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The Application of Medicare Data for Musculoskeletal Research in the United States: A Systematic Review

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Abstract

Introduction: Musculoskeletal conditions disproportionately affect the lives of aging adults. We aimed to examine the literature utilizing Medicare claims data in the U.S. for musculoskeletal surgical procedures.

Methods: Following the Preferred Reporting Items for Systematic Review and Meta-Analysis guidelines, we searched the PubMed and Medline databases for peer-reviewed manuscripts published between 1990 and 2015. We included the studies that 1) reported primary Medicare claims data use, 2) involved musculoskeletal surgery, and were 3) original peer-reviewed studies. We abstracted types of surgical procedure, aims, evaluated outcomes, and strengths and weaknesses of each included paper. We assessed quality of included articles with Newcastle Ottawa Assessment Scale.

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Results: The literature search returned 3,233 articles, of which 119 met our inclusion criteria. These studies focused on different outcomes: epidemiology and treatment variation (26), cost of care (15), hospital-level analyses (30), health outcomes (31), the validity and accuracy of Medicare claims data (4), disparities in healthcare (10), and policy evaluation (3).

Conclusion: Medicare claims data provide a unique way for researchers to study a nationally representative patient population longitudinally. A significant limitation of using claims data has been a lack of granularity on defining severity of a condition.

Level of Evidence: Therapeutic Level III

Keywords

Musculoskeletal Research; Medicare; Surgery; Systematic review; Quality of Care; Health Outcome; Disparities

INTRODUCTION

Owing to a declining mortality rate and aging of the population, musculoskeletal conditions are on the rise. The World Health Organization called “2000-2010” the Bone and Joint Decade to raise awareness about musculoskeletal conditions. Osteoarthritis, rheumatoid arthritis, osteoporosis, and low back pain are a few common examples of these common conditions, leading to persistent pain and loss of functioning. Musculoskeletal conditions affect individual’s activities of daily living, use of health systems, and direct and indirect cost of care. Direct cost of surgical treatment for these conditions varies. For example, the average incremental healthcare expenditures associated with distal forearm and hip fractures among Medicare beneficiaries were estimated to be \$7,788 and \$31,310, respectively.¹ Orthopedic-related conditions disproportionately affect older adults. Owing to confounding factors and inadequacy of medical coding system in the U.S., measuring health outcomes and complications for surgical treatment is a challenging task. For example, Manley et al. examined the association between hospital volume and revision for total hip replacement, but their study had a limitation of lack of information on pain and physical functioning.² A study by Ong et al. on the relationship between procedure duration and revision of total hip or knee replacement also had a limitation of lack of clinical information. The authors did not have information on surgical approach or the type of repair, which could affect duration, complications, and cost of treatment.³

Although originally created for payment and administrative purposes, Medicare claims data possess longitudinal records of utilization and costs of healthcare services from office visits to hospitalization that make this dataset useful for health services research among individuals aged 65 years or older. Since 2010, under the Affordable Care Act, the Centers for Medicare and Medicaid Services (CMS) have made efforts to not only be more transparent to the public but also to facilitate and encourage more investigators to use claims data for research.⁴⁻⁶ Musculoskeletal surgeries are prevalent and costly procedures. In addition, providing a coordinated post-acute care after these surgeries has been problematic and needs further investigation. Despite its importance, little is known about the range of

research on surgical outcomes of musculoskeletal conditions or strengths and weaknesses of these studies.

The purpose of this systematic review was to evaluate the literature on musculoskeletal surgical outcomes and their limitations, including studies on adverse health events after surgery and cost of care, using Medicare claims data. Medicare claims data were originally developed for billing purposes and researchers should be aware of the inherent limitations of the data for research. For example, a lack of detailed information regarding patients' clinical, functional, and socioeconomic status has been frequently cited for missing confounders. Some of these limitations can be overcome by merging claims data with other available datasets, such as census data, state inpatient data, the Area Resource File, or data from the American Hospital Association. In this study we aimed to determine types of research conducted in musculoskeletal surgery and to define the main advantages and limitations for each type of research conducted. Medicare claims data uniquely capture longitudinal records of diagnosis, surgical procedures, healthcare utilization and spending for millions of adults ages 65 and older throughout the United States. Our analytical evaluation of published musculoskeletal research based on Medicare claims data will equip administrators and investigators to expand their understanding and potential use of the data in future.

METHODS

Literature Search

We performed a systematic review of the literature in PubMed and Medline to identify all studies that used the Medicare database for research related to musculoskeletal surgeries (Figure 1). We followed the Preferred Reporting Items for Systematic reviews and Meta-analyses guidelines.⁷ The initial search used the key words "Medicare database" and "surgery," and related terms for each. We expanded these terms to include corresponding Medical Subject Headings. The search was limited to peer-reviewed manuscripts published in English after 1990. (Table 1). After eliminating duplicates, two reviewers separately screened the title and abstracts of publications followed by full text review to arrive at final inclusive articles. We manually checked citations of articles that met our study criteria to identify relevant articles not found through the initial search.

Study Criteria

Publications were included if they met all the following criteria: 1) studies reporting primary Medicare claims data use, 2) studies involving musculoskeletal surgery, 3) original peer-reviewed studies. We excluded all commentaries, abstracts, discussions, letters, reviews, editorials, and expert opinions, as well as studies that did not use Medicare data. Discrepancies regarding article inclusion/exclusion were resolved by consensus among authors who met at regular intervals.

Data Extraction and Quality Assessment

The full texts of all final manuscripts included in the study were reviewed between August 1st and December 15th of 2016. For each included article, we collected data regarding the author(s), journal, year of publication, type of Medicare data file used, type of

musculoskeletal condition evaluated, analyses performed, study sample characteristics, inclusion of control groups, types of outcomes evaluated, advantages and limitations of Medicare claims data, and specific measures undertaken to overcome those limitations, if any. We also performed a quality assessment of the included articles using the Newcastle Ottawa Assessment Scale. This tool assesses the quality of non-randomized case control and cohort studies and has a maximum score of nine, which represents highest quality.⁸ The minimum score for studies included in this systematic review was 5 (range between 5 and 8). Detailed information regarding each study included in this systematic review is available upon request.

RESULTS

After screening for eligibility criteria, 119 articles were included in the qualitative analysis. Between 1990 and 2015, the number of peer-reviewed publications reporting on Medicare claims data increased by 642% (Figure 2). Because of the heterogeneity of topics found, we categorized the articles into seven groups: (1) epidemiological trends and treatment variations, (2) cost, (3) hospital evaluation, (4) health outcomes, (5) evaluation of Medicare claims data, (6) disparity, and (7) policy evaluation (Figure 3). Quality assessment results are available in Figure 4.

Epidemiologic Trends and Treatment Variation Studies

Twenty-six studies focused on epidemiologic trends and variations in surgical treatment patterns evaluated conditions such as fractures, shoulder conditions, ankle, hip, and knee arthritis (Supplemental Table 1). The main outcomes of interest included frequency of certain musculoskeletal diagnoses and surgical procedures, providers' specialty and variation in outcomes, and frequency of complications, including mortality, rehospitalization, and repeated surgery. The main limitations included an inability to define preexisting conditions, the imprecision of the ICD-9 coding system, and unknown health conditions and health outcomes (Figure 5).

Five studies examined trends at the patient level by examining the utilization of different surgical techniques, such as arthrodesis compared to replacement for ankle arthritis, rates and outcomes of specific surgeries, and operative versus non-operative treatments. Specific outcomes examined included length of stay and complication rates. For example, Bozic et al. found no difference in revision rates in total hip arthroplasty patients across different bearing types; however, they found that metal-on-metal bearings were associated with a higher risk of joint infection, mechanical loosening, and deep vein thrombosis than other bearing types.⁹ Mahomed et al. concluded that the rates of primary total hip replacement were three to six times higher than revision total hip replacement. However, the 90-day post-operative adverse outcomes were higher after revision than after primary total hip replacement.¹⁰ They found that being an older African-American male and having low income were associated with adverse outcomes. Some of these studies linked Medicare claims with other data, such as American Hospital Association survey, Rural-Urban Commuting area, National Hospital Discharge Survey, or the Dartmouth Atlas of Musculoskeletal Care¹¹ to obtain more details on patients' socioeconomic status or providers' density information. Finally, some studies

focused on patient and provider factors that influenced surgical treatment,^{12,13} with some specifically focusing on physician specialty. Long et al. noted that despite lack of level-1 evidence for long-term effectiveness of vertebral augmentation procedures, use of vertebroplasty and kyphoplasty had increased between 2000 and 2010.¹⁴ Approximately 500,000 osteoporotic compression fractures occur annually among the elderly in the US, costing up to \$600 million/year. Zhong et al. found that among Medicare beneficiaries with rheumatoid arthritis, being white and having higher socioeconomic status increased the likelihood to receive surgical treatment.¹²

Cost Analysis Studies

Fifteen studies examined the cost of musculoskeletal surgeries from the beneficiary or payer perspective (Supplemental Table 2). These studies examined the mean health plan payment per hospital admission or the amount paid by Medicare, with further subdivision into professional services payments. Payment per beneficiary and hospital reimbursement and treatment charges, Medicare payments for the initial surgery, and any morbidities up to one year post surgery were also examined. The main limitations included imprecision in cost measurement, a lack of information on patient characteristics and capital loss as a result of a condition or procedure, and inability to measure any type of cost effectiveness and efficiency analysis (Figure 6).

Belatti et al. found that between 2000 and 2011, utilization of total joint arthroplasty grew substantially (27%) until 2005, after which the growth became stagnant.¹⁵ Owing to the new coding scheme, despite a decrease in physician reimbursement (−2.3% per year), increase in hospital reimbursement was associated with complicated cases (+4.5% per year) vs uncomplicated cases (−0.65%).¹⁵ Another study reported significant geographic variation in costs, particularly for costs of specific episodes of care and total annual cost of care among the ten costly and common conditions examined (i.e. knee joint or lower leg degeneration, joint degeneration of back or neck, etc).¹⁶ Cost-effectiveness analyses for treatment of knee osteoarthritis^{17,18} and vertebral compression fractures were investigated. For example, Gu et al. found that the societal benefits of hip fracture surgery outweigh its direct costs, with an average savings of around \$66,000 per patient.¹⁹ Cost comparisons, for example, between previously insured and uninsured Medicare beneficiaries revealed that previously uninsured adults had higher hospitalization rates, and therefore spent more when they were eligible for Medicare.²⁰ Annual per person Medicare spending for previously insured vs. uninsured was \$ 4773 vs. \$ 5796.²⁰ Also, cost comparisons between two-year post-surgical expenditures for vertebroplasty and kyphoplasty showed lower adjusted cumulative treatment costs for kyphoplasty reflecting lower utilization of medical resources.²¹ Finally, Ong et al. concluded that the economic burden of revision surgery for total hip and knee arthroplasty was more than the initial surgery.²² Belatti and Phisitkul estimated that between 2000 and 2011, economic burden of revision of foot and ankle surgery increased by 38%.²³ Owing to their main use as reimbursement mechanism, Medicare claims data provide an excellent source for cost and utilization analysis.

Hospital-Level Studies

Thirty studies investigated Medicare claims data at the hospital level (Supplemental Table 3). They compared hospitals based on their surgical complication rates, and by assessing the impact of the creation of new hospital arthroplasty programs on arthroplasty utilization. The main limitations included difficulty in measuring the patient case mix in each hospital, a lack of data on important clinical outcomes, difficulty assessing provider's volume, a lack of data on Medicare Managed Care beneficiaries, and potential miscoding errors (Figure 7).

Two studies explored factors influencing hospital choice among patients. For example, 74% of patients who had revision surgery for total hip arthroplasty had the surgery in a hospital with the same volume category as they had for their primary surgery (64% of this group chose the same hospital for both surgeries).²⁴ Hospital ownership, ranking, volume, specialization, location, and teaching status were also examined in relationship to utilization, cost of procedures performed, and outcomes (e.g. mortality, readmission rates, length of stay, etc.). For example, Cram et al. found no significant differences in postoperative complications and hospital length of stay after total knee arthroplasty between top-ranked hospitals, non-top-ranked hospitals, and hospitals ineligible for ranking.²⁵ Finally, five studies examined the association between hospital and surgeon procedure volume and outcomes. Katz et al. found that for total hip and knee replacements, high-volume surgeons and hospitals were associated with low rates of mortality and complications, and high rate of patient satisfaction.^{26,27} Manley et al. found that patients who had hip replacements performed by low-volume surgeons (fewer than 25 procedures/ year) were at a greater risk of having a revision surgery six months later.² Medicare claims data show better outcomes and fewer complications for complex surgical procedures.

Health Outcome Studies

Thirty-one studies primarily examined health outcomes that include major complications at 30 days and one year post surgery, reoperation and readmission for surgery-related complications, mortality, and readmission (Supplemental Table 4). The main complications included a lack of detailed outcome information, ambiguity and limitations of the ICD-9 coding system, potential coding errors, and exclusion of the Medicare Managed Care population from the data (Figure 8).

For example, Modhia et al. found that patients had lower readmission rates after decompression alone compared with fusion along with decompression procedure for lumbar spinal stenosis (7.2% vs. 9.7%).²⁸ Reduced readmissions are important and can improve the cost-effectiveness of this surgical treatment. Eight studies analyzed complications. Day et al. found that the incidence of venous thromboembolism after surgery was lower for shoulder arthroplasty compared with lower extremity arthroplasty (0.53% vs. 1.2%; $p < .001$).²⁹ Therefore, the current standard of care of no chemoprophylaxis after upper extremity arthroplasty is appropriate. Katz et al. found that total hip replacement revisions were most likely to happen within 18 months after the primary surgery.³⁰ Thus, more efforts targeted to monitor patients within the 18 months of postoperative period can minimize subsequent revisions. Effect of procedure length on outcomes was assessed in two studies as total knee arthroplasty procedures lasting 120 to 150 minutes had significantly lower revision rates

than those lasting less than 90 minutes ($p=.008$) or more than 150 to 180 minutes ($p=.004$).³ This indicates that longer procedure duration results in increased complications, impacts resource use, and insurance reimbursement. George et al. found that patients who underwent total knee arthroplasty experienced significant improvements in activities of daily living compared with patients who opted for non-operative treatment ($p<.010$).³¹ This will serve as an indicator to declining rates of disability in elderly along with effects of other public health measures, such as better health habits.

Validity of Medicare Claims Data

Four studies evaluated the validity and accuracy of Medicare claims data (Supplemental Table 5). They examined how well Medicare data identified revision of total hip replacements and detected surgical site infection, as well as the use of present-on-admission (POA) codes for common complications after total knee arthroplasty. The main limitations included potential coding errors, a lack of detailed medical information, and a lack of data on Medicare Managed Care beneficiaries (Figure 9).

Calderwood et al. found that claims-based surveillance was more accurate than traditional infection control surveillance (specific to each hospital) at detecting surgical site infections after total knee arthroplasty or total hip arthroplasty (1.8 to 4.7 fold increase).³² However, Katz et al. used Medicare claims data to identify revision hip replacement, as opposed to primary hip replacement on the contralateral hip, and found that Medicare data correctly identified revision of the primary operation only 71% of the time.³³ ICD-9 coding system does not specify the side of the operation and thus is not a reliable source for studying the risk of revision after hip replacement. Starting from October 1st, 2015, CMS adopted ICD-10 codes, which provide bilateral information on procedures performed. Cram et al. determined that POA information was completed by hospitals for only 60% to 75% of complications. POA codes – introduced by the CMS in October 2007 - are important because they add significant information for determining complications after total knee arthroplasty.³⁴ Finally, research shows that claims data lack adequate sensitivity to be used for selection of patients based on certain diagnoses, such as rheumatoid arthritis or avascular necrosis. A more conservative approach is warranted when defining patients' cohorts.

Disparity Analysis

Ten articles conducted disparity analyses to examine racial/ethnic disparities in utilization of knee and hip replacements (Supplemental Table 5). The main limitations included difficulty identifying Hispanic populations, a lack of data on patient characteristics such as smoking or body mass index, potential misidentification of race/ethnicity, and a lack of data on socioeconomic and functional status of patients (Figure 9).

Singh et al. found that compared with Caucasians, African-Americans had 40% lower probability of undergoing knee and hip replacement and 24% higher probability of readmission post-surgery. These disparities have remained consistent from 1991 to 2008.³⁵ Nguyen-Oghalai et al. observed that African-Americans and Hispanics waited longer (average 1.6 days and 1.7 days, respectively) to have surgery after hip fracture than Whites, (average 1.2 days) suggesting the need to monitor care among minorities with hip fracture.³⁶

Ecsarce et al. observed that racial differences existed in the usage of specific medical procedures and tests with African-Americans having lower usage rates than Whites.³⁷ Skinner et al. found that large variation in knee arthroplasty existed based on sex, race, and region.³⁸ Finally, Tsai et al. also noted that African-Americans compared with Whites had higher odds of 30-day readmission after surgery, which has implications for quality and cost of care.³⁹ Although Medicare is a publicly available insurance program, our results indicate wide racial/ethnic disparities in use of musculoskeletal surgeries.

Policy Evaluation

Three studies evaluated various policy changes (Supplemental Table 5). The main limitations included a lack of data on patient characteristics, health and socioeconomic status (Figure 9).

Johanson et al. observed a progressive increase in utilization of arthroscopy after Centers for Medicare and Medicaid changed their coverage policy of arthroscopic procedures.⁴¹ Less invasive and low cost arthroscopy had a 10.2 % failure rate after one year indicating its effectiveness in delaying arthroplasty and minimizing costs associated with revision arthroplasty.⁴¹ Miller et al. evaluated that the efficiency of integrated delivery systems for quality and cost was beneficial for ambulatory care and preventive services but not for inpatient surgery when compared with similar Accountable Care Organizations.⁴² Quality of care measured by operative mortality, postoperative complications, and readmissions and total episode cost for patients treated in Integrated Delivery System (IDS) and non-IDS hospitals were similar. FitzGerald et al. studied the effect of the Short Stay Transfer Policy (SSTP) that discourages early discharge to post-acute care (PAC) on joint replacement and hip fracture surgery.⁴⁰ The study found an immediate increase followed by stabilization in hospital length of stay for joint replacement and hip fracture surgeries (0.20 and 0.17 days, respectively), and a decrease in early discharge to PAC (4.3 and 3.0 percentage points, respectively).⁴⁰ SSTP implementation reduced the financial incentive for hospitals to discharge patients early to PAC.

Noted Limitations

Most common limitations across all seven categories were the potential inaccuracy in medical coding and the lack of detailed clinical data such as pain or functioning, fracture pathology, disease and complication severity, reason for revision surgery or readmission, patient satisfaction, surgical technique, and type of bearing surface. There was also a lack of laterality in ICD-9 codes, which is particularly important for hip and knee replacements, and an inability to capture issues related to patient and provider decision-making. Specific limitations of cost analysis studies were the discrepancy between charge and reimbursement data and significant geographic variations in cost of a procedure. Articles examining racial/ethnic disparity mentioned that the low number of Hispanics and African Americans as compared to Whites, especially in rural areas, might have underpowered some analyses.³⁶

Researchers overcame some limitations by linking Medicare data to other datasets such as American Hospital Association data, or U.S. News & World Report, Dartmouth Atlas of Health Care, Rural Urban Area Commuting data, and Census data. Some clinical data, such

as physical functioning, could be determined by supplementing Medicare claims data with surveys.^{29,31} One study validated laterality through medical records using a subset sample.²⁴ Another study collected data for three years prior to the index operation to determine whether prior surgery was performed, rather than relying on medical codes. Authors also suggested using POA codes (required on Medicare inpatient admissions since October 1, 2007) to distinguish between chronic and acute conditions.²⁹ Cost-analysis studies used MarketScan data, survey data,²⁰ or industry surveys of implant prices to indirectly determine the profitability of the procedure.¹⁵

DISCUSSION

Our systematic review examined all published literature between January 1990 and December 2015 on surgical treatment of musculoskeletal conditions utilizing Medicare claims data. This study is the first to systematically review the use of Medicare claims data for different musculoskeletal conditions in the U.S. Other systematic reviews on musculoskeletal conditions have focused on clinical conditions rather than on the use of secondary data such as Medicare claims data for different types of studies related to musculoskeletal conditions. We identified the aims achieved by these studies and grouped them into seven categories and detailed the challenges that these studies faced and whether they overcame the limitations of the data.

The main limitation or challenge in our systematic review was the heterogeneity of studies using Medicare claims data. We dealt with this challenge by stratifying final included studies into seven groups based on their defined objectives. Although the groups sometimes overlapped, for each group we explained how the data were used, what measures were defined as outcomes, and how complication rates have been defined. This heterogeneity in use of Medicare claims shows the growing popularity of this database in health services research.

Over the last two decades, use of claims data in health services research has evolved, with more researchers appreciating the unique opportunity provided by the data. Earlier work during the 1980s focused more on the hospital reimbursement system. By constructing episodes of care, researchers have been able to use the data for outcome analyses. Although there is no universal way of defining the sample cohort, researchers have used a combination of ICD-9 and CPT codes to define specific patient cohort and health outcomes.

Administrative claims data are not as granular as clinical data. Thus, researchers have had to use a variety of measures to define health outcomes. Mortality rate at certain time intervals after undergoing a certain procedure, recurrence of the same procedure, infection, or 30-day rehospitalization were used in different studies to measure health outcomes. With the implementation of the ICD-10 coding system, there will be more opportunities to develop new outcome and complication measures. The past few years have seen a surge in using Medicare claims data to evaluate policies such as the value-based system, hospital quality system, and preventative services. Use of Medicare claims data in research is expected to grow. Compared with clinical trials, the data are less expensive, population-based, allow patients and hospitals to be examined longitudinally, and are relatively reliable. Our review

findings will serve as a source of reference for researchers seeking to examine Medicare claims data on topics related to musculoskeletal conditions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
Schematic Flow of the Literature Search

Figure 2.
Number of Peer-Reviewed Publications on Musculoskeletal Surgical Procedures Using Medicare Claims Data

Figure 3.
Categories of Peer-Reviewed Publications on Musculoskeletal Surgical Procedures Using Medicare Claims Data

Figure 4.
Quality Assessment of Included Articles

Figure 5.
Limitations of Studies Using Medicare Claims to Evaluate Epidemiologic Trends and Treatment

Figure 6.
Limitations of Studies Using Medicare Claims to Evaluate Costs

Figure 7.
Limitations Studies Using Medicare Claims to Evaluate Hospitals

Figure 8.
Limitations Studies Using Medicare Claims to Evaluate Health Outcomes

Figure 9.
Limitations of Studies Using Medicare Claims to Evaluate Validity of Coding, Disparities, and Health Policy

Table 1:**Search Algorithm**

<p>PubMed Search:</p> <p>(medicare data[tiab] or "medicare dataset"[tiab] or "medicare database"[tiab] or "medicare claim"[tiab] or "medicare claims"[tiab] or "MBSF"[tiab] or "MedPar"[tiab] or "Medicare Inpatient Prospective Payment System"[tiab] or "outpatient file"[tiab] or "carrier file"[tiab] or "inpatient file"[tiab] or "outpatient files"[tiab] or "carrier files"[tiab] or "inpatient files"[tiab] or "Medicare HOS"[tiab] or "Medicare Current Beneficiary Survey"[tiab] or "Medicare Current Beneficiary Surveys"[tiab] or "Medicare Beneficiary Survey"[tiab] or "Medicare Current Beneficiaries Survey"[tiab] or ("medicare"[tiab] and "MCBS"[tiab]) or ("medicare"[tiab] and "administrative data"[tiab]) or "public use file"[tiab] or "public use files"[tiab] or "medicare enrollment database"[tiab] or ("medicare"[tiab] and "linked"[tiab])) AND ("surgery"[tiab] or "surgeries"[tiab] or "surgical"[tiab] or "operation"[tiab] or "operations"[tiab] or "procedure"[tiab] or "procedures"[tiab] or "operative"[tiab] or "surgery department, hospital"[mh] or "surgical procedures, operative"[mh]) AND "english"[la] AND "1990/01/01"[dp] : "3000"[dp]</p> <p>MEDLINE Search:</p> <p>((("medicare adj1 (data* or claim*)") or MBSF or MedPar or (Medicare Inpatient Prospective Payment System) or (outpatient file*) or (carrier file*) or (inpatient file*) or (Medicare HOS) or (Medicare Current Beneficiar* Survey*) or (medicare AND MCBS) or (medicare enrollment data*) or (medicare administrative data*) or (medicare AND linked)).mp. AND ((surg* or operat* or procedure*).mp. OR 'exp surgery department, hospital/ or exp surgical procedures, operative/) AND english.la AND limits: publication years 1990-current.</p>