International Journal of Research in Orthopaedics
Tye C et al. Int J Res Orthop. 2024 Jul;10(4):725-730
http://www.ijoro.org

DOI: https://dx.doi.org/10.18203/issn.2455-4510.IntJResOrthop20241696

Original Research Article

The cost-effectiveness of an additional surgical scrub in reducing prosthetic joint infections in total hip and knee arthroplasty

Cooper Tye[1]*, Jad Lawand[2], Vincent Moretti[1]

[1]Department of Orthopaedic Surgery, John Peter Smith Hospital, Ft. Worth, TX, USA
[2]University of Texas Medical Branch, School of Medicine, Galveston, TX, USA

Received: 11 May 2024
Revised: 14 June 2024
Accepted: 18 June 2024

***Correspondence:**
Dr. Cooper Tye,
E-mail: Cbtye3@gmail.com

ABSTRACT

Background: Surgical skin preparation prior to total knee and hip arthroplasty is an important step in infection prevention. Compared to a single application, repeat skin preparation after draping demonstrates greater efficacy in reducing the overall occurrence of surgical site infections in total joint arthroplasty. We sought to find if the addition of an extra surgical scrub after draping is a cost-effective means of decreasing prosthetic joint infection (PJI), and if so, under what conditions it would be most cost-effective.
Methods: We employed a model to assess the cost-effectiveness of repeat skin preparation in total knee and hip arthroplasty. This model determines a threshold at which the expenses associated with a new intervention is offset by its ability to reduce overall costs. Literature review and records from our institution were used to draw average expenses for treatment of PJI, as well as surgical prep scrubs, to evaluate at their cost-effectiveness. We also compared against hypothetical higher and lower costs and infection rates to gain further information on the additional surgical prep's cost-effectiveness.
Results: Each of the surgical scrubs is cost-effective at our institution's cost when an absolute risk reduction (ARR) of 0.01% is achieved. The cost-effectiveness was also noted with hypothetically higher infection rates and scrub cost prices. Lower potential two-stage revision costs make the additional surgical scrub less cost-effective.
Conclusions: Our findings demonstrate that an extra surgical scrub can be cost-effective way of decreasing PJI across a variety of different surgical scrub prices, arthroplasty revision costs, and PJI rates.

Keywords: Total hip arthroplasty, Total knee arthroplasty, PJI, Revision arthroplasty, Cost-effectiveness

INTRODUCTION

Total knee arthroplasty (TKA) and total hip arthroplasty (THA) are surgical procedures that alleviate pain and restore function in patients with knee and hip joint disease. These procedures have become increasingly prevalent due to the rising incidence of joint degeneration and an aging population.[1-3] Recent data reveals that 480,958 primary TKA, and 262,369 THA were performed in the United States in 2019. Projections for 2060 indicate a substantial increase, with an estimated 1,982,099 THA procedures and 2,917,959 TKA procedures.[4] As THA and TKA increase, a corresponding increase in the prevalence of PJI is expected to follow, which will lead to increased healthcare costs and patient morbidity.[5-9]As such, interventions to reduce infection, healthcare system burden, and financial costs are paramount.[6-10]

Skin flora is a nidus for PJI.[11-13] Surgical skin preparations are essential in infection prophylaxis as they reduce viable skin flora. It has been shown that the addition of an extra surgical prep scrub after draping decreased surgical site infection in total joint arthroplasty.[14] However, there are not current studies looking at whether the additional cost of an extra surgical scrub preparation introduced after draping is a cost-effective way to reduce PJI and the associated costs and morbidity associated with them. In this study, we sought to answer whether the additional cost of an extra surgical prep scrub used after draping is a cost-effective measure when attempting to reduce the incidence of PJI under standard conditions.

Additionally, we sought to further answer the question of under what conditions, including those with varied hypothetical costs for scrub preps and revision surgeries, and under different baseline PJI incidences, might the addition of an extra surgical prep scrub be cost-effective.

METHODS

This study took place between May 2023 and June 2024 at John Peter Smith hospital in Fort Worth, TX. For this study, we employed a cost-effectiveness model using the break-even analysis introduced by Hatch et al.[15] The model determines a threshold at which the expenses associated with a new intervention are offset by its ability to reduce overall costs. By considering initial PJI rates, the overall cost of revision arthroplasty due to PJI, and the expenses related to additional surgical prep scrubs, we are able to calculate the break-even infection rate and the ARR needed for the extra surgical scrub to be cost-effective.

Equation used to calculate break-even infection rate

$$S_{total} \times C_t \times IR_i = (S_{total} \times C_p) + (S_{total} \times C_t \times IR_f)$$

Solving for IR_f yields:

$$IR_f = \frac{(IRi\ x\ Ct) - Cp}{Ct}$$

Where,

S_{total} = total annual surgeries; C_t = total cost of treating an infection; C_p = cost of surgical prep; IR_i = initial infection rate; IR_f = breakeven infection rate.

To do this, we consulted the literature to determine the range of baseline infection rates after TKA and THA and obtained the values ranging from 0.7% to 2.4%.[5-9,16-20] Based on these numbers, we assume infection rates to be 1.7% for TKAs and 1.9% for THAs for our study. Regarding revision arthroplasty costs, we consulted the literature and determined the cost for two-stage revision THA and TKA surgeries to amount to $58,369 and $56,369 respectively.[21] Regarding the addition of a surgical scrub stick/tray to the case, we assumed that one additional chlorhexidine gluconate/isopropyl alcohol stick (26 mL), iodine povacrylex/isopropyl alcohol stick (26 mL), or iodine paint tray was added to the surgical field. The price for each of these surgical preps was obtained from the purchasing lists at our hospital. The costs for these were noted to be $5.95, $4.29, and $7.99 respectively.

We additionally performed more analyses using hypothetical values for PJI rates, revision costs, and prep scrub prices to further elucidate situations in which an additional surgical prep scrub may or may not be cost-effective. Two variables were always held constant while varying the third.

Using the information obtained from literature review, the cost-effectiveness model described the Hatch et al article, and baseline costs and infection rates, a study protocol was formed, and the analysis was performed. Microsoft excel was used for data calculation and analysis, as well as formation of tables.[15]

RESULTS

Tables 1 to 3 present the results of our analysis examining the association between antiseptic solution prices (chlorhexidine gluconate/isopropyl alcohol, iodine povacrylex/isopropyl alcohol, and iodine paint respectively) and the break-even infection rates and absolute risk reductions for total knee revision (TKR) and total hip revision (THR) procedures. Chlorhexidine gluconate/isopropyl alcohol prices ranging from 2 to 40 United States Dollars (USD) correspond to break-even infection rates of 1.70% to 1.63% for TKR and 1.90% to 1.83% for THR, with break-even ARR values of 0.00% to 0.07%.

With iodine povacrylex/isopropyl alcohol prices ranging from 1 to 40 USD, we found break-even infection rates of 1.70% to 1.63% for TKR and 1.90% to 1.83% for THR, with break-even ARR values of 0.00% to 0.07%. Iodine paint prices of 2 to 40 USD correspond to break-even infection rates of 1.70% to 1.63% for TKR and 1.90% to 1.83% for THR, with break-even ARR values of 0.00% to 0.07%.

Table 4 details the results of break-even analysis when initial infection rate was varied and surgical revision cost and surgical prep prices were kept the same. For TKA, the break-even infection rates ranged from 0.49% to 9.99%, with a consistent ARR of 0.01% for all antiseptic solutions. Similarly, for THA, the break-even infection rates also varied from 0.49% to 9.99%, with an accompanying ARR of 0.01% for each antiseptic.

Table 5 presents a break-even analysis for TKR and THR procedures when varying the revision surgery costs and maintaining the surgical prep costs and initial infection rates. For TKR, ARRs varied between 0.00% and 1.60% across varying revision costs, with higher PJI rate reductions needed to be cost-effective for the use of iodine paint. Similarly, for THR, ARR values ranged from 0.00% to 1.60%.

Table 1: Cost effectiveness of extra chlorhexidine gluconate/isopropyl alcohol surgical scrub.

Chlorhexidine gluconate/ isopropyl alcohol stick price (USD)[a]	TKR		THR	
	Break even infection rate	Break-even ARR	Break even infection rate	Break-even ARR
2	1.70%	0.00%	1.90%	0.00%
4	1.69%	0.01%	1.89%	0.01%
5.95[b]	1.69%	0.01%	1.89%	0.01%
10	1.68%	0.02%	1.88%	0.02%
20	1.66%	0.04%	1.87%	0.03%
40	1.63%	0.07%	1.83%	0.07%

ARR-Absolute risk reduction, USD-United States Dollar, [a]26 mL applicator, [b]Price at our hospital.

Table 2: Cost effectiveness of extra iodine povacrylex/isopropyl alcohol surgical scrub.

Iodine povacrylex/isopropyl alcohol price (USD)[a]	TKR		THR	
	Break even infection rate	Break-even ARR	Break even infection rate	Break-even ARR
1	1.70%	0.00%	1.90%	0.00%
2	1.70%	0.00%	1.90%	0.00%
4.29[b]	1.69%	0.01%	1.89%	0.01%
10	1.68%	0.02%	1.88%	0.02%
20	1.66%	0.04%	1.87%	0.03%
40	1.63%	0.07%	1.83%	0.07%

ARR-Absolute risk reduction, USD-United States Dollar, [a]26 mL applicator, [b]Price at our hospital

Table 3: Cost effectiveness of extra iodine paint surgical scrub.

Iodine paint price (USD)[a]	TKR		THR	
	Break even infection rate	Break-even ARR	Break even infection rate	Break-even ARR
2	1.70%	0.00%	1.90%	0.00%
4	1.69%	0.01%	1.89%	0.01%
7.99[b]	1.69%	0.01%	1.89%	0.01%
10	1.68%	0.02%	1.88%	0.02%
20	1.66%	0.04%	1.87%	0.03%
40	1.63%	0.07%	1.83%	0.07%

ARR-Absolute risk reduction, USD-United States Dollar, [a]Iodine prep tray, [b]Price at our institution.

Table 4: Break-even infection rates while maintaining cost of surgical prep and revision surgery cost while varying initial infection rate.

Initial infection rate	TKR						THR					
	Chlorhexidine gluconate/ isopropyl alcohol break-even rate	ARR	Iodine povacryle/ isopropyl alcohol break-even rate	ARR	Iodine paint break-even rate	ARR	Chlorhexidine gluconate/ isopropyl alcohol break-even rate	ARR	Iodine povacrylex/ isopropyl alcohol break-even rate	ARR	Iodine paint break-even rate	ARR
0.50%	0.49%	0.01%	0.49%	0.01%	0.49%	0.01%	0.49%	0.01%	0.49%	0.01%	0.49%	0.01%
1.00%	0.99%	0.01%	0.99%	0.01%	0.99%	0.01%	0.99%	0.01%	0.99%	0.01%	0.99%	0.01%
2.00%	1.99%	0.01%	1.99%	0.01%	1.99%	0.01%	1.99%	0.01%	1.99%	0.01%	1.99%	0.01%
3.00%	2.99%	0.01%	2.99%	0.01%	2.99%	0.01%	2.99%	0.01%	2.99%	0.01%	2.99%	0.01%
4.00%	3.99%	0.01%	3.99%	0.01%	3.99%	0.01%	3.99%	0.01%	3.99%	0.01%	3.99%	0.01%
5.00%	4.99%	0.01%	4.99%	0.01%	4.99%	0.01%	4.99%	0.01%	4.99%	0.01%	4.99%	0.01%
6.00%	5.99%	0.01%	5.99%	0.01%	5.99%	0.01%	5.99%	0.01%	5.99%	0.01%	5.99%	0.01%
7.00%	6.99%	0.01%	6.99%	0.01%	6.99%	0.01%	6.99%	0.01%	6.99%	0.01%	6.99%	0.01%
8.00%	7.99%	0.01%	7.99%	0.01%	7.99%	0.01%	7.99%	0.01%	7.99%	0.01%	7.99%	0.01%
9.00%	8.99%	0.01%	8.99%	0.01%	8.99%	0.01%	8.99%	0.01%	8.99%	0.01%	8.99%	0.01%
10.00%	9.99%	0.01%	9.99%	0.01%	9.99%	0.01%	9.99%	0.01%	9.99%	0.01%	9.99%	0.01%

ARR-Absolute risk reduction, [a]Assumes cost of chlorhexidine gluconate/isopropyl alcohol ($5.95), Iodine povacrylex/isopropyl alcohol ($4.29), Iodine tray ($7.99), [b]Assumes revision cost for TKA ($56,900) and THA ($58,369).

Table 5: Break-even infection rates while maintaining cost of surgical prep and infection rate while varying cost of revision surgery.

Cost to treat (USD)	TKR						THR					
	Chlorhexidine gluconate/ isopropyl alcohol break-even rate	ARR	Iodine povacrylex/ isopropyl alcohol break-even rate	ARR	Iodine paint break-even rate	ARR	Chlorhexidine gluconate/ isopropyl alcohol break-even rate	ARR	Iodine povacrylex /isopropyl alcohol break-ven rate	ARR	Iodine paint break-even rate	ARR
500	0.51%	1.19%	0.84%	0.86%	0.10%	1.60%	0.71%	1.19%	1.04%	0.86%	0.30%	1.60%
1,000	1.11%	0.60%	1.27%	0.43%	0.90%	0.80%	1.31%	0.60%	1.47%	0.43%	1.10%	0.80%
5,000	1.58%	0.12%	1.61%	0.09%	1.54%	0.16%	1.78%	0.12%	1.81%	0.09%	1.74%	0.16%
10,000	1.64%	0.06%	1.66%	0.04%	1.62%	0.08%	1.84%	0.06%	1.86%	0.04%	1.82%	0.08%
25,000	1.68%	0.02%	1.68%	0.02%	1.67%	0.03%	1.88%	0.02%	1.88%	0.02%	1.87%	0.03%
50,000	1.69%	0.01%	1.69%	0.01%	1.68%	0.02%	1.89%	0.01%	1.89%	0.01%	1.88%	0.02%
75,000	1.69%	0.01%	1.69%	0.01%	1.69%	0.01%	1.89%	0.01%	1.89%	0.01%	1.89%	0.01%
100,000	1.69%	0.01%	1.70%	0.00%	1.69%	0.01%	1.89%	0.01%	1.90%	0.00%	1.89%	0.01%

ARR- Absolute Risk Reduction, USD- United States Dollar, [a]Assumes cost of Chlorhexidine gluconate/isopropyl alcohol ($5.95), iodine povacrylex/isopropyl alcohol ($4.29), iodine tray ($7.99), [b]Assumes infection rate TKA (1.7%) and THA (1.9%).

DISCUSSION

The purpose of our study was to examine the cost effectiveness of the addition of an extra surgical scrub after draping in THA and TKA. Despite advancements in surgical techniques and infection control, PJI remains a major complication following TKA and THA.[6-9] In 2017 alone, the estimated annual cost of treating PJI in THA and TKA reached $903 million, imposing a substantial burden on patients and hospital resources.[22] In addition, the evolving physician reimbursement models underscore the significance of improving patient outcomes while minimizing costs.[23] Consequently, addressing PJI in a cost-effective manner becomes paramount. One promising approach to reduce increased total costs while increasing patient outcomes is the use of an additional surgical scrub preparation to the case, which has been shown to effectively decrease the incidence of PJI.[14,24] In this study, we provide an evaluation of the cost-benefit relationship between additional antiseptic solution (Chlorhexidine gluconate/isopropyl alcohol, iodine povacrylex/isopropyl alcohol, and iodine paint), and break-even infection rates needed for their addition to be cost-effective in primary TKA and THA.

Each of the evaluated surgical scrubs is cost-effective at our institution's cost when a corresponding ARR of 0.01% is achieved. Even when the scrub prices were hypothetically increased to $40, each scrub prep was still cost effective at an ARR of 0.07%. When accounting for hypothetical infection rates (0.5-10%) the ARR needed for cost-effectiveness remained at 0.01% ARR, and all scrub prep additions performed similarly. The largest variability in ARR needed for cost effectiveness was noted when variable two-stage revision costs were compared against standard infection rates and scrub prices. At more standard two-stage revision costs, the additional scrub preparations were cost effective with low ARRs, however when two-stage revision rates were varied to be lower than our estimates, the ARR needed to be cost effective increased to 1.6% for the use of iodine paint with a hypothetical two-stage revision cost of $500.

Prior work has reported the addition of a surgical scrub after draping reduced superficial surgical site infections in total joint arthroplasty by 4.7%.[14] This risk reduction achieved with the addition of a surgical preparation scrub is much higher than the ARR needed for the additional scrub to be cost-effective under our models, and our analysis highlights that the additional cost of a surgical prep scrub is cost-effective under many different circumstances.

This study has certain limitations that should be considered when interpreting the results. First, there is variability in the literature in regard to standard infection rates and revision costs, which may result in cost effectiveness variability when using different values for these parameters. Furthermore, we did not incorporate the cost associated with the additional procedure time required for the extra scrub, which could affect the overall cost-effectiveness of the protocol. Additionally, each institution will have a different price for each of the surgical skin preparations. Finally, the modeling approach employed in this analysis relied on assumptions and simplifications that may not fully capture the complexity of cost dynamics. Despite these limitations, our study provides valuable estimates based on the available literature and considering a variety of hypothetical infection rates, costs associated with skin preparation, and revision procedures. These findings aim to improve the generalizability of our results. Future research should aim to address these limitations and enhance the robustness and applicability of cost-effectiveness analyses in infection prevention protocols.

CONCLUSION

In conclusion, our research shows that adding an additional surgical skin scrub after standard prepping and draping during TKA and THA can be a cost-effective way to reduce PJI in patients undergoing TKA and THA. When evaluating with standard PJI rates, revision arthroplasty costs, and scrub prep costs, an additional scrub prep is cost-effective when achieving an ARR of 0.01%. This ARR needed to be cost-effective is much lower than the ARR achieved in patients in a prior study comparing PJI rates in patients receiving an extra surgical scrub after draping to those who did not receive the extra scrub. [14] Our findings also hold true when evaluating surgical prep scrubs at hypothetically higher costs and with varied initial PJI rates and revision arthroplasty costs.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

REFERENCES

1. Wallace IJ, Worthington S, Felson DT, Robert DJ, Kimberly TW, Heli M, et al. Knee osteoarthritis has doubled in prevalence since the mid-20th century. Proc Natl Acad Sci U S A. 2017;114(35):9332-6.
2. Prieto-Alhambra D, Judge A, Javaid MK, Cooper C, Diez-Perez A, Arden NK. Incidence and risk factors for clinically diagnosed knee, hip and hand osteoarthritis: influences of age, gender and osteoarthritis affecting other joints. Ann Rheum Dis. 2014;73(9):1659-64.
3. Zhan C, Kaczmarek R, Loyo-Berrios N, Sangl J, Bright RA. Incidence and short-term outcomes of primary and revision hip replacement in the United States. J Bone Joint Surg Am. 2007;89(3):526-33.
4. Shichman I, Roof M, Askew N, Leo N, Joshua CR, Thorsten MS, et al. Projections and Epidemiology of Primary Hip and Knee Arthroplasty in Medicare Patients to 2040-2060. JBJS Open Access. 2023;8(1):e22.00112.
5. Springer BD, Cahue S, Etkin CD, Lewallen DG, McGrory BJ. Infection burden in total hip and knee

arthroplasties: an international registry-based perspective. Arthroplast Today. 2017;3(2):137-40.
6. Natsuhara KM, Shelton TJ, Meehan JP, Lum ZC. Mortality During Total Hip Periprosthetic Joint Infection. J Arthroplasty. 2019;34(7S):S337-42.
7. Pansu N, Hamoui M, Manna F. Implant retention and high rate of treatment failure in hematogenous acute knee and hip prosthetic joint infections. Med Mal Infect. 2020;50(8):702-8.
8. Guren E, Figved W, Frihagen F, Watne LO, Westberg M. Prosthetic joint infection-a devastating complication of hemiarthroplasty for hip fracture. Acta Orthop. 2017;88(4):383-9.
9. Kurtz SM, Lau E, Watson H, Schmier JK, Parvizi J. Economic burden of periprosthetic joint infection in the United States. J Arthroplasty. 2012;27(8):61-5.
10. Bozic KJ, Kurtz SM, Lau E, Kevin O, Vanessa C, Thomas PV, et al. The epidemiology of revision total knee arthroplasty in the United States. Clin Orthop Relat Res. 2010;468(1):45-51.
11. Fairclough JA, Johnson D, Mackie I. The prevention of wound contamination by skin organisms by the pre-operative application of an iodophor impregnated plastic adhesive drape. J Int Med Res. 1986;14(2):105-109.
12. Lidwell OM, Lowbury EJ, Whyte W, Blowers R, Stanley SJ, Lowe D. Bacteria isolated from deep joint sepsis after operation for total hip or knee replacement and the sources of the infections with Staphylococcus aureus. J Hosp Infect. 1983;4(1):19-29.
13. Zywiel MG, Daley JA, Delanois RE, Naziri Q, Johnson AJ, Mont MA. Advance pre-operative chlorhexidine reduces the incidence of surgical site infections in knee arthroplasty. Int Orthop. 2011;35(7):1001-6.
14. Morrison TN, Chen AF, Taneja M, Küçükdurmaz F, Rothman RH, Parvizi J. Single vs Repeat Surgical Skin Preparations for Reducing Surgical Site Infection After Total Joint Arthroplasty: A Prospective, Randomized, Double-Blinded Study. J Arthroplasty. 2016;31(6):1289-94.
15. Hatch MD, Daniels SD, Glerum KM, Higgins LD. The cost effectiveness of vancomycin for preventing infections after shoulder arthroplasty: a break-even analysis. J Shoulder Elbow Surg. 2017;26(3):472-7.
16. Kurtz SM, Ong KL, Lau E, Bozic KJ, Berry D, Parvizi J. Prosthetic joint infection risk after TKA in the Medicare population. Clin Orthop Relat Res. 2010;468(1):52-6.
17. Pulido L, Ghanem E, Joshi A, Purtill JJ, Parvizi J. Periprosthetic joint infection: the incidence, timing, and predisposing factors. Clin Orthop Relat Res. 2008;466(7):1710-5.
18. Kurtz SM, Lau E, Schmier J, Ong KL, Zhao K, Parvizi J. Infection burden for hip and knee arthroplasty in the United States. J Arthroplasty. 2008;23(7):984-91.
19. Ahmed SS, Haddad FS. Prosthetic joint infection. Bone Joint Res. 2019;8(11):570-72.
20. Urquhart DM, Hanna FS, Brennan SL, Anita EW, Karin L, Peter AC, et al. Incidence and risk factors for deep surgical site infection after primary total hip arthroplasty: a systematic review. J Arthroplasty. 2010;25(8):1216-22.
21. Yao JJ, Hevesi M, Visscher SL, Jeanine ER, David GL, Daniel JB, et al. Direct Inpatient Medical Costs of Operative Treatment of Periprosthetic Hip and Knee Infections Are Twofold Higher Than Those of Aseptic Revisions. J Bone Joint Surg Am. 2021;103(4):312-8.
22. Premkumar A, Kolin DA, Farley KX. Projected Economic Burden of Periprosthetic Joint Infection of the Hip and Knee in the United States. J Arthroplasty. 2021;36(5):1484-9.
23. Bosko T, Hawkins C. Evolving Physician Reimbursement Structures: Moving the Medical Group to Value-Based Success. J Health Manag. 2016;61(3):176-80.
24. Kapadia BH, Zhou PL, Jauregui JJ, Mont MA. Does Preadmission Cutaneous Chlorhexidine Preparation Reduce Surgical Site Infections After Total Knee Arthroplasty? Clin Orthop Relat Res. 2016;474(7):1592-8.

Cite this article as: Tye C, Lawand J, Moretti V. The cost-effectiveness of an additional surgical scrub in reducing prosthetic joint infections in total hip and knee arthroplasty. Int J Res Orthop 2024;10:725-30.