American Journal of Infection Control 41 (2013) 221-6

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major article

Most relevant strategies for preventing surgical site infection after total hip arthroplasty: Guideline recommendations and expert opinion

Katharina M.D. Merollini PhD[a,*], Henry Zheng PhD[a], Nicholas Graves PhD[a,b]

[a] Institute of Health and Biomedical Innovation, Queensland University of Technology, Brisbane, Queensland, Australia
[b] Centre for Healthcare-Related Infection Surveillance and Prevention, Queensland Health, Brisbane, Queensland, Australia

Key Words:
Infection control
Orthopedics
Joint replacement
Prevention

Background: Numerous strategies are available to prevent surgical site infections in hip arthroplasty, but there is no consensus on which might be the best. This study examined infection prevention strategies currently recommended for patients undergoing hip arthroplasty.
Methods: Four clinical guidelines on infection prevention/orthopedics were reviewed. Infection control practitioners, infectious disease physicians, and orthopedic surgeons were consulted through structured interviews and an online survey. Strategies were classified as "highly important" if they were recommended by at least one guideline and ranked as significantly or critically important by ≥75% of the experts.
Results: The guideline review yielded 28 infection prevention measures, with 7 identified by experts as being highly important in this context: antibiotic prophylaxis, antiseptic skin preparation of patients, hand/forearm antisepsis by surgical staff, sterile gowns/surgical attire, ultraclean/laminar air operating theatres, antibiotic-impregnated cement, and surveillance. Controversial measures included antibiotic-impregnated cement and, considering recent literature, laminar air operating theatres.
Conclusions: Some of these measures may already be accepted as routine clinical practice, whereas others are controversial. Whether these practices should be continued for this patient group will be informed by modeling the cost-effectiveness of infection prevention strategies. This will allow predictions of long-term health and cost outcomes and thus inform decisions on how to best use scarce health care resources for infection control.
Copyright © 2013 by the Association for Professionals in Infection Control and Epidemiology, Inc. Published by Elsevier Inc. All rights reserved.

Over the last 4 decades, numerous studies have investigated approaches to preventing surgical site infection (SSI) after total hip arthroplasty (THA). This devastating complication is associated with higher mortality, substantially higher costs, and reduced quality of life and functional outcomes in affected patients.[1]

Numerous previous studies have assessed the effectiveness of infection control strategies in the surgical setting, and systematic reviews of some individual strategies for orthopedics are available.[2-4] The literature is contradictory, however, and evidence of effectiveness is heterogeneous. There are no agreed-upon standards in clinical practice regarding which SSI prevention strategies or combinations of strategies are appropriate to reduce the risk of infection after THA. There is a wide variability in practice by health care facilities. To maximize the efficient use of scarce resources, only cost-effective strategies should be implemented.

To help guide cost-effectiveness studies, it is important to understand variations in beliefs about the usefulness of infection prevention strategies for THA. The aim of this study was to identify the current most important strategies based on expert opinion and consider these in the context of clinical guideline recommendations. For this, we used 3 methods of data collection:

1. Review of guideline recommendations on SSI prevention in the clinical/orthopedic setting
2. Interviews with clinical experts to determine current relevance and general trends
3. Survey of clinical experts to rate the importance of relevant prevention methods.

METHODS

Guideline review

The aim of the review was to identify major or influential international and national guidelines relevant to the prevention of

* Address correspondence to Katharina M.D. Merollini, PhD, Institute of Health and Biomedical Innovation, Queensland University of Technology, 60 Musk Avenue, Kelvin Grove, QLD 4059, Australia.
E-mail address: k.merollini@qut.edu.au (K.M.D. Merollini).
Conflict of interest: None to report.

0196-6553/$36.00 - Copyright © 2013 by the Association for Professionals in Infection Control and Epidemiology, Inc. Published by Elsevier Inc. All rights reserved.
doi:10.1016/j.ajic.2012.03.027

SSI in THA. The most suitable guidelines from American, British, and Australian infection control entities were obtained by searching their Web sites. The following selection criteria were applied:

- Clinical guideline on SSI, including multiple strategies (eg, not only on hand hygiene or only antibiotic prophylaxis), or an orthopedic guideline specifying infection control aspects
- Published in the English language
- Priority given to the most recent guidelines (up to June 2010).

The following 4 clinical guidelines met the foregoing criteria:

- Centers for Disease Control and Prevention's (CDC) "Guideline for Prevention of Surgical Site Infection" (1999)[5]
- British Orthopaedic Association's (BOA) "Primary Total Hip Replacement: A Guide to Good Practice" (2006)[6]
- National Institute of Clinical Excellence's (NICE) "Surgical Site Infection: Prevention and Treatment of Surgical Site Infection" (2008)[7]
- National Health and Medical Research Council's (NHMRC) "Australian Guidelines for the Prevention and Control of Infection in Health Care" (2010).[8]

These guidelines were reviewed using the following process for the selection of infection prevention strategies:

- Inclusion of all strategies relevant for general and/or orthopedic surgery
- Exclusion of strategies specific to other surgical disciplines (eg, cardiac, bowel)
- Exclusion of strategies relevant to routine hospital hygiene procedures (eg, sterilization of medical equipment, cleaning of floors in operating room).

Interviews

The interviews were designed to elicit a general sense of experts' beliefs through discussion of infection control strategies available for orthopedics, and also to confirm the completeness of our list of strategies. Ethics approval was obtained by the University Human Research Ethics Committee. In a short, structured interview, a convenience sample of experts was asked how they would rate the level of importance (high/medium/low/not sure) of strategies mentioned in the guidelines, whether they would recommend the strategy for clinical practice (yes/no), and, if appropriate, whether they would add any other infection control strategies relevant to this topic. The interview protocol is available from the authors on request.

Survey

Experts on SSI prevention in THA were defined as infection control practitioners, infectious disease physicians, and orthopedic surgeons. An electronic survey was created using SurveyMonkey software. Only fully completed surveys with all questions addressed were uploaded for analysis. The link to the online survey was e-mailed to experts in Australia and the United Kingdom. For the sampling, a "snowballing" technique was applied,[9] with collaborating experts asked to forward the link to their colleagues to ensure that only currently practicing experts were involved. The survey was designed to anonymously rank 28 infection prevention strategies noted in the guidelines. Experts were asked to select one response per listed strategy according to its importance in reducing SSIs after THA: of little or no importance (score, 1), of limited importance (2), of significant importance (3), of critical importance (4), or no knowledge or comment (0).

Data analysis

The recorded responses given by experts during the interviews were transferred from tape into text format. The proportions of strategies recommended by experts were calculated using descriptive analyses of frequencies and percentages.

For the survey, average response scores were calculated from scores attached to each response, ranging from 0 to 4, with higher-scores indicating greater importance. These scores can be seen as a weighted average, and indicate the overall perception of importance. Variations of expert responses were given in ranges. All analyses were performed using SPSS version 18 (IBM, Armonk, NY).

Identification of currently most relevant strategies

An SSI prevention strategy was considered highly important for THA if it was recommended in at least one of the reviewed guidelines and was classified as significantly or critically important for infection prevention in THA by $\geq$75% of the experts surveyed (average response score, $\geq$2.5).

RESULTS

Guideline review

Guideline recommendations regarding the 28 relevant SSI prevention strategies are summarized in Table 1, and overall trends are indicated. The guidelines recommend the use of preoperative antibiotic prophylaxis, preoperative showering, antiseptic skin preparation of patients and hand/forearm antisepsis by surgical staff, tobacco cessation, and blood glucose control (highlighted in green). The only guideline referring to a nutritional intervention for immune system improvement was the CDC's guideline, but this approach is unresolved (in orange). Strategies for which evidence was found to increase infection were hair removal, jewelry/nail polish removal, and nasal decontamination (in red).

Regarding intraoperative infection prevention strategies, all guidelines recommend maximal sterile barrier precautions, including sterile gown/surgical attire, sterile gloves, and surgical mask. The CDC and BOA recommend the use of ultraclean air systems during surgery, and only the BOA advises the use of antibiotic-impregnated cement. The NICE recommends oxygen administration, whereas the CDC guidelines published 9 years earlier made no recommendation regarding oxygen owing to a lack of high-quality evidence. No clear trend is seen in the use of closed suction drainage, shoe covers, and warming of patients. Where mentioned, the guidelines advise against the use of UV radiation, wound irrigation, intracavity lavage, non–iodophor-impregnated incision drapes, and a diathermy incision technique as opposed to scalpel-made incision.

Surveillance is generally recommended for postoperative infection prevention. Furthermore, the CDC and NHMRC recommend maintaining a sterile wound dressing for 24-48 hours, and the BOA recommends antibiotic administration for up to 24 hours postsurgery. The NICE and NHMRC guidelines both advise against the use of topical antimicrobial agents for wound healing.

Interviews

All of the experts contacted agreed to participate. Interviews were conducted with 11 experts from 6 Queensland hospitals; demographic data are available from the authors on request. No strategies were added to the initial list. The strategies

Table 1
Guideline recommendations for infection prevention strategies

Infection prevention strategy	Recommended in clinical practice guidelines by*				Overall trend†
	CDC (1999)	BOA (2006)	NICE (2008)	NHMRC (2010)	
Preoperative					
Antibiotic prophylaxis	For (IA)	For	For (1+)	For (if according to ATG)	√
Preoperative showering	For (IB)	NA	For (1+)	For	√
Antiseptic skin preparation of patient	For (IB)	NA	For (1+)	For	√
Hand/forearm antisepsis by surgical staff	For (IB)	NA	For	For (B)	√
Tobacco cessation ≥30 days preoperatively	For (IB)	NA	NA	NA	√
Blood glucose control in diabetics	For (IB)	NA	NA	NA	√
Nutrition intervention for immune improvement	No recommendation	NA	NA	NA	?
Hair removal	Against (IA)	NA	Against (1+)	Against	×
Hand jewelry, artificial nails/nail polish	Against (II)	NA	Against (1+)	Against	×
Nasal decontamination	NA	NA	Against (1+)	Against	×
Intraoperative					
Sterile gowns/surgical attire	For (IB)	For	For	For (C)	√
Sterile gloves	For (IB)	NA	For (1−) (consider double-gloving)	For (GPP) (consider double-gloving)	√
Surgical mask	For (IB)	NA	NA	For (C)	√
Ultraclean air	For (IB)	For	NA	NA	√
Antibiotic-impregnated cement	NA	For	NA	NA	√
Administration of oxygen	No recommendation	NA	For (1+)	NA	√
Closed suction drain	For, if drainage is necessary (IB)	NA	NA	NA	?
Shoe cover	Against (IB)	NA	NA	No recommendation	?
Warming (above normal body temperature)	NA	NA	NA (only to maintain normal body temperature)	NA	?
UV radiation	Against (IB)	NA	NA	NA	×
Wound irrigation	NA	NA	Against (1+)	Against	×
Intracavity lavage	NA	NA	Against (1+)	Against	×
Incision drape	NA	NA	Against use of non−iodophor-impregnated incise drape (1+)	Against use of non−iodophor-impregnated incise drape	×
Diathermy for surgical incision (not scalpel)	NA	NA	Against (1+)	NA	×
Postoperative					
Surveillance	For (IB)	For	NA	For	√
Sterile wound dressing for 24-48 hours	For (IB)	NA	NA	For	√
Administration of antibiotics of up to 24 hours	NA	For	NA (only as SSI treatment)	NA (only as SSI treatment)	√
Topical antimicrobial agents for wound healing by primary intention	NA	NA	Against (1+)	Against	×

ATG, Australian Therapeutic Guidelines; *NA*, not applicable.
***CDC categories:**
IA, strongly recommended for implementation and supported by well-designed experimental, clinical, or epidemiologic studies.
IB, strongly recommended for implementation and supported by some experimental, clinical, or epidemiologic studies and strong theoretical rationale.
II, suggested for implementation and supported by suggestive clinical or epidemiologic studies or theoretical rationale.
NICE categories:
1+, well-conducted meta-analyses, systematic reviews of randomized controlled trials (RCTs), or RCTs with a low risk of bias.
1−, meta-analyses, systematic reviews of RCTs, or RCTs with a high risk of bias.
NHMRC categories:
B, body of evidence can be trusted to guide practice in most situations.
C, body of evidence provides some support for recommendation(s), but care should be taken in its application.
GPP, body of evidence is weak or nonexistent. Recommendations for best practice based on clinical experience and expert opinion.
†Overall trend: √, recommended;?, unresolved; ×, not recommended.

recommended by the majority of experts (>75%) were preoperative antimicrobial prophylaxis (100%; n = 11), recording of infection rates and provision of staff feedback (100%; n = 11), incision care and management (91%; n = 10), skin preparation of patient (91%; n = 10), skin preparation of staff (82%; n = 9), maximal sterile barrier precautions (82%; n = 9), and oxygen administration (82%; n = 9). Strategies considered of low importance by the experts (>25%) were shoe covers (64%; n = 7), UV light (55%; n = 6), and body exhaust suits (36%; n = 4). Strategies that more than 25% of the experts were unsure about were warming the patient (45%; n = 5), UV light (27%; n = 3), and antibiotic-impregnated implantable devices (27%; n = 3).

Survey

A total of 19 experts completed the survey, including 12 (63.2%) orthopedic surgeons, 5 (26.3%) infection control practitioners, and 2 (10.5%) infectious disease physicians. The results are illustrated in Figures 1-3. As shown in Figure 1, the highest-rated preoperative strategy was antibiotic prophylaxis, with an average response score of 3.9 (range, 3-4) and 100% of experts rating it as significantly or highly important. Antiseptic skin preparation of patients (mean, 3.8; range, 0-4) and hand decontamination of staff (mean, 3.6; range, 2-4) were ranked almost as high (95%; n = 18). Tobacco cessation (mean, 1.8; range, 0-3), jewelry/nail polish removal (mean, 2.1; range, 0-4), hair removal (mean, 2.3; range, 1-4), and nasal decontamination (mean, 2.3; range, 0-4) were considered of limited importance. Although blood glucose control (mean, 3.1; range, 2-4), nutrition intervention (mean, 2.8; range, 0-4), and preoperative showering (mean, 2.7; range, 2-4) had average response scores of >2.5, they did not reach agreement on importance by 75% of experts.

Rankings of infection prevention measures for the intraoperative phase are illustrated in Figure 2. Measures of limited importance were shoe covers (mean, 2.0; range, 1-4), UV light (mean, 2.0; range, 0-4), and closed suction drains (mean, 2.3; range, 1-4). The use of a sterile/surgical gown (mean, 3.7; range, 2-4) was the most highly rated strategy, with 95% of experts ($n = 18$) finding it significantly or critically important in reducing the risk of SSI. Antibiotic-impregnated cement (mean, 3.2; range, 0-4) and ultraclean air/laminar airflow (mean, 3.4; range, 2-4), were rated as highly important by 79% of experts ($n = 15$). Although the average response scores indicated an equally high or better outcome for wound irrigation (mean, 3.4; range, 0-4), not as many experts agreed on its importance. This was also the case for the other potentially important strategies highlighted in orange.

In the postoperative phase (Fig 3), only one strategy was of little importance: topical administration of antimicrobial agents to the incision site (mean, 1.4; range, 0-3). The other 3 strategies were potentially important, but only surveillance (mean, 3.1; range, 0-4) was viewed as significantly or critically important by >75% of experts (79%; $n = 15$). Table 2 summarizes the strategies that the experts classified as highly important.

DISCUSSION

Discussion of findings

Successful prevention of SSI after THA requires a comprehensive approach using a combination of interventions. Strategies considered most important by experts were preoperative antibiotic prophylaxis, antiseptic skin preparation of patients, hand/forearm antisepsis by surgical staff, intraoperative use of sterile gown/surgical attire, ultraclean/laminar air operating room, and antibiotic-impregnated cement, followed by postoperative surveillance. All of these strategies also were recommended by at least one of the guidelines reviewed.

Some measures were recommended by the guidelines but not classified as relevant because they did not fulfill the second criteria of expert appraisal. These included patient showering before the operation, use of surgical mask and sterile gloves, oxygen administration, application of a sterile wound dressing for 24-48 hours postsurgery, and administration of antibiotics for up to 24 hours postsurgery.

The only discrepancy in relevance between the expert survey and interviews was that antibiotic-impregnated cement was identified as highly important in the survey but was considered controversial in the interviews. Interestingly, although none of the guidelines reviewed contained any recommendation on nutrition interventions, the majority of experts interviewed (69%) considered it highly important.

The greatest agreement was on the topic of antibiotic prophylaxis, which was recommended in all of the guidelines and rated as highly important by 100% of the experts consulted. This strategy is recognized as highly effective in theory and in practice and is firmly established as a routine safety measure for patients undergoing THA. A high-quality systematic review of SSI prevention in total joint replacement by Glenny and Song[2] was published in 1999 and was recently updated by AlBuhairan et al[10] to include another 26 studies. The pooled results showed a risk reduction of 81% (relative risk, 0.19; 95% CI, 0.12-0.31) with preoperative antibiotic administration compared with no antibiotic prophylaxis. These results also showed that the type of antibiotic agent used plays no role in reducing the incidence of SSIs.

Surveillance was not included by the 2008 NICE guideline but was recommended in all of the other guidelines. This is because surveillance and reporting of SSI after orthopedic surgery became mandatory in England in 2004.[11]

There has been much debate and controversy about antibiotic-impregnated cement. Although its use was recommended in the BOA guideline, it was not included in the non–orthopedic-specific guidelines. The expert interviews highlighted the level of controversy and differing opinions among experts in the field. The use of cement for prosthesis fixation is associated with a decreased risk of revision but with an increased risk of deep infection.[12] The use of antibiotic-impregnated cement has been reported to decrease this risk.[3] A recent systematic review and meta-analysis by Parvizi et al[13] investigated the efficacy of gentamicin-impregnated cement in primary THA. A significantly lower rate of deep SSI was reported with the use of antibiotic cement compared with standard bone cement (1.2% vs 2.3%). The cost-effectiveness of this prevention measure in the United States was evaluated by Cummins et al.[14] When the rate of revision due to infection was used as an outcome measure, the incremental cost-effectiveness ratio for antibiotic-impregnated cement was found to be $37,355 per quality-adjusted life-year gained. That study demonstrated that antibiotic-impregnated cement was cost-effective for a relatively young patient group (age <71 years) and low cost of cement (<$650). This finding raised doubts about the usefulness of this approach, given that most US patients undergoing THA are older than 71 years. The generalizability of these conclusions to other countries is highly dependent on how deep SSI is treated, the age of patients, and the cost of cement.

The use of ultraclean/laminar air operating rooms was mentioned and recommended in 2 of the 4 guidelines and classified as highly important by the experts. This measure is costly, however, and its cost-effectiveness is unclear. Although older studies by Charnley and Eftekhar in 1969[15] and Lidwell et al in 1982[16] deemed this technology effective for infection prevention in THA, they did not adjust for some key confounding factors, particularly the use of antibiotic prophylaxis. Increasing evidence indicates no effect or even an increase in infection rate with the use of ultraclean/laminar air operating rooms. The guidelines recommending this technology were published in 1999 and 2006, before most of the contradictory findings were published.

A large cohort study by Brandt et al[17] based on German surveillance data investigated the impact on SSI rates with the use of HEPA-filtered laminar airflow ventilation compared with conventional turbulent ventilation. That analysis included 63 departments in 55 hospitals and a range of procedures. The results for THA ($n = 28,623$ procedures) showed significantly increased rates of deep SSI when laminar airflow was used (OR, 1.63; 95% CI, 1.06-2.52). Recent surveillance data from New Zealand for 1999-2008 ($n = 64$ hospitals) also indicated a significantly increased risk of early deep SSI requiring revision when THA was performed in a laminar airflow theater (0.148%) compared with a conventional theater (0.061%).[18] Similarly, an American study based on data from 256 hospitals found an increased risk (OR, 1.57; 95% CI, 0.75-3.31) in the cumulative 90-day incidence of infection subsequently requiring further surgery when laminar air systems were used.[19] This increased risk was not statistically significant, however, possibly owing to the small number of deep SSIs. Data from the Norwegian Arthroplasty Register evaluating outcomes of 22,170 THAs showed no significant difference between the use of laminar air and conventional operating theaters.[20] To date, no systematic review has been able to pool clinical effect sizes of this technology, given the heterogeneity of definitions and outcome measures.[21]

Study limitations

A limitation of this study is the relatively small sample of experts, who may or may not represent the opinion of the majority

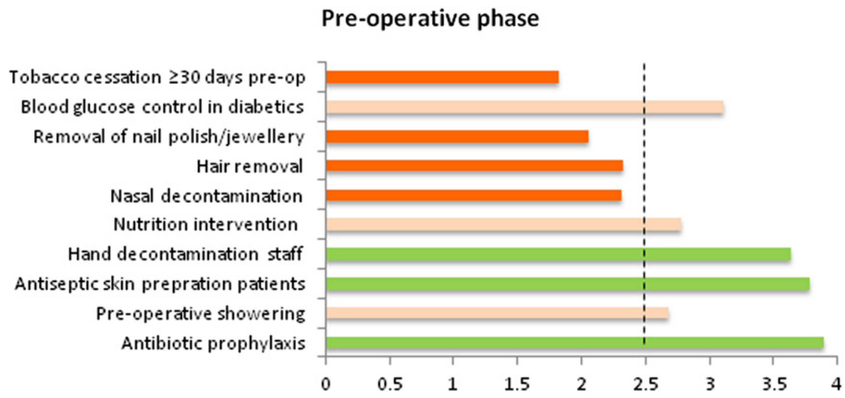

Fig 1. Experts' average response scores for the preoperative phase. The vertical line indicates the cutoff point for strategies rated as "critically or significantly important" by experts. Green denotes that the majority (≥75%) of experts classified the strategy as critically or significantly important; orange denotes that less than a majority of experts classified the strategy as critically or significantly important; and red denotes strategies of low importance.

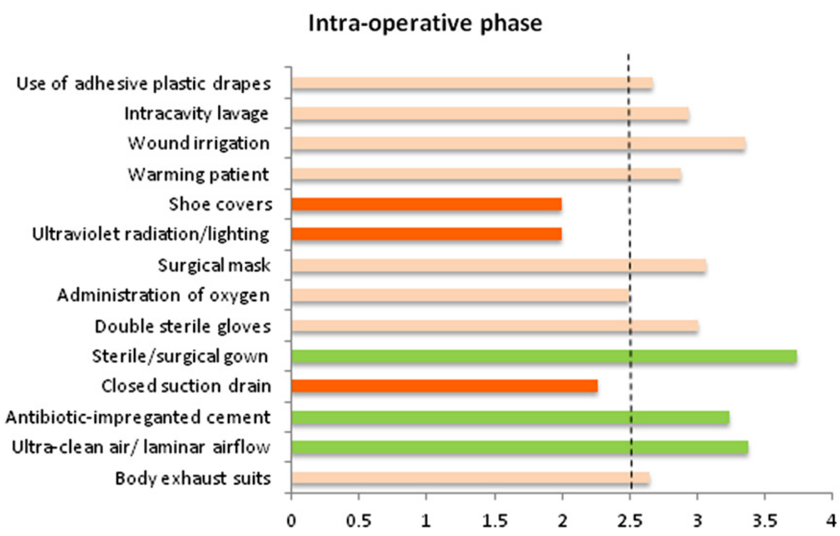

Fig 2. Experts' average response scores for the intraoperative phase. The vertical line indicates the cutoff point for strategies rated as "critically or significantly important" by experts. Green denotes that the majority (≥75%) of experts classified the strategy as critically or significantly important; orange denotes that less than a majority of experts classified the strategy as critically or significantly important; and red denotes strategies of low importance.

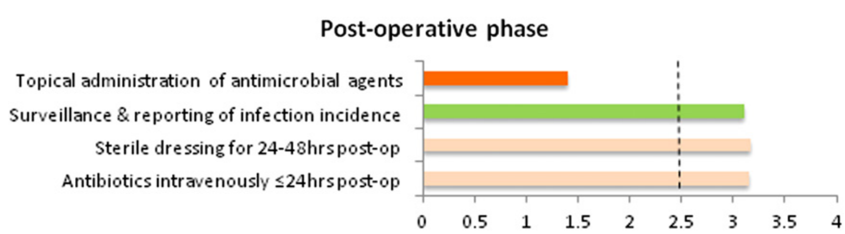

Fig 3. Experts' average response scores for the postoperative phase. The vertical line indicates the cutoff point for strategies rated as "critically or significantly important" by experts. Green denotes that the majority (≥75%) of experts classified the strategy as critically or significantly important; orange denotes that less than the majority of experts classified the strategy as critically or significantly important; and red denotes strategies of low importance.

of experts in the field. Despite the fact that a definition of strategies was given if required, the overall level of importance of orthopedic-specific measures might have been biased by a lack of in-depth knowledge by experts from other areas.

Snowball sampling was used for the survey because it has several advantages, in particular the potential to locate experts quickly and at low cost. One problem with this technique is doubts about the representativeness of the results, given that the participants are connected through a network and whether their opinions represent those of this group only or of all experts from selected areas. We tried to limit this concern by starting several "snowballs," that is, sending the initial survey to several experts from different disciplines and countries to access different pools of expertise. How many experts received the survey and refused to participate is unknown. Selection bias in the survey might have been an issue, and the reliability and validity of the results might be

Table 2
Overview of currently most relevant infection prevention strategies for THA

Preoperative
• Antibiotic prophylaxis
• Antiseptic skin preparation of patient
• Hand/forearm antisepsis by surgical staff
Intraoperative
• Sterile gowns/surgical attire
• Ultraclean/laminar air operating room
• Antibiotic-impregnated cement
Postoperative
• Surveillance

compromised. Nevertheless, given that the purpose of this study was to generate a hypothesis rather than to generalize results, a small sample of experts seemed sufficient to raise awareness of controversial strategies and emphasize agreement on the importance of other strategies. The cutoff of 75% of experts rating a strategy as significantly/highly important is somewhat arbitrary, but seems appropriate for representing the majority opinion.

Benefits of this work

Although guidelines are useful for determining the effectiveness for infection prevention measures, they can quickly become out of date if they fail to reflect the latest research evidence, as in the case of laminar air operating rooms. They also may fail to reflect the actual preferences of health care professionals. We have identified relevant strategies by assessing both guidelines and the preferences of health care professionals. The elicitation of expert opinion was crucial in determining not only the most relevant, but also the most controversial, strategies. We have shown that expert opinion varies, which confirms the lack of gold standard in SSI prevention after THA.

The results of this study provide a platform for cost-effectiveness modeling studies to inform decisions on SSI prevention after THA. The relative costs and health benefits of existing and controversial infection prevention strategies can be estimated and the results used to inform decision making. Analytic decision models are ideal tools to guide future decision making because they are designed to synthesize current evidence, such as the effectiveness of relevant SSI prevention measures in orthopedics, and incorporate information on costs and health outcomes (eg, mortality, morbidity).

References

1. Whitehouse JD, Friedman ND, Kirkland KB, Richardson WJ, Sexton DJ. The impact of surgical-site infections following orthopedic surgery at a community hospital and a university hospital: adverse quality of life, excess length of stay, and extra cost. Infect Control Hosp Epidemiol 2002;23:183-9.
2. Glenny A, Song F. Antimicrobial prophylaxis in total hip replacement: a systematic review. Health Technol Assess 1999;3:1-57.
3. Block JE, Stubbs HA. Reducing the risk of deep wound infection in primary joint arthroplasty with antibiotic bone cement. Orthopedics 2005;28:1334-45.
4. Parker MJ, Livingstone V, Clifton R, McKee A. Closed suction surgical wound drainage after orthopaedic surgery. Cochrane Database Syst Rev 2007;3: CD001825.
5. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR. Hospital Infection Control Practices Advisory Committee. Guideline for prevention of surgical site infection, 1999. Infect Control Hosp Epidemiol 1999;20:250-78.
6. British Orthopaedic Association. Primary total hip replacement: a guide to good practice. London: British Orthopaedic Association; 2006.
7. Welsh A, editor. Surgical site infection: prevention and treatment of surgical site infection. London: National Institute for Health and Clinical Excellence, National Collaborating Centre for Women's and Children's Health; 2008.
8. National Health and Medical Research Council (NHMRC). Australian guidelines for the prevention and control of infection in healthcare. Commonwealth of Australia; 2010.
9. Bowling A. Sample size and sampling for quantitative research. In: Bowling A, editor. Research methods in health: investigating health and health services. 3rd ed. Berkshire [UK]: Open University Press; 2009. p. 183-212.
10. AlBuhairan B, Hind D, Hutchinson A. Antibiotic prophylaxis for wound infections in total joint arthroplasty: a systematic review. J Bone Joint Surg Br 2008; 90B:915-9.
11. Wilson J, Charlett A, Leong G, McDougall C, Duckworth G. Rates of surgical site infection after hip replacement as a hospital performance indicator: analysis of data from the English mandatory surveillance system. Infect Control Hosp Epidemiol 2008;29:219-26.
12. Australian Orthopaedic Association. National Joint Replacement Registry: annual report. Adelaide [Australia]: Australian Orthopaedic Association; 2010.
13. Parvizi J, Saleh KJ, Ragland PS, Pour AE, Mont MA. Efficacy of antibiotic-impregnated cement in total hip replacement. Acta Orthop 2008;79:335-41.
14. Cummins JS, Tomek IM, Kantor SR, Furnes O, Engesaeter LB, Finlayson SR. Cost-effectiveness of antibiotic-impregnated bone cement used in primary total hip arthroplasty. J Bone Joint Surg Am 2009;91:634-41.
15. Charnley J, Eftekhar N. Postoperative infection in total prosthetic replacement arthroplasty of the hip joint, with special reference to the bacterial content of the air of the operating room. Br J Surg 1969;56:641-9.
16. Lidwell OM, Lowbury EJ, Whyte W, Blowers R, Stanley SJ, Lowe D. Effect of ultraclean air in operating rooms on deep sepsis in the joint after total hip or knee replacement: a randomised study. BMJ (Clin Res Ed) 1982;285:10-4.
17. Brandt C, Hott U, Sohr D, Daschner F, Gastmeier P, Ruden H. Operating room ventilation with laminar airflow shows no protective effect on the surgical site infection rate in orthopedic and abdominal surgery. Ann Surg 2008;248:695-700.
18. Hooper GJ, Rothwell AG, Frampton C, Wyatt MC. Does the use of laminar flow and space suits reduce early deep infection after total hip and knee replacement?: the ten-year results of the New Zealand Joint Registry. J Bone Joint Surg Br 2011;93:85-90.
19. Miner AL, Losina E, Katz JN, Fossel AH, Platt R. Deep infection after total knee replacement: impact of laminar airflow systems and body exhaust suits in the modern operating room. Infect Control Hosp Epidemiol 2007;28:222-6.
20. Engesaeter LB, Lie SA, Espehaug B, Furnes O, Vollset SE, Havelin LI. Antibiotic prophylaxis in total hip arthroplasty: effects of antibiotic prophylaxis systemically and in bone cement on the revision rate of 22,170 primary hip replacements followed 0-14 years in the Norwegian Arthroplasty Register. Acta Orthop Scand 2003;74:644-51.
21. Whitehead S, Bending M, Trueman P, Saxby R, Duffy S. Cost-effectiveness of hospital design: options to improve patient safety and well being. York [UK]: Health Economics Consortium; 2008.