Article:
Huynh, C, Puyraimond-Zemmour, D, Maillefert, JF et al. (18 more authors) (2018) Factors associated with the orthopaedic surgeon's decision to recommend total joint replacement in hip and knee osteoarthritis: an international cross-sectional study of 1905 patients. Osteoarthritis and Cartilage, 26 (10). pp. 1311-1318. ISSN 1063-4584

https://doi.org/10.1016/j.joca.2018.06.013

TITLE PAGE

Factors associated with the orthopaedic surgeon's decision to recommend total joint replacement in hip and knee osteoarthritis: an international cross-sectional study of 1905 patients

C. Huynh[1], D. Puyraimond-Zemmour[1], J.F. Maillefert[2], P.G. Conaghan[3], A.M. Davis[4], K.-P. Gunther[5], G. Hawker[6], M.C. Hochberg[7], M. Kloppenburg[8], K. Lim[9], L.S. Lohmander[10], N.N. Mahomed[11], L. March[12], K. Pavelka[13], L. Punzi[14], E.M. Roos[15], L. Sanchez-Riera[12,16], J.A. Singh[17], M.E. Suarez-Almazor[18], M. Dougados[19] and L. Gossec[1.]

AFFILIATIONS

[1.] Sorbonne Universités, UPMC Univ Paris 06, Institut Pierre Louis d'Epidémiologie et de Santé Publique (UMRS 1136), Paris, France ; Rheumatology Department, Hôpital Pitié Salpêtrière, AP-HP, PARIS, France

[2.] Department of Rheumatology, Dijon University Hospital, Dijon F-21078, France, University of Burgundy, Dijon F-21079, France, INSERM U1093, Dijon F-21079, France.

[3.] Leeds Institute of Rheumatic and Musculoskeletal Medicine, University of Leeds & NIHR Leeds Biomedical Research Centre, Leeds, United Kingdom.

[4.] Division of Health Care and Outcomes Research, Krembil Research Institute, Toronto, Ontario and Departments of Rehabilitation Science and Health Policy, Management and Evaluation, University of Toronto, Canada.

[5.] University Center of Orthopaedics and Traumatology, Technische Universität, Dresden, Germany.

[6.] Division of Rheumatology, Department of Medicine, Women's College Hospital and Women's College Research Institute; Faculty of Medicine, and Institute of Health Policy, Management and Evaluation, Dalla Lana School of Public Health, University of Toronto, Canada.

[7.] Division of Rheumatology & Clinical Immunology, Department of Medicine and Division of Gerontology, Department of Epidemiology and Public Health, University of Maryland School of Medicine, Baltimore, MD, USA.

[8.] Department of Rheumatology, Department of Clinical Epidemiology, Leiden

University Medical Center, Leiden, The Netherlands.

[9.] University of Melbourne Dept of Medicine (Western), Dept of Rheumatology, Western Health, and Australian Institute of Musculoskeletal Science, Melbourne, Australia.

[10.] Department of Clinical Sciences Lund, Orthopaedics, Lund University, Lund, Sweden.

[11.] Division of Orthopaedic Surgery, Toronto Western Hospital, University of Toronto, Arthritis Program, University Health Network, Toronto, Canada.

[12.] Institute of Bone and Joint Research, University of Sydney, Royal North Shore Hospital, St Leonards, Australia.

[13.] Institute of Rheumatology, Charles University Prague, Czech Republic.

[14.] Rheumatology Unit, Department of Medicine DIMED, University of Padova, Italy.

[15.] Institute of Sports and Clinical Biomechanics, University of Southern Denmark, Denmark.

[16.] University Hospital Bristol NHS Foundation Trust, Bristol, UK.

[17.] Birmingham VA Medical Center and University of Alabama, Birmingham, AL, USA.

[18.] Section of Rheumatology and Clinical Immunology, University of Texas, M.D. Anderson Cancer Center, Houston, TX, USA.

[19.] Paris Descartes University, Department of Rheumatology, Hôpital Cochin. APHP, INSERM (U1153): Clinical epidemiology and biostatistics, PRES Sorbonne Paris-Cité. Paris 14, France.

CORRESPONDING AUTHOR

Pr Laure Gossec, Hôpital Pitié-Salpêtrière, Service de Rhumatologie, 47-83, boulevard de l'Hôpital – 75013 Paris France. Tel: +33- 42 7842 ; Fax: +33-142177959. laure.gossec@aphp.fr

ABSTRACT (248 words)

Objective To determine factors associated with orthopaedic surgeons' decision to recommend total joint replacement (TJR) in people with knee and hip osteoarthritis (OA).

Design Cross-sectional study in eleven countries. For consecutive outpatients with definite hip or knee OA consulting an orthopaedic surgeon, the surgeon's indication of TJR was collected, as well as patients' characteristics including comorbidities and social situation, OA symptom duration, pain, stiffness and function (Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)), joint-specific quality of life, OARSI joint space narrowing radiographic grade (0-4), and surgeons' characteristics. Univariable and multivariable logistic regressions were performed to identify factors associated with the indication of TJR, adjusted by country.

Results In total, 1905 patients were included: mean age was 66.5 (standard deviation, SD, 10.8) years, 1082 (58.0%) were women, mean OA symptom duration was 5.0 (SD 7.0) years. TJR was recommended in 561/1127 (49.8%) knee OA and 542/778 (69.7%) hip OA patients. In multivariable analysis on 516 patients with complete data, the variables associated with TJR indication were radiographic grade (Odds Ratio, OR for one grade increase, for knee and hip OA, respectively: 2.90, 95% confidence interval [1.69-4.97] and 3.30 [2.17-5.03]) and WOMAC total score (OR for 10 points increase: 1.65 [1.32-2.06] and 1.38 [1.15-1.66], respectively). After excluding radiographic grade from the analyses, on 1265 patients, greater WOMAC total score was the main predictor for knee and hip OA; older age was also significant for knee OA.

Conclusion Radiographic severity and patient-reported pain and function play a major role in surgeons' recommendation for TJR.

KEYWORDS Knee, hip, osteoarthritis, total joint replacement, surgery.

RUNNING HEADLINE Total joint replacement in osteoarthritis

3447 words, 6 tables, 3 online tables

INTRODUCTION

With the global ageing and increasing obesity and sedentary lifestyle of the world's population, the prevalence of osteoarthritis (OA) is increasing along with its social and economic impacts [1,2]. Lower-extremity OA affects mainly the hip and the knee, which leads to pain and functional disability. In 2010, hip and knee OA were ranked as the 11th highest contributor condition to global disability worldwide and their disability burden keeps growing [2]. Total joint replacement (TJR) is the current treatment for moderate to severe knee and hip OA that has failed to respond to non-surgical management, including pharmacologic and non-pharmacologic modalities, and has the potential for significant improvement of pain, functional capacity and quality of life [3-5]. However, not all patients with OA will benefit from TJR. In the context of increasing burden of OA and consequent growing needs for this surgery, we need to better understand who receives an indication for TJR. This is linked to the ongoing studies on appropriateness criteria to consider TJR [6-13].

In studies exploring factors associated with TJR [14-20], some factors were key in the decision for TJR, such as levels of symptoms [5,14-19] and radiographic damage [14,15,18,19,21-23], whereas other factors were not linked to TJR, including patients' gender and body mass index [15-20]. For several factors, the association with TJR remained unclear, such as patients' age, comorbidities, and quality of life [16,19]. Furthermore, other previously unexplored factors may play a relevant role, like patients' social situation and surgeons' characteristics.

In 2010, a large international study was conducted under the auspices of the Osteoarthritis Research Society International (OARSI) and Outcome Measures in Rheumatology (OMERACT). The aim was to determine cut-offs for pain and

functional impairment related to the indication for TJR [24]. In the primary analyses, only pain and function were analysed: the main conclusions were that although both pain and function played a role in the surgeon's decision, because of substantial overlap no satisfactory cut-off values could be established to distinguish patients selected or not for TJR with an area under the receiver operating characteristic (ROC) curve greater than 0.64 [0.61;0.67] [24]. This dataset gave us the opportunity to explore more completely criteria involved in the indication of TJR, using the surgeon's opinion as the gold standard.

The objective of the present study was to determine the factors associated with the surgeon's recommendation to perform TJR in people with both knee and hip OA, in the context of a large, international, multi-site study.

PATIENTS AND METHODS

Study design

The study design has been described previously [24]. Briefly, this was a large international, observational, cross-sectional study with prospective inclusion, in the orthopaedic departments of secondary-care and tertiary-care centers in Europe (12 centers, one per country in Czech Republic, Italy, Spain, Sweden and the United Kingdom; two per country in France and the Netherlands; three in Germany), Canada (2 centers), the United States of America (2 centers), and Australia (2 centers). Ethical approval was obtained in all participating centers. All patients gave informed consent. The research forms were completed during a routine patient visit and no queries were sent to the investigators in case of missing data.

Study population

Consecutive outpatients with a clinical diagnosis of hip or knee OA (according to the orthopaedic surgeon and based on symptoms and radiographs) consulting an orthopaedic surgeon in one of the participating centers to discuss potential surgery were included for this analysis. Exclusion criteria were: prior TJR or prior osteotomy of the target joint, concomitant inflammatory joint disease, and patient inability to complete a questionnaire. Furthermore, among patients who had given data, only those with information on the surgeons' recommendations to perform TJR or not were included in the analysis.

Gold standard: Indication for TJR

The outcome analysed in the present study was the orthopaedic surgeon's indication regarding the requirement for TJR, i.e., the surgeon stating "surgery is recommended for the patient". This answer defined the 'indication for TJR', irrespective of whether the joint replacement surgery was performed or not.

Potential variables associated with surgeons' indication for TJR

Demographic data comprising age, gender, and body mass index (BMI, calculated based on height and weight, then analysed both as a continuous variable and categorised) were collected. Due to the high mean BMI in this population, the decision was taken to analyse BMI as above or below 35 kg/m2. Comorbidities were reported using a modified Charlson Comorbidity Index, and were analysed as the sum of the number of comorbidities (range, 0-14) [25]. Symptom severity was collected through the Western Ontario and McMaster Universities Osteoarthritis

(WOMAC) Index (total score; pain, function and stiffness subscales) [26]. WOMAC results were linearly transformed to a 0-100 score, where higher scores indicated worse status [24]. Patients' joint-related quality of life was evaluated by the Quality of Life subscale of the Hip disability and Osteoarthritis Outcome Score (HOOS) and Knee disability and Osteoarthritis Outcome Score (KOOS), as appropriate [27,28]. The HOOS/KOOS are two valid and reliable instruments with five individually calculated subscales that can be used for short-term and long-term follow-up of several types of hip/knee injury including OA. HOOS/KOOS scores are reported on a 0-100, worst to best, scale. Where radiographs of the target joint were available, the local investigator reported the OARSI joint space narrowing (JSN) radiological grade [29,30]. X-rays were taken in the context of usual care, according to local protocols. The score analyses JSN in categories from 0 to 4: (0) no narrowing, (1) < 25%, (2) 25-50%, (3) 50-75%, (4) > 75% of JSN [21,22]. The patients' social situation was collected by the physician as "living alone" (yes/no) and "being responsible for another person" (yes/no). Surgeons' characteristics such as gender and years of experience (year of certification as an orthopaedic surgeon) were collected.

Surgeon's reported reason(s) not to recommend TJR

If the surgeon selected "no indication for TJR", underlying reasons for not recommending surgery were collected from the surgeon as: symptoms not severe enough, patient declining surgery, comorbidity, main problem not being hip/knee OA, further investigations required, another treatment should be tried first.

Patients not recommended for TJR who were considered « not severe enough » were compared in terms of WOMAC total score with patients not recommended for other reasons.

Statistical analysis

Patient characteristics were described separately for knee and hip OA patients. To assess factors associated with indication for TJR, univariable analyses where OR with 95% confidence intervals have been calculated were performed in each patient population, evaluating each variable.

Forward multivariable logistic regressions were then performed, including variables with p<0.20 in univariable analyses and excluding colinear variables, eg WOMAC subscales (**online supplementary table 1**). Since OARSI JSN is a qualitative variable, radiographic severity was binarised as grade 1-2 versus 3-4. Surgeons' characteristics were analysed at the patient level rather than at the surgeon level.

There was no imputation of missing data. As there were many missing data for the radiographic grade and for surgeons' characteristics, a second multivariable logistic regression was performed excluding these variables, both for patients with knee and hip OA. All multivariable analyses were adjusted for country of residence as the objective was not to compare results between countries, given small sample sizes [24]. No formal testing was performed across countries.

All analyses were performed using R software, version 3.2.5.

RESULTS

Patient characteristics

In all, 1974 patients were enrolled between June 2008 and December 2010. Among them, 1905 patients (96.5%) had data for TJR indication and were analysed: 1127 knee OA and 778 hip OA patients. Patients were from: Europe (N=1121), Australia (N=394), Canada (N=204) and the United States of America (N=186). Patient characteristics were typical of established OA cohorts (**Table 1**). Mean age was 66.5 (standard deviation (SD) 10.8) years, 1082/1866 (58.0%) were women, mean OA symptom duration was 6.3 (SD 8.4) years in knee OA patients and 3.3 (SD 3.4) years in hip OA patients, mean BMI was 31.0 (SD 6.8) kg/m² in knee OA patients and 28.3 (SD 5.1) kg/m² in hip OA patients. WOMAC subscale scores for pain and functional disability (0-100) were respectively 52.8 (SD 21.8) and 55.4 (SD 20.9) for knee OA; 56.5 (SD 21.6) and 59.5 (SD 20.9) for hip OA. In all, 516 patients had all data available (**online supplementary Table 2**). Most patients for whom radiographic data were available had severe JSN: 351/512 (69.0%) knee OA patients and 311/403 (82.9%) hip OA patients had an OARSI JSN radiographic grade of 3 or 4.

Factors associated with TJR recommendation in univariable analysis

TJR was recommended in 561/1127 (49.8%) knee OA and 542/778 (69.7%) hip OA patients (**Table 1**).

Knee OA: In univariable analysis for knee OA (**Table 2**), the variables related to the decision to recommend total knee replacement (TKR) were older age (with more indications for TJR in the range 60 to 79 years old, **online supplementary table 3**), male gender, longer OA symptom duration, history of another TJR, patient living

alone, patient being responsible for another person, higher WOMAC total score and subscale scores, lower KOOS Quality of life subscale score, more severe OARSI JSN radiographic grade, surgeon's male gender and years of experience. In contrast, BMI (both continuous and categorized) and number of comorbidities were not associated with the indication of TKR.

Hip OA: In univariable analysis for hip OA (**Table 3**), factors associated with the decision to recommend total hip replacement (THR) were older age (again with most indications for TJR between 60 and 79 years of age, **online supplementary table 3**), longer OA symptom duration, patient living alone, higher WOMAC total score and subscale scores, lower HOOS Quality of life subscale score, more severe OARSI JSN radiographic grade and surgeon's male gender. THR would not appear to be recommended if patients' BMI is greater than 35 kg/m². Patients' gender, BMI (as a continuous variable), history of another TJR, number of comorbidities, patient being responsible for another person and surgeon's experience were not associated with the indication for THR.

Factors associated with indication for TJR in multivariable analysis

A first multivariate analysis adjusted by country was performed in the 516 patients for whom all data, including radiographic assessment, were available (**Tables 4 and 5 and online supplementary table 1**). Independent factors associated with TJR in both knee and hip OA patients were OARSI JSN grade (assessed for an increase of one point) and higher (i.e. more symptoms, disability and stiffness) WOMAC total score. The corresponding results were respectively for knee OA, Odds Ratio, for a 1-point increase of OARSI JSN radiographic grade, OR: 2.90, 95% Confidence Interval

[1.69;4.97] and OR for a 10-point increase of WOMAC total score: 1.65 [1.32;2.06]; and respectively for hip OA, OR: 3.30 [2.17;5.03] and OR: 1.38 [1.15;1.66]. The other demographic factors, including BMI (both continuous and categorized), patient's social situation or surgeon characteristics, were not independently associated with a TJR indication.

As there were many missing data for the OARSI JSN radiographic grade and for surgeons' characteristics, a second multivariable logistic regression was performed excluding these variables, both for knee and hip OA (**Tables 4 and 5**). In these analyses, 1265 patients contributed (characteristics in **online supplementary table 2**). Here, higher (i.e. more symptoms, disability and stiffness) WOMAC total score (knee: OR 1.25 [1.14;1.37] and hip: OR 1.49 [1.33;1.68]) was a significant factor associated with indication for TJR in knee and hip OA. Patients' older age (knee: OR 1.03 [1.01;1.04]) was a significant factor in knee OA. No other factors were independently associated with a TJR indication.

Surgeons' reasons to not recommend TJR

For both knee and hip OA, almost half of patients for whom the surgeons did not recommend TJR were considered by the surgeon to be "not symptomatic enough" (N=224/491 (45.6%) and N=102/219 (46.5%), respectively) (**Table 6**). For these patients, symptom levels were indeed less severe at the group level: in knee and hip OA, WOMAC total score was 42.2 (SD 19.9) and 35.3 (SD 19.7) respectively, vs 51.5 (SD 20.3) and 55.6 (SD 19.9), in patients for whom surgery was not recommended because "symptoms were not severe enough" and those for whom TJR was not indicated for "other reasons", respectively (both p<0.0001). The second most

196 frequent reason for the surgeon to not recommend TJR was because "another
197 treatment should be tried first", in both knee and hip OA (Table 6).
198
199
200 **DISCUSSION**
201
202 The present study brings relevant information on the reasons for orthopaedic
203 surgeons recommending TJR. It confirmed the role of radiographic scores and
204 symptoms as independent factors associated with surgeons' recommendation to
205 perform TJR. It appeared, on the sample of patients with available radiographic
206 scores, that the orthopaedic surgeon's decision to recommend a TJR was largely
207 based on radiographic severity, i.e., a state of moderate-to-severe OA, in the present
208 patients, who had pain and functional limitations. We also found that patient's age is
209 an important factor in particular for knee OA. This study confirmed that some other
210 factors were not associated with recommendation for TJR, such as patients' gender,
211 BMI and comorbidities. Finally, previously unexplored factors, linked to patients'
212 social situation or surgeons' characteristics that could be analysed, did not appear to
213 be associated with surgeon's recommendation for TJR.
214
215 This study has strengths and limitations. The main limitation is the high rate of
216 missing data, probably due to the large number of sites and the lack of queries sent
217 to investigators for missing data. This led to a smaller analysed population in the
218 multivariable logistic regressions. Nevertheless, to our knowledge, this is the only
219 international study and among the largest, possibly explaining the difficulty to obtain
220 information from all the involved participants (patients and practitioners). The factors

that were most frequently missing were OARSI JSN radiographic grade and surgeons' characteristics. Missing data on radiographs could be explained by lack of availability of the radiograph, or a lack of standardised assessment. Surgeons' characteristics were given by orthopaedic surgeons themselves while filling case report forms during the visit but this page was often not completed. A second analysis was therefore performed excluding these two factors. Of note, characteristics of the multivariable populations were similar compared to the initial 1905 included patients (**Online supplementary table 1**) which would be an argument in favour of random missing data. After excluding OARSI JSN radiographic grade and surgeons' characteristics, patient's age appeared to be a factor associated with indication for TJR, in knee OA: in this study population of a mean age of 69.0 years (SD 9.5), patients aged from 60 to 79 years were more likely to be recommended for TJR than younger patients (<60 years old) or older patients (>80 years old) (**Online supplementary table 3**). It is possible that older patients had more radiographic JSN however this is not the only factor given the U shape of the relationship. Restrictions in recommendation of TJR in younger patients could also be explained by a higher revision rate (with subsequent poorer outcomes), as mentioned in Verra et al's study [31]. Other limitations include the incomplete nature of the data collection; for example, psychological distress, ethnicity and socioeconomic status were not collected although it has been suggested that they are predictors of patients being offered joint replacement [6-7]. Finally, as variables from the univariable analysis were selected for entry into the multivariable model rather than all entered, we recognise some variables may have been missed. However, this method avoided colinearity between the variables.

In this group of patients with definite knee or hip OA, TJR was recommended in 49.8% and 69.7% respectively. These rates can be compared to prior studies which vary between 16% and 60% [14,15,18-20]. This indicates both the variability of surgery rates, and possibly differences between studies focused on surgery as the event, where rates were lower, and indication for surgery, where rates were comparable to the ones found here. Better clarity on appropriateness criteria for TJR would reduce inappropriate referrals and decisions [6-13].

In the present study, differences across countries were not analysed although recommendations for TJR may vary by country [14-20], due to differences in clinical practice and healthcare systems. Only a few centres participated in each country. Therefore, results of this present study cannot be considered representative of national practices. Furthermore, disparities among countries on pain and function evaluation have been previously pointed out within this cohort [24]. To account for national differences, results were adjusted by country.

The use of validated scores such as WOMAC and OARSI JSN radiographic scores, not systematically used in prior studies [14,20] is a strength of this study, although the use of the WOMAC total score is still in discussion [26].

The level of symptoms, in terms of pain and disability, and the radiographic severity, were higher among patients for whom TJR was indicated by the surgeon, which is in accordance with previous studies [15,18,19] and 4 national guidelines for assessing need for total knee and hip replacement : (1) the US National Institute of Health consensus guidelines, suggesting that knee and hip TJR should be considered in patients with persistent pain, radiographic damage and limitation in daily activities [36,37]; (2) Canadian criteria, isted by Hawker et al in 2000, considering that a total

WOMAC score ≥ 39, and clinical and radiographic evidences of OA should lead to TJR [38]; (3) the French severity index for OA by Lequesne, composed of 3 criteria (pain, maximum distance walked and activities of daily living) and suggesting knee or hip TJR when ≥ 14 out of a possible 24 [39]; and (4) the New Zealand score, considering that levels of pain, functional activity, movement and deformity, and other factors such as multiple joint disease or ability to work could determine indication for knee or hip TJR [40]. These guidelines or consensus statements, although using pain and functional impairment criteria in majority, reveal some heterogeneity and difficulty in application in practice. This could explain in part why, to this day, no validated international guidelines exist. [6-13]. Of note, in the present study, JSN (a qualitative score) was analysed as a binary variable, thus losing some granularity; however, radiographic severity is usually considered as present/absent when deciding on TJR. [29-30] The present study also confirmed the substantial overlap in symptoms and function between patients oriented or not towards TJR.[24]

Similarly to previous studies [16,18-20], the present study found that gender and BMI were not associated with indication for TJR. Of note, BMI was analysed using a cut-off of 35 kg/m2 but analyses with BMI as a continuous variable were similar. Factors which were doubtful or much less explored in previous studies appeared here not to be associated with indication for TJR, including comorbidities. Hawker et al also found no association with the number of comorbidities [16] although Maillefert et al concluded surgeons tended to indicate THR more often if patients had no severe cardiovascular comorbidity [19]. In the present study, each patient had around 3 comorbidities, but this factor was not associated with indication for TJR. This might reflect improvements in TJR and anesthesiology techniques, leading to a shorter

surgical time and less risks for the patient, regardless of medical history. In terms of quality of life, the present study did not find a link with indication for TJR, unlike the studies performed by Hawker et al and Maillefert et al [16,19], perhaps due to the use of different scales. Furthermore, as joint-related quality of life is strongly related to pain and function, this variable was not entered in the multivariable analysis. Among the new factors that this study was able to explore, related to patients' social situation and surgeons' characteristics, no significant links were found; though such findings would need to be further confirmed.

This cohort gave us the opportunity to explore indication for TJR rather than TJR itself, hence excluding a subset of confounding factors such as socio-economic criteria or patients' willingness, but also patients' expectations or psychological distress in order to determine factors that influence a surgeon's decision to recommend or not recommend TJR [32-35]. In this study, we collected the surgeon's reasons for not recommending TJR, when surgery was not recommended. For both knee and hip OA, almost half of patients for whom the surgeons did not decide on TJR were considered by them as "not symptomatic enough", and the second most frequent reason announced was "because another treatment should be tried first". These descriptive results suggest that patients might be referred perhaps too widely to orthopaedic surgeons. Other treatment options than surgery should be discussed first [41].

In summary, determining when to recommend TJR in knee and hip OA patients is difficult, but factors that help in such a decision are definitely the ones reflecting radiographic severity and higher levels of symptoms. Further studies are needed in

320 particular to better define potential candidates for TJR, in the context of high and
321 increasing world-wide burden of OA.

ACKNOWLEDGMENTS

Dr Hawker is supported as the Sir John and Lady Eaton Professor and Chair of Medicine at the University of Toronto, Toronto, Canada.

PGC is supported in part by the UK National Institute for Health Research (NIHR) Leeds Biomedical Research Centre. The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health.

Dr Jeffrey N. Katz is supported as Professor of Medicine and Orthopedic Surgery and Clement B. Sledge and Thomas S. Thornhill Chair in Orthopedic Surgery, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA.

AUTHOR CONTRIBUTIONS

All the authors contributed to

(1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data

(2) drafting the article or revising it critically for important intellectual content

(3) final approval of the version to be submitted.

Laure Gossec (laure.gossec@aphp.fr) takes responsibility for the integrity of the work as a whole, from inception to finished article.

ROLE OF THE FUNDING SOURCE

The study sponsors played no role in the study design, in the collection, analysis and interpretation of data; in the writing of the manuscript; or in the decision to submit the manuscript for publication.

CONFLICTS OF INTEREST

None relevant to the present work.

REFERENCES

1. Gupta S, Hawker GA, Laporte A, Croxford R, Coyte PC. **The economic burden of disabling hip and knee osteoarthritis (OA) from the perspective of individuals living with this condition.** *Rheumatology (Oxford).* 2005;44:1531–7.

2. Cross M, Smith E, Hoy D, Nolte S, Ackerman I, Fransen M, et al. **The global burden of hip and knee osteoarthritis: estimates from the global burden of disease 2010 study.** *Ann Rheum Dis.* 2014;73:1323–30.

3. Liang MH, Cullen KE, Larson MG, Thompson MS, Schwartz JA, Fossel AH, et al. **Cost-effectiveness of total joint arthroplasty in osteoarthritis.** *Arthritis Rheum.* 1986;29:937–43.

4. Zhang W, Moskowitz RW, Nuki G, Abramson S, Altman RD, Arden N, et al. **OARSI recommendations for the management of hip and knee osteoarthritis, Part II: OARSI evidence-based, expert consensus guidelines.** *Osteoarthritis Cartilage.* 2008;16:137–62.

5. Singh JA, Lewallen DG. **Patient-level improvements in pain and activities of daily living after total knee arthroplasty.** *Rheumatology (Oxford)*. 2014;53:313–20.

6. Katz JN, Winter AR, Hawker G. **Measures of the Appropriateness of Elective Orthopaedic Joint and Spine Procedures.** *J Bone Joint Surg Am.* 2017;99(4):e15.

7. Frankel L, Sanmartin C, Hawker G, De Coster C, Dunbar M, Bohm E, et al. **Perspectives of orthopaedic surgeons on patients' appropriateness for total joint arthroplasty: a qualitative study.** *J Eval Clin Pract.* 2016;22:164-70.

8. Hawker G, Bohm ER, Conner-Spady B, De Coster C, Dunbar M, Hennigar A, et al. **Perspectives of Canadian Stakeholders on Criteria for Appropriateness for Total Joint Arthroplasty in Patients With Hip and Knee Osteoarthritis.** *Arthritis Rheum.* 2015;67:1806-15.

9. Riddle DL, Jiranek WA, Hayes CW**. Use of a validated algorithm to judge the appropriateness of total knee arthroplasty in the United States: a multicenter longitudinal cohort study.** *Arthritis Rheum.* 2014;66:2134–43.

10. Frankel L, Sanmartin C, Conner-Spady B, Marshall DA, Freeman-Collins L, Wall A, et al. **Osteoarthritis patients' perceptions of "appropriateness" for total joint replacement surgery.** *Osteoarthritis Cartilage.* 2012;20:967–73.

11. Ghomrawi HM, Schackman BR, Mushlin AI. **Appropriateness criteria and elective procedures--total joint arthroplasty.** *N Engl J Med.* 2012;367:2467-9.

12. Sanmartin C, Murphy K, Choptain N, Conner-Spady B, McLaren L, Bohm E, et al. **Appropriateness of healthcare interventions: concepts and scoping of the published literature.** *Int J Technol Assess Health Care.* 2008;24:342–9.

13. Quintana JM, Escobar A, Arostegui J, Bilbao A, Azkarate J, Goenaga JI, et al. **Health-related quality of life and appropriateness of knee or hip joint replacement.** *Arch Intern Med.* 2006;166:220–6.

14. Birrell F, Afzal C, Nahit E, Lunt M, Macfarlane GJ, Cooper C, et al**. Predictors of hip joint replacement in new attenders in primary care with hip pain.** *Br J Gen Pract*. 2003;53:26–30.

15. Gossec L, Tubach F, Baron G, Ravaud P, Logeart I, Dougados M. **Predictive factors of total hip replacement due to primary osteoarthritis: a prospective 2 year study of 505 patients.** *Ann Rheum Dis.* 2005;64:1028–32.

16. Hawker GA, Guan J, Croxford R, Coyte PC, Glazier RH, Harvey BJ, et al. **A prospective population-based study of the predictors of undergoing total joint arthroplasty.** *Arthritis Rheum.* 2006;54:3212–20.

17. Skou ST, Roos EM, Laursen MB, Rathleff MS, Arendt-Nielsen L, Simonsen O, et al. **Criteria used when deciding on eligibility for total knee arthroplasty - Between thinking and doing.** *Knee.* 2016;23:300-5.

18. Lievense AM, Koes BW, Verhaar JAN, Bohnen AM, Bierma-Zeinstra SMA. **Prognosis of hip pain in general practice: a prospective followup study.** *Arthritis Rheum.* 2007;57:1368–74.

19. Maillefert JF, Roy C, Cadet C, Nizard R, Berdah L, Ravaud P. **Factors influencing surgeons' decisions in the indication for total joint replacement in hip osteoarthritis in real life.** *Arthritis Rheum.* 2008;59:255–62.

20. Zeni JA, Axe MJ, Snyder-Mackler L. **Clinical predictors of elective total joint replacement in persons with end-stage knee osteoarthritis.** *BMC Musculoskelet Disord.* 2010;11:86.

21. Maillefert JF, Gueguen A, Nguyen M, Berdah L, Lequesne M, Mazieres B, et al. **A composite index for total hip arthroplasty in patients with hip osteoarthritis.** *J Rheumatol.* 2002;29:347–52.

22. Kellgren JH, Lawrence JS. **Radiological assessment of osteo-arthrosis.** *Ann Rheum Dis.* 1957;16:494–502.

23. Maillefert JF, Gueguen A, Nguyen M, Berdah L, Lequesne M, Mazières B, et al. **Relevant change in radiological progression in patients with hip osteoarthritis. I. Determination using predictive validity for total hip arthroplasty.** *Rheumatology (Oxford).* 2002;41:142–7.

24. Gossec L, Paternotte S, Maillefert JF, Combescure C, Conaghan PG, Davis AM, et al. **The role of pain and functional impairment in the decision to recommend total joint replacement in hip and knee osteoarthritis: an international cross-sectional study of 1909 patients. Report of the OARSI-OMERACT Task Force on total joint replacement.** *Osteoarthritis Cartilage.* 2011;19:147–54.

25. Charlson ME, Charlson RE, Peterson JC, Marinopoulos SS, Briggs WM, Hollenberg JP. **The Charlson comorbidity index is adapted to predict costs of chronic disease in primary care patients.** *J Clin Epidemiol.* 2008;61:1234–40.

26. Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. **Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee.** *J Rheumatol.* 1988;15:1833–40.

27. Nilsdotter AK, Lohmander LS, Klässbo M, Roos EM. **Hip disability and osteoarthritis outcome score (HOOS)--validity and responsiveness in total hip replacement.** *BMC Musculoskelet Disord.* 2003;4:10.

28. Collins NJ, Prinsen CA, Christensen R, Bartels EM, Terwee CB, Roos EM. **Knee Injury and Osteoarthritis Outcome Score (KOOS): systematic review and meta-analysis of measurement properties.** *Osteoarthritis Cartilage.* 2016 ;24:1317-29.

29. Altman RD, Hochberg M, Murphy WA, Wolfe F, Lequesne M. **Atlas of individual radiographic features in osteoarthritis.** *Osteoarthritis Cartilage.* 1995;3 Suppl A:3–70.

30. Gossec L, Jordan JM, Lam M-A, Fang F, Renner JB, Davis A, et al. **Comparative evaluation of three semi-quantitative radiographic grading techniques for hip osteoarthritis in terms of validity and reproducibility in 1404**

radiographs: report of the OARSI-OMERACT Task Force. *Osteoarthritis Cartilage.* 2009;17:182–7.

31. Verra WC, Witteveen KQ, Maier AB, Gademan MGJ, van der Linden HMJ, Nelissen RGHH. **The reason why orthopaedic surgeons perform total knee replacement: results of a randomised study using case vignettes.** *Knee Surg Sports Traumatol Arthrosc.* 2016;24:2697–703.

32. Charlson ME, Allegrante JP. **Disparities in the use of total joint arthroplasty.** *N Engl J Med.* 2000;342:1044–5.

33. Milner PC, Payne JN, Stanfield RC, Lewis PA, Jennison C, Saul C. **Inequalities in accessing hip joint replacement for people in need.** *Eur J Public Health.* 2004;14:58–62.

34. Yong PFK, Milner PC, Payne JN, Lewis PA, Jennison C. **Inequalities in access to knee joint replacements for people in need.** *Ann Rheum Dis.* 2004;63:1483–9.

35. Dixon T, Shaw M, Ebrahim S, Dieppe P. **Trends in hip and knee joint replacement: socioeconomic inequalities and projections of need.** *Ann Rheum Dis.* 2004;63:825–30.

36. **NIH consensus conference: Total hip replacement. NIH Consensus Development Panel on Total Hip Replacement.** *JAMA.*1995;273:1950–6.

37. **NIH Consensus Statement on total knee replacement.** *NIH Consens State Sci Statements.* 2003;20:1–34.

38. Hawker GA, Wright JG, Coyte PC, Williams JI, Harvey B, Glazier R, et al. **Differences between men and women in the rate of use of hip and knee arthroplasty.** *N Engl J Med.* 2000;342:1016–22.

39. Lequesne MG. **The algofunctional indices for hip and knee osteoarthritis.** *J Rheumatol.* 1997;24:779–81.

40. Hadorn DC, Holmes AC**. The New Zealand priority criteria project. Part 1: Overview.** *BMJ.* 1997;314:131–4.

41. Allen KD, Choong PF, Davis AM, Dowsey MM, Dziedzic KS, Emery C, et al. **Osteoarthritis: Models for appropriate care across the disease continuum.** *Best Pract Res Clin Rheumatol.* 2016;30:503-535.

Table 1. Characteristics of 1905 patients with established knee or hip OA consulting an orthopedic surgeon.

Variable	All patients N= 1905	Knee patients N= 1127	Hip patients N= 778
Indication for TJ R, N (%)	1103 (57.9)	561 (49.8)	542 (69.7)
Age, years, mean (SD)	66.5 (10.8)	67.6 (10.4)	65.0 (11.3)
Gender, female, N (%)	1082 (58.0)	654 (58.8)	428 (56.8)
Body mass index, kg/m², mean (SD)	29.9 (6.3)	31.0 (6.8)	28.3 (5.1)
Body mass index > 35 kg/m², N (%)	366 (18.8)	216 (16.7)	150 (22.8)
OA symptom duration, years, mean (SD)	5.0 (7.0)	6.3 (8.4)	3.3 (3.4)
Pain, WOMAC subscale (0-100), mean (SD)	54.5 (22.0)	52.8 (21.8)	56.5 (21.6)
Function, WOMAC subscale (0-100), mean (SD)	54.3 (19.9)	55.4 (20.9)	59.5 (20.9)
Stiffness, WOMAC subscale (0-100), mean (SD)	61.2 (26.1)	57.5 (25.6)	58.8 (23.8)
WOMAC total score (0-100), mean (SD)	56.6 (20.4)	55.1 (20.4)	58.6 (20.2)
HOOS/KOOS Quality of life subscale (0-100), mean (SD)	27.6 (19.0)	27.7 (18.7)	27.3 (19.5)
OARSI J SN radiographic grade (3-4), N (%)	662 (72.3)	351 (69.0)	311 (82.9)
Surgeon's gender, male, N (%)	1044 (90.9)	615 (90.5)	429 (91.2)
Surgeon's experience, years, mean (SD)	17.8 (9.2)	17.8 (9.0)	17.9 (9.4)

SD=standard deviation. WOMAC subscale and total scores were linearly transformed to 0-100 scores where 100=worst state. HOOS/KOOS Quality of life subscale were transformed to 0-100 scores where 0=worst state.
All % are % of available data. The most frequently missing data were OARSI J SN radiographic grade (for knee and hip OA respectively, 512 and 403 patients with data available), surgeon's experience (for knee and hip OA respectively, 662 and 460 patients with data available and surgeon's gender (for knee and hip OA respectively, 679 and 470 patients with data available).

Table 2. Factors associated with indication for knee replacement in 1127 patients with knee OA: univariable analysis

Variable	TKR recommended N= 561	TKR not recommended N= 566	OR [95% CI]	P value
Age, years, [N] mean (SD)	[447] 69.0 (9.5)	[434] 66.0 (11.0)	1.03 [1.17-1.52]	<0.0001
Gender, female, n/N (%)	210/553 (38.0)	249/560 (44.5)	0.76 [0.60-0.97]	0.03
BMI, kg/m², [N] mean (SD)	[434] 30.9 (6.2)	[435] 31.0 (7.5)	1.00 [0.98-1.02]	0.81
BMI > 35kg/m², n/N (%)	98/434 (22.6)	102/435 (23.4)	0.95 [0.69-1.31]	0.76
OA symptom duration, years, [N] mean (SD)	[296] 7.1 (8.0)	[332] 5.6 (8.7)	1.00 [1.00-1.01]	0.03
Comorbidities (KCS score), [N] mean (SD)	[474] 3.2 (1.7)	[358] 3.1 (1.7)	1.03 [0.95-1.12]	0.46
History of another joint replacement (yes), n/N (%)	122/542 (22.5)	73/528 (13.8)	1.81 [1.32-2.50]	<0.001
Patient living alone, n/N (%)	175/546 (32.1)	135/530 (25.5)	1.38 [1.06-1.80]	0.02
Patient being responsible for another person, n/N (%)	120/543 (22.1)	142/529 (26.8)	0.77 [0.58-1.02]	0.07
Pain, WOMAC subscale (0-100), [N] mean (SD)	[540] 57.0 (20.5)	[520] 48.0 (22.0)	1.11 [1.07-1.14]	<0.001
Function, WOMAC subscale (0-100), [N] mean (SD)	[479] 45.6 (14.5)	[480] 38.9 (16.2)	1.03 [1.02-1.04]	<0.001
Stiffness, WOMAC subscale (0-100), [N] mean (SD)	[536] 61.9 (25.0)	[507] 52.5 (25.2)	1.20 [1.12-1.28]	<0.001
WOMAC total score (0-100), [N] mean (SD)	[471] 57.0 (18.0)	[451] 48.7 (20.3)	1.02 [1.02-1.03]	<0.001
KOOS Quality of life subscale (0-100), [N] mean (SD)*	[518] 23.7 (19.6)	[536] 31.8 (16.8)	0.98 [0.97-0.98]	<0.0001
OARSI J SN radiographic grade (3-4), n/N (%)	187/206 (90.8)	164/306 (45.5)	8.52 [5.17-14.77]	<0.0001
Surgeon's gender, male, n/N (%)**	268/288 (93.0)	347/391 (88.7)	1.70 [0.90-3.01]	0.04
Surgeon's experience, years, [N] mean (SD)	[284] 19.1 (9.3)	[375] 16.8 (8.7)	1.03 [1.01-1.05]	0.001

% are % of available data. N=number of patients with available data.
*Lower scales indicate worse status
**This line indicates that 93.0% of patients recommended for surgery had seen a male surgeon

Table 3. Factors associated with indication for hip replacement in 778 patients with hip OA: univariable analysis

Variable	THR recommended N= 542	THR not recommended N= 236	OR [95% CI]	P value
Age, years, [N] mean (SD)	[449] 65.8 (10.5)	[199] 63.1 (12.8)	1.02 [1.01-1.04]	0.004
Gender, female, n/N (%)	292/524 (55.7)	133/229 (58.1)	1.08 [0.79-1.47]	0.65
BMI, kg/m², [N] mean (SD)	[449] 28.3 (4.8)	[182] 28.3 (5.9)	1.00 [0.97-1.04]	0.92
BMI > 35kg/m², n/N (%)	42/446 (9.4)	24/181 (13.2)	0.68 [0.40-1.17]	0.16
OA symptom duration, years, [N] mean (SD)	[306] 3.7 (3.7)	[127] 2.3 (2.3)	1.00 [1.00-1.01]	<0.0001
Comorbidities (KCS score), [N] mean (SD)	[466] 3.1 (1.6)	[163] 2.9 (1.6)	1.04 [0.93-1.17]	0.51
History of another joint replacement (yes), n/N (%)	122/526 (23.2)	42/218 (19.3)	1.27 [0.65-1.13]	0.24
Patient living alone, n/N (%)	147/526 (27.9)	77/220 (35.0)	0.72 [0.52-1.01]	0.06
Patient being responsible for another person, n/N (%)	111/521 (21.3)	49/218 (22.5)	0.93 [0.64-1.37]	0.72
Pain, WOMAC subscale (0-100), [N] mean (SD)	[520] 60.4 (19.0)	[221] 47.5 (24.5)	1.16 [1.11-1.21]	<0 .0001
Function, WOMAC subscale (0-100), [N] mean (SD)	[475] 63.7 (18.1)	[202] 49.8 (23.4)	1.05 [1.04-1.06]	<0 .0001
Stiffness, WOMAC subscale (0-100), [N] mean (SD)	[517] 63.4 (22.6)	[214] 48.8 (25.6)	1.36 [1.25-1.49]	<0 .0001
WOMAC total score (0-100), [N] mean (SD)	[461] 62.6 (17.7)	[189] 48.5 (22.3)	1.04 [1.03-1.05]	<0 .0001
HOOS Quality of life subscale (0-100), [N] mean (SD)*	[500] 22.7 (16.3)	[215] 38.1 (22.0)	0.96 [0.95-0.97]	<0 .0001
OARSI J SN radiographic grade (3-4), n/N (%)	232/246 (94.3)	79/169 (61.2)	10.49 [5.64-20.67]	<0 .0001
Surgeon's gender, male, n/N (%)**	287/307 (93.5)	142/163 (87.1)	2.12 [1.11-4.07]	0.02
Surgeon's experience, years, [N] mean (SD)	[299] 18.3 (9.7)	[161] 17.1 (8.8)	1.01 [0.99-1.03]	0.21

% are % of available data. N=number of patients with available data.
*Lower scales indicate worse status
**This line indicates that 93.5% of patients being recommended for surgery had seen a male surgeon

Table 4. Factors associated with indication for TKR : multivariate analysis adjusted on country

Variable	Complete model OR [95% CI]	Second model OR [95% CI]
OARSI J SN radiographic grade (3-4), for 1-point increase	**2.90 [1.69-4.97]**	Not analysed
WOMAC total score (0-100), for 10-point increase	**1.65 [1.32-2.06]**	**1.25 [1.14-1.37]**
Age, years	1.01 [0.97-1.06]	**1.03 [1.01-1.04]**
Gender, female	1.01 [0.47-2.12]	0.90 [0.95-0.99]
Patient being responsible for another person	1.21 [0.44-3.24]	0.93 [0.61-1.43]
Surgeon's experience, years	1.06 [0.99-1.13]	Not analysed

The complete model included all variables but due to missing data only 243 patients contributed to the model
The second model was performed after excluding the variables with most missing data, radiographic OARSI grade and surgeon's experience. In this model 754 patients were analysed.
Significant results are presented in bold type.

Table 5. Factors associated with indication for THR: multivariate analysis adjusted on country

Variable	Complete model OR [95% CI]	Second model OR [95% CI]
OARSI J SN radiographic grade (3-4), for 1-point increase	**3.30 [2.17-5.03]**	Not analysed
WOMAC total score (0-100), for 10-point increase	**1.38 [1.15-1.66]**	**1.49 [1.33-1.68]**
Age, years	1.02 [0.98-1.04]	1.02 [1.00-1.04]
BMI >35kg/m²	1.32 [0.41-4.97]	0.72 [0.37-1.48]
Patient living alone	1.18 [0.55-2.62]	0.60 [0.37-0.96]
Surgeon's gender, male	1.04 [0.27-3.61]	Not analysed

The complete model included all variables but due to missing data only 273 patients contributed to the model
The second model was performed after excluding the variables with most missing data, radiographic OARSI grade and surgeon's gender. In this model 511 patients were analysed.
Significant results are presented in bold type.

Table 6. Surgeons' announced reasons for « non-indication for TJ R »

Reasons	Knee, N=491 N (%)	Hip, N=219 N (%)
Symptoms were not severe enough	224 (45.6)	102 (46.5)
Another treatment should be tried first	147 (29.9)	50 (22.8)
Because of comorbidity	36 (7.3)	13 (5.9)
Patient declined surgery	26 (5.3)	17 (7.8)
Further investigations are required	22 (4.5)	20 (9.1)
Main problem was not hip/knee OA	12 (2.4)	9 (4.1)
Other causes	24 (4.9)	8 (3.7)