Epidemiology, trends, and disparities in regional anaesthesia for orthopaedic surgery

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**Abstract**

Recent studies have linked the use of regional anaesthesia to improved outcomes. Epidemiological research on utilization, trends, and disparities in this field is sparse; however, large nationally representative database constructs containing anaesthesia-related data, demographic information, and multiyear files are now available. Together with advances in research methodology and technology, these databases provide the foundation for epidemiological research in anaesthesia. We present an overview of selected studies that provide epidemiological data and describe current anaesthetic practice, trends, and disparities in orthopaedic surgery in particular. This literature suggests that even among orthopaedic surgical procedures, which are highly amenable to regional anaesthetic techniques, neuraxial anaesthetics and peripheral nerve blocks are used in only a minority of procedures. Trend analyses show that peripheral nerve blocks are gaining in popularity, whereas use of neuraxial anaesthetics is remaining relatively unchanged or even declining over time. Finally, significant disparities and variability in anaesthetic care seem to exist based on demographic and health-care-related factors. With anaesthesia playing an increasingly important part in population-based health-care delivery and evidence indicating improved outcome with use of regional anaesthesia, more research in this area is needed. Furthermore, prevalent disparities and variabilities in anaesthesia practice need to be specified further and addressed in the future.

**Key words:** anaesthesia; anaesthesia, spinal; epidemiological data; epidemiology; healthcare disparities; regional anaesthesia; trends

Although regional anaesthesia has been part of perioperative medicine for more than a century, recent studies have sparked new enthusiasm for this practice by supporting the notion that regional anaesthetic techniques can have significant impact on perioperative and perhaps even long-term outcomes. Despite these developments, traditional epidemiological research in this field remains sparse and lags behind that available in most other medical specialties. As such, epidemiological data on utilization, trends in practice, and disparities in care are needed in order to define the current scope of practice, track its development, specify factors affecting its use, and identify whether disparities in its provision exist between various parts of the population. With evidence of improved outcomes attributable to the use of regional anaesthesia, potential underutilization among patient populations should be addressed. In this context, important population-based research has suggested that patients receiving neuraxial vs general anaesthesia (GA) can have improved medical and economic outcomes, including fewer
adverse respiratory events, infections, blood transfusions, and intensive care unit admissions.1-3 This review provides an overview of currently available evidence in this field by sequentially addressing the epidemiology, utilization, trends, and disparities in care related to regional anaesthesia. The focus is on orthopaedic surgery, for which most solid data are available because patients undergoing orthopaedic procedures of the extremities are representative of the surgical population and uniquely amenable to regional anaesthetic approaches.

**Anaesthesia-related epidemiological research**

Epidemiological research is important to define practice patterns, study trends, and identify disparities in health care. In order to gain valuable insights into these and other related areas, access to information from large patient cohorts representative of all or significant parts of the population and linkage to specialty specific data points is needed. Although large data-collection constructs have existed for decades, including those administered by governmental agencies such as the Centers for Disease Control and Prevention, such information was traditionally difficult to access, analyse, and interpret. Most importantly, such databases are primarily designed for administrative purposes, routinely lack detailed clinical information, and are almost devoid of relevant anaesthesia-related data fields. Thus, information defining anaesthesia-related practice patterns and trends was, in the past, difficult to come by and frequently limited to representative single-institutional and academic practice data. Furthermore, analysis of large databases was inhibited by the lack of appropriate methodology and computing power. More recently, database administrators and designers have understood the importance of anaesthesia-related factors in clinical epidemiological research, and such information is now available in a number of data sets. Advances in methodological research and technology have facilitated the manipulation of very large data sets by a larger number of researchers.

One of the earliest nationally representative surveys to collect anaesthesia type and provider information was the National Survey of Ambulatory Surgery (NSAS), which was initially conducted between 1993 and 1996 by the Centers for Disease Control and Prevention.4 The goal of the survey was to answer important questions regarding ambulatory care in the USA, which had increased dramatically in an era driven by cost-effectiveness endeavours. Realizing that anaesthesia-related factors are major determinants of medical and economic outcomes, this information was included with specific data fields, such as anaesthesia type and provider (physician vs nurse anaesthetist).4

With limited clinical information available in administrative data sets, initiatives with more clinical focus, such as the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP), have expanded the range of perioperative epidemiological research.6 Containing, among other important clinical variables, information on the type of anaesthesia, the ACS-NSQIP has spurred the ASA endeavour to collect anaesthesia-specific data on a large scale. As a consequence, the Anaesthesia Quality Institute (AQI) is administering the National Anaesthesia Clinical Outcomes Registry (NACOR), a data-collection construct that encompasses data from various clinical settings throughout the country, with important research emerging from its use.9 10 This database is still evolving as it addresses issues such as uniform and complete reporting among participants and the availability of solid outcome data. Further sources of data for anaesthesia-related epidemiological research are provided by commercial vendors, such as Premier Perspective Inc., which makes anaesthesia-related information available through the provision of billing codes.11 12 Important recent analyses have also used data from the New York State’s Department of Health State-wide Planning and Research Cooperative System (SPARCS).13 14

These sources by no means represent an exhaustive list of databases for anaesthesia-related research, because other national and international constructs exist, such as insurer-based projects; nonetheless, they do represent a group of data sets from which many recent anaesthesia-related epidemiological studies have borrowed data. The Global Orthopaedic Registry (GLORY), for instance, as an international registry, enables the investigation of practices and outcomes in elective orthopaedic surgery within 13 participating countries,15 and the National Hip Fracture database of the UK allows the evaluation of quality and outcomes in care provided by the National Health Service.16 This database is managed by the Clinical Effectiveness and Evaluation Unit of the Royal College of Physicians.17

Although many outcome studies have been based on the data collected, the ability to perform epidemiological studies including utilization, disparities, and trend analyses assumes that all contain at least some information representative of a significant part of the population. Moreover, they include multiyear files allowing for trend analysis and specify demographic information regarding race, gender, and socioeconomic status, in addition to regional aspects allowing for the analysis of disparities in care.

While providing many advantages and opening new possibilities, one has to mention the significant limitations associated with the use of secondary large data sets for clinical research, the details of which have been discussed extensively.8 In brief, the retrospective nature of the data and the limited number of clinical variables collected can result in significant confounding. As such, many important clinical details, such as haemodynamic data, are missing. Coding bias and completeness of the data collected are additional concerns. Furthermore, only associations rather than causalities can be determined, thus limiting the value of results. Therefore, reasons for interventions and outcomes can only be speculated on, and considerable uncertainty regarding cause and effect remains.

Nevertheless, the value for epidemiological research, which in terms of the analyses of trends and utilization patterns tends to be descriptive in nature, remains high and forms the basis of much of the information presented in this review. Future advances, including those related to more specialty-specific data design and research methodology, will certainly improve many of the shortcomings of today’s databases and the research they produce. Endeavours such as specialty registries for regional anaesthesia and multicentre collaborations, such as the Multicenter Perioperative Outcomes Group, which uses electronic
Regional anaesthesia in orthopaedics

Epidemiology and utilization of regional anaesthesia

The growing demand for orthopaedic surgeries has increased interest in regional anaesthesia because these procedures are highly amenable to related techniques.22 23 Moreover, evidence has linked the use of regional anaesthesia to beneficial medical and economic outcomes.24 25 Advantages attributed to the use of regional anaesthesia in orthopaedics cover a wide spectrum of perioperative outcomes. Studies have shown that neuraxial anaesthesia (NA) can positively impact haemodynamics and reduce blood loss.26 27 Surgical injury is followed by profound endocrine, metabolic, and inflammatory responses that in turn trigger pathological events related to postoperative morbidity. Neuraxial anaesthesia can block afferent stimuli from surgical tissue injury and therefore blunt the neuroendocrine stress response.28–30 Moreover, studies have associated neuraxial block with a decrease in mortality and other serious complications, and concurrently assigned economic benefits to this technique.8 31 Likewise, peripheral nerve blocks (PNBs) have superior results in terms of pain management, with significantly reduced opioid requirement.32 Other reported benefits are reduced risk for nausea and vomiting, superior recovery profile, diminished utilization of resources, and shorter times to discharge.24 33–35

While the wider impact of regional anaesthesia has remained at the forefront of academic debates, little attention has been paid to the generation of data on the nationwide utilization of these techniques. Some insight into the practice of regional anaesthesia has been obtained because of the emergence of large population-based studies containing anaesthesia-related information. We present an overview of selected studies that provide epidemiological data and describe current anaesthetic practice in the context of orthopaedic surgery (Table 1).

Neuraxial anaesthesia

A number of population-based studies have examined the differential perioperative outcomes with the use of NA and concurrently presented valuable data on patterns of utilization.1 8 9 12 14–16 36 37 39 43–49

<table>
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<th>Year</th>
<th>Study</th>
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<th>From</th>
<th>To</th>
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<th>NA (%)</th>
<th>PNB (%)</th>
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A more recent study on knee arthroplasties by Fleischut and colleagues\(^5\) showed significant variation in the use of anaesthesia techniques based on patient and provider characteristics. The research team used data from the NACOR AQI, the largest US national anaesthesia-specific database, and identified 108 625 TKA patients between 2010 and 2013. In this population, 42.1% of procedures were performed under regional anaesthesia, and most patients received GA. The NACOR database was established by the AQI in 2009 as an instrument for performance measurement, quality management, and outcomes-based research particularly in the field of anaesthesiology.\(^52\) Nonetheless, this project has not been without criticism because many data fields are incomplete and the ability to study outcomes is thus far limited.

Using data from the commercially available Premier Perspective Inc. database, Stundner and colleagues\(^4\) studied patients undergoing simultaneous bilateral TKA. Here, the utilization of GA appeared to be higher than in the previously mentioned studies. Of 15 687 patients, GA was administered to 80.1% and NA was used in 19.9% of patients. Premier Perspective Inc. captures healthcare-related information from more than 3000 US hospitals through coding of billable items.\(^11\) In another study of comparative effectiveness, Memtsoudis and colleagues\(^4\) investigated THA and TKA collectively. They analysed 382 236 THA and TKA patients between 2006 and 2010 from Premier Perspective Inc. They found a lower utilization rate for NA in this population compared with findings from ACS-NSQIP and NACOR AQI throughout similar time periods. In this population, NA was performed in only 25.2% of the patients, whereas GA was administered to the majority. This variability in reported utilization rates of anaesthesia techniques among different data sources reflects potential differences between US hospitals captured by different data constructs. In a subgroup analysis of the same data set, Memtsoudis and colleagues\(^12\) focussed on THA and TKA patients diagnosed with sleep apnoea, and likewise, found that NA was used in the minority of patients. Considering recommendations by the ASA Practice advisory to prefer regional anaesthesia in sleep apnoea patients, the fact that more than three-quarters of these patients underwent GA is rather surprising.\(^43\) This is important, because evidence has shown that regional anaesthesia is associated with lower postoperative opioid-related distress scores,\(^45\) a factor of immediate relevance to patients with sleep-disordered breathing, who are thought to be more sensitive to narcotic agents. Thus, perioperative management of sleep apnoea deserves further discussion and attention because the prevalence of this co-morbidity is estimated to involve a quarter of the surgical patient population and appears to be particularly high in orthopaedics.\(^56\)

A more international perspective is offered by the GLORY, which enrolled 15 020 THA and TKA patients from 100 hospitals in 13 countries (Australia, Brazil, Bulgaria, Canada, Columbia, Germany, Italy, Japan, Poland, Spain, Turkey, UK, and USA).\(^15\) Pooled data showed that for THA, GA was administered to 51% of patients, spinal anaesthesia was given to 41%, and epidural anaesthesia was administered to 14%. In TKA, however, data from the registry revealed that GA was used in 43% of patients, spinal anaesthesia in 46%, and epidural anaesthesia in 20%. The GLORY is a physician-directed registry that was created to examine practices and outcomes in elective orthopaedic surgery. Overall, it appears internationally that use of GA may be lower and the utilization of NA higher compared with US data.

Although not sufficient to reflect nationwide patterns, findings by Chang and colleagues\(^47\) differ substantially from other reported data. The authors studied 3081 THA and TKA patients from the Longitudinal Health Insurance Database of Taiwan. From 2002 to 2006, they found that NA was administered in 61.3% of patients and GA was used in the minority. General anaesthesia was associated with a higher risk for surgical site infections.

### Hip fractures

Neuman and colleagues\(^45\) investigated 18 158 hip fracture patients from 2007 to 2008 using the New York State Inpatient Database. Their results showed that 29% of procedures were performed with regional anaesthesia and more than two-thirds of patients received GA. After statistical analysis, regional anaesthesia was associated with lower odds for inpatient mortality and pulmonary complications. Two years later, the same research team studied mortality and length of hospital stay in hip fracture patients aged 50 yr or older.\(^14\) Using data from the SPARCS database, they identified 56 729 hip fracture patients between 2004 and 2011. Findings in terms of anaesthesia techniques were almost identical to their previous study, with a 28% utilization rate for NA. However, mortality was not different between GA and regional anaesthesia. SPARCS is a comprehensive all-payer data-reporting system, initially established in 1979 in a cooperation between the health-care industry and government. The database aggregates information on patient characteristics, diagnoses and treatments, services and charges from different facility types, including hospital inpatient and ambulatory surgery, in New York State.\(^13\)

Other researchers confirmed the results of Neuman and colleagues in 6133 hip fracture patients from the ACS NSQIP database.\(^3\) Fields and colleagues\(^37\) reported a utilization rate of 27.4% for spinal anaesthesia from 2010 to 2012, with the remaining procedures performed under GA. Utilization of regional anaesthesia in hip fractures was very similar even two decades earlier according to O’Hara and colleagues.\(^48\) who identified 6206 procedures from 20 metropolitan hospitals in the USA in patients aged 60 yr or older. They found that NA was used in 34.2% of the procedures, suggesting that GA was the preferred technique. Although containing information of more historical value, this analysis did not show any differences in mortality and morbidity according to anaesthesia technique. However, data from Premier Perspective Inc. showed significantly lower utilization of NA in 73 284 patients with hip fracture.\(^39\) The authors found that 84% of the procedures between 2007 and 2011 were performed under GA, and regional anaesthesia was administered in <20% of the patients.

Data on global use of regional anaesthesia techniques is very sparse. A survey from the UK reported fairly different patterns from those found in the USA.\(^46\) In 1195 patients with hip fracture from 22 hospitals of the Hip Fracture Anaesthesia Network, White and colleagues\(^46\) reported that NA was administered to 49% of patients, 51% received GA, and 19% received a PNB. In 2012, the National Health Service Hip Fracture Anaesthesia Network of England, Wales, and Northern Ireland extended its data set to include anaesthesia information. After this inclusion, White and colleagues\(^46\) were able to identify 59 191 patients with hip fracture from January to December 2012 with recorded anaesthesia modality. Consistent with their previous survey, they found that GA was used in 53.9% of patients, with the remaining patients being treated with NA. Among those receiving
GA, ∼7% also received spinal or epidural anaesthesia, suggesting that NA was performed in more than half. Considering the annual rate of hip fractures in England and Wales of 70,000, these data from initially 65,535 recorded instances from the National Hip Fracture Database within 2012 are highly representative of the nationwide utilization of anaesthesia in this particular surgery. These findings indicate that in hip fracture patients the practice of clinical anaesthesia appears shifted towards regional anaesthesia in the UK compared with the USA, where GA was used at a significantly higher rate for these fractures.

Patterns seem to differ even more substantially in Sweden according to Holmström and colleagues, who investigated utilization of NA about two decades ago using a nationwide survey. Questionnaires were sent to all 105 anaesthesia departments in Sweden, with a response rate of 64.6%. Interestingly, utilization of GA for patients undergoing THA, TKA, and hip fracture repair was similar to that found in patients with hip fracture in the UK (58.1, 43.5, and 58.1%, respectively); however, use of NA was higher than in the UK and substantially higher than utilization reported in the USA at 74.1, 59.7, and 80.6% for THA, TKA, and hip fracture, respectively.

Peripheral nerve blocks

Data on patterns of utilization of PNBs in orthopaedic surgery are less available than for other regional anaesthetic techniques. In shoulder arthroplasty, evidence has suggested that PNBs added to GA are highly effective for anaesthesia and analgesia and can significantly reduce the need for systemic analgesics while facilitating improved rehabilitation and earlier discharge. Stundner and colleagues studied use of PNBs in 17,157 total shoulder arthroplasty patients using data from Premier Perspective Inc. Peripheral nerve blocks were administered in 21% of the patients between 2007 and 2011; analysis did not reveal any difference in complication risk but a trend towards shorter length of stay. Using the same database, Danninger and colleagues identified in 27,201 ambulatory rotator cuff repair patients a PNB utilization rate of 15.4%, which was combined with GA. The authors concluded that the use of PNBs in addition to GA reduced the need for postoperative hospital admissions after ambulatory surgery.

Mentzos and colleagues investigated the risk for inpatient falls by anaesthesia type after TKA. They identified 191,570 patients between 2006 and 2010 in the Premier Perspective Inc. database. Peripheral nerve blocks were administered to 12.1% of patients, and despite common concerns, no association was established between the use of PNBs and inpatient falls. The authors concluded that the lack of association to common used fall-prevention programmes and other preventative practices. Likewise, PNBs were used in 10.9% of 108,625 patients undergoing TKA identified by Fleischut and colleagues in the NACOR AQI database. In 59,191 hip fractures, White and colleagues reported that PNBs were administered in ∼23.2% of patients as adjuncts to GA, and 6.7% received PNBs together with spinal anaesthesia.

Variability in care

Significant variation in anaesthetic care for THA, TKA, and hip fracture surgery exists. Although GA is the predominant approach in the USA, rates of NA are higher in European countries. Further research is needed to provide explanations for these differences, particularly with mounting evidence of favourable outcomes related to regional anaesthesia. While the data discussed may represent true variation in care, one has to consider that different databases include different hospital universes and collect information for different purposes, perhaps explaining some of the variability. Administrative data, such as that of Premier Perspective Inc., is collected with the purpose of generating revenue and not for clinical or research purposes, and information is coded to standardize billing practices. Despite quality assurance, these data tend to show bias towards billable diagnoses. Other limitations result from possible coding errors, lack of clinical detail, and temporal information. These limitations are less frequent in registries because they usually collect data of high accuracy that is mostly intended for quality improvement and research. However, registries are usually expensive and often encompass smaller populations.

With evidence assigning beneficial outcomes to the use of PNBs, it is surprising that their utilization is fairly low. Peripheral nerve blocks have been shown to reduce opioid requirement, improve postoperative recovery, and decrease time to discharge. However, the lack of evidence regarding causal relationships has presumably fed controversies over the real benefits of regional anaesthesia and analgesia. Furthermore, as presented by Hadzic and colleagues in a nationwide survey among practicing anaesthetists, adequate training and clinical skills are crucial for the choice of anaesthesia pathway in clinical practice. Although NA appears to be well covered in residency programmes, this may be less true for PNBs. In the USA, for example, the Accreditation Council for Graduate Medical Education programme requires residents to perform 40 spinals, 40 epidurals, and 40 PNBs during their training. In contrast to NA, however, there is significant heterogeneity regarding anatomy, difficulty, and success rates within the spectrum of PNBs. Consequently, NA may be performed more readily, whereas PNBs pose a challenge because of their diversity. Furthermore, studies have demonstrated challenges in implementing changes in health care, despite evidence supporting change, with obstacles including traditional preferences and lack of resources, knowledge, and skills.

Trends

Despite a dramatic increase in orthopaedic surgical procedures over the past decades and expectation of continued growth, information on temporal changes in terms of anaesthesia techniques in this patient population remains rare. Over the years, the emergence of new medications, technology, and knowledge has revolutionized perioperative medicine, and as a consequence, interest in how these changes affect anaesthetic care and practice has emerged. Among the most defining changes in health care is the move of many procedures from an inpatient to an outpatient setting, with significant impact in anaesthesia demands.

Inpatient surgery

Many of the outcome studies presented in the foregoing sections contain valuable information on temporal trends, because the adjustment for practice changes over time has become virtually mandatory for any database study focusing on outcomes. For example, among others, Fleischut and colleagues demonstrated that TKA was disproportionately performed under GA, with a significant increase in utilization of PNB from 9.7% in 2010 to 16.1% in 2013. Likewise, Mentzos and colleagues demonstrated that among 191,570 TKA patients identified in the Premier Perspective Inc. database, use of PNBs increased from 12.4% in 2006 to 24.8% in 2010.
A preliminary analysis on trends in the use of regional anaesthetic techniques among THA and TKA patients, using data from the Premier Perspective Inc. between 2006 and 2013, showed that the utilization of NA decreased from 21.4 to 18.6% in THA patients and from 24.7 to 20.1% in TKA patients (Fig. 1). On the contrary, the opposite trend applied to PNBs, in that their utilization increased from 9.1 to 9.5% in THA patients and from 15.3 to 24.5% in TKA patients (Fig. 2).

**Ambulatory surgery**

Changes in anaesthetic care in ambulatory surgery might be affected by different drivers compared with inpatient surgery. Memtsoudis and colleagues71 investigated changes in ambulatory knee and shoulder surgery between 1996 and 2006 by using the NSAS database. Apart from the evident increase in surgical volume over the decade, they report a significant increase in utilization of PNBs from 0.6 to 9.8% for meniscectomies, from 1.5 to 13.7% for ligamentoplasties, and from 11.5 to 23.9% for shoulder arthroscopies. Utilization of NA decreased from 11.8 to 6.3% for meniscectomies and from 13.6 to 7.3% for ligamentoplasties from 1996 to 2006. The NSAS is conducted by the Centers for Disease Control and Prevention and provides information on ambulatory surgery in hospital-based and free-standing facilities. This programme receives data from Medicare-participating hospitals in all 50 states and the District of Columbia.72

Another study by Patel and colleagues72 investigated trends in ambulatory upper extremity fractures between 1996 and 2006 using data from the NSAS database. They demonstrated a significant increase of extremity fractures, with a 505% increase in the number of procedures performed at free-standing surgical centres compared with hospital facilities. Although GA remained the predominant technique over the decade, utilization of PNBs increased from 16.6% in 1996 to 20.6% in 2006. This study confirms the shift in anaesthesia practice towards regional anaesthesia.

**Changes in regional anaesthesia care over time**

Evidence indicates increased utilization of PNBs over the last two decades in both inpatient and ambulatory orthopaedic surgery. Use of PNBs for knee arthroplasties increased by two-fold, and this change was even higher in ambulatory knee and shoulder arthroplasties.60 71 Considering the growing evidence in favour of regional anaesthesia, these observations are not surprising because their potential advantages have probably encouraged wider implementation.62 63 73–76 Among the many reasons for these trends are certainly improvements in anaesthesia technology, including the evolution of ultrasound-guided regional anaesthesia.77–79 In this context, recommendations by the American and European societies of regional anaesthesia and pain medicine to train residents and physicians in ultrasound-guided regional anaesthesia have probably promoted the increased administration of PNBs.80

Interestingly, utilization of NA appears to be decreasing in both inpatient and ambulatory orthopaedic surgery. Reasons for such trends may be multifactorial, but the advent of short-acting i.v. anaesthetics and introduction of the laryngeal mask airway make GA a feasible alternative even for short procedures. Neuraxial anaesthesia, with its often fixed time of action, can be less desirable. Furthermore, factors such as younger age among ambulatory patients can predispose them to adverse events, such as postdural puncture headache. Other factors, such as urinary retention and transient neurological symptoms, should also be considered. Use of lidocaine in connection with early ambulation has been associated with transient neurological symptoms and possibly contributed to the decrease in ambulatory spinala.81–83 Reduced use of NA might also be explained by increased utilization of PNbs, which can achieve many of the goals of NA in terms of providing analgesia and analgesia to the operative limb while avoiding instrumentation of the neuraxis, which is associated with rare but potentially devastating consequences.84 However, in the absence of conclusive data, reasons for observed trends have to remain speculative, and more research is required to establish driving factors.

**Disparities in regional anaesthetic care**

Disparities in health care represent a major health-care challenge because they are prevalent in settings ranging from...
prostate cancer screening and treatment to emergency medical services in stroke patients.95 96 Fewer data are available for the anaesthesia setting, with the exception of the demonstration of racial and ethnic disparities in pain treatment and in neuraxial analgesia for labour.97 98 As large national databases containing anaesthesia-related information become increasingly available, such research is now possible and necessary to assess whether significant differences in care and the potential for disparities related to patient and hospital factors do indeed exist. For example, one study assessing utilization of NA in ambulatory hernia repair found that Black patients were 64% less likely to receive epidural anaesthesia compared with White patients.99 Comparable studies would be particularly important in the setting of orthopaedic surgery because these interventions are increasing in frequency and are amenable to regional anaesthetic techniques.100 Disparities in surgical care among the orthopaedic population have been demonstrated, because the odds of undergoing THA or TKA and related outcomes after these procedures are worse for Black patients and those on Medicaid.101 As anaesthetic care is among the important factors influencing postoperative outcome, these findings suggest potential disparities in this setting. To date, there are no large-scale studies that focus on disparities in regional anaesthetic care for orthopaedic surgeries. However, while focusing on outcomes, several studies provide information on disparities in that they show stratification of anaesthesia type by demographics. A study using Premier Perspective Inc. data for 382 236 patients with recorded anaesthesia type undergoing THA by demographics. A study using Premier Perspective Inc. data for 382 236 patients with recorded anaesthesia type undergoing THA and TKA showed NA to be used in 17% of Black patients compared with 25% of White patients.102 Using the same database but in 73 284 hip fracture surgeries, Patorno and colleagues103 also found a difference, albeit less pronounced; white patients received regional anaesthesia at a rate of 16%, compared with 13% in Black patients.

Findings depend on the database used, because none of the large databases containing anaesthesia information represent the entire US population. Using data from the ACS NSQIP, Helwani and colleagues104 demonstrated utilization of regional anaesthesia in THA (n=12 929; 2007–2011) to be lower in White (37%) vs non-White patients (48%). Differences by gender appear less pronounced; white patients received regional anaesthesia at a rate of 16%, compared with 13% in Black patients.

Reasons for disparities in anaesthetic care

There are numerous potential explanations for disparities in care, including patient characteristics, differences in health insurance, geographical proximity to care, or insufficient literacy and knowledge.105 Hospital policies and patient and physician preferences are factors that are frequently overlooked. These factors may explain some of the racial, ethnic, and gender disparities in use of health-care resources. For example, one can compare a particular hospital with relatively many minority patients that does not offer regional anaesthesia services for THA and TKA with a hospital that has relatively few minority patients and provides regional anaesthesia for the majority of hip and knee patients. Data from these two hospitals might lead to the conclusion that minority patients have lower odds of receiving regional anaesthesia because of disparities, whereas the main driver is the difference in institutional practice. These differences in care have been shown in many circumstances and also exist in the setting of anaesthesia. Figure 3 shows the difference in percentage use of PNBs in THA and TKA between hospitals in a large US claims-based database (2006–2013, n=1 062 152; Premier Perspective Inc.). Likewise, variability in regional anaesthetic care among populations has been reported from the NACOR AQI.106 In this study of 108 625 patients undergoing TKA where type of anaesthesia was recorded, relative to GA, when NA or PNB was administered, the anaesthetist was more frequently board certified. Physician certification status can differ greatly between hospitals. In addition, other hospital-related factors have been demonstrated to influence differences in regional anaesthetic care. Fleischut and colleagues107 108 describe a higher utilization of NA and PNB in university hospitals (compared with medium-sized hospitals), while hospitals in the Midwest had the highest utilization of regional anaesthesia. Studies using other databases also provide information on this issue. An investigation using the Premier Perspective Inc. database showed the highest utilization of PNBs in TKA patients to be in medium-sized hospitals (16%) and non-teaching hospitals (14%) use and non-teaching hospitals (14%) use. Another study using the same database on 73 284 hip fracture surgeries found regional anaesthesia to be used more often in non-teaching hospitals (19% use) vs teaching hospitals (10% use).109 These studies highlight that hospital factors play a role in utilization of regional anaesthetic techniques; this might differ depending on the procedure of interest.

Patient and physician attitudes and preferences might also play an underappreciated role in the choice of regional anaesthesia. Although few studies have linked patient preferences to disparities in care, evidence exists on differential patient preferences by subgroup in this setting.110 Younger age, for example, is associated with choosing GA over other forms of anaesthesia among patients undergoing hernia repair surgery.111 Another study focusing on patient perceptions of anaesthesia in several

![Fig 3 Hospital variation of peripheral nerve block use.](https://academic.oup.com/bja/article-abstract/115/suppl_2/ii57/272903)
types of surgeries reported that female patients preferred GA, with the main factors being related to hearing and seeing the surgery and the fear of feeling pain. The disparities literature in obstetric analgesia also offers insights into this issue. One investigation found Hispanic women to accept NA less commonly than other groups. Given their potential role in differences in care and potential disparities, more research in the field of regional anaesthesia preferences in orthopaedic surgeries is needed. This seems particularly true for research that focuses on differential preferences related to factors traditionally identified in disparities research, e.g. race or ethnicity, insurance status, or socioeconomic status.

Summary and conclusions

The advent of large-database research has allowed investigators to gain insights into epidemiology-related questions in the field of anaesthesia. Although data are still rare and variable in quality, more research is clearly needed. Studies have identified that regional anaesthesia is used in a minority of orthopaedic patients in the USA, whereas utilization is higher in European countries. Low utilization seems surprising in the face of multiple reports that regional anaesthesia may be associated with better outcome. Regional anaesthesia practice has changed over time, with the use of PNBs increasing and NA stagnating among THA and TKA patients. The use of NA among ambulatory patients has decreased dramatically. Finally, significant disparities and variability in anaesthetic care seem to exist and require further study. In conclusion, the nascent field of epidemiological research in anaesthesiology has provided important information on anaesthetic practice at a population level. As anaesthetists will play an increasingly important part in the health-care delivery of entire countries, the need for evidence-based anaesthesia at a population level is evident. The disparities literature in anaesthesia for hip fracture surgery. An observational audit of 65,535 patients: an evidence based review. Br J Anaesth 2013; 111: 532–4


D’Angelo R, Smiley RM, Riley ET, Segal S. Serious complications related to obstetric anesthesia: the serious complication repository project of the Society for Obstetric Anesthesia and Perinatology. Anesthesiology 2014; 120: 1505–12

Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the

Authors’ contributions

All authors designed the manuscript, reviewed and approved the final document.

Declaration of interest

S.G.M. is a non-paid consultant for B. Braun. Other authors have no interests to declare. The sponsors had no role in the design and conduct of the study, collection, management, analysis, and interpretation of the data, nor in preparation, review, and approval of the manuscript.

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References


22. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the
randomized, triple-masked, placebo-controlled study. Anesthesiology 2006; 105: 999–1007
64. Austin PC. An introduction to propensity score methods for reducing the effects of confounding in observational studies. Multivariate Behav Res 2011; 46: 399–424
66. Corvetto MA, Echevarria GC, Espinoza AM, Altermatt FR. Which types of peripheral nerve blocks should be included in residency training programs? BMC Anesthesiol 2015; 15: 32
88. Papaioannou A, Fraidakis O, Michaloudis D, Balalis C, Askitopoulou H. The impact of the type of anesthesia on...

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