The health-economic burden of hip and knee periprosthetic joint infections in Europe

a comprehensive analysis following primary arthroplasty

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Aims
Periprosthetic joint infections (PJIs) pose significant challenges to patients and healthcare systems worldwide. The aim of this study was to estimate the health-economic burden of reimbursement payment in Europe for PJIs following primary hip and knee arthroplasty.

Methods
The calculation was based on health-economic modelling using data on primary hip and knee arthroplasties for the year 2019 from the Statistical Office of the European Union (Eurostat) and published infection rates to estimate the total number of hip and knee PJIs in 30 European countries. Revision procedures were stratified into: 1) debridement, antibiotics, and implant retention (DAIR); 2) one-stage exchange; and 3) two-stage revision procedures. The cases were then multiplied by the respective healthcare system reimbursement payments. Payment data were acquired from a survey of 13 countries (Austria, Croatia, France, Germany, Italy, Lithuania, Netherlands, Norway, Portugal, Slovenia, Switzerland, Turkey, and the UK) and extrapolated for the remaining countries.

Results
In 2019, a total of 2,048,778 primary total joint replacements were performed (total hip arthroplasty (THA) = 1,147,316 and total knee arthroplasty (TKA) = 901,462), with an estimated 20,416 cases of PJIs (11,131 hip and 9,285 knee) in Europe. This results in an estimated total reimbursement burden of €346,262,026 for European healthcare systems. The breakdown for hip PJI reimbursement was €197,230,953 (€9,751,962 for DAIR procedures, €45,135,894 for one-stage revisions, and €142,343,097 for two-stage revisions). For knee PJIs, the analysis yielded a total reimbursement of €149,031,073 (€9,335,075 for DAIR procedures, €48,058,479 for one-stage revisions, and €91,637,518 for two-stage revisions).

Conclusion
This is the first study to evaluate the health-economic burden of PJIs in Europe, revealing a substantial impact on healthcare systems with an estimated case load of 20,414 cases and overall reimbursement of €346,262,026 for primary THAs and TKAs performed in 2019.

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Take home message

- This is the first study to evaluate the health-economic burden of periprosthetic joint infections in Europe of primary arthroplasties of the hip and knee performed in 2019, revealing a substantial impact on healthcare systems with an estimated case load of 20,414 cases and overall reimbursement of €346,262,026.

Introduction

Periprosthetic joint infection (PJI) is a formidable and serious postoperative complication that may arise following total joint replacement, inclusive of total hip arthroplasty (THA) or total knee arthroplasty (TKA). Epidemiologically, the PJI incidence after primary arthroplasty in Europe is documented to range from 0.6% to 1.3%.[1] The prevalence of PJI is demonstrating an upward trajectory, owing primarily to an ageing population and the ever-increasing caseload of joint arthroplasty surgeries.[2,3] In Germany alone, it is projected that the number of primary implantations will further increase by 45% for TKA and 23% for THA by 2040.[2]

The management of PJI is inherently complex and financially burdensome, often necessitating multiple surgical interventions, prolonged antibiotic therapy, and extended hospitalization. The clinical sequelae can be severe, potentially leading to immobility, amputation, diminished quality of life, and considerable psychological distress[4] with a reported 3.7-fold increased risk of death within the first two years of the diagnosis.[5,6] Consequently, PJI imposes a considerable burden on both patients and the healthcare system, manifesting in substantial socioeconomic costs.[7] Recent projections estimate that the combined annual hospital costs related to knee and hip PJI in the USA will reach $1.85 billion by 2030.[8] Furthermore, other studies have estimated a base-case cost of $390,806 for each 65-year-old patient with an infected THA.[9]

While some studies offer insights into direct healthcare costs associated with PJI, there is a notable paucity of data regarding reimbursement payment from healthcare funders. Predominantly, these reports emanate from single-centre studies and typically focus on costs associated with specific treatment methods, such as debridement, antibiotics, and implant retention (DAIR),[10] or two-stage revisions.[11-16] Furthermore, these studies often feature limited sample sizes, ranging from eight to 61 patients.[16,17] A comprehensive analysis focusing on Europe is lacking and is needed to facilitate detailed economic analyses and inform future medical and health-economic policymaking.[18] Consequently, the primary objective of this study was to estimate the health-economic burden of reimbursement payments for PJI following primary hip and knee arthroplasty in Europe over a one-year period.

Methods

This paper reports the outcome of a project developed by the European Bone and Joint Infection Society (EBJIS). The study included 30 countries, listed alphabetically: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Lithuania, Luxembourg, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, and the UK.

Health-economic modelling

The health-economic model was conducted from a healthcare payors' perspective to evaluate the financial impact on healthcare systems across the 30 included countries. This analysis primarily focused on the reimbursement burden of public healthcare systems, which are predominant in Europe. Reimbursement from the public system was assumed to be similar for basic payments from the private sector as the used data from the Statistical Office of the European Union (Eurostat) do not distinguish between private and public healthcare sectors. This approach can be deemed conservative as private healthcare provision is normally associated with higher costs and higher reimbursement.

The model used a five-step calculation process (Figure 1) using data from Eurostat for the year 2019 on primary hip and knee arthroplasties and published infection rates to estimate the overall number of hip and knee PJIs for 30 European countries (Figure 1, equation 1).

Revision procedures were stratified into: 1) DAIR; 2) one-stage exchange; and 3) two-stage revision interventions for hip and knee PJIs based on published ratios (Figure 1, equation 2). These were then multiplied with the respective reimbursement payments of the healthcare funders (Figure 1, equation 3). Data on these payments were acquired through a survey conducted in 13 countries (Austria, Croatia, France, Germany, Italy, Lithuania, Netherlands, Norway, Portugal, Slovenia, Switzerland, Turkey, and the UK) and extrapolated to the other countries using gross domestic product (GDP) mean values. The expenses for the DAIR, one-stage, and two-stage procedures were then calculated and summarized for each country for hip and knee PJIs, respectively (Figure 1, equation 4). The sum of these payments yields the estimated overall financial burden for healthcare funders of the 30 European countries for hip and knee PJIs following primary hip arthroplasty in 2019 (Figure 1, equation 5).

Number of hip and knee PJIs in Europe after primary arthroplasty performed in 2019

To estimate the annual number of PJIs following primary hip and knee arthroplasty, data on the total number of primary arthroplasties were requested from the Statistical Office of the European Union (Eurostat),[19] based on the Operation and Procedure Classification System (OPS) codes '5 to 820, Implantation of an endoprosthesis of the hip joint' and '5 to 822, Implantation of an endoprosthesis of the knee joint' (Figure 1, equation 1).

We adopted published infection rates of 1.03% following primary TKA and 0.97% following primary THA,[1] to calculate the total number of hip and knee PJIs for each country and across Europe.

Estimation of DAIR, one-stage, and two-stage procedures per country

As reimbursement payments are contingent upon the type of treatment, PJI cases were subsequently stratified according to the treatment procedure into: 1) DAIR; 2) one-stage exchange; and 3) two-stage revision to facilitate a detailed health-economic analysis. The distribution of these three surgical strategies for knee revisions in Germany was calculated using OPS codes from the Federal Statistical Office of Germany (Destatis), as recently published.[3] An analogous approach was

Equation 1:

$$\text{Number of PJI per country} = \text{Number of primary arhtroplasties per country} \times \text{infection rate of primary arthroplasties}$$

Equation 2#:

$$\text{Number of PJI revision procedures per country} = \text{Number of infections per country} \times \text{rate of revision procedures}$$

Equation 3#:

$$\text{Costs of PJI revision procedures per country} = \text{Number ofrevision procedures per country} \times \text{costs of revision procedures per country}$$

Equation 4:

$$\text{Overall costs of all PJI revision procedures per country} = \text{costs for DAIR} + \text{costs for one} - \text{stage} + \text{costs for two} - \text{stage procedures}$$

Equation 5:

$$\text{Overall costs of revision procedures for Europe} = \sum \text{Overall costs of all revision procedures per country for all countries}$$

Fig. 1

Equations used for the health-economic modelling. Calculations were done for hip and knee periprosthetic joint infection (PJI), respectively. #Number and costs of revision procedures were calculated for debridement, antibiotics, and implant retention (DAIR), one-stage, and two-stage PJI procedures, respectively.

employed for hip revision procedures using the OPS codes '5 to 821, Endoprosthetic joint and bone arthroplasty: revision, arthroplasty and removal of an endoprosthesis of the hip joint'. These ratios were used and multiplied with the total number of infections per country yielding the total number of treatment procedures per country (Figure 1, equation 2). The calculations were separately performed for knee and hip PJIs.

Calculation of reimbursement payments

In the next step, data on reimbursement payments for DAIR, one-stage, and two-stage procedures received by hospitals from public healthcare funders for PJI treatment were collected from 13 countries (Austria, Croatia, France, Germany, Italy, Lithuania, Netherlands, Norway, Portugal, Slovenia, Switzerland, Turkey, and the UK). These data were obtained through a survey conducted by the Country Delegates Group of the EBJIS.

For all other countries, clustering into higher- and lower-income European countries was performed based on the GDP per capita. Information on the GDP per capita was sourced from Eurostat.[19] Data ranged from 42 GDP per capita in purchasing power standards (PPS) for North Macedonia to 261 GDP per capita in PPS for Luxembourg. The average GDP per capita in PPS for all European countries was 101, which served as the cut-off for this categorization (Table I).

The payments for DAIR, one-, and two-stage procedures, were then multiplied with the number of the respective interventions per country to calculate the payments for each procedure (Figure 1, equation 3). The sum of all payments for the three procedures per country yielded the overall payments per country for hip and knee PJIs (Figure 1, equation 4). In the final step, these payments were summed up to estimate the overall financial burden for healthcare payors across all 30 European countries (Figure 1, equation 5). Costs in currencies other than EUR were converted to EUR using the exchange rates on 26 May 2023.

It was assumed that reimbursement from the public healthcare systems would be similar to those from private health payors as separation of the two sectors was not possible. This approach was adopted for a conservative estimation in the model.

Results

Total number of hip and knee PJIs in Europe for primary arthroplasty performed in 2019

According to the data provided by Eurostat, the Statistical Office of the European Union for 2019, there were 901,462 primary TKAs and 1,147,316 primary THAs performed, with a combined total of 2,048,778 primary THA and TKA procedures in Europe. Most procedures were performed in Germany (THA: 261,675, TKA: 188,985, THA + TKA: 450,660), followed by France (THA: 169,458, TKA: 124,648, THA + TKA: 294,106), the UK (THA: 124,322, TKA: 98,651, THA + TKA: 222,973), and Italy (THA: 115,821, TKA: 82,067, THA + TKA: 197,888) (Table II).

Assuming infection rates for TKA and THA of 1.03% and 0.97%, respectively, as reported by Springer et al[1] in a review summarizing PJI incidence rates from various arthroplasty registries, the estimated total annual number of hip and knee PJIs is 20,416. This figure includes 11,131 hip PJI cases and 9,285 knee PJI cases, arising from primary THAs and TKAs performed in 2019 (Table II).

Estimation of DAIR, one-stage, and two-stage procedures per country

For an accurate allocation of surgical procedures for PJI treatment, the OPS codes provided by Destatis, Germany, were analyzed. This yielded a distribution of 11.4% for DAIR, 42.6% for one-stage, and 46.0% for two-stage procedures for knee revisions and 8.3% for DAIR, and 33.5% for one-stage and 58.2% for two-stage procedures for hip revisions. Based on these proportions, the number of DAIR, one-, and two-stage procedures per country were calculated and extrapolated to

Table I. Extrapolation of reimbursement payments of different European healthcare systems for DAIR, one-, and two-stage procedures for hip and knee periprosthetic joint infection treatment, based on classification of lower versus higher income European country depending on the gross domestic product per capita.

Country	Gross domestic product per capita in purchasing power standards in 2022	Classification in higher-income or lower-income European country	Hip			Knee		
			Reimbursement per hip DAIR procedure (€)	Reimbursement per hip one-stage procedure (€)	Reimbursement per hip two-stage revision (€)	Reimbursement per knee DAIR procedure (€)	Reimbursement per knee one-stage procedure (€)	Reimbursement per knee two-stage revision (€)
Belgium	120	Higher	13,885	15,209	29,456	12,814	16,944	30,737
Bulgaria	59	Lower	6,240	6,986	11,207	4,753	5,325	9,774
Cyprus	92	Lower	6,240	6,986	11,207	4,753	5,325	9,774
Czechia	91	Lower	6,240	6,986	11,207	4,753	5,325	9,774
Denmark	137	Higher	13,885	15,209	29,456	12,814	16,944	30,737
Estonia	87	Lower	6,240	6,986	11,207	4,753	5,325	9,774
Finland	109	higher	13,885	15,209	29,456	12,814	16,944	30,737
Hungary	77	lower	6,240	6,986	11,207	4,753	5,325	9,774
Ireland	233	Higher	13,885	15,209	29,456	12,814	16,944	30,737
Luxembourg	261	Higher	13,885	15,209	29,456	12,814	16,944	30,737
North Macedonia	42	Lower	6,240	6,986	11,207	4,753	5,325	9,774
Poland	80	Lower	6,240	6,986	11,207	4,753	5,325	9,774
Romania	77	Lower	6,240	6,986	11,207	4,753	5,325	9,774
Serbia	44	Lower	6,240	6,986	11,207	4,753	5,325	9,774
Slovakia	68	Lower	6,240	6,986	11,207	4,753	5,325	9,774
Spain	85	Lower	6,240	6,986	11,207	4,753	5,325	9,774
Sweden	120	Higher	13,885	15,209	29,456	12,814	16,944	30,737

DAIR, debridement, antibiotics, and implant retention.

all other countries, resulting in an estimated total number of 925 DAIRs, 3,728 one-stage procedures, and 6,478 two-stage procedures for hip PJI treatment (Supplementary Table i). For knee PJI treatment, the estimates were 1,058 DAIRs, 3,955 one-stage, and 4,271 two-stage procedures (Supplementary Table ii).

Reimbursement payments for DAIR, one-stage, and two-stage PJI procedures per country

As previously reported, detailed information on reimbursement payments for DAIR, one-, and two-stage PJI procedures were obtained from 13 countries (Austria, Croatia, France, Germany, Italy, Lithuania, Netherlands, Norway, Portugal, Slovenia, Switzerland, Turkey, and the UK) (Table III). Generally, reimbursement was lowest for DAIR procedures, and highest for two-stage revisions. The lowest and highest reimbursement payments across all procedure types were observed in Turkey and Switzerland, respectively. For DAIR procedures, reimbursement rates ranged from €978 in Turkey to €32,698 in Switzerland. For one- and two-stage procedures, reimbursement rates were €3,467 and €5,266 in Turkey, and €45,899 and €78,597 in Switzerland, respectively.

To extrapolate reimbursement payments for the remaining countries without available billing data, these were classified as lower- or higher-income European countries based on their GDP per capita (Table I). Initially, mean values per procedure were estimated by averaging the available data from lower-income countries (Croatia, Lithuania, Portugal, Slovenia, and Turkey). This resulted in a mean amount of €6,240 for DAIR procedures (range: Turkey: €1,331 EUR to Slovenia: €13,918), €6,986 for one-stage exchanges (range: Lithuania: €3,667 EUR to Slovenia: €14,893), and €11,207 for two-stage treatment (range: Lithuania: €3,667 EUR to Slovenia: €28,936) for hip PJI treatment (Table I). For knee PJIs, mean values were €4,753 for DAIR procedures (range: Turkey: €978 EUR to Croatia: €7,949), €5,325 for one-stage exchanges (range: Turkey: €3,467 EUR to Croatia: €11,267), and €9,774 for two-stage revisions (range: Lithuania: €3,580 EUR to Slovenia: €19,064). Averaging the data from higher income countries yielded mean values of €12,814 for DAIR procedures (range: UK: €4,919 EUR to Switzerland: €32,698), €16,944 for one-stage exchanges (range: Norway: €8,715 EUR to Switzerland: €78,597), and €30,737 for two-stage revisions (range: Italy: €16,605 EUR to Switzerland: €45,899) with respect to knee PJIs. For hip PJIs, the average estimates were €13,885 for DAIR procedures (range: UK: €7,028 EUR to Switzerland: €31,229), €15,209 for one-stage exchanges (range: Norway: €10,534 EUR to Switzerland: €31,417), and €29,456 for two-stage revisions (range: Italy: €16,605 EUR to Switzerland: €62,834) (Table I).

Table II. Number of primary total hip arthroplasties and total knee arthroplasties implanted in 2019 per country in Europe and the estimated number of resulting hip and knee periprosthetic joint infections from these primary implantations.

Country	Number of primary THAs implanted in 2019	Estimated number of hip PJIs of primary THAs implanted in 2019	Number of primary TKAs implanted in 2019	Estimated number of knee PJIs of primary TKAs implanted in 2019
Austria	26,183	254	20,296	209
Belgium	32,552	316	24,373	251
Bulgaria	9,241	90	2,525	26
Croatia	5,885	57	3,020	31
Cyprus	522	5	410	4
Czechia	22,136	215	15,942	164
Denmark	13,281	129	10,541	109
Estonia	2,241	22	1,458	15
Finland	16,075	156	13,721	141
France	169,458	1,644	124,648	1,284
Germany	261,675	2,538	188,985	1,947
Hungary	14,369	139	9,172	94
Italy	115,821	1,123	82,067	845
Ireland	6,165	60	2,426	25
Lithuania	5,474	53	3,652	38
Luxembourg	1,216	12	1,037	11
Netherlands	29,370	285	38,090	392
North Macedonia	1,417	14	400	4
Norway	14,303	139	6,279	65
Poland	68,021	660	28,508	294
Portugal	9,387	91	6,441	66
Romania	14,966	145	5,127	53
Serbia	10,272	100	2,693	28
Slovenia	4,164	40	2,865	30
Slovakia	6,965	68	5,472	56
Spain	60,501	587	65,316	673
Sweden	24,959	242	13,833	142
Switzerland	26,835	260	22,312	230
Turkey	49,540	481	101,202	1,042
UK	124,322	1,206	98,651	1,016
Total	**1,147,316**	**11,131**	**901,462**	**9,285**
Total primary hip and knee arthroplasties implanted in 2019				**2,048,778**
Estimated number of resulting hip and knee PJIs from these primary implantations.				**20,416**

PJI, periprosthetic joint infection; THA, total hip arthroplasty; TKA, total knee arthroplasty.

Health-economic burden of PJI after primary THA and TKA performed in 2019 for Europe

For hip PJI treatment following primary arthroplasties performed in 2019, the total reimbursement payments across all European countries were estimated to be €197,230,953 (Table IV). The country-specific values ranged from €47,593 in Cyprus to €58,334,220 in Germany. For knee PJI treatment following primary TKA performed in 2019, the total anticipated reimbursement burden is €149,031,073, with values ranging from €30,102 in North Macedonia to €41,804,330 in Germany (Table V).

A major cost driver for both hip and knee PJI reimbursement is the two-stage exchange, as this is the most frequently performed and expensive treatment modality in all countries.

Table III. Reimbursement payments of different European healthcare systems for DAIR, one-stage, and two-stage procedures for hip and knee periprosthetic joint infection treatment, for which detailed information could be gathered in a survery. All values are presented in €.

Country	Hip			Knee		
	Reimbursement per hip DAIR procedure	Reimbursement per hip one-stage procedure	Reimbursement per hip two-stage revision	Reimbursement per knee DAIR procedure	Reimbursement per knee one-stage procedure	Reimbursement per knee two-stage revision
Austria	10,500	11,000	27,000	10,500	11,000	27,000
Croatia	7,949	10,073	10,073	7,949	11,267	11,267
France	11,545	11,545	19,596	11,545	11,545	19,596
Germany	13,918	14,893	28,936	11,203	16,047	29,050
Italy	8,215	11,932	16,605	8,215	11,932	16,605
Lithuania	3,667	3,667	3,667	3,580	3,580	3,580
Netherlands	18,113	17,985	36,097	14,720	18,050	34,013
Norway	10,534	10,534	21,068	8,715	8,715	17,430
Portugal	5,528	5,528	11,415	4,009	4,009	13,793
Slovenia	13,918	14,893	28,936	7,249	7,620	19,064
Switzerland	31,229	31,417	62,834	32,698	45,899	78,597
Turkey	1,331	4,089	5,266	978	3,467	4,483
UK	7,028	12,365	23,608	4,919	12,365	23,608

DAIR, debridement, antibiotics, and implant retention.

Overall, European healthcare systems are expected to face a total reimbursement burden of approximately €197,230,953 + €149,031,073 = €346,262,026 for PJI treatment for primary hip and knee arthroplasties performed in 2019.

Discussion

This is the first study to comprehensively examine the economic burden of hip and knee PJI within European healthcare systems. Reimbursement for PJI treatment is a critical element in managing this complex condition. The data revealed an estimated total case load of 11,131 hip PJIs and 9,285 knee PJIs in 2019, resulting in a combined total of 20,416 PJI cases. The associated reimbursement expenses were significant, totaling €197,230,953 for hip PJI and €149,031,073 for knee PJI, with an overall financial burden in 2019 of €346,262,026.

The study was conducted from a healthcare payors' perspective and focusing on infections following primary THA and TKA performed in 2019. It is important to note that this does not represent the annual revision cases performed for PJI. This delineation carries several rationales and implications. First, the goal of the study was to assess the overall burden of PJI across Europe based on available data from Eurostat. As this institution does not provide data on revision arthroplasty surgery, the study relied on information regarding primary implantations, which is available for 30 European countries from Eurostat. This design enabled the calculation of the disease burden that would arise from a single 'primary arthroplasty year' in Europe, assuming an overall infection rate of 0.97% for hip and 1.03% knee PJIs.[1] Second, the focus from a healthcare funder's perspective emphasizes the reimbursement burden on healthcare payors rather than the direct costs borne by hospitals for patient treatment. This perspective was selected to diminish heterogeneity and improve the generalizability of the model, as direct costs analyses often reflect the unique financial situation of an individual hospital. These costs can vary considerably between different hospitals within the same country. However, reimbursement rates within a country are relatively uniform across all healthcare facilities.

The analysis clearly demonstrated that countries with the highest case load for primary arthroplasties accounted for the highest reimbursement burden. Eurostat data revealed a total of 2,048,778 primary THA and TKA procedures conducted in 2019 in Europe. The highest numbers were reported in Germany (450,660 cases), France (294,106 cases), the UK (222,973 cases), and Italy (197,888 cases). Collectively, these four countries accounted for 1,165,627 primary hip and knee implantations in 2019, representing 56.9% of all primary arthroplasty procedures in the 30 European countries. This volume translates into a total of 11,603 PJI cases, comprising 6,511 hip and 5,092 knee PJIs, according to the current health-economic model. This represents 61.7% of all reimbursement payments for PJIs (hip PJI: 61.8%, knee PJI: 61.6%). The relatively higher reimbursement ratios compared with the number of PJIs in these four countries can be attributed to the higher reimbursement payments per procedure relative to most other European countries.

Most previous studies have focused on direct healthcare costs of PJIs, assessing the treatment expenses for hospitals. For instance, in the USA in 2012, direct healthcare costs for PJI were reported to be between $24,200 and $31,300.[7] Further analysis of treatment expenses revealed that the costs associated with DAIR in septic TKA revisions amounted to $38,776. The costs for two-stage revisions were found to be $56,900.[20] Similar health-economic studies have been conducted in Europe. For example, the cost of knee

Table IV. Reimbursement payments for DAIR, one-stage exchange, and two-stage revision procedures, per country for hip periprosthetic joint infection treatment for primary total hip arthroplasty implanted in 2019.

Country	Number of DAIR procedures for hip PJI treatment of primary THA implanted in 2019	Reimbursement per hip DAIR procedure (€)	Total reimbursement for hip DAIR procedures (€)	Number of one-stage procedures for hip PJI treatment of primary THA implanted in 2019	Reimbursement per hip one-stage procedure (€)	Total reimbursement for hip one-stage procedures (€)	Number of two-stage procedures for hip PJI treatment of primary THA implanted in 2019	Reimbursement per hip two-stage procedure (€)	Total reimbursement for hip two-stage procedures (€)	Total reimbursement for hip PJI treatment of primary THA implanted in 2019
Austria	21	10,500	220,500	85	11,000	935,000	148	27,000	3,996,000	5,515,000
Belgium	26	13,885	361,010	106	15,209	1,612,154	184	29,456	5,419,904	7,393,068
Bulgaria	7	6,240	43,680	30	6,986	209,580	53	11,207	593,971	847,231
Croatia	5	7,949	39,745	19	10,073	191,379	33	10,073	332,394	563,518
Cyprus	0	6,240	0	2	6,986	13,972	3	11,207	33,621	47,593
Czechia	18	6,240	112,320	72	6,986	502,992	125	11,207	1,400,875	2,016,187
Denmark	11	13,885	152,735	43	15,209	653,987	75	29,456	2,209,200	3,015,922
Estonia	2	6,240	12,480	7	6,986	48,902	13	11,207	145,691	207,073
Finland	13	13,885	180,505	52	15,209	790,868	91	29,456	2,680,496	3,651,869
France	136	11,545	1,570,120	551	11,545	6,361,295	957	19,596	18,753,372	26,684,787
Germany	211	13,918	2,936,698	850	14,893	12,659,050	1477	28,936	42,738,472	58,334,220
Hungary	12	6,240	74,880	46	6,986	321,356	81	11,207	907,767	1,304,003
Italy	93	8,215	763,995	376	11,932	4,486,432	654	16,605	10,859,670	16,110,097
Ireland	5	13,885	69,425	20	15,209	304,180	35	29,456	1,030,960	1,404,565
Lithuania	4	3,667	14,668	18	3,667	66,006	31	3,667	113,677	194,351
Luxembourg	1	13,885	13,885	4	15,209	60,836	7	29,456	208,649	283,370
Netherlands	24	18,113	434,712	95	17,985	1,708,575	166	36,097	5,992,102	8,135,389
North Macedonia	1	6,240	6,240	5	6,986	34,930	8	11,207	89,656	130,826
Norway	12	10,534	126,408	46	10,534	484,564	81	21,068	1,706,508	2,317,480
Poland	55	6,240	343,200	221	6,986	1,543,906	384	11,207	4,303,488	6,190,594
Portugal	8	5,528	44,224	31	6,986	216,566	52	11,415	593,580	854,370
Romania	12	6,240	74,880	49	6,986	342,314	84	11,207	941,388	1,358,582
Serbia	8	6,240	49,920	34	6,986	237,524	58	11,207	650,006	937,450
Slovenia	3	13,918	41,754	13	14,893	193,609	24	28,936	694,464	929,827
Slovakia	6	6,240	37,440	23	6,986	160,678	39	11,207	437,073	635,191
Spain	49	6,240	305,760	197	6,986	1,376,242	341	11,207	3,821,587	5,503,589
Sweden	20	13,885	277,700	81	15,209	1,231,929	141	29,456	4,153,296	5,662,925
Switzerland	22	31,229	687,038	87	31,417	2,733,279	151	62,834	9,487,934	12,908,251

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Country	Number of DAIR procedures for hip PJI treatment of primary THA implanted in 2019	Reimbursement per hip DAIR procedure (€)	Total reimbursement for hip DAIR procedures (€)	Number of one-stage procedures for hip PJI treatment of primary THA implanted in 2019	Reimbursement per hip one-stage procedure (€)	Total reimbursement for hip one-stage procedures (€)	Number of two-stage procedures for hip PJI treatment of primary THA implanted in 2019	Reimbursement per hip two-stage procedure (€)	Total reimbursement for hip two-stage procedures (€)	Total reimbursement for hip PJI treatment of primary THA implanted in 2019
Turkey	40	1,331	53,240	161	4,089	658,329	280	5,266	1,474,480	2,186,049
UK	100	7,028	702,800	404	12,365	4,995,460	702	23,608	16,572,816	22,271,076
Total	**925**		**9,751,962**	**3,728**		**45,135,894**	**6,478**		**142,343,097**	**197,230,953**

DAIR, debridement, antibiotics, and implant retention; PJI, periprosthetic joint infection; THA, total hip arthroplasty.

Table V. Reimbursement payments for DAIR, one-stage exchange, and two-stage revision procedures, per country for knee periprosthetic joint infection treatment for primary total knee arthroplasty implanted in 2019.

Country	Number of DAIR procedures for knee PJI treatment of primary TKA implanted in 2019	Reimbursement per knee DAIR procedure (€)	Total reimbursement for knee DAIR procedures (€)	Number of one-stage procedures for knee PJI treatment of primary TKA implanted in 2019	Reimbursement per knee one-stage procedure (€)	Total reimbursement for knee one-stage procedures (€)	Number of two-stage procedures for knee PJI treatment of primary TKA implanted in 2019	Reimbursement per knee two-stage procedure (€)	Total reimbursement for knee two-stage procedures (€)	Total reimbursement for knee PJI treatment of primary TKA implanted in 2019
Austria	24	10,500	250,231	89	11,000	979,603	96	27,000	2,596,386	3,826,220
Belgium	29	12,814	366,721	107	16,944	1,812,057	115	30,737	3,549,486	5,728,264
Bulgaria	3	4,753	14,092	11	5,325	58,997	12	9,774	116,931	190,019
Croatia	4	7,949	28,188	13	11,267	149,302	14	11,267	161,218	338,707
Cyprus	0	4,753	2,288	2	5,325	9,580	2	9,774	18,987	30,855
Czechia	19	4,753	88,972	70	5,325	372,485	76	9,774	738,261	1,199,719
Denmark	12	12,814	158,602	46	16,944	783,690	50	30,737	1,535,106	2,477,398
Estonia	2	4,753	8,137	6	5,325	34,066	7	9,774	67,519	109,722
Finland	16	12,814	206,449	60	16,944	1,020,114	65	30,737	1,998,215	3,224,778
France	146	11,545	1,689,746	547	11,545	6,314,313	591	19,596	11,573,049	19,577,107
Germany	222	11,203	2,486,015	829	16,047	13,306,628	895	29,050	26,011,688	41,804,330
Hungary	11	4,753	51,189	40	5,325	214,304	43	9,774	424,748	690,241
Italy	96	8,215	791,623	360	11,932	4,296,637	389	16,605	6,456,579	11,544,839
Ireland	3	12,814	36,502	11	16,944	180,366	11	30,737	353,303	570,171
Lithuania	4	3,580	15,352	16	3,580	57,367	17	3,580	61,945	134,664
Luxembourg	1	12,814	12,814	5	16,944	77,098	5	30,737	151,020	240,932
Netherlands	45	14,720	658,356	167	18,050	3,016,720	180	34,013	6,138,340	9,813,416
North Macedonia	0	4,753	2,232	2	5,325	9,346	2	9,774	18,524	30,102
Norway	7	8,715	64,254	28	8,715	240,107	30	17,430	518,541	822,902
Poland	33	4,753	159,102	125	5,325	666,090	135	9,774	1,320,183	2,145,376
Portugal	8	4,009	30,320	28	4,009	113,302	31	13,793	420,927	564,549
Romania	6	4,753	28,614	22	5,325	119,793	24	9,774	237,427	385,834
Serbia	3	4,753	15,030	12	5,325	62,922	13	9,774	124,711	202,662
Slovenia	3	7,249	24,386	13	7,620	95,791	14	19,064	258,782	378,959
Slovakia	6	4,753	30,539	24	5,325	127,853	26	9,774	253,404	411,797
Spain	77	4,753	364,527	287	5,325	1,526,111	309	9,774	3,024,732	4,915,370
Sweden	16	12,814	208,134	61	16,944	1,028,440	66	30,737	2,014,526	3,251,101

(Continued)

(*Continued*)

Country	Number of DAIR procedures for knee PJI treatment of primary TKA implanted in 2019	Reimbursement per knee DAIR procedure (€)	Total reimbursement for knee DAIR procedures (€)	Number of one-stage procedures for knee PJI treatment of primary TKA implanted in 2019	Reimbursement per knee one-stage procedure (€)	Total reimbursement for knee one-stage procedures (€)	Number of two-stage procedures for knee PJI treatment of primary TKA implanted in 2019	Reimbursement per knee two-stage procedure (€)	Total reimbursement for knee two-stage procedures (€)	Total reimbursement for knee PJI treatment of primary TKA implanted in 2019
Switzerland	26	32,698	856,647	98	45,899	4,493,539	106	78,597	8,308,823	13,659,009
Turkey	119	978	116,217	444	3,467	1,539,536	479	4,483	2,149,576	3,805,329
UK	116	4,919	569,797	433	12,365	5,352,325	467	23,608	11,034,578	16,956,700
Total	**1,058**		**9,335,075**	**3,955**		**48,058,479**	**4,271**		**91,637,518**	**149,031,073**

DAIR, debridement, antibiotics, and implant retention; PJI, periprosthetic joint infection; TKA, total knee arthroplasty.

DAIR procedures in Spain was reported to be €19,270.[10] A wide range of direct healthcare costs has been reported for two-stage knee revisions, with figures ranging from €11,282 to 18,383 in Germany[14,21] to €20,577 in France,[16] €23,113 in Ireland,[11] and up to €60,257 in Spain[10], and €66,684 in Switzerland.[15] Similarly, the cost for hip two-stage revisions also shows considerable variation, with reported figures ranging from €14,379 to 27,551 in Germany[13,21,22] to €22,152 in France,[16] €60,394 in Italy[12], and €79,715 in Switzerland.[15] The direct cost for hip septic revision in the UK was reported to be €25,545.[23] These direct hospital costs cannot be directly equated with the reimbursement payments of healthcare payors due to differing health-economic perspectives. Nevertheless, a comparison is of interest to identify potential disparities between the expenses borne by hospitals for PJI treatment and the remuneration received from healthcare funding systems. This issue has been highlighted in several studies. For example, Haenle et al[24] reported a deficit of €6,355 for hip PJI management in Germany, Sabalić et al[25] noted a shortfall of €1,695 in Croatia, and Sousa et al[17] identified losses of €2,828 for DAIR and €6,247 for two-stage hip PJI revisions. Similarly, in the UK it was reported that the current NHS tariffs do not fully reimburse the costs of revision knee surgery.[26] In Switzerland, the financial loss to the treating hospital for two-stage revisions for PJI after TKA and THA, was €36,684 and €44,715, respectively.[15] In contrast, in the USA the projected annual cost is estimated to reach $1.85 billion by 2030, with an estimated base-case cost of $390,806 per 65-year-old patient with an infection, a figure significantly higher than those reported in this study for Europe.[8,9]

The present analysis also illustrates that absolute reimbursement payments vary across different countries, leading to potential disparities in access to care. It is evident that the reimbursement rates in higher-income countries, such as France, Germany, Italy, Switzerland, the Netherlands, and the UK differ markedly from those in lower-income countries, such as Croatia, Lithuania, and Turkey. Notably, there is a striking contrast between countries with reimbursement payments of €1,331 and €31,229 per hip DAIR procedure for Turkey and Switzerland, respectively, or €3,580 and €78,597 for two-stage knee revision for Lithuania and Switzerland, respectively. Such low reimbursement rates in certain countries may pose challenges for healthcare providers in delivering comprehensive and effective PJI treatment. These discrepancies could lead to unequal access to specialized services and potentially compromise patient outcomes. Addressing this critical issue necessitates collaboration among stakeholders, particularly in light of the increasing incidence of PJI.[6,27,28] It is imperative for healthcare policymakers, insurance companies, healthcare providers, and professional societies to collaboratively establish reimbursement models that accurately reflect the true costs associated with PJI treatment and cover the entire spectrum of required services.

Moreover, research focusing on the economic impact of PJI treatment and the evaluation of cost-effectiveness can inform reimbursement policies and help optimize resource allocation. By conducting comprehensive cost analyses and comparative studies across different treatment methods and countries, policymakers may gain valuable insights into the financial implications of PJI treatment and make informed decisions to improve reimbursement practices.

The health-economic model employed in this study, incorporating five equations, is based on several assumptions, each with its unique strengths and weaknesses. One of the model's strengths is the differentiation of treatment costs between DAIR, one-stage, and two-stage PJI treatment. This was undertaken to accurately reflect the varying treatment efforts and associated reimbursement payments for each treatment type. However, for this purpose, ratios for DAIR, one-stage, and two-stage knee revision procedures were used from previously published data for Germany based on OPS codes from the Federal Statistical Office of Germany (Destatis).[3] A similar approach was employed for hip procedures, resulting in ratios of 8.3%, 33.5%, and 58.2% for DAIR, one-stage, and two-stage hip procedures, respectively, and 11.4%, 42.6%, and 46.0% for knee procedures. These ratios were then extrapolated to all other countries in the study, which represents a limitation; however, this was a necessary step due to the lack of comparable data from Eurostat. Despite this, we elected to use this approach, as the benefits of procedure stratification outweigh the drawbacks of extrapolation. Further, if we were to assume a ratio of 20% for one-stage procedures, the calculation would yield a total of €380,609,478 (hip €212,049,518 + knee €168,559,960), representing a deviation of €34,347,452 from the actual analysis. In comparison with the 17th Annual Report of the National Joint Registry (NJR) from 2020,[29] which does include infection procedures from primary arthroplasties from 2019, our assumed ratios for the different revision procedures show a comparable distribution, particularly for the hip PJI revision interventions. Unfortunately, DAIR procedures are not shown separately in the NJR but are included in single-stage procedures. If our data for DAIR and one-stage are summarized as well, there is almost no difference for the hip revisions (our data: one-stage: 42%, two-stage: 58%; NJR: one-stage: 44%, two-stage: 56%) and a tolerable difference for the knee procedures (our data: one-stage: 54%, two-stage: 46%; NJR: one-stage: 60%, two-stage: 40%). This additional comparison with NJR data strengthens our assumption and our modelling for the revision procedures.

The decision to use data from 2019 for this analysis was strategically made to avoid the potential impact of the COVID-19 pandemic on the number of procedures performed. It is important to clarify that the choice of the year 2019 for primary arthroplasties does not directly correspond to the number of PJI revisions performed in the same year. This approach specifically targets PJIs resulting from primary arthroplasties implanted in 2019, which would manifest over time. A recent observational study on 100,674 primary THAs reported a cumulative incidence of PJI at 15 years of 1.44%, with 62% of PJI cases occurring within two years of the index surgical procedure and 98% occurring within ten years.[30] These data are not only clinically relevant, suggesting that 98% of cases are expected to arise in the first ten years by 2029, but also hold relevance for considering inflation rates in this health-economic analysis. We chose to exclude deduction calculations to maintain the clarity and focus of the study, given its existing complexity. This choice is particularly justified considering that over 60% of PJI cases are projected to occur within the first two years following surgery. This approach ensures a more streamlined and manageable analysis, while still capturing the majority of PJI instances expected in the postoperative period. Another limitation of the study is the limited availability of reimbursement data, which were accessible for 12 of the 30 countries. Consequently, average reimbursement rates were extrapolated to the remaining 18 countries based on clustering of higher- and lower-income countries according to GDP per capita. Additionally, the analysis of reimbursement payments was conducted specifically for PJI cases without severe comorbidities. This approach was necessitated by the lack of available comprehensive data that included detailed information on patient comorbidities. In the context of the German Diagnosis-Related Group system, significant variances in remuneration reaching up to €13,148 per hip PJI case have been reported, contingent upon the comorbidities of the patient.[22] In addition, the analysis suffers from the fact that only the number of PJI cases, but not the total number of surgical revisions for these cases, could be considered. For example, neither exchange revision PJI cases, which constitute up to 16.2% of the total cases after one- or two-exchange procedures,[31] nor failed DAIR procedures with re-revision rates between 0% and 40%,[32] were taken into account.

Consequently, the presented numbers are likely to underestimate the overall reimbursement burden. For instance, assuming higher infection rates such as 1.5% for THA and 2.5% for TKA, the total estimated cost would nearly double to a total of €666,700,226 (hip €304,967,551 + knee €361,732,674). This conservative estimation approach was deliberately chosen to ensure a cautious and restrained perspective on the topic, while acknowledging the potential for higher actual costs in practice.

In conclusion, this is the first study to quantify the health-economic burden of PJIs in Europe after primary hip and knee arthroplasty. It reveals a substantial socioeconomic challenge in Europe, with an estimated case load of 20,416 cases and a total reimbursement cost of €346,262,026 for healthcare payors from primary THA and TKA performed in 2019. The primary limitation of this study stems from the focus solely on PJIs following primary arthroplasty procedures conducted in 2019, without including subsequent infection revision surgeries. This approach suggests that the analysis presented may represent an underestimation of the comprehensive PJI burden.

Supplementary material

Tables showing the number of debridement, antibiotics, and implant retention (DAIR), one-stage exchange, and two-stage revision procedures, per country for hip periprosthetic joint infection (PJI) treatment for primary total hip arthroplasty implanted in 2019 assuming a rate of 8.3% for DAIR, 33.5% for one-stage, and 58.2% for two-stage procedures; and the number of DAIR, one-stage exchange, and two-stage revision procedures, per country for knee PJI treatment for primary total knee arthroplasty implanted in 2019 assuming a rate of 11.4% for DAIR, 42.6% for one-stage, and 46.0% for two-stage procedures.

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