The Importance and Implications of Aseptic Techniques During Regional Anesthesia

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Infectious complications may occur with any regional anesthetic technique. However, those associated with neuraxial anesthesia and analgesia are of greatest concern because of their potentially devastating sequelae including meningitis, paralysis, and even death. Fortunately, the frequency of such complications appears to be relatively low. Aromaa et al.[1] reported 8 cases of bacterial infection to the spine or central nervous system (CNS) after 170,000 epidural and 550,000 spinal anesthetics, for an overall frequency of 1.1 per 100,000 blocks. However, these results are contrasted in a more recent survey by Wang and colleagues,[2] who estimated the incidence of epidural abscess after epidural analgesia to be 1 in 1,930 and the risk of persistent neurologic deficit to be 1 in 4,343 catheters. This enormous discrepancy and apparent increase in the number of reported complications may be explained by several factors. These include data-collection techniques, varying definitions of "infection" and/or "colonization," improved postoperative monitoring and reporting, an overall increase in the total number of epidurals being performed, or a true increase in infection rates.[3] Differences in aseptic technique(s) may also account for reported differences. For example, the use of protective barriers (masks, gloves, and gowns), preprocedural handwashing, bacterial filters, and the type and concentration of skin disinfectant varies tremendously among investigations. Variables that often differ among investigations, and therefore make interstudy comparisons difficult, are listed in Table 1.[4]

The frequency of infection associated with peripheral nerve block remains even more undefined. Sporadic cases of localized infection and/or bacteremia have been reported after both single-injection[5] and continuous peripheral techniques.[6-11] Nseir and colleagues[5] have reported the only fatality associated with a peripheral technique and attributed specifically to an infectious etiology. A case of streptococcal necrotizing fasciitis was described after a single-injection axillary block in an elderly patient undergoing carpal tunnel decompression. However, clinicians must remain cognizant that as peripheral techniques continue to be used with greater frequency, infectious complications will undoubtedly become more common within the literature.

Sources of Injection

The etiology of infectious complications is often unclear. Potential sources may be classified as either intrinsic or extrinsic. Intrinsic sources are generally related to the underlying health of the patient and include such conditions as trauma, intravenous drug abuse, malignancy, diabetes mellitus, pregnancy, and other immune-depressed states. In a review of 39 patients with spinal and epidural infection, Baker and colleagues[12] identified several intrinsic sources of infection, with hematogenous spread from remote sites of infection accounting for over 25% of cases. *Staphylococcus aureus* was most commonly isolated (21/39 patients, 54%), followed by species of streptococci, *Escherichia coli*, and *Pseudomonas aeruginosa*. In contrast to these findings, Darchy et al.[13] concluded that infectious foci distant to an epidural catheter site do not increase the likelihood of subsequent epidural infections. They investigated 75 patients who received care in the intensive care unit who were given epidural analgesia for more than 48 hours. Four (19%) of 21 patients with a remote infectious foci experienced a subsequent catheter-related infectious complication versus 5 of 54 (9%) patients with no remote-site

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Table 1. Interstudy Variables That May Influence Infectious Complications

Definition of "colonization" and/or "infection" (Range: 1-1,000 cfus per mL)
Site of catheter placement
Neuraxial: thoracic vs. lumbar vs. caudal
Peripheral: interscalene vs. axillary vs. femoral vs. popliteal
Choice of antiseptic and technique of application
Choice of barrier protection (masks, gloves, gowns)
Timing and selection of perioperative antibiotics
Duration of catheter use in situ
Use of bacterial filters
Dressing type(s): transparent vs. dry gauze dressing; use of antiseptic dressings
Technique of catheter removal and subsequent culture methods

infection ($P = .60$). Furthermore, of the 4 patients with epidural catheter-related infections, the microorganism isolated from the epidural catheter site was not the same as that isolated from the distant infectious foci. Although these findings did not achieve statistical significance, the small sample size of the investigation makes definitive conclusions difficult. Because of the limited evidence available, additional investigations are necessary to better define the relationship between remote infectious foci and concomitant catheter-related infections.

Extrinsic sources of infection include invasion of skin bacteria through a needle tract,[14-18] contaminated syringes,[19] catheter hubs,[20] local anesthetics,[21] or breaches in aseptic technique.[21-24] The migration of skin bacteria through needle puncture sites is considered to be a major source of epidural colonization.[14] Several investigations have shown that organisms persist on the skin surface after preparation with a variety of antiseptic solutions.[4,25-29] The detection of these organisms lends support to the possibility that the needle may "push" pathogens into the epidural space during catheter placement.[30] However, the most frequently detected microorganism on the skin surface is *Staphylococcus epidermidis* (65%-69% of skin flora), whereas *S aureus* (1%-2% of skin flora) is the most prevalent microorganism in epidural infections.[27] This discrepancy suggests that *S aureus* may be more resistant to disinfectants than other organisms or that the bactericidal effect of some disinfectants may not be rapid enough to prevent inoculation of *S aureus* into the epidural space.

Finally, Sato and colleagues[14] have also shown that resident bacteria are hidden deep in hair follicles and orifices of sebaceous glands, locations that are often protected from disinfectants by lipids overlying the stratum corneum. Therefore, despite meticulous attention to skin disinfection, microorganisms may still persist under the skin when using antiseptics that are unable to penetrate the stratum corneum.[14] For this reason, antiseptic solutions with an alcohol base capable of penetrating the stratum corneum are generally recommended to more effectively eradicate deeply hidden microorganisms.

Aseptic Technique

The investigations described earlier repeatedly stress the importance of "strict aseptic technique" before epidural catheterization or other regional techniques. However, the concept of what is "essential" for asepsis remains controversial. Sellors et al.[31] surveyed obstetric anesthetists in Australia to determine what practitioners believe to be "essential" aseptic precautions when inserting an epidural catheter for labor analgesia. Surprisingly, there was a wide variation in what was considered to be "essential" (Table 2). These findings likely reflect the paucity of scientific evidence currently available to support, or refute, the efficacy of these aseptic precautions. The following discussion will examine the role of 4 components of aseptic technique: (1) hand washing, artificial nails, and the removal of jewelry; (2) the use of gloves and sterile gowns; (3) surgical mask utilization, and (4) the use of bacterial filters.

Table 2. Survey of "Essential Components" Necessary for Proper Aseptic Technique

Essential Aseptic Technique	Yes (% of Respondents)	No (% of Respondents)
Jewelry removed		
Rings	55	44
Watch/bracelet	86	14
Protective barriers		
Surgical scrubs	17	83
Mask	71	29
Surgical cap	26	73
Gown	87	12
Sterile gloves	99	1
Hand washing		
None	2	—
Soap and water	7	—
Antiseptic hand wash	48	—
Full surgical scrub	42	—
Other	1	—
Skin preparation		
Iodine	41	—
Chlorhexidine	19	—
Chlorhexidine + alcohol	13	—
Alcohol	14	—
No preference	5	—
Other	5	—
Surgical drape		
Full	62	—
Partial	32	—
None	2	—
Not specified	4	—
Other		
Not talking	16	—

Hand Washing

The hands of health care providers are the most common vehicle by which microorganisms are transmitted between patients.[32,33] As a result, hand washing is considered to be one of the most important techniques in the prevention of cross-infection.[32-35] Soap and water alone moves bacteria but is not effective at killing organisms. However, several respondents (7%) in the survey believe this is more than adequate before performing a regional technique. In contrast, full surgical scrub was believed necessary by 42% of respondents, with 48% suggesting that this should be performed with an antiseptic solution. Antiseptic solutions with an alcohol component or alcoholic solutions alone provide superior disinfection when compared with nonalcoholic antiseptics (povidone iodine, 4% chlorhexidine, hexachlorophene, and triclosan) or standard nonantimicrobial soaps.[33] For example, a 1-minute hand rub with 60% isopropanol by volunteers who then put on surgical gloves has an immediate bacterial reduction lasting 3 hours, which is significantly greater than that resulting from the use of nonalcoholic antiseptics.[36] Alcohols are rapidly germicidal when applied to the skin but have very little persistent activity. However, when combined with other antiseptic compounds, bacterial regrowth occurs at a significantly slower rate. Extended antimicrobial activity appears to be greatest for alcohol-based solutions containing 2% or 4% chlorhexidine gluconate, followed by hexachlorophene, triclosan, and the iodophors.[33] Because hexachlorophene is absorbed into the blood after repeated use, it is seldom used as a surgical scrub. Of note, antiseptic solutions containing 60% to 95% alcohol appear to be most effective, with higher concentrations being less potent because protein denaturization requires the presence of water.

Despite these encouraging findings, there have been no randomized, controlled trials that have examined the influence of hand washing on reducing surgical-site infections or infections related to regional anesthesia. Furthermore, no prospective clinical trials have been conducted that indicate a reduction in surgical-site infections when preoperative scrubbing is performed by the surgeon with an antiseptic agent rather than a nonantimicrobial soap. However, several factors suggest that a preoperative scrub with an alcohol-based antiseptic solution is still warranted. These include (1) bacteria on the hands of surgeons can cause wound infections if introduced into the operative field during surgery, (2) rapid multiplication of bacteria occurs under surgical gloves if hands are washed with a nonantimicrobial soap, (3) bacterial growth is slowed after preoperative scrubbing with an antiseptic agent, (4) reducing skin flora on the hands of the surgical team for the duration of a procedure reduces the risk of bacteria being released into the surgical field if gloves become punctured or torn during surgery, and (5) an increase in surgical-site infections have been reported when surgeons switched from an antiseptic surgical scrub preparation to a nonantimicrobial solution.[33] Clearly, these surgical recommendations are difficult to extrapolate to the performance of a regional anesthetic technique, where patient exposure times are significantly shorter and the degree of invasiveness much less. However, in an effort to maximally reduce the risk of clinical infections and cross-contamination from patient to patient, adherence to these recommendations may be warranted before performing a regional anesthetic technique.

Fingernails and artificial nails. Currently, it is unclear whether or not the use of artificial nails or the length of natural fingernails contributes to an increased risk of hospital-related infections. Health care workers with artificial nails are more likely to harbor gram-negative pathogens on their hands and fingertips both before and after hand washing when compared with health care workers with natural fingernails alone.[37,38] Studies have shown that the subungual region of the hand harbors high concentrations of bacteria, primarily coagulase-negative staphylococcus, gram-negative rods, *Corynebacteria*, and yeast.[39,40] At present, nail length does not appear to be a significant risk factor for either infectious complications or cross-contamination because the majority of bacterial growth occurs along the proximal 1 mm of nail adjacent to the subungual skin. The application of nail polish to artificial or natural-borne fingernails does not increase the number of bacteria recovered from the periungual region. However, chipped or poorly maintained nail polish may increase the number of transient microorganisms present.[41]

Jewelry. The majority of respondents in the survey by Sellors et al[31] (86%) indicated that removing wristwatches was essential, a view held by many infection-control experts.[42] However, there was less agreement on the removal of rings, an issue that nearly divided the respondents equally.[31] Higher microbial counts after hand washing have been found in health care workers who prefer not to remove rings.[43] Bernthal[44] suggested that this practice may place patients at higher risk for nosocomial infections. Finally, it is important to emphasize that proper hand washing should occur not only before regional techniques or other interventional procedures but throughout the patient's entire perioperative experience.[45,46]

Gloves and Gowns

Although gloves may be considered a useful and important component of asepsis, they should only be regarded as a supplement to, not replacement for, hand washing.[47] For example, Olsen and colleagues[48] report possible microbial contamination of hands and transmission of infection despite gloves being worn. In this prospective investigation, quantitative hand cultures were obtained from 137 health care workers before and after contaminated patient care procedures (endotracheal tube care, digital rectal examinations, and routine dental examinations). All health care workers wore single-use, nonsterile disposable latex or vinyl gloves. External glove surfaces were also quantitatively cultured after each patient contact. Used gloves were then tested for leaks by using the American Society for Testing Materials' watertight test. Eighty-six (64%) of the 135 glove cultures had gram-negative rods or enterococci on the external surface after use and were therefore sources of potential hand contamination. Microbial contamination of the health care workers' hands occurred in 11 (13%) of these 86 events and was more frequent with vinyl (24%) versus latex gloves (2%, $P < .01$). After use, glove leaks were also found to be more frequent among vinyl gloves (43%) when compared with latex gloves (9%, $P < .001$). Although appropriate glove use prevented hand contamination in the vast majority of cases, 23% of hands were found to be contaminated after patient care when a glove leak occurred.[48] The authors concluded that latex gloves, and to a lesser extent vinyl gloves, provide substantial protection to health care workers during hand contact with contaminated mucosal membranes. However, nonsterile gloves cannot reliably provide an impenetrable barrier between patient and health care provider and must therefore always be considered potential extrinsic infectious foci. At present, no investigation has examined the risk of microbial contamination or glove leaking with sterile surgical latex or neoprene gloves. Single-use sterile or disposable gloves should never be washed, resterilized, or disinfected, with new gloves being worn during each patient encounter.[47]

Gowns are generally considered a means of preventing cross-contamination between patients by preventing infectious material from coming into contact with the clothes of health care providers. Recent investigations have shown that the use of gowns did not reduce patient colonization, infection, or mortality rates in neonatal intensive care units.[49,50] Furthermore, the universal use of gloves and gowns was found to be no better than the use of gloves alone in preventing colonization of vancomycin-resistant enterococci in medical intensive care units.[51] However, there is currently insufficient data to make definitive recommendations with regard to routine gown use within the operating room environment during regional block.

Surgical Masks

The issue of wearing surgical masks during regional techniques has also received a tremendous amount of attention and controversy.[52-57] Several clinicians contend that surgical masks are a critical component of asepsis,[58,59] whereas others argue their use is not based on definitive scientific evidence.[60] A British survey reports that 51% of practitioners do not routinely wear masks when performing central neuraxial block.[61] This practice is supported by the work of Schweizer,[62] who showed that surgical masks may significantly increase the amount of wound contamination. It is postulated that under these conditions, skin friction with the mask may release skin scales that carry a significant amount of bacterial contaminants. These findings were also confirmed by Orr,[63] who reported a 50% decrease in wound infections when surgical face masks were not worn during procedures. However, this investigation is often criticized for its lack of controls. Tunevall[64] subsequently performed a prospective, randomized investigation to examine whether or not face masks significantly increase the amount of bacterial "fall-out" into the surgical wounds of 3,088 patients undergoing a variety of general surgical procedures. Postoperative infections were identified in 73 of 1,537 (4.7%) patients in which face masks were used and in 55 of 1,551 (3.5%) patients in which no surgical face masks were worn (not significant [NS]), showing no added benefit of wearing masks during surgery. As a result, Tunevall suggested that the routine use of face masks be reconsidered if the intent is to protect the patient. However, he goes on to recommend that surgical masks may be worn if the intent is to protect operating room personnel against blood droplets or airborne infections originating from patient encounters.[64]

In contrast to the investigations noted earlier, Philips and colleagues[65] showed that wearing a face mask results in a marked reduction in the bacterial contamination of a surface in close proximity to the upper airway. Bacterial colonies grew on more than 50% of agar plates placed 30 cm away from providers who were speaking without a mask. A fresh mask nearly abolished contamination, whereas a small increase did occur after 15 minutes of wear. Although this increase was statistically insignifi-

cant, the authors recommend that it may be advisable to wear a new face mask for each procedure or patient encounter. It should be kept in mind that organisms grown in the upper airway are of low pathogenicity and virulence. Therefore, the likelihood of causing a wound infection in a patient with an intact immune system is extremely small.[65,66]

Additional case reports and prospective investigations have since confirmed the work of Philips et al.[21,23,55,56] In particular, Schneeberger and colleagues[23] reported a cluster of 4 patients who developed streptococcal meningitis after spinal anesthesia that was performed by the same anesthesiologist who was under treatment for recurrent tonsillitis, did not wear a mask, and often spoke during the procedure. Similarly, North and Brophy[21] described an epidural abscess that was proven to be caused by a strain of *Staphylococcus* cultured from the nose of the anesthesiologist who placed the epidural catheter. Despite these limited case series and anecdotal case reports, definitive evidence that wearing a face mask causes fewer postoperative wound infections is still lacking.[67] However, it does appear that face masks may be critically important in protecting patients from clinicians with sore throats,[68] those suffering from recurrent tonsillitis,[23,64] or those who are chronic nasal carriers of *S aureus*.[69]

Bacterial Filters and Catheter Disconnects

Catheter hub contamination with subsequent colonization of the catheter lumen and/or epidural space remains a concern of many providers. Du Pen et al.[15] and Hunt et al.[70] have described hub contamination as the cause of catheter colonization in 54% and 40% of patients, respectively. This finding suggests that bacterial filters should be a valuable tool for preventing epidural colonization.[19] In general, micropore filters are considered to serve 2 primary purposes: (1) to prevent foreign material from gaining access to the epidural space and (2) to filter bacteria present within the perfusing solution. However, several investigators have reported epidural abscesses despite the use of micropore filters.[15,71-73] There are several possible explanations for such observations: (1) the filter loses its antimicrobial efficacy after a prolonged period of time; (2) the catheter hub is directly contaminated during the filter-changing maneuvers, thereby bypassing the filter barrier; (3) bacteria traverses from the skin to the epidural space along the catheter tract; or (4) hematogenous spread occurs from a distant infectious foci.[73] DeCicco and colleagues[73] showed a significant correlation between the incidence of catheter hub colonization and the filter change frequency, particularly when the skin close to the filter-hub connection is contaminated. It is believed that the Luer-Lok connection of the filter, contaminated by skin flora, may trail microorganisms from the skin to the hub during the filter change. Therefore, it is recommended that filter changes occur less frequently than the traditional 1-week period during long-term epidural catheterization, particularly when some filters have been shown to maintain an intact antimicrobial function for up to 60 days.[73] During short-term epidural catheterization (<24 hours), the use of bacterial micropore filters is generally not recommended.[74]

Finally, the use of an epidural catheter for a prolonged period of time increases its risk of becoming disconnected at some point, particularly in a less intensely monitored setting (i.e., hospital ward). Therefore, the question often arises on the safety of reconnecting a disconnected catheter. Langevin and colleagues[75] inoculated epidural catheters in vitro containing a 5 μg/mL fentanyl solution with *S aureus*, *E coli*, or *P aeruginosa*. Eight hours after contamination, no bacteria were detected more than 20 cm from the contaminated catheter hub, provided the fluid within the catheter had remained static (i.e., no displacement of fluid toward the patient from the disconnected end). This determination can be made at the bedside. If these conditions are met (i.e., a recognized disconnect within 8 hours and a static fluid column), a segment of the catheter 10 inches from the disconnected end should be immersed in povidone iodine for 3 minutes and allowed to dry completely. The catheter should then be cut with a sterile instrument in the center of this area and reconnected with a sterile connector. However, when an unwitnessed disconnection has occurred, or when the distal meniscus appears to have migrated more than 5 inches from the disconnected end (i.e., a nonstatic fluid state), the authors recommend that the catheter be removed as soon as possible.[75] Unfortunately, the authors did not evaluate bacterial migration in the presence of local anesthetic solutions nor did they investigate the effect of local anesthetic injection after bacterial inoculation.

Summary

In summary, tremendous controversy exists as to what comprises the "essential" components of strict aseptic technique. There appears to be significant differences based on geographic locale, with Europe, Australia, and North America all reporting variations in clinical practice. However, those components commonly cited to minimize the risk of wound contamination and subsequent colonization are summarized in Table 3. Although supportive scientific evidence may be lacking for some of these components, it is generally well accepted that at-

Table 3. Important Components of Aseptic Technique

Major
Removal of watches and jewelry
Preprocedural hand washing with antiseptic solution
Protective barriers
Surgical hat and mask
Sterile gloves
Appropriate selection and application of skin disinfectant
Proper sterile draping technique(s)
Maintenance of a sterile field
Appropriate dressing techniques
Minor
Proper use of bacterial filters during long-term catheterization
Prevention of catheter, hub, and site violations

tempts to reduce the risk of extrinsic infectious etiologies may nevertheless be prudent because of the high morbidity and mortality associated with systemic or central neuraxial infection.

Antiseptic Solutions for Regional Anesthesia

Controversy still exists regarding the most appropriate and safe antiseptic solution to use before regional blockade. Essential characteristics of an ideal disinfectant include (1) effectiveness against a wide array of microorganisms, (2) immediate onset of efficacy, (3) long-term effect, (4) lack of inactivation by organic material (blood, pus, and body fluids), and (5) minimal toxic effects to the skin. Some of the more commonly used solutions include povidone iodine (i.e., Betadine; Purdue Pharma, Stamford, CT), chlorhexidine gluconate (i.e., Hibiclens; Regent Medical, Norcross, GA) with or without isopropyl alcohol, an iodophor preparation in isopropyl alcohol (i.e., Duraprep; 3M Healthcare, St. Paul, MN), and isopropyl alcohol alone. Of these, povidone iodine and chlorhexidine gluconate have received the most attention within the literature.

Chlorhexidine Gluconate

Chlorhexidine gluconate is a potent broad-spectrum germicide that is effective against nearly all nosocomial yeasts and bacteria (gram-positive and gram-negative).[26,76,77] The compound efficiently alters cell wall permeability, immediately precipitating components of the cell membrane and cytoplasm.[29] The addition of isopropyl alcohol further accelerates these bactericidal effects. A distinct advantage of chlorhexidine is its ability to adhere to the stratum corneum, thus extending its duration of action several hours beyond its initial application. In general, it induces fewer and less severe skin reactions than other compounds and remains effective in the presence of organic compounds such as blood or other proteinaceous material. Finally, bacterial resistance to chlorhexidine is extremely rare.[4] Chlorhexidine solutions are currently Food and Drug Administration (FDA) approved for, "the preparation of the patient's skin prior to surgery."[78] It has not received specific FDA approval for use before regional anesthesia (spinal, epidural, and peripheral block) because of a lack of clinical testing. At present, the Material Safety Data Sheet registered with the FDA does not describe adverse neurologic or central nervous system events after recommended chlorhexidine use.

Povidone Iodine

Povidone iodine is a germicidal compound that has good activity against most gram-negative and gram-positive microorganisms. Its bactericidal effect relies on the continuous release of iodine, which penetrates cell walls and alters or discontinues protein synthesis.[29] This mechanism of action, unlike that of chlorhexidine, requires several minutes to achieve maximal effect. The addition of isopropyl alcohol further increases the release of iodine. A distinct disadvantage of povidone iodine is its limited duration of effect, often requiring reapplication every 24 hours to maintain antimicrobial activity. Furthermore, its effect may be inhibited or neutralized by organic compounds such as blood or other proteinaceous material.[79] Finally, acute skin reactions may occur after application, resulting in focal erythema, urticaria, or weeping vesicular lesions. Bacterial resistance may also occur with povidone iodine, particularly with various strains of *S aureus*.[27] Povidone iodine is currently FDA approved for, "preparation of the skin prior to surgery to help reduce bacteria that can potentially cause skin infection."[78] It has not received specific FDA approval for use before regional anesthesia (spinal, epidural, and peripheral block) because of a lack of clinical testing. At present, the Material Safety Data Sheet registered with the FDA does not describe adverse neurologic or central nervous system events after recommended povidone iodine use.

Several investigations have compared the antiseptic effects of chlorhexidine and povidone iodine under a variety of experimental conditions.[4,14,25-29,77,80,81] In all but 1 investigation,[25] chlorhexidine resulted in a more rapid and superior bactericidal effect that extended several hours beyond its initial application. Sakuragi and colleagues[27] performed a comprehensive evaluation of these 2 compounds on 4 strains of methicillin-resistant and 2 strains of methicillin-susceptible *S aureus*, the pathogen most commonly associated with epidural space infections. All 6 strains grew colonies after 60 seconds of exposure

to 10% povidone iodine, and 5 of 6 strains grew colonies after the same exposure to 0.5% chlorhexidine gluconate (without ethanol). A limited number of strains even grew colonies after 4 minutes of exposure to both of these disinfectants. In contrast, no bacteria grew after exposure to 0.5% chlorhexidine in 80% ethanol after 15 seconds of exposure. The chlorhexidine-alcohol solution clearly had superior bactericidal activity and a more rapid onset of action (secondary to the alcohol component) when compared with all other disinfectants. Therefore, for continuous epidural block, the authors suggest that 0.5% chlorhexidine in 80% ethanol may be the most effective in maintaining an aseptic state on the skin surface for a prolonged period of time and therefore reducing the overall risk of catheter colonization.

Kinirions et al.[4] also compared epidural colonization rates using 0.5% chlorhexidine in alcohol or an aqueous solution of 10% povidone iodine. Epidural colonization was defined as the growth of ≥1,000 colony-forming units (cfu)/mL as recommended by the Centers for Disease Control and Prevention for intravascular devices.[82] Chlorhexidine in alcohol was superior to povidone iodine in nearly all culture samples (Table 4). Catheters inserted after skin preparation with chlorhexidine were one sixth as likely and less quickly colonized when compared with catheters inserted after skin preparation with povidone iodine. These results are in accordance with those of Sato and colleagues,[14] who previously showed the superior bactericidal effects of chlorhexidine.

Limited information is currently available on the neurotoxic risk associated with chlorhexidine use.[83-85] Henschen and Olson[83] showed a significant dose-dependent degeneration of adrenergic nerves when chlorhexidine buffered in a sodium-acetate solution or in 70% isopropyl alcohol was injected into the anterior chamber of the eye in albino rats. Severe degenerative changes occurred with higher doses within 2-days of administration, with only 40% showing signs of regeneration at 7 weeks. The authors concluded that the thin, unmyelinated nerves of the central nervous system may be equally affected. However, in the absence of clinical or extended animal investigations examining the neurotoxic potential of chlorhexidine, the FDA has chosen not to formally approve its use for skin antisepsis before lumbar puncture.

Methods of Antiseptic Application

The optimal method of antiseptic application has also been reported within the literature.[86,87] Moen and colleagues[86] examined the efficacy of povidone-iodine spray application (5% aerosol Betadine spray) versus a traditional 5-minute aqueous iodophor soap (10%) scrub and subsequent paint technique. No scrub was performed on patients receiving a spray application. Blood agar plates were applied directly to the skin after 1 and 3 minutes of drying on the spray side and immediately after completing the traditional scrub-paint technique. The mean number of colonies present after antiseptic application was 1.83 ± 3.16 cfu for the 1-minute spray technique (96.72% reduction from baseline), 0.40 ± 1.15 cfu for the 3-minute spray technique (99.53% reduction from baseline), and 0.87 ± 2.97 cfu for the traditional scrub-paint technique (98.89% reduction from baseline). Both the 3-minute spray ($P < .001$) and 5-minute scrub-paint ($P = .003$) technique were statistically more effective than the 1-minute spray at reducing bacterial counts. Potential advantages of spray techniques include minimizing trauma to the skin surface, shorter application times, and a reduced cost when compared with current methods. However, the ability of spray techniques to reduce and/or prevent wound infections remains to be seen.

In a more recent investigation, Robins and colleagues[87] examined the efficacy, convenience, and cost of chlorhexidine application using a multiuse spray preparation (0.5% chlorhexidine in an alcoholic solution) versus single-use swabs (aqueous chlorhexidine 0.05%) in patients scheduled for elective cesarean section under a combined spinal and epidural regional technique. Aseptic precautions, including surgical handwashing, face mask, sterile gown, and gloves were used in all patients.

Table 4. Positive Bacteriologic Cultures*

Culture Site	0.5% Chlorhexidine	10% Povidone Iodine	*P*
Epidural catheters yielding any microorganisms (n = 20)	5 (4.3 per 100 catheter days)	15 (16.7 per 100 catheter days)	<.001
Colonized epidural catheters (>1,000 cfu, n = 6)	1 (0.9 per 100 catheter days)	5 (5.6 per 100 catheter days)	.02
Positive insertion site cultures	12 (23%)	20 (45%)	.03
Positive catheter hub cultures	4 (8%)	1 (2%)	.40

*No deep infections (abscess, meningitis) occurred in any patient.

Swab skin cultures were taken immediately before antiseptic application (baseline) and on removal of the epidural catheter. Both methods were found to be effective skin preparations, significantly increasing the number of patients with negative cultures when compared with baseline. However, the number of postoperative cultures that showed a reduction in the number of bacterial colonies was not significantly different between groups. Time to achieve skin preparation was significantly shorter with the spray technique (2.6 minutes) when compared with the single-use swabs (4.5 minutes, $P = .002$). In addition, a total of 10 multiuse spray bottle nozzles were collected and cultured during the study period. No growth was reported on any of the nozzles, despite the bottles having a median lifespan of 5.1 months. This is in contrast to multiuse povidone iodine bottles, which have been shown to become contaminated after repeated use.[88]

Antiseptic Dressings

The elimination of skin flora with an appropriate antiseptic solution is considered a critical step in the prevention of infectious complications. However, solutions applied to the skin undergo drug decay, inactivation by tissue fluids, and loss from desquamation. As a result, previously suppressed microorganisms may now readily grow back and invade compromised skin sites within hours of the initial antiseptic application. In an effort to prevent the regeneration of microorganisms, investigators have examined the use of antiseptic-impregnated dressings to provide ongoing protection after neuraxial or peripheral nerve catheter placement.[89,90] Shapiro and colleagues[89] evaluated the efficacy of a chlorhexidine patch in preventing the expansion of skin microorganisms at the site of epidural catheter insertion among parturients scheduled for elective cesarean section. The dressing consisted of a urethane composite material to which chlorhexidine gluconate was chemically bound. The dressing was held in place by a clear urethane film with an acrylic adhesive.[89] Chlorhexidine dressings were well tolerated and did not cause any adverse skin reactions. They reduced microbial colony counts an average of 2 $\log^{10}$ compared with nonmedicated control dressings. Skin washes showed that the dressing was able to delivery a steady state of drug for up to 5 days after the initial application. Furthermore, only 1 (3.8%) of 26 epidural catheters that were covered by the medicated patch were colonized on removal (mean duration 3.6 days) versus 9 (29%) of 31 control catheters (mean duration 3.7 days) that were positively colonized ($P = .006$). Finally, chlorhexidine-impregnated dressings were found to absorb blood and other exudates from the catheter tracts, preventing the accumulation of potential growth substrates for microorganisms.[89]

Mann and colleagues[90] performed a similar investigation examining the efficacy of a donut-shaped chlorhexidine-impregnated foam disc (2.5-cm diameter). The small patch is placed circumferentially around a neuraxial or peripheral nerve catheter, creating a "medicated zone" of chlorhexidine that surrounds the catheter insertion site. This "zone" is designed to suppress the regeneration of skin microorganisms and therefore reduce the risk of bacterial migration and subsequent catheter colonization by extrinsic factors. Investigators cultured epidural exit sites at the time of catheter removal in women undergoing elective gynecologic surgery and postoperative epidural analgesia. They found that only 1 (3.45%) of 29 patients in whom the chlorhexidine patch was used had evidence of skin colonization. In contrast, 11 (42.3%) of 26 control patients showed evidence of microbial colonization ($P = .001$). Control catheters remained in situ a significantly shorter period of time when compared with those catheters surrounded by the chlorhexidine-patch (3.07 vs. 3.63 days, $P = .05$). Currently, there is no evidence to suggest that the skin culture results can be extrapolated to epidural catheters. Therefore, comment cannot be made with regard to the ability of the chlorhexidine-impregnated patch to reduce epidural catheter colonization. However, the authors conclude that minimizing all extrinsic factors, including the colonization of epidural insertion sites, remains critically important because of the high morbidity associated with an epidural abscess or other neuraxial infection.[90]

Guidelines for Prevention of Surgical Site Infections

The Centers for Disease Control and Prevention published an extensive Guideline for the Prevention of Surgical Site Infections (formerly called surgical wound infections) in 1999. The guidelines represent a consensus of the Hospital Infection Control Practices Advisory Committee regarding strategies for the prevention of surgical site infections. Although the recommendations are derived from well-designed, prospective investigations whenever possible, many of the infection control measures routinely used by surgical teams and mandated by federal agencies (Occupational Safety and Health Administration) cannot be rigorously studied because of ethical or logistical reasons (i.e., surgical glove use). Therefore, some of the recommendations are based upon strong theoretical rationale

Table 5. Centers for Disease Control Guidelines for the Prevention of Surgical Site Infections

Preoperative	
Use an appropriate antiseptic agent for skin preparation.	Category IB
Apply preoperative antiseptic skin preparation in concentric circles moving toward the periphery.	Category II
Keep nails short and do not wear artificial nails.	Category IB
Perform a preoperative surgical scrub for at least 2 to 5 minutes using an appropriate antiseptic. Scrub the hands and forearms up to the elbows.	Category IB
Dry hands with a sterile towel and don a sterile gown and gloves.	Category IB
Do not wear hand or arm jewelry.	Category II
Administer a prophylactic antimicrobial agent only when indicated. Select the agent based upon commonly identified pathogens for a specific surgery or procedure.	Category IA
Administer the initial dose of antibiotic by the intravenous route, and timed such that bactericidal concentrations are achieved in the serum and tissues at incision.	Category IA
Intraoperative	
Wear a surgical mask that fully covers the mouth and nose in the operating room if an operation is underway, or if sterile instruments are exposed.	Category IB*
Wear a cap or hood to fully cover hair when entering the operating room.	Category IB*
Do not wear shoe covers for the purpose of preventing surgical site infections.	Category IB*
Wear sterile gloves if a scrubbed surgical team member. Put on gloves after donning a sterile gown.	Category IB*
Use surgical gowns that are effective barriers when wet.	Category IB
Postoperative	
Protect a primarily-closed incision with a sterile dressing for 24 to 48 hours.	Category IB
Wash hands before and after dressing changes.	Category IB
When a dressing must be changed, use sterile technique.	Category II

NOTE. Category IA: strongly recommended for implementation and supported by well-designed experimental, clinical, or epidemiological studies; category IB: strongly recommended for implementation and supported by some experimental, clinical, or epidemiological studies and strong theoretical rationale; and category II: suggested for implementation and supported by suggestive clinical or epidemiological studies or theoretical rationale.

*Practices required by federal regulation.

and suggestive evidence in the absence of confirmatory scientific knowledge.[91] Specific perioperative aseptic guidelines for the prevention of surgical site infections are listed in Table 5.[91] The guidelines listed may be extrapolated to regional anesthesia use and are provided for comparative purposes only. The guidelines are not intended to address procedures performed outside the operating room (i.e., endoscopic procedures, pain injections, and bronchoscopy) or within remote procedural locations (interventional radiology and cardiac catheterization).[91]

Conclusion

In summary, although differences in catheter and skin colonization have been identified when comparing various antiseptic solutions, techniques of application, or dressing types, no definitive conclusions can be made with regard to the frequency and/or likelihood of reducing clinical infections (abscess, meningitis). Furthermore, many of the proposed guidelines and recommendations described later are derived from the medical or surgical literature and require extrapolation when applied to regional anesthesia. However, until the relationship between contamination, colonization, and clinical infection are better defined, most experts recommend that exhaustive efforts should be directed at minimizing both intrinsic and extrinsic sources of infection whenever performing a regional anesthetic technique.

Recommendations

These recommendations may be considered appropriate for all regional anesthetic techniques. However, many of the recommendations have been extrapolated from the medical or surgical literature. With the exception of antiseptic solutions, very few components of asepsis have been prospectively investigated in the context of regional anesthesia. In particular, studies examining the role of asepsis during peripheral nerve block are lacking.

The recommendations are intended to encourage quality patient care, although observing them cannot guarantee any specific patient outcome. Their value should ultimately be determined by those who use them. The recommendations are subject to revision from time to time, as warranted by the evolution of technology, scientific evidence, and clinical practice. Importantly, the recommendations address only the issue of aseptic technique and their application during regional anesthesia in the otherwise healthy patient.

The recommendation grading scheme is derived from the United States Agency for Health Care Policy and Research[92] and is outlined in Appendix 1. The recommendations are as follows:

1. Thorough hand washing greatly reduces the risk of cross-contamination and should occur before performing any regional anesthetic technique. Alcohol-based antiseptic

solutions will provide the maximal degree of antimicrobial activity with extended duration when compared with nonalcoholic antimicrobial or nonantimicrobial preparations (Grade A).

2. The duration and method of washing (standard hand washing vs. full surgical scrub) required to reduce infectious complications is currently unknown.
3. Higher microbial counts have been identified in health care workers who do not remove jewelry before hand washing. Therefore, it may be prudent to remove all jewelry items (rings, watches, and so on) before hand washing to reduce the risk of contamination (Grade B).
4. Sterile surgical gloves should be used and considered a supplement to, not replacement for, hand washing. The use of surgical gloves is advocated not only to protect patients from cross-contamination but also to protect health care workers from blood-borne pathogen exposure as required by the Occupational Safety and Health Administration (Grade A).
5. Several intensive care unit–based investigations have shown that the use of surgical gowns does not reduce patient colonization, infection, or mortality rates beyond that achieved with gloves alone. However, there is currently insufficient data to make recommendations with regard to routine use during regional techniques within the operating room environment.
6. The use of surgical masks during regional anesthesia will maximize sterile barrier precautions. In particular, surgical masks have been found to significantly reduce the likelihood of site contamination from microorganisms grown in the upper airway of clinicians. Although the routine use of masks have not been found to reduce infectious complications related to regional anesthesia, they do remain a vital protective measure against blood-borne pathogen exposure as recommended by the Occupational Safety and Health Administration (Grade B).
7. Currently, the literature does not support the routine use of bacterial filters with short-term (i.e., days) epidural or perineural catheter infusions (Grade B).
8. Alcohol-based chlorhexidine antiseptic solutions significantly reduce the likelihood of catheter and site colonization and maximize the rapidity and potency of bactericidal activity when compared to other solutions. Therefore, alcohol-based chlorhexidine solutions should be considered the antiseptic of choice before regional anesthetic techniques (Grade A).

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Appendix 1: Key to Evidence Statements and Grades of Recommendations

Statements of Evidence

Ia Evidence obtained from meta-analysis of randomized controlled trials.

Ib Evidence obtained from at least one randomized controlled trial.

IIa Evidence obtained from at least one well-designed controlled study without randomization.

IIb Evidence obtained from at least one other type of well-designed quasi-experimental study.

III Evidence obtained from well-designed nonexperimental descriptive studies, such as comparative studies, correlation studies, and case reports.

IV Evidence obtained from expert committee reports or opinions and/or clinical experiences of respected authorities.

Grades of Recommendations

A Requires at least one prospective, randomized, controlled trial as part of a body of literature of overall good quality and consistency addressing the specific recommendation. (Evidence Levels Ia and Ib).

B Requires the availability of well-conducted clinical studies, but no prospective, randomized clinical trials on the topic of recommendation. (Evidence Levels IIa, IIb, III).

C Requires evidence obtained from expert committee reports or opinions and/or clinical experiences of respected authorities. Indicates an absence of directly applicable clinical studies of good quality (Evidence Level IV).