patient with Anterior Knee Pain After Total Knee Arthroplasty Show Altered 3D Knee Kinematics: Case Control Study

Alex Fuentes[1], Nicola Hagemeister[2], Célia Planckaert[1], Gabriel Larose, Marc Lacelle[3], Julio Cesar Fernandes, Hai Nguyen[3], Guy Grimard[4], Pierre Ranger[3]
[1]Imaging and Orthopaedic Research Lab, CRCHUM, [2]Ecole de technologie supérieure, École De Technologie Supérieure, [3]Hopital Jean-Talon, [4]CHU Sainte-Justine

INTRODUCTION:

About 8% of total knee arthroplasty (TKA) patients report anterior knee pain after surgery. Once known causes of anterior knee pain such as infection, implant loosening, or rotational error have been ruled out, it is often difficult to understand the source of symptoms and how to manage them. Since altered knee kinematics has been associated with patient symptoms in populations with other knee pathologies, the aim of this study is to compare 3D knee kinematics during gait of painful TKA patients to an asymptomatic (AS) TKA group and a control group. We hypothesised that the painful TKA group would exhibit kinematic characteristics previously reported in patients diagnosed with patellofemoral (PF) pain syndrome such as, dynamic flexion contracture, functional valgus, or an externally rotated tibia in regards to the femur.

METHODS:

Nineteen painful TKA patients, reporting a pain level higher than 6 out 20 on the Western Ontario and McMaster Universities Arthritis Index (WOMAC) pain scale, calculated from the Knee Injury Osteoarthritis Outcome Scale (KOOS), and 20 asymptomatic TKA patients were included in this study. The same posterior-stabilized knee implant combined with patella resurfacing was done for all patients. A clinical and radiological work up was done at a mean follow up of two years post-surgery for both TKA groups to exclude those with previously reported known causes of pain (in example: loosening, malrotation, infection, and clinical instability). Seventeen healthy participants were also recruited to form a control group. Each participant underwent a 3D knee kinematic assessment during treadmill walking and filled out the KOOS as a patient reported outcome measure. A power analysis established that 17 patients per group were needed to measure a difference of 4° in flexion during the gait loading phase between the two TKA groups (α=0.05 and β=0.2). Both Student T-test and ANCOVA, with age and BMI as co-factors, with a P-value set at 0.05 were used to compare groups.

RESULTS:

Patient demographics and KOOS scores are presented in Table 1. Computed tomography (CT) scan evaluation revealed for the painful TKA group a neutral mean combined tibial and femoral component rotation (1.4°±7.0° of internal rotation), while the AS TKA group was externally rotated (7.3°±6.1°) (P<0.01). There was no evidence of infection, aseptic loosening, or abnormal instability. Painful TKA group adopted a stiff knee gait characterized by an absence of flexion movement during the loading phase of the gait cycle with maximum loading flexion reaching 14.1°±5.7° for the painful group and 18.0°±6.6° for AS group P<0.05. Interestingly, both TKA groups showed lower flexion movement during loading and swing phase compared to the control group P<0.01 (see * in Figure 1). The painful TKA group also demonstrated a mean neutral functional lower-limb alignment during stance phase compared to the AS TKA group that exhibited a slight varus functional alignment (4.1°) (P<0.05). Painful TKA group presented a valgus functional alignment compared to AS TKA group during terminal stance phase and push off phase (P<0.05) (see Figure 2).

DISCUSSION AND CONCLUSION:

Patient reported outcomes confirmed poorer results for the painful TKA patients in all sub-scales of the KOOS (pain, symptoms, function, and quality of life) compared to both the control group and the AS TKA group. Based on AS group CT scan evaluation, results of the present study support previous reports stating that excessive implant external malrotation is well tolerated by patients. Stiff knee gait characterized by a lack of flexion movement to absorb body weight during loading was previously reported in patients with PF pain syndrome. It was suggested that patient might adopt this strategy to reduce pain since the loading phase requires a quadriceps eccentric contraction while increasing knee flexion, and therefore, increasing significantly PF loads. The valgus functional lower-limb alignment in the painful TKA group during terminal stance could help explain symptoms. Indeed, a valgus functional lower-limb alignment is known to increase the Quadriceps angle and lateralize the patella, which increases PF stresses.

Kinematic assessment showed that although neither TKA group fully restored normal gait patterns, the painful TKA group show adaptive gait strategy to limit symptoms, and show functional frontal plane alignment differences providing new insight on origin of symptoms. Future studies should assess if addressing the valgus functional alignment in painful TKA patients through conservative treatments can help reduce symptoms.

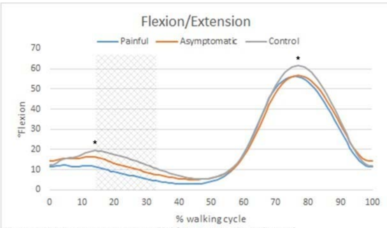

Figure 1. Hatched area show where ANCOVA was significant (P<0.05)

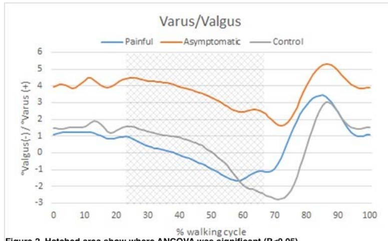

Figure 2. Hatched area show where ANCOVA was significant (P<0.05)

Parameters	Asymptomatic Mean(SD)	Painful Mean(SD)	T-Test P	Control Mean(SD)	ANCOVA P
n (subjects/knees)	20/24	19/21		17/17	
Sex (%)					
Woman	54.2	57.1	N.S	35.3	N.S
Man	45.8	42.9	N.S	64.7	N.S
Age (year)	69.9 (7.9)	65.0 (8.3)	P<0.05*	56.8 (8.1)	P<0.001*
BMI (Kg/m^2)	28.3 (3.6)	31.6 (5.3)	P<0.05*	26.0 (3.8)	P<0.01*
Walking pace (m/s)	0.7 (0.2)	0.8 (0.3)	N.S	0.7 (0.3)	N.S
Time from surgery (year)	2.1 (0.3)	2.0 (0.4)	N.S	N/A	
Questionnaires					
KOOS pain	90.0 (11.2)	59.5 (17.7)	P<0.001*	93.1 (15.1)	P<0.001*
KOOS symptom	84.4 (16.0)	62.1 (21.1)	P<0.001*	91.7 (11.6)	P<0.001*
KOOS ADL	90.0 (10.3)	60.9 (16.3)	P<0.001*	94.0 (14.7)	P<0.001*
KOOS sport	55.0 (23.2)	23.3 (19.1)	P<0.001*	87.2 (22.3)	P<0.001*
KOOS QoL	82.3 (21.1)	43.5 (29.3)	P<0.001*	86.7 (24.4)	P<0.001*
Implant malrotation					
Tibial rotation (°)	7.8 (5.4)	0.8 (6.8)	P<0.001*	N/A	
Woman	7.4 (6.8)	-2.6 (4.1)	P<0.01*	N/A	
Man	8.3 (3.6)	2.5 (7.6)	P<0.05*	N/A	
Femoral rotation (°)	-0.5 (2.3)	-2.1 (2.6)	N.S	N/A	
Woman	0.7 (1.8)	-0.5 (2.6)	N.S	N/A	
Man	-1.8 (2.3)	-3.0 (2.2)	N.S	N/A	
Combined rotation (°)	7.3 (6.1)	-1.4 (7.0)	P<0.001*	N/A	
Woman	8.1 (7.6)	-2.9 (4.1)	P<0.01*	N/A	
Man	6.6 (4.1)	-0.5 (8.4)	P<0.05*	N/A	

Table 1: Group' characteristics N/A: Not Applicable, N.S: Not significant (P > 0,05) For implant malrotation : negative vule means excessive internal rotation and positive value means excessive external rotation in regards to normal values.