Does the Use of Ultrasound Affect Contamination of Musculoskeletal Injections Sites?

Thomas Sherman MD, Joseph Ferguson MD,
William Davis MD, Matthew Russo MD,
Evan Argintar MD

Received: 24 April 2014 / Accepted: 14 August 2014 / Published online: 28 August 2014
© The Association of Bone and Joint Surgeons® 2014

Abstract

Background Therapeutic musculoskeletal injections require a clean or sterile skin preparation to minimize the risk of infections. Ultrasound guidance for this procedure requires the use of transmission gel in proximity to the injection site, and its effect on maintaining sterility is unknown.

Questions/purposes We asked: (1) Does sterile ultrasound transmission gel increase skin contamination during therapeutic orthopaedic injections? (2) Does nonsterile gel application result in increased contamination? (3) Does a

manufacturer-approved ultrasound probe disinfecting agent in the form of 17.2% isopropanol and 0.28% diisobutyl-phenoxethoxyethyl dimethyl benzyl ammonium chloride wipes adequately decontaminate the ultrasound transducer? (4) Does 70% isopropyl alcohol effectively decontaminate skin for administration of musculoskeletal injections?

Methods Twenty-six healthy volunteers in an outpatient orthopaedic clinical setting were recruited. The subjects' skin was prepared to simulate a therapeutic intraarticular shoulder injection under ultrasound guidance. Four skin swabs for culture from each subject were taken: one sample before preparation with isopropyl alcohol, one sample after skin preparation, one after simulated injection procedure with sterile ultrasound transmission gel using the transducer, and one after mock procedure with nonsterile ultrasound transmission gel. In addition, samples were taken from the nonsterile ultrasound transmission gel and the transducer for culture analysis. Aerobic and anaerobic cultures were incubated during a 5-day period for bacterial species identification.

Results Sterile ultrasound gel use results in an increase in skin contamination (odds ratio [OR], 9; 95% CI, 1.4–57.1; $p = 0.005$). Compared with sterile gel use, application of nonsterile gel did not increase contamination proportion (OR, 1.1; 95% CI, 0.8–1.7; $p = 0.56$). All cultures from nonsterile gel were negative. None of the samples cultured directly from the ultrasound probe were positive for bacteria (0%). Skin preparation with 70% alcohol decreased the proportion of contamination when compared with unprepared skin (OR, 21.0; 95% CI, 3.1–142.2; $p = 0.001$).

Conclusions Use of ultrasound probes and transmission gel results in greater contamination in simulated intraarticular injections of the shoulder. As such, sterile preparation of the entire injection field, including the

Each author certifies that he or she, or a member of his or her immediate family, has no funding or commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research*® editors and board members are on file with the publication and can be viewed on request.

Clinical Orthopaedics and Related Research® neither advocates nor endorses the use of any treatment, drug, or device. Readers are encouraged to always seek additional information, including FDA-approval status, of any drug or device prior to clinical use.

Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

This work was performed at MedStar Georgetown Orthopaedic Institute, Washington Hospital Center, Washington, DC, USA.

T. Sherman (✉), J. Ferguson, W. Davis, M. Russo
MedStar Georgetown Orthopaedic Institute, Georgetown
University Hospital, 3800 Reservoir Road, PHC Floor 1,
Washington, DC 20007, USA
e-mail: Thomas.i.Sherman@gmail.com

E. Argintar
MedStar Georgetown Orthopaedic Institute, Washington
Hospital Center, Washington, DC, USA

adjacent skin where the gel and probe are applied, may be prudent. Future studies are needed to determine if such a preparation decreases contamination and thereby infection rates related to musculoskeletal injections.

Level of Evidence Level II, therapeutic study. See the Instructions for Authors for a complete description of levels of evidence.

Introduction

Localized injectable corticosteroid is commonly used for treatment of several orthopaedic disorders, most commonly in the knee and shoulder. Steroids have shown clinical effectiveness and typically are prescribed in the ambulatory clinic setting, thus making them an attractive, facile treatment option for the practitioner and patient [3, 22]. Although injecting corticosteroids has proven largely safe, its risks are not negligible [3, 4]. A catastrophic complication of this treatment is infection by inoculation with a contaminated needle from the overlying skin [16, 23, 26]. Postinjection infections may manifest acutely or as indolent processes mistaken for more common shoulder disorders, such as rotator cuff tears and glenohumeral arthritis, which may result in delay of appropriate treatment [16, 23, 26].

In the United States, there are an estimated 27,000 practicing orthopaedic surgeons and 5000 rheumatologists, and more than 200,000 general practitioners of whom some also perform musculoskeletal injections [1, 2, 9]. It is not uncommon for many of these practitioners to perform several hundred injections per year [6]. Therefore, considering the frequency of musculoskeletal injections in the context of an estimated incidence of postinjection infection of 4.6 per 100,000 injections, the effect of this complication should not be underestimated [12, 21].

Paramount to prevention of this complication is preparation of the skin at the injection site with an antiseptic or cleaning agent. Furthermore, the sterility of the site must be maintained, which may prove challenging when using ultrasound guidance that requires ultrasound equipment and transmission gel in proximity to the injection site. It is unknown whether this practice may increase the risk of postinjection musculoskeletal infections and if additional precautionary steps are required to reduce this risk. Because clinical studies regarding infection risk associated with musculoskeletal injections would require an impractically large cohort, surface contamination may provide a suitable surrogate to guide improvement of precautionary methods against infection and direct future studies on this topic.

We therefore sought to answer the following questions: (1) Does sterile ultrasound transmission gel increase skin contamination during therapeutic orthopaedic injections?

(2) Does nonsterile gel application result in increased contamination? (3) Does a manufacturer-approved ultrasound probe disinfecting agent in the form of 17.2% isopropanol and 0.28% diisobutylphenoxyethoxyethyl dimethyl benzyl ammonium chloride wipes adequately decontaminate the ultrasound transducer? (4) Does 70% isopropyl alcohol effectively decontaminate skin for administration of musculoskeletal injections?

Patients and Methods

Participants/Study Subjects

A single cohort of volunteers from the outpatient office of the senior author (EA) was recruited to participate in this study during a 2-week period. All participants were between 32 and 66 years old and were eligible to participate as long as the primary complaint was not current musculoskeletal infection. A total of 28 individuals were asked to participate and all met inclusion criteria; 26 of 28 individuals agreed and consented to participate. Our institutional review board approved this study.

Description of Experiment, Treatment, or Surgery

All subjects were prepared for a mock therapeutic injection under ultrasound guidance of their shoulder using the senior author's (EA) typical procedural protocol. This consisted of preparing the injection site approximately 6 cm in diameter with one 70% isopropyl alcohol swab and applying sterile ultrasound transmission gel superior to the injection site where the probe, which has been disinfected, is to be used. The surgeon then thoroughly washes his or her hands and applies sterile gloves. One hand is used to operate the probe while the other is kept sterile for preparation and injection of the agent with the help of an assistant. No actual injections were performed for the purpose of this study. Four skin swabs from each participant's skin at the mock injection sites were cultured. All swabs were taken using one polyurethane sponge swab (BBL™ CultureSwab EZ™; Becton, Dickinson and Company, Sparks, MD, USA). The same ultrasound transducer (HFL50x; FUJIFILM SonoSite Inc, Bothell, WA, USA) was used for each participant and was disinfected between subjects within 5 minutes of use with a manufacturer's-approved agent consisting of 17.2% isopropanol and 0.28% diisobutylphenoxyethoxyethyl dimethyl benzyl ammonium chloride wipes (CaviWipes™; Metrex® Research, Romulus, MI, USA).

First, a skin swab was taken at the mock injection site, which was the posterolateral aspect of the shoulder. Next,

the injection site was prepared using a prepackaged, disposable 70% isopropyl alcohol swab (Kendall WEBCOL™; Covidien, Mansfield, MA, USA) using a circular motion of 5 cm in diameter and repeated. The second culture was swabbed after skin preparation. Then, sterile ultrasound transmission gel (Sterile Aquasonic 100® Ultrasound Transmission Gel; Parker Laboratories Inc, Fairfield, NJ, USA) was applied over the posteroinferior aspect of the acromion and the transducer was placed on the subject and transmission gel smeared in the region of the mock injection site. The third skin swab was taken after this sterile gel application and mock injection.

Then, leaving the sterile gel in place, nonsterile transmission gel (Aquasonic 100® Ultrasound Transmission Gel; Parker Laboratories Inc) was applied over the same region and introduced to the mock injection site using the transducer. To best simulate typical clinical use, previously used 0.25-L bottles of nonsterile ultrasound transmission gel, stored in the senior author's (EA) office for this clinical purpose, were used. The fourth culture was taken after nonsterile gel use. All samples were obtained by two of the authors (TS, JF) using sterile gloves that were applied immediately after handwashing.

Ten sample swabs of the nonsterile ultrasound transmission gel from the same bottles also were processed for bacterial culture. Additionally, 10 samples for culture of the transducer were taken 3 minutes after disinfection with the 17.2% isopropanol and 0.28% diisobutylphenoxyethoxyethyl dimethyl benzyl ammonium chloride wipes, as this is the typical time between disinfection and patient use and best simulates clinical practice.

All samples were processed by our institution's microbiology department, which was blinded to the nature of the samples. All samples underwent a typical 5-day incubation period for anaerobic and aerobic culture. Antibiotic sensitivity profiling was not performed.

Statistical Analysis and Study Size

The frequency of positive cultures at each stage of the mock procedure was determined, and the rate of conversion of culture status among the four stages was evaluated. The culture status at each stage was assumed to be a steady state, and McNemar's test was used to calculate the *p* values using individual patients as their own matched pair. A *p* value less than 0.0125 was required to achieve a level of significance of 0.05 because four comparisons were performed (ie, $0.05/4 = 0.0125$). Odds ratios (OR) were derived from the Mantel-Haenszel estimate for stratified categorical data between the culture specimens at each stage.

Table 1. Frequency of culture conversion between stages of preparation

Culture swab	Positive to negative culture (N = 26)	Negative to positive culture (N = 26)	<i>p</i> value
First to second	20 (77%)	0 (0%)	< 0.001*
Second to third	0 (0%)	8 (31%)	0.005*
Second to fourth	0 (0%)	7 (27%)	0.008*
Third to fourth	2 (8%)	1 (4%)	0.56

* Statistically significant.

Table 2. Frequency of positive cultures by stage of preparation

Culture swab of positive cultures (N = 26)	Number of positive cultures (N = 26)
First (prepreparation)	21 (81%)
Second (preparation)	1 (4%)
Third (sterile gel)	9 (35%)
Fourth (nonsterile gel)	8 (31%)

Results

After alcohol preparation, sterile ultrasound gel use results in an increase in skin contamination (OR, 9.0; 95% CI, 1.4–57.1; *p* = 0.005), where eight of 26 patients (31%) (Table 1) had negative cultures turn positive (Table 2) and the culture for the one patient with the positive culture remained positive.

With previous sterile gel use and contamination caused by a mock injection procedure, use of nonsterile gel did not increase the contamination proportion as compared with risk associated with sterile gel application (OR, 1.1; 95% CI, 0.75–1.7; *p* = 0.56). Cultures from one of 26 patients (4%) converted from negative to positive, and cultures from two of 26 (8%) patients converted from positive to negative. The latter may represent false-negative cultures. The other positive cultures at this stage were for the same patients who had positive cultures after application of sterile gel. As a secondary finding, all cultures of the nonsterile gel did not yield any bacterial growth.

Decontamination with 17.2% isopropanol and 0.28% diisobutylphenoxyethoxyethyl dimethyl benzyl ammonium chloride wipes was adequate. None of the samples cultured directly from the ultrasound transmission gel was positive for bacteria (0%).

Skin preparation with 70% alcohol decreased the proportion of contamination (OR, 21; 95% CI, 3.1–142.2; *p* = 0.001). Twenty of 26 patients (77%) who initially had positive cultures showed no contamination after alcohol preparation; cultures

Table 3. Culture results for subjects at each stage or preparation

Before preparation	After preparation	After sterile gel contamination	After nonsterile gel contamination
<i>Micrococcus</i> species <i>Staphylococcus aureus</i>	No growth	<i>Micrococcus</i> species <i>S aureus</i>	No growth
<i>Staphylococcus epidermidis</i>	No growth	No growth	No growth
<i>S epidermidis</i>	No growth	No growth	No growth
Skin flora*	No growth	No growth	No growth
Skin flora*	<i>S epidermidis</i>	<i>S epidermidis</i>	Skin flora*
<i>S epidermidis</i>	No growth	No growth	No growth
Skin flora*	No growth	No growth	No growth
<i>S epidermidis</i>	No growth	<i>S epidermidis</i>	<i>S epidermidis</i>
<i>S epidermidis</i>	No growth	No growth	No growth
Skin flora*	No growth	<i>Bacillus</i> species	<i>S epidermidis</i>
Skin flora*	No growth	<i>Corynebacterium</i>	No growth
		<i>S epidermidis</i>	
<i>S epidermidis</i>	No growth	No growth	No growth
No growth	No growth	No growth	No growth
No growth	No growth	No growth	No growth
Skin flora*	No growth	Skin flora*	Skin flora*
Skin flora*	No growth	Skin flora*	Skin flora*
No growth	No growth	No growth	No growth
No growth	No growth	No growth	No growth
<i>S epidermidis</i>	No growth	No growth	<i>S epidermidis</i>
<i>S epidermidis</i>	No growth	No growth	No growth
<i>S epidermidis Streptococcus pneumoniae</i>	No growth	<i>S epidermidis</i>	<i>S epidermidis</i>
		<i>S pneumoniae</i>	<i>S pneumoniae</i>
<i>S epidermidis</i>	No growth	<i>S epidermidis</i>	<i>S epidermidis</i>
No growth	No growth	No growth	No growth
<i>S epidermidis</i>	No growth	No growth	No growth
<i>S epidermidis</i>	No growth	No growth	No growth
<i>S epidermidis</i>	No growth	No growth	No growth

* Skin flora is defined by our institution as those containing two or more of the following bacterial types: diphtheroids, coagulase-negative *staphylococcus*, non- β -hemolytic *Streptococcus*, *Propionibacterium*, and *Acinetobacter* that are part of the normal skin microbiome.

from five of 26 (19%) patients who initially had negative cultures remained negative. Cultures from one patient of 26 (4%) remained positive after preparation (Table 3).

Discussion

Despite the popularity of therapeutic musculoskeletal injections, there is a paucity of data to support any one technique that best maximizes the therapeutic effect while mitigating potential complications; arguably iatrogenic infection from direct inoculation is the most catastrophic [3, 22]. The effect of ultrasound transmission gel on injection-site sterility and musculoskeletal infections is unknown. Clinical studies to investigate such an effect would require an inordinately large cohort, and therefore we elected to use surface contamination as a surrogate of this. Our intent is to use the results of our investigation to

guide clinical practices for prevention of musculoskeletal injection site contamination regarding skin preparation, ultrasound transmission gel use, and ultrasound instrumentation decontamination. Additionally, we hope that these results will provide direction for future studies on this topic.

Our findings should be considered in the context of our protocol that required the use of sterile gloves during specimen collection. This is important to consider as the individual performing the injection is a potential source of bacterial contamination, and among practitioners there is marked inconsistency in precautions against contamination [6]. The reason for this variability is unknown but is likely attributable to training, resources, perceived risk, and experience. There is also wide variability in the perceived risk of postinjection joint sepsis among practitioners [3, 6]. In a survey distributed to providers who performed intra-articular injections, 5.4% perceived this risk as negligible,

36.5% believed infection rates were one or fewer per 1000 injections, 39.2% reported a perceived rate of one or fewer per 100, and none perceived the risk as five or greater per 100 injections. Of those surveyed, 12.6%, reported having seen patients with a septic joint after intraarticular injection [6]. In a separate survey of 853 orthopaedists, 50% reported a perceived infection risk of one per 1000, and those who performed injections recalled 68 cases of post-injection infection [10]. The expanding use of ultrasound for injection guidance provide another variable for potential contamination [27].

This study had several limitations. First, our results are applicable only to shoulders because this was the only body part we studied; however, it is feasible that similar results would be found for other body regions because we think the ultrasound transmission gel or ultrasound probe can serve as a vector to transport bacteria from one area of skin to another. Second, our incubation period was only 5 days, and additional time may be required to cultivate certain pathogens that are particularly relevant to shoulder infections, such as *Propionibacterium acnes* [24]. Third, the effect of nonsterile gel on contamination was not assessed independent of sterile gel. That is, nonsterile gel was applied after and in the presence of sterile gel, at which point nine of 26 (35%) patients' injection sites already showed contamination. Because of this limitation, it is impossible to determine whether there is a difference in contamination rates between use of sterile and nonsterile gels. Fourth, there was no comparison group. Comparison with other preparation protocols with varying areas of preparation would have been valuable for determining the optimal technique.

We found that sterile ultrasound gel is associated with skin contamination. The origin of the contaminating bacteria is unknown; however, potential sources include the gel, bacteria transported by the gel from the adjacent unprepared skin, or the probe. Because, there were no positive cultures from the probe and the manufacturer sterilely processes the gel, it is most likely the bacteria present in the adjacent skin are transported to the injection site by the ultrasound transmission gel. Although these gels possess parabens and methyl benzoate that inhibit bacterial growth, they do not kill bacteria and potentially can be a medium for bacterial proliferation [18–19]. Additionally, certain bacterial species may possess an intrinsic ability to degrade parabens, rendering them nonfunctional [13]. This is an important consideration as use of ultrasound guidance requires transmission gel in close proximity, if not over, the injection site [8].

Nonsterile gel was not associated with more contamination compared with sterile gel. Although a direct comparison between sterile and nonsterile gels is lacking because of the imitations already discussed, we believe this

finding merits discussion. Because bacteria were not cultivated from the nonsterile gel bottle, it may be assumed that any additional positive cultures from the patients would be attributable to contamination of bacteria from adjacent skin introduced by the gel and not the actual nonsterile gel. To our knowledge, there are no reports of musculoskeletal infection attributable to contaminated ultrasound transmission gel; however, there are several reports of gel serving as a source for nosocomial infection [7, 19, 20, 29]. Although there are reported cases in which the manufacturer contaminated the gel, the majority are believed to have occurred through cross-contamination from inappropriate use patterns [7, 19, 20, 29]. Recognizing this, the FDA has made recommendations for safe use of ultrasound gel [28]. This includes using only sterile ultrasound gel for invasive procedures.

When cleansed according to the manufacturer's instructions, decontamination of the transducer using 17.2% isopropanol and 0.28% diisobutylphenoxyethoxyethyl dimethyl benzyl ammonium chloride wipes was adequate. Several studies have investigated contamination and cleanliness of ultrasound probes in various clinical settings and found that bacterial colonization was common [11, 14, 18, 25]. These authors recommended several different cleaning techniques, of which wiping the probe with a nonsterile towel alone or in combination with alcohol wipes were most frequently suggested [11, 18]. Other recommendations included more thorough cleansing when using the probe in the inguinal or axillary body regions or on individuals at high risk for infection [11]. Mirza et al. [17] compared cleaning techniques of ultrasound probes with a sterilized paper towel, 0.9% normal saline, or soap and water bath. They reported that the soap cleaning technique was most effective at decreasing bacterial counts. Our practice is to wipe residual gel with a nonsterile clean paper cloth between uses and with 17.2% isopropanol and 0.28% diisobutylphenoxyethoxyethyl dimethyl benzyl ammonium chloride wipes several minutes before using the probe. We find this to be a time-efficient practice with the added antimicrobial benefit of the wipes.

We found 70% isopropyl alcohol was an effective skin decontaminant. Isopropyl alcohol swabs are the most common injection site preparatory agents used for the purposes of in-office intraarticular injections [6]. Cawley and Morris investigated colonization of needles used for intraarticular injections immediately after withdrawal from the joint using either isopropyl alcohol or chlorhexadine preparations of the overlying skin [5]. They did not find a statistically significant difference in colonization between the two techniques; however this may be attributable to the small sample size. Although there is paucity of data regarding infection risk and colonization related to

Fig. 1 With our recommended protocol, sterile towels are used to drape the procedure site. The entire skin area is cleaned with isopropyl alcohol followed by an iodine- or chlorhexidine-based preparation. Ultrasound transmission gel then is applied. The operator wears sterile gloves.

musculoskeletal injections, recommendations of preparatory agents for surgical procedures can be extrapolated for this purpose. Saltzman et al. [24] reported that combination chlorhexadine and alcohol-based preparations were superior to combinations of iodine and alcohol-based preparations at decreasing overall bacterial colonization in patients undergoing shoulder surgery. This trend also was consistent specifically to species of staphylococcus but not *P. acnes* [24]. A systematic review and meta-analysis showed that fewer surgical site infections and greater cost-effectiveness were associated with use of chlorhexadine-based solutions as opposed to iodine-based solutions [15]. Therefore, although 70% isopropyl alcohol was effective in our model as a skin decontaminant, one may consider using chlorhexadine given its superior properties in the surgical setting. However, future investigations are required to determine the optimal preparatory agent specifically for outpatient musculoskeletal injections, particularly in the shoulder region, where *P. acnes* is clinically relevant to joint infection. A study similar to that of Cawley and Morris with the intent of evaluating the colonization of *P. acnes* may be particularly useful in this regard.

Although therapeutic injections generally are safe and effective, iatrogenic bacterial seeding is possible. We showed that the use of ultrasound transmission gel results in contamination of musculoskeletal injection sites likely from adjacent areas of skin that were not effectively decontaminated. These findings suggest that practitioners should consider preparing the skin adjacent to the injection site where gel will be applied and the probe used. The senior author (EA) has changed his protocol to reflect this (Fig. 1). Although we cannot draw definitive conclusions regarding differences in contamination between use of

sterile or nonsterile gel based on these results, the recommendations of the FDA suggest that exclusive use of sterile ultrasound gel is advisable. Comparing bacterial colonization of injection sites after use of various preparation protocols in combination with ultrasound gel may offer additional insight into determining the optimal protocol to prevent skin contamination in conjunction with ultrasound-guided musculoskeletal injections.

Acknowledgments We thank Nick Sever AB, of the Milken Institute School of Public Health at The George Washington University, and Sameer Desale MS, of the Biostatistics and Bioinformatics Department of MedStar Health Research Institute.

References

1. Agency for Healthcare Research and Quality. The number of practicing primary care physicians in the United States: primary care workforce facts and stats no. 1. Available at: <http://www.ahrq.gov/research/findings/factsheets/primary/pcwork1/index.html>. Accessed: August 3, 2014.
2. American Academy of Orthopaedic Surgeons Department of Research and Scientific Affairs. Orthopaedic Practice in the U.S. 2012. Available at: <http://www.aaos.org/research/stats/Surgeonstats.asp>. Accessed August 3, 2014.
3. Baima J, Isaac Z. Clean versus sterile technique for common joint injections: a review from the physiatry perspective. *Curr Rev Musculoskelet Med*. 2008;1:88–91.
4. Bellamy N, Campbell J, Robinson V, Gee T, Bourne R, Wells G. Intraarticular corticosteroid for treatment of osteoarthritis of the knee. *Cochrane Database Syst Rev*. 2006;CD005328.
5. Cawley PJ, Morris IM. A study to compare the efficacy of two methods of skin preparation prior to joint injection. *Br J Rheumatol*. 1992;31:847–848.
6. Charalambous CP, Tryfonidis M, Sadiq S, Hirst P, Paul A. Septic arthritis following intra-articular steroid injection of the knee: a survey of current practice regarding antiseptic technique used during intra-articular steroid injection of the knee. *Clin Rheumatol*. 2003;22:386–390.
7. Chittick P, Russo V, Sims M, Robinson-Dunn B, Oleszkowicz S, Sawarynski K, Powell K, Makin J, Darnell E, Boura JA, Boyanton B, Band J. An outbreak of *Pseudomonas aeruginosa* respiratory tract infections associated with intrinsically contaminated ultrasound transmission gel. *Infect Control Hosp Epidemiol*. 2013;34:850–853.
8. Daley EL, Bajaj S, Bisson LJ, Cole BJ. Improving injection accuracy of the elbow, knee, and shoulder: does injection site and imaging make a difference? A systematic review. *Am J Sports Med*. 2011;39:656–662.
9. Deal CL, Hooker R, Harrington T, Birnbaum N, Hogan P, Bouchery E, Klein-Gitelman M, Barr W. The United States rheumatology workforce: supply and demand, 2005–2025. *Arthritis Rheum*. 2007;56:722–729.
10. Farooq MA, Devitt AT. Perceived efficacy and risks of infection following intra-articular injections: a survey of orthopaedic surgeons. *Ir J Med Sci*. 2005;174:26–32.
11. Fowler C, McCracken D. US probes: risk of cross infection and ways to reduce it: comparison of cleaning methods. *Radiology*. 1999;213:299–300.
12. Gray RG, Tenenbaum J, Gottlieb NL. Local corticosteroid injection treatment in rheumatic disorders. *Semin Arthritis Rheum*. 1981;10:231–254.

13. Hutchinson J, Runge W, Mulvey M, Norris G, Yetman M, Valkova N, Villemur R, Lepine F. Burkholderia cepacia infections associated with intrinsically contaminated ultrasound gel: the role of microbial degradation of parabens. *Infect Control Hosp Epidemiol.* 2004;25:291–296.
14. Karadeniz YM, Kilic D, Kara Altan S, Altinok D, Guney S. Evaluation of the role of ultrasound machines as a source of nosocomial and cross-infection. *Invest Radiol.* 2001;36:554–558.
15. Lee I, Agarwal RK, Lee BY, Fishman NO, Umscheid CA. Systematic review and cost analysis comparing use of chlorhexidine with use of iodine for preoperative skin antisepsis to prevent surgical site infection. *Infect Control Hosp Epidemiol.* 2010;31:1219–1229.
16. Leslie BM, Harris JM 3rd, Driscoll D. Septic arthritis of the shoulder in adults. *J Bone Joint Surg Am.* 1989;71:1516–1522.
17. Mirza WA, Imam SH, Kharal MS, Aslam M, Ali SA, Masroor I, Ahmad MN. Cleaning methods for ultrasound probes. *J Coll Physicians Surg Pak.* 2008;18:286–289.
18. Muradali D, Gold WL, Phillips A, Wilson S. Can ultrasound probes and coupling gel be a source of nosocomial infection in patients undergoing sonography? An in vivo and in vitro study. *AJR Am J Roentgenol.* 1995;164:1521–1524.
19. Oleszkowicz SC, Chittick P, Russo V, Keller P, Sims M, Band J. Infections associated with use of ultrasound transmission gel: proposed guidelines to minimize risk. *Infect Control Hosp Epidemiol.* 2012;33:1235–1237.
20. Olshtain-Pops K, Block C, Temper V, Hidalgo-Grass C, Gross I, Moses AE, Gofrit ON, Benenson S. An outbreak of achromobacter xylosoxidans associated with ultrasound gel used during transrectal ultrasound guided prostate biopsy. *J Urol.* 2011;185:144–147.
21. Pal B, Morris J. Perceived risks of joint infection following intra-articular corticosteroid injections: a survey of rheumatologists. *Clin Rheumatol.* 1999;18:264–265.
22. Petrella RJ, Petrella M. A prospective, randomized, double-blind, placebo controlled study to evaluate the efficacy of intraarticular hyaluronic acid for osteoarthritis of the knee. *J Rheumatol.* 2006;33:951–956.
23. Rhee YG, Cho NS, Kim BH, Ha JH. Injection-induced pyogenic arthritis of the shoulder joint. *J Shoulder Elbow Surg.* 2008;17:63–67.
24. Saltzman MD, Nuber GW, Gryzlo SM, Marecek GS, Koh JL. Efficacy of surgical preparation solutions in shoulder surgery. *J Bone Joint Surg Am.* 2009;91:1949–1953.
25. Sanz GE, Theoret J, Liao MM, Erickson C, Kendall JL. Bacterial contamination and cleanliness of emergency department ultrasound probes. *CJEM.* 2011;13:384–389.
26. Schneeberger AG, Yian E, Steens W. Injection-induced low-grade infection of the shoulder joint: preliminary results. *Arch Orthop Trauma Surg.* 2012;132:1387–1392.
27. Sharpe RE, Nazarian LN, Parker L, Rao VM, Levin DC. Dramatically increased musculoskeletal ultrasound utilization from 2000 to 2009, especially by podiatrists in private offices. *J Am Coll Radiol.* 2012;9:141–146.
28. U.S. Food and Drug Administration. Update on bacteria found in ortho-sonic generic ultrasound transmission gel poses risk of infection: FDA Safety Communication. Available at: <http://www.fda.gov/medicaldevices/safety/alertsandnotices/ucm299409.htm>. Accessed August 3, 2014.
29. Weist K, Wendt C, Petersen LR, Versmold H, Ruden H. An outbreak of pyoderma among neonates caused by ultrasound gel contaminated with methicillin-susceptible Staphylococcus aureus. *Infect Control Hosp Epidemiol.* 2000;21:761–764.