Lifetime risk of total knee replacement and temporal trends in incidence by health care setting, socioeconomic status and geographic location

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Abstract

Objectives: To estimate the lifetime risk of total knee replacement (TKR) and examine temporal trends in TKR incidence in the state of Victoria, Australia.

Methods: A retrospective analysis of a population-based longitudinal cohort of patients (aged ≥40) who received a primary TKR in Victoria from 1999 to 2008. Hospital separations and life tables were used to estimate lifetime risk. Temporal changes in TKR incidence were examined according to healthcare setting (public versus private), socio-economic status (SES) and geographic location (regional versus metropolitan).

Results: There were 43,570 incidents of primary TKRs identified over the study period. In 2008, the lifetime risk of surgery was 10.4% (95% CI: 10.13%-10.64%) for males and 11.9% (95% CI: 11.63%-12.13%) for females. TKRs increased steadily over the study period in private hospitals (overall increase of 90%) with a smaller growth in procedure numbers for public hospitals (overall increase of 40%). From 2002-2003 onwards, the low SES tertile showed a lower incidence of TKR compared to middle and high SES group with incidence rates of 1.09 (95% CI: 1.04-1.15), 1.22 (95% CI: 1.17-1.28) and 1.20 (95% CI: 1.16-1.25) per 1000 population respectively (based on 2007-08 figures). Increased numbers of TKRs were also found to be occurring among people residing in regional areas of Victoria (from 1.1 (95% CI: 1.04-1.31) to 1.8 (95% CI: 1.72-2.02) per 1000 population.

Conclusion: Increases in lifetime risk of TKR were evident. Although improved access to TKR for those living in regional areas was observed, sustained disparities relating to healthcare setting and SES warrant further investigation.

Keywords: Arthroplasty, osteoarthritis, epidemiology, access to care
Significance & Innovation

• Lifetime risk is a measure of disease risk with potential utility for the public, health professionals and policy-makers. For this study, lifetime risk of total knee replacement (TKR) was used to estimate the probability of having knee replacement surgery over an individual’s lifetime.

• Lifetime risk of TKR increased over the 9-year study period to 10.4% for males and 11.9% for females.

• Sustained disparities in access to TKR relating to healthcare setting and socioeconomic status were observed, although the incidence of people receiving knee replacement surgery in more remote areas increased over time.
Introduction

Lifetime risk of total knee replacement (TKR) refers to the probability of having knee replacement surgery over an individual’s lifetime. While data on incidence of TKR may be instructive for researchers, the estimation of ‘lifetime risk’ produces more tangible information for health professionals and policy makers to assess utilisation and unmet need in the community and make decisions about the allocation of resources. Examining changes in lifetime risk over time can inform population health strategies and potentially facilitate the uptake of primary and secondary prevention strategies within populations. Where studies from the United States have estimated the lifetime risk of symptomatic hip and knee OA\(^1\),\(^2\), two recent studies have also investigated lifetime risk of TKR. Using a primary care database, Culliford et al\(^3\) estimated the lifetime risk of TKR in the UK to range from 8-11% for females aged 50 to 70 years, and 6-8% for males in these age groups. Over a 15-year period from 1991 to 2006, lifetime risk of TKR increased substantially for females (+6.9%) and males (+4.4%),\(^3\) although potential explanations for this finding were not provided. Weinstein et al\(^4\) used national health survey data from 2005 to 2008 and estimated the cumulative lifetime risk of a 25 year-old to have a TKR in the United States was 7.0% (95% CI: 6.1% to 7.8%) for males and 9.5% (95% CI: 8.5% to 10.5%) for females. As these studies represent the only available data on lifetime risk of TKR, whether risk of knee replacement surgery is similar in other developed countries and how risk may change over time remains unknown.

A range of factors could affect access to TKR over time and potentially contribute to changes in lifetime risk of knee replacement surgery. These include insurance coverage or health care setting\(^5\), socioeconomic status (SES)\(^6\),\(^7\), and geographical location\(^8\),\(^9\). The aims of this retrospective, population-based longitudinal cohort study were to:

- quantify the lifetime risk of having a TKR in Victoria, Australia over time; and
- describe temporal changes in the incidence of TKR according to healthcare setting
Methods

Data Sources

We used data from the Victorian Admitted Episodes Dataset (VAED), a hospital admissions dataset maintained by the Victorian State Department of Health to provide casemix funding to hospitals and support health service planning. It includes routinely collected patient-level data on all public and private hospital episodes within the state of Victoria, which has a population of approximately 5.5 million. Records are internally linked to identify all hospital admissions for a single patient over time using a combination of probabilistic and stepwise deterministic linkage methods at the Department of Health. Following ethics approval from the Monash University Ethics Committee, we obtained data from the VAED on all patients with a hospital episode which included the clinical specialty codes for orthopaedics or rheumatology. We also obtained population-level data on the age- and gender-specific Victorian population, the population by socio-economic groupings from the Australian Bureau of Statistics (ABS) socio-economic index for areas (SEIFA), the population by regional and metropolitan residence and life tables for the study period from the ABS.

Participant Inclusion Criteria

We included participants in our cohort if they met the following criteria: had a hospital episode between 1 January 1999 and 31 December 2008, received a primary TKR procedure (see Supplemental File) during the study period and were aged ≥40 years at the time of their TKR episode (as TKRs are rarely undertaken in patients <40 years). TKRs were identified using International Statistical Classification of Disease and Related Health Problems, Australian Modification, 10th revision (ICD-10-AM) operative procedure codes.

Covariates of interest

Individual age, gender, country of birth and hospital type (public or private) data were...
extracted from the VAED. Age at time of hospital admission for TKR was categorised into ten-year groupings (40-49, 50-59, 60-69, 70-79 and >80 years). Patient co-morbidities were defined using ICD-10-AM codes\textsuperscript{15}, incorporating a look-back period through any hospital admission one year prior to the TKR admission\textsuperscript{16}. A diagnosis of OA or rheumatoid arthritis (RA) at the time of the TKR admission was defined using ICD-10-AM codes; 99\% of primary TKRs in Australia are performed for these two diagnoses\textsuperscript{17}.

Each patient’s statistical local area of residence (SLA) at the time of hospital admission was linked to the Australian SEIFA\textsuperscript{12}; Australian 2001 Census data were used for patients admitted until June 2002, and 2006 Census data were used for patients admitted after June 2002. The SEIFA measure is an Australia-wide index of SES based on geographical area of residence. The index score of Economic Resources, one of four area-based measures of SES, was utilised for this study. This index score is a continuous number based on the sum of weighted characteristics (income, employment and housing status) of economic resources in each geographical area. The economic resources score was chosen as it was thought to most closely reflect economic capacity to purchase health insurance. For cases with missing SLA data (n=15.6\%), we used a simple mean imputation of the economic resource scores\textsuperscript{12} from all non-missing cases. We then grouped the scores into tertiles based on the distribution of the scores throughout the Australian population.

Each patient’s SLA was also linked to the Australian Standard Geographical Classification (ASGC) Remoteness Structure to derive a measure of geographical access to healthcare. The ASGC classifies Census districts into five categories of remoteness (major cities, inner regional cities, outer regional cities, remote locations and very remote locations) based on the road distance to the nearest urban centre. We grouped major and inner regional cities into one category and outer regional, remote and very remote locations into another category for our analyses. The latter regions align closely with districts of medical workforce shortage assigned by the Australian Department of Health and Ageing\textsuperscript{18} and were thought to be a good proxy for limited access to care. For cases with missing SLA data (15.6\%), we
conducted a nearest neighbour imputation sorting data by admission date, separation date and hospital.

Statistical analysis

Chi-square analyses were undertaken for comparisons between all categorical variables. For a hypothetical cohort of 100,000 people in Victoria, the number of years of life lived at each year of age is estimated by the ABS using all-cause mortality rates for the Victorian population. These methods have been described elsewhere\(^1\). The lifetime risk of TKR was calculated for each age group by dividing the total number of incident TKRs by the total number of people expected to be alive at beginning of the interval (Figure 1). Lifetime risk within each ten-year age group and overall lifetime risk were calculated at three time periods (1999-2000, 2003-2004, 2007-2008). Separate risk calculations were undertaken for males and females due to known gender differences in arthritis prevalence and TKR rates\(^3,17,19\). Confidence intervals (95%) were estimated using a Poisson model, as this is the recommended method for rate-based analyses\(^20\).

The most recent financial year in our dataset (2007-2008) was used for single-year estimates and temporal trends were estimated using the entire time period (1999-2008). We calculated the annual incidence of TKR over the study period according to factors potentially related to disparities in care including health care setting, SES, and geographical location. As population data for socio-economic groupings were not available in each year, the previous Census year data was used (for example, the denominator for 1999/2000 and 2000/2001 was 1996 Census data and 2001/2002-2005/06 was 2001 Census data). Confidence intervals for incidence rates were calculated according to methods described elsewhere\(^21\).

All statistical analyses were performed using Microsoft Excel 2010 (Microsoft Corporation, Redmond, WA), and Stata version 12.1 (StataCorp, College Station, Texas USA).
Results

Characteristics of the cohort

There were 43,570 incidents of primary TKRs identified over the study period. The number of TKR procedures in the VAED was consistent with data reported to the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) by individual hospitals, indicating complete case ascertainment (data not shown).

The descriptive characteristics of the cohort are reported in Table 1. Although the Victorian population aged over 40 years increased by 18% from 1999 to 2008, the number of primary TKRs increased by 84% over the same period. The majority of procedures were performed for females (59.0%). Those who had a TKR were more likely to be from the middle and high SES tertiles (38.7% and 34.4%, respectively) and least likely to be from the low SES tertile (26.9%). As expected given the geographic distribution of the population, most TKRs were performed for people living in metropolitan or inner regional areas (91.5%). People residing in outer regional/rural locations were more likely to be treated in a public hospital (48.7% versus 34.3% from metropolitan/inner regional residences, p<0.01) and more likely to be from the lowest socioeconomic group (48.6% compared to 24.9% from metropolitan/inner regional residences, p<0.01).

Most patients (95.6%) had a concomitant diagnosis of OA and few had RA (2.3%). Overall, almost 16% of the cohort had hypertension (n=6,851), 6.3% had uncomplicated diabetes (n=2,743), 5.8% were current smokers (n=2,506), 2.4% had hyperlipidaemia (n=1,026), 1.9% had chronic lung disease (n=827) and 1.2% had chronic heart failure (n=508). When compared to people from middle and high socio-economic groups, people from low socioeconomic backgrounds were more likely to suffer from diabetes (6.8% vs 6.1%, respectively, p=0.01), obesity (2.4% vs 2.0%, respectively, p=0.01), be smokers (6.3% vs 5.5%, respectively, p<0.01) and have hyperlipidemia (2.6% vs 2.2%, respectively, p=0.03).
Lifetime risk of primary total knee replacement

As presented in Figure 2, lifetime risk of TKR was examined at three time points (1999-2000, 2003-2004 and 2007-2008). For a person aged 40-49 years, the mortality-adjusted lifetime risk rose from 7.8% for both males (95% CI: 7.55%-8.03%) and females (95% CI: 7.59%-8.01%) in 1999-2000 to 10.4% (95% CI: 10.13%-10.65%) for males and 11.9% (95% CI: 11.63%-12.13%) for females in 2007-2008. The widest gap between females and males was evident in 2004-2005 (Figure 2). The lifetime risk of TKR increased across all age categories for both females and males from 1999/00 to 2007/08. For a female aged 60-69 receiving a primary TKR, the lifetime risk of ever having a TKR increased from 4.6% in 1999/00 to 5.9% in 2004/05 and to 6.1% in 2007/08. For males aged 60-69 receiving a primary TKR, the lifetime risk increased from 4.4% in 1999/00 to 4.7% in 2004/05 and to 4.8% in 2007/08. (Tables 2.1 and 2.2, respectively).

Temporal changes in the incidence of primary total knee replacement

Substantial differences in the incidence of TKR according to healthcare setting were identified. In 1999-2000, a slightly higher incidence of TKR was seen for private hospitals, compared to public hospitals (Figure 3). While the incidence of TKR in private hospitals increased steadily over the study period, the incidence in public hospitals plateaued. By 2004-2005, the incidence of TKR in the private hospitals was double that of the public hospitals (1.4 (95% CI: 1.34.-1.42) per 1000 population, compared to 0.7 (95% CI: 0.65-0.72) per 1000 for public hospitals). In 1999, 53.2% and 42.0% of people in the lowest and highest SES tertiles, respectively, had their TKR performed in public hospitals. In 2008, 45.4% and 34.3% of people in the lowest and highest SES tertile, respectively, had their TKR performed in public hospitals.

There was some evidence of SES disparities in the incidence of TKR over the study period. From 2002-2003 to 2004-2005, the low SES tertile demonstrated the lowest incidence of
TKR each year, compared with the middle and high tertiles (Figure 4). In 2005-2006, incidence of TKR was similar for the low SES (0.99 per 1000 population, 95% CI: 0.94-1.04) and middle SES tertiles (1.02 per 1000 population, 95% CI: 0.98-1.02). However, in subsequent years, the incidence of TKR was again lowest for the low SES tertile. In 2006-2007, the incidence was 0.99 per 1000 population (95% CI: 0.94-1.04) in the lowest SES group, compared to 1.15 (95% CI: 1.10-1.20) per 1000 population in the middle SES group. In 2007-08, the incidence was 1.09 (95% CI: 1.04-1.15) per 1000 population in the lowest SES group, compared to 1.22 (95% CI: 1.17-1.28) per 1000 population in the middle SES group.

While the incidence of TKR for patients residing in metropolitan/inner regional locations increased slightly over the study period (from 0.7 (95% CI: 0.63-0.72) per 1000 population to 1.0 (95% CI: 0.94-1.03) per 1000), there was a sharper increase in incidence for patients residing in outer regional/remote locations (from 1.1 (95% CI: 1.04-1.31 ) per 1000 to 1.8 (95% CI: 1.72-2.02) per 1000) (Figure 5).

**Discussion**

Estimating lifetime risk of TKR is a relatively new approach, with only two other recent publications using this technique\(^3\). Incorporating comprehensive data from both public and private hospital settings in Australia, our study has shown a clear increase in mortality-adjusted lifetime risk of TKR surgery over a 9-year period, most notably for females. We have also provided age- and gender-specific estimates. These data, considered in combination with estimates of the OA burden over time, can be helpful in policy settings to inform population health strategies and motivate uptake of primary and secondary prevention strategies. For example, increases in the lifetime risk of TKR without concomitant increases in the burden of severe OA, can signal changes in patient preferences, surgical decision-making, or the effects of healthcare policies. Gaining insight into these population-wide fluctuations, which are independent of disease burden, can be useful for budget priority
setting and assessing the impact of policy changes on healthcare utilisation. These data may also support advocacy activities for policy and funding changes. International comparisons of TKR lifetime risk could provide insight into the extent of unmet need within a country or region.

Our lifetime risk estimates for TKR were significantly higher than estimates reported for the UK\(^3\) and the US\(^4\). This is unlikely to relate to differences in risk factors for OA or OA prevalence between countries, but rather to differences in health care provider characteristics (for example, variation in thresholds at which surgery is offered\(^{22,23}\)) and international variation in health systems (such as the availability of TKR surgery and the proportion of the population covered by health insurance). Of the 3 countries, Australia and the UK have the most in common with regard to the structure of their health care systems.

Both Australia and the UK offer universal health care, where interventions such as TKR can be accessed through taxpayer-funded systems (public hospitals in Australia and the National Health Service in the UK). Both countries also have parallel private health systems which can be accessed by those who hold private health insurance, or by those who can afford to pay for the costs associated with treatment. However, the proportion of people with private health insurance in Australia is considerably higher than in the UK (40-45% versus 10%)\(^ {24}\). In Australia, the private health system offers two main advantages for patients considering TKR: choice of surgeon and avoidance of lengthy waiting times for consultation and surgery. In the US, publicly funded health care is only provided for specific groups (for example, people aged 65 years and over, those with very low income and people who are severely disabled). Health care in the US is provided by a range of private, public and non-profit organisations and treatment can be associated with significant expenses\(^ {25}\). There was also a sharper temporal increase in lifetime risk for males in Australia when compared to the UK. It is unknown if this is related to gender differences in uptake of TKR between countries\(^ {22}\).

Although limited data are currently available, similar analyses from other countries will be useful for exploring international patterns of lifetime TKR risk and differences in unmet need.
The observed increase in lifetime risk of TKR over the study period could be partly attributed to the ageing population, with more people age over 80 receiving TKRs, increased rates of sporting injuries\textsuperscript{26}, rising rates of obesity (all risk factors for knee OA incidence \textsuperscript{27, 28, 29, 30}), and an increasing prevalence of severe joint disease\textsuperscript{28, 29, 30}. As we identified increased utilisation of TKR in the private hospital setting, other potential drivers of growth could include financial incentives to having private health insurance, timelier access to TKR surgery in private hospital settings and greater awareness of effective surgical interventions as these become increasingly common. An increase in knee arthroscopies for OA within the Australian private health system over this time period has also been demonstrated\textsuperscript{31}. According to recent data from the AOANJRR, 69.4\% of knee replacements in Australia are now performed in the private health system\textsuperscript{17}. As significant health insurance reforms were introduced in Australia over a decade ago, these initiatives may have contributed to the observed rise in incidence of TKR in private hospitals. In 1999-2000, initiatives introduced by the Australian government to boost the number of people with private health insurance (including substantial rebates and incremental loadings on insurance premiums according to age) saw the proportion of Australians with private health insurance increase from 38\% in 1998 to 51\% in 2001\textsuperscript{32}. In our data, rates of TKR increased in the private system over the time period, while the rates of TKR in the public system have remained constant. The shifting of patients into the private system may have improved access to the public system for individuals who previously would not have received care. However, in 1999/00, 12.4\% of patients in public hospitals waited more than 365 days for a TKR\textsuperscript{33}, while 14.9\% waited 365 days or more in 2008/09.\textsuperscript{34} This suggests there may still be considerable unmet need, which may be related to the increasing growth in the ageing population over this time period. Improved access and utilisation of care has been demonstrated in other countries after healthcare systems encouraged the uptake of private health insurance; however, inequities in care may become more pronounced\textsuperscript{35}.

Lower SES was associated with reduced incidence of TKR during the study period. In Australia, people with low SES generally have reduced access to the private hospital
system. Our finding is consistent with studies from England and Canada which have reported reduced utilisation of TKR by lower SES groups\(^7,36,37\). In contrast to these studies, a cross-sectional Australian study reported higher rates of TKR for Australians living in the most disadvantaged areas compared with those living in the least disadvantaged areas\(^38\). However, this study assessed TKR in one year (2006-07) and used the socio-economic index for measuring disadvantage (i.e. low income, unskilled occupations). We used the index of economic resources, which is a measure of income, as we considered this measure would more closely reflect ability to afford health insurance. However, we also found that the lower SES group in our study had higher rates of co-morbidities (such as chronic heart failure and diabetes), which may contraindicate surgery. Other studies have shown that co-morbidities are a major barrier to accessing joint replacement for the poorest individuals\(^39\).

On a positive note, we found an increasing incidence of TKR over time for people residing in outer regional and remote areas, suggesting improved access to TKR surgery for these individuals. However, it should be noted that the incidence of TKR in regional areas was already greater than metropolitan areas at the beginning of the study period. This builds on the findings from an earlier Australian cross-sectional study, which demonstrated higher rates of knee replacements in regional areas of Australia compared to major cities over a two year period from 2005 to 2007\(^38\). The increased incidence of TKRs in outer regional and remote areas could reflect a greater need for TKR surgery due to an older population in these regions, supported by median age data for regional Victoria, compared with metropolitan Melbourne (the capital of Victoria)\(^40\). People living in outer regional and remote areas may also be at greater risk for knee OA due to occupational risk factors such as manual labour. The larger increase in incidence for these individuals could also relate to greater previously unmet need and the increased provision of orthopaedic services in regional areas over the past decade.

A major strength of our study design was the inclusion of public and private hospital data to improve the accuracy of our estimates and the external validity of the study. We
acknowledge that this study utilised administrative data collected primarily for hospital reimbursement purposes, and while all procedures were primary TKRs, we do not have information on whether patients had previously received a primary TKR for the contralateral knee. This could overestimate the age at first TKR. Although the majority of the cohort had a diagnosis of OA (96%), we also utilised data from people who had other diagnoses (such as RA) and this may conflate the risk estimates due to the different course of each disease. However, our sensitivity analysis (limited to people with OA) produced similar findings for lifetime risk. We relied on area-based measures of socio-economic status and rurality, which are known to have limitations. These indices were based on patients’ residential locations rather than where they received treatment. There were 15.6% of cases with missing SLA data due to missing address information within the hospital admission records, where we imputed economic resource scores and rurality codes. We conducted a sensitivity analysis where we excluded cases with missing data and this did not alter the trends we identified. We also acknowledge that changes in population factors (for example, age, injury rates and SES distribution) may have contributed to temporal changes in lifetime risk and TKR incidence, but population data on these factors were not available for our analyses.

Comorbidity data was obtained from the hospital episode records for the TKR admission and any admission within the year prior to the TKR. However, comorbidities have been shown to be under-reported within hospital administrative data. Only 2.2% of the cohort was found to be obese, which is well below the population estimates of obesity for Australia (20.5%) and these data were therefore not included in our analyses. As comorbidities were not included in the analysis of lifetime risk, this is unlikely to change our estimates. Finally, although we did not have access to national hospital data, as Australia’s second most populous state, it is reasonable to expect the Victorian data to be representative of other large Australian states. However, there may have been state-based policy initiatives to improve access to TKR (for example, in regional areas) during the study period of which we are not aware.
Conclusion

Increases in lifetime risk of TKR were evident over a 9-year period, although our understanding of contributing factors remains limited. While growth in risk factors for OA and greater disease severity may have partly driven this increase, government incentives to encourage the uptake of private health insurance may have also improved access to care for some people. Although the rising incidence of TKR for those living in more remote areas is encouraging, the observed disparities relating to healthcare setting and SES are concerning and warrant further investigation.
Acknowledgments

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Disclosures
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Figure 1. Schematic Diagram of Lifetime Risk calculations

Hospital episodes between 1 January 1999 and 31 December 2008 involving a primary TKR (patients aged 40+ years)

\[ R_x = \text{Number of people who have TKRs by age-group}_x \]

Count of TKRs from 1999-2000 by age group and gender

Count of TKRs from 2004-2005 by age group and gender

Count of TKRs from 2007-2008 by age group and gender

\[ S_x = \text{Population Proportion who survive to age group}_x \]

Life table data 1999/2000 (count of population alive/deceased by age group and gender)

Life table data 2004/2005 (count of population alive/deceased by age group and gender)

Life table data 2007/2008 (count of population alive/deceased by age group and gender)

\[ \text{Lifetime Risk}^* = \sum_{x=40-49}^{80+} S_x \times R_x \]

*Calculations were conducted separately for males and females based on the gender-specific values of S and R
Table 1. Descriptive characteristics of the cohort compared to the Victorian population

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<td></td>
<td>n</td>
<td>%</td>
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* Figures are based on the population average aged 40+ over the time period 10
** Based on the entire population of Australia, as age-specific data were not available.†
† Tertiles of economic resources scores were used to derive these categories.
Figure 2. Temporal changes in lifetime risk of receiving total knee replacement by gender
Table 2.1. Risk of future primary knee replacement in 1999-2000, 2004-05 and 2007-2008 according to age, Females

<table>
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<th></th>
<th></th>
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<td>60-69</td>
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<td>ever</td>
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Table 2.2. Risk of future primary knee replacement in 1999-2000, 2004-05 and 2007-2008 according to age, Males

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<tbody>
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</tbody>
</table>
Figure 3. Temporal changes in the incidence of total knee replacement by health care setting
Figure 4. Temporal changes in the incidence of total knee replacement by tertile of socioeconomic status (SES)*

* Index of Economic Resources
Figure 5. Temporal changes in the incidence of total knee replacement by geographical location*

*data on the Victorian metropolitan and regional population were not available from the Australian Bureau of Statistics for 1999/2000.
Author/s:
Bohensky, MA; Ackerman, I; DeSteiger, R; Gorelik, A; Brand, CA

Title:
Lifetime Risk of Total Knee Replacement and Temporal Trends in Incidence by Health Care Setting, Socioeconomic Status, and Geographic Location

Date:
2014-03-01

Citation:
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