

Has the bacteriology of periprosthetic joint infection after total knee arthroplasty changed over time? A retrospective cohort study of 2171 patients

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ABSTRACT

Introduction: Periprosthetic joint infection (PJI) is an uncommon but serious complication of total knee arthroplasty (TKA). A previous retrospective cohort study at our institution reported a PJI incidence of 1.34% between 1993 and 2013. The present study aimed to determine whether the incidence of PJI after TKA has changed at our hospital and to evaluate changes in microbiological patterns between 2014 and 2021.

Methods: In total, 2171 primary TKAs were performed at Queen Mary Hospital between 1 January 2014 and 31 December 2021. All cases of PJI were identified using the Musculoskeletal Infection Society criteria. Patient demographics, PJI occurrence, and microbiological data were collected and compared with the previously published findings from the 1993–2013 PJI cohort.

Results: The incidence of PJI after TKA was 0.64% between 2014 and 2021, representing a significant decrease from the incidence of 1.34% observed at our institution between 1993 and 2013 ($P=0.018$). There was no significant difference in the incidence of early-onset infection ($P=0.095$). Methicillin-sensitive *Staphylococcus aureus* was the most common causative organism, accounting for 57.1%

($n=8$) of our cohort and 26.5% ($n=9$) in the previous cohort.

Conclusion: The incidence of PJI decreased significantly from 1.34% to 0.64% between the two study periods, suggesting the effectiveness of infection-reduction measures implemented at our institution. Minimal differences were observed in the microbiological patterns of PJI between the cohorts.

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New knowledge added by this study

- Between 2014 and 2021, the incidence of periprosthetic joint infection (PJI) after elective primary total knee arthroplasty (TKA) performed at our institution was 0.64%.
- Methicillin-sensitive *Staphylococcus aureus* remains the most common causative organism in cases of PJI.
- Antibiotic-resistant microorganisms are less prevalent than expected in cases of PJI.

Implications for clinical practice or policy

- Multidisciplinary, protocol-driven optimisation of modifiable risk factors—both preoperatively and perioperatively—directly lowers PJI rates. Hospitals should adopt restrictive transfusion policies and aggressive medical co-morbidity management as standard of care for all patients undergoing TKA.
- Initiating antibiotics only after obtaining appropriate microbiological samples (eg, joint aspiration) significantly improves organism identification. This allows targeted antimicrobial therapy rather than empirical coverage, which is particularly important given the changing bacteriological profile. Clinicians should avoid prescribing empirical antibiotics before sampling to prevent false-negative cultures and subsequent treatment failure.

Introduction

Periprosthetic joint infection (PJI) is an uncommon but severe complication of total knee arthroplasty (TKA). The existing literature indicates that

approximately 1% to 2% of patients undergoing primary arthroplasty experience PJI; moreover, PJI is the leading cause of revision arthroplasty.^{1,2} Individuals with PJI may experience a substantial

decrease in quality of life and must undergo complex and costly treatments to resolve this complication.³

A previous study at our institution, Queen Mary Hospital in Hong Kong, examined 2543 patients who underwent elective primary TKA between 1993 and 2013.⁴ During that period, the reported incidence of PJI was 1.34% and the most common causative organism was methicillin-sensitive *Staphylococcus aureus* (MSSA).⁴ The number of TKAs performed at our centre is rapidly increasing. In the past 8 years, clinicians at our institution have performed 85% of the total number of TKAs between 1993 and 2013, a span of 20 years. Considering the rapid population ageing in Hong Kong, we anticipate a continued increase in the number of TKAs. In recent years, various measures have been proposed to further reduce the incidence of PJI, including restrictions on blood transfusion rates, preoperative optimisation of modifiable risk factors, and the implementation of stringent culture techniques to improve microbial yield.⁵⁻⁷ However, the limited availability of local data makes it difficult to assess the effectiveness of these techniques in reducing PJI incidence. It is important to analyse the efficacy of these interventions as part of ongoing efforts to improve surgical outcomes at our centre. Furthermore, the increasing consumption of antibiotics over the past two decades has led to inevitable changes in the microbiological landscape of infectious organisms.⁸

This study had three objectives. First, it aimed to provide current local data on the incidence of PJI after elective primary TKA. Second, it sought to identify changes in the microbiological landscape of PJI; this information may guide future treatment and prevention strategies. Third, it aimed to showcase the efficacy of interventions to reduce PJI incidence and encourage their adoption beyond our institution.

Considering the measures introduced to reduce infection at our institution, we hypothesised that the incidence of PJI after primary TKA decreased over the past decade. We also hypothesised that the proportion of methicillin-resistant *S aureus* (MRSA)-related PJI increased during this period due to the increasing global consumption of antibiotics.

Methods

This retrospective cohort study compared the incidence and bacteriology of PJI after TKA at our institution. Participants were included if they underwent primary elective TKA at our institution between 2014 and 2021, and met the 2011 Musculoskeletal Infection Society (MSIS) criteria for PJI.⁹ Exclusion criteria were infection after revision arthroplasty, knee arthroplasty for malignant joint conditions, and active bacteraemia. The primary outcomes of interest were the incidence and bacteriological patterns of PJI. Secondary outcomes

全膝關節置換術後周圍關節感染的微生物學模式是否隨時間出現變化？一項涵蓋2171名患者的回顧性隊列研究

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引言：周圍關節感染是全膝關節置換術中一種不常見但嚴重的併發症。本院先前的回顧性隊列研究顯示，1993至2013年間全膝關節置換術後周圍關節感染的發生率為1.34%。本研究旨在確定本院全膝關節置換術後周圍關節感染的發生率是否出現變化，並評估2014至2021年間微生物學模式的變化。

方法：2014年1月1日至2021年12月31日期間，本院共進行2171例初次全膝關節置換術。所有周圍關節感染病例均根據肌肉骨骼感染學會（MSIS）標準予以確認。我們收集患者的人口統計學資料、周圍關節感染發生情況及微生物學數據，並與先前發表的1993至2013年間周圍關節感染隊列研究結果進行比較。

結果：2014至2021年間，周圍關節感染的發生率為0.64%，較1993至2013年間本院觀察到的1.34%顯著下降（ $P=0.018$ ）。早期感染的發生率並無顯著差異（ $P=0.095$ ）。甲氧西林敏感金黃色葡萄球菌為最常見的致病菌，在本研究隊列中佔57.1%（ $n=8$ ），而既往隊列中該菌佔26.5%（ $n=9$ ）。

結論：在兩個研究時期之間，周圍關節感染的發生率由1.34%顯著下降至0.64%，顯示本院所實施的感染預防措施具成效。兩個隊列之間的周圍關節感染的微生物學模式差異不大。

included preoperative patient demographics and time to onset of PJI.

Study population

The Hong Kong Hospital Authority's Clinical Data Analysis and Reporting System and the Local Joint Replacement Registry were utilised to identify all TKAs performed at our institution between 2014 and 2021. Records were then searched using the keywords 'orthopaedic aftercare' and 'periprosthetic joint infection' to identify potential cases of PJI. Patients who did not meet the 2011 MSIS criteria for PJI were excluded; the remaining patients comprised the study cohort.¹⁰ Two senior authors of this study (PK Chan and KY Chiu) independently screened the patient database using the 2011 MSIS criteria to identify suitable patients for further data collection. Any uncertainties or disagreements were resolved through discussion.

Using a predefined data extraction form, the same two senior authors extracted the following data from the records of all included patients: intraoperative joint fluid culture results, age, sex, medical co-morbidities (eg, diabetes mellitus, rheumatoid arthritis, and immunosuppression), date of the index operation, surgical technique, operative time, date of re-operation, and postoperative

antibiotic regimen.

A previous retrospective cohort study by Siu et al⁴ assessed the incidence and bacteriology of PJI among patients who underwent TKA at our institution between 1993 and 2013. From that study, we extracted data on the incidence and bacteriology of PJI, patient demographics, and time to onset of infection for comparison with our cohort. For both cohorts, we recorded the mean operative time, number of joint specialists involved, surgical technique, use of patient-specific instrumentation, and infection control protocols; these data were used to identify potential confounders that could influence the incidence of PJI.

Patients in our cohort were classified according to the time to infection onset as early, delayed, or late. Early-onset PJI was defined as infection occurring within 3 months of the index operation. These infections commonly arise from intraoperative contamination by highly virulent microorganisms and therefore constitute a key focus of intervention. Delayed-onset PJI was defined as infection occurring between 3 and 24 months after the index operation. These infections are also typically acquired during surgery but involve less virulent microorganisms. Late-onset PJI was defined as infection occurring over 24 months after surgery. These infections are often caused by haematogenous pathogens unrelated to the index operation.¹¹

In accordance with our institution's guidelines, patients were invited to attend follow-up at 2 weeks,

3 months, 6 months, and 12 months postoperatively. Patients without complications were subsequently scheduled for annual follow-up. Regarding infection control, the preoperative, perioperative, and postoperative protocols for elective primary TKA remained consistent throughout the study period in both cohorts. Intravenous antibiotic prophylaxis (1 g of cefazolin, or vancomycin for patients with a penicillin allergy) was administered 1 hour prior to skin incision. Intraoperatively, laminar airflow and body exhaust systems were utilised. Antibiotic-loaded cement was not routinely used, and a single postoperative wound management and rehabilitation programme was implemented throughout the study period. Postoperative antibiotics were not routinely administered.

Statistical analyses

Categorical variables were grouped for analysis; prevalence was calculated and group differences were tested with the Chi squared test. Continuous variables were compared using independent two-tailed *t* tests. A *P* value <0.05 was considered statistically significant. All statistical analyses were conducted using SPSS (Windows version 27.0; IBM Corp, Armonk [NY], United States).

Results

In total, 2543 and 2171 primary TKAs were performed at our institution between 1993-2013⁴ and 2014-2021, respectively. The incidence of PJI was 0.64% (n=14; 95% confidence interval=0.39-0.89) between 2014 and 2021, significantly lower than the 1.34% (n=34; 95% confidence interval=0.97-1.71) recorded between 1993 and 2013 (*P*=0.018).⁴

The mean age of the 14 patients with PJI in our cohort was 68.5 ± 7 years (range, 56-85). Of these patients, eight were men (57.1%) and six were women (42.9%). In terms of medical co-morbidities, seven patients had diabetes mellitus (50.0%), one had rheumatoid arthritis (7.1%), and one had end-stage renal disease requiring immunosuppression (7.1%). The mean follow-up period in our cohort was 4 years 9 months (interquartile range [IQR], 4 years 0 months to 6 years 11 months). There were no significant differences in age, sex distribution, or medical co-morbidities (diabetes mellitus and rheumatoid arthritis) between the two cohorts. The cohort demographics are compared in Table 1.⁴

Confounding factors

We analysed other potential confounding factors (eg, mean operative time, number of joint specialists involved, and surgical approach) to minimise their effects on the primary and secondary outcomes.¹² The indications for TKA did not change at our institution during the two time periods. Our

TABLE 1. Patient demographics in the two cohorts*

	TKA (1993-2013) [n=34] [†]	TKA (2014-2021) [n=14]	P value
Demographics			
Sex			0.071 [†]
Male	10 (29.4%)	8 (57.1%)	
Female	24 (70.6%)	6 (42.9%)	
Age, y	69 ± 9	68.5 ± 7	0.680 [‡]
Co-morbidities			
Diabetes mellitus	9 (26.5%)	7 (50.0%)	0.116 [†]
Rheumatoid arthritis	7 (20.6%)	1 (7.1%)	0.256 [†]
Immunosuppression	N/A	1 (7.1%)	N/A [§]
Time to infection			
Onset			0.095 [†]
Early	10 (29.4%)	1 (7.1%)	
Late	24 (70.6%)	13 (92.9%)	

Abbreviations: N/A = not applicable; TKA = total knee arthroplasty

* Data are shown as No. (%) or mean ± standard deviation, unless otherwise specified

[†] Chi squared test

[‡] Meta-analysis

[§] Statistical comparison not performed

institutional guidelines state that patients with Kellgren and Lawrence Grade 3 or 4 end-stage knee osteoarthritis and debilitating symptoms refractory to nonoperative treatment are candidates for TKA. The mean operative times for primary elective TKA were 1 hour 56 minutes during 1993-2013⁴ and 1 hour 33 minutes during 2014-2021. The difference was not statistically significant (P=0.170). The number of joint specialists involved increased from four to six between the two periods. From 1993 to 2019, all TKAs were exclusively performed using the conventional approach.

After the computed tomography-based robotic arm-assisted system for total joint arthroplasty was introduced in 2019,¹³ surgeons at our institution could choose between robotic-assisted TKA and conventional TKA. Currently, there are no specific indications for either approach; the choice remains a matter of surgeon preference.¹⁴ To our knowledge, no studies have compared PJI incidence between robotic-assisted and conventional TKA; future research should explore the infection rate associated with each procedure. Patients undergoing robotic-assisted TKA at our institution follow the same postoperative protocol established for those undergoing conventional TKA (follow-up at 2 weeks, 3 months, 6 months, 12 months, and annually thereafter). Because robotic-assisted TKA was recently introduced at our institution, the mean follow-up duration for patients treated with this approach was short (14 months; IQR, 4.5-26).

Time to infection

Early-onset PJI occurred in 7.1% (n=1) of patients in the study cohort, arising 60 days after arthroplasty. In the 1993-2013 cohort, 29.4% (n=10) of patients experienced early-onset infection at a median of 17 days after arthroplasty (IQR, 9-32).⁴ However, the incidence of early-onset PJI did not differ significantly between the two cohorts (P=0.095) [Table 1]. Delayed-onset PJI occurred in 28.6% (n=4) of patients in the study cohort, occurring at a median of 6 months after arthroplasty (IQR, 5-7). Late-onset PJI occurred at a median of 3 years after arthroplasty (IQR, 2 years 1 month to 3 years 7 months). A larger proportion of patients experienced infection during the first year after surgery in the 1993-2013 cohort⁴ compared with the 2014-2021 cohort (59% vs 36%).

Bacteriology

Methicillin-sensitive *S aureus* remained the most common causative organism in cases of PJI between 2014 and 2021, affecting 57.1% (n=8) of patients. The proportion of PJI cases caused by MSSA was significantly greater in the 2014-2021 cohort than in the 1993-2013 cohort, in which 26.5% (n=9) of patients were infected with MSSA (P=0.043) [Table 2].⁴

Methicillin-resistant *S aureus* was the second most common causative organism in cases of PJI between 1993 and 2013 (17.6%, n=6)⁴; *Streptococcus* spp. (14.3%, n=2) was the second most common causative organism between 2014 and 2021. The two cases of streptococcal infection in the 2014-2021 cohort comprised one with *Streptococcus dysgalactiae* and one with *Streptococcus agalactiae*. Other causative organisms in PJI cases within the 2014-2021 cohort included MRSA (7.1%, n=1), methicillin-sensitive coagulase-negative staphylococci (7.1%, n=1), and *Escherichia coli* (7.1%, n=1). Methicillin-resistant strains accounted for 40% of all staphylococcal infections between 1993 and 2013⁴; this proportion was 11.1% between 2014 and 2021. Table 2 compares the microbiological patterns of PJI between the two cohorts.

There was a non-significant decrease in the proportion of patients with culture-negative PJI between the two cohorts, from 23.5% (n=8) between

TABLE 2. Microbiological patterns in the two cohorts*

Causative organism	TKA (1993-2013) [n=34] ⁴	TKA (2014-2021) [n=14]	P value
MSSA	9 (26.5%)	8 (57.1%)	0.043†
MRSA	6 (17.6%)	1 (7.1%)	0.349†
<i>Streptococcus</i> spp.	3 (8.8%)	2 (14.3%)	0.573†
MS-CONS	2 (5.9%)	1 (7.1%)	0.870†
<i>Escherichia coli</i>	2 (5.9%)	1 (7.1%)	0.870†
<i>Salmonella</i>	2 (5.9%)	N/A	N/A‡
MR-CONS	1 (2.9%)	N/A	N/A‡
<i>Mycobacterium tuberculosis</i>	1 (2.9%)	N/A	N/A‡
Culture-negative	8 (23.5%)	1 (7.1%)	0.186†

Abbreviations: MR-CONS = methicillin-resistant coagulase negative staphylococci; MRSA = methicillin-resistant *Staphylococcus aureus*; MS-CONS = methicillin-sensitive coagulase negative staphylococci; MSSA = methicillin-sensitive *Staphylococcus aureus*; N/A = not applicable; *Streptococcus* spp. = *Streptococcus* species; TKA = total knee arthroplasty

* Data are shown as No. (%), unless otherwise specified

† Chi squared test

‡ Statistical comparison not performed

TABLE 3. Interventional measures to reduce the incidence of periprosthetic joint infection at our institution

Study	Summary
Chan et al ⁵	<ul style="list-style-type: none"> Refer patients with persistently elevated erythrocyte sedimentation rate or C-reactive protein level to a rheumatologist for further assessment and treatment Universal glycated haemoglobin and fructosamine screening Enhanced patient education to optimise weight control
Chan et al ⁶	<ul style="list-style-type: none"> Restrictive blood transfusion policy to minimise transfusion-related complications Maintain blood mass via haemoglobin maintenance, haemostasis optimisation, and decreased blood loss

1993 and 2013⁴ to 7.1% (n=1) between 2014 and 2021 (P=0.186) [Table 2].

Discussion

This study showed that the incidence of PJI after primary TKA at our institution significantly decreased. Worldwide, the reported incidence of PJI after primary elective TKA ranges from 1% to 2%.^{1,2} Over the years, our institution has implemented various measures to reduce the incidence of PJI after TKA, including a preoperative patient optimisation programme and a restrictive blood management programme. These measures are summarised in Table 3.^{5,6}

Medical risk factors

The association between blood transfusion and increased perioperative morbidity in patients undergoing TKA is well documented.^{15,16} The American College of Surgeons National Surgical Quality Improvement Program reported that patients receiving transfusions experienced up to a tenfold increase in the risk of adverse postoperative outcomes.¹⁷ Based on these findings, a more restrictive transfusion approach has been implemented in the past several years after the 2015 study¹⁷ to improve postoperative outcomes. A retrospective study of 12590 patients demonstrated significant decreases in complications, 30-day readmissions, and hospital length of stay following implementation of a patient blood management programme for patients undergoing prosthetic joint arthroplasty.¹⁸ The programme aimed to reduce transfusion requirements by optimising red cell mass, minimising blood loss, and defining appropriate indications for transfusion.¹⁸ A patient blood management programme was introduced at our institution in 2014; subsequently, the mean transfusion rate among patients undergoing TKA decreased from 31.3% in 2013 to 1.9% in 2018.⁶

Preoperative optimisation

The preoperative optimisation programme at our institution emphasises the optimisation of modifiable risk factors for PJI prior to TKA.⁵ Rheumatological diseases such as rheumatoid arthritis, juvenile inflammatory arthritis, ankylosing spondylitis, and psoriatic arthritis are known to increase the risk of PJI.^{19,20} A previous review of 2543 TKAs showed that the incidence of PJI was 3.1% in patients with rheumatoid arthritis, significantly higher than the 1.2% observed in patients without rheumatoid arthritis.⁴ At our institution, patients with rheumatoid arthritis who exhibit a persistently elevated erythrocyte sedimentation rate or C-reactive protein level are referred to a rheumatologist for further assessment and treatment prior to

surgery. Diabetes mellitus is also strongly associated with an increased risk of PJI. All patients scheduled for elective TKA at our institution undergo universal glycated haemoglobin and fructosamine screening, with referral to an endocrinologist for optimisation if the glycated haemoglobin level exceeds 7.5%.²¹ Other modifiable risk factors monitored at our institution include weight control, vitamin D status, and nutritional status.²²

Antimicrobial resistance

From 2014 to 2021, MSSA was the most common causative organism in cases of PJI at our institution (57.1%, n=8). This finding is consistent with the existing literature, which indicates that *S aureus* is the most common causative organism in PJI after primary joint arthroplasty (19%-29% of cases worldwide).²³⁻²⁵ The unique virulence factors of *S aureus* enhance its ability to adhere to implants, facilitating aggressive biofilm formation and enabling replication and survival within this microenvironment.^{26,27}

Owing to the increasing use of antibiotics in the community, we hypothesised that the number of antibiotic-resistant causative organisms would increase in our cohort of patients with PJI. The SENTRY Antimicrobial Surveillance Program evaluated 20-year trends in antimicrobial susceptibility among *S aureus* isolates across 427 centres in 45 countries.²⁸ The authors reported that the prevalence of MRSA peaked at 44.2% in 2005-2008, then declined to 42.3% in 2009-2012 and 39.0% in 2013-2016.²⁸ The incidence of MRSA among PJI cases in our study was consistent with findings from other regions. For example, a multicentre study in New Zealand showed that 9.1% of PJIs were attributable to MRSA.²⁹

It is well established that early-onset infection typically occurs during surgery through intraoperative contamination, whereas late-onset PJI commonly arises from haematogenous spread.¹⁰ We observed a decrease in the proportion of early-onset infection between the two cohorts; however, this difference was not statistically significant (P=0.095). Additional measures should be implemented to further reduce the incidence of PJI after primary TKA at our institution.

Culture-negative periprosthetic joint infection

In recent years, the incidence of culture-negative PJI has increased among patients undergoing total joint arthroplasty.³⁰ This increase has been hypothesised to result from a higher prevalence of low-virulence organisms, premature antibiotic treatment, and failure to use enriched culture media.^{31,32} An inability to identify causative organisms in cases of PJI represents a serious problem for surgeons and

infection control teams because of the uncertainties associated with antimicrobial selection. To reduce the incidence of culture-negative PJI, our institution implemented recommendations published by Tan et al,⁷ including extending the incubation period, using blood culture bottles and flasks, and collecting an adequate number of separate intraoperative tissue samples from patients with suspected PJI.⁷ The incidence of culture-negative PJI at our institution declined; however, this decline was not statistically significant ($P=0.186$).

Limitations

This study had several limitations. First, it included patients treated at a single academic centre in Hong Kong; therefore, the findings may not accurately reflect changing trends in PJI incidence and bacteriology across the region. Further multicentre studies are warranted to better understand these trends. Second, the duration of patient recruitment differed between the present and former studies (7 years vs 20 years). Third, the number of patients varied between the two cohorts (2543 vs 2171). Despite this difference, we proceeded with the 7-year recruitment period considering the clinical value of evaluating recent PJI incidence and bacteriology in Hong Kong. Considerable effort was made to standardise patient characteristics and baseline co-morbidities to ensure comparability between cohorts. Fourth, given the relatively short mean follow-up duration (4 years 9 months), some cases of late-onset PJI may have occurred after completion of follow-up. Fifth, inconsistencies in record-keeping over the past decade prevented analysis of all documented risk factors for PJI; this limitation was unavoidable because of the retrospective study design. Sixth, the limited number of PJI cases hindered further subgroup analyses (ie, assessment and comparison of PJI incidence between conventional and robotic-assisted approaches). A similar study with a larger cohort may therefore be beneficial. Despite these limitations, the present study represents the largest series of PJI cases in Hong Kong to compare bacteriological patterns across two time periods. We believe that the findings have important clinical implications for PJI management in local hospitals.

Conclusion

This is the first study in Hong Kong to assess changes in the incidence and microbiological patterns of PJI after TKA across two time periods. Our findings have substantial clinical implications, as they demonstrate the effectiveness of interventional measures implemented at our institution in reducing the incidence of PJI, the rate of culture-negative PJI, and the number of early-onset cases. Prevention of PJI improves patient outcomes and reduces the

economic burden on the healthcare system. Larger, multicentre, prospective studies are required to further elucidate bacteriological trends in PJI in Hong Kong.

Author contributions

Concept and design: All authors.

Acquisition of data: JR Khoo.

Analysis or interpretation of data: JR Khoo, PK Chan.

Drafting of the manuscript: JR Khoo.

Critical revision the manuscript for important intellectual content: All authors.

All authors had full access to the data, contributed to the study, approved the final version for publication, and take responsibility for its accuracy and integrity.

Conflicts of interest

All authors have disclosed no conflicts of interest.

Declaration

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Ethics approval

This research was approved by the Institutional Review Board of The University of Hong Kong/Hospital Authority Hong Kong West Cluster, Hong Kong (Ref No.: UW 25-585). The requirement for informed patient consent was waived by the Committee due to the retrospective nature of the research.

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