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Evolution of Posturographic and Dynamic Baropodometry 4 Weeks after Total Knee Arthroplasty

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Abstract **Original Research Article**

This is a prospective study, which included patients followed for advanced knee osteoarthritis (N = 10, mean age 72 ± 7.9 years) candidates for total knee arthroplasty (TKA). Functional status was carried out by WOMAC score. Posturological and dynamic baropodometric analysis were carried out before (M0) and 4 weeks after TKA (M1) using a PRESSCAM® stabilometry platform (SIDAS®, 38,000 VOIRON, MEDICAPTEURS®). Data provided information on the distribution of foot pressures on the operated and non-operated side. Comparison of baropodometric parameters was performed before (M0) and 4 weeks after TKA (M1). The total WOMAC score decreased significantly after TKA (P <0.05). The changes in posturographic and dynamic parameters of surfaces, pressure and force measured at M1 were not significant. At M0, the stabilogram position was deviated in all patients towards the contralateral operated side. At M1, we noted normalization of the stabilogram position in 2 patients. Surface of COP ellipse was superior to 1 cm2 (%) in one patient before TKA and in 2 patients after TKA. Comparison of medio lateral indexes indicated significant changes in surface area and average pressure (p<0.05). In conclusion posturographic and dynamic baropodometry analysis could help clinicians to correct the postural instability after total knee arthroplasty. Long-term follow-up studies will be able to confirm the use of baropodometry in evaluating TKA.

Keywords: Total knee arthroplasty, posturography, dynamic baropodometry.

INTRODUCTION

Total knee arthroplasty (TKA) is one of the most successful surgeries performed in orthopedics. It is able to reduce knee pain and improve function and quality of life [1]. The effect of TKA on stability is a relevant point which should also be taken into consideration in the management of these patients [2]. Only a few data focused on this subject [3]. An increase in motion and in balance index after surgery was found in a previous published data [4, 5]. According to another study which evaluated postural stability instrumentally (Balance Master System), the implant improved dynamic stability [3]. Moreover, assessing baropodometry after TKA showed a progressive recovery of stability after TKA from the immediate postoperative to the subsequent months. The same study argued that the clinical and functional improvement correlated with a load redistribution between the two limbs [6]. This stability is greater with bilateral prosthesis than unilateral one. There is a scarce in studies combining posturographic and dynamic analysis after TKA. The purpose of our study was, therefore, to study the evolution of posturographic and dynamic baropodometric parameters 4 weeks after TKA.

MATERIAL AND METHODS

We designed a prospective observational study to assess postural and dynamic baropodometry following

TKA. Between January and December 2019, ten consecutive patients were recruited through orthopedic department of the Military Hospital of Instruction Mohammed V-Rabat (HMIMV). Patients were assessed in rheumatology outpatient clinic of El Ayachi hospital. The Ethical Committee of the Faculty of Medicine and Pharmacy, Mohammed V University, Rabat, Morocco, approved the study protocol in accordance with the Declaration of Helsinki (1964) and all participants signed consent. The patients scheduled to undergo TKA were assessed 1 day before surgery (M0) and 4 weeks (M1) after knee surgery.

Patients:

We included patients aged over 50 years with symptomatic knee osteoarthritis scheduled for prosthetic knee surgery. Patients suffering from other pathologies of the musculoskeletal system, or other pathologies which could affect their balance, or their movement (myopathies, neurological and cardiovascular pathologies) were excluded. Socio-demographic and anthropometric data of the patients were collected (age, sex, body mass index (BMI)). The functional impact was evaluated by the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) [7]. The WOMAC is made up of 24 items grouped into three categories: pain, joint stiffness, and function with a score of 0 to 100 mm for each item. The final WOMAC score is obtained by adding intermediate scores corresponding to the estimate of pain, stiffness and function.

Pedobarographic Measurements:

The posturographic examination by baropodometry was carried out in a standing position, for 30 seconds at 50 Hz. The orientation is determined from the study of the mean position of the center of pressure (COP) along the anteroposterior axes (X) and lateral (Y). The mean position of the antero-posterior and medio-lateral COP corresponded respectively to Xmoy and Ymoy. We collected data providing information on surfaces, plantar pressures and weight distribution of the body on the feet of the operated side and the non-operated side.

Stabilization is informed via an analysis of the trajectory of the COP, also called a statokinesigram or stabilogram. The baropodometric variables collected were as follows:

- The total length of the COP displacement (in mm),
- The length of the COP displacement on X axis (in mm),
- The length of the COP displacement on Y axis (in mm),
- The area of the ellipse of the displacement (in mm^2),
- The length / surface ratio of the COP displacement,
- The speed of COP displacement (mm / s),

In physiological situations, the area swept by COP displacements is ≤1 cm2 and the average position of the stabilogram is centered and located slightly behind the right of the center of the baropodometric platform [8]. Comparing the evolution before and after TKA, we looked for significant variations in COP ellipse surface and deviations of the stabilogram position.

To perform the dynamic examination, we used a "Two steps" baropodometric acquisition protocol with a comfortable walking pace. This method is recommended by the HAS (Haute Autorité de la Santé) because it has the best reproducibility of measurements on a baropodometric platform [9]. Thus, the platform was placed in the room in such a way that the patient took a step before and after his passage over the sensor. The instruction given to the patient was to walk as normally as possible, performing 3 to 5 passages. The measurement of the 2nd step was recorded. We used a dynamic multiple recording mode.

Variables measured during a dynamic examination included maximum and average pressure, force, and area. The mean pressure plots represent the average value of the pressures applied to the entire foot during the full stance phase. The maximum pressure plots represent the highest-pressure value recorded by each sensor over the entire stance phase.

The step sequence was studied by looking for 3 parameters: the “initial comma” and the two physiological phases of slowing down the COP movement. We collected mediolateral (M/L) index of the maximum and average support forces, surfaces and pressures. All the baropodometric parameters were compared before and 4 weeks after TKA.

Statistics:

The statistical analysis was calculated using SPSS (Statistical Package for Social Sciences) software version 25. Quantitative variables data are presented as mean, standard, median and minimum-maximum deviation. For qualitative variables, data are expressed in numbers and percentages.

Group comparisons were made by using the T Student test (when the measures were normally distributed) or by a nonparametric test (Mann-Whitney test) for quantitative variables when the measures were not normally distributed and the Chi-square test for qualitative variables. Paired tests were used to compare WOMAC and baropodometric parameters before TKA and 4 weeks after surgery.

RESULTS

The 10 patients included in this study have a mean age of 72 ±7.9 years. The median duration of knee osteoarthritis was 9.5 years. The average BMI was 36.7±4.6 Kg / m2. TKA involved the right knee in 70%

of cases. The characteristics of the patients and their knee osteoarthritis are shown in Table I. The total WOMAC score decreased significantly after TKA (66 ±8.7 at M0 and 40.4± 13.4 at M1, P <0.05). The 3 components (pain, function and stiffness) of WOMAC score improved significantly after TKA (P <0.05).

Table I: Characteristics of patients eligible for total knee osteoarthritis at inclusion (M0)

Characteristics	N=10
Age (years)	72 ±7.9
Women %	80
BMI (Kg / m2)	36.7±4.6 [31-44]
Disease duration (years)*	9.3 [5.1. 10.2]
Global score of WOMAC*	66 ±8.7[54-75]
Site of TKA (Right %)	70
Treatments Analgesics (%) NSAIDs (%) Slow-acting antiarthrosis drugs (%)	 90 70 40

BMI: body mass index; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index;

Pedobarographic Measurements

Table II compares posturographic parameters before (M0) and 4 weeks (M1) after TKA. All the changes were no significant (p>0.05).

Table II: Comparison of posturographic parameters measured before (M0) and 4 weeks (M1) after total knee arthroplasty (TKA)

Posturographic parameters	**M0**	**M1**	***p***
Total surface (cm2)	276±22.1	265±30.1	0.82
Peak plantar pressure (g/cm2)	770±80.2	802.5±105.4	0.64
Mean plantar pressure (g/cm2)	341.1±28.1	343.4±33	0.89
Plantar surface on the operated side (cm2)	131±15.1	129.1±17.4	0.58
Plantar surface on the non operated side (cm2)	138.6±11	135±15.8	0.75
Weight distribution on the operated side (kg)	41±6.5	39.4±6.6	0.43
Weight distribution on the non operated side (kg)	47.1±2.7	47.7±5.9	0.74
Mean position of the antero-posterior (Xmean)	2.3 (-7.8, 13.5)	3.1(-10.2, 12.9)	0.2
Mean position of the medio-lateral COP (Ymean)	-11.75 (-17.1,-6.5)	-12.3 (-18.6,-5.5)	0.43
Total length of the displacement of the COP (mm)	91.8±23.1	85.2±20.3	0.09
Length of the displacement of the COP in X (mm)	1.9 ±0.8	2.1 ±1.1	0.31
Length of the displacement of the COP in Y (mm)	2.3 ±1.1	2.2 ±0.4	0.86
Area of the ellipse of the displacement of the COP (mm^2)	65.6±24.2	68.2±35.9	0.84
Length / surface ratio of the displacement of the COP	1.5±0.4	1.5±0.8	0.9
Speed of movement of the COP (mm / s)	2.8±0.7	2.6±0.6	0.78

Comparison of posturographic abnormalities before (M0) and 4 weeks (M1) after total knee arthroplasty (TKA) showed that the stabilogram position was deviated in all patients toward the contralateral side of TKA. After surgery, we noted normalization of the stabiligram position in 2 patients (p> 0.05). The total surface of the COP ellipse was superior to 1 cm2 in one patient before TKA and in 2 patients after TKA.

Results of the distribution of pressures, forces and surfaces in dynamic baropodometry are shown in table III. The mediolateral index parameters of force, area, mean and maximum pressure between the lateral supinator and medial pronator of the foot. Comparison of mediolateral index parameters showed significant changes in surface area and average pressure (p<0.05).

Table III: Comparison of characteristics of mediolateral index measured by dynamic baropodometry before (M0) and 4 weeks (M1) after total knee arthroplasty (TKA)

Characteristics of mediolateral index	M0	M1	*p*
Mediolateral index of force in operated limb	1.11±0.25	1.29±0.4	0.37
Mediolateral index of surface in operated limb	1.12±0.22	1.47±0.34	0.06
Mediolateral index of mean pression in operated limb	1.03±0.22	0.87±0.11	0.04
Mediolateral index of peak pression in operated limb	0.97±0.04	0.95±0.07	0.42

DISCUSSION

This study showed the evolution, after TKA, of distribution of plantar pressures, force, surface, and trajectory of COP, spectrum of step path, and evolution of mediolateral index parameters given by static and dynamic baropodometric examinations.

Plantar pressures on the side of the knee scheduled for TKA were low compared to the opposite limb. This could be explained by the pain and functional discomfort generated by knee osteoarthritis. Indeed, our patients had advanced osteoarthritis, a source of significant pain and functional impairment.

After surgery, we noted several changes after 4 weeks, illustrated by the results of posturographic and dynamic baropodometry examinations. The majority of these results remain nonsignificant. This lack of statistical significance was expected due to the small number of patients.

The changes, although not significant, show the effect of TKA surgery on plantar pressure and support surfaces. The improvement of pain and function by surgery allows the patient to regain support on the operated limb, thus increasing the surface area and the supporting pressures. The COP trajectory, initially deviated in the 10 patients towards the side contralateral to TKA, was corrected in 2 patients. We suppose that the changes in COP positioning would require a longer period after TKA. In addition, our patients had other factors involved in postural stability. The majority of our patients were over 70 years old, and they were overweighted. It is well known that physiological changes in COP position occur in the elderly and that obesity also impairs the postural balance [8, 10].

Comparison of COP oscillations between M0 and M1 would be explained by the short time to patient assessment. Therapeutic management, focusing on the rehabilitation of proprioception, would improve the stability of patients after TKA [11].

Dynamic baropodometry confirms the results of posturography on the distribution of pressures, forces and surfaces. The mediolateral index is an objective and interesting tool which allows us to assess the distribution of the parameters of force, area, mean and maximum pressure between the lateral supinator and medial pronator of the foot [12, 13]. Comparison of this index made it possible to individualize significant changes in surface area and average pressure. This tool has been used by several authors in the follow-up of foot surgery and has demonstrated its interest in the follow-up [10].

Some limitations should be pointed out in our study. The first one is the sample size and the absence of a control group. We encountered enormous difficulties in including patients and seeing them again 1 month later. Most of the patients contacted did not agree to come to our hospital for a baropodometric examination since surgery was decided anyway.

However, despite the small number of patients, the present study was able to provide us with a database of baropodometric pictures, graphs and videos illustrating a lot of information given by baropodometry.

The second point is the short time frame for evaluating the patients. It would have been interesting to continue the follow-up and to reassess measurements after 6 months. This was not possible to schedule for logistical reasons and since the patients were scheduled to begin functional rehabilitation.

Finally, it would be also interesting to evaluate clinically these patients to assess the risk of falls providing a clinical overview of the stability of patients at inclusion and after TKA.

Despite the small sample size, this study gave us a comprehensive overview of the static, posturographic and dynamic baropodometric variations that occurred in our patients 1 month after TKA. She provided a beautiful iconography illustrating the changes in plantar pressures in posturographic and dynamic as well as those in the posturographic oscillations of the antero-posterior and latero-medial pressure center after surgery.

CONCLUSION

Baropodometry is a simple, noninvasive examination allowing exploration of plantar pressure, postural stability and gait characteristics. This study is an example of the multiple possible applications of baropodometry. It highlights the changes that occurred 1 month after TKA. Posturographic and dynamic analysis give us a global view on the evolution of trajectory of COP, the changes in stabilogram position, step path and mediolateral index characteristics. All those detailed information and illustrations provided by this exam could help clinician in the assessment and monitoring of postural instability in clinical practice. The short-term results obtained are encouraging. Long-term follow-up studies will be able to confirm the use of baropodometry in evaluating TKA.

Competing Interests: Authors declared they have no conflict of interest.

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