Epidemiology and burden of prosthetic joint infections

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Whilst improvements in patient care have reduced the risk of infection in patients undergoing prosthetic joint surgery, the substantial and growing number of hip and knee arthroplasty procedures undertaken translates into a continued and potentially increasing burden on patients, healthcare providers and the wider economy. Increases in patient obesity will raise further challenges to prevention efforts given the associated elevated risk of infection. Ongoing monitoring of infection rates remains a critical means to identify and address local and national changes in the epidemiology of prosthetic joint infection and to assess the impact of interventions.

Keywords: surgical wound infection, hip prosthesis, knee prosthesis

Introduction

The advancement of surgical practice has unquestionably brought immense improvement to our quality of life. For an ageing population, hip and knee arthroplasty provide mobility and relief from pain and discomfort for patients with a range of musculoskeletal disorders. For these benefits to be realized, the occurrence of potential complications needs to be minimized. Infection represents one such threat, which not only undermines the success of surgery but can leave patients in a far worse condition than their pre-operative state.

Burden of infection

Improvements in perioperative care, including skin preparation, antibiotic prophylaxis and wound management, have led to substantial reductions in the risk of infection. As replacement or resurfacing of the hip or knee joint are the more common joint arthroplasties performed, our understanding of the risk of infection is far greater in these patients than for other types of surgery. Amongst European countries participating in ECDC’s surveillance network (HAI-Net), infection rates average at 0.8% for patients undergoing knee replacement and 1.2% for hip replacement, with considerable variation in rates between countries.1 Whilst standard case definitions are adopted by participating countries,2 broadly based on those developed by CDC,3 variations in SSI rates are nonetheless partly due to methodological differences in case ascertainment, in particular the methods employed to identify infections arising post-discharge. Incidence density measures offer a means of standardization by calculating rates of infection according to the total follow-up time (number of days in hospital post-surgery), although this is only helpful for types of surgery where a sizeable proportion of infections arise during the inpatient stay. Differences in patient populations undergoing joint arthroplasty, reflecting different approaches to the clinical management of underlying conditions, could also serve to affect the infection rates observed.4

Whilst the risk of infection in patients undergoing joint arthroplasty is low, the high frequency of these procedures translates these low risks into a substantial burden of infection. National surveillance data submitted to the Health Protection Agency (now Public Health England) Surgical Site Infection Surveillance Service for patients undergoing surgery in the 2010/11 financial year in England identified 0.78% and 0.66% of hip and knee replacement patients to have developed SSI as detected during their inpatient stay or on readmission to hospital within 1 year of surgery (unpublished observations). Within England and Wales, data from the National Joint Registry indicate that ~80,000 hip and ~85,000 knee replacements were carried out in 2011.5 As such, the relatively low infection risk equates to a sizeable number of infections. This was evidenced by the point prevalence survey in England in 2011, which identified orthopaedics/trauma as the most common source of SSIs detected among inpatients, despite a considerably lower infection risk compared with other types of surgery.6,7 Data from countries participating in the Organisation for Economic Co-operation and Development (OECD) provide longitudinal trends in healthcare utilization across nations. These indicate marked increases in the numbers of hip and knee replacements undertaken in many countries over the past decade (Figure 1).8 In the USA and Denmark, population rates for knee replacement more than doubled between 2000 and 2009.8 If these trends are maintained, the public health burden of SSIs in these patients has the potential to increase further in the absence of any new interventions.

Adverse impact of infection

Whereas infection rates provide a sense of overall risk to patients undergoing arthroplasty, the true burden becomes apparent through assessment of the impact of these infections on both the patient and the hospital facility. At best, SSIs following hip
and knee replacement result in additional pain, discomfort, hospital stays and treatment. At worst, they can result in further re-operation, long-term disability and death. A small study from Australia assessed the longer-term impact of infection on several quality-of-life measures in patients undergoing hip and knee replacement and found substantial detriments to mobility, independent living and psychological health in patients whose surgery was complicated by infection. The impact of any infection will of course be highly dependent on the nature of the clinical interventions and timelines for successful resolution, with poorest outcomes associated with the most recalcitrant infections. As such, any increase in numbers of prosthetic joint infections due to antibiotic-resistant Gram-negative pathogens could potentially have a direct impact on the frequency of adverse surgical outcomes.

Data from the USA and the UK indicate that 23%–25% of revision procedures following knee arthroplasty are due to infection, making this one of the most common indications. A smaller yet sizeable proportion of hip revisions is also due to infection, estimated at 12%–15% in the USA and the UK. For surgical patients in England and Wales, this totals to >2200 revisions per year due to infection for hip and knee patients combined. Whilst many studies report on higher mortality rates in patients who develop SSI, few have demonstrated this whilst adjusting for patient comorbidity and surgical risk factors, presumably owing to the large study size required to do this. One such study in England that did undertake this assessment found the adjusted risk of death to be 2.5- and 7-fold higher in patients undergoing hip and knee replacement who developed a deep or organ/space infection.

Aside from the impact on patients themselves, the extended length of stay, readmissions and reoperations translate into considerable excess costs to the health economy. Costs of revisions due to infection are substantial and potentially several-fold higher than for other revision indications. An in-depth study from France measured the direct costs due to revision of infected hip prostheses and calculated these at just over €32,000 per patient, 3.6 times the cost of the primary procedure and 2.6 times the cost of revision for other indications. Multiplied by the total population of patients requiring revision of hip replacement as a result of infection, this represents a substantial burden on any healthcare economy.

**Epidemiology of infection**

Data from the national SSI surveillance programme in England illustrate the time course from surgery to infection up to the maximum 1 year follow-up (Figure 2). Of 1221 infections detected in 72000 patients having hip and knee replacement surgery in 2010/11 through inpatient, readmission and other post-discharge

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**Figure 1.** Trends in hip and knee replacement surgery across OECD countries. Data extracted from Figures 4.7.3 and 4.7.4, Health at a Glance 2011: OECD Indicators (http://www.oecd.org/els/health-systems/49105858.pdf). Hip data for 25 OECD countries; knee data for 21 OECD countries.

**Figure 2.** Onset of surgical site infection [infections detected during the inpatient stay or post-discharge (community-based surveillance or readmission/attendance hospital)] in patients undergoing knee and hip arthroplasty according to time since surgery, England 2010/11. Source: PHE Surgical Site Infection Surveillance Service.
methods, the majority of infections (85%) occurred within the first 30 days of surgery, with a median time to infection of 14 days. Of the infections detected over the first year, 42% were classified as superficial, 43% as deep incisional and 15% as organ/space infections, with superficial incisional infections only recorded within the first 30 days post-surgery. Long-term follow-up data from the USA illustrate the continued risk beyond the first year, with nearly one-quarter of infections following primary hip and knee arthroplasty diagnosed between 2 and 10 years post-surgery.

To fully understand the burden and characteristics of SSIs in hip and knee patients, clearly one must employ systems to collect data on infections diagnosed post-discharge. Duration of follow-up and methods for identifying cases fundamentally impact on not just the observed rates but also on the nature of the infections identified. Inclusion of infections identified through readmission to hospital improves detection of more serious, deep incisional or joint infections whereas the addition of infections identified by community healthcare providers or patients themselves improves recording of superficial infections.

**Causative pathogens**

As clinically defined events, only a proportion of post-surgical infections will be subject to microbiological sampling and yield a causative pathogen. Inclusion of non-laboratory-confirmed infections is essential to providing a comprehensive and comparable measure of incidence given the possibility of interhospital differences in sampling practice. However, understanding the distribution of causative pathogens provides invaluable evidence to direct prevention strategies at both local and national levels, including importantly the choice of antibiotic agents for prophylaxis. Based on studies capturing information on causative organisms, *Staphylococcus aureus* is typically the most common cause of SSI in patients undergoing hip and knee arthroplasty. National surveillance data for England indicated that 44% of microbologically confirmed SSIs detected within 1 year of surgery in patients undergoing hip/knee arthroplasty in 2010/11 were due to *S. aureus* infection (Figure 3), of which 20% were methicillin resistant. Coagulase-negative staphylococci also featured prominently (31%), with the remaining infections divided between enterococci (12%) and *Escherichia coli*, *Enterobacter* spp., *Pseudomonas* spp. and streptococci (7% each). Overall, 28% of infections were polymicrobial. Monitoring changes in the etiology of SSI has shown the impact of the introduction of successive pre-admission methicillin-resistant *S. aureus* (MRSA) screening and decolonization policies in England, initially for selected high-risk groups (2006) and then for all patients (2009). Between 25% and 30% of SSIs in hip/knee patients were due to MRSA prior to 2006, after which the proportion fell to 8% in 2010/11. Alongside a number of other interventions, these pre-admission screening policies are likely to have played a role in the substantial reductions in hospital rates of invasive MRSA infection in England.

**Risk factors for infection**

Whilst not all factors that increase the risk of SSI are amenable to modification, identifying and understanding the interplay between them is critical to the formulation of prevention strategies. Furthermore, the relative importance of these factors is by no means static given the evolving nature of surgical and infection control practice and the wider secular trends in our surgical population. As such, keeping abreast of changes in the relative impact of different independent risk factors is essential.

Surgical factors that influence the risk of infection have been well described and encompass a range of parameters affecting the likelihood of microbial contamination of the wound or development of infection given contamination. These include surgical technique, presence of tissue trauma, duration of operation, skin

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**Figure 3.** Distribution of organisms (the top 10 ranking organisms are identified to genus/species level) causing surgical site infection in patients undergoing knee and hip arthroplasty, England 2010/11. Source: PHE Surgical Site Infection Surveillance Service.
preparation, nasal decolonization, post-operative wound care and administration of antimicrobial prophylaxis (agents, dose and timing of administration). Despite its widespread adoption, the use of laminar air flow in surgical theatres as a means to reduce SSI in orthopedic patients remains controversial with some recent studies suggesting no added benefit despite its considerable cost. Further research is clearly needed to demonstrate its benefit to patients.

Numerous patient factors have been associated with risk of SSI in patients undergoing hip and knee replacement surgery, including pre-operative health (immune status, diabetes, nutritional status and smoking), colonization or active infection, age and male sex. National surveillance data from England for hip and knee replacement patients illustrate the elevation in SSI risk in both underweight and overweight patients (Figure 4), with obese patients (BMI ≥30 kg/m²) having a rate of infection double that of normal weight patients (BMI 18.5–24.9 kg/m²). Given that the average BMI of patients undergoing primary hip and knee replacement in England and Wales is increasing, reaching 28.6 and 30.6, respectively, in 2011, the attributable risk of infection due to obesity may increase substantially in the UK.

For multisite surveillance programmes where pooled SSI data are used to provide participating hospitals with a benchmark to compare themselves against, methods of adjusting for differences in the risk profiles of the operations included can be beneficial. The risk index developed by CDC’s National Nosocomial Infection Surveillance System programme, the predecessor to the National Healthcare Safety Network (NHSN), has been widely adopted for this purpose. This composite score is based on three major risk factors, namely the level of wound contamination, the duration of surgery and the patient’s pre-operative health as measured by the American Society of Anesthesiologists’ score. For hip/knee replacement patients in England, risk of SSI in patients scoring 0 on the risk index is considerably lower at 0.5% than for patients with a score of 1 (1.1%) or 2 and 3 combined (2.1%) (Figure 5). The ability of the NHSN risk index to effectively adjust for surgical complexity and case mix varies according to surgical category and ultimately it may not substantially alter the ranking of hospitals, depending on their heterogeneity.

Figure 4. Risk of surgical site infection in patients undergoing knee and hip arthroplasty according to BMI, England 2010/11. Source: PHE Surgical Site Infection Surveillance Service.

Figure 5. Risk of surgical site infection in patients undergoing knee and hip arthroplasty according to National Healthcare Safety Network risk index, England 2010/11. Source: PHE Surgical Site Infection Surveillance Service.

Conclusions

The increasing demand for knee and hip replacement in many nations serves to emphasize the importance of implementing strategies to minimize the risk of infection. Considerable variation in rates of infection between individual hospitals, beyond that which can be explained by case mix or other local variation, are still evident, suggesting more could be done to reduce the risk of infection. Integration of surveillance for post-operative infections into an infection prevention programme provides an essential platform for ensuring quality of patient care through timely identification and response to changes in infection rates. Our faith in surveillance to fulfil this function is dependent on the sensitivity and specificity of the signal generated as well as the responsiveness of local staff to departures from the expected rate of infection. Proactive education and promotion of surveillance within hospitals is essential for such a response to be generated.

Whilst surveillance offers an effective means to reduce the incidence of SSI, it requires considerable resources to maintain on an ongoing basis. The use of routinely collected data could revolutionize the comprehensiveness of surveillance coverage, bringing added benefits to patients with minimal additional cost to the health economy. Linkage of existing datasets to augment our current surveillance, already being realized, is central to the future public health strategy for England. In the absence of such solutions, an intelligent and considered approach to SSI surveillance that balances the need for a sensitive measure with the effort needed to generate this signal is essential. National SSI surveillance systems should be founded on this principle and provide hospitals with a robust infrastructure to monitor and compare their rates of infection in a cost-effective manner as well as generating evidence to inform future prevention strategies.

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