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Increased periprosthetic hip and knee infection projected from 2014 to 2035 in Taiwan

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A B S T R A C T

Background: Periprosthetic joint infection (PJI) is a disastrous complication associated with hip and knee arthroplasty. The literature suggests that the economic consequences associated with treating PJI are substantial. Our study aimed to investigate the past trends of PJI rates, and to estimate the projected number of PJI cases, consequent bed-day requirements, and medical expenses in Taiwan up to year 2035.
Methods: A nationwide epidemiological study was conducted using the inpatient database of the Bureau of National Health Insurance from 2004 through 2013. Patients with the International Classification of Disease-Clinical Modification, ninth revision (ICD9-CM) code 99,666 (PJI) who had received surgical treatment including debridement, removal of hip or knee prosthesis, or revision of total hip/knee arthroplasty (THA/TKA) were identified. Projections were performed with Poisson regression on historical incidence rates in combination with projections of arthroplasty numbers from 2014 to 2035.
Results: A total of 4935 hip (1871) and knee (3064) PJIs were identified between 2004 and 2013. The rates of PJI were 2.46% for hip arthroplasty and 1.63% for knee arthroplasty. The number of PJIs was expected to increase markedly with time from 728 in 2013 to 3542 in 2035 (a 4.87-fold increase). The bed-day requirements for treating PJI was 17,205 in 2013 and is expected to be 82,509 bed-days in 2035 (a 4.79-fold increase). The total hospitalization cost will increase 4.86-fold by 2035.
Conclusions: The number of PJI cases is increasing rapidly due to the increasing numbers of arthroplasty surgery and the cumulative number of latent infection. This may place a large economic burden on the health care system.
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Introduction

Hip and knee arthroplasty are successful operations that provide significant and durable pain relief and the majority of patients return to normal activity levels following the procedure [1,2]. However, along with the increasing demand for primary total hip arthroplasty (THA) and primary total knee arthroplasty (TKA), there is a projected increase in the frequency of revision surgery over the coming decades secondary to many causes, including periprosthetic joint infection (PJI) [3,4]. PJI is a devastating complication following joint arthroplasty. The incidence of PJI following primary THA is 1–2% [5–7], while that following primary TKA is 1–4% [7–10]. PJI accounted for 14.8% of revisions after hip arthroplasty and was the most common cause of revision after knee arthroplasty (25.2%) [11,12]. The estimated hospital cost for treating PJI cases was around 30,000 for hip PJI and 25,000 for knee PJI. The average total charges were approximately 80,000 for infected hip revision and 60,000 U.S. dollars for infected knee revision, according to the U.S. Nationwide Inpatient Sample (NIS) [4].

National arthroplasty registries had been implemented in many countries, including Scandinavian countries, England, Australia, Canada, and the United States [3,13–16]. Arthroplasty registry allowed people to obtain and calculate the annual number of

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arthroplasties, and to project the possible number of surgeries in the future [17–19]. Previous studies showed significantly increasing numbers of knee and hip arthroplasty, which may account for the increasing numbers of PJI. Kurtz et al. projected the possible number of hip and knee arthroplasty based on NIS [3], and the possible number and cost of PJI up to 2020 [4].

To our knowledge, no study has focused on the PJI burden in an Asian country. To allocate adequate resources to train surgeons and to plan for future hospital capacity, we attempted to use the Taiwan National Health Insurance Research Database (NHIRD) to predict the future burden of hip and knee arthroplasty and related PJI, thus providing new knowledge to policy makers in the government, education, and industry.

Using the Taiwan NHIRD, which is a nationwide database with epidemiological information on hip and knee arthroplasty, our study aimed to (1) determine the incidence of hip and knee arthroplasty from 2004 to 2013, (2) estimate the age and sex of the patients, and period effects, (3) predict the burden of hip and knee arthroplasty up to 2035 based on historical numbers and population projection published by the Council for Economic Planning and Development in Taiwan [19], and (4) predict the burden of hip and knee PJI and economic cost based on projected arthroplasty numbers up to 2035.

Materials and methods

Experimental procedures

The National Health Insurance (NHI) program, which is a single-pipeline public insurance system for the entire population of Taiwan, was established in March 1995. The NHI program provides healthcare for all citizens, and the program currently has a coverage rate of up to 99.8%. We conducted a nationwide survey of hip and knee arthroplasty in Taiwan from January 2004 to December 2013 based on the NHIRD, to estimate the future projection of arthroplasty and PJI. This healthcare database makes epidemiological analysis of hip and knee arthroplasty and PJI possible, because almost all patients who underwent hip and knee surgery in Taiwan were supported by this healthcare system. Data confidentiality is in accordance with the data regulations specified by the Bureau of NHI and the National Health Research Institutes (NHRI).

Patients who underwent hip or knee arthroplasty surgery according to the International Classification of Disease-Clinical Modification, ninth revision (ICD-9-CM) treatment code were included in our study. Specifically, primary total hip and knee arthroplasty were identified by the ICD-9-CM codes 81.51 and 81.54, respectively. For revisions, the relevant codes are 81.53 and 81.55. Patients with ICD-9-CM code 996.66 (infection due to internal joint prosthesis) were included for PJI. PJI patients were further validated using the surgical procedure codes characteristic for hip and knee arthrotomy, synovectomy, and removal of prosthesis surgery (Hip: 80,05, 80.15, 80.75, 80.95, 86.22, and 86.28; Knee: 80.06, 80.16, 80.76, 80.96, 86.22, and 86.28). Information on sex and age was also recorded. PJI patients who did not undergo surgical debridement or were amputated at diagnosis were not included.

Projection methodology and statistical analyses

Number of hip and knee arthroplasty

To estimate the future number of hip and knee PJI, the trends of hip and knee arthroplasty were identified first through calculating their number from 2004 to 2013. We used a Poisson regression model including sex, age group, calendar year, and the two-way interactions of these variables to calculate and project the year-specific incidence. Age was categorized into eight subgroups (<45, 45–54, 55–64, 65–69, 70–74, 75–79, 80–84, and ≥85 years). The projected numbers of hip and knee arthroplasty were estimated by applying the arthroplasty incidence estimated from the regression model to the projected population data for each subgroup. The projected national total is the sum of the projected number of arthroplasty from each subpopulation.

Demographic information from 2004 to 2013 and the population projection up to 2035 were obtained from the census data of the Council for Economic Planning and Development in Taiwan [20]. The data are derived from the official statistics released by the government and are updated every two years with the results of the latest population census. Three demographic projections (high-, median-, and low-growth) were produced based on a number of assumptions related to the rates of birth, immigration, and death. We used the median projection for our analysis of the projected number of arthroplasty.

Numbers of hip and knee PJI

PJI cases were identified first from 2004 to 2013. PJI occurrence is divided into two parts: (a) infection within one year post-arthroplasty and (b) latent infection beyond the first year. The rate of PJI was calculated separately and was allowed to vary linearly with the calendar year. Thus, the future number of PJI was based on the infection rate from 2004 to 2013 and the projected numbers of hip and knee arthroplasty up to 2035. The estimated PJI number in each subgroup was calculated separately. The total number of PJI cases after 2013 was calculated based on the sum of the estimated number of such cases for each demographic and surgery subgroups.

Hospital stay and cost

The length of stay (LOS) in both hip and knee arthroplasty was analyzed from 2004 to 2013. Because the average LOS decreased from 2004 to 2013, while it remained stable during the last five years, we used the average LOS of the last five years, combined with the projected numbers of PJI, to estimate the bed-day requirements up to 2035. The hospital cost for hip PJI did not change significantly between 2004 and 2013, and remained relatively stable between 2006 and 2013; therefore, we used the average hospital cost between 2006 and 2013, combined with the projected numbers to estimate the annual hospital cost for hip PJI up to 2035. The hospital cost for knee PJI varied in 2008 and 2009, but was stable in the other calendar years; therefore, we used the average hospital cost excluding 2008 and 2009, combined with the projected numbers to estimate the annual hospital cost for knee PJI up to 2035.

Ethics

All researchers, who plan to use the NHIRD, are required to sign a written agreement declaring that the data in the NHIRD would not be used to obtain information that could potentially violate patient privacy. The study protocol was reviewed by the NHRI, which agreed to the planned analysis of the NHIRD data. This study was also approved by the Institutional Review Board (IRB) of our hospital, which is certificated by the Ministry of Health and Welfare, Taiwan.

Results

A total of 264,011 hip (76,028) and knee (187,983) replacements were performed by NHIRD between 2004 and 2013 (Table 1 and Fig. 1). The projected numbers up to 2035 were 143,023 hip (17,200) and knee (125,823) replacements (Table 2). A total of 4935 infected hip (1871) and knee (3064) replacements were performed by NHIRD between 2004 and 2013 (Table 1 and Fig. 2). The annual number of infected hip arthroplasty cases increased from

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Table 1
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Year	TKA	Knee PJI	Knee LOS	THA	Hip PJI	Hip LOS
2004	12,992	81	30.95	6794	45	31.02
2005	13,716	162	24.77	6767	99	32.62
2006	14,722	245	25.42	6966	156	31.96
2007	17,521	310	25.5	7482	190	24.96
2008	18,773	325	27.36	7532	188	26.99
2009	20,068	341	22.79	7652	232	23.41
2010	20,726	401	22.7	7736	220	26.77
2011	21,462	338	21.85	8044	250	24.51
2012	23,637	386	24.43	8309	238	26.16
2013	24,366	475	21.83	8746	253	25.91

THA: total hip arthroplasty, TKA: total knee arthroplasty, PJI: periprosthetic joint infection, LOS: length of stay.

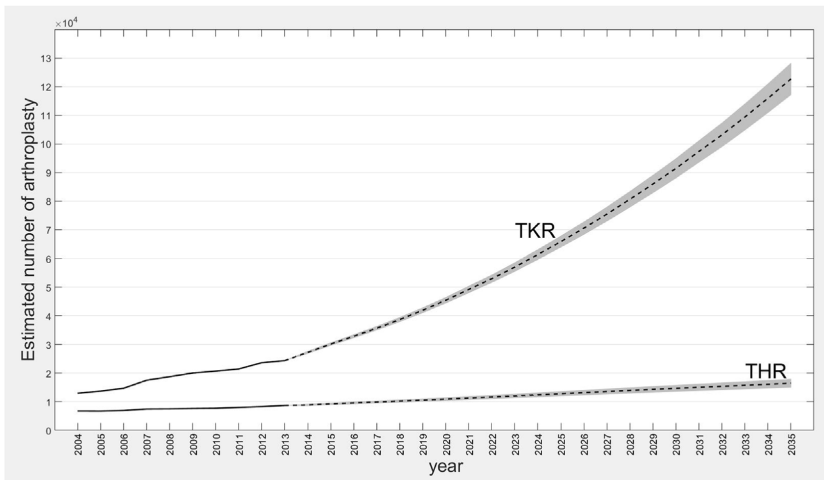

Fig. 1. Historical and projected number of total hip arthroplasty (THA) and total knee arthroplasty (TKA) procedures in Taiwan (2004–2035). The dashed lines represent the projected values per surgery type, and the grey zone around dashed lines represents the 95% confidence intervals (CIs) of the statistical projections (2014–2035).

45 (2004) to 253 (2013). The PJI incidence was calculated as the percentage of the total number of hip arthroplasties. The PJI incidence was low in 2004 and 2005 (0.662% and 1.463%), but was stabilized and increased gradually later (from 2.239% to 2.892%) (Table 1). The annual number of infected knee arthroplasty cases increased from 81 in 2004 to 475 in 2013. Similar to hip PJI incidence, the infected knee arthroplasty incidence was low in 2004 and 2005 (0.623% and 1.181%, respectively), but was stabilized and increased steadily later (from 1.664% to 1.949%) (Table 1). We hypothesized that, after having undergone arthroplasty surgery, patients will have higher possibility of infection during the first year, while this possibility will decrease during the following years. We calculated the possible infection burden and based on the projected arthroplasty numbers, we projected the PJI numbers up to 2035 for hip and knee arthroplasty. The projected PJI number for hip arthroplasty increased from 253 (2013) to 774 (2035), showing a 3.06-fold increase. The projected PJI number for knee arthroplasty increased from 475 (2013) to 2768 (2035), showing a 5.83-fold increase (Table 2 and Fig. 2).

Despite the annual increase in PJI number, the LOS required for hip arthroplasty patients decreased from 31.02 days to 25.91 days, and for knee arthroplasty patients from 30.95 days to 21.83 days (Fig. 3). Because the average LOS decreased between 2004 and 2013, while it remained relatively stable for the last five years, we used the average LOS of the last five years (25.35 days for hip and 22.72 days knee PJI), combined with the projected numbers of PJI to estimate the bed-day requirements up to 2035. The estimated bed-day requirements increased 4.79-fold from 17,205 in 2013 (6413 for hip and 10,792 for knee PJI) to 82,509 in 2035 (19,621 for hip and 62,888 for knee PJI).

The estimated hospital costs for treating PJI cases remained relatively stable over the study period for hip PJI patients, except for the first two years (2004 and 2005) (Fig. 4). We used the average cost between 2006 and 2013 (167,735 New Taiwan dollars per patient) to estimate hospital costs up to 2035. For knee PJI patients, the hospital costs remained stable over the study period except for 2009 (Fig. 4). We used the average cost between 2004 and 2013, excluding 2009 (160,018 NT dollars) to estimate hospital costs up to 2035. The estimated hospital costs requirement in PJI patients increased from 117,000,000 NT dollars in 2013 (70,000,000 for hip and 68,000,000 for knee PJI) to 569,000,000 NT dollars in 2035 (126,000,000 for hip and 443,000,000 for knee PJI), showing a 4.86-fold increase.

Discussion

Hip and knee arthroplasty are successful operations with significant pain relief, functional recovery, and durable survivorship [1,2]. As there is increasing demand for primary THA and TKA, many studies attempted to use national arthroplasty registries to project the possible operation number in the future [17–19]. Increased arthroplasty numbers are accompanied with increased PJI incidence, which accounted for 14.8% of revisions after hip arthroplasty and was the most common cause of revision after knee arthroplasty (25.2%) [11,12]. According to the U.S. NIS, PJI continues to pose great impact on the medical systems [11,21]. The current options available to treat PJI are imperfect [22–24], with variable success rates between 65 and 90% [12,22]. Kurtz et al. attempted to use NIS [3] to project the possible number of hip and knee arthroplasty, and to project the possible number and cost of PJI up to 2020 [4]. For the

Table 2
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Year	TKA	Knee PJI	THA	Hip PJI
2014	27260.8	515.7	8900.0	281.3
	26,862–27,659	513.0–518.4	8629.6–9170.5	278.7–283.8
2015	30160.9	566	9296.3	298.8
	29,687–30,633	561.1–570.9	8992.7–9600.0	294.5–303.1
2016	32,872	620.7	9615.0	316.7
	32,317–33,426	614.0–627.4	9277.1–9952.8	310.9–322.5
2017	35701.8	678.8	9931.8	335.1
	35,054–36,348	670.1–687.5	9556.9–10306.6	327.8–342.5
2018	38,721	741.5	10256.5	354.1
	37,968–39,473	730.8–752.2	9841.7–10671.2	345.3–362.9
2019	41955.1	809.6	10590.1	373.6
	41,082–42,827	796.6–822.6	10132.8–11047.5	363.1–384.0
2020	45470.2	883.6	10940.6	393.4
	44,460–46,479	868.1–899.1	10437.7–11443.5	381.3–405.6
2021	49223.5	963.5	11320.0	414.2
	48,060–50,386	945.1–981.9	10767.9–11872.1	400.2–428.1
2022	52973.9	1047.8	11672.5	435.3
	51,644–54,303	1026.2–1069.4	11070.3–12274.7	419.6–450.9
2023	57047.4	1137.1	12047.8	457
	55,531–58,563	1112.2–1162.1	11392.2–12703.4	439.6–474.4
2024	61372.2	1232.1	12434.3	479.3
	59,650–63,094	1203.4–126-.1	11722.5–13146.0	460.0–498.7
2025	65893.6	1332.8	12819.8	502.3
	63,945–67,841	1299.9–1365.7	12049.9–13589.7	480.9–523.7
2026	70569.9	1438.9	13203.5	525.7
	68,376–72,763	1401.4–1476.4	12373.4–14033.5	502.1–549.3
2027	75483.4	1550.8	13586.7	549.7
	73,022–77,944	1508.3–1593.3	12694.6–14478.9	523.8–575.5
2028	80654.8	1668.9	13966.7	574
	77,901–83,408	1620.8–1717.0	13010.8–14922.5	545.8–602.3
2029	85,975	1792.7	14338.7	598.8
	82,908–89,041	1738.6–1846.9	13317.8–15359.6	568.0–629.5
2030	91,453	1922.1	14696.1	623.8
	88,049–94,856	1861.4–1982.8	13609.4–15782.7	590.4–657.2
2031	97352.5	2058.8	15056.2	649.2
	93,579–101,125	1990.9–2126.7	13901.8–16210.6	613.1–685.3
2032	103142.8	2200.4	15395.7	674.7
	98,986–107,299	2124.7–2276.0	14173.7–16617.8	635.8–713.6
2033	109400.6	2348.9	15763.4	700.8
	104,822–113,978	2433.0–2433.0	14469.8–17057.1	658.9–742.7
2034	115927.8	2504.9	16119.6	727.2
	110,897–120,958	2411.8–2598.0	14753.6–17485.6	682.3–772.2
2035	122672.8	2667.8	16482.0	754.1
	117,159–12,8186	2564.9–2770.7	15041.5–17922.6	705.9–802.2

THA: total hip arthroplasty, TKA: total knee arthroplasty, PJI: periprosthetic joint infection, LOS: length of stay.

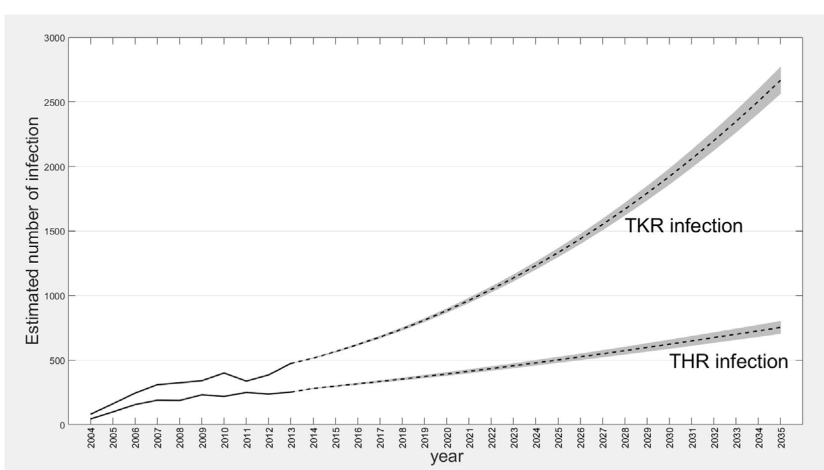

Fig. 2. Historical and projected number of infected total hip arthroplasty (THA) and total knee arthroplasty (TKA) procedures in Taiwan (2004–2035). The dashed lines represent the projected values per PJI type, and the grey zone around dashed lines represents the 95% confidence intervals (CIs) of the statistical projections (2014–2035).

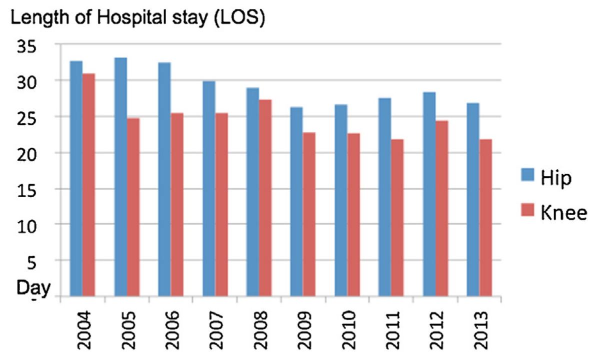

Fig. 3. The length of stay (LOS) of hip and knee periprosthetic joint infection (PJI) cases between 2004–2013. The LOS reached a plateau during the last five years.

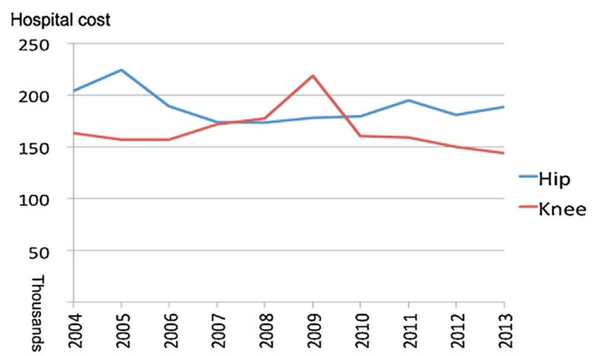

Fig. 4. The estimated hospital costs for treating PJI cases between 2004–2013. The cost of hip periprosthetic joint infection (PJI) remained relatively stable except for the first two years (2004 and 2005). For knee PJI patients, the hospital costs remained stable except for 2009.

same purpose, we attempted to use a medical insurance database that includes the whole population of our country to project the arthroplasty numbers and the possible PJI numbers, costs, and LOS. This projection makes future policy decisions related to the distribution of medical resources possible. Our study found that PJI will increase from 728 cases in 2013 (Hip: 253, Knee: 475) to 3542 in 2035 (Hip: 774, Knee: 2768), showing a 5.83-fold increase (Hip: 3.06-fold, Knee: 5.83-fold). The estimated bed-day requirements will increase from 17,205 in 2013 (6413 for hip and 10,792 for knee PJI) to 82,509 in 2035 (19,621 for hip and 62,888 for knee PJI), showing a 4.79-fold increase. The estimated hospital costs will increase from 117,000,000 New Taiwan dollars in 2013 (70,000,000 for hip and 68,000,000 for knee PJI) to 569,000,000 NT dollars in 2035 (126,000,000 for hip and 443,000,000 for knee PJI), showing a 4.86-fold increase.

The NHI program in Taiwan, which is a single-pipeline public insurance system for the entire population of Taiwan, was established in March 1995. The NHI program provides healthcare for all citizens, and the program currently has a coverage rate of up to 99.8% [25]. NHIRD covers diagnostic records, hospital admissions, prescriptions, disease profiles, etc., and diagnoses are recorded with maximum three ICD-9 codes in each visit. Arthroplasty and PJI treatment were supported by NHIRD, thus rendering our study possible. To ensure the validity of ICD-9 codes, NHI Bureau randomly assigns senior orthopedic surgeons, who do not have any conflicts of interest with patients' hospitals, to regularly inspect the original contents of patient charts. Therefore, we infer that the validity of arthroplasty and PJI diagnosis in our data set is high, and our data sets are reliable for calculating the incidence of arthroplasty and PJI, and for predicting future PJI rates in Taiwan.

A key strength of our study is the use of a large and nationally representative data set of hospital discharges by NHIRD. There are some well-known National arthroplasty registries in the world, including in Scandinavia, England, Australia, Canada, and the United States [3,13–16]. Compared to other arthroplasty registries, most arthroplasty registries could only trace PJI post-OP one or two years. Our PJI data was sortied from the whole nation health insurance database, that patients could be traced in this database as long as the patient kept in this health insurance system, which could better collect and analyze the latent PJI. We combined the census data of the Council for Economic Planning and Development in Taiwan [20] to generate more accurate projections of arthroplasty. We projected arthroplasty by including the Demographic information and population projections up to 2035 from the census data of the Council for Economic Planning and Development in Taiwan [20]. The latest population census was generated using official statistics that were released by the government and is updated every two years. To avoid over- or under-estimation of arthroplasty numbers, the median projection was chosen for our analysis. Combining arthroplasty projection based on census data of the Council for Economic Planing and Development in Taiwan and adequate collecting of acute and latent PJI, we expect to have the reasonable projection of arthroplasty and PJI.

There were only two studies that have attempted to project the PJI rate. One varied the PJI rate linearly with calendar year, and the PJI numbers with rates plus projected arthroplasty depended on future population [12]. The other one included diabetes and obesity into the projection model and attempted to predict the exponential increase of PJI secondary to diabetes and obesity [26]. We attempted to use the same methods; however, the PJI numbers increased exponentially and unreasonably. To modify and more reasonably project the PJI numbers, we divided the PJI rate into two parts. In the first part, we calculated the PJI rate within one year post-OP (1-year post-operate), which is believed to be higher compared to post-OP beyond the first year. In the second part, we calculated the latent PJI annually, which was lower compared to the 1-year post-operatively. We used the PJI numbers between 2004 and 2013 to estimate the PJI rate, and then we projected the PJI by including the PJI rate in the number of arthroplasty that was projected with the regression model based on the census data of the Council of Economic Planning and Development in Taiwan [20]. The increase in the PJI rate was not as high as in a previous study [12], but still was 3.06-fold higher for hip and 5.83-fold for knee PJI by 2035. The Taiwan Medical Association reports that from 1998 to 2011, the number of board certified orthopedic surgeons has been constant with an increase number at around 5%. By 2035, it is estimated that there will be about 1.8-fold increase in the number of orthopedic surgeons in Taiwan according to the current rate [27]. In contrast, the increase in the PJI number may result in a supply-demand imbalance in the near future.

Despite the increasing number of PJI, total LOS and medical cost of each PJI case affect the distribution of medical resources. The average LOS and cost were stabilized during the last five year of the period between 2009–2013. The total increase of LOS and cost was dramatically affected by the PJI number. The increasing trend may be inhibited if PJI is prevented or better treated. However, monitoring time trends regarding the rate of PJI is important for exploring and understanding new ways of preventing PJI. However, the projection model was based on two major parts. First, the number of arthroplasty projected according to census data from the Council for Economic Planning and Development in Taiwan [20]. Second, the rate of PJI calculated based on data during 2004–2013. The projection may be not correct if the population growth was not

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in median projection, or the incidence of PJI was improved in the future.

Limitations

There are several limitations of our study. First, during the process of estimating the projection of arthroplasty and PJI, misclassification of diseases and coding errors may occur when using an administrative database. These errors can be partially corrected by taking into account the type of treatment (most patients with PJI received surgical debridement), although there is a potential for bias. Our results were also limited by inadequate clinical data collection related to PJI, such as the organism responsible for the infection. Second, the inclusion criteria, which were employed by the operation codes, excluded patients who did not receive surgical treatment but received antibiotic treatment only. Thus, the incidence of PJI was likely to be underestimated. Third, the estimated hospital cost in this study did not include the cost from other hospital admissions (e.g., infection specialists' admission); neither it included costs from outpatient departments, including physical therapy, rehabilitation, home care, and outpatient pharmaceutical treatments. Thus, as far as the cost estimates are concerned, the economic burden of infection calculated in the present study is almost definitely understated. Fourth, population projections are limited by the assumptions made. Many social and economic factors may influence changes in the population. However, projections of the number of arthroplasty were based on elderly adults, which is usually a more stable population than children/young adults, because fluctuations of this population do not rely on projecting levels of fertility and are much less affected by migration. Finally, we projected the PJI based on the number of arthroplasties, thus rendering our estimate more reliable.

Conclusions

In conclusion, the annual number of PJI is increasing due to the annual increase in arthroplasty surgeries and the increased cumulative number of latent infection; in addition, the number of arthroplasties is increasing due to population growth and aging. By 2035, there will be a 4.87-fold increase in the number of PJI and a 4.79-fold increase in the number of bed days required. Hospitalization cost will increase by 4.86-fold. This may place a larger economic burden on the health care system. Our study provides quantitative measures that may be used for future policy decisions related to the distribution of medical resources.

Conflicts of interests

There were no conflicts of interests for all authors.

Ethical approval

After institutional review board approval (No. 104-6538B), clinical records in this study were retrieved from the National Health Insurance Research Database provided by the Bureau of National Health Insurance of Taiwan.

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