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ORIGINAL PAPER

International survey of primary and revision total knee replacement

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Abstract
Purpose Total knee arthroplasty (TKA) is currently the international standard of care for treating degenerative and rheumatologic knee joint disease, as well as certain knee joint fractures. We sought to answer the following three research questions: (1) What is the international variance in primary and revision TKA rates around the world? (2) How do patient demographics (e.g., age, gender) vary internationally? (3) How have the rates of TKA utilization changed over time?

Methods The survey included 18 countries with a total population of 755 million, and an estimated 1,324,000 annual primary and revision total knee procedures. Ten national inpatient databases were queried for this study from Canada, the United States, Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, and Switzerland. Inpatient data were also compared with published registry data for eight countries with operating arthroplasty registers (Denmark, England & Wales, Norway, Romania, Scotland, Sweden, Australia, and New Zealand).

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Results The average and median rate of primary and revision (combined) total knee replacement was 175 and 149 procedures/100,000 population, respectively, and ranged between 8.8 and 234 procedures/100,000 population. We observed that the procedure rate significantly increased over time for the countries in which historical data were available. The compound annual growth in the incidence of TKA ranged by country from 5.3% (France) to 17% (Portugal). We observed a nearly 27-fold range of TKA utilization rates between the 18 different countries included in the survey.
Conclusion It is apparent from the results of this study that the demand for TKA has risen substantially over the past decade in countries around the world.

Introduction

Total knee arthroplasty (TKA) is currently the international standard of care for treating degenerative and rheumatologic knee joint disease, as well as certain knee joint fractures. National registries have been established in certain European countries, Canada, Australia, and New Zealand, to monitor the rates of revision replacement surgery [1]. Although primary and revision total knee replacement surgery is widely recognized as highly cost effective procedures [2–6], the utilization of joint arthroplasty has come under increased administrative scrutiny in an era of concern over limited healthcare resources [3].

Relatively few studies have broadly compared the international utilization of joint arthroplasty [1, 7, 8]. Scheerlinck et al. [7] distributed a postal survey to teaching hospitals in the European Union to determine international patterns in the utilization of primary hip arthroplasty, but knee replacement surgery was not included in their study. Researchers have also recently performed international comparisons of arthroplasty registers [1, 8]; however, these reviews focused on the operational aspects, rather than the outcomes, of joint arthroplasty registers.

Overall, the international variation in the utilization of primary and revision knee arthroplasty remains poorly understood. In the United States, the utilization of total knee arthroplasty has increased substantially in the past decade [9–11]. It is not known whether the trend of increased TKA utilization over time can be generalized to countries other than the United States. However, in light of previous reviews highlighting differences in the practice of orthopaedic surgery between different countries [1, 8], international variations in the rates of knee arthroplasty surgery would also be anticipated.

The goal of this study was to compare the epidemiology and historical trends of utilization for TKA around the world. We sought to answer the following three research questions: (1) What is the international variance in primary and revision TKA rates around the world? (2) How do patient demographics (e.g., age, gender) vary internationally? (3) How have the rates of TKA utilization changed over time?

Methods

International collaborators with access to national inpatient data and primary registry data were invited to participate in this research. The ten national inpatient databases queried for this study included the Nationwide Inpatient Sample (United States), Hospital Morbidity Database (Canada), Registro de Altas – CMBD (Spain), National Hospital Discharge Register (Portugal, Netherlands, Finland), National Hospital Database (France), Hospital Discharge Records Database (Italy), Hospitals Statistics, FSO (Switzerland), and the German Federal Statistical Office database (Destatis). These databases were all selected based on their size and representativeness, making them well suited for epidemiological studies of primary and revision total knee replacement. Each database was queried for the most recent ten years of available data, but because the date of creation for each database as well as the data collection mechanism varied by country, the same time period of arthroplasty data was not always available. A brief description of these nationally representative administrative databases, along with the years of available data analysed in the study, is summarized below.

The Nationwide Inpatient Sample (NIS) was used to identify primary and revision knee arthroplasty procedures performed in the United States between 1997 and 2008. The NIS is an annual, statistically valid survey of ~1,000 hospitals conducted by the Federal Healthcare Cost and Utilization Project (HCUP). NIS contains approximately 20% of the inpatient hospitalizations performed in the United States, regardless of payment source. The analytical files for NIS are publicly available and include sample weights enabling the projection of national number of procedures. First implemented in 1988, the NIS database was specifically designed for performing national healthcare research and informing healthcare policy in the United States.

The Hospital Morbidity Database (HMDB) was used to identify primary and revision knee arthroplasty procedures performed in Canada between 2002 and 2008. HMDB was established by the Canadian Institute for Health Information (CIHI) and contains nationally representative data on diagnoses, procedures, and patient characteristics. We did not use data from the Canadian Joint Replacement Registry (CJRR) in the present study. CJRR is a voluntary registry

and thus only captures data from a subset of primary and revision hip and knee replacement procedures. Because of the limited scope of CJRR and based on the recommendations of experts from CIHI, we relied instead on the HMDB for the present study.

The French National Hospital Database was used to identify primary and revision knee arthroplasty procedures performed in France in both public and private hospitals between 2002 and 2007. TKA procedures were included in the study only if they were accompanied by an appropriate diagnosis for knee disease or fracture. The analysis of French data included patients living in metropolitan France.

The Registro de Altas – CMBD (El Conjunto Mínimo Básico de Datos de hospitalización), was used to identify primary and revision knee arthroplasty procedures performed in Spain between 1997 and 2008. This nationally representative database is compiled from hospital discharges in the National Health Service by the Institute for Health Information in the Ministry of Health and Social Policy.

The National Hospital Discharge Register was used to identify primary and revision knee arthroplasty operations in continental Portugal between 1997 and 2008. In Portugal, the national system of health is universal and free for the entire population. Due to the high costs involved, arthroplasties are almost always treated in public hospitals, and for that reason the National Hospital Discharge Register represents the totality of admissions with diagnosis of knee arthroplasties and revisions nationwide. The register is updated every month by all public hospitals, and it is managed by the National Administration of the Central Health System (Administação Central do Sistema de Saúde – ACSS) of the Portuguese Health Ministry. No such data are available for the Portuguese archipelagos of Azores and Madeira, and hence the analyses focused on continental Portugal.

The Dutch Hospital Discharge Register (HDR) was used to identify knee arthroplasty operations in the Netherlands between 1997 and 2007. The HDR is recognized by Statistics Netherlands as a nationally representative database with a high coverage rate and contains discharge records of inpatient and outpatient hospital stays [12]. The HDR is maintained by Prismant (Utrecht).

The Hospital Discharge Records Database (HDRDB) was used to identify primary and revision knee arthroplasty operations in Italy between 1999 and 2008. The HDRDB was established in 1994 within the public National Health System, but only since 1999 has the quality of collected data been considered of sufficiently high quality for nationally representative analyses. The HDRDB contains information about all the hospital admissions performed nationally (more than 12 million per year). Data collection using the Hospital Discharge Collection Form (HDCF) is mandatory for both ordinary and day-hospital admissions. At discharge, clinicians code diagnoses (up to 6) and procedures (up to 6) by means of the ICD-9-CM (1997) system. Information about pharmaceuticals is not collected. Data are transmitted by the hospitals to the Regional Health Authority and then to the Ministry of Health. Hospital admissions are reimbursed by the National Health Systems using the DRG calculated on the collected main diagnosis that is the condition that requested the highest expenditures. In 2000, the Ministry of Health stated that HDCF would be considered not merely for administrative purposes but also to support management and control of the hospital activities and to perform epidemiological analyses. For the years 1999 and 2000, we had available only the records including TKA or TKR as main procedure.

The Hospitals Statistics from the Swiss Federal Statistical Office (SFSO) was used to identify primary and revision knee arthroplasty procedures performed in Switzerland between 1998 and 2008. The registration of each patient in Switzerland is obligatory and the hospital statistics contains a complete dataset on diagnoses, procedures, and patient characteristics.

The German Federal Statistical Office database (Destatis) was used to identify primary and revision knee arthroplasty operations in Germany between 2005 and 2008. This database was only created in 2005, but provides a detailed overview of primary and revision TKA scenarios. Data can be requested free of charge if one provides the so-called "OPS" codes of interest.

The Finnish National Hospital Discharge Register was used to identify primary and revision knee arthroplasty operations in Finland between 1997 and 2009. Reporting to the register is mandatory for both public and private hospitals. Finland also maintains a National Arthroplasty Register, but for the present survey, national experts extracted primary and revision data from the Discharge Register.

For the present study, we also analysed the registry data for eight countries with operating national arthroplasty registers and publicly available annual reports that are published via the Internet (Romania, Denmark, England & Wales, Sweden, Scotland, New Zealand, Norway, and Australia). A recent review has described the characteristics of the 23 independent orthopaedic registries around the world [1], but not all of them are nationally representative nor do they all publish their data. The study authors (SMK, CR, MT) extended written invitations to researchers involved in the orthopaedic registries, inviting them to participate in the study.

Experts from Australia provided access to raw registry data for use in this study and aided in the interpretation of their national data. Data extracted from the Australian Orthopaedic Association, National Joint Replacement

Registry (AOA - NJRR) was used in this study. The AOA - NJRR has full national data on knee joint arthroplasty performed in Australia from 2002 onwards [13]. The present study included primary and revision total knee replacement procedures performed in Australia between January 1, 2002 and December 31, 2008.

Total knee replacement surgeries were identified from inpatient databases using country-specific codes. In the United States, Spain, Portugal, Italy, and Switzerland, primary (81.54) and revision (81.55) total knee procedures were identified using the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM). More detailed ICD-9-CM codes for revision knee arthroplasty (00.80-00.84), introduced in 2005, were also included in the analysis of recent revision data for the United States, Switzerland, and Spain. In France, procedures were classified by the Catalog of Medical Procedures until 2004–2005, at which time the "Common Classification of Medical Procedures" was adopted. In Germany, procedures were classified by the German modification of the ICD-10 procedure coding system. In the Netherlands, the national procedure coding system captures total knee arthroplasty but does not distinguish between primary and revision procedures. In Finland, surgical procedures were identified using the Finnish version of the Nordic Medico-Statistical Committee's (NOMESCO) classification system, which is maintained by the Nordic Centre for Classifications in Health Care. Population statistics were based on census data from the European Commission (Eurostat), U.S. Census Bureau, the Australian Bureau of Statistics, Statistics Canada, Statistics New Zealand, and the Office for National Statistics (United Kingdom).

The rate of knee arthroplasty was calculated annually as the number of procedures per 100,000 persons in the population. The change in arthroplasty rate over time was estimated by linear regression with year as the independent variable. Pearson correlations were computed between rates of surgery and proportion of elderly patients or the proportion of female patients.

Results

The survey included 18 countries with a total population of 755 million, and an estimated 1,324,000 annual primary and revision total knee procedures, according to the most recent data available (Table 1). The average and median rates of primary and revision (combined) total knee replacement were 175 and 149 procedures/100,000 population, respectively, and ranged between 8.8 and 234 procedures/100,000 population for Romania and the United States, respectively (Table 1). The rate of total knee revision surgery could be computed for 17 of the 18 countries, with the exception of the Netherlands. The average and median

Table 1 International utilization of total knee arthroplasty

Country (year)	National population (million)	Primary total knee procedures (thousand)	Revision total knee procedures (thousand)	Primary+revision total knee procedures (thousand)	Primary total knee procedures/ 100,000 population	Revision total knee procedures/ 100,000 population	Primary+revision total knee procedures/ 100,000 population
Australia* (2008)	21.7	35.9	3.2	39.1	165.5	14.7	180.2
Canada (2008)	33.5	48.1	3.1	51.3	143.7	9.4	153.1
Denmark* (2008)	5.4	7.7	0.9	8.6	143.3	16.8	160.1
England and Wales* (2009/10)	54.8	79.3	5.2	84.5	144.6	9.5	154.1
Finland (2009)	5.4	9.5	0.7	10.2	177.5	13.3	190.9
France (2007)	63.6	62.4	5.0	67.4	98.1	7.9	105.9
Germany (2008)	82.2	154.7	22.7	177.4	188.3	27.6	215.8
Italy (2008)	59.8	56.6	3.4	60.1	94.7	5.7	100.4
Netherlands (2007)	16.4			19.8			121.2
New Zealand* (2009)	4.2	6.012	0.433	6.4	142.4	10.3	152.6
Norway* (2008)	4.7	3.984	0.362	4.3	84.8	7.7	92.5
Portugal (2008)	10.1	5.61	0.315	5.9	55.4	3.1	58.5
Romania* (2009)	21.5	1.841	0.051	1.9	8.6	0.2	8.8
Scotland* (2009)	5.1	6.884	0.567	7.5	135.0	11.1	146.1
Spain (2008)	45.7	37.9	4.5	42.4	82.9	9.9	92.8
Sweden* (2008)	9.1	10.155	0.467	10.6	111.6	5.1	116.7
Switzerland (2008)	7.6	13.4	1.2	14.7	176.8	16.3	193.1
United States (2008)	304	648.5	63.4	711.9	213.3	20.9	234.2

Sources: National inpatient administrative databases, registries*, and census data

Table 2 Demographic breakdown of total knee arthroplasty

Country (year)	% Female (overall)	% <65 years (overall)
Australia* (2008)	56.0%	35.5%
Canada (2008)	60.1%	37.7%
Finland (2009)	67.0%	33.8%
France (2007)	65.4%	22.8%
Germany (2008)	66.1%	26.7%
Italy (2008)	71.0%	21.4%
Netherlands (2007)	68.7%	35.7%
Portugal (2008)	72.8%	27.3%
Spain (2008)	72.3%	19.7%
Switzerland (2008)	62.2%	31.6%
United States (2008)	62.4%	43.6%

Sources: National inpatient administrative databases, registries*, and census data

rate of revision total knee replacement was 15.0 and 9.9 procedures/100,000 population, respectively, and ranged between 0.2 and 28 procedures/100,000 population for Romania and Germany, respectively (Table 1).

The percentage of female patients was 65.8% (range, 56.0–72.8%), and the percentage of patients <65 years of age was 30.5% (range, 19.7–43.6%) (Table 2). Of the factors studied, the national population was positively correlated with the annual number of TKA procedures performed per country (Spearman's rho=0.85, $p<0.0001$). However, there was no significant correlation between the patient factors (%<65Y, % female) and the national rates of surgery, except for a negative correlation between % female and procedure rate (Spearman's rho=0.65, $p=0.03$).

We observed that the procedure rate increased over time for the countries in which historical data were available (Table 3). The compound annual growth in the number of TKA procedures ranged by country from 5.3% (France) to 17% (Portugal).

Discussion

We observed nearly a 27-fold range of TKA utilization rates between the 18 different countries included in the survey. These international variations do not appear to be simply explained by patient demographics (e.g., age or gender). It is also apparent from the results of this study that the demand for TKA has risen substantially over the past decade in countries besides the United States. In addition, it is not yet clear whether observed differences might be explained by national factors, such as the type of healthcare system (i.e., public vs. private), access to care, number and distribution of orthopaedic surgeons, and the prevalence of joint disease, which could not be included in our study at this time.

Our data were derived from national inpatient databases and arthroplasty registers, and are not without limitations. The administrative data that form the basis for national inpatient databases contain basic patient demographic data (e.g., age, gender) but limited clinical information, such as patient comorbidities. Because these administrative datasets are established to track the reimbursement of procedures, typically the implant related information is also limited to what is captured in ICD-9-CM codes, which further constrain the granularity of available data. In the Netherlands, for example, administrative claims do not distinguish between primary and revision knee arthroplasty. Thus, we were unable to compare the rates of revision surgery in the Netherlands with the other countries in this study.

Partial knee replacement includes a variety of procedures including hemi-arthroplasty, patellotrochlear replacement, as well as partial resurfacings that have been available in recent years. Although the present study was focused on total knee

Table 3 Compound annual growth rates of total knee arthroplasty (TKA)

Country	Years of available TKA data	Annualized growth in TKA procedures	Annualized growth in procedure rate/10^5
Australia*	2003-2008	6.7%	5.0%
Canada	2002-2008	10.3%	9.1%
Finland	1997-2009	7.2%	6.9%
France	2002-2007	5.3%	3.6%
Germany	2005-2008	6.9%	7.1%
Italy	1999-2008	12.8%	12.2%
Netherlands	1997-2007	9.4%	8.8%
Portugal	1997-2008	17.0%	16.6%
Spain	1997-2008	11.5%	10.1%
Switzerland	1998-2008	14.7%	14.0%
United States	1997-2008	7.9%	6.8%

Sources: National inpatient administrative databases, registries*, and census data

arthroplasty, it is not possible to distinguish between partial and total knee arthroplasty using the ICD-9-CM codes that form the basis for administrative data collection in many of the countries of this study. It was also not possible to distinguish primary and revision unicondylar knee procedures in all of the annual public reports provided by national registers. Exceptions were Germany and Canada, which employ a detailed, national version of the ICD-10 procedure coding system, as were countries with orthopaedic registries, and for which we were able to discriminate between partial and total knee arthroplasty. Thus, among countries in which primary and revision unicondylar knee replacements could be identified (e.g., Germany and Australia), we generally excluded partial knee replacements from the present study. However, the inherent lack of procedure coding granularity must be kept in mind when comparing the total knee arthroplasty rates of the United States, Spain, Portugal, the Netherlands, Canada, Italy, and Switzerland with the other countries in this study that had more detailed procedure coding systems and for which we could effectively exclude partial knee operations. Nevertheless, the lack of specificity in knee arthroplasty operations in certain countries is not judged to be a major limitation for this study, because of the relative low incidence of partial knee arthroplasty, which accounts for 8–15% of the total volume of knee replacement surgeries [14].

National joint arthroplasty registers, which arguably contain the highest quality population-based data on the utilization of total knee arthroplasty [15], are now only established in less than half of the countries considered for the present study. Thus, the breadth of our study would have been dramatically reduced had we restricted our attention to countries with orthopaedic registries. Indeed, the countries with the highest rates of knee arthroplasty, namely, the United States, Germany, and Switzerland, do not currently have fully operational orthopaedic surgery registers [16]. Thus, despite the limitations of administrative data sets, they provide the only means to effectively survey the current utilization of joint arthroplasty for many countries around the world, including countries with the highest rates of knee replacement surgery.

Few studies have evaluated the international temporal trends of total joint replacements. Kurtz et al. found that between 1990 and 2003, the incidence of primary and revision knee replacement tripled in the United States [9]. Similarly, an increase in the knee surgery rates was likewise observed in the United Kingdom between 1991 and 2006 [17], as well as in the Republic of Korea between 2002 and 2005 [18]. In Italy, an increase of 64% was measured in a five-year period (2001–2005) [19]. These previous studies are in general agreement with the findings from the present survey, in which we observed a significant increase in total knee surgery rates that was country-specific. The reasons underlying the growth in total knee replacement were not explicitly studied as part of this study, but are expected to include a combination of the aging of the population, changes in national patterns of obesity, increases in the number of knee surgeons, and growing acceptance of the effectiveness of total knee arthroplasty among surgeons, patients, and society. The growth in demand for total knee surgery has important implications for national healthcare delivery systems. In the United States alone, the growth in demand for joint replacement surgery is projected to exceed available surgical and economic resources if the historic growth rates continue for the coming two decades [10, 11]. In some countries with public healthcare, such as Canada, Finland, and the United Kingdom, the demand for joint replacement is managed by waiting lists, and an important quality metric for satisfaction with healthcare in these countries is the time spent by the patient waiting for joint replacement surgery. The data reported in this study are thus expected to be useful for policy and planning purposes in Australia, Europe, and the United States.

The long-term goal of this research is to assemble a comprehensive survey of knee replacement surgery around the world, but only a few countries with established nationally representative inpatient databases and joint replacement registers have been analysed thus far. Our study included countries in North America, Europe, and the South Pacific, based on publicly available data sources and the collaboration with healthcare data experts in the participating countries. In Japan, a new national database for collecting inpatient records has only recently been created but as of yet contains relatively few reported cases of total knee replacement (16,600 cases combined in 2006 and 2007) [20]. Our research team welcomes the opportunity to collaborate with researchers in Latin America, Africa, and Asia to further expand the international survey.

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Conflict of Interest The authors declare that they have no conflict of interest.

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