THE JOURNAL OF THE AMERICAN DENTAL ASSOCIATION

JADA

Dental procedures and subsequent prosthetic joint infections : Findings from the Medicare Current Beneficiary Survey

Daniel D. Skaar, Heidi O'Connor, James S. Hodges and Bryan S. Michalowicz

JADA 2011;142;1343-1351

Dental procedures and subsequent prosthetic joint infections

Findings from the Medicare Current Beneficiary Survey

Daniel D. Skaar, DDS, MS, MBA; Heidi O'Connor, MS; James S. Hodges, PhD; Bryan S. Michalowicz, DDS, MS

Debate continues concerning the need for antibiotic prophylaxis to prevent patients from developing prosthetic joint infections (PJIs) after undergoing dental procedures. The 2009 American Academy of Orthopaedic Surgeons' (AAOS') recommended that clinicians consider prescribing antibiotic prophylaxis for all patients who have undergone total joint arthroplasty before those patients undergo any invasive procedures that may cause bacteremia, regardless of the time since joint implantation, because of the potential for adverse outcomes and cost of treating PJIs.[1] The AAOS statement did not define invasive dental procedures that frequently produce a transient bacteremia. Previous statements promulgated jointly by the AAOS and the American Dental Association[2,3] (ADA) did not advocate that clinicians consider prescribing antibiotic prophylaxis for invasive dental procedures that are associated with a high incidence of bacteremia two years after the patient has had total joint arthroplasty, except for patients

ABSTRACT

JADA CE CONTINUING EDUCATION ARTICLE 1

Background. The publication of the 2009 American Academy of Orthopedic Surgeons' (AAOS') guidelines for antibiotic prophylaxis after joint replacement (arthroplasty) has renewed debate concerning appropriate prophylaxis for dental patients. The authors examined an administrative data set to assess whether dental procedures were associated with prosthetic joint infections (PJIs).

Methods. Using data for the years 1997 through 2006 from the Medicare Current Beneficiary Survey (MCBS), the authors identified participants who had undergone total joint arthroplasty and those who had experienced a PJI. They explored associations between dental procedures and subsequent PJIs by using time-to-event analyses (N = 1,000). A nested case-control study included case participants who had had PJIs (n = 42) and matched control participants who had had total arthroplasty but had no PJIs (n = 126). The authors calculated hazard ratios (HRs) and odds ratios (ORs).

Results. Control participants (people without PJIs) were more likely than were case participants (those with PJIs) to have undergone an invasive dental procedure, though this trend was not statistically significant in either the time-to-event analysis (HR = 0.78; 95 percent confidence interval [CI], 0.18-3.39) or the case-control analysis (OR = 0.56; 95 percent CI, 0.18-1.74). Only four of 42 case participants had undergone an invasive dental procedure in the 90 days before the infection occurred. Consideration of all dental procedures yielded similar results.

Conclusions. Dental procedures were not associated significantly with subsequent risk for PJIs, although this study's power was somewhat low. The clinical importance of prophylactic antibiotics in dentistry for patients who have undergone joint arthroplasty, therefore, may be questioned.

Clinical Implications. These results support the view that the 2009 AAOS Information Statement on antibiotic prophylaxis for people with prosthetic joints should be reconsidered for patients in that population who are receiving oral health care.

Key Words. Prosthetic joint arthroplasty; prosthetic joint infection; antibiotic prophylaxis; dental procedures.
JADA 2011;142(12):1343-1351.

Dr. Skaar is an assistant professor, Department of Developmental and Surgical Sciences, School of Dentistry, University of Minnesota, 7-368 Moos Health Sciences Tower, 515 Delaware St. SE, Minneapolis, Minn. 55455, e-mail "skaar003@umn.edu". Address reprint requests to Dr. Skaar.
Ms. O'Connor is a research fellow, Division of Health Policy and Management, School of Public Health, University of Minnesota, Minneapolis.
Dr. Hodges is an associate professor, Division of Biostatistics, School of Public Health, University of Minnesota, Minneapolis.
Dr. Michalowicz is a professor and holder of the Erwin Schaffer Chair in Periodontal Research, Division of Periodontology, Department of Developmental and Surgical Sciences, School of Dentistry, University of Minnesota, Minneapolis.

with any of the following conditions:
- those who are immunocompromised;
- those who have had a previous prosthetic joint infection;
- those who have high-risk comorbidities.

The AAOS statement has been criticized[4-6] for its lack of input from organized dentistry and its reliance on several assumptions:
- PJIs can arise from dental procedures that induce bacteremias associated with oral flora;
- a temporal relationship exists between dental procedures and PJI;
- antibiotic prophylaxis may prevent dental procedure–related bacteremias and subsequent PJIs;
- comparisons between late PJI and infective endocarditis are questionable because of differing anatomy, blood supply, microorganisms and infection mechanisms.

More than 750,000 total joint arthroplasties are completed annually in the United States; about 7 percent of these are revisions involving the replacement of existing prosthetic joints.[7] Given the aging U.S. population, the demand for primary and revision total hip and knee arthroplasties is expected to rise substantially. Between 2005 and 2030, Kurtz and colleagues[8] projected, the number of primary total hip arthroplasties will increase an estimated 174 percent to 572,000 cases annually and the number of total knee arthroplasties will increase an estimated 673 percent to 3.48 million. During this period, Kurtz and colleagues[8] estimated, the total number of hip and knee revisions will grow by 137 percent (96,700 cases annually) and 601 percent (268,200 cases annually), respectively. In addition to patient morbidity, the financial burden of revision arthroplasties is substantial. Medical costs alone for revision procedures have been estimated to be 4.8 times higher than the costs for primary joint arthroplasties.[9]

The need for antibiotic prophylaxis for patients who have undergone total joint arthroplasty has been debated at length without producing a consensus.[10] Previous recommendations have been based on relatively limited data,[11-13] and several authors have questioned the need for antibiotic prophylaxis because of the lack of supporting data.[14,15] The 1997 and 2003 ADA/AAOS advisory statements attempted to clarify clinical decision making by providing guidelines to assist dentists in determining which patients undergoing which dental procedures could benefit from antibiotic prophylaxis and by providing appropriate antibiotic regimens.[2,3] The 2009 AAOS statement appears contrary to some of the previous recommendations and has created confusion and uncertainty for oral health care providers treating patients who have a history of total joint arthroplasty.

To address the renewed controversy surrounding the need to provide antibiotic prophylaxis before dental procedures to prevent PJI, we used a nationally representative administrative data set—that from the Medicare Current Beneficiary Survey (MCBS), which is sponsored by the Centers for Medicare and Medicaid Services[16] (CMS)—to assess the prevalence of total joint arthroplasty and PJIs in adults seeking oral health care. We also aimed to test for associations between dental procedures and PJIs. With the recent finding that high- and low-risk dental procedures were not associated with PJIs in a tertiary care hospital,[17] we hypothesized that dental procedures, including invasive ones associated with a higher risk of experiencing bacteremia, were not associated with an increased risk of developing PJIs in a nationally representative sample of Medicare beneficiaries who are aged or have disabilities.

METHODS

The MCBS is an annual, continuous, nationally representative survey of the U.S. Medicare population that includes all beneficiaries 65 years and older and people with disabilities younger than 65 years.[16] The data are collected from the CMS Medicare enrollment file and disseminated by WESTAT (Rockville, Md.). The MCBS file gives a continuous, complete profile of demographic characteristics, health care and dental service utilization, health outcomes and prescribed drugs. The survey's rotating panel design allows approximately 12,000 participants to be interviewed three times annually for up to four consecutive years. Approximately 4,000 participants exit the study annually because of death, refusal to participate and rotation out of the survey; they are replaced. For this study, we analyzed data from the 1997-2006 MCBS Cost and Use files for community-dwelling beneficiaries.[16] Given that the MCBS is a deidentified public data set, the University of Minnesota Institutional Review Board determined that the study protocol was exempt from review.

ABBREVIATION KEY. AAOS: American Academy of Orthopaedic Surgeons. **ADA:** American Dental Association. **CMS:** Centers for Medicare and Medicaid Services. **ICD-9-CM:** International Classification of Diseases (Ninth Revision, Clinical Modification). **JR:** Joint replacement. **LRD:** Last relevant date. **MCBS:** Medicare Current Beneficiary Survey. **PJI:** Prosthetic joint infection.

TABLE 1

ICD-9-CM* joint replacement and infection diagnosis codes.

PROCEDURE OR DIAGNOSIS	ICD-9-CM PROCEDURE OR DIAGNOSIS CODES
Joint Replacement	81.5, 81.51, 81.52, 81.54, 81.56, 81.57, 81.80, 81.81, 81.84, 81.9
Infection and Inflammatory Reaction Due to Internal Prosthetic Device Implant and Graft	996.66

* ICD-9-CM: International Classification of Diseases, Ninth Revision, Clinical Modification.[18]

We used data for the years 1997 through 2006, data that described dental visits and procedures, inpatient hospitalization for joint replacements and infections, antibiotic prescriptions and sociodemographic characteristics. We identified inpatient hospitalization procedure codes, including total joint arthroplasty and infection, according to diagnostic codes from the International Classification of Diseases, Ninth Revision, Clinical Modification[18] (ICD-9-CM) (Table 1). Dental procedures recorded in the survey include radiographs, teeth cleaning, examinations, restorations (called "fillings" in the MCBS), extractions, endondontic procedures (called "root canals" in the MCBS), crowns, bridges and complete and removable dentures, orthodontics and other services. The survey included periodontal procedures in the "teeth cleaning" category. We designated as invasive the following procedures: teeth cleanings, extractions and endodontic procedures. These procedures frequently involve "manipulation of gingival tissue or the peri-apical region of teeth or perforation of oral mucosa," as described in the 2007 American Heart Association guidelines regarding procedures likely to result in bacteremias.[19] We considered all other procedures, including restorations, to be noninvasive. Antibiotic prescriptions for drugs commonly prescribed for joint prophylaxis (such as oral amoxicillin, cephalexin, cephradine and clindamycin) were recorded in the survey according to brand and generic names.

We used two approaches to test for associations between demographic variables, dental procedures and PJIs. First, we identified all participants who had undergone total joint arthroplasty while they were enrolled in the survey, some of whom experienced a subsequent PJI. We conducted time-to-event analyses to determine if having a dental procedure in the preceding 90- and 180-day periods was associated with PJI. We considered dental-visit status a time-varying covariate (predictor) because a participant's status—that is, whether he or she had undergone a dental procedure in the preceding 90 or 180 days—changed across time. We considered each dental procedure and the designated invasive dental procedures individually. Thus, we performed four time-to-event analyses, considering any dental procedure performed in the preceding 90 days and 180 days and considering only invasive dental procedures performed in the same periods. Because of the small number of PJI events recorded in this cohort (see the Results section), our adjusted time-to-event analyses included only a single adjuster at a time, either education (12 years or less versus more than 12 years), age in years, or score on the Charlson comorbidity index.[20] This validated, weighted index is used widely; it is based on a number of comorbid medical conditions of increasing severity. Investigators use it in longitudinal studies to predict mortality risk. We calculated hazard ratios (HRs), computed in the natural log scale and back-transformed, for dental visits versus no dental visits in the preceding periods.

Next, we conducted a nested case-control analysis after identifying all participants who had experienced a PJI in the 10-year survey period. This included participants in the time-to-event analyses in addition to those who experienced a PJI while in the survey but who had undergone total joint arthroplasty at some indeterminable time before entering the survey. We selected three participants who did not have a PJI as controls for each case participant. Control participants had undergone total joint arthroplasty while taking part in the survey and were matched to case participants according to age groups (0-44, 45-64, 65-69, 70-74, 75-79, 80-84 and 85 years or older), sex and number of comorbid conditions (which we defined arbitrarily as four or fewer or more than four). We compared case and control participants according to receipt of any dental procedure and any invasive dental procedure in the 90 and 180 days before the last relevant date. The last relevant date for case participants was the date of the reported PJI and for control participants was their date of death or Dec. 31 of the last year in which they were enrolled in the survey. We compared the receipt of dental procedures (any or none) during the preceding

TABLE 2

Characteristics of Medicare beneficiaries with primary joint replacement (JR) procedures and subsequent prosthetic joint infections (PJIs).

PARTICIPANT CHARACTERISTIC	NO. (PERCENTAGE) OF BENEFICIARIES, ACCORDING TO CONDITION		
	With JR (n = 1,000)	With JR and Subsequent PJI (n = 18)	With JR but Without Subsequent PJI (n = 982)*
Age (in Years)			
Younger than 65	66 (6.6)	2 (11.1)	64 (6.5)
65 to 74	359 (35.9)	6 (33.3)	353 (36.0)
75 to 84	412 (41.2)	7 (38.9)	405 (41.2)
85 or older	163 (16.3)	3 (16.7)	160 (16.3)
Sex			
Male	358 (35.8)	12 (66.7)	346 (35.2)
Female	642 (64.2)	6 (33.3)	636 (64.8)
Race			
White	905 (90.5)	16 (88.9)	889 (90.5)
Nonwhite	95 (9.5)	2 (11.1)	93 (9.5)
Income			
0 to $25,000	582 (58.2)	14 (77.8)	569 (57.9)
$25,001 or more	418 (41.8)	4 (22.2)	413 (42.1)
Education			
High school graduate or less	639 (63.9)	14 (77.8)	625 (63.6)
More than high school	361 (36.1)	4 (22.2)	357 (36.4)
Marital Status			
Not married	498 (49.8)	7 (38.9)	491 (50.0)
Married	502 (50.2)	11 (61.1)	491 (50.0)
Census Bureau Region of Residence†			
Northeast	150 (15.0)	1 (5.6)	149 (15.2)
Midwest	284 (28.4)	6 (33.3)	278 (28.3)
South	375 (37.5)	6 (33.3)	368 (37.5)
West South Central	182 (18.2)	4 (22.2)	179 (18.2)
Puerto Rico	9 (0.9)	1 (5.6)	8 (0.8)
Self-Reported Health			
Excellent/Very good/Good	691 (69.1)	11 (61.1)	679 (69.1)
Fair/Poor	284 (28.4)	7 (38.9)	278 (28.3)
Data missing/Unknown	25 (2.5)	0 (0.0)	25 (2.5)
Number of Comorbid Conditions			
None to three	580 (58.0)	11 (61.1)	568 (57.8)
Four or more	393 (39.3)	7 (38.9)	387 (39.4)
Data missing/Unknown	27 (2.7)	0 (0.0)	27 (2.7)
Charlson Comorbidity Index Score‡			
0	18 (1.8)	0 (0.0)	18 (1.8)
1 to 3	560 (56.0)	12 (66.7)	548 (55.8)
4 or higher	398 (39.8)	6 (33.3)	392 (40.0)
Data missing/Unknown	24 (2.4)	0 (0.0)	24 (2.4)

* Of these 982 participants in the Medicare Current Beneficiary Survey, 404 were followed for less than one year after undergoing arthroplasty, 320 were followed for one to less than two years and 258 were followed for two to less than three years.
† Source: U.S. Census Bureau.[21]
‡ Source: Charlson and colleagues.[20]

periods of interest between case and control participants by using Mantel-Haenszel tests stratified by groups formed by a case participant and his or her three matching control participants. We considered *P* values of less than .05 to be significant.

RESULTS

Participants who underwent total joint arthroplasty while enrolled in the MCBS. For the years 1997 through 2006, 1,000 participants (358 men, 642 women) underwent primary total joint arthroplasty surgery while par-

ticipating in the MCBS. Two participants experienced a PJI before undergoing arthroplasty while enrolled in the survey, which indicated that they had entered the survey with a prosthetic joint. We included these two participants in the time-to-event analysis, with their "clock" starting at the date of the arthroplasty recorded in the MCBS data set; neither participant had a subsequent PJI recorded during the MCBS.

Among the 1,000 participants, 468 had received hip prostheses, 501 had received knee prostheses and 31 had undergone replacement of another joint. Eighteen of these people experienced a subsequent PJI while taking part in the survey (1.8 percent; 95 percent confidence interval [CI], 1.0 percent-2.6 percent). The percentage of participants who had experienced a PJI was similar for those who reported having had a dental visit after undergoing total joint arthroplasty (seven of 457 [1.5 percent]; 95 percent CI, 0.4 percent-2.7 percent) and those who did not (11 of 543 [2.0 percent]; 95 percent CI, 0.8 percent-3.2 percent). Table 2 lists selected demographic and dental visit characteristics for participants who had undergone a total joint arthroplasty while taking part in the MCBS and for those who subsequently had experienced a PJI.

Case and matched control participants. Overall, 42 PJIs were recorded in the MCBS dataset. This total includes the 18 participants who experienced a PJI after undergoing total joint arthroplasty while they were enrolled in the MCBS and 24 who underwent arthroplasty before entering the survey (two of whom experienced a PJI and follow-up arthroplasty while they were enrolled in the survey). Table 3 provides characteristics of the 42 case and 126 matched control participants without PJIs, including basic demographic information such as age, sex, education and U.S. Census Bureau[21] region of residence as well as the number of comorbid conditions and their scores on the Charlson comorbidity index.[20]

Time-to-event analyses involving 1,000 participants who had undergone total joint arthroplasty. Prior dental procedures were not associated with PJI. HRs for procedures performed within 90 or 180 days before the PJI were not significant (Table 4, page 1349). HRs were less than 1.0 for all dental procedures and invasive procedures, indicating that participants reporting having undergone any dental procedure in the preceding period were less likely to experience a PJI than were those who did not report having undergone a dental procedure. None of the HRs were statistically significantly different from 1.0. Adjustment for individual characteristics did not change the results appreciably (Table 4).

Case-control analyses. Only four case participants had undergone invasive dental procedures in the 90-day period preceding the PJI. In the same years in which they experienced their PJIs, all four of these participants received an antibiotic typically used for prophylaxis, although the date of their receipt of the antibiotic is unknown.

Of the 42 participants with a PJI, 20 had their PJI at least one year after total joint arthroplasty or entry into the survey; eight experienced their PJI at least two years after undergoing arthroplasty or entering the study. Of these 20 "late" infections (defined here as occurring two or more years after joint arthroplasty), five participants underwent a dental procedure and two underwent an invasive dental procedure in the 90 days before the PJI developed. Both participants who reported having undergone an invasive procedure had a prescription for an antibiotic appropriate for prophylaxis during the year of the invasive dental procedure (data not shown).

Four of 42 case participants (9.5 percent) and 20 of 126 control participants (15.9 percent) had undergone an invasive dental procedure in the 90 days preceding the PJI (for case participants) or study exit (for control participants) (Table 5, page 1350). For each of the comparisons shown in Table 5, the estimated odds ratio (OR) was less than 1.0, indicating that case participants were less likely than control participants to have undergone dental procedures, although not significantly so.

DISCUSSION

We hypothesized that dental procedures were not associated with risk for PJI. The results of the time-to-event analyses showed no significant associations between participants' dental visits and PJIs in the 90 and 180 days preceding a PJI. The comparisons of case and control participants according to dental visits or invasive procedures experienced 90 and 180 days before PJI or survey exit showed that participants in the control group were more likely to have had dental visits involving any procedure and involving more invasive procedures, although not significantly so. We used similar analyses (data not shown) to measure the association between case-control status and occurrence of dental visits at any time between entry into the study or joint replacement (whichever occurred later) and either the infection or exit from the study and to measure the association between case-

TABLE 3

Selected characteristics of prosthetic joint infection case participants and age–, sex– and medical comorbidity–matched control participants.

PARTICIPANT CHARACTERISTIC	NO. (PERCENTAGE) OF CASE PARTICIPANTS (n = 42)	NO. (PERCENTAGE) OF MATCHED CONTROL PARTICIPANTS (n = 126)*
Age (in Years)		
Younger than 65	5 (11.9)	15 (11.9)
65 to 74	13 (31.0)	39 (31.0)
75 to 84	18 (42.9)	54 (42.9)
85 and older	6 (14.3)	18 (14.3)
Sex		
Male	26 (61.9)	78 (61.9)
Female	16 (38.1)	48 (38.1)
Race		
White	36 (85.7)	115 (91.3)
Nonwhite	6 (14.3)	11 (8.7)
Annual Income		
0 to $25,000	30 (71.4)	83 (65.9)
$25,001 or higher	12 (28.6)	43 (34.1)
Education		
High school graduate or less	29 (69.0)	95 (75.4)
More than high school	13 (31.0)	31 (24.6)
Marital Status		
Not married	25 (59.5)	54 (42.9)
Married	17 (40.5)	72 (57.1)
Census Bureau Regions†		
Northeast	3 (7.1)	21 (16.7)
Midwest	10 (23.8)	28 (22.2)
South	20 (47.6)	57 (45.2)
West South Central	8 (19.0)	20 (15.9)
Puerto Rico	1 (2.4)	0 (0.0)
Self-Reported Health		
Excellent/Very good/Good	23 (54.8)	82 (65.1)
Fair/Poor	18 (42.9)	42 (33.3)
Data missing/Unknown	1 (2.4)	2 (1.6)
Number of Comorbid Conditions		
None to three	20 (47.6)	57 45.2)
Four or more	22 (52.4)	66 (52.4)
Data missing/Unknown	0 (0.0)	3 (2.4)
Charlson Comorbidity Index Score‡		
0	1 (2.4)	3 (2.4)
1 to 3	23 (54.8)	59 (46.8)
4 or higher	18 (42.9)	62 (49.2)
Data missing/Unknown	0 (0.0)	2 (1.6)

* Of these matched control participants in the Medicare Current Beneficiary Survey, 63 participants were followed for less than one year after undergoing total joint arthroplasty, 35 were followed for one to less than two years and 28 were followed for two to less than three years.
† Source: U.S. Census Bureau.[21]
‡ Source: Charlson and colleagues.[20]

control status and the rate of dental visits. All analyses yielded similar results: either no association at all or a nonsignificant trend for control participants to have had more dental visits. Although none of these findings individually rules out the possibility that dental procedures are risk factors for PJIs, the evidence was consistent and does not support the hypothesis that dental procedures are a common cause of or even associated with PJIs.

Given an aging U.S. population with increasing demand for prosthetic joint arthroplasties as well as the substantial morbidity and treatment costs associated with PJI, it is appropriate that the AAOS periodically review and update antibiotic prophylaxis guidelines.[8,9] Although the 2009 AAOS[1] Information Statement recommended only that health care

providers "consider" the new guidelines as a supplement to their clinical judgment rather than require that they follow the guidelines, the practical result likely is to be increased prescribing of antibiotics as clinicians seek to minimize medicolegal risks. Adding to the uncertainty is the new statement's failure to define what is meant by "invasive dental procedures." Major concerns raised in recent editorial responses to the new guidelines include the lack of collaboration with organized dentistry in producing them and an absence of evidence-based support for the changes made to the joint 2003 ADA/AAOS advisory statement.[4-6]

The importance of dental procedures as an ultimate cause of late PJIs remains unresolved. Researchers have shown transient bacteremias to be caused by several dental procedures (extractions, periodontal probing, ultrasonic scaling, brushing), but bacteremias also are caused by daily activities such as chewing.[22-24] Some investigators have proposed that poor oral health and routine daily activities may create a greater risk of experiencing bacteremias than may dental procedures.[25,26] Also, the majority of late PJIs are associated with staphylococci, including *Staphylococcus aureus* and *Staphylococcus epidermidis,* which make up a small percentage of the oral microbiota.[17,27]

TABLE 4

Hazard ratios for dental procedures and risk for prosthetic joint infection.

VARIABLE(S) IN THE ANALYSIS, ACCORDING TO TYPE OF DENTAL PROCEDURE	HAZARD RATIO (95% CONFIDENCE INTERVAL*)
All Dental Procedures	
Any in preceding 90 days	
Procedures only	0.50 (0.12-2.18)
Procedures and education†	0.57 (0.13-2.51)
Procedures and age‡	0.49 (0.11-2.14)
Procedures and comorbidities§	0.49 (0.11-2.12)
Any in preceding 180 days	
Procedures only	0.56 (0.18-1.71)
Procedures and education	0.66 (0.21-2.05)
Procedures and age	0.55 (0.18-1.69)
Procedures and comorbidities	0.54 (0.18-1.66)
Invasive Dental Procedures¶	
Any in preceding 90 days	
Procedures only	0.78 (0.18-3.39)
Procedures and education	0.90 (0.20-4.01)
Procedures and age	0.77 (0.18-3.35)
Procedures and comorbidities	0.76 (0.18-3.32)
Any in preceding 180 days	
Procedures only	0.59 (0.17-2.04)
Procedures and education	0.70 (0.20-2.47)
Procedures and age	0.59 (0.17-2.02)
Procedures and comorbidities	0.58 (0.17-2.04)

* Wald interval on the log-hazard ratio scale back-transformed to the hazard ratio scale.
† Twelve years or less or more than 12 years.
‡ Years, entered as a continuous measure.
§ According to score on the Charlson comorbidity index (Charlson and colleagues[20]) and entered as a continuous measure.
¶ Teeth cleanings, extractions and endodontic procedures only.

Prosthetic joint infections have been variously classified as early, delayed and late according to time of onset after surgery.[6,28,29] Early infections generally are defined as occurring within three months of surgery and are thought to be related to the implantation procedure. Late PJIs purportedly result from hematogenous seeding from bacterial sources that include the skin, the respiratory and urinary tracts, and the mouth.[22] Late infections have been defined variably as occurring after six to 24 months after surgery.[15,28-30] Defining late infections as occurring more than one year after surgery in our study, we found only two of 20 participants with a late infection underwent an invasive dental procedure in the 90-day period before the PJI occurred, suggesting that late PJIs are preceded infrequently by invasive dental procedures.

Limitations. This study has several limitations. The MCBS data set includes records of dental visits and antibiotic use derived from self-reports or proxy reports, which are subject to recall error. Recall bias likely is minimized because the survey conducts periodic participant interviews and collects receipts and claim forms; nonetheless, dental care use and antibiotic use may be underestimated. Also, the MCBS records antibiotic prescriptions only according to calendar year, and we could not determine the dates when prescriptions were written or filled, or whether the participant used the antibiotic. Therefore, we could not ascertain directly from the MCBS data participants' antibiotic use for prosthetic joint prophylaxis. Overall, 234 of 512 participants (45.7 percent) who had undergone an invasive dental procedure received an antibiotic appropriate for prophylaxis in the same year. Eleven of the 42 case participants who had PJI received a prescription for an antibiotic appropriate for prophylaxis in the year in which they experienced their PJI, including the four participants who underwent invasive dental procedures within 90

TABLE 5

Association between preceding dental visit procedures and prosthetic joint infection (PJI).

DENTAL PROCEDURE	PARTICIPANTS, NO. (PERCENTAGE)		ODDS RATIO (95% CI)*	*P* VALUE†
	Case Participants (n = 42)	Control Participants (n = 126)		
Any Dental Procedure				
90 days before LRD‡	5 (11.9)	26 (20.6)	0.52 (0.19-1.45)	.26
180 days before LRD	8 (19.0)	41 (32.5)	0.49 (0.21-1.15)	.12
Invasive Dental Procedure§				
90 days before LRD	4 (9.5)	20 (15.9)	0.56 (0.18-1.74)	.45
180 days before LRD	6 (14.3)	30 (23.8)	0.53 (0.20-1.39)	.28

* This confidence interval (CI) does not account for the clustering of a case participant with his or her three matched control participants.
† From Mantel-Haenszel test.
‡ LRD: Last relevant date. For participants with PJI, the LRD is the date of infection; for control participants, the LRD is the date of death or Dec. 31 of the last year in which they took part in the survey.
§ Teeth cleanings, extractions and endodontic procedures only.

days of their PJI.

The MCBS does not record dentulous status, and some participants reporting a dental visit may have been edentulous. Invasive procedures as we defined them, however, would not have been reported for edentulous participants. As an administrative claims data set, the MCBS also does not provide information regarding specific bacteria isolated from infected prostheses. We do not know which, if any, of the 42 PJIs were associated with oral bacteria.

We could not reliably estimate prevalence and incidence rates for PJIs because more than one-half of the PJI case participants underwent arthroplasty before entering the survey. Moreover, those who underwent arthroplasty while in the survey were followed for variable amounts of time, depending on the timing of their joint replacement surgery. Nevertheless, the nationally representative MCBS provides a unique opportunity to analyze longitudinal associations between total joint arthroplasties, dental procedures and the occurrence of PJIs.

For infrequent events (such as invasive dental procedures performed in the 90 days before a PJI), confidence intervals for the HRs and ORs (Tables 4 and 5) are broad and include clinically relevant values. Thus, we cannot exclude the possibility that dental visits were associated with a slight increase in the risk of developing PJI. Nonetheless, the estimated HRs and ORs were less than one, suggesting that this study's null findings did not arise from a lack of statistical power. (Note, too, that the prospective and case-control analyses were not independent; some of the same participants appeared in both analyses.)

A further limitation of the case-control study is that the exposure of particular interest—dental procedures' occurring within an interval preceding the joint infection—is defined by means of the bad outcome that case participants necessarily experienced and control participants did not. To address this difference between case and control participants, we considered a variety of definitions of exposure, all of which gave qualitatively the same result.

Finally, the MCBS includes Medicare beneficiaries who are aged or institutionalized or have disabilities. Although medical comorbidities were fairly frequent in this group, our results may have differed had we studied only people who were more medically compromised or were living in institutional settings.

A critical need in assessing the clinical value of antibiotic prophylaxis to prevent PJIs is the development of more evidence-based study protocols. The results of placebo-controlled, randomized clinical trials would provide more definitive guidance regarding which patients need prophylaxis. However, investigators conducting such studies would face ethical concerns related to withholding antibiotic prophylaxis from people, an action that may increase the patient's risk of experiencing a serious infection and the logistical challenges of recruiting a large study population, given the low frequency of PJIs. Practically, more helpful information for future practice guidelines may need to come from additional prospective case-control or cohort studies.

CONCLUSIONS

In this retrospective MCBS database analysis, which we conducted across a 10-year period, we found 42 participants who had PJIs and a low overall rate of subsequent PJIs (1.8 percent) among those who had undergone total joint arthroplasty while participating in the survey. We found no significant increase in risk of developing PJI after dental visits, including

those involving more invasive procedures. The study results support the contention that the 2009 AAOS Information Statement on antibiotic prophylaxis for patients with prosthetic joints should be reconsidered for patients in that population who are receiving oral health care.[4-6] ■

Disclosure. None of the authors reported any disclosures.

The research described in this article was supported in part by the Erwin Schaffer Chair in Periodontal Research (held by Dr. Bryan S. Michalowicz).

The authors thank Marc F. Swiontkowski, MD, professor, Orthopaedic Surgery, University of Minnesota, Minneapolis, for his contributions.

1. American Academy of Orthopaedic Surgeons. Information statement: antibiotic prophylaxis for bacteremia in patients with joint replacements. "www.aaos.org/about/papers/advistmt/1033.asp". Accessed Sept. 27, 2011.
2. American Dental Association, American Academy of Orthopaedic Surgeons. Antibiotic prophylaxis for dental patients with total joint replacements. JADA 1997;128(7):1004-1008.
3. American Dental Association, American Academy of Orthopaedic Surgeons. Antibiotic prophylaxis for dental patients with total joint replacements. JADA 2003;134(7):895-899.
4. Marek CL, Ernst EJ. The new American Academy of Orthopaedic Surgeons' recommendations regarding antibiotic prophylaxis: where's the evidence? Spec Care Dentist 2009;29(6):229-231.
5. Napenas JJ, Lockhart PB, Epstein JB. Comment on the 2009 American Academy of Orthopaedic Surgeons' information statement on antibiotic prophylaxis for bacteremia in patients with joint replacements. J Can Dent Assoc 2009;75(6):447-449.
6. Little JW, Jacobson JJ, Lockhart PB; American Academy of Oral Medicine. The dental treatment of patients with joint replacements: a position paper from the American Academy of Oral Medicine. JADA 2010;141(6):667-671.
7. Buie VC, Owings MF, DeFrances CJ, Golosinskiy A. National Hospital Discharge Survey: 2006 summary. National Center for Health Statistics. Vital Health Stat 2010;13(168).
8. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am 2007;89(5):780-785.
9. Bozic KJ, Katz P, Cisternas M, Ono L, Ries MD, Showstack J. Hospital resource utilization for primary and revision total hip arthroplasty. J Bone Joint Surg Am 2005;87(3):570-576.
10. Curry S, Phillips H. Joint arthroplasty, dental treatment, and antibiotics: a review. J Arthroplasty 2002;17(1):111-113.
11. Segreti J. Is antibiotic prophylaxis necessary for preventing prosthetic device infection? Infect Dis Clin North Am 1999;13(4):871-817, vii.
12. Rubin R, Salvati EA, Lewis R. Infected total hip replacement after dental procedures. Oral Surg Oral Med Oral Pathol 1976;41(1):18-23.
13. Sullivan PM, Johnston RC, Kelley SS. Late infection after total hip replacement, caused by an oral organism after dental manipulation: a case report. J Bone Joint Surg Am 1990;72(1):121-123.
14. Lockhart PB, Loven B, Brennan MT, Fox PC. The evidence base for the efficacy of antibiotic prophylaxis in dental practice. JADA 2007;138(4):458-474.
15. Uckay I, Pittet D, Bernard L, Lew D, Perrier A, Peter R. Antibiotic prophylaxis before invasive dental procedures in patients with arthroplasties of the hip and knee. J Bone Joint Surg Br 2008;90(7):833-838.
16. Centers for Medicaid and Medicare Services. Medicare Current Beneficiary Survey (MCBS): overview. "www.cms.gov/mcbs/". Accessed Sept. 27, 2011.
17. Berbari EF, Osmon DR, Carr A, et al. Dental procedures as risk factors for prosthetic hip or knee infection: a hospital-based prospective case-control study. Clin Infect Dis 2010;50(1):8-16.
18. National Center for Health Statistics, Centers for Medicare and Medicaid Services. International Classification of Diseases, 9th Revision, Clinical Modification. Baltimore: Centers for Medicare and Medicaid Services; 2010.
19. Wilson W, Taubert KA, Gewitz M, et al. Prevention of infective endocarditis: guidelines from the American Heart Association—a guideline from the American Heart Association Rheumatic Fever, Endocarditis and Kawasaki Disease Committee, Council on Cardiovascular Disease in the Young, and the Council on Clinical Cardiology, Council on Cardiovascular Surgery and Anesthesia, and the Quality of Care and Outcomes Research Interdisciplinary Working Group. JADA 2007;138(6):739-745, 747-760.
20. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 1987;40(5):373-383.
21. U.S. Census Bureau. Census regions and divisions of the United States. "www.census.gov/geo/www/us_regdiv.pdf". Accessed Oct. 30, 2011.
22. Jacobson JJ, Millard HD, Plezia R, Blankenship JR. Dental treatment and late prosthetic joint infections. Oral Surg Oral Med Oral Pathol 1986;61(4):413-417.
23. Kinane DF, Riggio MP, Walker KF, MacKenzie D, Shearer B. Bacteraemia following periodontal procedures. J Clin Periodontol 2005;32(7):708-713.
24. Lockhart PB, Brennan MT, Sasser HC, Fox PC, Paster BJ, Bahrani-Mougeot FK. Bacteremia associated with toothbrushing and dental extraction (published online ahead of print June 9, 2008). Circulation 2008;117(24):3118-3125. doi:10.1161/CIRCULATIONAHA.107.758524.
25. Oswald TF, Gould FK. Dental treatment and prosthetic joints: antibiotics are not the answer! J Bone Joint Surg Br 2008;90(7):825-826.
26. Lockhart PB, Brennan MT, Thornhill M, et al. Poor oral hygiene as a risk factor for infective endocarditis-related bacteremia. JADA 2009;140(10):1238-1244.
27. Forner L, Larsen T, Kilian M, Holmstrup P. Incidence of bacteremia after chewing, tooth brushing and scaling in individuals with periodontal inflammation. J Clin Periodontol 2006;33(6):401-407.
28. LaPorte DM, Waldman BJ, Mont MA, Hungerford DS. Infections associated with dental procedures in total hip arthroplasty. J Bone Joint Surg Br 1999;81(1):56-59.
29. Zimmerli W, Trampuz A, Ochsner PE. Prosthetic-joint infections. N Engl J Med 2004;351(16):1645-1654.
30. Waldman BJ, Mont MA, Hungerford DS. Total knee arthroplasty infections associated with dental procedures. Clin Orthop Relat Res 1997;(343):164-172.