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The effectiveness of the surgical helmet system in reducing infection and contamination in arthroplasty procedures: An integrative review

Abstract

Background: Peri-prosthetic joint infections are a serious complication of primary arthroplasty procedures. While surgical helmet systems are commonly used, limited guidelines exist to support their effectiveness in preventing infection.

Aim: This integrative review aims to synthesise relevant literature on the role of the surgical helmet system in arthroplasty procedures.

Design: An integrative review process was undertaken.

Method: A literature search was conducted for primary literature in PubMed, Scopus and ESBCO using the keywords 'surgical helmet' AND 'contamination OR infection' AND NOT 'COVID'. Studies involving COVID-19 were excluded. Of the 44 retrieved studies, 13 met the inclusion criteria after removing duplicates and reviewing titles. This included one randomised controlled trial, six quasi-experimental studies, five observational analytical studies, and one observational descriptive study. The quality of the literature was assessed using EQUATOR network (Enhancing QUAlity and Transparency Of health Research network) guidelines.

Findings: Findings indicate that the use of the surgical helmet system is associated with lower infection rates in arthroplasty procedures when compared to standard surgical attire. Additionally, the literature explores techniques to further reduce contamination rates with the surgical helmet system, including wrapping the glove–gown interface, treating the sterile surgical helmet system hood as unsterile, delaying fan activation, running the fan for three minutes before entering the operating room, covering the back of the surgical gown and having a non-sterile team member apply the sterile surgical helmet system hood.

Conclusion: The use of a surgical helmet system in arthroplasty procedures reduces infection rates compared to standard surgical attire. This integrative review highlights the importance of implementing additional practices to reduce intra-operative contamination rates when using the surgical helmet system. Further research is needed to strengthen the findings from this integrative review.

Keywords: surgical helmet, contamination, peri-prosthetic joint infection, perioperative attire, orthopaedic surgery, glove–gown interface

Introduction

Peri-prosthetic joint infection is a serious complication of elective arthroplasty procedures[1]. It can result in decreased quality of life and restricted mobility for the patient, and an increased rate of mortality and morbidity[2]. Furthermore, it places a significant financial burden on the health care system[3]. The causes of peri-prosthetic joint infections are complex and multifactorial[4].

Sterile surgical attire, worn by the surgical team intra-operatively, routinely includes the use of the surgical helmet system (SHS) in arthroplasty procedures[5]. Once surgical hand antisepsis is complete, a sterile hood is placed over the SHS before the gown and gloves are donned. The SHS offers full coverage of the face and head, serving as personal protective equipment against surgical debris[6]. However, despite its common application in arthroplasty procedures, there are limited guidelines on the intra-operative use of the SHS and its impact on peri-prosthetic joint infection rates[5].

Aims

This integrative review focuses on the effectiveness of the SHS in reducing infection and contamination in arthroplasty procedures. This paper aims to provide relevant literature that assists perioperative nurses in making informed decisions about using the SHS in arthroplasty procedures.

Methods

Design

This review used an integrative review design where both quantitative and qualitative research data were included and followed the framework of Whittemore and Knafl[7].

Search strategy

A comprehensive literature search was undertaken using the databases PubMed, Scopus, ESBCO: CINAHL Complete, Health Source: Nursing/Academic Edition, Medline and Medline Complete. The search strategy included Boolean operators and keywords/phrases as follows: 'Surgical helmet' AND 'Contamination OR infection' AND 'NOT COVID'.

Inclusion and exclusion criteria

Inclusion criteria included literature that was published in English within the last five years, full text articles and research that focused on the SHS and either infection or contamination.

Exclusion criteria included poor quality papers that did not align with the EQUATOR network (Enhancing QUAlity and Transparency Of health Research network) checklists, non-primary literature, papers older than five years, papers that discussed modifying the SHS for any reason and research that investigated SHS application in COVID-19 cases because during the pandemic the SHS was used in surgeries other than those it is traditionally used in.

Data extraction

Guided by the research aims, a total of 44 studies were initially retrieved. The removal of duplication papers left 16 articles. The titles and abstracts were screened and articles that did not meet the inclusion criteria were removed. A total of 13 articles remained and were included in this review. This is represented in Figure 1 as the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram[8]. The quality of the studies varied. There was one randomised control trial, six quasi-experimental studies, five observational analytical studies, and one observational descriptive study.

Data evaluation

The EQUATOR network guidelines were used to appraise the primary research studies included in the review to ensure that the selected papers were of good quality. CONSORT (Consolidated Standards of Reporting Trials) was used for randomised control studies, TREND (Transparent Reporting of Evaluations with Non-randomized Designs) for quasi-experimental studies and STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) for observational studies.

Discussion

The SHS is commonly used in orthopaedic arthroplasty procedures to protect against surgical debris[6]. The SHS consists of a helmet with an internal fan and is covered during a procedure with a single-use sterile hood with a visor, applied by either a sterile or non-sterile team member[6]. The SHS surgical attire is made up of the SHS with a sterile hood, gown and gloves[6]. A variant, known as the Toga, combines the sterile hood and gown into one piece with a zipper to close the gown at the back[9]. Standard surgical attire includes a surgical cap or hood, mask, gown and gloves[6]. Although there may be differences in the sterile attire that can be worn intra-operatively, perioperative nurses must follow evidence-based standards of practice set out in the Australian College of Perioperative Nurses (ACORN) Asepsis standard[10] to ensure the quality and safety of health care provided to patients. However, there are currently no standardised guidelines for the use of the SHS

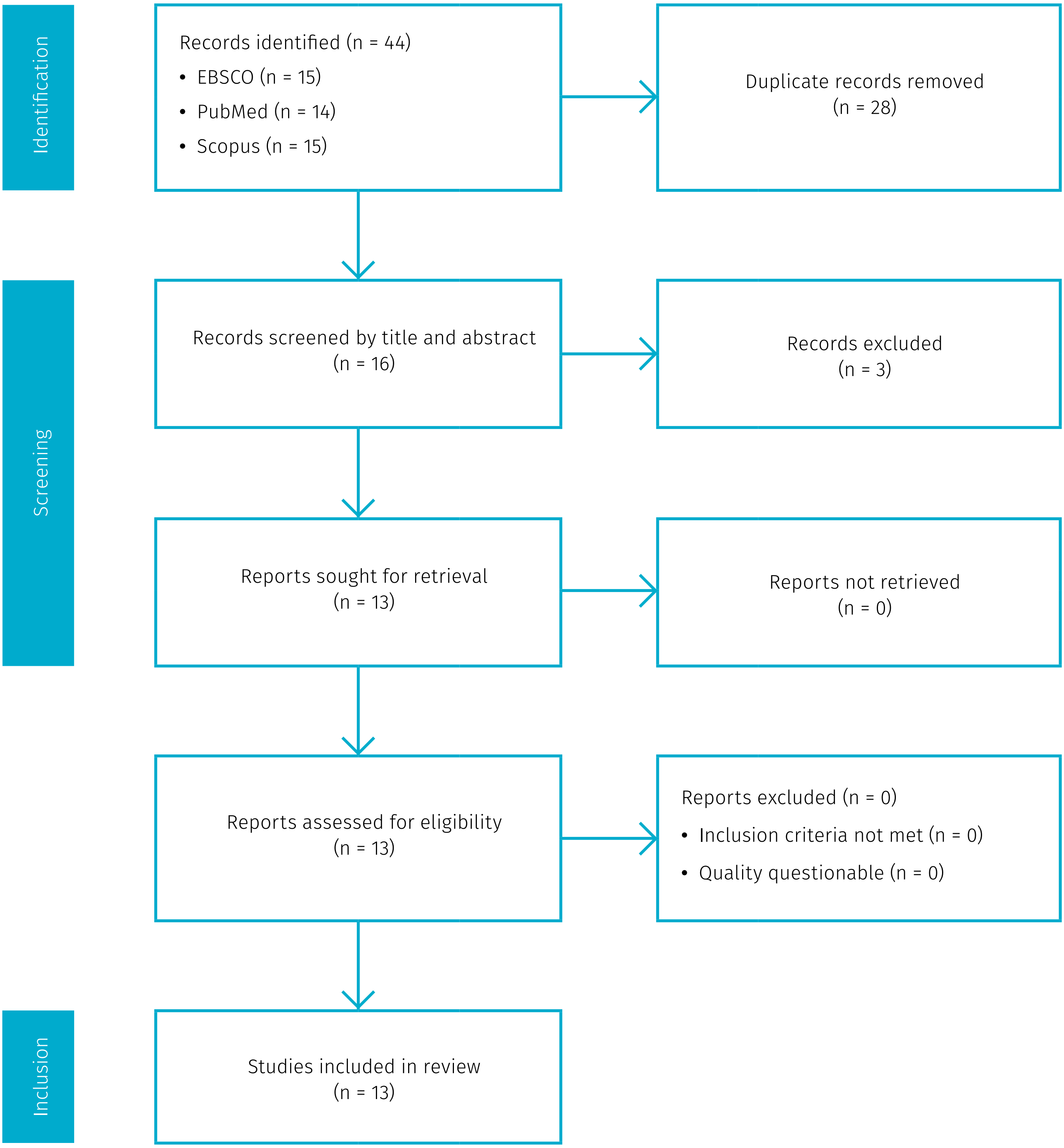

Figure 1: PRISMA flow diagram of paper selection process

during arthroplasty procedures. This integrative review aims to address this knowledge gap and promote evidence-based practices.

Of the thirteen papers included in this review a thematic analysis highlighted four themes – 'infection control in surgery – the case for using the surgical helmet system and its effect on patient outcomes and team contamination', 'impact of delayed fan activation in the surgical helmet system', 'evaluating positive pressure challenges of the surgical helmet system' and 'optimising donning techniques for the surgical helmet system'.

Infection control in surgery – the case for using the surgical helmet system and its effect on patient outcomes and team contamination

The SHS not only protects the patient from possible surgical site infection but also protects the wearer from contamination by airborne particles. Two of the included studies[5,10] analysed post-operative infection rates in arthroplasty procedures, comparing the SHS surgical attire to standard surgical attire. Rahardja et al.[5] performed an observational analytical study with a case-controlled design (n = 19322) investigating prosthetic joint infection after primary total knee arthroplasty surgery. Data was collected from the New Zealand Surgical Site Infection Improvement Programme and the New Zealand Joint Registry. A lower rate of prosthetic joint infection was found when SHS surgical attire was used compared to when standard surgical attire was used – 0.35 per cent compared to 0.58 per cent ($p = 0.008$)[5]. After adjustment, the revision rate for deep infection with the SHS surgical attire was 0.42 per cent compared to 0.49 per cent for standard surgical attire, with a statistically significant difference (adjusted OR = 0.55, $p = 0.022$)[5]. The significant p values indicate a reduction in infection and revision associated with the SHS compared to standard surgical attire in primary total knee arthroplasty surgery[5]. This study was performed in New Zealand but remains highly relevant to the Australian context due to comparable standards of care.

On the other hand, So et al.[11] performed an observational analytical study of total ankle arthroplasty patients that compared infection rates with the surgeon wearing SHS surgical attire (n = 109) and the surgeon wearing standard surgical attire (n = 151). No significant difference was detected in overall infection or peri-prosthetic joint infection rates ($p = 0.411$)[11]. However, this study only analysed ankle arthroplasty procedures conducted in multiple centres in the United States with a sample size of 260, which affects the robustness of the findings[11]. In comparison, Rahardja et al.[5] analysed a sample size of 19322. Furthermore, the arthroplasty procedures performed in both studies are different, which may contribute to the different results.

As well as protecting the patient, SHSs also protect the wearer from exposure to airborne contaminating particles. In their observational descriptive study employing a cross-sectional design, Putzer et al.[12] demonstrated the need for staff members exposed to high amounts of contamination from aerosol-generating procedures to wear an SHS. The simulation experiment investigated the particles and aerosol created during high-speed burring and found that particles smaller than 0.3µm were generated[12]. Surgical masks may not filter such small particles; therefore, it is recommended that all sterile staff wear the SHS during aerosol-generating procedures[12].

Impact of delayed fan activation in the surgical helmet system

The SHS fan can be activated before or after donning sterile attire. Eggers et al.[13] explored this in a randomised controlled trial comparing contamination rates for three cohorts – standard surgical attire, SHSs with delayed fan activation and SHSs without delayed fan activation. The Toga style of SHS hood was used (a combined gown and SHS hood with a zipper at the back[9]). Various areas of the sterile person within the sterile field were swabbed at the end of the procedure (n = 180).

Positive culture rates for the surgical cases were 15 per cent for the standard surgical attire, 18 per cent in the SHS surgical attire with delayed fan activation and 25 per cent in the SHS surgical attire without delayed fan activation ($p = <0.05$)[13]. After excluding positive culture rates from the SHS hood, contamination rates were seven per cent for the SHS surgical attire with delayed fan activation and eight per cent for the SHS surgical attire without delayed fan activation[13].

Contamination rates from the face shield were 18 per cent for the SHS surgical attire with delayed fan activation and 25 per cent ($p = <0.05$) for the SHS surgical attire without delayed fan activation but the difference was not statistically significant[13]. Based on their results, the authors recommend delaying fan activation and excluding the helmet and face shield from the sterile field[13].

A limitation of this study is that the standard surgical attire cohort included any orthopaedic procedures while the two SHS cohorts included arthroplasty procedures[13].

Thaler et al.[14] explored the contamination of the SHS helmet and surgical gloves during and after arthroplasty procedures. In this observational study without a control group (n = 49) swabs were taken during and at the end of the arthroplasty procedure from the sterile team member's gloves and the SHS helmet. The researchers found that contamination of either the gloves or the SHS helmet was evident in 20 of the 49 arthroplasty procedures studied[14]. These results reinforce those of Eggers et al. that contamination can exist on the SHS helmet intra-operatively and it should be deemed unsterile. However, as Thaler et al. did not measure contamination rates of standard surgical attire their findings, while valuable, lack significance when comparing the SHS surgical attire to standard surgical attire[14].

Moores et al.[15] compared contamination of hands and gown when using standard orthopaedic hoods and SHSs with the fan activated and not activated in a quasi-experimental prospectively controlled study (n = 18). The researchers counted particles and took culture samples three times from two locations, inside and outside laminar flow areas, when a standard orthopaedic hood was used and when the SHS was used, with and without the fan activated. No positive cultures were found on the agar plates in the experiment; however, the background colony count increased 3.7 times with the SHS fan switched on (p = 0.004)[15]. This suggests that when the fan from the SHS is on it could contribute to the contamination of surgical attire and parts of the sterile field that are close to the SHS[15].

Similarly, an experimental prospectively controlled study (n = 21) by Kang et al.[6], found that if the fan in the SHS was activated before the surgeon donned their gown and gloves, contamination was evident in most body regions of the surgeon. In contrast, when the fan in the SHS was activated later, after the surgeon donned their gown and gloves, minor levels of contamination were found in only two of 11 body regions[6]. Additionally, when the fan in the SHS was activated before the surgeon donned their gown and gloves, contamination occurred on the sterile member donning the sterile SHS hood[6].

Furthermore, in an observational study without a control group (n = 20), Lynch et al.[16] analysed the relationship between bacterial load and the initial run time of an SHS fan. Agar plates were placed under the outflow vents of surgical helmets and exchanged at different time points. The results indicate that the first minute of fan operating time produced the highest number of colonies (27) on the agar plate, possibly indicating dispersal of contaminants present on the helmet before the fan was activated[16]. There was a significant reduction in the number of colonies at three, four and five minutes (five, three and four colonies (p = <0.01), respectively)[16]. The researchers recommend that SHS fans are run for at least three minutes before entering the operating room[16].

Similarly, Tarabichi et al.[17] demonstrated the SHS as a contamination source in an observational study without a control group (n = 132) that involved swabbing the SHS. Among the swab samples from the SHS, 73 per cent yielded bacteria on culture[17]. This study demonstrated that SHSs harbour common pathogens that could cause surgical site infections[17] and the fan could facilitate their spread onto the sterile field.

The results of these studies suggest that combining the recommendations – that is, turning the fan on for three minutes outside the operating room, then turning it off until after scrubbing and donning surgical attire – may be worth considering.

Evaluating positive pressure challenges of the surgical helmet system

Positive pressure is created when air is blown into the SHS suit. Chen et al.[18] conducted a quasi-experimental prospectively controlled study that compared leakage through the glove–gown interface when SHS was used, when SHS was not used and when the glove–gown interface was sealed and not sealed. The results identified a consistently higher leakage intensity via the glove–gown interface when SHS was used and the glove–gown interface was not sealed (p=0.05)[18]. Sealing the glove-gown interface is recommended when using SHS to reduce the risk of contamination[18].

Positive pressure in the SHS results in particles being blown out through areas of low resistance. Some SHSs have a second fan to release air and, in theory, reduce pressure. Vermeiren et al.[19] conducted a quasi-experimental prospectively controlled study comparing particle contamination of the gown in single-fan versus two-fan SHSs (n = 20). No difference was found in overall gown particle contamination between the systems but all tests displayed contamination at the gown–glove interface[19] further suggesting the need for the glove-gown interface to be sealed.

The back of the sterile surgical gown provides a way for air and airborne contaminants to escape from the SHS[9]. Konopitski et al.[9] conducted a quasi-experimental prospectively controlled study (n = 36) comparing contamination rates of a standard, rear-tied gown, a standard gown with a vest that covers the back of the gown, and Toga-style gown closed with a zipper. Airborne microbial particles were collected on agar plates positioned behind the surgeon, and bacterial colony-forming units (CFUs) were counted after the plates were incubated[9]. The highest contamination rate was found with the standard gown (331.7 ± 52.0 CFU/m2/h), the rate decreased by 45 per cent (182.2 ± 30.8 CFU/m2/h) with the gown and vest, and by 49 per cent (170.5 ± 41.9 CFU/m2/h) with the Toga-style gown (P = 0.01)[9]. The researchers recommend that staff within the surgical field either use a vest to cover the back of the sterile surgical gown or wear a gown closed by a zipper to reduce contamination rates in the surrounding sterile field[9].

Optimising donning techniques for the surgical helmet system

There is a range of techniques used for donning SHS hoods and currently no recommendations for the most appropriate method[20]. McAleese et al.[20] conducted a quasi-experimental prospectively controlled study (n = 100) comparing the bacterial contamination on the gloves of two groups of surgeons each using a different SHS hood–donning technique performed under laminar airflow with late fan activation. In the first group, the scrubbed and gloved surgeon placed the SHS hood over a colleague and then immediately press-inoculated all five fingers of both gloves in separate agar plates. In the second group, a non-sterile colleague, wearing sterile gloves, placed the SHS hood on the scrubbed but not gloved surgeon. The surgeon then donned sterile gloves and immediately press-inoculated all five fingers of both gloves in separate agar plates. The researchers found no significant difference in bacterial contamination between the groups; nonetheless, the researchers advise that operating surgeons should be very careful when putting an SHS hood on a colleague to reduce the risk of contamination.[20]

McAleese et al.[20] also investigated the baseline sterility of the SHS hood. Immediately after the hood was over the helmet, sterile culture swabs were collected from the screen and neckline. Six of the 50 hoods tested (12%) were found to have a positive culture that isolated an organism. The researchers therefore suggest that the SHS hood should not be presumed to be sterile after application and intra-operative adjustment is inadvisable.

Kang et al.[6] investigated the effect of early and late SHS fan activation and found that contamination levels of a gowned and gloved scrub nurse who put the SHS hood on the surgeon were higher when the SHS fan was activated before the surgeon donned their gown and gloves (early activation) than when the SHS fan was activated after the surgeon donned their gown and gloves (late activation)[6]. This indicates that optimal donning technique should include a non-sterile team member applying the sterile SHS hood before the SHS fan is activated but after the sterile team member has donned their gown and inner gloves[6].

Conclusion

This integrative review provides an overview of recent literature about the effectiveness of the SHS in reducing infection and contamination in arthroplasty procedures. The findings indicate that the SHS reduces the rate of infections in arthroplasty procedures, compared to standard surgical attire, and protects the surgical team from debris and aerosol particles. Best practices to minimise potential contamination include wrapping the glove–gown interface, treating the sterile SHS hood as unsterile, delaying fan activation, running the fan for three minutes before entering the operating room, covering the back of surgical gown or using a zipper-closed gown, and having a non-sterile team member apply the SHS hood.

The insights gained from this integrative review can inform perioperative nursing practices involving the SHS for arthroplasty procedures, enabling high-quality and safe health care for patients. Nonetheless, further research into the use of SHSs in arthroplasty procedures is needed to develop evidence-based practice recommendations.

Declaration of conflicting interests

The authors have declared no competing interests with respect to the research, authorship and publication of this article.

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References

1. Scigliano NM, Carender CN, Glass NA, Deberg J, Bedard NA. Operative time and risk of surgical site infection and periprosthetic joint infection: A systematic review and meta-analysis [Internet]. Iowa Orthop J. 2022 [cited 2024 Oct 15];42(1):155–61. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC9210401/
2. Tubb CC, Polkowksi GG, Krause B. Diagnosis and prevention of periprosthetic joint infections [Internet]. J Am Acad Orthop Surg. 2020 [cited 2024 Oct 15];28(8):e340–8. DOI: 10.5435/jaaos-d-19-00405
3. Fan Y, McCanne M, Yuh J, Lekkala S, Leape CP, Hugard S et al. The efficacy of antibiotic-eluting material in a two-stage model of periprosthetic joint infection [Internet]. J Orthop Res. 2023 [cited 2024 Oct 14];42(2):460–73. DOI: 10.1002/jor.25681
4. Ali KA, He L, Deng X, Pan J, Huang H, Li W. Assessing the predictive value of pre- and post-operative inflammatory markers in patients undergoing total knee arthroplasty [Internet]. J Orthop Surg Res. 2024 [cited 2024 Oct 14];19:614. DOI: 10.1186/s13018-024-05104-0
5. Rahardja R, Morris AJ, Hooper GJ, Grae N, Frampton CM, Young SW. Surgical helmet systems are associated with a lower rate of prosthetic joint infection following total knee arthroplasty: Combined results from the New Zealand Joint Registry and Surgical Site Infection Improvement Programme [Internet]. J Arthroplasty. 2022 [cited 2024 Oct 6];37(5):930–5.e1. DOI: 10.1016/j.arth.2022.01.046
6. Kang L, Dewar D, Lobo A. Examination of surgical helmet and surgical hood application methods in reducing contamination in arthroplasty surgery [Internet]. Arthroplast Today. 2021 [cited 2024 Oct 6];7:157–60. DOI: 10.1016/j.artd.2020.11.013
7. Whittemore R, Knafl K. The integrative review: Updated methodology [Internet]. J Adv Nur. 2005 [cited 2022 Apr 28];52(5):546–53. DOI:10.1111/j.1365-2648.2005.03621.x
8. Page M, McKenzie, JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow, CD et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews [Internet]. BMJ. 2021[cited 2022 Apr 28];Mar 29:372:n71. DOI: 10.1136/bmj.n71
9. Konopitski AP, Jones H, Mathis KB, Noble PC, Rodriguez-Quintana D. Wearing a surgical vest with a sterile surgical helmet system decreases contamination of the surgical field [Internet]. J Arthroplasty. 2024 [cited 2024 Oct 6];39(9):2377–82. DOI: 10.1016/j.arth.2024.04.066
10. Australian College of Perioperative Nurses Ltd (ACORN). Asepsis. In: The New ACORN Standards: Volume 3 – standards for safe and quality care in the perioperative environment (SSQCPE) for organisations. Adelaide: ACORN; 2023.
11. So E, Juels CA, Seidenstricker C, Walker R, Scott RT. Postoperative infection rates after total ankle arthroplasty: A comparison with and without the use of a surgical helmet system [Internet]. J Foot Ankle Surg. 2022 [cited 2024 Oct 6];61(4):802–6. DOI: 10.1053/j.jfas.2021.11.021
12. Putzer D, Dammerer D, Huber C, Boschert H, Thaler M, Nogler M. Aerosol morphology and particle size distribution in orthopaedic bone machining: A laboratory worst-case contamination simulation. Is high-speed bone machining potentially harmful by pollution and quality schemes and what measures could be taken for prevention? [Internet]. Int Orthop. 2022 [cited 2024 Oct 6];46(7):1647–55. DOI: 10.1007/s00264-022-05398-x
13. Eggers JP, Krumme JW, Kotwal S. Iatrogenic contamination with a surgical helmet system in orthopedic surgery [Internet]. Orthopedics. 2021 [cited 2024 Oct 6];44(6) e753–6. DOI: 10.3928/01477447-20211001-16
14. Thaler M, Khosravi I, Lechner R, Ladner B, Coraça-Huber DC, Nogler M. An intraoperative assessment of bacterial contamination on surgical helmets and gloves during arthroplasty surgeries [Internet]. Hip Int. 2020 [cited 2024 Oct 6];32(4):426–30. DOI: 10.1177/1120700020963544
15. Moores TS, Khan SA, Chatterton BD, Harvey G, Lewthwaite SC. A microbiological assessment of sterile surgical helmet systems using particle counts and culture plates: Recommendations for safe use whilst scrubbing [Internet]. J Hosp Infect. 2019 [cited 2024 Oct 6];101(3):354–60. DOI: 10.1016/j.jhin.2018.06.005
16. Lynch BC, Swanson DR, Marmor WA, Gibb B, Komatsu DE, Wang ED. The relationship between bacterial load and initial run time of a surgical helmet [Internet]. J Shoulder Elbow Arthroplasty. 2022 [cited 2024 Oct 6];6: 24715492221142688. DOI: 10.1177/24715492221142688
17. Tarabichi S, Chisari E, Van DS, Krueger CA, Parvizi J. Surgical helmets used during total joint arthroplasty harbor common pathogens: A cautionary note [Internet]. J Arthroplasty. 2022 [cited 2024 Oct 6];37(8):1636–9. DOI: 10.1016/j.arth.2022.03.066
18. Chen HK, Chan VWK, Yan CH, Fu H, Chan PK, Chiu K. The effect of the surgical helmet system on intraoperative contamination in arthroplasty surgery [Internet]. Bone Jt Open. 2023 [cited 2024 Oct 6];4(11):859–64. DOI: 10.1302/2633-1462.411.bjo-2023-0078.r1
19. Vermeiren A, Verheyden M, Verheyden F. Do double-fan surgical helmet systems result in less gown-particle contamination than single-fan designs? [Internet]. Clin Orthop Relat Res. 2020 [cited 2024 Oct 6];478(8):1359–65. DOI: 10.1097/corr.0000000000001121
20. McAleese T, Doinn TÓ, Broderick JM, Farrington R, Prior AR, Quinlan JF. Surgical helmet systems in total joint arthroplasty: Assessment of hood sterility and donning technique [Internet]. Arthroplasty. 2023 [cited 2024 Oct 6];5(1):53. DOI: 10.1186/s42836-023-00212-4