# 3 The Prevalence of Disabling Musculoskeletal Conditions and the Demand for Orthopedic Surgery in the Twenty-First Century

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**Objectives**

- To document the prevalence of musculoskeletal diseases which require hospitalization and often surgical treatment
- To present the typical outcomes of surgical treatment of musculoskeletal conditions
- To present the risk and incidence of complications associated with surgical care of musculoskeletal conditions

**Key Points**

- The majority of hospitalizations and indications for surgery for musculoskeletal conditions result from degenerative diseases of the spine and major lower extremity joints.
- Spinal surgery, which follows careful selection criteria, typically results in pain relief, improved function, and improved quality of life which is maintained over long-term periods of observation.
- Complications following spinal surgery are affected by the age of the patient, anatomic location of disease, and the surgical approach. Older patients with preexisting comorbidities, posterior approaches to the cervical spine, and anterior approaches to the thoracolumbar spine are associated with higher risks of postoperative complications.
- Rapid growth in the demand for total hip and total knee arthroplasty has occurred over the past decade reflecting aging of the population as well as the success and safety of these procedures.
- Morbidity and mortality following total hip replacement (THR) and total knee replacement (TKR) are rare, and the incidence of complications and death has decreased over time. Thromboembolic events have been reduced with adoption of routine prophylaxis protocols.
- Myocardial infarction occurs in approximately 3% of patients, and stroke in 0.5% and patients over 70 years of age appear to be at greater risk.

## Introduction

Musculoskeletal conditions are among the most disabling and costly conditions affecting the American population. As the US population rapidly ages, musculoskeletal impairments will increase. By the year 2030, the number of individuals in America over the age of 65 will double, with people above 85 years of age constituting the fastest-growing segment of our society [1]. Similar demographic changes are predicted for Europe. Bone and joint disorders account for more than one half of reported conditions in people over the age of 50 and are the most common cause of pain and disability. In 2011 53% of the US population was considered to have musculoskeletal disorders or diseases [1].

The economic impact of musculoskeletal disease is enormous. The projection of direct costs of the medical care required to treat musculoskeletal conditions from 2002 to 2004 was $510 billion, or 4.6% of our nation's gross domestic product (GDP). Indirect costs resulting from lost wages due to inability to perform one's job added another $331 billion, or 3.1% of GDP [1]. From 1998 to 2011, these costs were estimated to have increased 105%. Advances in the care

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of patients with musculoskeletal diseases that mitigate the long-term suffering and economic impact of these conditions and help these patients return to full and active lives are clearly the goal for all physicians involved in their care.

The majority of hospitalizations and indications for surgery for musculoskeletal conditions result from degenerative diseases of the spine and major lower extremity joints. The aims of this chapter are to review the current incidence of degenerative disorders of the spine that lead to reconstructive spine surgery and to review the incidence of complications resulting from spine surgery as well as the incidence and prevalence of osteoarthritis of the hip and knee leading to the frequency of total hip and total knee arthroplasty procedures. The frequency of complications following these procedures will also be reviewed.

## Incidence of Degenerative Disorders of the Spine

Lumbar spine disorders are more common than cervical spine disorders, but combined they represent one of the most frequent reasons for physician visits and hospitalization. The majority of patients presenting with back pain are in the age group between 18 and 64 years of age [1]. In many of these cases, patients lose work days compounding the financial and societal impacts of the problem.

Lower back pain is the most frequently reported single site of pain in the back. In 2004, between 30% and 40% of people in the USA report experiencing low back pain in a previous 3-month period [2, 3]. Overall, about one in two persons report experiencing back pain at least once a year, which is a greater rate of pain than that reported for hips, knees, or upper limbs (Fig. 3.1). Degenerative disk disorder of the spine is the most common disease entity associated with lower back pain. In 2004, lumbar disk disorders, including disk degeneration and herniation, comprised 27% of hospitalizations and were seen most frequently among persons aged 45–74. In 2011 52 million US citizens visited a physician for evaluation and treatment of low back pain [1]. Although cervical/neck pain is less common than lower back pain, it is still a very common reason for physician visits, accounting for 1.5% of all health-care visits. Both low back pain and neck pain are found more commonly among females.

## Incidence of Spine Procedures

Nonsurgical intervention is usually the preferred initial treatment for back pain. Spine surgery may be indicated in cases of severe intractable pain that causes significant disability.

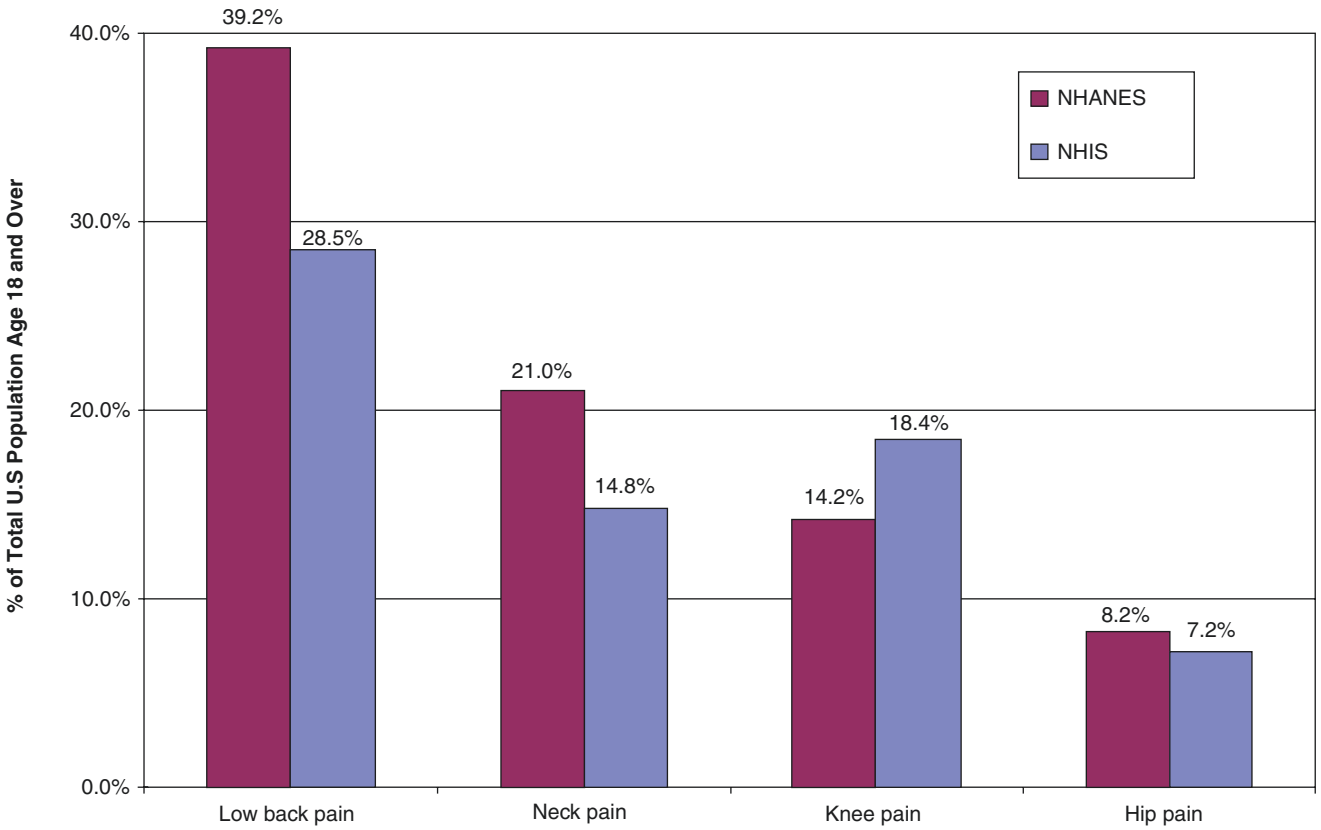


**Fig. 3.1** Prevalence of self-reported joint pain by site for persons aged 18 and over in two national health surveys, USA 1999–2005. *NHANES* National Health and Nutrition Examination Survey, *NHIS* National Health Interview Survey. (Used with permission of AAOS from Jacobs [91])

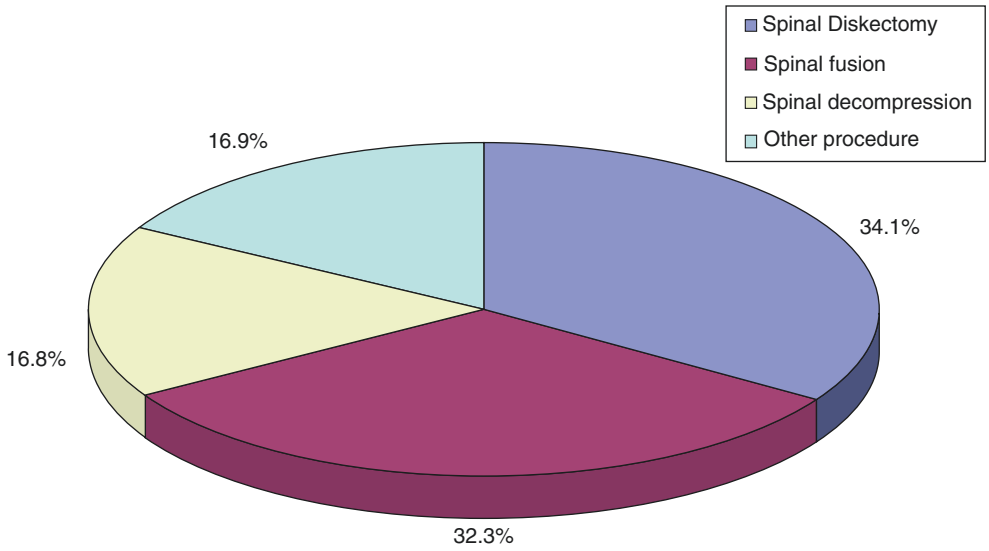


**Fig. 3.2** Select spine procedures as a proportion of all spine procedures, USA 2004. (Used with permission of AAOS from Jacobs [91])

The three most frequently performed spine procedures in 2004 were diskectomy, spinal fusion, and spinal decompression (Fig. 3.2).

Spinal diskectomy was the most common spine procedure in 2004, performed in 325,300 cases accounting for 34% of all spine procedures. As of 2011 this figure has risen to 370,000 cases [4]. Approximately 60% of these diskectomies were performed for degenerative disease of the lumbar spine (disk degeneration, spondylosis, spinal stenosis) and around 30% for cervical indications. The most common primary diagnosis in cervical spine fusion cases is cervical disk displacement (19%).

Spinal fusion, the second most common spine procedure performed in 2004, may be done in conjunction with spinal decompression. In 2004, over 307,800 spine fusion procedures were performed (32% of all spine procedures). That number has risen to 450,000 for 2011. Lumbar spinal fusion rates have increased more rapidly than the rates of cervical or thoracic fusion [5, 6], and in 2004, the number of lumbar fusion procedures was higher than cervical procedures, accounting for 46% versus 41% of all fusion procedures. It should be noted, however, that rates of lumbar fusion vary dramatically among geographic regions, hospitals, and even between surgeons in the same hospital, probably due to the variation in consensus regarding the indications for and the outcomes of lumbar fusion [7]. Decompression procedures that are presumably performed for spinal stenosis were performed in 160,000 cases during 2004 and 170,000 by 2011 representing 17% of spine procedures.

The population of lumbar spine stenosis represents a growing public health challenge for spine surgeons around the world. The literature showed good outcomes after elective surgical management of lumbar stenosis and stable pain relief up to 10 years [8–10]. A recent observational cohort study sought to compare the improvement in patient self-reported quality of life after lumbar spine surgery (decompression alone or decompression and fusion) with the benchmark set by total joint arthroplasty [11]. With strict patient selection criteria and appropriate nonsurgical management, the results of this study showed excellent improvement in patient-reported quality of life after both decompression alone and decompression and fusion for lumbar stenosis. At 2 years after surgery, 85% and 80% of patients reported improved physical and mental quality of life questionnaires, respectively, which is comparable to that of total hip and total knee arthroplasties. Several studies have shown that the initial results of surgery, particularly regarding relief of leg symptoms, can be reasonably maintained (60–80%) in the long term with an approximate reoperation rate of 1–2% per year [10, 12–16].

The incidence of spinal fusion expressed as the number of procedures performed per 100,000 persons in the population has increased dramatically over the past 15 years. In 1998 the incidence was 85 per 100,000, which has risen to 122 per 100,000 in 2004. The likely explanations for this increase are advances in spinal instrumentation technology, improvements in the resolution of diagnostic imaging, and the broadening of indications for spine surgery. However, some of the increase must be attributed to the aging of the population with an accompanying increased incidence of spinal disorders as well as increased training in spinal surgery.

## Incidence of Complications After Spine Surgery

Before reviewing the literature for incidence of complications in spine surgery, it is crucial to realize that reported incidence rates vary significantly due to several factors,

including: (1) definition and classification of complications, (2) study methodology, (3) surgeon-related factors, (4) procedure-related factors, and (5) patient-related factors.

## Definition and Classification of Complications

Efforts to understand, report, and reduce complications in spine surgery have been hampered as a result of the lack of a meaningful and universally acceptable definition. The complex field of spine surgery has been a particularly challenging area for the development of a consensus to constructively define and classify complications. The term "complication" is typically used with an emphasis on events that occur intraoperatively or immediately after surgery. Some authors developed severity scores to better measure the severity of adverse events [17], whereas others used spine surgeon surveys that are validated through parallel assessment of patients undergoing spine surgery [18]. Several studies have graded complications as minor, moderate, or major [19–21].

Rampersaud and colleagues used the term "adverse events" to describe "any unexpected or undesirable event(s) occurring as a direct or indirect result of surgery" and defined a complication as a disease or disorder resulting from surgery that will change the expected outcome of the patient [22]. According to these definitions, 98 intraoperative adverse events out of 700 surgeries (14%) were reported, but only 23 of them resulted in acute postoperative clinical complications (3%). For example, a dural tear was reported in 58 cases, but after primary repair, only 8 patients continued to have CSF leak and headache. Therefore, a study investigating the incidence of CSF leaks may underestimate the incidence of dural tears, leading to conflicting incidence reports, and a false sense of security that overlooks protocols that could easily minimize or prevent these typically "inconsequential" adverse events. Unfortunately, the overall strength of the evidence to establish a standardized system for grading and defining complications in spine surgery is low indicating that further exploration and standardization are needed [23].

## Study Methodology

Retrospective studies may underestimate actual complication incidence through the introduction of investigator recall bias [24, 25]. A disproportionate reliance on the memory of investigators and accuracy of medical records may lead to falsely low or high reported rates of complication. Also, the reliance on the International Classification of Diseases (ICD-9) codes to search complications and procedures compromises the quality of data. This method inherently limits the scope and therefore the incidence of complications. In addition, ICD-9 codes do not address the severity of complication. For example, Deyo and colleagues [26] retrospectively analyzed a statewide hospital discharge registry and compiled data on more than 18,000 hospitalizations over a 2-year period. The authors reported an overall complication rate of 10.3% for the surgical treatment of degenerative lumbar spine disease. However, since they used ICD-9 codes for identifying complications, the most frequently listed complications were unspecified or unclassified (2.5%); thus, it was impossible to gauge their severity. Moreover, ICD-9-CM codes were used to describe the surgical procedure, which do not provide more details about the procedures such as the number of levels, use of microsurgical techniques, or methods of arthrodesis.

One systematic review of spine surgery articles assessing complications of surgery indicated that retrospective reviews underestimate the incidence of complications. Overall, prospective studies reported a higher incidence of complications (19.9%) than did retrospective studies (16.1%, $p < 0.001$, OR 1.3) [19]. Moreover, duration of follow-up correlated with complication incidence, with longer periods of follow-up associated with an increased incidence of operative complications.

## Surgeon-Related Factors

Due to the wide range of complication rates of spine surgery, some authors have questioned the effect of the surgeon's experience on complication rates. Wiese and colleagues compared the incidence of durotomy between surgeons who had performed 50–100 and those who performed >500 microdiskectomies and demonstrated a higher incidence of overall complications rate in the former group (10.7% versus 2.2%, $p < 0.001$) [27]. However, another recent retrospective study of more than 108,000 cases performed by members of the Scoliosis Research Society (SRS) did not find a difference in the incidence of durotomy depending on surgeon experience, with active members presumably having more and candidate members presumably having less experience [28]. Although not specifically assessed, the vast majority of candidate members of the SRS are fellowship-trained spine surgeons dedicated to the treatment of complex spinal conditions. This may contrast with the less experienced group described in the study of Wiese and coauthors.

## Procedure-Related Factors

Complications also vary in severity and incidence among the different surgical approaches and anatomical regions. For example, in cervical spine surgery, the posterior

approach-related complications include pain from injury to paraspinal muscles, epidural hematoma, and neurological injury, whereas dysphagia, recurrent laryngeal nerve damage, and rarely tracheal or esophageal perforation can occur with an anterior approach [29, 30]. As for the different anatomical regions of the spine, one meta-analysis indicates that thoracolumbar procedures have significantly more complications than in cervical procedures (17.8% versus 8.9%, $p < 0.001$) [19].

Overall complication rates in cervical spine surgery range from 0.1% to 19.3% and the mortality rates from 0.1% to 0.8% [23]. Although an anterior approach is associated with a greater incidence of dysphagia and hoarseness, the posterior approach, particularly posterior fusion procedures, has been consistently associated with greater incidence of complications and perioperative morbidity and nearly double resource utilization including hospital length of stay, inflation adjusted cost, and likelihood of discharge to an assisted-living facility [31–33]. A population-based analysis of 771,932 anterior cervical spine fusions from the National Hospital Discharge Survey (NHDS) showed an overall procedure-related complication rate of 7.23% in the period 1990–1994, 5.05% in 1995–1999, and 4.82% in 2000–2004 [34]. See Fig. 3.3. A reduction was seen for all organ-specific complications between 1990 and 2004, except for cardiac and respiratory. In-hospital mortality decreased from 0.93 to 0.2 and 0.18% in the time periods 1990–1994, 1995–1999, and 2000–2004.

In lumbar procedures, the overall complication rates range from 3.7% to 12.8% [23]. Reoperation rates range from 0.5% to 19% and are highest in fusion procedures. In general, fusion procedures appear to be associated with a higher overall rate of complication [26, 35]. The introduction of minimally invasive approaches and techniques does not appear to have reduced this higher complication risk when fusion accompanies decompression [36]. In a recent study, data collected between 1998 and 2006 from the National Inpatient Sample were analyzed to assess the incidence of perioperative morbidity and mortality in anterior, posterior, and anterior/posterior non-cervical spine fusion [37]. 261,356 admissions were identified during which a primary spine fusion procedure was performed. Of those, 77% were anterior, 14% were posterior, and 9% were anterior/posterior fusions. Procedure-related complications were more frequent among anterior/posterior spine fusions (23.8%) as compared to anterior (18.7%) and posterior (15%) spine fusion (Table 3.1). Also, the incidence of thromboembolic events was higher among anterior/posterior spine fusion patients. While anterior procedures in the cervical regions appear to be associated with fewer complications, this study indicates that this does not hold true for thoracic and lumbar regions of the spine. Procedures involving the anterior thoracolumbar spine are associated with higher morbidity and mortality, possibly due to the entry of abdominal and thoracic cavity and the proximity of vital organs. The highest rate of morbidity and mortality was seen in the anterior/posterior fusion

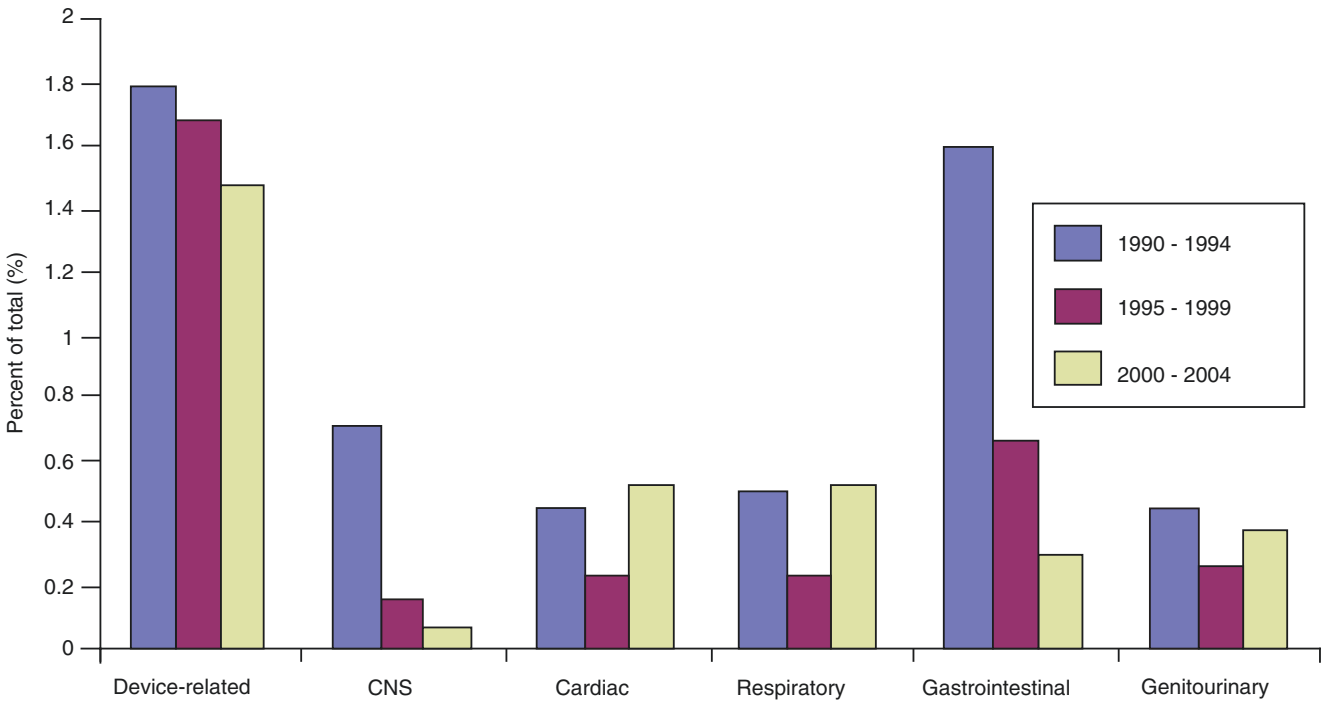


**Fig. 3.3** Prevalence of procedure-related complications following anterior cervical spine fusion, United States 1990–2005. (Used with permission of Wolters Kluwer from Marwar et al. [92])

**Table 3.1** Prevalence of procedure-related complications after non-cervical spine fusion, USA 1998–2006

| Complication | Non-cervical spine fusion | | | |
|---|---|---|---|---|
| | Anterior, % ($N$ = 36,224) | Posterior, % ($N$ = 201,885) | Anterior/posterior, % ($N$ = 113,991) | All procedures, % ($N$ = 261,356) |
| Complications affecting specific body system | | | | |
| Central nervous system | 0.4 | 10.2 | 0.8 | 0.9 |
| Cardiopulmonary | 3.2 | 2.4 | 5.3 | 2.8 |
| Gastrointestinal | 4.8 | 2.1 | 5.6 | 2.8 |
| Genitourinary | 0.9 | 1.1 | 1.2 | 1.1 |
| Other complications of procedure | | | | |
| Postoperative shock | 0.1 | 0.1 | 0.2 | 0.1 |
| Hematoma | 1.5 | 1.6 | 2.7 | 1.6 |
| Postoperative infection | 0.8 | 0.5 | 1.2 | 0.6 |
| Thromboembolic events | 0.9 | 0.7 | 1.3 | 1.2 |
| Pulmonary embolism | 0.3 | 0.3 | 0.5 | 0.5 |
| Death | 0.5 | 0.3 | 0.4 | 0.3 |

Used with permission of Wolters Kluwer from Memtsoudis et al. [37]
$p < 0.001$ between all approach types

patients, which can be explained by longer surgical times, more blood loss, and increased surgical complexity.

Medical complications that results from spine surgery are challenging to manage. A significant number of patients undergoing orthopedic surgery are elderly, predisposing them to several medical complications. The rates of cerebrovascular, cardiopulmonary, gastrointestinal, and genitourinary complications in the National Inpatient Sample from 1998 to 2006 were 0.9%, 2.8%, 2.8%, and 1.1%, respectively (Table 3.1) [37]. In another single-center prospective study of 248 consecutive patients undergoing spine surgery in 2008, the rates of specific medical complications were reported, including myocardial infarction (1.2%), pulmonary embolism (0.8%), cerebrovascular accident (0.4%), urinary tract infection (15.7%), pneumonia (2.0%), and death (0.8%) [21].

In the context of surgical complications after spine fusion, there has been an appreciation in the more recent spine surgery literature that frequent and occasionally catastrophic complications are associated with the use of recombinant human bone morphogenetic protein-2 (rhBMP-2). When it was first introduced in 2002, preliminary human trials for a variety of spinal fusion techniques found no adverse events associated with rhBMP-2 use [38, 39]. As the use of BMP increased, with 25% of all fusions utilizing BMP in 2006 [40], a series of studies reported serious complications associated with rhBMP-2 use, ranging from 10% to 50% depending on the approach [41]. These complications were associated with swelling of neck and throat leading to compression of airways and/or neurological compromise in the cervical region and radiculitis, ectopic bone formation, and osteolysis in the lumbar region. Epstein and Chrastil separately summarized multiple adverse events attributed to the use of BMP/Infuse in spine surgery [36].

Mortality rates among patients undergoing cervical and lumbar spine surgeries are <1%. Though death events are rare in the cervical and lumbar spine, they are more common after thoracic spine surgery with rates as high as 64% among vertebroplasty patients and 7.5% among balloon kyphoplasty patients [23].

### Patient-Related Factors

Another factor leading to the increased variation in reported complications is the patient population. As would be expected in any surgical procedure, the risk of postoperative complications in spine surgery increases in older patients and patients with multiple comorbidities such as cardiac disease and diabetes [20, 31, 33, 42–44]. Patients with preoperative neurologic abnormalities are at higher risk of developing postoperative complications (OR, 2.88; CI, 1.42–5.83) [30, 31]. Complication rates are also affected by the primary diagnosis for the patient. Reoperation rates have been reported to be higher in patients diagnosed with herniated disk disease [45].

## Prevalence of Osteoarthritis and Related Reconstructive Surgeries of the Hip and Knee

Osteoarthritis (OA) is the most common type of arthritis, frequently affecting knees and hips, leading to progressive damage to the cartilage and other joint tissues. In a study conducted in Johnston County, NC, the prevalence of knee and hip OA among adults aged 45 years and older was 17% and 10%, respectively [46, 47]. The prevalence is higher in older age groups and among women but lower in Hispanics (16.5% versus 22% for non-Hispanics and African Americans) [48].

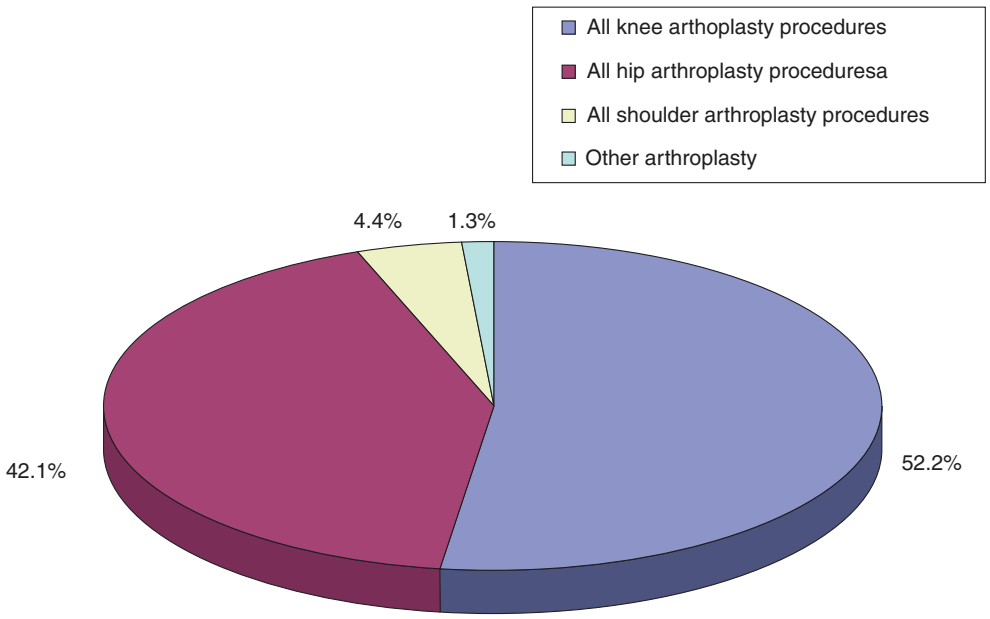


**Fig. 3.4** Arthroplasty procedures by type, USA 2004. (Used with permission of AAOS from Jacobs [91])

Although a great variety of medications have been used to address the pain and disability associated with osteoarthritis, total joint arthroplasty remains the definitive treatment for advanced, symptomatic joint destruction. Total joint arthroplasty is indicated for arthritis and a variety of other rheumatic conditions, but osteoarthritis remains the principle diagnosis in 82.5% of total hip replacements and 96.8% of all total knee replacements [2]. The hip and the knee are the most frequently replaced joints. In 2004, hip and knee replacements accounted for 95% of the 1.07 million arthroplasty procedures performed (Fig. 3.4). Over 232,000 primary total hip arthroplasty procedures were performed (25% of all arthroplasty procedures), and over 454,000 primary total knee arthroplasty procedures were performed (48%). By 2011 these figures increased to 300,000 total hip arthroplasties and 650,000 total knee replacements. Females undergo 62% of all total joint replacement procedures, and they undergo total knee arthroplasty twice as frequently as men reflecting the greater prevalence of knee OA in females than in males. In terms of age distribution, 60% of primary and revision total hip and knee arthroplasty procedures are performed in patients above 65 years of age.

Data on the survival of total joint replacement implants come from several national registries. Survival rates vary depending on several factors such as patient age, implant type, and the use of cement versus cementless fixation. Analysis of the Finnish arthroplasty registry showed that for patients older than 55 years of age, the survival rates of total hip implants ranged from 92% to 98% at 10 years, 86–93% at 15 years, and 77–82% at 20 years, with the endpoint defined as revision due to aseptic loosening of the implant [49]. Revision rates represent a crude measure of implant failure, as the need for revision operation is probably the only quantifiable event that forces the patient to return to hospital. In a systematic review, national registries were analyzed to identify revision rates after total hip and knee arthroplasties [50]. After primary hip replacement, a mean of 1.29 revisions per 100 observed component years was seen. Similarly, after total knee replacement, 1.26 revisions per 100 observed component years were seen. As for the patient's subjective measure of health-related quality of life, several studies compared patients undergoing total joint replacement with a reference health group with a similar age and sex distribution [51, 52]. Patients that benefited from joint replacement had remarkably improved physical and psychosocial scores from 1 to 2 years postoperatively, and these scores were maintained up to 3–5 years.

The annual number of total joint replacement has been increasing from 1991 to 2011. There has been a threefold increase in total knee replacements, while the annual number of total hip replacements doubled. These increases in joint arthroplasty utilization outnumber the increase in incidence of OA as would be expected from an aging population. This probably represents broadening of the indications of arthroplasty procedures due to their safety and durability. There has been a parallel increase in the total estimated cost of performing total knee replacement procedures from $5.4 billion in 1998 to $14.3 billion in 2004. Projected growth model for hip and knee replacement procedures estimates that by 2030 there will be over 570,000 primary total hip replacements performed annually in the USA and nearly 3.5 million primary total knee replacements, with associated need for manpower, operating room capacity, and health care costs [1].

## The Incidence of Complications After Total Knee and Total Hip Arthroplasty

### General Trends

Despite the efficacy of total knee and total hip arthroplasty, complications can occur which result in poor functional outcomes for a subset of patients. In light of the prevalence and the increasing trends of these procedures, documenting and reviewing associated adverse events remains a priority to help optimize patient care. The National Hospital Discharge Survey (NHDS) was analyzed from 1990 to 2004 in order to elucidate temporal changes in demographics, hospital stay, in-hospital complications, and mortality of patients undergoing primary total knee [53] and total hip [54] arthroplasty during a 15-year study period in the USA. Frequencies of procedure-related complications over time were identified using ICD-9-CM diagnosis codes. In their analysis, the authors created three 5-year periods to simplify temporal changes (1990–1994, 1995–1999, and 2000–2004).

A total of 3,830,420 patients had undergone total knee arthroplasty from 1990 to 2004 based on the NHDS [53]. As expected, there was an increased utilization of primary total knee arthroplasty, increased proportion of younger patients, as well as an increased number of comorbidities among patients. Despite an increase in the rate of comorbidities, the procedure-related complication rate decreased from 12% during the period from 1990 to 1994 to 7% during the period from 2000 to 2004 (Table 3.2). Approximately half were categorized as organ-specific. Although mortality rate declined from 0.50% during the period from 1990 to 1994 to 0.21% during the period from 1995 to 1999, mortality increased slightly to 0.28% during the period from 2000 to 2004. Despite progressive increase in the use of thromboprophylaxis during these time periods, the authors did not find a concomitant decline in mortality or pulmonary embolism during the most recent time period (2000–2004). In fact, the rate of pulmonary embolism increased from 0.29% in the period from 1995 to 1999 to 0.52% in the period from 2000 to 2004 (Table 3.2). An increase in patient comorbidities could explain recent trends toward increasing rates of pulmonary embolism and overall mortality.

As for total hip arthroplasty, 2,288,579 patients were identified between 1990 and 2004 [54]. The trends were generally similar to those in total knee arthroplasty. The utilization of this procedure has increased, with the highest percent of increase in the group of patients aged between 45 and 64. Also, there has been an increase in the number of comorbidities, with hypertension being the most common comorbidity occurring in nearly half of all patients in the most recent time period studied (2000–2004). Nevertheless, procedure-related complications and adverse events decreased over the study period, from 15% in the period from 1990 to 1994 to 9% in the period from 2000 to 2004 (Table 3.3). In-hospital mortality rate remained low and slightly decreased (0.33% in 1990–1994 to 0.29% in 2000–2004). Fortunately, the incidence of pulmonary embolism has decreased from 0.46% to 0.26%, which is reassuring as much effort and creation of practice guidelines have been devoted to reduction of these thromboembolic events. Since 2010 after passage of the Affordable Care Act, a database of hospital readmissions has been maintained [55].

### Specific Complications: Medical

As the prevalence of hip and knee osteoarthritis increases with increasing age, more of total joint replacement procedures will be performed in patients with some degree of cardiac, pulmonary, cerebral, renal, and hepatic disease.

**Table 3.2** Prevalence of procedure-related complications in patients undergoing total knee arthroplasty, USA 1990–2004

| | Total knee arthroplasty | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1990–1994 ($N$ = 807,687) | | 1995–1999 ($N$ = 1,204,109) | | 2000–2004 ($N$ = 1,818,624) | | 1990–2004 ($N$ = 3,830,420) | |
| Complications | $n$ | % of total | $N$ | % of total | $n$ | % of total | $n$ | % of total |
| Complications affecting specific body system | | | | | | | | |
| Central nervous system | 143 | 0.02 | 3180 | 0.26 | 2405 | 0.13 | 5758 | 0.15 |
| Cardiopulmonary | 24,923 | 3.09 | 31,041 | 2.57 | 31,888 | 1.75 | 87,852 | 2.29 |
| Gastrointestinal | 9224 | 1.14 | 13,159 | 1.09 | 16,096 | 0.89 | 38,479 | 1.01 |
| Genitourinary | 12,188 | 1.51 | 13,554 | 1.13 | 11,611 | 0.64 | 37,353 | 0.98 |
| Other complications of procedure | | | | | | | | |
| Postoperative shock | 396 | 0.05 | 71 | 0.01 | 129 | 0.01 | 596 | 0.02 |
| Hematoma | 11,017 | 1.36 | 18,403 | 1.53 | 14,400 | 0.79 | 43,820 | 1.14 |
| Postoperative infection | 2090 | 0.26 | 1748 | 0.15 | 4325 | 0.24 | 8163 | 0.21 |
| Thromboembolic events | 6876 | 0.85 | 6954 | 0.58 | 10,816 | 0.59 | 24,646 | 0.64 |
| Pulmonary embolism | 2872 | 0.36 | 3518 | 0.29 | 9546 | 0.52 | 15,936 | 0.42 |
| Death | 4028 | 0.50 | 2502 | 0.21 | 5094 | 0.28 | 11,624 | 0.30 |

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$p < 0.001$ between all time periods

**Table 3.3** Prevalence of procedure-related complications in patients undergoing total hip arthroplasty, USA 1990–2004

| | Total hip arthroplasty | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1990–1994 ($N$ = 603,528) | | 1995–1999 ($N$ = 731,921) | | 2000–2004 ($N$ = 953,130) | | 1990–2004 ($N$ = 2,288,579) | |
| Complications | $n$ | % of total | $N$ | % of total | $n$ | % of total | $n$ | % of total |
| Complications affecting specific body system | | | | | | | | |
| Central nervous system | 140 | 0.02 | 1752 | 0.24 | 2025 | 0.21 | 3917 | 0.17 |
| Cardiopulmonary | 13,760 | 2.28 | 16,083 | 2.19 | 18,310 | 1.92 | 48,153 | 2.11 |
| Gastrointestinal | 7107 | 1.18 | 7521 | 1.03 | 7157 | 0.75 | 21,785 | 0.95 |
| Genitourinary | 9612 | 1.59 | 6345 | 0.87 | 8877 | 0.93 | 24,834 | 1.09 |
| Other complications of procedure | | | | | | | | |
| Postoperative shock | 449 | 0.07 | 49 | 0.01 | 524 | 0.06 | 1022 | 0.05 |
| Hematoma | 8304 | 1.38 | 12,494 | 1.71 | 13,700 | 1.44 | 34,498 | 1.51 |
| Postoperative infection | 4160 | 0.69 | 4738 | 0.65 | 1884 | 0.20 | 10,783 | 0.47 |
| Thromboembolic events | 3588 | 0.60 | 1941 | 0.27 | 3082 | 0.32 | 8611 | 0.38 |
| Pulmonary embolism | 2787 | 0.46 | 2193 | 0.30 | 2481 | 0.26 | 7461 | 0.33 |
| Death | 1977 | 0.33 | 2446 | 0.33 | 2839 | 29.00 | 7262 | 0.32 |

Used with permission of Springer Nature from Liu et al. [54]
$p \leq 0.001$ between all time periods

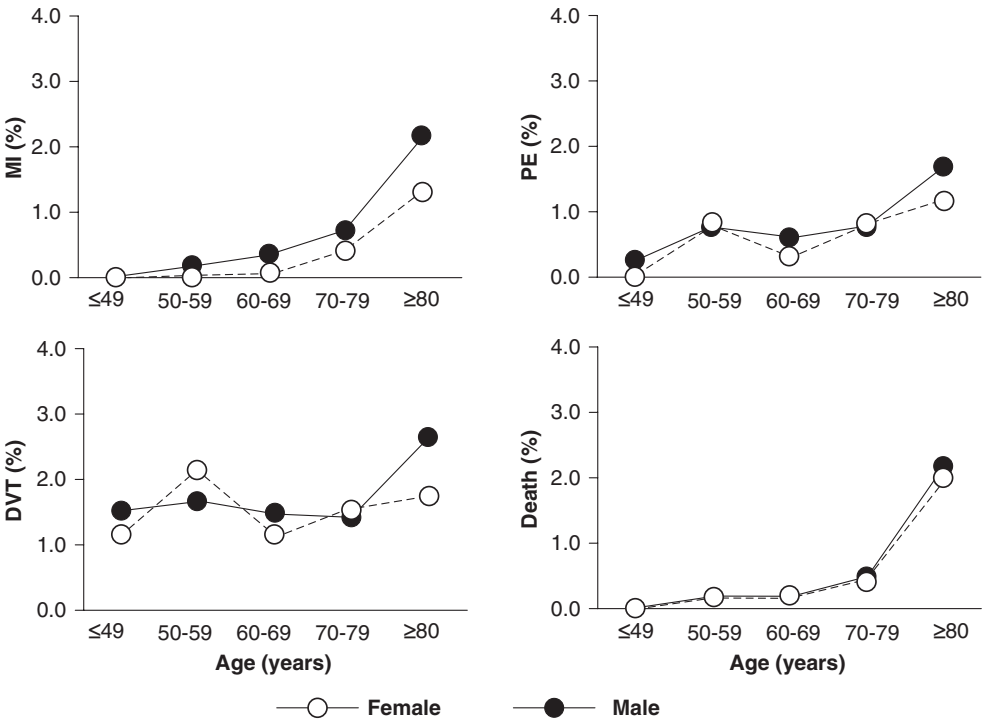


**Fig. 3.5** Frequency of myocardial infarction (MI), pulmonary embolism (PE), deep venous thrombosis (DVT), or death within 30 days after primary total hip or knee arthroplasty according to age and gender. (Used with permission of Wolters Kluwer from Mantilla et al. [56])

Therefore, accurate knowledge of rates of perioperative medical complications in elderly population is valuable for the decision-making process when considering elective surgeries. Prospectively collected data from the total joint registry at the Mayo Clinic during a 10-year period (1986–1995) were used to identify patients with postoperative myocardial infarction, pulmonary embolism, deep venous thrombosis, or death within 30 days after total hip or knee arthroplasties [56]. Out of 10,244 patients, the overall rate of myocardial infarction, pulmonary embolism, deep venous thrombosis, and death were 2.2%, 0.4%, 0.7%, 1.5%, and 0.5%, respectively (Fig. 3.5). Eighty-three percent of myocardial infarction occurred within 3 days and were more frequent among males and patients aged 70 years or older. There was no difference in the overall adverse event frequency between total knee and total hip procedures, except for pulmonary embolism, which was highest in patients undergoing bilateral knee operations. A separate study investigated the incidence of perioperative stroke and found that 36 of 18,745 patients (0.2%) undergoing total hip and knee arthroplasties between 2000 and 2007 suffered a perioperative stroke [57]. Nine of the 36 patients died within the first year (25%). This study indicates that perioperative stroke is a rare but devastating complication of total joint arthroplasty.

### Infection

Deep periprosthetic joint infection remains the most complex and costly complication. Even with a two-stage exchange implant-exchange protocol, failure rates in hips infected with methicillin-resistant organisms can reach as high as 21% [58]. A retrospective review of 8494 primary knee and hip arthroplasties reported a 0.5% overall rate of infection (30 of 5719 knees and 13 of 2775 hips) [59]. Obesity, diabetes, and younger age were identified as risk factors for infection in total joint arthroplasty. The rate of infection following total hip arthroplasty in the medicare beneficiary population from 1995 to 1996 was around 0.2% (137 of 58,521) for primary arthroplasty and 0.96% (124 of 12,956) for revision surgery [60]. A more recent review of discharge data from over 139,000 patients undergoing primary total hip arthroplasty between 1995 and 2005 reported a higher wound infection rate of 0.7% [61]. Total knee arthroplasty appears to have a slightly higher infection rate than total hip arthroplasty [59, 62, 63]. The exact reason for knees having higher infection rates remains subject to debate. Possible explanations include differences in vascular supply, skin thickness, joint motion, the use of tourniquet, and surgical approach.

Antibiotic prophylaxis is fundamental to the reduction of primary periprosthetic infection and has been shown by meta-analysis to reduce the relative risk of wound infection by 81% [64]. As *clostridium difficile* infections are thought to be an iatrogenic complication of antimicrobial prophylaxis [65], particularly third-generation cephalosporins, clindamycin, and ciprofloxacin, several investigators sought to identify the incidence of *Clostridium difficile* infections in patients undergoing total joint arthroplasty [66, 67]. These studies showed a very low incidence of 0.17%.

Although the risk of infection after total joint arthroplasty is small (<1%), considering the large number of arthroplasty procedures performed every year, and considering the mean cost of $68,053–$107,264 to treat each infection [68], this risk poses a significant economic burden.

### Dislocation

Dislocation is one of the most common complications after total hip arthroplasty [69]. Reported rates of dislocation (≤90 days postoperatively) vary and range between 1.39 [61] and 3.2% [70] for primary arthroplasties. A comprehensive review published by Morrey in 1992 concluded that the long-term dislocation rate averaged 2.25% in the primary total hip arthroplasty setting [71]. As in infections, rates were higher after revision surgery reaching 8% [60]. Dislocations are also seen following total knee arthroplasties but to a lesser extent. A study of 2033 total knee arthroplasties in medicare beneficiaries from 2002 to 2004 reported only four cases of dislocation (0.2%) [72].

### Venous Thromboembolism

Venous thromboembolism is a serious complication that is used by the government and insurance payers as a performance measure of hospitals as well as surgeons. Prior research showed that 35% of patients die within 1 year after the onset of venous thromboembolism [73]. In the Danish total hip registry from 1995 to 2006, 686 of 67,469 (1.02%) patients were rehospitalized due to venous thromboembolism at a median of 22 days following surgery. Ninety-three percent of the 67,469 patients received pharmacological prophylaxis with use of a low-molecular-weight heparin. The prevalence of symptomatic deep vein thrombosis was 0.7% (499 patients), and the prevalence of nonfatal pulmonary embolism was 0.3% (205 patients). The rate of mortality due to venous thromboembolism was 0.05% (38 patients). However, these rates are lower than previous reports as there are differences in study populations, study design, proportion of patients receiving pharmacological prophylaxis, and type and duration of treatment [74–77].

### Periprosthetic Fractures

Periprosthetic fractures are fractures that occur in association with an orthopedic implant. These fractures are of great importance as one study has documented a higher risk of death after periprosthetic fracture as compared with a similar population of patients undergoing uncomplicated total hip arthroplasty [78]. Incidence of periprosthetic fractures about a total hip arthroplasty is variable, with multiple studies noting an incidence of 0.1–18% [79–82]. The incidence is greater after revision arthroplasty as revision surgery is associated with problems with bone stock about the components resulting from stress shielding, osteolysis, and other factors. Data from the Mayo Clinic joint registry revealed fracture rates of 1% after primary total hip arthroplasty and 4% after revision total hip arthroplasty [83]. The prevalence of periprosthetic fracture about total hip arthroplasty continues to increase with time as more and more patients are undergoing total hip arthroplasty, with more surgeries being performed on older patients who may be at an increased risk of falls [78, 83, 84]. Similarly, rates of periprosthetic fractures about total knee arthroplasty are increasing as the population ages [85, 86]. The incidence is 0.3–2.5% for primary total knee arthroplasty and up to 38% for revision [87–89].

## Summary

As our population continues to age with a growing incidence of degenerative musculoskeletal disease, a large number of surgical procedures will be performed every year. Spine and total joint replacement procedures gained popularity with the increasing evidence of their long-term efficacy. Advances in the surgical techniques and perioperative care broadened sur-

gical indications, which paralleled the rapid growth of the elderly population suffering from degenerative diseases. Therefore, the increasing number of older individuals with multiple comorbidities opting for surgery is not necessarily accompanied by an increase in complication rates. Nevertheless, these complications constitute a large economic burden and a major challenge for orthopedic surgeons and physicians [90]. As such, accurate reporting of these complications and more cautious analysis of epidemiological studies are crucial to implement optimal medical and surgical management.

**Summary Bullet Points**

- As the population of the USA ages, the demand for orthopedic surgery for degenerative conditions has risen. Total joint replacement and spinal reconstructive procedures are highly successful, but success depends on proper surgical indications and technique.
- Complications following total joint replacement are rare. Thromboembolic events resulting in myocardial infarction, stroke, and pulmonary embolism are among the most common complications, but the incidence of these has fallen with adoption of routine prophylaxis.
- Patients of advanced age and/or with poorly controlled diabetes are at the highest risk of complications following elective orthopedic surgery.

## References


1. The burden of musculoskeletal diseases in the United States: prevalence, societal and economic costs. http://www.boneandjointburden.org/.
2. National Center for Health Statistics. National hospital discharge survey. 2004.
3. National Center for Health Statistics. National health and nutrition examination survey data 1998–2004. 2004.
4. Agency for Healthcare Research and Quality. Healthcare cost and utilization project. 2004. The HCUP Nationwide Inpatient Sample: www.hcup-usarhq.gov/nisouqview.isp.
5. Deyo RA. Epidemiology of spinal surgery, comparative effectiveness, Cost and Outcomes Research Center, University of Washington. 2011. http://depts.washington.edu/ccor/studies/SpineSurgEpi.shtml. Accessed 26 Nov 2011.
6. Ong K, Lau E, Kurtz S, et al. Cervical, thoracic, and lumbar fusion rates in the U.S.: perspective from two health databases. 53rd annual meeting, Orthopaedic Research Society; 2007.
7. Abraham DJ, Herkowitz HN, Katz JN. Indications for thoracic and lumbar spine fusion and trends in use. Orthop Clin North Am. 1998;29:803.
8. Amundsen T, Weber H, Nordal HJ, Magnaes B, Abdelnoor M, Lilleâs F. Lumbar spinal stenosis: conservative or surgical management?: a prospective 10-year study. Spine (Phila Pa 1976). 2000;25:1424–35. discussion 1435–6
9. Gibson JN, Waddell G. Surgery for degenerative lumbar spondylosis: updated Cochrane review. Spine (Phila Pa 1976). 2005;30:2312–20.
10. Javid MJ, Hadar EJ. Long-term follow-up review of patients who underwent laminectomy for lumbar stenosis: a prospective study. J Neurosurg. 1998;89:1–7.
11. Rampersaud YR, Ravi B, Lewis SJ, Stas V, Barron R, Davey R, et al. Assessment of health-related quality of life after surgical treatment of focal symptomatic spinal stenosis compared with osteoarthritis of the hip or knee. Spine J. 2008;8:296–304.
12. Atlas SJ, Keller RB, Wu YA, Deyo RA, Singer DE. Long-term outcomes of surgical and nonsurgical management of lumbar spinal stenosis: 8 to 10 year results from the Maine lumbar spine study. Spine (Phila Pa 1976). 2005;30:936–43.
13. Chang Y, Singer DE, Wu YA, Keller RB, Atlas SJ. The effect of surgical and nonsurgical treatment on longitudinal outcomes of lumbar spinal stenosis over 10 years. J Am Geriatr Soc. 2005;53:785–92.
14. Iguchi T, Kurihara A, Nakayama J, Sato K, Kurosaka M, Yamasaki K. Minimum 10-year outcome of decompressive laminectomy for degenerative lumbar spinal stenosis. Spine (Phila Pa 1976). 2000;25:1754–9.
15. Jansson KA, Nemeth G, Granath F, Blomqvist P. Spinal stenosis re-operation rate in Sweden is 11% at 10 years – a national analysis of 9,664 operations. Eur Spine J. 2005;14:659–63.
16. Kornblum MB, Fischgrund JS, Herkowitz HN, Abraham DA, Berkower DL, Ditkoff JS. Degenerative lumbar spondylolisthesis with spinal stenosis: a prospective long-term study comparing fusion and pseudarthrosis. Spine (Phila Pa 1976). 2004;29:726–33. discussion 733–4
17. Mirza SK, Deyo RA, Heagerty PJ, Turner JA, Lee LA, Goodkin R. Towards standardized measurement of adverse events in spine surgery: conceptual model and pilot evaluation. BMC Musculoskelet Disord. 2006;7:53.
18. Ratliff JK, Lebude B, Albert T, Anene-Maidoh T, Anderson G, Dagostino P, et al. Complications in spinal surgery: comparative survey of spine surgeons and patients who underwent spinal surgery. J Neurosurg Spine. 2009;10:578–84.
19. Nasser R, Yadla S, Maltenfort MG, Harrop JS, Anderson DG, Vaccaro AR, et al. Complications in spine surgery. J Neurosurg Spine. 2010;13:144–57.
20. Schoenfeld AJ, Ochoa LM, Bader JO, Belmont PJ Jr. Risk factors for immediate postoperative complications and mortality following spine surgery: a study of 3475 patients from the National Surgical Quality Improvement Program. J Bone Joint Surg Am. 2011;93:1577–82.
21. Yadla S, Malone J, Campbell PG, Maltenfort MG, Harrop JS, Sharan AD, et al. Early complications in spine surgery and relation to preoperative diagnosis: a single-center prospective study. J Neurosurg Spine. 2010;13:360–6.
22. Rampersaud YR, Moro ER, Neary MA, White K, Lewis SJ, Massicotte EM, et al. Intraoperative adverse events and related postoperative complications in spine surgery: implications for enhancing patient safety founded on evidence-based protocols. Spine (Phila Pa 1976). 2006;31:1503–10.
23. Dekutoski MB, Norvell DC, Dettori JR, Fehlings MG, Chapman JR. Surgeon perceptions and reported complications in spine surgery. Spine (Phila Pa 1976). 2010;35:S9–21.
24. Hess DR. Retrospective studies and chart reviews. Respir Care. 2004;49:1171–4.
25. Sauerland S, Lefering R, Neugebauer EA. Retrospective clinical studies in surgery: potentials and pitfalls. J Hand Surg Br. 2002;27:117–21.
26. Deyo RA, Cherkin DC, Loeser JD, Bigos SJ, Ciol MA. Morbidity and mortality in association with operations on the lumbar spine.

The influence of age, diagnosis, and procedure. J Bone Joint Surg Am. 1992;74:536–43.
27. Wiese M, Kramer J, Bernsmann K, Ernst WR. The related outcome and complication rate in primary lumbar microscopic disc surgery depending on the surgeon's experience: comparative studies. Spine J. 2004;4:550–6.
28. Williams BJ, Sansur CA, Smith JS, Berven SH, Broadstone PA, Choma TJ, et al. Incidence of unintended durotomy in spine surgery based on 108,478 cases. Neurosurgery. 2011;68:117–23. discussion 123–4
29. Fountas KN, Kapsalaki EZ, Nikolakakos LG, Smisson HF, Johnston KW, Grigorian AA, et al. Anterior cervical discectomy and fusion associated complications. Spine (Phila Pa 1976). 2007;32:2310–7.
30. Newhouse KE, Lindsey RW, Clark CR, Lieponis J, Murphy MJ. Esophageal perforation following anterior cervical spine surgery. Spine (Phila Pa 1976). 1989;14:1051–3.
31. Boakye M, Patil CG, Santarelli J, Ho C, Tian W, Lad SP. Cervical spondylotic myelopathy: complications and outcomes after spinal fusion. Neurosurgery. 2008;62:455–61. discussion 461–2
32. Shamji MF, Cook C, Pietrobon R, Tackett S, Brown C, Isaacs RE. Impact of surgical approach on complications and resource utilization of cervical spine fusion: a nationwide perspective to the surgical treatment of diffuse cervical spondylosis. Spine J. 2009;9:31–8.
33. Wang MC, Chan L, Maiman DJ, Kreuter W, Deyo RA. Complications and mortality associated with cervical spine surgery for degenerative disease in the United States. Spine (Phila Pa 1976). 2007;32:342–7.
34. Marawar S, Girardi FP, Sama AA, Ma Y, Gaber-Baylis LK, Besculides MC, et al. National trends in anterior cervical fusion procedures. Spine (Phila Pa 1976). 2010;35:1454–9.
35. Malter AD, McNeney B, Loeser JD, Deyo RA. 5-Year reoperation rates after different types of lumbar spine surgery. Spine (Phila Pa 1976). 1998;23:814–20.
36. Epstein NE. Lower complications and reoperation rates for laminectomy rather than MI TLIF/other fusions for degenerative lumbar disease/spondylolisthesis: a review. Surg Neurol Int. 2018; https://doi.org/10.4130/sni.sni_26_18.
37. Memtsoudis SG, Vougioukas VI, Ma Y, Gaber-Baylis LK, Girardi FP. Perioperative morbidity and mortality after anterior, posterior, and anterior/posterior spine fusion surgery. Spine (Phila Pa 1976). 2011;36:1867–77.
38. Boden SD, Kang J, Sandhu H, Heller JG. Use of recombinant human bone morphogenetic protein-2 to achieve posterolateral lumbar spine fusion in humans: a prospective, randomized clinical pilot trial: 2002 Volvo Award in clinical studies. Spine (Phila Pa 1976). 2002;27:2662–73.
39. Boden SD, Zdeblick TA, Sandhu HS, Heim SE. The use of rhBMP-2 in interbody fusion cages. Definitive evidence of osteoinduction in humans: a preliminary report. Spine (Phila Pa 1976). 2000;25:376–81.
40. Cahill KS, Chi JH, Day A, Claus EB. Prevalence, complications, and hospital charges associated with use of bone-morphogenetic proteins in spinal fusion procedures. JAMA. 2009;302:58–66.
41. Carragee EJ, Hurwitz EL, Weiner BK. A critical review of recombinant human bone morphogenetic protein-2 trials in spinal surgery: emerging safety concerns and lessons learned. Spine J. 2011;11:471–91.
42. Cook C, Tackett S, Shah A, Pietrobon R, Browne J, Viens N, et al. Diabetes and perioperative outcomes following cervical fusion in patients with myelopathy. Spine (Phila Pa 1976). 2008;33:E254–60.
43. Li G, Patil CG, Lad SP, Tian W, Boakye M. Effects of age and comorbidities on complication rates and adverse outcomes after lumbar laminectomy in elderly patients. Spine (Phila Pa 1976). 2008;33:1250–5.
44. Oldridge NB, Yuan Z, Stoll JE, Rimm AR. Lumbar spine surgery and mortality among Medicare beneficiaries, 1986. Am J Public Health. 1994;84:1292–8.
45. Ciol MA, Deyo RA, Kreuter W, Bigos SJ. Characteristics in Medicare beneficiaries associated with reoperation after lumbar spine surgery. Spine (Phila Pa 1976). 1994;19:1329–34.
46. Jordan JM, Helmick CG, Renner JB, Luta G, Dragomir AD, Woodard J, et al. Prevalence of hip symptoms and radiographic and symptomatic hip osteoarthritis in African Americans and Caucasians: the Johnston County Osteoarthritis Project. J Rheumatol. 2009;36:809–15.
47. Jordan JM, Helmick CG, Renner JB, Luta G, Dragomir AD, Woodard J, et al. Prevalence of knee symptoms and radiographic and symptomatic knee osteoarthritis in African Americans and Caucasians: the Johnston County Osteoarthritis Project. J Rheumatol. 2007;34:172–80.
48. Hootman JM, Helmick CG. Projections of US prevalence of arthritis and associated activity limitations. Arthritis Rheum. 2006;54:226–9.
49. Makela KT, Eskelinen A, Pulkkinen P, Paavolainen P, Remes V. Total hip arthroplasty for primary osteoarthritis in patients fifty-five years of age or older. An analysis of the Finnish arthroplasty registry. J Bone Joint Surg Am. 2008;90:2160–70.
50. Labek G, Thaler M, Janda W, Agreiter M, Stöckl B. Revision rates after total joint replacement: cumulative results from worldwide joint register datasets. J Bone Joint Surg Br. 2011;93:293–7.
51. O'Boyle CA, McGee H, Hickey A, O'Malley K, Joyce CR. Individual quality of life in patients undergoing hip replacement. Lancet. 1992;339:1088–91.
52. Wiklund I, Romanus B. A comparison of quality of life before and after arthroplasty in patients who had arthrosis of the hip joint. J Bone Joint Surg Am. 1991;73:765–9.
53. Memtsoudis SG, Della Valle AG, Besculides MC, Gaber L, Laskin R. Trends in demographics, comorbidity profiles, in-hospital complications and mortality associated with primary knee arthroplasty. J Arthroplasty. 2009;24:518–27.
54. Liu SS, Della Valle AG, Besculides MC, Gaber LK, Memtsoudis SG. Trends in mortality, complications, and demographics for primary hip arthroplasty in the United States. Int Orthop. 2009;33:643–51.
55. Kurtz SM, Lau EC, Ong KL, Adler EM, Kolisek FR, Manley MT. Which clinical and patient factors influence the national economic burden of hospital readmissions after total joint arthroplasty. Clin Orthop Relat Res. 2017;475(12):2926–37.
56. Mantilla CB, Horlocker TT, Schroeder DR, Berry DJ, Brown DL. Frequency of myocardial infarction, pulmonary embolism, deep venous thrombosis, and death following primary hip or knee arthroplasty. Anesthesiology. 2002;96:1140–6.
57. Mortazavi SM, Kakli H, Bican O, Moussouttas M, Parvizi J, Rothman RH. Perioperative stroke after total joint arthroplasty: prevalence, predictors, and outcome. J Bone Joint Surg Am. 2010;92:2095–101.
58. Leung F, Richards CJ, Garbuz DS, Masri BA, Duncan CP. Two-stage total hip arthroplasty: how often does it control methicillin-resistant infection? Clin Orthop Relat Res. 2011;469:1009–15.
59. Malinzak RA, Ritter MA, Berend ME, Meding JB, Olberding EM, Davis KE. Morbidly obese, diabetic, younger, and unilateral joint arthroplasty patients have elevated total joint arthroplasty infection rates. J Arthroplasty. 2009;24:84–8.
60. Katz JN, Losina E, Barrett J, Phillips CB, Mahomed NN, Lew RA, et al. Association between hospital and surgeon procedure volume and outcomes of total hip replacement in the United States medicare population. J Bone Joint Surg Am. 2001;83-A:1622–9.
61. Soohoo NF, Farng E, Lieberman JR, Chambers L, Zingmond DS. Factors that predict short-term complication rates after total hip arthroplasty. Clin Orthop Relat Res. 2010;468:2363–71.

62. Ritter MA, Olberding EM, Malinzak RA. Ultraviolet lighting during orthopaedic surgery and the rate of infection. J Bone Joint Surg Am. 2007;89:1935–40.
63. Wojkowska-Mach J, Jaje E, Romaniszyn D, Kasparek M, Frańczuk B, Bulanda M, et al. Comparison of SSI rates in endoarthroplasty of hip and knee in a Cracow patient population and the importance of postdischarge surveillance. Infection. 2008;36:36–40.
64. AlBuhairan B, Hind D, Hutchinson A. Antibiotic prophylaxis for wound infections in total joint arthroplasty: a systematic review. J Bone Joint Surg Br. 2008;90:915–9.
65. Harbarth S, Samore MH, Carmeli Y. Antibiotic prophylaxis and the risk of Clostridium difficile-associated diarrhoea. J Hosp Infect. 2001;48:93–7.
66. Jenkins PJ, Teoh K, Simpson PM, Dave J, Simpson AH, Breusch S. Clostridium difficile in patients undergoing primary hip and knee replacement. J Bone Joint Surg Br. 2010;92:994–8.
67. Kurd MF, Pulido L, Joshi A, Purtill JJ, Parvizi J. Clostridium difficile infection after total joint arthroplasty: who is at risk? J Arthroplasty. 2008;23:839–42.
68. Parvizi J, Pawasarat IM, Azzam KA, Joshi A, Hansen EN, Bozic KJ. Periprosthetic joint infection: the economic impact of methicillin-resistant infections. J Arthroplasty. 2010;25:103–7.
69. Soong M, Rubash HE, Macaulay W. Dislocation after total hip arthroplasty. J Am Acad Orthop Surg. 2004;12:314–21.
70. Woo RY, Morrey BF. Dislocations after total hip arthroplasty. J Bone Joint Surg Am. 1982;64:1295–306.
71. Morrey BF. Instability after total hip arthroplasty. Orthop Clin North Am. 1992;23:237–48.
72. Huddleston JI, Maloney WJ, Wang Y, Verzier N, Hunt DR, Herndon JH. Adverse events after total knee arthroplasty: a national Medicare study. J Arthroplasty. 2009;24:95–100.
73. Heit JA, Silverstein MD, Mohr DN, Petterson TM, O'Fallon WM, Melton LJ 3rd. Predictors of survival after deep vein thrombosis and pulmonary embolism: a population-based, cohort study. Arch Intern Med. 1999;159:445–53.
74. Eriksson BI, Dahl OE, Rosencher N, Kurth AA, van Dijk CN, Frostick SP, et al. Dabigatran etexilate versus enoxaparin for prevention of venous thromboembolism after total hip replacement: a randomised, double-blind, non-inferiority trial. Lancet. 2007;370:949–56.
75. Schiff RL, Kahn SR, Shrier I, Strulovitch C, Hammouda W, Cohen E, et al. Identifying orthopedic patients at high risk for venous thromboembolism despite thromboprophylaxis. Chest. 2005;128:3364–71.
76. Warwick D, Friedman RJ, Agnelli G, Gil-Garay E, Johnson K, FitzGerald G, et al. Insufficient duration of venous thromboembolism prophylaxis after total hip or knee replacement when compared with the time course of thromboembolic events: findings from the Global Orthopaedic Registry. J Bone Joint Surg Br. 2007;89:799–807.
77. White RH, Romano PS, Zhou H, Rodrigo J, Bargar W. Incidence and time course of thromboembolic outcomes following total hip or knee arthroplasty. Arch Intern Med. 1998;158:1525–31.
78. Lindahl H, Oden A, Garellick G, Malchau H. The excess mortality due to periprosthetic femur fracture. A study from the Swedish national hip arthroplasty register. Bone. 2007;40:1294–8.
79. Beals RK, Tower SS. Periprosthetic fractures of the femur. An analysis of 93 fractures. Clin Orthop Relat Res. 1996;327:238–46.
80. Lewallen DG, Berry DJ. Periprosthetic fracture of the femur after total hip arthroplasty: treatment and results to date. Instr Course Lect. 1998;47:243–9.
81. Lindahl H, Malchau H, Herberts P, Garellick G. Periprosthetic femoral fractures classification and demographics of 1049 periprosthetic femoral fractures from the Swedish National Hip Arthroplasty Register. J Arthroplasty. 2005;20:857–65.
82. Schwartz JT Jr, Mayer JG, Engh CA. Femoral fracture during non-cemented total hip arthroplasty. J Bone Joint Surg Am. 1989;71:1135–42.
83. Berry DJ. Epidemiology: hip and knee. Orthop Clin North Am. 1999;30:183–90.
84. Lindahl H, Garellick G, Regner H, Herberts P, Malchau H. Three hundred and twenty-one periprosthetic femoral fractures. J Bone Joint Surg Am. 2006;88:1215–22.
85. Kim KI, Egol KA, Hozack WJ, Parvizi J. Periprosthetic fractures after total knee arthroplasties. Clin Orthop Relat Res. 2006;446:167–75.
86. Su ET, DeWal H, Di Cesare PE. Periprosthetic femoral fractures above total knee replacements. J Am Acad Orthop Surg. 2004;12:12–20.
87. Healy WL, Siliski JM, Incavo SJ. Operative treatment of distal femoral fractures proximal to total knee replacements. J Bone Joint Surg Am. 1993;75:27–34.
88. Inglis AE, Walker PS. Revision of failed knee replacements using fixed-axis hinges. J Bone Joint Surg Br. 1991;73:757–61.
89. Ritter MA, Faris PM, Keating EM. Anterior femoral notching and ipsilateral supracondylar femur fracture in total knee arthroplasty. J Arthroplasty. 1988;3:185–7.
90. Bozic KJ, Kamath AF, Ong K, Lau E, Kurtz S, Chan V, et al. Comaprative epidemiology of revision arthroplasty: failed THA poses a greater clinical and economic burden than failed TKA. Clin Orthop Relat Res. 2015;473(6):2131–8.
91. Jacobs JJ. United States Bone and Joint Initiative. The burden of musculoskeletal diseases in the United States: prevalence, societal and economic cost. Rosemont: © American Academy of Orthopedic Surgeons; 2008.
92. Marwar S, Girardi FP, Sama AA, Ma Y, Gaber-Baylis LK, Besculides M, et al. National trends in anterior cervical fusion procedures. Spine (Phila Pa 1976). 2010;35:1454–9.