

مجموعه مقالات نشست بین‌المللی «هم‌رأیی» درباره عفونت مفاصل مصنوعی

رؤسای جلسه:

دکتر جواد پرویزی، دکتر تورستن گرک

Proceedings of the International Consensus Meeting on Periprosthetic Joint Infection

Chairmen:

Javad Parvizi MD, FRCS; Thorsten Gehrke, MD

قسمت نهم: محیط جراحی

(Ninth Section: Operative Environment)

Question 11: What restrictions should be placed on the use of portable electronic devices (such as mobile phones, laptops, tablets, or music devices) in the operating room?

Consensus: We recognize that portable electronic devices may be contaminated with bacteria. We also recognize that increased levels of talking are associated with higher levels of bacteria in the operating room environment. Accordingly we recommend that portable electronic device usage be limited to that necessary for patient care.

Delegate Vote: Agree: 84%, Disagree: 14%, Abstain: 2% (Strong Consensus)

Justification: Many studies have shown a high rate of contamination of cell phones and other portable electronic devices used in hospitals by healthcare workers, from 44% to 98%, with a high percentage of resistant strains, namely extended-spectrum β -lactamase-producing gramnegative bacteria and methicillin-resistant *Staphylococcus aureus* (MRSA).⁴³⁻⁴⁹ Ulger et al. demonstrated that 52% of *Staphylococcus aureus* strains isolated from cell phones were methicillin-resistant.⁴⁸ Brady et al. showed that cleaning mobile phones with an alcohol-based solution significantly reduced contamination of mobile phones,⁴³ similar to what was previously observed by Singh et al. for pagers⁵⁰ and Hassoun et al. for personal digital assistants.⁵¹ Thus, regular cleaning of portable electronic devices with alcohol is highly recommended, as efforts towards maintaining hand hygiene to prevent nosocomial infections, including SSI, may be compromised by the use of handheld electronic devices that act as reservoirs of pathogens. Limitation of portable electronic devices in the OR is also advised, although no evidence in the literature is able to link their use to an increased risk of SSI.

Question 12: Does prolonged surgical time predispose to an increased risk of PJI?

Consensus: We recognize that SSI rates increase directly with the duration of surgery. We recognize that some surgeries present a marked and inescapable level of complexity that will require more time. We recognize that minimizing the duration of surgery is an important goal and a cooperative effort on the base of the entire surgical team as well as the institution. We recommend that a coordinated effort be made to minimize the duration of surgery without technical compromise of the procedure.

Delegate Vote: Agree: 96%, Disagree: 3%, Abstain: 1% (Strong Consensus)

Justification: Numerous studies have linked increased operative time to the risk of infection after TJA with statistical significance.⁵²⁻⁶⁵ Skramm et al. investigated the incidence of SSI following THA and TKA for fractures after the implementation of surveillance policies. When considering the risk factors for infection, the duration of surgery was the only significant independent factor in a logistic regression model, also taking into account age, American Society of Anesthesiologists's physical status score, and level of emergency.⁶¹ The study by van Kasteren et al supported the use of duration of surgery more than the 75th percentile as a risk factor for PJI,⁶⁴ as previously suggested by the National Nosocomial Infections Surveillance (NNIS) risk index.⁶⁶ In a population-wide study based on the Danish national hip arthroplasty registry that included 80, 756 cases of primary THA, surgical time was a significant independent risk factor for revision due to infection.⁵⁷ Similar results were reported in countries such as Norway and England.^{60,62} Peersman et al. suggested using operative times as a predictive risk factor for infection after TKA in a risk stratification model.⁵⁸ In a

systematic review of only observational studies that investigated deep SSI in THA and included more than 100 patients, Urquhart et al found just two studies that examined operative time.^{54,60} After merging data from these two studies, they reported duration of surgery as an independent risk factor for SSI. In addition, in a recent analysis of 56,216 primary TKAs, Namba et al. identified a 9% increase in the risk of deep SSI per 15 minute-increment increase in operative time.⁵⁶

Nevertheless, methodological concerns exist regarding the studies that support the role of operative time as a risk factor for PJI, including missing data,⁹ failure to consider potential confounding factors,^{57,58} and statistical considerations.⁵⁹⁻⁶¹ On the other hand, there are studies that failed to demonstrate such a correlation⁶⁷ or even found an opposite relationship.⁶⁸ Moreover, none of the previous studies considered the potential confounding role of repeat doses of antibiotic prophylaxis during prolonged procedures. Procedure duration may be an indicator of complexity of surgery (extensive surgical exposure and more severe tissue damage), surgical indication (previous procedures and indications other than osteoarthritis), inexperienced surgical team, surgeon with slow pace, perioperative complications, inadequate optimal standardization program, or patient's preexisting medical conditions.^{57,69,70} Perhaps staff education in how to operate efficiently and follow systematically defined steps might decrease the risk of SSI. Interestingly, it has also been demonstrated that procedures with a longer duration are at increased risk for revision due to aseptic failure.⁶²

Question 13: Should the scheduling of elective TJA be ordered such that clean cases are not preceded by known infected, dirty, or contaminated cases?

Consensus: We recognize the concern regarding risk of infection to a clean surgery following a contaminated surgery. We recognize that studies have not demonstrated increased infection rates in clean surgery performed subsequent to contaminated cases. We recommend thorough cleaning as defined by local institutional standards, after contaminated surgery and before further surgery.

Delegate Vote: Agree: 89%, Disagree: 8%, Abstain: 3% (Strong Consensus)

Justification: Although performing an infected arthroplasty procedure before non-infected procedures is theoretically risky for cross-contamination between procedures, there is inadequate evidence to support or oppose this practice. However, this policy may allow the hygiene staff a thorough clean down procedure at the end of OR working day when there is no economical concern regarding the duration of time that might be required for a compliant OR disinfection.

Literature: A common practice in orthopaedic surgery, especially in arthroplasty, is to organize the OR in a manner so that confirmed or suspicious cases of infection

are operated on at the end of the OR session after clean procedures. Whether the practice of performing a clean arthroplasty procedure following an infected case increases the probability of infection or not has not been adequately studied. Microbiologic studies have demonstrated long-term survivorship of common nosocomial pathogens on inanimate surfaces.⁷¹ This may support the theoretical risk of cross-contamination between procedures if there is no efficient preventive strategy for disinfection of these surfaces after every procedure. There are only two retrospective studies that have addressed this issue, but both had inadequate power and inconsistent conclusions.^{72,73} Despite the lack of evidence, a sound practice consists of thoroughly addressing this potential factor of PJI, even though there is inadequate evidence for cross-contamination between procedures. Abolghasemian et al. evaluated 85 primary and revision cases performed after TJA resection for PJI and evaluated the risk of infection in those patients,⁷² After a minimum follow-up of 12 months, an increased rate of superficial or deep infections was not witnessed in this cohort when compared to 321 patients matched for demographic factors who did not undergo TJA after an infected TJA in the same operating room. The one patient who developed a deep PJI in the study group had a different infecting organism than the one responsible for the PJI of the preceding surgical case. Cleaning the OR after an infected case did not differ from cleaning after an aseptic case. Namdari et al. undertook a similar endeavor when they evaluated the development of infection in 39 cases of primary TJA performed after dirty cases. They identified one case of PJI in this cohort when the causative infecting organism (*Propionibacterium acnes*) was the same as the one causing the infection in the preceding septic case. However, no advanced microbiological testing was performed to certify that both organisms were of identical strains.⁷³

Question 14: Does patient normothermia have an essential role in preventing infectious complications?

Consensus: We recognize the significance of patient normothermia and the data from nonorthopedic procedures. We support general recommendations from the general surgery literature and identify this as a field that requires further research.

Delegate Vote: Agree: 92%, Disagree: 1%, Abstain: 7% (Strong Consensus)

Literature: Kurz et al. undertook an RCT of major colorectal surgery patients and demonstrated significant decrease in SSI rates in patients receiving warmed fluids and forced-air warming (FAW) blankets compared to patients who did not receive aggressive maintenance of normothermia.⁷⁴ Melling et al. conducted an RCT in non-orthopaedic clean surgery and identified a significant role for patient warming in preventing SSI.⁷⁵ A systematic protocol using FAW blankets or local warming protocols

using a radiant heat dressing led to a significant decrease in SSI. No such RCT was identified specifically for TJA or orthopaedic procedures in general.

Question 15: Do Forced Air Warming (FAW) blankets increase the risk of SSI?

Consensus: We recognize the theoretical risk posed by forced air warming blankets and the fact that no studies have shown an increase in SSI related to the use of these devices. We recommend further study but no change to current practice.

Delegate Vote: Agree: 89%, Disagree: 5%, Abstain: 6% (Strong Consensus)

Literature: Recent studies have raised concern about the possibility of bacterial air contamination by FAW devices. Some authors evaluated disruptions in airflow. McGovern et al. conducted an experimental study where they found that FAW blankets lead to a disruption in the airflow at the surgical site under laminar flow conditions when compared to conductive fabric warmers in simulated THA and spine surgery.⁷⁶ Legg et al. found increased air particles above the surgical site when using FAW compared to radiant warming.⁷⁷ On the contrary, Sessler et al. did not identify any worsening in air quality with use of FAW under laminar flow conditions.⁷⁸ Memarzadeh et al. reported the results of a computational study conducted by the National Institutes of Health which showed negligible disruption of laminar flow by FAW.⁷⁹

Other authors have investigated the bacterial contamination of OR air. Moretti et al. undertook air sampling in experimental conditions and demonstrated increased bacterial contamination of air after turning FAW blankets on; however, this was much lower than worsening of air quality induced by personnel placing a patient in the OR.⁸⁰ Tumia et al. undertook air sampling under laminar flow conditions in orthopaedic procedures and failed to identify any significant rise in air bacterial counts with the use of FAW.⁸¹ Sharp et al. also performed air sampling in laminar flowequipped ORs to study the effect of FAW on air quality using volunteer patients with psoriasis who had increased shedding of skin cells.⁸² Air at 30cm from a theoretical operating site was sampled and there were no positive cultures. In addition, a smoke test that was used to visually assess airflow found no disturbance by the FAW device. Zink et al. were also concerned by possible contamination of the OR environment with FAW, but did not resort to air sampling. Instead, they placed culture plates on the abdomen of volunteers with use of FAW and failed to identify increased contamination rates with this method.⁸³ Albrecht et al. found that the intake filters used in air blowers were not optimally efficient and resulted in colonization of the internal parts of the device. Overall, 92% of the devices they tested resulted in positive bacterial growth with organisms that are typically

implicated in PJI (mostly Staphylococci species).⁸⁴ However, there is no concrete evidence to link the use of FAW system with SSI/PJI. McGovern et al studied a change of a warming system from forced air to an alternative system in 1,437 patients. A significant increase in deep joint infection, as demonstrated by an elevated infection odds ratio (3.8, p=0.024), was identified during a period when forced-air warming was used compared to a period when conductive fabric warming was used. The authors conceded that the study was observational and may have been affected by other infection prevention measures instituted by the hospital.⁷⁶

Question 16: Should OR personnel be required to decontaminate their hands with at least an alcohol-based foam every time their hands have been in contact with inanimate objects (including medical equipment) located in the immediate vicinity of the patient?

Consensus: We support current recommendations for hand hygiene in patient care.

Delegate Vote: Agree: 86%, Disagree: 8%, Abstain: 6% (Strong Consensus)

Justification: Properly performed hand hygiene affords protection to both the patient and healthcare worker from cross transmission of infectious agents. Hand hygiene should be performed by OR personnel involved in examination, manipulation and placement of the patient, in accordance with the World Health Organization's (WHO's) 5 Moments for Hand Hygiene.⁸⁵ There is ample evidence to confirm that transmission of pathogens from/to a patient to/from their immediate environment, defined below, occurs. However, there is inadequate evidence to show the influence of hand decontamination on this sequence. High-quality clinical investigations are required to study the efficiency of hand decontamination on prevention of SSI and PJI. Frequent hand decontamination has been suggested,⁸⁶ but concerns have been expressed regarding skin irritation and contact dermatitis.⁸⁷ Moreover, some risk of change of bacterial flora to colonizing bacteria with skin damage might exist.⁸⁸

Literature: Five sequential steps for cross-transmission of microbial pathogens have been described.⁸⁶ These steps include shedding of skin flora to inanimate objects surrounding the patients, transfer of the bacteria to the healthcare worker's hands, adequate survival of the microbes on the healthcare worker's hands, inadequate hand antisepsis technique by the healthcare worker, and transmission of bacteria from the healthcare worker's hands to other patients or inanimate objects that can potentially be in contact with patients.

Approximately 106 skin squames containing microorganisms are shed daily from normal skin.⁸⁹ Therefore, surfaces located in the close vicinity of the patient (such as floor, bed lines, gowns, furniture, and medical equipment

such as blood pressure cuffs) can become contaminated with patients' skin flora.^{86, 90-92} Hands or gloves of healthcare workers can be contaminated after contact with inanimate objects in patient rooms.^{93, 94} Laboratory-based studies have demonstrated that many bacteria, including *Staphylococcus aureus*, gram-negative bacilli, and *Enterococci*, can be transferred to the hands by touching contaminated surfaces.^{86, 94, 95}

Microorganisms can survive on hands for different lengths of time varying between a few minutes to several hours and healthcare workers' hands can be progressively colonized due to poor hygiene, longer duration of care, and higher quantity of contamination.⁸⁶ In one study, the use of an alcohol gel hand wash was associated with a 36% decrease in nosocomial infection rates.⁹⁶ There is substantial evidence that demonstrates improvement in the rate of healthcare-associated infections with hand hygiene promotional programs that include the use of an alcohol-based hand rub, although studies with improved design methodology are needed.⁸⁶

Question 17: What are the guidelines for hand hygiene and glove use for personnel in contact with the patient for examination, manipulation, and placement on the OR table?

Consensus: We support current recommendations in patient care in accordance with principles of Standard Precautions.

Delegate Vote: Agree: 92%, Disagree: 1%, Abstain: 7% (Strong Consensus)

Justification: Gloves should be used by OR personnel as dictated by the principles of Standard Precautions.⁹⁷ Added protection to the healthcare worker, via glove use, is required in the event of potential contact with blood, body fluids, secretions, excretions, mucous membranes, nonintact skin or contaminated equipment.⁹⁷ Glove use does not preclude the need for application of hand hygiene principles. In the event that the patient is on contact precautions, gloves should be used for all contact with the patient and/or the immediate patient environment. The dynamics of contamination are similar between gloved and ungloved hands.⁸⁶ Gloves can be contaminated after touching the patient or inanimate objects in patient rooms.^{92, 93, 98, 99} Risk of cross-contamination through contaminated gloves is similar to that of naked hands.^{92, 99}

Therefore, when gloves are used in patient care, hand hygiene must be performed prior to donning gloves and following glove removal. A single pair of gloves may not be used in the care of more than one patient.

Question 18: Should triple gloving be used to prevent contamination during TJA?

Consensus: We recommend double gloving and recognize the theoretical advantage of triple gloving.

Delegate Vote: Agree: 89%, Disagree: 7%, Abstain: 4% (Strong Consensus)

Justification: A relatively high rate of inner glove contamination has been identified with double-gloving in TJA, leading to the consideration of triple-gloving practices.^{100, 101} Hester et al. compared the rate of inner glove perforation with 3 different gloving protocols in TJA: latex/cloth, latex/latex, and latex/cloth/latex.¹⁰² They found a reduced rate of perforation when the outer glove was a cloth glove compared to a latex glove, and interposing a cloth glove between two latex gloves yielded the lowest rate of perforation. While double-gloving with an outer cloth glove had a notable impact on tactile sensation and was troublesome when manipulating cement, triple-gloving with a cloth glove between two latex gloves was not perceived as having such an important impact. However, reported differences in rates were not shown to be statistically significant. Sebold et al. demonstrated that the use of a cloth glove between two latex gloves was able to reduce inner glove perforation rates to zero in their institution.¹⁰³ According to their observations, surgeon dexterity was not affected by this gloving practice. In addition, the authors showed that the use of orthopaedic outer gloves yielded lower inner glove puncture rates than regular latex gloves. Sutton et al. showed that a triple-gloving protocol with a cut-resistant liner interposed between the two latex gloves significantly reduced the rate of perforation compared to double-gloving with two latex gloves.¹⁰⁴ Overall, triple-gloving seems to decrease inner glove perforation rates; however, this is at the expense of a decrease in surgical dexterity and tactile sensation.

Question 19: How frequently should gloves be changed during surgery?

Consensus: We recognize the advantage of glove changes at least every 90 minutes or more frequently and the necessity of changing perforated gloves. Permeability appears to be compromised by the exposure to methacrylate cement and gloves should be changed after cementation.

Delegate Vote: Agree: 89%, Disagree: 6%, Abstain: 5% (Strong Consensus)

Justification: Al-Maiyah et al. conducted a RCT on THA procedures where the study group consisted of changing outer gloves every 20 minutes and before implant cementation, compared to changing only before cementation in the control group.¹⁰⁵ This change in practice led to a significant reduction in perforation and contamination rates of outer gloves. Kaya et al. reported that glove perforations occurred after 90 minutes on average and suggested changing gloves every 90 minutes.¹⁰⁶ Dawson-Bowling et al. evaluated glove contamination after draping and before opening the final components and found 12 and 24% contamination rates respectively.¹⁰⁷ Beldame et al. identified a significantly higher rate of glove contamination before prosthesis implantation and advised changing gloves before this

surgical step.¹⁰⁸ The authors also showed that when the outer gloves were contaminated, changing them lead to noncontaminated outer gloves in 80% of cases. Furthermore, in a prospective study, Carter et al. found that a surgeon's outer glove perforation occurred in 3.7 and 8.3% of primary and revision arthroplasty, respectively. They also found that inner glove perforation was ignored in 19% of double glove perforations and recommended careful inspection of the inner glove whenever outer glove perforation is noted.¹⁰⁰

Question 20: When should instrument trays be opened?

Consensus: We recommend that the timing of opening trays should occur as close to the start of the surgical procedure as possible with the avoidance of any delays between tray opening and the start of surgery.

Delegate Vote: Agree: 98%, Disagree: 1%, Abstain: 1% (Strong Consensus)

Justification: Dalstrom et al. recently demonstrated a direct correlation between the duration of open exposure of instrument trays and the risk of bacterial contamination.¹⁰⁹ Some trays were found to be contaminated immediately after opening. After eliminating those trays, they reported contamination rates of 4% at 30 minutes, 15% at 1 hour, 22% at 2 hours, 26% at 3 hours, and 30% at 4 hours. Brown et al. demonstrated that bacterial air counts during preparation and draping were 4.4 times higher

than during surgery, leading them to recommend opening instruments after patient preparation and draping.¹¹⁰

Question 21: Should trays be covered with sterile drapes/towels when not in use?

Consensus: We recognize a theoretical advantage to covering trays when not in use for extended periods, and that larger covers may be disadvantageous, if they are moved from contaminated areas across the sterile field. We recommend further study of this question regarding timing and techniques.

Delegate Vote: Agree: 90%, Disagree: 4%, Abstain: 6% (Strong Consensus)

Justification: Chosky et al. demonstrated that covering the instruments with sterile drapes reduced bacterial contamination rates 4-fold.¹¹¹ The Association of Perioperative Registered Nurses (AORN) guideline for maintaining a sterile surgical field does not recommend covering the sterile table with sheets that fall below the table top because such a practice may cause air currents that can transfer micro-organisms from a nonsterile area (below the table level) to the sterile field over the table at the time of drape removal.¹¹² Nevertheless, Dalstrom et al. showed that covering trays significantly reduced the risk of contamination and did not identify any increased risk of contamination when uncovering them.¹⁰⁹

References

43. Brady RR, Chitnis S, Stewart RW, Graham C, Yalamarathi S, Morris K. NHS connecting for health: healthcare professionals, mobile technology, and infection control. *Telemed J E Health*. 2012;18(4):289-91.
44. Jeske HC, Tiefenthaler W, Hohlrieder M, Hinterberger G, Benzer A. Bacterial contamination of anaesthetists' hands by personal mobile phone and fixed phone use in the operating theatre. *Anaesthesia*. 2007;62(9):904-6.
45. Lee YJ, Yoo CG, Lee CT, et al. Contamination rates between smart cell phones and non-smart cell phones of healthcare workers. *J Hosp Med*. 2013;8(3):144-7.
46. Sadat-Ali M, Al-Omran AK, Azam Q, et al. Bacterial flora on cell phones of health care providers in a teaching institution. *Am J Infect Control*. 2010;38(5):404-5.
47. Singh A, Purohit B. Mobile phones in hospital settings: a serious threat to infection. *Occup Health Saf*. 2012;81(3):42-4.
48. Ulger F, Esen S, Dilek A, Yanik K, Gunaydin M, Leblebicioglu H. Are we aware how contaminated our mobile phones with nosocomial pathogens? *Ann Clin Microbiol Antimicrob*. 2009;8:7.
49. Ustun C, Cihangiroglu M. Health care workers' mobile phones: a potential cause of microbial cross-contamination between hospitals and community. *J Occup Environ Hyg*. 2012;9(9):538-42.
50. Singh D, Kaur H, Gardner WG, Treen LB. Bacterial contamination of hospital pagers. *Infect Control Hosp Epidemiol*. 2002;23(5):274-6.
51. Hassoun A, Vellozzi EM, Smith MA. Colonization of personal digital assistants carried by healthcare professionals. *Infect Control Hosp Epidemiol*. 2004;25(11): 1000-1.
52. Carroll K, Dowsey M, Choong P, Peel T. Risk factors for superficial wound complications in hip and knee arthroplasty. *Clin Microbiol Infect*. Mar 7 2013.
53. Cordero-Ampuero J, de Dios M. What are the risk factors for infection in hemiarthroplasties and total hip arthroplasties? *Clin Orthop Relat Res*. 2010;468(12):3268-77.
54. Huotari K, Agthe N, Lyttikainen O. Validation of surgical site infection surveillance in orthopedic procedures. *Am J Infect Control*. 2007;35(4):216-21.
55. Masgala A, Chronopoulos E, Nikolopoulos G, et al. Risk factors affecting the incidence of infection after orthopaedic surgery: the role of chemoprophylaxis. *Cent Eur J Public Health*. 2012;20(4):252-6.
56. Namba RS, Inacio MC, Paxton EW. Risk factors associated with deep surgical site infections after primary

total knee arthroplasty: an analysis of 56,216 knees. *J Bone Joint Surg Am.* 2013;95(9):775-82.

57. Pedersen AB, Svendsson JE, Johnsen SP, Riis A, Overgaard S. Risk factors for revision due to infection after primary total hip arthroplasty. A population-based study of 80,756 primary procedures in the Danish Hip Arthroplasty Registry. *Acta Orthop.* 2010;81(5):542-7.

58. Peersman G, Laskin R, Davis J, Peterson MG, Richart T. Prolonged operative time correlates with increased infection rate after total knee arthroplasty. *HSS J.* 2006;2(1):70-2.

59. 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.

60. Ridgeway S, Wilson J, Charlet A, Kafatos G, Pearson A, Coello R. Infection of the surgical site after arthroplasty of the hip. *J Bone Joint Surg Br.* 2005;87(6):844-850.

61. Skramm I, Saltyte Benth J, Bukholm G. Decreasing time trend in SSI incidence for orthopaedic procedures: surveillance matters! *J Hosp Infect.* 2012;82(4): 243-7.

62. Smabrekke A, Espehaug B, Havelin LI, Furnes O. Operating time and survival of primary total hip replacements: an analysis of 31,745 primary cemented and uncemented total hip replacements from local hospitals reported to the Norwegian Arthroplasty Register 1987-2001. *Acta Orthop Scand.* 2004;75(5):524-32.

63. Urquhart DM, Hanna FS, Brennan SL, et al. Incidence and risk factors for deep surgical site infection after primary total hip arthroplasty: a systematic review. *J Arthroplasty.* 2010;25(8):1216-1222 e1211-3.

64. van Kasteren ME, Mannien J, Ott A, Kullberg BJ, de Boer AS, Gyssens IC. Antibiotic prophylaxis and the risk of surgical site infections following total hip arthroplasty: timely administration is the most important factor. *Clin Infect Dis.* 2007;44(7):921-7.

65. Willis-Owen CA, Konyves A, Martin DK. Factors affecting the incidence of infection in hip and knee replacement: an analysis of 5277 cases. *J Bone Joint Surg Br.* 2010;92(8):1128-33.

66. Culver DH, Horan TC, Gaynes RP, et al. Surgical wound infection rates by wound class, operative procedure, and patient risk index. National Nosocomial Infections Surveillance System. *Am J Med.* 1991;91(3B):152S-7S.

67. Wymenga AB, van Horn JR, Theeuwes A, Muyltjens HL, Slooff TJ. Perioperative factors associated with septic arthritis after arthroplasty. Prospective multicenter study of 362 knee and 2,651 hip operations. *Acta Orthop Scand.* 1992;63(6):665-71.

68. de Boer AS, Geubbels EL, Wille J, Mintjes-de Groot AJ. Risk assessment for surgical site infections following total hip and total knee prostheses. *J Chemother.* 2001;13 Spec No 1(1):42-7.

69. Jaffer AK, Barsoum WK, Krebs V, Hurbanek JG, Morra N, Brotman DJ. Duration of anesthesia and venous thromboembolism after hip and knee arthroplasty. *Mayo Clin Proc.* 2005;80(6):732-8.

70. Strum DP, Sampson AR, May JH, Vargas LG. Surgeon and type of anesthesia predict variability in surgical procedure times. *Anesthesiology.* 2000;92(5):1454-66.

71. Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. *BMC Infect Dis.* 2006;6:130.

72. Abolghasemian M, Sternheim A, Shakib A, Safir OA, Backstein D. Is arthroplasty immediately after an infected case a risk factor for infection? *Clin Orthop Relat Res.* 2013;471(7):2253-8.

73. Namdari S, Voleti PB, Baldwin KD, Lee GC. Primary total joint arthroplasty performed in operating rooms following cases of known infection. *Orthopedics.* 2011;34(9):e541-545.

74. Kurz A, Sessler DI, Lenhardt R. Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. Study of Wound Infection and Temperature Group. *N Engl J Med.* 1996;334(19):1209-1215.

75. Melling AC, Ali B, Scott EM, Leaper DJ. Effects of preoperative warming on the incidence of wound infection after clean surgery: a randomised controlled trial. *Lancet.* 2001;358(9285):876-80.

76. McGovern PD, Albrecht M, Belani KG, et al. Forced-air warming and ultra-clean ventilation do not mix: an investigation of theatre ventilation, patient warming and joint replacement infection in orthopaedics. *J Bone Joint Surg Br.* 2011;93(11):1537-44.

77. Legg AJ, Cannon T, Hamer AJ. Do forced air patient-warming devices disrupt unidirectional downward airflow? *J Bone Joint Surg Br.* 2012;94(2):254-6.

78. Sessler DI, Olmsted RN, Kuelpmann R. Forced-air warming does not worsen air quality in laminar flow operating rooms. *Anesth Analg.* 2011;113(6):1416-21.

79. Memarzadeh F. Active warming systems to maintain perioperative normothermia in hip replacement surgery. *J Hosp Infect.* 2010;75(4):332-3.

80. Moretti B, Larocca AM, Napoli C, et al. Active warming systems to maintain perioperative normothermia in hip replacement surgery: a therapeutic aid or a vector of infection? *J Hosp Infect.* 2009;73(1):58-63.

81. Tumia N, Ashcroft GP. Convection warmers--a possible source of contamination in laminar airflow operating theatres? *J Hosp Infect.* 2002;52(3):171-4.

82. Sharp RJ, Chesworth T, Fern ED. Do warming blankets increase bacterial counts in the operating field in a laminar-flow theatre? *J Bone Joint Surg Br.* 2002;84(4):486-8.

83. Zink RS, Iaizzo PA. Convective warming therapy does not increase the risk of wound contamination in the operating room. *Anesth Analg.* 1993;76(1):50-3.

- 84. Albrecht M, Gauthier RL, Belani K, Litchy M, Leaper D.** Forced-air warming blowers: An evaluation of filtration adequacy and airborne contamination emissions in the operating room. *Am J Infect Control*. 2011;39(4):321-8.
- 85. World Health Organization.** Clean care is safer care. <http://who.int/gpsc/5may/background/5moments/en>. Accessed July 30, 2013.
- 86. Pittet D, Allegranzi B, Sax H, et al.** Evidence-based model for hand transmission during patient care and the role of improved practices. *Lancet Infect Dis*. 2006;6(10):641-52.
- 87. Chou DT, Achan P, Ramachandran M.** The World Health Organization '5 moments of hand hygiene': the scientific foundation. *J Bone Joint Surg Br*. 2012;94(4):441-5.
- 88. Larson EL, Hughes CA, Pyrek JD, Sparks SM, Cagatay EU, Bartkus JM.** Changes in bacterial flora associated with skin damage on hands of health care personnel. *Am J Infect Control*. 1998;26(5):513-21.
- 89. Noble WC.** Dispersal of skin microorganisms. *Br J Dermatol*. 1975;93(4):477-85.
- 90. Bonten MJ, Hayden MK, Nathan C, et al.** Epidemiology of colonisation of patients and environment with vancomycin-resistant enterococci. *Lancet*. 1996;348(9042):1615-9.
- 91. Boyce JM, Potter-Bynoe G, Chenevert C, King T.** Environmental contamination due to methicillin-resistant *Staphylococcus aureus*: possible infection control implications. *Infect Control Hosp Epidemiol*. 1997;18(9):622-7.
- 92. Hayden MK, Blom DW, Lyle EA, Moore CG, Weinstein RA.** Risk of hand or glove contamination after contact with patients colonized with vancomycin-resistant enterococcus or the colonized patients' environment. *Infect Control Hosp Epidemiol*. 2008;29(2):149-54.
- 93. Bhalla A, Pultz NJ, Gries DM, et al.** Acquisition of nosocomial pathogens on hands after contact with environmental surfaces near hospitalized patients. *Infect Control Hosp Epidemiol*. 2004;25(2):164-7.
- 94. Boyce JM, Opal SM, Chow JW, et al.** Outbreak of multidrug-resistant *Enterococcus faecium* with transferable vanB class vancomycin resistance. *J Clin Microbiol*. 1994;32(5):1148-53.
- 95. McFarland LV, Mulligan ME, Kwok RY, Stamm WE.** Nosocomial acquisition of *Clostridium difficile* infection. *N Engl J Med*. 1989;320(4):204-10.
- 96. Hilburn J, Hammond BS, Fendler EJ, Groziak PA.** Use of alcohol hand sanitizer as an infection control strategy in an acute care facility. *Am J Infect Control*. 2003;31(2):109-16.
- 97. Centers for Disease Control and Prevention.** 2007 Guideline for isolation precautions: preventing transmission of infectious agents in healthcare settings. http://www.cdc.gov/hicpac/2007ip/2007ip_table4.html. Accessed July 30, 2013.
- 98. Lucet JC, Rigaud MP, Mentre F, et al.** Hand contamination before and after different hand hygiene techniques: a randomized clinical trial. *J Hosp Infect*. 2002;50(4):276-80.
- 99. McBryde ES, Bradley LC, Whitby M, McElwain DL.** An investigation of contact transmission of methicillin-resistant *Staphylococcus aureus*. *J Hosp Infect*. 2004;58(2):104-8.
- 100. Carter AH, Casper DS, Parvizi J, Austin MS.** A prospective analysis of glove perforation in primary and revision total hip and total knee arthroplasty. *J Arthroplasty*. 2012;27(7):1271-5.
- 101. Demircay E, Unay K, Bilgili MG, Alataca G.** Glove perforation in hip and knee arthroplasty. *J Orthop Sci*. 2010;15(6):790-4.
- 102. Hester RA, Nelson CL, Harrison S.** Control of contamination of the operative team in total joint arthroplasty. *J Arthroplasty*. 1992;7(3):267-9.
- 103. Sebold EJ, Jordan LR.** Intraoperative glove perforation. A comparative analysis. *Clin Orthop Relat Res*. 1993(297):242-4.
- 104. Sutton PM, Greene T, Howell FR.** The protective effect of a cut-resistant glove liner. A prospective, randomised trial. *J Bone Joint Surg Br*. 1998;80(3):411-3.
- 105. Al-Maiyah M, Bajwa A, Mackenney P, et al.** Glove perforation and contamination in primary total hip arthroplasty. *J Bone Joint Surg Br*. 2005;87(4):556-9.
- 106. Kaya I, Ugras A, Sungur I, Yilmaz M, Korkmaz M, Cetinus E.** Glove perforation time and frequency in total hip arthroplasty procedures. *Acta Orthop Traumatol Turc*. 2012;46(1):57-60.
- 107. Dawson-Bowling S, Smith J, Butt D, Cottam H, Umasankar S, Armitage A.** Should outer surgical gloves be changed intraoperatively before orthopaedic prosthesis implantation? *J Hosp Infect*. 2011;78(2):156-7.
- 108. Beldame J, Lagrave B, Lievain L, Lefebvre B, Frebourg N, Dujardin F.** Surgical glove bacterial contamination and perforation during total hip arthroplasty implantation: when gloves should be changed. *Orthop Traumatol Surg Res*. 2012;98(4):432-40.
- 109. Dalstrom DJ, Venkatarayappa I, Manternach AL, Palcić MS, Heyse BA, Prayson MJ.** Time-dependent contamination of opened sterile operating-room trays. *J Bone Joint Surg Am*. 2008;90(5):1022-5