Received: 29 September 2022 | Accepted: 16 November 2022
DOI: 10.1111/iwj.14032

REVIEW ARTICLE

IWJ WILEY

A systematic review of cost and well-being in hip and knee replacements surgical site infections

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Abstract

This systematic review examined peer-reviewed literature published from 2010 to 2020 to investigate the health care system costs, hidden out-of-pocket expenses and quality of life impact of surgical site infections (SSIs) and to develop an overall summary of the burden they place on patients. SSI can significantly impact patients' treatment experience and quality of life. Understanding patients' SSI-related burden may assist in developing more effective strategies aimed at lessening the effects of SSI in financial and well-being consequences. Peer-reviewed articles on adult populations (over 18 years old) in orthopaedic elective hip and knee surgeries published from 2010 to 2020 were considered. Only publications in English and studies conducted in high-income countries were eligible for inclusion. A search strategy based on the MESH term and the CINAHL terms classification was developed. Five databases (Scopus, EMBASE, CINAHL, Medline, Web of Science) were searched for relevant sources. Reviewers categorised and uploaded identified citations to Covidence and EndNoteX9. Reviewers will assess article titles, abstracts and the full text for compliance with the inclusion criteria. Ongoing discussions between reviewers resolved disagreements at each selection process stage. The final scoping review reported the citation inclusion process and presented search results in a PRISMA flow diagram. Four main themes were extracted from a thematic analysis of included studies (N = 30): Hospital costing (n = 21); Societal perspective of health system costing (n = 2); Patients and societal well-being (n = 6) and Epidemiological database and surveillance (n = 22). This systematic review has synthesised a range of themes associated with the overall incidence and impact of SSI that can inform decision making for policymakers. Further analysis is required to understand the burden on SSI patients.

KEYWORDS
elective surgery, orthopedic surgery, out-of-pocket cost, quality of life, surgical site infections

Key Messages

- high prevalence and incidence rate of surgical site infection globally.
- body of research focuses on the significant economic impact on the overall healthcare system.
- common effects include multiple readmissions, time cost of carers and loss in employment power.
- SSI also imposes financial and quality-of-life consequences on patients.
- SSI experience in patients needs to be the focus of future research.

1 | INTRODUCTION

The World Health Organisation defines surgical site infections (SSI) as a form of health care-associated infection (HAI) after operative procedures. Superficial SSI develops within 30 days, while deep, organ or space SSI occurs up to 90 days post-surgery.[1] HAIs vary among procedures; common complications include wound, urine and blood infections, mainly caused by widely used antimicrobials, resulting in multi-resistance in microorganisms. In high-income countries, seven inpatients out of every 100, will experience at least one HAI, compared with 15 of 100 admissions in low- and middle-income countries.[2]

Despite being one of the most preventable HAIs, SSI continues to pose a significant global burden on morbidity, mortality and higher costs for health care systems and service payers. The rate of SSI in the first month is 12.3% globally, varying from 9.4% in high human development index (HDI) countries like the United Kingdom to 23.2% in low HDI countries like South Sudan.[3,4] Up to 20% of caesarean section patients in Africa suffer from a wound complication, risking their health and their capacity to care for newborns. Surgical site infection (SSI), which affects 3% of procedures,[5,6] is also one of the most frequent post-operative complications in Australia.[7] In high-income countries, hospitals detected 45% of SSI after discharge, leading to increased intentional follow-ups, revealing an additional increase in SSI incidences.[4,8]

The frequency of SSI varies significantly across countries and is greatly influenced by surgery performed. The highest infection rates for elective procedures in high-income countries like France were at 2.81% and 1.72% in gastrointestinal and gynaecological surgeries respectively.[9] In contrast, in the United States, obstetrics and gynaecology have the lowest infection rate of 0.06%.[10] Total joint arthroplasties in Europe and the United States are at an estimated incidence of 2.91% and 3.7%, respectively, with a rise in the severity of complications, as an increasing burden to older populations.[11] Based on a study[12] performed in acute care hospitals in England, the incidence rates for total hip replacement (THR) and hip hemiarthroplasty (HH) are 1.4 and 2.3 SSIs per 1000 post-operative hospitalisations respectively. Revision surgery associated with a 2.7% infection risk, which was noticeably higher than the 1.1% likelihood of infection in the initial surgery. The rate of THR and HH vary between hospitals; overall, the total incidence rates of SSI are 1.26% and 4.06% respectively. A Singaporean study[13] has examined the overall total knee arthroplasty infection rate was 1.10%.

Apart from general surgery, no recent studies specifically examined the financial and well-being scope for specific elective surgery such as orthopaedics. As the most common elective procedures in high-income countries like Australia, the incidence of total joint replacement is anticipated to rise by more than 208%.[14] Excluding the impact initiated by infections, orthopaedic elective surgeries will result in a total cost of AUD 5.32 billion (USD 3.7 billion) and AUD 3.54 billion (USD 2.43 billion) to the health care system and the private sector by 2030.[14] Beyond the existing cumulative SSI incidence of 1.3 and 2.4 per 100 in hip and knee procedures, elective orthopaedic procedure in Europe also exhibits a considerable positive trend in SSI risk index and anticipated incidence.[15] Despite the epidemiological results, risk factors and primary consequences reported for SSIs, a comprehensive systematic review is required to evaluate the measurements of well-being and financial burden outcomes associated with SSI for elective orthopaedic surgeries. Future preoperative and postoperative studies are necessary to compare and dissect the burden of SSI among orthopaedic arthroplasties.

It is also recognised that SSIs negatively impact hospitals and patients in terms of mortality, morbidity, leading to high health care costs as well as productivity loss in the health system.[4] More than 400 000 additional days are spent in the hospital by patients as a result of repeated readmissions caused by SSI, costing an additional USD 10 billion annually.[2] In high-income countries, hip replacements have an average of 21 per 1000 hospitalisations because of unplanned or unexpected public hospital readmissions within 28 days. Complications such as SSI is one of the main reasons.[16] The extra cost in elective surgeries ranges from 1.73 to 3.39 times higher in SSI patients.[17-19] Following total knee arthroplasty, SSI patients with periprosthetic joint infection (PJI) required multiple procedures, including debridement, implant removal and revision arthroplasty.[13] However, most studies associated patient cost contribution to extra follow-up episodes because of infection with the hospital payer point of view, reflecting limited research on the financial burden for patients on an individual level. A study in Spain[20] measured infection costs beyond the hospital viewpoint showing that SSI costs were associated with an estimated 78.7% of productivity costs, 10.8% of carer costs and 10.5% of health costs,[19,20] reflecting 90% of the cost related to the societal perspective in community care and productivity loss. Following elective surgery, a New Zealand study[21] found that SSIs also had a negative correlation with patients' quality of life and satisfaction ratings for up 60 days. Furthermore, research in the US[22] about postoperative SSI in abdominal surgery revealed gaps in the care pathway, especially after discharge, leading to the patient the sense of disconnection from health care providers. Significant physical and emotional impacts of infection on quality of life include pain, fluid leakage, readmissions and anxiety.

A comprehensive assessment of the current body of evidence is needed to identify better the scope of impacts in orthopaedic patients associated with SSI. This systematic review aimed to justify research questions further through observational data of SSIs and their effects at an individual level. Orthopaedic elective surgeries in the review involved hip and knee procedures and eliminated other elective surgeries such as spinal and lower abdominal surgeries. Regarding the previous projection of growing hip and knee surgeries[14] and their association with unexpected readmissions[12,15] especially in the older population,[11] the review objective was to investigate the epidemiology of SSI in hip and knee surgeries and related impacts regarding costs and quality of life.

2 | METHOD

The proposed review was carried out according to the JBI scoping review methodology[23] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) model.[24-26] Considering JBI covers structural systematic review guidelines for prevalence, incidence, costs and impacts of interventions or procedures, the methodology aligns with the nature of SSIs burden research in this review.

A search strategy based on the MESH term and the CINAHL terms classification was developed. All index terms and search keywords in the search strategy were modified to adapt each included database. The following search phrases were used to look for relevant sources in a total of five databases (Medline, EMBASE, Scopus, Web of Science and CINAHL):

Concept 1 'Surgical site complication' OR 'Hospital-acquired complication*' OR 'Hospital-acquired infection*'.*

Concept 2 'Orthop? edic surgery' OR 'Orthop? edic elective*'.*

Concept 3 'Quantify' OR 'Cost*' OR 'Cost-effectiveness' OR 'Quality of life' OR 'Health utility'.*

Wildcards were used to ensure articles of either British or American spelling were identified through the search. According to the selection criteria in Table 1, peer-reviewed papers published from 2010 to 2020 were reviewed, including studies on adult populations (over 18 years old) in orthopaedic elective hip and knee replacement surgeries. The reference list for all included evidence was also checked by reviewers for any additional studies. Only publications in English and studies conducted in high-income countries and published after 2010 were included. As the core concept is to demonstrate the financial and societal strain on patients because of SSI, the review converges on postoperative costing and well-being burden. We excluded any preoperative procedures analysis such as antibiotics usage comparison, risk assessment and management for SSI prevention.

All identified citations were collated, and duplicates removed in Covidence. To maximise the retrieval of appropriate studies, two or more independent reviewers

TABLE 1 Selection criteria

	Inclusion criteria	Exclusion criteria
Population	Adults above 18 years old	Paediatric patients under 18 years old
	Orthopaedic surgeries (hip and knee only)	General surgeries excluding orthopaedic surgeries
Study design and features	Economic analysis	Prevention and management protocol
	Quantitative epidemiology	Animal study
	Burden analysis tools	Antibiotics utilisation
	Conducted in high-income countries	Conducted in low- or middle-income countries
	Published after 2010	Published before 2010
	Case study format	General concept or theoretic format
	In English language	In other languages

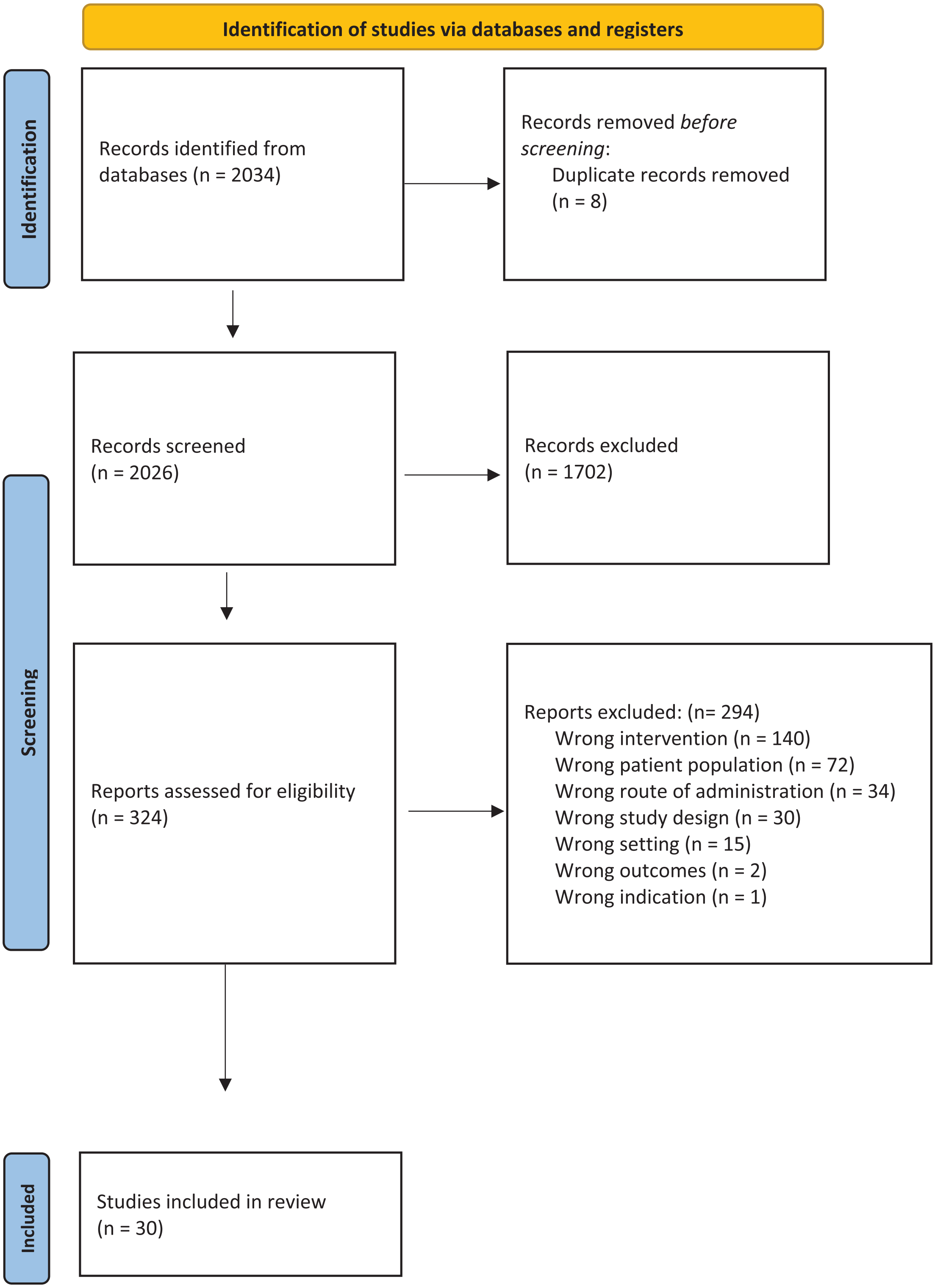

FIGURE 1 PRISMA diagram[24]

evaluated abstracts in accordance with the above criteria. Reviewers imported citations into EndNote X9, examined the full text of selected citations, documented the reasoning for eliminating sources of evidence in reporting findings. In order to report the final scoping review as shown in the PRISMA diagram (Figure 1), reviewers obtained consensus through discussion at each stage of the selection process.

2.1 | Quality assessment

As most extracted articles are case–control studies with cost-effectiveness interventions, we utilised the ROBINS-I tool[27] for quality assessments. ROBINS-I is intended for analysing the quality of studies that do not adopt randomisation in allocation units, including individuals and clusters or into comparison groups. If the study is a randomised trial study, instead of ROBINS-I, we proceeded with the Rob2 tool, designed for individually randomised parallel-group, cluster-randomised parallel-group, individually randomised cross over or matched trials.[28] Both tools evaluate the risk of bias in estimating comparative effectiveness in impacts and benefits of interventions.

Most studies are matched case–control studies; we proceeded with specifying confounding domains relevant to most studies, including the differences in co-interventions among intervention groups that potentially impact outcomes. Numerical results from the study are also assessed. Confounders including those listed in the review protocol and relevant to the setting of each study are considered preliminarily. We then performed the risk of bias assessment by utilising potential markers to determine the level of confounding. The five domains for reviews are (a) participant selection, (b) intervention categorisation, (c) missing Data, (d) outcome measurement, and (e) reporting of the result. The overall bias will be rated in five levels: low, moderate, severe, critical, to no information. Studies were then examined under risk of bias as ROBINS-I under five domains to provide an overall bias rating. Only articles with a low to moderate overall bias risk were included.

For each criterion, bias risk assessment was graded as low, moderate, severe, critical or no information. Of the included articles, 23 (76.7%) and 7 (23.3%) studies displayed low and moderate bias risk (see Table A1). According to the guidelines,[27,28] we categorised research as low risk of bias with no or very little confounding, indicating the study is equivalent to a well-conducted randomised trial. In contrast, a study with moderate risk of bias offers sound support for a non-randomised analysis, however, it is not comparable to randomised trial study. Among included studies, selection bias was the main issue with the loss of follow-ups for general patients after the initial surgery, especially those who did not develop SSI, which leads to a certain extent of missing data for comparison.

2.2 | Data analysis

A narrative review approach was selected because of substantial heterogeneity in sample size, study design and populations of the included publications. After authors resolved any disagreements on the final interpretation of the results, data in the included studies were presented and categorised based on the characteristics of the study (see Table A1). Studies were further classified into four themes (see Table A2), while most represented more than one theme, focusing on epidemiological results, hospital costs, patient costs and/or well-being.

2.3 | Characteristics of included studies

This systematic review included 30 publications. Table A1 describes the main characteristics and study design of included studies. Majority of the studies were conducted in North America, including the United States and Canada (n = 14), and Europe (n = 13). Of the studies that were included, two were conducted out in Australia and one in New Zealand. Cohort research designs were the most common among the studies (n = 18), mainly retrospective cohort study (n = 12), then followed by economic burden or costing study (n = 11) and a qualitative study using a descriptive design (n = 1). The population varied in the sample. Most studies include a specific population of selected procedures only, for example, total hip and knee arthroplasties (n = 17), followed by the general population of all elective surgical procedures (n = 11). Lastly, only patients encountered health care-associated SSIs (n = 2). The sample sizes of included studies varied from 15 to 478 222.

3 | RESULTS

Among various themes, Hospital system costing describes how patients incurred the cost of admissions and direct hospital expenses. Measurements include extra length of stay and real cost burden evaluation focusing on hospital and health system costing (n = 21). Patients and societal perspective costing describe social and indirect community follow-up costs (n = 2). Patients and societal perspective well-being refer to the quality of life and health effects on patients, not limited to psychological and mental health, with results translated into quantitative indicators such as quality-adjusted life years (QALYs) and disability-adjusted life years (DALYs) (n = 6). Epidemiological databases and surveillance provide general incidence and estimated prevalence of patients undertaking elective surgeries, usually up with other themes as initial background research, hence developing infections through specific databases or software (n = 22).

3.1 | Hospital costing (n = 21)

Detailed studies associated with hospital system costing are shown in Table A2. Of the 30 studies included, 19[29,31,32,34-36,38,40,41,43,44,46-49,51,53,54,56] provided adequate data on hospital and direct health system expenses because of SSI. As the sample size and timeframe measured varied, comparing cost calculations was challenging. SSIs were the central theme for most studies, with a few articles also studying other health or hospital-associated infections. Three studies[32,35,41] assessed direct hospital costs particularly, with two cohort studies[32,41] and one cost comparison analysis.[35] These studies indicated direct hospital expenses such as revision care, prolonged length of stay and pharmaceutical costs for inpatients and outpatients.

3.1.1 | Revision care cost

A cohort study[41] with 358 patents calculated the hospital costs for patients treated for tibia fractures. The multivariate linear analysis with a 95% confidence level determined hospitalisation, day admission, materials and pharmaceutical costs among infections developed after fracture fixation. The mean total health care treatment costs were USD 45 378 in deep SSI infection patients, which was approximately 6.5-times higher in comparison with USD 6995 in general patients. The cost of total joint arthroplasty (TJA) was examined using a negative binomial regression.[46] Over the first 30 days after TJA, the base cost for patients without modifying variables was AUD 13 060. (USD 8997). Since SSI contributed an additional $97 million AUD (USD 65.9 million) in arthroplasty expenditures in the first 30 days following surgery, it is a substantial cost driver. Another study,[32] with a population of 1768, also demonstrated that infections tripled the cost of a TJA. Wound care and procedures as the most expensive services for infection revisions care. The mean cost of a TJA was €7200 (USD 7336), with an excess expense of €18 900 (USD 19 257) for a prosthetic joint infection. A two-stage revision costs €44 600 (USD 45 444). Other extra costs for debridement, antibiotics and implant retention treatment were €12 800 (USD 13 042).

3.1.2 | Prolonged length of stay

A cohort research[46] further supported the four-day median length of stay and the 4% readmission rate in the first 30 days after index joint arthroplasty. Given that the extra length of stay is another significant consequence of SSI, a cost-comparison analysis in the US[35] estimated the relationship between medical harm and hospital care cost in 12 states. A linear regression model showed that SSI is one of the most expensive inpatient harms, costing an additional USD 30 000 for each index stay because of infection. The hospital costs of the 90-day additional SSI and other blood infection events are the highest, exceeding USD 34 000.

3.2 | The societal perspective of health system costing (n = 2)

Of the studies reviewed, two were economic burden studies. The first calculated hospital costing from a societal perspective,[47] and the second evaluated patients' well-being based on social care costs.[39]

3.2.1 | Employment power loss

SSI is classified as one of the health care-associated infections in hospitals. An economic burden study[47] reviewed social costs attributed to health care-associated infections (HAI) patients for all surgeries. The general HAIs expenditure is TRY 832 167 (USD 46 846). In addition to communal costs of TRY 6 013 101 (USD 338 501), the financial worth of the work power loss suffered by the HAIs working-age patients was TRY 126 154 (USD 7102). HAIs patients experience 14 times longer inpatient stay with a treatment expenditure of 23 times higher.

3.2.2 | Societal care system cost

An economic burden study[39] measured total expenses for patients and caregivers in the National Health Service (NHS) and Personal Social Services (PSS). The variation in overall NHS and PSS expenses throughout a 1-year follow-up between patients with and without SSIs was £1242 (USD 1487). In the deep SSI group, costs were higher from 0 to 6 months and from 3 to 6 months after index surgery. Nevertheless, over the course of 6 to 9 months, total expenses were higher among individuals without deep SSI. However, the deep SSI population in this study is relatively small (n = 35). Hence, the reliability and potential to generalise this finding to a larger population is uncertain.

3.3 | Patients and societal well-being (n = 6)

Two studies[33,57] exclusively report patients' well-being through interviews and translate results into disutility rating and quality of life impact through content analysis. Several studies concentrated on standard health utility scores and SF-36 measurements in QALYs or DALYs.[30,34,39,45]

3.3.1 | Interview study

An in-time trade-off interview[33] compared the health state between SSIs and non-SSIs patients undergoing joint and spinal surgeries. Lower utilities were founded in superficial SSIs, deep SSIs and deep SSIs required two-stage revision arthroplasty, and SSIs not requiring surgery. Depending on the severity of infection and treatment interventions, the disutility score of SSIs ranged from −0.03 to −0.32. A second interview study[57] on the experiences of people with deep SSIs discovered a strong correlation between the development of deep SSIs and the onset of superficial SSIs. It indicated that inadequate patient-professional relationships in treatments negatively impact patients' physical and emotional well-being.

3.3.2 | Health Utility Score

A cost analysis study[34] covered hospital costing and patient well-being. Cost differences for SSIs were tested with linear regression analysis. Total hip replacement (THA) expenditures per SSI were €21 569 (USD 21 977), primarily because of an extended hospital stay. THA was associated with the highest individual disease burden of 1200 DALYs/year and 250 DALYs/100 SSIs. Another economic burden study,[39] revealed that deep SSI patients had lower EQ-5D-3L derived QALYs and higher health and social care expenses over the course of the subsequent 12-month period. In contrast, there is no statistically significant correlation between total NHS and PSS expenses and QALYs produced by SF-6D during a 1-year follow-up for deep SSI. Therefore, a comprehensive well-being measurement is required to investigate further the variance of QALYs among various health utility calculation tools.

Two database analysis studies[30,45] in Europe further investigated patients' well-being through SSI incidence in hospitals. An analysis from German[30] estimated hospital SSI incidence as a type of health care-associated infection (HAI), further adjusting for comorbidities and estimating DALYs. Regarding the average duration of inpatient hospital stay, number of discharges and patient days, Germany has a lower HAI prevalence but a high number of HAIs per 100 000 compared with the EU. In another study,[45] acknowledged hospitalised patients older than 65 years old have a higher SSI burden. According to median incidence and DALYs per 100 000 populations, the annual SSI incidence per 100 000 was 156.5, with 58.2 DALYs per 100 000. SSI ranked fourth among HAIs in terms of the total well-being burden.

A retrospective cohort study[29] observed that surgical associated infection (SAI) patients have 1-year post-orthopaedic mortality of 22.38%, nearly 18% higher than those without SAI. Another cohort study,[42] has pointed out the inpatient case mortality in patients with hip or knee arthroplasty infections (HKAIs) was 11.4%.

3.4 | Epidemiological database and surveillance (n = 21)

A total of four studies[11,37,42,55] mapped the epidemiology of SSI patients undergoing hip and knee arthroplasty or both.

3.4.1 | Database projection

According to a burden prediction study,[37] more than 15 million initial and revision orthopaedic elective surgeries will be performed between 2020 and 2030, leading to an estimation of 77 000 postoperative complications. SSIs post hip joint replacements accounted for 54% of all SSIs following arthroplasties. The overall number of SSIs from hip and knee arthroplasties will increase by 13% and 14%, respectively, with the elderly accounting for 60%-70% of these procedures and infections.

3.4.2 | Retrospective incidence estimation

The incidence rate of HKAI was calculated by a cohort study.[42] With a readmission rate of 1.1%, the first 2 months following surgery accounted for 70% of HKAIs. In a population of 1739 patients, the incidence rate of HKAI was reported to be 1.76%. Another cohort study,[11] revealed the 1-year HKAI incidence as 1.31%, with density incidences in hip and knee being 2.2 and 2.5 per 100 person-years, respectively. During the initial 30 days following surgery, 30% of HKAI incidents occurred, while there is an increased chance of infection in individuals who are 75 years or older. A validation study[55] performed an electronic screening analysis. With the 9.5% of possible SSIs estimated from 42 173 total joint replacement procedures, 1.04% of case-patients resulted in SSI.

Hospital costing and database analysis involved 16 articles.[29,31,36,38,40,43,44,46,48-54,56] Hospital raw data are commonly analysed initially to provide incidence and demographics as a reference for further total cost analysis. Applying data from hospital database, a cohort study[49] conducted an analysis at all surgical patients who underwent common surgeries. SSI patients bear double in-hospital care and postoperative costs after orthopaedic surgery such as primary hip or knee arthroplasty compared with general patients. A cost analysis[31] demonstrated hospital costs of SSI from a return of investment perspective. Combining with the 5-year SSI incidence, the $624 384 USD invested in surgical quality improvement programs reduced SSI incidence by 2.88%. The investment yielded US $3.07 for every dollar invested and saved US $1.4 million from avoided infections. Another non-intentional retrospective cohort study,[29] reported that knee surgeries with a hazard ratio of 0.8 were associated with a lower SAI risk than hip surgeries. SAI patients were also associated with 4.4 times and 7.7 times hospitalisations and hospital days.

In terms of health care resources allocation in inpatient, outpatient and readmissions, this study[46] concluded 4% of readmissions occurred within 30 days after index joint arthroplasty, with a majority of 74% developed a SSI. Patients with PJI incurred higher expenditures, according to a matched case–control research.[43] Following total knee arthroplasty, PJIs increased the rate of readmission by almost four times, the average length of stay by two times, and the episode cost per patient by nearly five times. As a result of these factors, the mean annual health care cost of PJI patients was $116 383 USD, compared with $28 249 USD in the control group.[43] Another matched case–control study,[36] also concurred that SSI was related to a noticeably longer length of stay. The extra costs of SSI in joint replacement procedures varied from $12 689 USD to $12 890 USD. 0.72% of 158 516 patients were readmitted because of SSI within a 90-day episode of care period. Regarding age, 0.84% of adults older than 45 years old had infection-related readmissions. It was also found that patients undergoing older patients encountered more revision THA, leading to higher care costs.[48]

An economic burden study[38] identified the incidence of complex SSI from a local infection prevention and control database with a population size of 24 512. In complex SSI patients, the mean 12-month total expenses were substantially higher. After standardising for patient characteristics, the extent of the cost disparity remained the same at CAD $95 321 (USD 73 597) vs CAD $19 893 (USD 15 374). A cost of illness study[56] used a prediction for infections in primary hip and knee arthroplasties following an SSI incidence estimation in Germany. The research also examined treatment costs such as medical and pharmaceutical expenses, concluding SSI revision for hip and knee arthroplasty incurred additional costs of at least €22 407 350 (USD 22.8 million) and €13 760 280 (USD 14 million) respectively.

4 | DISCUSSION

This systematic review examines SSI rates and consequences in health systems through the lens of hospitals and patients' burden from 30 published studies in 2010 to 2020. All included studies reported data from high-income countries. Extracted articles acknowledge that SSI leads to complex clinical and economic hardships in health care and social systems. Articles mainly concentrate on the following subthemes to explore the size of the burden. Because of a lack of uniformity among multiple studies, hospital-related health care costs are challenging to compare.[58,59]

4.1 | Hospital incidence and costing

SSIs, contribute to post-surgery infections in hip and knee replacements as one of the leading health care or hospital-associated infections. Several studies[30,39,46] support the prevention and surveillance of SSI to utilise resources for treatment planning and improvement through providing background epidemiological data and cost determinants to demonstrate complication outcomes. As hospital incidence analysis is usually the base reference for health system costing estimation, a range of comprehensive SSI incidence analyses over time in different countries were found in this review. However, the study population size varied, limiting generalisation and comparison among hospitals or countries.

Upon evaluating hospital expenses from incidence analysis, many factors were associated with postoperative SSIs rising hospital costs. For instance, patients age 65 or above,[37,45] or 45 or above,[36] were more prone to develop SSIs, deriving higher financial strain to hospitals than younger patients during SSI treatments. Older populations are associated with higher infection risk, yet there was no specification and unified definition for an age range of the older population, which will lead to variance in reporting the impact of complications. Also, because of the inconsistent study population, as some studies[37,42,45] included all adult patients, while one[36] focused on adults older than 45 years old, additional information will be required to reflect the relationship between age groups SSI incidence in the future, to assist policymakers in implementing equitable health services and ensure better patient experiences.

Preventable hospitalisations after elective surgeries contributed as a major factor in hospital costing. Most hospital cost analysis primarily focuses on the length of stay and readmission studies as raw data and patient records were initially available in the hospital database. Some studies[32,41,56] also further examined the pharmaceutical and debridement costs provided to patients upon admission. All relevant studies[29,31,32,34-36,38,40,41,43,44,46-49,51,53,54,56] agreed that SSI negatively impacted the length of stay and number of revision care to a certain extent. In terms of readmissions, the cost of two-stage revision because of deep SSI was exceptionally high.[32,33] The revision timeframe in studies ranged from 30 days, 90 days to a year post-surgery, which is believed to be associated with the type of SSI of interest: superficial, deep SSIs or both. Studies should include further discussion of the kind of SSIs attempted to capture. Social care and national health system costs also required further investigation. An intervention[39] with a relatively smaller population size described costs in deep SSIs might not be as high as those without deep SSIs during specific treatment periods. Still, there were insufficient studies, making it challenging to conclude on social care costs.

Therefore, future studies and policies should aim to close the gap in hospital and social care costs and clarify the relationship between types of SSIs and cost factors, such as revisions comparison between superficial and deep SSI patients.

4.2 | Patients costing and well-being

Regarding the previous section of social care expenses in the health system, individual-level patient costs were included in studies.[39,47] Research is gradually trending towards this direction, but there is still a substantial research gap because of limited studies conducted solely on hip and knee replacements. This lack of evidence leads to insufficient data on how orthopaedic surgeries and complications impact patients' lives during or after their treatment journey, providing finite information for decision makers to generate a recovery program that considers health equity among patients with various backgrounds and conditions.

Studies focusing SSI on other surgeries, such as vascular surgery, agree infections may have devastating consequences, affecting the physical and emotional health of patients both while they are being treated in hospitals and after discharge.[60] Most studies reporting health system costs pointed out concerns in cost underestimation because of limitations in incorporating the societal burden of SSI into their calculation. Although the impact of SSIs on hospitals is well-established, the field is still developing and further research can demonstrate the value of patient-centred interventions in minimising SSIs.[61]

However, no actual patient out of pocket costs were measured in the included studies. Although public hospital patients are covered with support like Medicare or private insurance in most high-income countries, indirect costs like loss of employment days, extra transportation and inconvenience because of readmissions have always been neglected. A study[39] discussed loss in employment power in SSI patients. The rest of the studies interpret patient costs as a burden to the societal perspective of health systems instead of focusing on patients' financial struggles. As various SSI patients do not often return to the same hospital or seek assistance in the community, it might be complex to trace patients postoperatively. Future research can considerably investigate SSI patients' journeys to capture social care, and indirect patient costs better.

Several studies[29,30,33,34,39,45,57] introduced patient well-being measurement through health utility scores and interviews. Most studies related to SSI hospital costs instead of patients' well-being; measurement of quality of life might be complicated as surveys or interviews require patients to recall unpleasant memories. For articles examining patients' well-being, two[33] provided an interview opportunity to express views and struggles towards SSI treatment pathways beyond preassigned questions. Few studies[29,30,33,34,39,45] measured disutility, mortality, and changes in quality-of-life years with DALY and QALY. They all represented a negative association of quality of life. More detail and constructive analysis of how SSI leads to well-being changes in different patents demographics will be worth measuring. A study[39] used a standardised SF-36 survey to measure overall patients' well-being in terms of mortality. Like the revision costing section, a guided timeframe will be ideal for interpreting the types of SSIs considered. It will clarify whether the research was on well-being for superficial SSIs within 30 days postoperative or other deep SSIs beyond this timeframe.

Future studies can investigate patients' voices and connect them with quantitative research like health utility scores, improving patient recovery pathways and resources allocation.

4.3 | Strengths and limitations

From 2010 to 2020, the articles were primarily on hospital systems, emphasising health system expenditure and resource allocation to provide decision-making guidelines for policymakers to utilise resources better. There was also an enhanced focus on patient well-being since 2016, with numbers of studies published from 2018 to 2019, suggesting a transition in societal and quality of life impact.

Hospital database analysis was essential for estimating SSI incidence in elective surgeries, especially inpatients. A few studies utilised reliable patient data to perform an incidence projection for future policy planning. However, some outpatients developed SSI in the community. When the population is seeking additional social care because of SSI, there is a chance that the hospital database failed to capture them accordingly. Another limitation for incidence and database monitoring is that some SSI follow-ups do not return to the same hospital. Methods to recapture patients through patients' identifiers and hospital locality codes differ among countries. Some patients were out in the community seeking assistance because of SSI, so expenses reflected social care instead of hospital costing. However, few articles about societal costing from the health systems or patients' perspective, mainly concerning hospital costs. The relationship between postoperative SSI incidence and primarily indirect costing remained uncertain and required additional research.

The included studies were mainly observational in terms of characteristics, with most of the data collected retrospectively in a database cohort for various periods and across different years. With a wide range of population sizes, comparison and generalisation of results were problematic. Few post-discharge outcomes studies were available, which may be because of the difficulty of tracking revision care handled by the community instead of hospitals, recruiting or monitoring SSI patients for well-being and financial investigations post-surgery.

A primary key strength of this review is that it sheds light on future research methodology in capturing SSI counts accurately to be epidemiologically reliable. It identifies a research gap in SSI patient financial and well-being measurement. An extensive research base in hospital costing highlights a lack of focus on the societal and patient burden. Considering societal and economic aspects through the lens of both health systems and patients guides future studies to present a fuller picture of the SSI burden.

4.4 | Research gap and future opportunities

The review provides adequate data to support a hypothesis that SSI burdens health systems and patients. It also reveals that infections following orthopaedic procedures are linked to severe financial hardship, high risks of mortality and morbidity.[29,30,37,39,41,43,46,57]

The extent to which the review answers the research question is sufficient regarding current background hospital incidence and cost. Further work in educating preventable hospitalisations[30,46] and economic evaluation[39] will be the next step in enhancing policy planning and risk reduction. However, with only eight studies evaluating the impact of patients' costs and well-being, research should focus on reducing socioeconomic impact[41] apart from treatment strategies on direct costs from readmission, pharmaceuticals and length of stay.

Future studies designed and implemented based on evaluating indirect and out-of-pocket costs borne by patients instead of hospitals will provide an entire perspective on the total costs associated with postoperative SSI. Patient mortality and morbidity were also measured as a comprehensive study from the hospitals' incidence estimation and resource monitoring. As a result of insufficient patient-professional relationships, patients' concerns should be addressed when planning individual care.[57] Hence, upcoming patient well-being studies should concentrate on the feedback and potential improvements towards the SSI experience.

5 | CONCLUSION

This systematic review has synthesised a scope of themes associated with the overall incidence and burden of SSI that can advise potential policymakers to future decision-making. The return on investment on preventable hospitalisations supports the introduction of surveillance and prevention programs to lessen the burden for patients and health systems. Further analysis is required to understand the hardships behind patients with postoperative SSI. This potential data, incorporated with the review findings, can be integrated into the health economics of SSI control and treatment, strengthening the body of evidence for future policy framework.

AUTHOR CONTRIBUTIONS

The initial draft of the manuscript was written by Yoey Gwan Venise Hon, with expertise and academic input from Prof. Joanne Travaglia and Dr. Daniel Demant. All authors reviewed and approved the final version of the manuscript.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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How to cite this article: Hon YGV, Demant D, Travaglia J. A systematic review of cost and well-being in hip and knee replacements surgical site infections. *Int Wound J*. 2022;1-17. doi:10.1111/iwj.14032

APPENDIX A

TABLE A1 Characteristics of included studies (n = 30)

References	Country	Year (s)	Type of study	Population	Sample size (n=)	Themes	Risk of bias
Hardtstock et al[29]	Germany	2020	Cohort (non-interventional retrospective)	Adult patients from 2012 to 2015 who underwent at least one of the chosen procedures	74 327	(i, iv)	Moderate
Zacher et al[30]	Germany	2019	Database analysis (R package)	Health care associated infections patients in 2011-2012	478 222	(iii, iv)	Low
van Katwyk et al[31]	Canada	2019	Return-on-investment analysis (retrospective case costing study)	Patients admitted to hospitals and underwent surgery from April 2010 to January 2015	A teaching hospital providing tertiary care with 1118 beds.	(i, iv)	Low
Puhto et al[32]	Finland	2019	Cohort (retrospective)	Patients who underwent total joint replacements in the Oulu University Hospital from 2013 to 2015.	18 aseptic revisions, 42 prosthetic joint infections, and 1708 complete joint arthroplasties without problems were all eligible for evaluation.	(i)	Low
Matza et al[33]	United Kingdom	2019	Qualitative study - Interview	Participants from the community had to be UK citizens over 18 years old and have the ability to comprehend interview questions.	213 participants attended interviews; 201 participants completed interview	(iii)	Low
Koek et al[34]	Netherlands	2019	Cost-analysis (retrospective)	Patients included in the 2001 National SSI Surveillance Network	Matching 122 individuals without SSI to 62 individuals with SSI under the same type of surgery	(i, iii) DALYs	Moderate
Anand et al[35]	United States	2019	Cost comparison analysis	State Inpatient Databases for 12 states from the Health care Cost and Utilisation Project from 2009 to 2011.	Not stated	(i)	Low
Adeyemi and Trueman[36]	United States	2019	Case control study with propensity score matching	SSI-related hospital readmission patients vs non-SSI patients during the 90-day treatment episode after total orthopaedic arthroplasty in reference to the Nationwide Readmissions Database in 2013.	48 143 patients above the age of 45 who satisfied the inclusion criteria were found	(i, iv)	Low

(Continues)

TABLE A1 (Continued)

References	Country	Year (s)	Type of study	Population	Sample size (n=)	Themes	Risk of bias
Wolford et al[37]	United States	2018	Database-projected SSI consequences	Referring to the Nationwide Inpatient Sample, participants experienced joint arthroplasty from 2012 to 2014. National Health care Safety Network Data from 2012 to 2015 were also used to derive stratified complex SSI rates	247 733 509 (2015) for projection	(iv)	Low
Rennert-May et al[38]	Canada	2018	Economic burden	Patients who experienced primary joint replacements from 1 April 2012 to 31 March 2015, in Alberta, Canada	24 512	(i, iv)	Low
Parker et al[39]	United Kingdom	2018	Economic burden	Patients from the Major Trauma Network in the United Kingdom, which consists of 24 specialist trauma hospitals.	460	(ii, iii)	Low
Zawadzki et al[40]	United States	2017	Cohort (retrospective)	Patients who discharged from hospitals through the MS-DRG 470 total joint arthroplasty in various states between 2009 and 2013	Not stated	(i, iv)	Moderate
Metsemakers et al[41]	Belgium	2017	Cohort	All patients who underwent surgical treatment for tibia fractures of types 41, 42 and 43 between 1 January 2009 and 1 January 2014	358	(i)	Moderate
Le Meur et al[42]	France	2016	Cohort (retrospective)	Patients who received joint replacements in 2011	1739	(iv)	Low
Kapadia et al[43]	United States	2016	Case–control (matched)	Patients who experienced total hip replacement surgery between 2007 and 2011, including those who developed SSIs	16 consecutive SSI cases matched at ratio of 1:2 with 32 non-SSI controls from 2458 patients.	(i, iv)	Low
Gow et al[44]	New Zealand	2016	Case–control (retrospective)	All patients, including those with SSI after joint replacements in their first year of SSII programme, from 1 March 2013 to 28 February 2014	710 bed tertiary referral centre matched at ratio of 1:2.	(i, iv)	Low

TABLE A1 (Continued)

References	Country	Year (s)	Type of study	Population	Sample size (n=)	Themes	Risk of bias
Cassini et al[45]	Switzerland	2016	Databases analysis (incidence estimation)	Database estimates of the occurrence of specified HAIs from the point prevalence survey from the European Centre for Disease Prevention and Control from 2011 to 2012	273 753 patients in 1149 hospitals	(iii, iv)	Moderate
Peel et al[46]	Australia	2015	Cohort (retrospective)	Patients receiving total joint replacements at a facility in Melbourne, Australia, from January 2011 to June 2012.	827	(i, iv)	Low
Kurutkan et al[47]	Turkey	2015	Economic burden	Collection of patients data including those diagnosed with HAIs between 2011 and 2013 by the Infection Committee of the Düzce University Research and Application Hospital	749	(i, ii)	Low
Grammatico-Guillon et al[11]	France	2015	Cohort (retrospective)	Hospital database of patients in a French region who had their index hip or knee replacements in the previous 5 y.	In a population of 2.5 million, 39 private and public hospitals treated 32 678 patients with arthroplasty codes.	(iv)	Low
Bozic et al[48]	United States	2015	Cohort (retrospective)	Patients who underwent total joint arthroplasty revision surgery were assessed with the Nationwide Inpatient Sample between October 1, 2005 and December 31, 2010	235 857 THA revisions and 301 718 TKA revisions	(i, iv)	Low
Schweizer et al[49]	United States	2014	Cohort (retrospective)	129 Veterans Affairs (VA) hospitals providing surgical care to patients. SSI-related expenses for veterans who underwent surgery in fiscal year 2010.	54 233 VA patients had procedures	(i, iv)	Low
Schairer et al[50]	United States	2014	Cohort	Patients from a single institution	1415	(i, iv)	

(Continues)

TABLE A1 (Continued)

References	Country	Year (s)	Type of study	Population	Sample size (n=)	Themes	Risk of bias
Berger et al[51]	United States	2014	Cohort (retrospective)	Major elective surgery patients who received the procedure between 1 January 2007 and 31 December 2009	327 618	(i, iv)	Low
Shepard et al[52]	United States	2013	Cohort (retrospective)	Individuals who were admitted to the selected four hospitals from January 1, 2007 to December 31, 2010	25 849 surgical operations of interest and 399 627 inpatient admissions	(i, iv)	Low
Merollini et al[53]	Australia	2013	Cohort (retrospective)	Patients receiving primary THA and infection treatment in Queensland hospitals between January 2006 and December 2009	114	(i, iv)	Low
Jenks et al[54]	United Kingdom	2013	Cohort (retrospective)	Patients at NHS Trust Plymouth Hospitals who received major surgical procedures between April 2010 and March 2012.	University hospital with 1200 beds, 13 854 emergency surgical procedures and 58 203 elective procedures were carried out.	(i, iv)	Low
Inacio et al[55]	United States	2011	Validation	Patients who underwent total joint arthroplasty between January 2006 and December 2008 within a major health maintenance organisation (HMO).	42 173	(iv)	Low
Hanstein and Gaiser[56]	Germany	2011	Cost of illness	Data from Krankenhaus-Infektions-Surveillance-System (KISS) module was utilised to project SSI cases in primary total joint replacements throughout Germany.	372 851	(i, iv)	Moderate
Andersson et al[57]	United States	2010	Qualitative study – Interview	Patients who had undergone a medical examination with a deep SSI diagnosed	15 patients from Sahlgrenska University Hospital were selected.	(iii)	Moderate

Themes:

i. Hospital costing (n = 21).
ii. The societal perspective of health system costing (n = 2).
iii. Patients and societal well-being (n = 6).
iv. Epidemiological database and surveillance (n = 22).

TABLE A2 Themes of included studies

References	Theme (i)	Theme (ii)	Theme (iii)	Theme (iv)
Hardtstock et al[29]	X			X
Zacher et al[30]			X	X
van Katwyk et al[31]	X			X
Puhto et al[32]	X			
Matza et al[33]			X	
Koek et al[34]	X		X	
Anand et al[35]	X			
Adeyemi and Trueman[36]	X			X
Wolford et al[37]				X
Rennert-May et al[38]	X			X
Parker et al[39]		X	X	
Zawadzki et al[40]	X			X
Metsemakers et al[41]	X			
Le Meur et al[42]				X
Kapadia et al[43]	X			X
Gow et al[44]	X			X
Cassini et al[45]			X	X
Peel et al[46]	X			X
Kurutkan et al[47]	X	X		
Grammatico-Guillon et al[11]				X
Bozic et al[48]	X			X
Schweizer et al[49]	X			X
Schairer et al[50]	X			X
Berger et al[51]	X			X
Shepard et al[52]	X			X
Merollini et al[53]	X			X
Jenks et al[54]	X			X
Inacio et al[55]				X
Hanstein and Gaiser[56]	X			X
Andersson et al[57]			X	
Total	21	2	6	22