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# The economic impact of periprosthetic infection in total hip arthroplasty

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**Background:** Periprosthetic joint infection (PJI) is the third leading cause of total hip arthroplasty (THA) failure. Although controversial, 2-stage revision remains the gold standard treatment for PJI in most situations. To date, there have been few studies describing the economic impact of PJI in today's health care environment. The purpose of the current study was to obtain an accurate estimate of the institutional cost associated with the management of PJI in THA and to assess the economic burden of PJI compared with primary uncomplicated THA.

**Methods:** We conducted a review of primary THA cases and 2-stage revision THA for PJI at our institution. Patients were matched for age and body mass index. All costs associated with each procedure were recorded. Descriptive statistics were used to summarize the collected data. Mean costs, length of stay, clinic visits and readmission rates associated with the 2 cohorts were compared.

**Results:** Fifty consecutive cases of revision THA were matched with 50 cases of uncomplicated primary THA between 2006 and 2014. Compared with the primary THA cohort, PJI was associated with a significant increase in mean length of hospital stay (26.5 v. 2.0 d,  $p < 0.001$ ), mean number of clinic visits (9.2 v. 3.8,  $p < 0.001$ ), number of readmissions (12 v. 1,  $p < 0.001$ ) and average overall cost (Can\$38 107 v. Can\$6764,  $t = 8.3$ ,  $p < 0.001$ ).

**Conclusion:** Treatment of PJI is a tremendous economic burden. Our data suggest a 5-fold increase in hospital expenditure in the management of PJI compared with primary uncomplicated THA.

**Contexte :** L'infection articulaire périprothétique (IAP) arrive au troisième rang des principales causes d'échec de l'arthroplastie (ou prothèse) totale de la hanche (PTH). Même si elle est controversée, la révision en 2 étapes demeure le traitement standard pour l'IAP dans la plupart des cas. À ce jour, peu d'études ont décrit l'impact économique de l'IAP dans l'environnement actuel des soins de santé. Le but de la présente étude était d'obtenir une estimation précise des coûts institutionnels associés à la prise en charge de l'IAP dans la PTH et d'évaluer le fardeau économique de l'IAP comparativement à une PTH primaire non compliquée.

**Méthodes :** Nous avons passé en revue les cas de PTH primaire et de révision de PTH en 2 étapes pour cause d'IAP dans notre établissement. Les patients ont été assortis selon l'âge et l'indice de masse corporelle. Tous les coûts associés à chaque intervention ont été consignés. Des statistiques descriptives ont servi à résumer les données recueillies. Nous avons comparé les coûts moyens, la durée des séjours, les visites à la clinique et les taux de réadmission associés aux 2 cohortes.

**Résultats :** Cinquante cas consécutifs de révision de PTH ont été assortis à 50 cas de PTH primaire non compliquée entre 2006 et 2014. Comparativement à la cohorte de PTH primaire, les cas d'IAP ont été associés à une augmentation significative de la durée moyenne du séjour hospitalier (26,5 j c. 2,0 j,  $p < 0,001$ ), du nombre moyen de visites à la clinique (9,2 c. 3,8,  $p < 0,001$ ), du nombre des réadmissions (12 c. 1,  $p < 0,001$ ) et du coût global moyen (38 107 \$ CA c. 6764 \$ CA,  $t = 8,3$ ,  $p < 0,001$ ).

**Conclusion :** Le traitement de l'IAP représente un énorme fardeau économique. Selon nos données, les dépenses hospitalières associées à sa prise en charge sont 5 fois plus grandes que pour la PTH primaire non compliquée.

**D**eep infection is a devastating complication in total hip arthroplasty (THA) resulting in significant patient and institutional burden. Current literature suggests that the incidence of periprosthetic joint infection (PJI) is 1%–2%, and it is projected to increase as the population ages and as indications for THA continue to expand.<sup>1–6</sup> In North America, 2-stage revision surgery remains the gold standard in treatment, leading to successful eradication of infection in up to 90% of patients with PJI.<sup>7,8</sup> Most of these revisions are performed in tertiary care centres by surgeons with specialty training in adult reconstructive surgery.<sup>9</sup> By its nature, treatment is a costly institutional endeavour, requiring multiple surgeries and hospital admissions. Previous studies suggest a 2- to 4-fold increase in health care expenditure for PJI compared with primary uncomplicated THA.<sup>6,10,11,12</sup> These expenditures are largely driven by length of hospital stay, operating room expenses, implants and inpatient resource use. To date, much of our knowledge in this area has been obtained from large-volume databases, where costs have often been derived from hospital billings rather than from direct institutional case costing data.<sup>6,7,11</sup> This makes it difficult to extrapolate findings to other facilities and health care models and, in turn, may limit our ability to identify potential for cost containment at the institutional level. Cost data have become particularly important with the emergence of quality-based funding or bundled reimbursement models, which require surgeons to be cost conscious while providing high-quality, equitable care. With this in mind, the purpose of our study was to obtain an accurate estimate of the institutional cost associated with the management of PJI in THA and to assess the economic burden of PJI compared with primary THA with respect to direct institutional cost and hospital resource utilization.

## METHODS

This was a single-centre, retrospective study that compared patients who underwent 2-stage revision for infection with a cohort of patients matched on age and body mass index (BMI) who underwent uncomplicated primary THA between 2006 and 2014. The diagnosis of PJI was made using the Musculoskeletal Infection Society's criteria.<sup>13</sup> Osteoarthritis was the indication for all primary THA. Patients with prior ipsilateral revision hip surgery and patients who died before second-stage revision were excluded. All patients had a minimum follow-up of 2 years. All cost- and procedure-related data were obtained from an institutional database at a single Canadian academic centre. Information in this database reflects the practices of 6 fellowship-trained arthroplasty surgeons.

We identified 61 consecutive cases of infected THA between 2012 and 2014. Fifty patients met the inclusion criteria and were thus entered into our analysis. A compar-

ative cohort of 50 consecutive cases of primary THA was matched to the cohort of patients with infected THA on the basis of age and body mass index (BMI) and was used to establish a control group. Data pertaining to inpatient resource utilization were collected by a single independent reviewer, using an electronic medical record system. Unit costs pertaining to operating time, operative equipment, implants, antibiotics, anticoagulation, transfusions, postoperative recovery, length of hospital stay, readmission rates, inpatient consults, inpatient physical therapy and investigations (including imaging and blood work) were obtained using current administrative data from the case costing department at our institution.

## Statistical analysis

Microsoft Excel for Mac (version 15.31) was used for all analyses. Descriptive statistics including means and ranges were calculated to describe each cohort. Patients with PJI were compared with the matched cohort of patients who underwent primary THA using the  $\chi^2$  test (for categorical variables) and the *t* test (for continuous variables). The Mann–Whitney test was applied where nonparametric data were identified. The study was powered at 0.90 with an  $\alpha$  of 0.05 to detect a difference in overall cost between cohorts. Statistical significance was considered at a *p* value of less than 0.05.

## RESULTS

Sixty-one cases of infected THA were reviewed for entry into this study; 11 of them were eventually excluded. Seven patients were excluded because an initial irrigation and débridement was performed at an outside institution before the patient presented to our centre for staged revision. Three patients were excluded because they died before stage 2 revision could be completed, and 1 patient was excluded after opting not to move forward with stage 2. After exclusions, 50 cases of infected THA were entered into our analysis and were compared with 50 cases of primary uncomplicated THA. The mean age and BMI of patients was 64 (range 50–83) years and 32 (range 19–41) in the revision cohort and 67 (range 52–82) years and 29 (range 19–39) in the primary THA cohort, respectively (Table 1).

**Table 1. Patient characteristics**

Characteristic	Cohort; mean (range)		<i>p</i> value
	Primary THA <i>n</i> = 50	Infected THA <i>n</i> = 50	
Age, yr	67 (52–82)	64 (50–83)	0.13
BMI	29 (19–39)	32 (19–41)	0.12

BMI = body mass index; THA = total hip arthroplasty.

The average cost of 2-stage revision for infected THA was Can\$38 107 (range \$17 789–\$118 247). This procedure was 5.6 times more costly than the average primary THA (Can\$6764 [range \$5823–\$8523]) and the difference between groups was significant ( $p < 0.001$ ) (Table 2). The Mann–Whitney test was applied to correct for non-parametric data and also indicated statistical significance, with the median cost of 2-stage revision being greater than the median cost of primary THA (Can\$29 711 v. Can\$6634,  $z = 7.03$ ,  $p < 0.001$ ). Six patients (12%) in the cohort with infected THA required at least 1 repeat stage 1 revision before receiving a definitive second-stage surgery. *Staphylococcus aureus* was the most commonly isolated organism (38%) with the methicillin-resistant form (MRSA) accounting for 22% of the infections in the entire cohort of patients with infected THA. The average cost associated with management of MRSA PJI was similar to the cost of managing other isolated pathogens (Can\$39 558 v. Can\$40 065). PJI was also associated with a significant increase in mean length of hospital stay (26.5 v. 2.0 d,  $p < 0.001$ ), mean number of clinic visits (9.2 v. 3.8,  $p < 0.001$ ) and number of readmissions (12 v. 1,  $p < 0.001$ ) when patients in the infected THA group were compared with those who underwent primary THA (Table 3). Inpatient resource use was also greater among the patients with infected THA. There was an 8-fold increase in costs associated with laboratory testing and imaging (Can\$898 v. Can\$116) and a 20-fold increase in medications costs secondary to prolonged antibiotic and anticoagulant use while in hospital (Can\$1167 v. Can\$54) (Table 4).

**Table 2. Average cost of total hip arthroplasty**

Category	Cohort; cost, Can\$, mean (range)		p value
	Primary THA	Infected THA	
Inpatient	1765 (924–3455)	21 387 (4825–77 009)	< 0.001
Operative	4998 (4039–5638)	16 720 (14 547–64 551)	< 0.001
Total	6764 (5823–8523)	38 107 (17 789–118 247)	< 0.001

THA = total hip arthroplasty.

**Table 3. Length of hospital stay, clinic visits and readmissions associated with primary and 2-stage revision total hip arthroplasty**

Outcome	Cohort		p value
	Primary THA	Infected THA	
Mean length of hospital stay, d	2.0	26.5	< 0.001
Mean no. of clinic visits	3.8	9.2	< 0.001
No. of patients readmitted	1	12	< 0.001

THA = total hip arthroplasty.

**Table 4. Summary of expenses in total hip arthroplasty**

Resource	Cohort; cost, Can\$, mean (range)	
	Primary THA	Infected THA
Operating room services	1701 (966–2194)	7392 (4976–21 265)
Implants	2452 (2427–2481)	6942 (4087–18 662)
Anesthesia	312 (210–402)	1530 (1062–4424)
Hospital bed charges	1394 (719–2624)	17 423 (3135–65 221)
Investigations	116 (20–387)	898 (391–2735)
Medications	54 (30–124)	1167 (142–3199)
Physical therapy	94 (47–141)	809 (157–3265)

THA = total hip arthroplasty.

**DISCUSSION**

As annual THA volumes continue to increase, so too will the number of revision procedures for management of PJI. For every 9 patients who undergo primary THA, it is estimated that 1 is admitted for revision.<sup>14</sup> Periprosthetic joint infection is the third leading cause of failure following primary THA,<sup>14</sup> and treatment in the United States alone was projected to impart a financial burden in excess of US\$400 million by 2020.<sup>6</sup>

In our study, 2-stage revision for PJI was associated with a greater than 5-fold increase in hospital expenditure when compared with primary uncomplicated THA. The bulk of this expense (83%) was attributed to hospital bed charges, operating room services and implant use. Patients who underwent treatment for PJI were also more likely to be readmitted, had more outpatient clinic visits and consumed more resources than those who underwent primary THA. To our knowledge, this is one of few studies to evaluate the cost of PJI in THA using direct institutional case costing.<sup>10,11</sup> This differs from most prior studies, which derived estimates from institutional billing data. This type of data may vary greatly across institutions and its interpretation requires knowledge of centre-specific cost-to-charge ratios.<sup>12</sup> Direct case costing, on the other hand, better reflects consumed resources and services and thus more accurately reflects true institutional burden. In theory, these data should be similar among institutions that serve similar regions and operate with similar practice patterns. Although the cost of delivering orthopedic care is substantially lower in Canada than in other countries, the relative cost of primary and 2-stage revision is remarkably similar to that observed in the US. This suggests that our data are generalizable and thus may be used to guide future resource allocation and budget planning at tertiary centres that offer similar care.

Our study corroborates the findings of previously published work. Bozic and Ries<sup>10</sup> conducted a retrospective cost

analysis involving a cohort of 25 patients who underwent 2-stage revision for periprosthetic hip infection. In this study the total hospital cost associated with treatment of PJI was 4.4 times greater than the cost of primary THA (US\$96 166 v. US\$21 654,  $p < 0.001$ ). These authors also noted a significant increase in length of hospital stay (28.2 v. 6.2 d,  $p < 0.001$ ) and outpatient visits among patients treated with 2-stage revision (54.6 v. 17.2,  $p < 0.001$ ). Unlike us, these authors did not comment on other specific factors that contributed to the cost of care in PJI.

Most recently, Kapadia and colleagues<sup>11</sup> published the results of a retrospective study examining the economic impact of periprosthetic hip infection. In this study, 16 patients who underwent 2-stage revision were compared with a cohort of patients who underwent primary uncomplicated THA. They analyzed a combination of billing and direct cost data from their institution. Treatment of periprosthetic infection was found to be 3.5 times more costly than primary THA (US\$88 623 v. US\$25 659,  $p < 0.001$ ). Similar to our study, Kapadia and colleagues<sup>11</sup> also reported longer hospital stays (7.6 v. 3.3 d,  $p = 0.02$ ), more readmissions (2 v. 0,  $p < 0.0001$ ) and a significant increase in resource utilization among patients with periprosthetic hip infection.<sup>11</sup> Interestingly, average length of stay in the infected cohort was much shorter than we observed in our study (7.6 v. 26.5 d). This is an important finding given that both studies identified length of hospital stay as the greatest contributing factor to the total cost of care in periprosthetic hip infection. Although this may indicate a difference in practice pattern, it may also simply reflect a difference in the way length of hospital stay was defined in each study. In our study, length of hospital stay was calculated as the sum total of days spent in hospital across all stages of revision. It should be noted that all patients were discharged home between stages.

Collectively, this body of work suggests that the economic impact of PJI can be reliably estimated to be 4–5 times the cost of primary THA. In doing so, this study also illustrates the need to further explore measures that may contain or reduce the burden PJI. With length of hospital stay contributing most significantly to the burden of care, institutions may benefit from the creation of well-defined clinical pathways, which better coordinate interdisciplinary care. In our experience, similar pathways have shortened hospital stays in primary arthroplasty and also enabled the delivery of safe outpatient surgery in select patients.

Single-stage revision is a cost-effective approach that continues to show promise in well-defined populations with PJI of the hip, knee and shoulder.<sup>14,15,16</sup> In 2012, Beswick and colleagues<sup>14</sup> performed a systematic review of 62 studies involving more than 4000 patients who were treated with 1- or 2-stage revision for periprosthetic hip infection. The incidence of recurrent infection was similar between groups (10.2% [95% confidence interval (CI) 7.7%–12.9%] v. 8.6% [95% CI 4.5%–13.9%]). Although

weakened by heterogeneity, these findings suggests the need for a prospective, randomized controlled trial to further evaluate the efficacy of single-stage revision for PJI.

### Limitations

The limitations of this study are largely related to its retrospective design. Most notably, this study is susceptible to selection bias. We aimed to minimize bias by entering patients into the study in consecutive fashion and by limiting exclusion criteria. Cohorts were also matched for age and BMI in an attempt to limit the influence of variables that are known to effect resource utilization.<sup>17</sup> The overall accuracy of our estimate is closely tied to the quality of available institutional data pertaining to resource utilization. Our system enabled us to identify most resources using electronic medical records and intraoperative reports; however, some expenses (for bowel regimens, antiemetics and analgesics, for example) are reliably captured only prospectively. Although this is a limitation, it is unlikely to have had a significant impact on the magnitude of the difference between groups, given that these expenses are quite small relative to more significant drivers of cost such as LOS and operating room services. It should be noted that this study does not capture out-of-pocket patient expenses such as those related to prescription medication, respite care and time away from employment for both patients and their caregivers. Additionally, costs pertaining to home-based physiotherapy, antibiotic administration, wound care and peripherally inserted central line care were purposely not captured. We do not consider this a limitation given that our aim was to strictly describe the institutional cost burden of PJI in THA so that data can be used as a resource for institutional budget planning. In Canada, these outpatient expenses are directly funded by the provincial and territorial governments.

### CONCLUSION

Periprosthetic joint infection has a profound economic impact on tertiary care centres. Our data suggest a 5-fold increase in hospital expenditure in the management of PJI when compared with primary uncomplicated THA. The major cost-contributing factors are hospital bed, operating room and implant expenses, which together accounted for 83% of total hospital expenditures in our study. These data may be useful in guiding future resource allocation decisions and institutional budget planning for THA. This study also highlights the need for further investigation of potential cost-containing measures in the management of PJI.

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**Competing interests:** J. Howard reports receiving grants from Stryker and DePuy, personal fees from Stryker, DePuy, Smith & Nephew and Intellijoint, and institutional research support from Stryker, DePuy, Smith & Nephew, Zimmer and MicroPort, all outside the submitted work. He holds stock in PersaFix Technologies. B. Lanting reports receiving personal fees from Smith & Nephew, Stryker, DePuy, Integra and Intellijoint, and institutional support from Smith & Nephew, DePuy, Stryker and Zimmer, all outside the submitted work. E. Vasarhelyi reports receiving grants from DePuy, grants and personal fees from DePuy and Hip Innovation Technology, and institutional support from DePuy, Stryker and Smith & Nephew, all outside the submitted work. No other competing interests were declared.

**Contributors:** J. Akindolire, J. Howard, B. Lanting and E. Vasarhelyi designed the study. All authors acquired and analyzed the data. J. Akindolire, M. Morcos, J. Howard, B. Lanting and E. Vasarhelyi wrote the article. All authors critically reviewed the article and approved the final version for publication.

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