SHORT REPORT

Short running: Under-recorded osteoarthritis in UK primary care

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Under-recording of osteoarthritis in United Kingdom primary care electronic health record data

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Abstract:

Purpose: Primary care electronic health records (EHR) are increasingly used to estimate the occurrence of osteoarthritis (OA). We aimed to estimate the extent and trend over time of under-recording of severe OA patients in UK primary care electronic health records using first primary total hip and knee replacements (THR/TKR) - >90% of which are performed for OA - as the reference population.

Patients and methods: We identified patients with a first primary THR or TKR recorded in the UK Clinical Practice Research Datalink (CPRD) between 2000 and 2015.

We then searched for a diagnostic/problem code for OA up to 10 years prior to THR/TKR using three definitions: 'diagnosed OA (joint-specific)', 'diagnosed OA (any joint)', `clinical OA' (diagnosed OA or relevant peripheral joint pain symptom code).

Results : Among 34,299 THR patients identified, 28.1%, 53.4%, and 74.4% had a prior record of diagnosed OA (hip), diagnosed OA (any), and clinical OA, respectively. Among 47,588 TKR patients, the corresponding figures were, 25.5% (diagnosed OA (knee)), 43.7% and 74.8%. In CPRD, the proportion of patients with prior recorded OA decreased between 2000 and 2015.

Conclusion: An increasing trend of under-recording of OA or joint pain among patients with THR or TKR (severe OA patients) between 2000 and 2015 was identified. An under-estimate healthcare demand could be derived based on consultation incidence and prevalence of OA from EHR data that relies on osteoarthritis diagnostic codes. Further studies are warranted to investigate the validity of OA or joint pain recorded in primary care settings, which might be used to correct the consultation incidence and prevalence of OA.

Keywords: Joint pain; total knee replacement; total hip replacement; sensitivity

Introduction

Primary care electronic health records (EHR) provide an efficient and continuous source of data with which to estimate disease incidence and prevalence and trends in these across time [1]. However, the interpretation of such estimates relies either on the verification, sensitivity analysis, or assumption of the completeness and validity of recording used for patient definitions. Blanket assertions on the validity of recording in whole databases are not uncommon, but in truth the validity of coding varies across different aspects of the EHR (e.g. by disease depending on the existence of objective criteria for diagnosis, availability of disease-specific prescriptions to augment diagnostic/problem codes, and incentives for completeness of recording) [2] and across time (e.g. changing diagnostic criteria and coding behaviour).

Osteoarthritis (OA) presents just such a challenge. Diagnosis is made on clinical grounds without requiring confirmation by imaging [3], although the value of disease diagnosis has been debated [4]. There are no pharmacological treatments specific to OA meaning that identification of patients in the EHR records relies on diagnostic/problem coding. In the UK it is not one of the long-term conditions whose management has been specifically incentivised within the General Medical Services contract introduced in 2004 [5]. Previous studies examining the validity of OA patient definitions within administrative and clinical EHR databases have typically found specificity ≥89% (i.e. few false-positives) against the reference standards of medical chart abstraction or patient-reported doctor-diagnosed OA, particularly when using restrictive algorithms (e.g. requiring 2 or more OA diagnostic codes within a period of time) [6]. These studies have generally reported lower sensitivity (higher false-negative rate), ranging from 29% [7] to 83% [8]. An acknowledged limitation in these existing studies is the potential for misclassification in the reference standard [6].

In the current study, we focus on estimating the sensitivity of different definitions for OA based on diagnostic/problem codes in the primary care EHR using the reference standard of primary total hip or knee replacement (THR/TKR). According to the National Joint Registry (NJR), 90% of primary THR and 98% of primary TKR are performed for hip OA and knee OA: a proportion that has changed little since NJR data collection began in 2003 [9]. These proportions provide a benchmark and an upper limit against which to compare the sensitivity of diagnostic/problem coding of OA in UK primary care records. In addition, we sought to investigate changes in sensitivity over time.

Material and methods

We undertook a descriptive study using routinely collected longitudinal data from the UK Clinical Practice Research Datalink (CPRD), which was established in 1987 and contains computerised primary care records from general practices covering around 7% of the UK population [10]. CPRD includes anonymised patient demographics, consultations, diagnoses, prescriptions, and tests from primary care, and also includes those referrals to specialists, hospital admissions, and diagnoses made in secondary care, reported back to the general practitioners and recorded by them within their computerised records. CPRD has reported high validity for a range of diagnoses (but not including OA) [11]. The study was approved by the Independent Scientific Advisory Committee (ISAC) for Clinical Practice Research Datalink research (Protocol reference: 14_09010_193R and 15_211). No further ethical permissions were required for the analyses of these anonymised patient level data.

Patients aged 40 years and with recorded incident primary THR or TKR between 2000 and 2015 were included in this study. Each eligible incident THR patient had to have at least 10-years of continuous registration prior to THR during which there was no evidence of a previous THR or TKR. Each eligible incident TKR patient had to have at least 10-years of continuous registration

prior to TKR during which there was no evidence of a previous THR or TKR. Primary THR and TKR were identified within CPRD using the Read code list developed and applied in CPRD by Culliford and colleagues [12], and validated by Hawley et al [13].

We defined OA patients in three ways based on established Read codes [14] (available from www.keele.ac.uk/mrr): firstly, patients of OA were defined restrictively as having at least one consultation with a recorded diagnosis of hip OA or knee OA ('diagnosed OA (joint-specific)'); secondly, patients of 'OA' were defined as having at least one consultation with a recorded diagnosis of OA, including where the involved joint was not specified ('diagnosed OA (any joint)'); finally to maximise sensitivity and capture the greatest number of new consulting patients of osteoarthritis, patients were defined as having either at least one consultation with a recorded diagnosis of OA or, in adults aged over 45 years, at least one consultation with a recorded peripheral joint pain symptom code affecting the knee, hip, and hand/wrists (the joints most commonly affected by osteoarthritis) likely to reflect OA ('clinical OA').

Look-back periods from 1 to 10 years were applied both for patients with incident primary THR and patients with incident primary TKR. In each look-back period, the proportion of patients with one or more OA diagnostic/problem code (sensitivity) was calculated. To observe the period effect on the recorded OA diagnosis, the analyses were repeated stratified by year of THR/TKR between 2000 and 2015. We present the findings for 3- and 10-year look-back periods in the main results, as we have shown previously that the 3-year is the minimum period needed to pick up recorded OA in CPRD [15] and 10-year is the reasonable maximum period to capture existing diagnosis of OA as shown in previous studies [2, 15, 16]. The full set of findings is provided in Supplementary data.

We conducted additional analyses aimed at exploring possible reasons for under-recording of OA in the primary care EHR. We chose two calendar years, 2006 and 2015, and stratified our analyses by patient age (<65 years/≥65 years) and sex with our hypothesis being that under-

recording would be greatest in older adults and in women reflecting greater levels of comorbid illness in these sub-populations.

Poisson regression was used to model the trend over time in the proportion of THR/TKR patients receiving an osteoarthritis diagnosis with the first calendar year (2000) as the reference, and results expressed as crude and age-sex-adjusted rate ratios with 95% confidence intervals.

Data management and analysis were performed using Stata MP Software V14.1 (StataCorp, College Station, TX, USA).

Results

34,299 incident primary THR patients and 47,588 incident primary TKR patients between 2000 and 2015 were recorded in CPRD. In the 3 years prior to THR, 69.9%, 44.7% and 24.5% of THR patients had recorded clinical OA (diagnosed OA or peripheral joint pain symptom code), diagnosed OA (any joint) and diagnosed OA (hip), respectively. In the 3 years prior to TKR, 71.6%, 36.7% and 23.4% of TKR patients had recorded clinical OA, diagnosed OA (any joint) and diagnosed OA (knee), respectively. In the 10 years prior to joint replacement, the figures were 74.7%, 53.4% and 28.1% for THR, and 74.8%, 43.7%, and 25.5% for TKR patients.

Between 2000 and 2015 the sensitivity of each type of OA diagnosis appeared to reduce over time, regardless of whether a 3- or 10-year look-back period was used, (Figure-1; Supplemental Table 1-6).

When stratified by age and sex, the pattern of under-recording differed between knee OA and hip OA (Supplementary table 7 & 8). For knee OA, sensitivity was lower among younger patients (aged < 65 years at TKR) than older patients, particularly for diagnosed OA (any joint) and diagnosed OA (knee) and this same pattern was seen in 2006 and in 2015. There was little difference by sex. By contrast, for hip OA, sensitivity was higher in the younger patients and slightly higher among male patients. Sensitivity for diagnosed OA (any joint) and diagnosed OA (hip) among the younger patients showed the least decline between 2006 and 2015.

Between 2000 and 2015, both unadjusted and adjusted rate ratios reduced for each type of OA diagnosis, regardless of whether a 3- or 10-year look-back period was used, (Table 1-2). In comparison with patients who underwent THR in 2000, for patients receiving THR in 2015, the adjusted rate ratios for having clinical OA, diagnosed OA (any joint) and diagnosed OA (hip) were 0.748 (95 confidence interval: 0.673 to 0.832), 0.552 (0.486 to 0.627) and 0.611 (0.516 to 0.724), respectively. Similarly, compared with patients receiving TKR in 2000, for patients receiving TKR in 2015, in the 3 years prior to TKR, the adjusted rate ratios for having clinical OA, diagnosed OA (any joint) and diagnosed OA (knee) was 0.834 (0.758 to 0.918), 0.478 (0.420 to 0.543) and 0.545 (0.458 to 0.648), respectively. In the 10 years prior to joint replacement, the rate ratios were 0.804 (0.726 to 0.891), 0.627 (0.557 to 0.705) and 0.570 (0.488 to 0.665) for THR, and 0.857 (0.780 to 0.940), 0.583 (0.519 to 0.656), and 0.576 (0.494 to 0.672) for TKR patients.

Discussion

We found evidence of substantial under-recording of OA diagnosis/problem codes in UK primary care electronic record datasets using patients with total joint replacement as the reference population. Using the broadest definition of clinical OA, 25% patients underwent total hip or knee replacements without evidence of a joint pain Read code recorded in the prior 10 years.

Given the very high proportion performed for osteoarthritis, we have argued that receipt of primary total hip and knee replacement is a reasonable choice of reference standard. According to the figure of NJR in 2017, >90% THR and >95% TKR were performed for patients with OA. However, it is important to note that the record of THR and TKR in CPRD is subject to some misclassification. A previous study found that among all diagnosed hip OA and knee OA patients recorded in CPRD, using THR and TKR recorded in Hospital Episode Statistics as the reference standard within 60-day interval, the sensitivity and positive predictive value were 86.6% and 72.8% for THR recorded in CPRD, and 88.0% and 74.6 for TKR recorded in CPRD, respectively [13]. This is insufficient to explain the extent of under-recording of osteoarthritis diagnoses.

Furthermore, we might expect lower sensitivity when considering not simply those receiving joint replacement but the entire spectrum of OA severity since less severe patients are known to be less likely to have a recorded OA diagnosis [20].

Unlike diseases managed both in primary and secondary care for which sensitivity of diagnosis could be improved by linking the primary and secondary care data [21], OA is largely managed in primary care with secondary care being accessed via primary care. Together with our use of a 10-year look-back period, justified by findings from previous studies [2, 15, 16], we think it unlikely that linkage to secondary care in this instance would substantially increase the number of patients with an OA diagnosis.

In this descriptive study, reasons for the under-recording of OA diagnosis and the worsening of this over time are necessarily speculative. A gradual shift in coding behaviour from OA diagnosis to non-specific symptom coding may contribute although the decline in sensitivity of diagnosed OA did not appear to be compensated by an increase in sensitivity for 'clinical OA'. The exclusion from the General Medical Services contract may also play a role although the lack of any clear break in trend at the time of its introduction in 2004 would argue against this being a major explanation. Patients and/or clinicians giving OA lower priority in the context of multimorbidity may also contribute but stratifying our findings for age and sex did not provide clear evidence in support for this explanation. Recording of clinical and diagnosed OA was lower among older patients undergoing THR compared with younger patients. This may reflect the effect of competing comorbidity but also other indications for THR in the older age group, notably for fracture of the neck of femur. Based on National Joint Registry data, only 2.8% of elective THR are performed for this indication, insufficient to fully explain our findings, although the primary care EHR may capture emergency as well as elective THR. It was not possible to distinguish between elective and non-elective joint replacements in our study, and hence to determine whether non-elective replacements have increased over time. Among younger THR patients, the proportion with a prior OA diagnosis was comparatively high and did not decline as much over

time. The age-related pattern was reversed for knee OA with older TKR patients more likely than younger patients to have a recorded diagnosis of OA. One speculative reason for this might be the use of specific non-OA codes in the younger age group (e.g. degenerative meniscal lesions) which we not included in our 'clinical OA' codelist. Irrespective of these differences, it should be noted that each group and sex saw a decline in sensitivity of recording for each patient definition of OA suggesting that broader systems-wide factors are likely to be responsible for the observed decline in recording of OA. We are not aware of any significant change in coding systems over the period of observation that would contribute to such a pattern of results. Irrespective of the underlying reasons, the effect is most likely a substantial under-estimate of the consultation incidence and prevalence of osteoarthritis in UK primary care when relying on diagnostic codes alone to identify patients. Future studies addressing the validity of OA diagnosis made in primary care settings will be planned, which could be used to correct the consultation incidence and prevalence estimates,

Conclusion

Our findings suggest a worsening trend in the under-recording of osteoarthritis in UK primary care. While our study does not provide clear evidence on the cause of this nor on a solution, researchers, practitioners, and policymakers should expect that estimates of the consultation incidence and prevalence of OA from these data that rely on osteoarthritis diagnostic codes are likely to seriously under-estimate the scale of healthcare demand.

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Regulatory Agency. The interpretation and conclusions contained in this study are those of the authors alone.

Author contributions

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; gave final approval of the version to be published; and agree to be accountable for all aspects of the work.

Disclosure

The author reports no conflicts of interest in this work.

REFERENCES

1. Coorevits P, Sundgren M, Klein GO, et al. Electronic health records: new opportunities for clinical research. *J Intern Med*. 2013;274(6):547-560.

2. Kopec JA, Rahman MM, Sayre EC, et al. Trends in physician-diagnosed osteoarthritis incidence in an administrative database in British Columbia, Canada, 1996-1997 through 2003-2004. *Arthritis Rheum*. 2008;59(7):929-934.

3. National Clinical Guideline Centre (UK). Osteoarthritis: Care and Management in Adults. 2014. doi: NBK248069 [bookaccession].

4. Bedson J, McCarney R, Croft P. Labelling chronic illness in primary care: a good or a bad thing?. *Br J Gen Pract*. 2004;54(509):932-938.

5. Gabriel SE, Crowson CS, O'Fallon WM. A mathematical model that improves the validity of osteoarthritis diagnoses obtained from a computerized diagnostic database. *J Clin Epidemiol*. 1996;49(9):1025-1029.

6. Shrestha S, Dave AJ, Losina E, Katz JN. Diagnostic accuracy of administrative data algorithms in the diagnosis of osteoarthritis: a systematic review. *BMC Med Inform Decis Mak*. 2016;16:82-016-0319-y.

7. Rahman MM, Kopec JA, Goldsmith CH, Anis AH, Cibere J. Validation of Administrative Osteoarthritis Diagnosis Using a Clinical and Radiological Population-Based Cohort. *Int J Rheumatol*. 2016;2016:6475318.

8. Harrold LR, Yood RA, Straus W, et al. Challenges of estimating health service utilization for osteoarthritis patients on a population level. *J Rheumatol*. 2002;29(9):1931-1936.

9. National Joint Registry for England and Wales: 14th Annual report. 2017.

10. Herrett E, Gallagher AM, Bhaskaran K, et al. Data Resource Profile: Clinical Practice Research Datalink (CPRD). *Int J Epidemiol*. 2015;44(3):827-836.

11. Herrett E, Thomas SL, Schoonen WM, Smeeth L, Hall AJ. Validation and validity of diagnoses in the General Practice Research Database: a systematic review. *Br J Clin Pharmacol*. 2010;69(1):4-14.

12. Culliford D, Maskell J, Judge A, et al. Future projections of total hip and knee arthroplasty in the UK: results from the UK Clinical Practice Research Datalink. *Osteoarthritis Cartilage*. 2015;23(4):594-600.

13. Hawley S, Delmestri A, Judge A, et al. Total Hip and Knee Replacement Among Incident Osteoarthritis and Rheumatoid Arthritis Patients Within the UK Clinical Practice Research Datalink (CPRD) Compared to Hospital Episode Statistics (HES): A Validation Study. *Pharmacoepidemiol drug safety*. 2016;25(Suppl. 3):251.

14. Brilleman SL, Salisbury C. Comparing measures of multimorbidity to predict outcomes in primary care: a cross sectional study. *Fam Pract*. 2013;30(2):172-178.

15. Yu D, Jordan KP, Bedson J, et al. Population trends in the incidence and initial management of osteoarthritis: age-period-cohort analysis of the Clinical Practice Research Datalink, 1992-2013. *Rheumatology (Oxford)*. 2017;56(11):1902-1917.

16. Marshall DA, Vanderby S, Barnabe C, et al. Estimating the Burden of Osteoarthritis to Plan for the Future. *Arthritis Care Res (Hoboken)*. 2015;67(10):1379-1386.

17. Hollowell J. The General Practice Research Database: quality of morbidity data. *Popul Trends*. 1997;87:36–40.

18. Lawson DH, Sherman V, Hollowel J. The General Practice Research Database. Scientific and Ethical Advisory Group. *QJM*. 1998;91(6):445-52.

19. Porcheret M, Hughes R, Evans D, et al. Data quality of general practice electronic health records: the impact of a program of assessments, feedback, and training. *J Am Med Inform Assoc*. 2004;11(1):78-86.

20. Jordan KP, Tan V, Edwards JJ, et al. Influences on the decision to use an osteoarthritis diagnosis in primary care: a cohort study with linked survey and electronic health record data. *Osteoarthritis Cartilage*. 2016;24(5):786-793.

21. Millett ER, Quint JK, De Stavola BL, Smeeth L, Thomas SL. Improved incidence estimates from linked vs. stand-alone electronic health records. *J Clin Epidemiol*. 2016;75:66-69

Table-1. Rate ratios for osteoarthritis diagnosis among patients with an incident primary total hip replacement between 2000 and 2015

*Proportion of osteoarthritis diagnosis in 2000 was used as reference group. Estimation derived from 3- and 10-year run-in period methods were presented. *Age and gender were adjusted.*

	Clinical Osteoarthritis		**Diagnosed Osteoarthritis**		**Hip Osteoarthritis**	
	3-yr	**10-yr**	**3-yr**	**10-yr**	**3-yr**	**10-yr**
	Unadjusted Rate Ratios					
2000	**Reference**	**Reference**	**Reference**	**Reference**	**Reference**	**Reference**
2001	0.976 (0.865 to 1.102)	0.975 (0.866 to 1.098)	0.944 (0.820 to 1.087)	0.924 (0.809 to 1.055)	0.821 (0.674 to 0.998)	0.792 (0.663 to 0.946)
2002	0.970 (0.863 to 1.090)	0.976 (0.871 to 1.094)	0.955 (0.834 to 1.093)	0.940 (0.828 to 1.068)	0.904 (0.752 to 1.088)	0.869 (0.735 to 1.027)
2003	0.912 (0.814 to 1.023)	0.916 (0.819 to 1.024)	0.908 (0.796 to 1.036)	0.892 (0.788 to 1.010)	0.857 (0.716 to 1.026)	0.799 (0.678 to 0.941)
2004	0.934 (0.836 to 1.044)	0.943 (0.846 to 1.050)	0.882 (0.775 to 1.003)	0.886 (0.785 to 1.000)	0.825 (0.692 to 0.984)	0.753 (0.642 to 0.885)
2005	0.921 (0.825 to 1.028)	0.920 (0.826 to 1.025)	0.870 (0.765 to 0.989)	0.886 (0.786 to 0.999)	0.867 (0.729 to 1.032)	0.805 (0.688 to 0.943)
2006	0.928 (0.832 to 1.034)	0.926 (0.833 to 1.029)	0.883 (0.778 to 1.002)	0.873 (0.775 to 0.983)	0.848 (0.714 to 1.007)	0.765 (0.654 to 0.895)
2007	0.921 (0.828 to 1.025)	0.926 (0.835 to 1.027)	0.853 (0.753 to 0.965)	0.861 (0.766 to 0.967)	0.804 (0.680 to 0.952)	0.740 (0.635 to 0.863)
2008	0.892 (0.803 to 0.991)	0.895 (0.807 to 0.993)	0.787 (0.696 to 0.891)	0.813 (0.725 to 0.913)	0.787 (0.666 to 0.930)	0.707 (0.607 to 0.824)
2009	0.870 (0.784 to 0.965)	0.879 (0.794 to 0.973)	0.763 (0.676 to 0.862)	0.775 (0.692 to 0.869)	0.770 (0.653 to 0.907)	0.688 (0.593 to 0.799)
2010	0.871 (0.786 to 0.965)	0.885 (0.801 to 0.978)	0.723 (0.641 to 0.815)	0.771 (0.690 to 0.863)	0.711 (0.604 to 0.837)	0.654 (0.564 to 0.759)
2011	0.850 (0.767 to 0.941)	0.875 (0.792 to 0.967)	0.683 (0.606 to 0.770)	0.736 (0.658 to 0.823)	0.718 (0.610 to 0.844)	0.662 (0.572 to 0.767)
2012	0.830 (0.750 to 0.919)	0.854 (0.773 to 0.943)	0.643 (0.571 to 0.725)	0.703 (0.628 to 0.785)	0.663 (0.564 to 0.779)	0.608 (0.525 to 0.704)
2013	0.809 (0.731 to 0.896)	0.850 (0.770 to 0.938)	0.627 (0.556 to 0.707)	0.711 (0.636 to 0.795)	0.644 (0.548 to 0.757)	0.608 (0.525 to 0.703)
2014	0.778 (0.702 to 0.862)	0.815 (0.738 to 0.901)	0.580 (0.513 to 0.655)	0.646 (0.577 to 0.723)	0.626 (0.532 to 0.737)	0.596 (0.514 to 0.690)
2015	0.751 (0.672 to 0.839)	0.806 (0.724 to 0.898)	0.555 (0.485 to 0.635)	0.630 (0.557 to 0.713)	0.614 (0.514 to 0.734)	0.573 (0.487 to 0.674)
	Adjusted Rate Ratios*					
2000	**Reference**	**Reference**	**Reference**	**Reference**	**Reference**	**Reference**
2001	0.976 (0.870 to 1.095)	0.975 (0.871 to 1.091)	0.943 (0.825 to 1.078)	0.923 (0.814 to 1.047)	0.819 (0.680 to 0.987)	0.791 (0.668 to 0.936)
2002	0.970 (0.868 to 1.084)	0.976 (0.876 to 1.088)	0.954 (0.839 to 1.085)	0.939 (0.832 to 1.060)	0.903 (0.758 to 1.077)	0.867 (0.740 to 1.017)
2003	0.912 (0.818 to 1.016)	0.915 (0.823 to 1.017)	0.907 (0.801 to 1.028)	0.891 (0.792 to 1.003)	0.856 (0.721 to 1.015)	0.797 (0.682 to 0.931)
2004	0.933 (0.840 to 1.037)	0.942 (0.850 to 1.044)	0.881 (0.779 to 0.996)	0.885 (0.789 to 0.993)	0.823 (0.696 to 0.973)	0.751 (0.645 to 0.875)
2005	0.920 (0.829 to 1.022)	0.920 (0.830 to 1.019)	0.869 (0.769 to 0.982)	0.885 (0.790 to 0.992)	0.866 (0.735 to 1.021)	0.804 (0.692 to 0.933)

2006	0.927 (0.836 to 1.028)	0.925 (0.836 to 1.023)	0.882 (0.782 to 0.994)	0.872 (0.779 to 0.976)	0.847 (0.719 to 0.997)	0.763 (0.658 to 0.885)
2007	0.920 (0.832 to 1.018)	0.925 (0.838 to 1.021)	0.851 (0.757 to 0.957)	0.859 (0.770 to 0.960)	0.803 (0.684 to 0.942)	0.738 (0.638 to 0.854)
2008	0.891 (0.806 to 0.985)	0.894 (0.811 to 0.986)	0.785 (0.698 to 0.883)	0.812 (0.727 to 0.906)	0.785 (0.670 to 0.920)	0.705 (0.610 to 0.814)
2009	0.869 (0.787 to 0.959)	0.878 (0.797 to 0.967)	0.761 (0.678 to 0.855)	0.773 (0.694 to 0.862)	0.768 (0.657 to 0.898)	0.686 (0.595 to 0.790)
2010	0.869 (0.789 to 0.958)	0.884 (0.804 to 0.972)	0.720 (0.642 to 0.808)	0.769 (0.692 to 0.856)	0.709 (0.607 to 0.828)	0.652 (0.566 to 0.750)
2011	0.848 (0.770 to 0.935)	0.874 (0.795 to 0.961)	0.680 (0.607 to 0.763)	0.734 (0.659 to 0.816)	0.715 (0.613 to 0.834)	0.659 (0.574 to 0.758)
2012	0.828 (0.752 to 0.912)	0.853 (0.776 to 0.937)	0.641 (0.572 to 0.718)	0.700 (0.630 to 0.778)	0.660 (0.566 to 0.770)	0.605 (0.527 to 0.695)
2013	0.808 (0.733 to 0.889)	0.849 (0.773 to 0.932)	0.624 (0.557 to 0.699)	0.709 (0.638 to 0.788)	0.641 (0.550 to 0.748)	0.605 (0.526 to 0.695)
2014	0.776 (0.704 to 0.855)	0.814 (0.740 to 0.895)	0.577 (0.514 to 0.647)	0.643 (0.578 to 0.716)	0.623 (0.534 to 0.727)	0.593 (0.515 to 0.682)
2015	0.748 (0.673 to 0.832)	0.804 (0.726 to 0.891)	0.552 (0.486 to 0.627)	0.627 (0.557 to 0.705)	0.611 (0.516 to 0.724)	0.570 (0.488 to 0.665)

Table-2. Rate ratios for osteoarthritis diagnosis among patients with an incident primary total knee replacement between 2000 and 2015

*Proportion of osteoarthritis diagnosis in 2000 was used as reference group. Estimation derived from 3- and 10-year run-in period methods were presented. *Age and gender were adjusted.*

	Clinical Osteoarthritis		**Diagnosed Osteoarthritis**		**Knee Osteoarthritis**	
	3-yr	**10-yr**	**3-yr**	**10-yr**	**3-yr**	**10-yr**
	Unadjusted Rate Ratios					
2000	**Reference**	**Reference**	**Reference**	**Reference**	**Reference**	**Reference**
2001	0.991 (0.888 to 1.105)	0.989 (0.889 to 1.100)	0.956 (0.836 to 1.092)	0.971 (0.856 to 1.102)	0.904 (0.750 to 1.090)	0.920 (0.778 to 1.087)
2002	0.984 (0.885 to 1.094)	0.974 (0.878 to 1.080)	0.942 (0.828 to 1.072)	0.962 (0.852 to 1.088)	0.925 (0.774 to 1.107)	0.944 (0.804 to 1.108)
2003	0.977 (0.882 to 1.082)	0.970 (0.878 to 1.072)	0.904 (0.797 to 1.025)	0.905 (0.803 to 1.020)	0.872 (0.733 to 1.039)	0.838 (0.716 to 0.982)
2004	0.987 (0.893 to 1.090)	0.978 (0.887 to 1.078)	0.896 (0.792 to 1.012)	0.901 (0.802 to 1.012)	0.893 (0.754 to 1.058)	0.863 (0.741 to 1.006)
2005	0.998 (0.906 to 1.100)	0.982 (0.893 to 1.080)	0.895 (0.795 to 1.009)	0.914 (0.816 to 1.023)	0.907 (0.769 to 1.069)	0.886 (0.764 to 1.028)
2006	0.987 (0.896 to 1.088)	0.973 (0.885 to 1.070)	0.856 (0.759 to 0.964)	0.888 (0.793 to 0.994)	0.894 (0.759 to 1.054)	0.849 (0.731 to 0.985)
2007	1.010 (0.919 to 1.110)	0.990 (0.902 to 1.086)	0.862 (0.767 to 0.969)	0.889 (0.796 to 0.993)	0.868 (0.739 to 1.020)	0.811 (0.701 to 0.939)
2008	0.976 (0.889 to 1.071)	0.961 (0.878 to 1.053)	0.777 (0.692 to 0.872)	0.826 (0.740 to 0.921)	0.819 (0.699 to 0.960)	0.783 (0.678 to 0.903)
2009	0.963 (0.878 to 1.057)	0.947 (0.865 to 1.036)	0.732 (0.653 to 0.821)	0.782 (0.702 to 0.872)	0.766 (0.654 to 0.898)	0.725 (0.629 to 0.837)
2010	0.954 (0.871 to 1.046)	0.941 (0.861 to 1.029)	0.674 (0.601 to 0.755)	0.727 (0.653 to 0.810)	0.705 (0.602 to 0.824)	0.672 (0.583 to 0.774)

2011	0.931 (0.850 to 1.021)	0.923 (0.844 to 1.010)	0.618 (0.551 to 0.693)	0.684 (0.614 to 0.762)	0.688 (0.588 to 0.805)	0.668 (0.580 to 0.770)
2012	0.916 (0.836 to 1.004)	0.919 (0.841 to 1.005)	0.620 (0.553 to 0.695)	0.690 (0.620 to 0.769)	0.679 (0.580 to 0.794)	0.663 (0.576 to 0.764)
2013	0.887 (0.809 to 0.973)	0.891 (0.815 to 0.975)	0.560 (0.499 to 0.629)	0.651 (0.584 to 0.725)	0.621 (0.530 to 0.728)	0.628 (0.545 to 0.724)
2014	0.873 (0.796 to 0.958)	0.882 (0.806 to 0.965)	0.528 (0.470 to 0.594)	0.621 (0.557 to 0.693)	0.589 (0.502 to 0.691)	0.619 (0.536 to 0.714)
2015	0.835 (0.755 to 0.924)	0.858 (0.778 to 0.946)	0.481 (0.421 to 0.551)	0.587 (0.518 to 0.664)	0.548 (0.457 to 0.657)	0.579 (0.493 to 0.681)
	Adjusted Rate Ratios					
2000	**Reference**	**Reference**	**Reference**	**Reference**	**Reference**	**Reference**
2001	0.991 (0.893 to 1.099)	0.989 (0.894 to 1.094)	0.955 (0.842 to 1.084)	0.971 (0.861 to 1.095)	0.903 (0.757 to 1.078)	0.919 (0.784 to 1.077)
2002	0.984 (0.890 to 1.088)	0.974 (0.883 to 1.074)	0.942 (0.833 to 1.065)	0.962 (0.856 to 1.081)	0.925 (0.780 to 1.096)	0.943 (0.810 to 1.099)
2003	0.977 (0.887 to 1.077)	0.969 (0.882 to 1.066)	0.903 (0.801 to 1.017)	0.904 (0.807 to 1.012)	0.871 (0.738 to 1.028)	0.837 (0.720 to 0.972)
2004	0.986 (0.897 to 1.084)	0.978 (0.891 to 1.072)	0.895 (0.796 to 1.005)	0.900 (0.806 to 1.005)	0.892 (0.760 to 1.048)	0.862 (0.745 to 0.997)
2005	0.998 (0.910 to 1.094)	0.982 (0.897 to 1.075)	0.894 (0.799 to 1.002)	0.913 (0.820 to 1.017)	0.906 (0.775 to 1.060)	0.885 (0.769 to 1.019)
2006	0.987 (0.900 to 1.082)	0.973 (0.889 to 1.064)	0.854 (0.763 to 0.957)	0.887 (0.797 to 0.988)	0.893 (0.764 to 1.044)	0.847 (0.736 to 0.976)
2007	1.010 (0.923 to 1.105)	0.990 (0.907 to 1.081)	0.861 (0.771 to 0.962)	0.888 (0.799 to 0.986)	0.867 (0.744 to 1.010)	0.810 (0.705 to 0.930)
2008	0.976 (0.893 to 1.066)	0.961 (0.881 to 1.048)	0.775 (0.694 to 0.865)	0.824 (0.743 to 0.914)	0.817 (0.703 to 0.950)	0.781 (0.681 to 0.895)
2009	0.963 (0.882 to 1.051)	0.946 (0.869 to 1.031)	0.730 (0.654 to 0.814)	0.780 (0.704 to 0.865)	0.764 (0.658 to 0.888)	0.723 (0.631 to 0.828)
2010	0.954 (0.874 to 1.040)	0.940 (0.864 to 1.024)	0.671 (0.602 to 0.748)	0.725 (0.654 to 0.803)	0.702 (0.605 to 0.815)	0.669 (0.585 to 0.766)
2011	0.931 (0.853 to 1.015)	0.922 (0.847 to 1.004)	0.615 (0.552 to 0.686)	0.681 (0.615 to 0.755)	0.685 (0.590 to 0.796)	0.665 (0.582 to 0.761)
2012	0.915 (0.839 to 0.998)	0.918 (0.844 to 0.999)	0.617 (0.553 to 0.687)	0.688 (0.621 to 0.762)	0.676 (0.583 to 0.785)	0.661 (0.578 to 0.755)
2013	0.886 (0.812 to 0.967)	0.890 (0.818 to 0.969)	0.557 (0.499 to 0.622)	0.648 (0.584 to 0.718)	0.618 (0.532 to 0.719)	0.625 (0.546 to 0.716)
2014	0.872 (0.799 to 0.952)	0.881 (0.808 to 0.959)	0.525 (0.469 to 0.586)	0.618 (0.557 to 0.686)	0.586 (0.503 to 0.682)	0.616 (0.538 to 0.706)
2015	0.834 (0.758 to 0.918)	0.857 (0.780 to 0.940)	0.478 (0.420 to 0.543)	0.583 (0.519 to 0.656)	0.545 (0.458 to 0.648)	0.576 (0.494 to 0.672)