■ ARTHROPLASTY

Estimating incidence rates of periprosthetic joint infection after hip and knee arthroplasty for osteoarthritis using linked registry and administrative health data

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Aims

The aim of this study was to estimate the 90-day periprosthetic joint infection (PJI) rates following total knee arthroplasty (TKA) and total hip arthroplasty (THA) for osteoarthritis (OA).

Methods

This was a data linkage study using the New South Wales (NSW) Admitted Patient Data Collection (APDC) and the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR), which collect data from all public and private hospitals in NSW, Australia. Patients who underwent a TKA or THA for OA between 1 January 2002 and 31 December 2017 were included. The main outcome measures were 90-day incidence rates of hospital readmission for: revision arthroplasty for PJI as recorded in the AOANJRR; conservative definition of PJI, defined by T84.5, the PJI diagnosis code in the APDC; and extended definition of PJI, defined by the presence of either T84.5, or combinations of diagnosis and procedure code groups derived from recursive binary partitioning in the APDC.

Results

The mean 90-day revision rate for infection was 0.1% (0.1% to 0.2%) for TKA and 0.3% (0.1% to 0.5%) for THA. The mean 90-day PJI rates defined by T84.5 were 1.3% (1.1% to 1.7%) for TKA and 1.1% (0.8% to 1.3%) for THA. The mean 90-day PJI rates using the extended definition were 1.9% (1.5% to 2.2%) and 1.5% (1.3% to 1.7%) following TKA and THA, respectively.

Conclusion

When reporting the revision arthroplasty for infection, the AOANJRR substantially underestimates the rate of PJI at 90 days. Using combinations of infection codes and PJI-related surgical procedure codes in linked hospital administrative databases could be an alternative way to monitor PJI rates.

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Introduction

Total knee arthroplasty (TKA) and total hip arthroplasty (THA) are effective treatments for late-stage osteoarthritis (OA), and have the potential to substantially increase patient quality of life after the surgery.[1] The rising demand for TKA and THA to treat OA is expected to continue in the next decade due to increasing levels of obesity, an ageing population, and growth in sports-related injuries.[2,3] However, the success of both interventions can be undermined by the increasing incidence of periprosthetic joint infection (PJI),[4] which is one of the most devastating and costly complications following arthroplasty surgery. The infection can leave patients in a worse condition than their preoperative state.[5] Aside from the health impact, PJI often leads to readmissions to hospital and in some cases revision surgeries, which add to the significant economic burden of PJI.[6-8]

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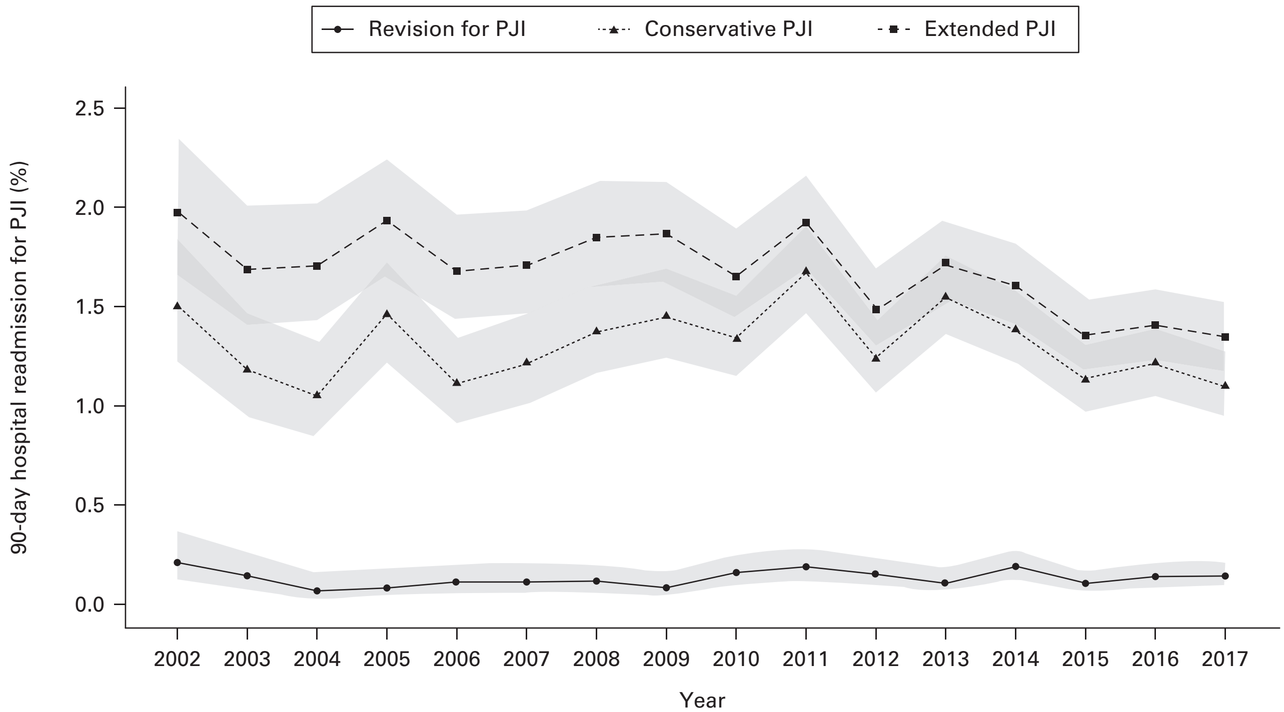


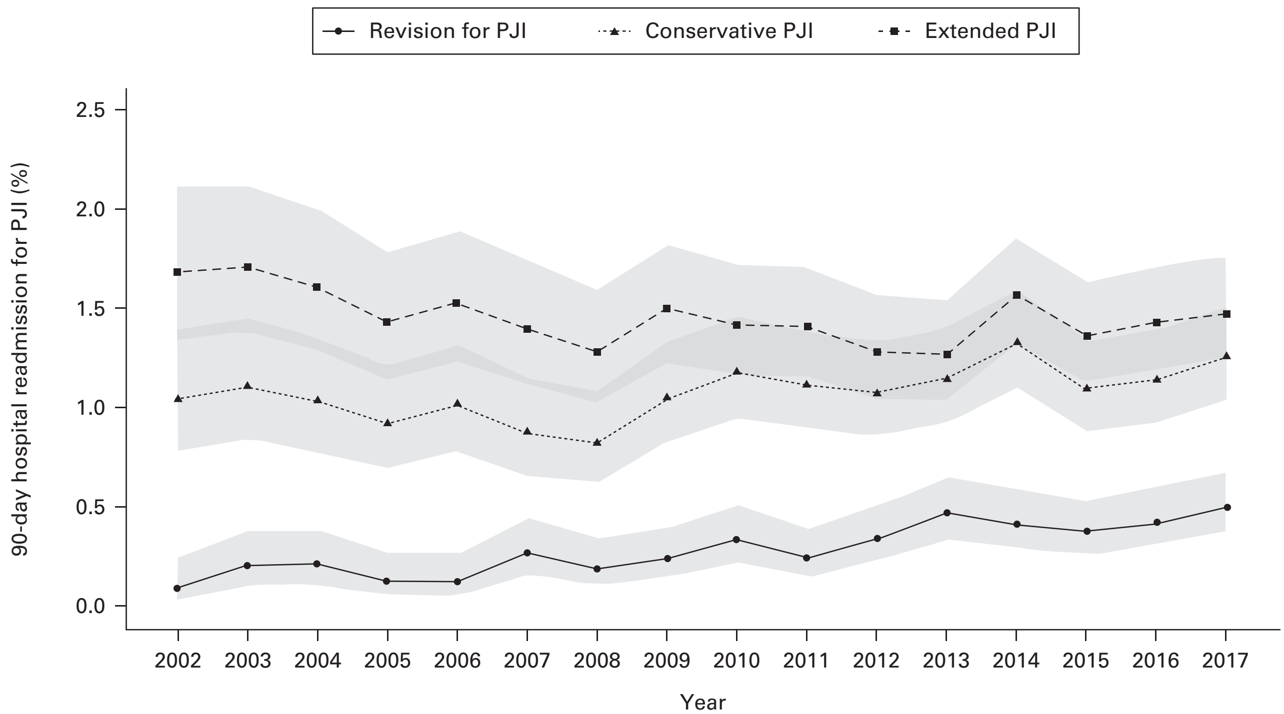
Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
n	6,330	7,137	7,632	8,843	9,549	9,829	10,857	11,259	12,651	13,545	14,354	14,960	15,625	16,239	16,205	16,899
Revision	13 (0.2%)	10 (0.1%)	5 (0.1%)	7 (0.1%)	10 (0.1%)	11 (0.1%)	12 (0.1%)	9 (0.1%)	20 (0.2%)	25 (0.2%)	21 (0.1%)	16 (0.1%)	29 (0.2%)	16 (0.1%)	22 (0.1%)	24 (0.1%)
Conservative	95 (1.5%)	84 (1.2%)	80 (1.0%)	129 (1.5%)	106 (1.1%)	119 (1.2%)	149 (1.4%)	163 (1.4%)	169 (1.3%)	227 (1.7%)	177 (1.2%)	232 (1.6%)	216 (1.4%)	183 (1.1%)	197 (1.2%)	185 (1.1%)
Extended	125 (2.0%)	120 (1.7%)	130 (1.7%)	171 (1.9%)	160 (1.7%)	168 (1.7%)	201 (1.9%)	210 (1.9%)	209 (1.7%)	260 (1.9%)	213 (1.5%)	257 (1.7%)	250 (1.6%)	219 (1.3%)	227 (1.4%)	227 (1.3%)

Fig. 1

Annual 90-day hospital readmission rate for periprosthetic joint infection (PJI) following primary total knee arthroplasty for osteoarthritis.

Despite the clinical and health economic significance of PJI, the exact incidence rate is unknown. Arthroplasty registries have been used to estimate the incidence rate of PJI, but these registries only report a revision if a component of the implant was removed or added. Relying on revision for infection reported in an arthroplasty registry is likely to underestimate the true incidence rate of PJI, because not all PJIs require revision arthroplasty, and the first treatment option for many PJIs is non-surgical antibiotic treatment, surgical debridement, and irrigation.[9] Routinely collected administrative databases capturing hospital diagnosis and procedure codes are a potential data source for identifying PJIs that did not undergo revision surgery.[10] While such databases could serve as valuable sources of information to study the incidence rate of PJI, there is no consensus on what codes should be used to identify PJIs following TKA and THA. Recent international studies combining a PJI diagnosis code with a relevant surgical procedure code have shown promising accuracy in the detection of PJIs from administrative databases when referencing to standard medical chart review.[11,12] In Australia, the occurrence of PJI after TKA and THA was previously reported to be 1.7% over two years using administrative admission data from four hospitals.[13] However, incidence rates of PJI identified in state-wide administrative databases, using different combinations of diagnosis and procedure codes, have not been compared against reference cases of known revision arthroplasty performed for PJI in linked arthroplasty registry data. Estimating the rate of PJI using different strategies will help facilitate future studies to identify risk factors for PJI using linked administrative databases.

This study aimed to develop coding algorithms which combine diagnosis codes according to the International Classification of Disease, 10th revision, Australian Modification (ICD-10-AM) with Australian Classification of Health Intervention (ACHI) procedure codes to identify 90-day hospital readmissions for PJI,[14] and compare the resulting incidence rate with the rate identified by the PJI diagnosis code (T84.5) only and the rate of revision arthroplasty for infection as determined by a national arthroplasty registry.



Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
n	4,514	4,972	5,230	5,663	5,702	5,954	6,328	6,678	7,149	7,473	7,657	7,892	8,509	8,525	8,542	8,624
Revision	4 (0.1%)	10 (0.2%)	11 (0.2%)	7 (0.1%)	7 (0.1%)	16 (0.3%)	12 (0.2%)	16 (0.2%)	24 (0.3%)	18 (0.2%)	26 (0.3%)	37 (0.5%)	35 (0.4%)	32 (0.4%)	36 (0.4%)	43 (0.5%)
Conservative	47 (1.0%)	55 (1.1%)	54 (1.0%)	52 (0.9%)	58 (1.0%)	52 (0.9%)	52 (0.8%)	70 (1.0%)	84 (1.2%)	83 (1.1%)	82 (1.1%)	90 (1.1%)	113 (1.3%)	93 (1.1%)	97 (1.1%)	108 (1.3%)
Extended	76 (1.7%)	85 (1.7%)	84 (1.6%)	81 (1.4%)	87 (1.5%)	83 (1.4%)	81 (1.3%)	100 (1.5%)	101 (1.4%)	105 (1.4%)	98 (1.3%)	100 (1.3%)	133 (1.6%)	116 (1.4%)	122 (1.4%)	127 (1.5%)

Fig. 2

Annual 90-day hospital readmission rate for periprosthetic joint infection (PJI) following primary total hip arthroplasty for osteoarthritis.

Methods

We used records from the New South Wales (NSW) Admitted Patient Data Collection (APDC) and the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR), linked probabilistically by the Centre for Health Record Linkage with rates of false positive and false negative links estimated at 0.5%.[15] The APDC data collection records all admitted patient services provided by public and private hospitals in NSW, Australia. The AOANJRR records details of all primary and revision knee and hip arthroplasties performed in Australia. We included patients who underwent a TKA or a THA with a primary diagnosis of OA in NSW, Australia between 1 January 2002 and 31 December 2017.

Data linkage procedure for index arthroplasty. Primary TKA and THA procedures were identified from the AOANJRR. Procedure records were restricted to those with a primary diagnosis of OA and those performed in a hospital in NSW. These records were subsequently matched to the hospital admissions for the primary procedure recorded in the APDC. Records were retained in the study if they demonstrated good matching quality, which was defined by the following criteria: the surgical operation date recorded in the AOANJRR fell within the date range of the closest matched hospital stay recorded in the APDC; or the matched hospital stay had a procedure code of TKA or THA that corresponded to the same joint and procedure type information recorded in the AOANJRR. The ACHI procedure codes used for TKA and THA are listed in Supplementary Table i.

Definitions of readmission for PJI. The primary and secondary diagnosis and procedure codes of all hospital admissions within 90 days of the initial admission for the primary TKA or THA were examined for any codes indicating a PJI. The 90-day period was suggested as the minimum follow-up period to track surgical site infection rates for TKA and THA from linked administrative data.[16,17] Given that there is no gold-standard definition for PJI, we estimated the incidence of 90-day readmission for PJI using three levels of definitions: revision arthroplasty for PJI, as recorded by the AOANJRR; conservative definition of

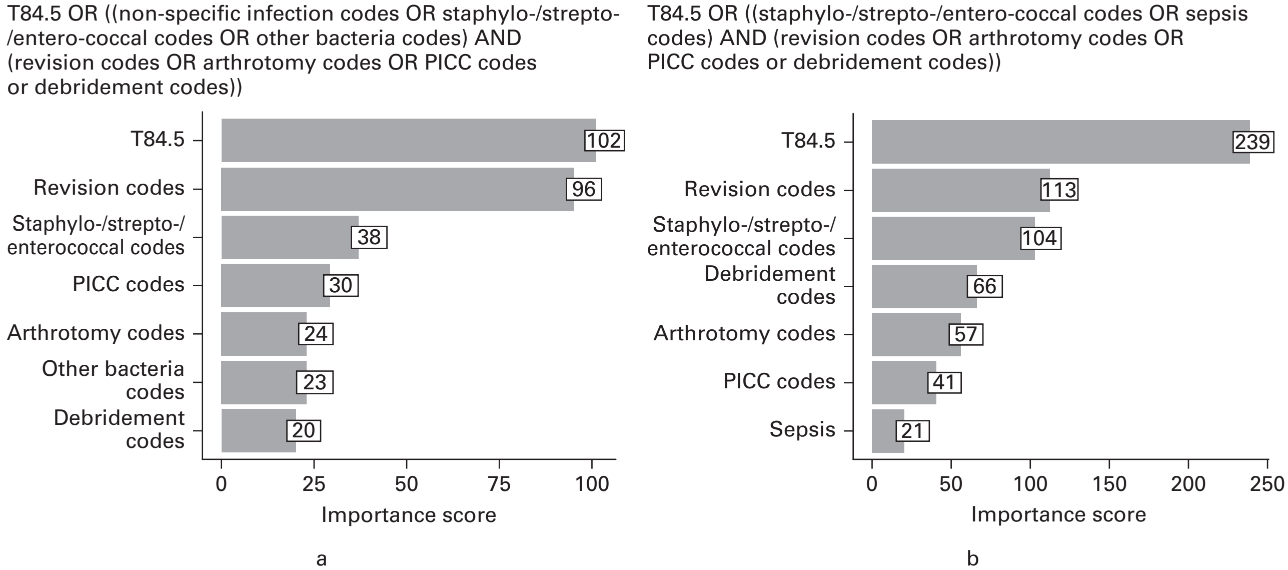


Fig. 3

Extended definition of periprosthetic joint infection and importance score of code groups identified from binary recursive partitioning for a) total knee arthroplasty and b) total hip arthroplasty. PICC, peripherally inserted central catheter.

PJI, as defined by the presence of T84.5 as a primary or secondary diagnosis in the APDC irrespective of the presence of an associated surgical procedure code; and extended definition of PJI, as defined by either T84.5 being recorded as a primary or secondary diagnosis in the APDC, or one or more readmissions in the APDC identified by a combination of diagnosis and procedure code groups determined via expert review and machine learning algorithms, as described below.

Developing algorithms for the extended definition of PJI. Algorithms for detecting 90-day readmissions for PJI in this study were developed in two steps. First, we conducted an expert review process with three experienced orthopaedic surgeons (IH, RS, SEG) who specialize in hip or knee arthroplasty to select a list of potential ICD-10-AM diagnosis codes and ACHI procedure codes that could indicate a joint infection. The presence of each selected code group was flagged in hospital admission data within 90 days of the index arthroplasty. Then, binary recursive partitioning was applied to the TKA and THA data separately to derive code groups that were predictive of PJIs. Binary recursive partitioning, also known as classification and regression tree, is a non-parametric method used to predict dichotomous outcome. The method creates a decision tree by repeatedly dividing the sample into subgroups, with each subdivision being formed by separating the sample on the value of one of the predictor variables.[18] All diagnosis and procedure code groups identified in the expert review were used as predictor variables with the reference outcome being a revision arthroplasty for infection confirmed by the records in the AOANJRR, which had been used internationally to estimate infection burden in total joint replacement.[19] Multiple decision trees were created with ten-fold cross-validation and hyperparameter tuning. Because it is impractical to verify a PJI that was not treated with revision arthroplasty in this large-scale linkage study, the best decision tree was selected based on the highest positive predictive value (PPV), which is the proportion of true positive (i.e. revision for infection) in the total number of test positives (i.e. model-predicted revision for infection). The code groups included in the best decision tree were subsequently used in the extended definition of the 90-day readmission for PJI.

Statistical analysis. Statistical analyses were performed using R (v. 4.0.4, R Foundation for Statistical Computing, Austria). Binary recursive partitioning was performed using the R package 'rpart' (v. 4.1.15). Importance scores of the identified code groups from the best decision tree were calculated based on the reduction of Gini impurity index, which measured the sum of probability of the reference outcome (i.e. revision arthroplasty for infection) being wrongly classified by a code group when randomly selected.[20] The incidence rates of 90-day readmission for PJI following TKA and THA over the study period were calculated for the three definitions mentioned earlier and compared on a yearly basis. The 95% confidence intervals for incidence rates were estimated using the Clopper-Pearson interval.

Results

Data on 301,326 primary total arthroplasty procedures (191,914 TKAs and 109,412 THAs) performed in 107 hospitals from 1 January 2002 to 31 December 2017 were included. Figures 1 and 2 compare the 90-day incidence rates of PJI across the three definitions following primary TKA and THA, respectively.

Revision for infection. The mean 90-day revision for infection rate was 0.1% (0.1% to 0.2%) following primary TKA and 0.3% (0.1% to 0.5%) following primary THA. The revision for infection rate after THA appeared to have increased in recent years, while the rate after TKA remained stable over time.

Conservative definition of PJI. When hospital readmission for PJI was defined by T84.5 diagnosis code alone, the mean 90-day PJI rate was 1.3% (1.1% to 1.7%) after primary TKA and 1.1% (0.8% to 1.3%) after primary THA.

Extended definition of PJI: binary recursive partitioning algorithm. The binary recursive partitioning model identified six code groups which were important to detect PJI following TKA (non-specific postprocedural infection, strepto-/staphylo-/enterococcus infection, other bacterial infection, peripherally inserted central catheter, debridement, and arthrotomy) and five code groups for THA (strepto-/staphylo-/enterococcus infection, sepsis, peripherally inserted central catheter, debridement, and arthrotomy). Figure 3 shows the extended definition of PJI for TKA and THA and the calculated variable importance score of the identified code groups in detecting revision for PJI.

Annual readmission rates for PJI. The mean annual readmission rates for PJI identified by the extended definition were 1.9% (1.5% to 2.2%) and 1.5% (1.3% to 1.7%) within 90 days following TKA (Figure 1) and THA (Figure 2), respectively. These rates were higher than the rates identified by the conservative definition of PJI using the diagnosis code T84.5 alone.

Discussion

To our knowledge, this is the first study to compare 90-day incidence rates of PJI by refined use of hospital administrative data linked to an arthroplasty registry in Australia. The yearly 90-day hospital readmission rates for PJI ranged from 1.0% to 2.0% following TKA for OA, and from 0.8% to 1.7% following THA for OA, depending on the coding definitions. We found that revision arthroplasties for infection recorded in the AOANJRR only made up a small proportion of the 90-day hospital readmissions for PJI. At 90 days, the actual incidence rate of PJI may be more than ten times higher than the revision arthroplasty rate for infection after TKA, and more than four times higher than that after THA.

The PJI rates estimated from the present study are close to the findings from a previous study, which reported a PJI occurrence rate of 1.7% within two years following a TKA or THA in four hospitals in Australia,[13] using routinely collected administrative admission data. The subtle difference in the incidence rates between the present study and the previous one could be attributable to the different PJI definitions used, different duration of follow-up, different patient characteristics in the included hospitals, and the inclusion of reasons other than OA for the primary arthroplasty, such as rheumatoid arthritis, which is an independent risk factor for PJI.[21,22] Nevertheless, our findings of 90-day readmissions for PJI being higher after primary TKA compared to THA are consistent with those that have been previously reported.[13,23,24]

A few international studies have previously reported the underestimation of PJI rates using joint arthroplasty registry data alone.[25–28] The 'true' incidence rates of PJI were underestimated by approximately 40% in the Danish Arthroplasty Register[26] and 33% in the Swedish Hip Arthroplasty Register.[27] The New Zealand Joint Registry reported a sensitivity of only 63% when using revision arthroplasty rates for PJI as compared to the audit of hospital records.[25] A recent cross-validation study also reported that the 90-day incidence of revision arthroplasty due to infection from the Dutch Arthroplasty Register was 0.6% compared to the true PJI rate of 1% in a cohort of nine hospitals.[29] Our results are in line with the findings of these studies, showing that the revision arthroplasty rate for infection recorded in the AOANJRR significantly underestimated 90-day readmissions for PJI.

The main strength of the present study rests on the refined use of linked data between hospital administrative data and the national arthroplasty registry to estimate the 'true' incidence rates of PJI. The linked data created a state-wide cohort representative of all primary TKA and THA procedures performed for OA. In addition, we used an innovative machine-learning method to develop an extended definition of PJI, which could be used in future registry-based studies on PJI after arthroplasty for OA. Intuitively, using combinations of infection diagnosis codes and surgical procedure codes in the extended PJI definition should deliver an improvement in detection over a PJI code alone. A definitive PJI diagnosis is usually not made at the time of hospital admission and it requires subsequent laboratory tests such as periprosthetic cultures. In contrast, surgical procedures such as peripheral insertion of a central catheter, which facilitates extended administration of antibiotics, are unlikely to be performed for reasons other than treatment for PJI.

We acknowledge there are limitations in the present study. First, the use of routinely collected administrative data to detect a PJI may underestimate or overestimate the incidence rates of PJI due to variation in recording PJI across different hospitals.[30] Because of the large scale of data in this study, it was not practical to validate the identified hospital admissions for PJI by medical chart reviews or pathology reports. However, previous international studies have reported results of promising accuracy in identifying PJI using administrative data. For example, a Danish study using data from administrative discharge registers was able to achieve a PPV of 86% in PJI detection after primary hip arthroplasty when the detection algorithm combined T84.5 with an infection-related surgical procedure code.[31] Similarly, a recent Canadian study also demonstrated a sensitivity of 88% when using the T84.5 alone and a sensitivity of 95% when combing with a joint arthroplasty procedure code or a peripherally inserted central catheter code.[12] Lastly, the extended definition of PJI was developed from decision trees which predict infections leading to a revision arthroplasty, rather than PJIs in general. As a result, the extended definition may still underestimate the actual rate of PJIs.

Further cross-validation of the extended definition of PJIs is required in the future to enable register-based studies on PJI after joint arthroplasty. Ideally, the diagnosis of PJI should be ascertained by clinical notes review, microbiological culture and histology, according to the latest international guidelines.[32,33] Similar studies with data linkage between hospital administrative data and the joint arthroplasty in other jurisdictions in Australia will allow standardized comparison of 90-day readmission rate for PJI across states.

Using revision arthroplasty for infection alone for monitoring acute PJI following TKA and THA substantially underestimates the incident rate of 90-day readmission for PJI. Using combinations of infection diagnosis codes and PJI-related surgical procedure codes in linked hospital administrative databases can be an alternative way to monitor PJI rates.

Take home message

- Records of revision arthroplasty for infection from arthroplasty registries underestimate the true incidence rate of periprosthetic joint infection (PJI).
- National arthroplasty registry data linked to hospital administrative data indicated that the 90-day hospital readmission rate for PJI could be ten times and four times higher than the revision arthroplasty rate for infection after total knee and total hip arthroplasty, respectively.
- Algorithms combining infection codes and PJI-related surgical procedure codes in linked hospital administrative databases may improve the detection of PJI.

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Supplementary material

Table of diagnostic and procedure codes used to develop periprosthetic joint infection detection algorithms.

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