Optimal Approaches to Skin Preparation Prior to Neurosurgery

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Abstract

Surgical site infections have always been and will likely remain a significant concern for physicians around the world. When almost 40% of nosocomial surgical infections are related to the incision site, appropriate preperation of the skin becomes a particular concern. Neurosurgery is no stranger to surgical site infection. Infections of this type in the neurosurgical patient can have serious, long-lasting consequences should infection spread deeper than skin level. In this article, the current recommendations for skin preparation at the start of surgery are reviewed, taking into account specific considerations that must be made for the neurosurgical patient. In addition, the use of adjunct methods, i.e. antibiotic-impregnated drapes, and the effects of clipping versus shaving hair at the operative site are discussed.

Infections have been and will likely always remain a significant concern for surgeons throughout the world. Surgical site infections (SSI) are a considerable burden for both patients and healthcare systems alike, often resulting in patient morbidity and mortality as well as significant costs to the healthcare organization. Healthcare costs associated with SSIs have been estimated to range from $10,000 to $25,000 per case.[1,2] In the US alone there are an estimated 1.7 million healthcare-associated infections per year, 22% of which are SSIs.[3,4]

SSIs are the most common nosocomial infection in the post-surgical patient, constituting 38% of such infections in surgical patients.[5] They accounted for a total of 8,205 deaths during 2002 in the US alone.[4] Data from the National Nosocomial Infections Surveillance System for 2002 showed that there were more than 270,000 SSIs, translating into approximately two infections per 100 surgical procedures.[4]

SSIs are caused by a variety of bacteria and yeasts. The etiology of a SSI is most commonly skin flora (including *Staphylococcus aureus* and coagulase-negative staphylocci), *Enterococcus* spp., *Escherichia coli*, *Pseudomonas aeruginosa*, and *Enterobacter* spp.[5] The prevalence of particular organisms varies with type of case and pre-existing patient diagnosis. For example, one study looking at SSIs in spinal patients found *S. aureus* to be the causative organism in 73% of deep infections.[6] In another series of patients (n=503), the bacterial pathogens isolated were *S. aureus* (71.0%), *Staphylococcus epidermidis* (12.9%), and *Acinetobacter baumannii* (16.1%).[7] Of significant concern to the surgeon is the growing incidence of antibiotic-resistant bacteria and their colonization of patients, which can result in particularly virulent SSIs, e.g. methicillin-resistant *S. aurus* and vancomycin-resistant *enterococcus*.

Neurosurgeons are no strangers to SSIs. In neurosurgery they are a serious hazard in view of their proximity to, or location within, the central nervous system. Complications for cranial surgeries include calvarial osteomyelitis, meningitis, and infections of the cerebral parenchyma.[8] Spinal surgeries list a different series of complications, including superficial skin infections, epidural abscesses, and the need for removal of in-dwelling devices/hardware. These complications often result in re-operation and longer hospital and rehabilitation stays.

There are likely many risk factors that predispose patients to SSIs in neurosurgery, and these factors may differ across cranial and spine subspecialties. In a study of 503 spinal surgery patients, there was an overall infection rate of 6.2%,[7] which was noted to be slightly higher than the <5% level of infectious complications considered acceptable for clean neurosurgical operations.[9,10] Risk for infection was found to

increase with patient age, operation type (e.g. shunts), presence of foreign bodies, diabetes, and intracranial pressure monitoring.[7]

In a case series of 1,747 patients from a Milan hospital, Valentini et al. identified that surgical duration of greater than two hours and the patient's age being in the 16–50 years range as being significant risk factors for infection.[11] A similar French case series involving 7,399 patients identified the type of operation, operation modality, timing (higher risks with postponed operations), and duration of surgery as significant risk factors predisposing to SSI. They also noted a slight increase in risk with cerebrospinal fluid shunts.[12]

Cronquist et al. noted that obesity may play a pivotal role in neurosurgical SSI (relative risk 2.5) during a study attempting to correlate presurgical bacterial colonization density with infection risk.[13] This case series also addressed the duration of surgery, noting an increase in risk with every additional 30 minutes and the patient's age as factors.

Several studies looking at spine surgery alone have identified diabetes and pre-existing trauma as important negative predictive variables.[6,14] Deep brain stimulation surgery has also been reported to have a 5.7% SSI (skin infection) rate, which was a major factor associated with prolonged hospital stays and the need for repeated surgery.[15]

In this article, the currently-available options for skin preparation prior to neurosurgery and their likely impact on reducing SSIs are explored.

Current Options for Pre-surgical Skin Preparation

A variety of antiseptic agents are available for preparing skin prior to surgery. Options include alcohol (ethyl alcohol 60–90% or isopropyl alcohol 50–91%), chlorhexidine (with or without alcohol), iodophors (with or without alcohol), and para-chloro-meta-xylenol and trichlosan (used in surgical scrubs). An overview of the current recommended practices and most frequently used skin preparations are presented in *Table 1* and detailed in the following sections.

It is important to remember that the performance of the currently available surgical antiseptics is variable. For example, aqueous iodophors (e.g. Betadine® skin cleanser) for scrubs/paint application have an immediate onset and last for approximately two hours.[16] Alcohol-iodophors (e.g. DuraPrep) have a similar rapid onset and last for significantly longer (48–96 hours).[17] Other important adjuncts to direct skin preparation include antibiotic-impregnated drapes, the use of pre-operative antibiotic therapy, and good sterile technique.

The use of antibiotic-impregnated drapes has increased in recent years. In early studies, such drapes were not shown to reduce infection, but decreased overall bacterial count (iodine-impregnated drape versus paint alone or versus paint with non-impregnated drape).[18] In one notable study, the effect of an iodophor-impregnated plastic adhesive drape (Ioban) applied to operation sites 24 hours prior to orthopedic surgery was analyzed. The contamination of deep surgical wounds with bacteria shown to be present on the skin prior to disinfection and surgery was investigated. Bacterial sampling of the wounds after surgery showed that without the drapes there was a 15% rate of deep wound infection, but this was reduced to 1.6% when the drapes had been applied.[19]

In addition, pre-operative antibiotic therapies and good sterile techniques have always been recognized in literature as helpful in reducing the risk for SSIs.[20,21]

Comparison between Iodine- and Clorhexidine-based Compounds

Both iodine-based and chlorhexidine-based preparations have specific properties that prevent infection. Aqueous-based iodophors, in particular povidone-iodine, allow for the release of free iodine when in a solution. Iodine is an elemental compound that works by destroying microbial proteins and DNA. These products are used widely because of their broad-spectrum antimicrobial action and their efficacy and safety on nearly all skin surfaces.

Alcohol is fast and short-acting. It also has broad-spectrum activity and is relatively inexpensive. Flammability can be an issue but can be avoided by allowing the skin to dry completely and avoiding the preparation of areas of the body with excessive body hair that can delay vaporization.

Alcohol-based solutions may have greater efficacy, easier application, improved durability, and a superior cost profile compared with traditional aqueous-based solutions.[22] Iodine povacrylex in isopropyl alcohol (DuraPrep) is one example of such a solution. It has the unique property of increased durability in the surgical and procedural environment because it enhances adhesion between the prepared skin surface and the surgical drapes. This is thought to limit the spread of organisms onto the surgical field.

In a 2009 prospective randomized trial, povidone-iodine and chlorhexidine were compared to study the efficacy of the reduction of bacterial colonization and subsequent surgical wound infection rates. Five hundred surgical patients were randomized to two separate groups, each receiving one of the two preparations. Bacterial colonization via cultures taken at the time of operation and resultant infection rates were utilized and the data analyzed. A significant reduction in the rates of bacterial colonization and subsequent infection in the chlorhexidine group compared with the povidone-iodine group was clearly demonstrated.[23] A similar study performed in a multihospital setting found comparable results. Pachareon et al. randomized 500 adults undergoing clean-contaminated surgery in six hospitals into two groups having their surgical sites prepared with either a chlorhexidine group (CHG)-alcohol solution or an iodophor-alcohol solution. The primary outcome was SSI within 30 days of surgery. The results demonstrated a significantly lower SSI rate in the CHG-alcohol group than in the povidone-iodine group.[24] It was also noted that the CHG-alcohol preparation was significantly more protective against superficial/deep skin infections, but not against organ-space infections. However, the results of more recent studies suggest the opposite effect. One notable but non-randomized, study was performed by Swenson et al. at a single center. Over 3,000 general surgery patients received three different skin preparations during three sequential six-month periods. These preparations included:

Table 1: Overview of the Current Most Frequently Used Skin Preparations Prior to Surgery

Antiseptic Agent	Mechanism of Action	Gram + Bacteria	Gram – Bacteria	Viruses	Rapidity of Action	Persistent/ Residual Activity	Use on Eye or Ear	Use on Mucous Membranes	Contra-indications	Cautions
Alcohol	Denatures proteins[36]	Excellent[36]	Excellent[36]	Good[36]	Excellent[35]	None[36]	No. Can cause corneal damage or nerve damage[36]	No	—	Flammable. Does not penetrate organic material. Optimum concentration is 60–90%[35]
Chlorhexidine gluconate	Disrupts cell membrane[36]	Excellent[36]	Good[36]	Good[36]	Moderate[36]	Excellent[36]	No. Can cause corneal damage. Can cause deafness if in contact with inner ear[36]	Use with caution[36]	Known hypersensitivity to drug or any other ingredient.[37] Lumbar puncture and use on meninges[37]	Prolonged skin contact may cause irritation in sensitive individuals. Rare severe hypersensitivity reactions have been reported.[37] Use with caution on mucous membranes
Povidone-iodine	Oxidation/ substitution with free iodine[36]	Excellent[36]	Good[36]	Good[36]	Moderate[36]	Minimal[36]	Yes. Moderate ocular irritant	Yes	Sensitivity to povidoneiodine (shellfish allergies are not a contraindication)[38]	Prolonged skin contact may cause irritation. May cause iodism in susceptible individuals; avoid use in neonates.[39,40] Inactivated by blood[41,42]
Chlorhexidine gluconate with alcohol	Disrupts cell membrane and denatures proteins[36,37]	Excellent	Excellent	Good	Excellent	Excellent	No. Can cause corneal damage. Can cause deafness if in contact with inner ear	No	Known hypersensitivity to drug or any ingredient. Lumbar puncture and use meninges	Flammable
Iodophor with alcohol	Oxidation/ substitution by free iodine/ denatures proteins[36,39,40]	Excellent[36,39,40]	Excellent	Good	Excellent	Moderate	No. Can cause corneal damage or nerve damage	No	Sensitivity to povidoneiodine (shellfish allergies are not a contraindication)	Flammable
Parachoro-xylenol (PCMX)	Disrupts cell membrane[36]	Good[36]	Fair[36]	Fair[36]	Moderate[36]	Moderate[36]	Yes[43]	Yes[43]	Known hypersensitivity to PCMX or any other ingredient[43]	Minimally effective in the presence of organic matter. The FDA has classified PCMX as Category III (data are insufficient to classify it as safe and effective). The FDA continues to evaluate PCMX[43]

FDA = US Food and Drug Administration. Source: Association of periOperative Registered Nurses, 2010.[44]

- povidone-iodine scrub-paint in combination with an alcohol paint;
- 2% CHG and 70% isopropyl alcohol (Chloraprep); and
- iodine povacrylex in isopropyl alcohol (DuraPrep).

The infection rates following these three treatments for each period were 6.4, 7.1, and 3.9%, respectively.[25] These results suggest that iodophor-based preparations may be superior to CHG preparations in the general surgery population.

Why Do Neurosurgical Procedures Pose Different Challenges for Skin-site Preparation?

When deciding on the appropriate skin preparation for a neurosurgical procedure, e.g. a craniotomy, a number of different points must be taken into consideration that impact and limit the number of options available. Two such limitations are readily apparent:

- first, the head is covered with hair, which impacts what can be achieved in terms of skin preparation; and
- second, chlorhexidine gluconate is considered less suitable for use in neurosurgery as *in vivo* evidence suggests that it is neurotoxic.

Since the head is largely covered in hair, traditional preparation for craniotomies and other intracranial procedures involves extensive shaving of the operation site. The rationale was that removing all hair as completely as possible from the scalp would reduce the risk for infection. However, the overall evidence in the literature over the past decade suggests that shaving does not decrease the risk for SSI and may even possibly increase it.

Two studies from the late 1990s in children[26] and adults[27] suggested a similar level of infection control with or without shaving the scalp. A study reviewing 225 neurosurgical procedures performed in the US showed that shaved patients incurred a higher rate of SSIs—5.88% in the shaved population compared with 3.37% among non-shaved patients.[27] Winston et al. demonstrated similar findings in a study involving 638 patients undergoing craniotomies and cerebrospinal fluid shunts.[28] Currently, many surgeons have moved towards minimal shaving of the incision site or to the use of clippers instead of shaving.

Despite having superior antiseptic properties to iodophor solutions, CHG is considered by many to be inappropriate for neurosurgery due to neurotoxicity. While this is not an issue for most general surgery cases, it becomes a major consideration for neurosurgical cases, wherein exposure of neural tissue to CHG could have long-lasting negative effects.

Reports in older studies from the 1970s suggested CHG as causing hearing loss following otosurgery and causing taste disturbance after oral surgery.[29–33] Animal model investigations in later years confirmed this. A study by Henschen and Olsen[33] in 1984 showed CHG to damage autonomic nerve fibers in the eyes after exposure. This damage was still evident as long as 50 days after exposure. They also noted that the damage was most apparent in unprotected tissues.[33] These data effectively limit the options available to neurosurgeons when choosing an appropriate skin preparation for surgery.

Current Guidelines and Future Developments

It is unfortunate that there are no clear current guidelines directing the choice of skin preparation in neurosurgery. Many institutions have developed their own body of recommendations based on literature reviews, but the choice of skin preparations largely remains a function of the individual neurosurgeon and what preparations are available at a particular institution. The Society for Healthcare Epidemiology of America/Infectious Diseases Society of America, Association of periOperative Registered Nurses, Centers for Disease Conrol and Prevention, and the Joint Commission National Patient Safety Goals 2010 all discourage the practice of shaving surgical sites. It is recommended that hair is either pinned out of the way or removed via the use of clippers. The use of alcohol-based preparations has also been discouraged in hairy areas by the American Society of Anesthesiologists due to the flammability risk.[34] If such solutions must be used, one hour of time is recommended for the solutions to dry.[35] It is also known that while much in the literature recommends the use of chlorhexidine, this solution is worrisome for neurotoxicity. This limitation should be considered in neurosurgical cases. One thing is certain; the use of pre-operative antibiotics given 30–60 minutes prior to incision is recommended to decrease the risk for peri-operative infection.[20]

As greater attention is turned to the effects of various skin preparations in neurosurgery, one expects to see a number of developments. It is very likely that there will be greater use of iodine-based preparations (povidone/iodine antiseptic paints and scrubs, likely with alcohol) as opposed to chlorhexidine gluconate because of the associated neurotoxicity concerns. While it is unlikely that alcohol will be eliminated from the iodoform-based preparations that are used, the authors believe that more time will be given to allow these preparations to dry prior to the initiation of surgery to comply with US Food and Drug Administration (FDA) regulations and improve patient safety. It is anticipated that current guidelines from the general surgery literature will begin to emphasize these points for the neurosurgical subspecialty soon.

One also expects to see a complete elimination of shaving and extensive clipping of surgical sites as traditional methods are abandoned and evidence from microbiological studies are accepted. In its place, one would likely see an increased use of minimal clipping combined with antiseptic shampoos followed by an iodophor-based preparation at the surgical site. There is also likely to be an increased use of self-adhesive drapes containing iodine (i.e. Ioban). Neurosurgical studies are already beginning to show the effectiveness of this method in addition to the standard aqueous iodophor preparations.[27]

Conclusion

Changes in practice, the use of povidone or iodine-based skin preparations, the use of antibiotic-impregnated drapes, the elimination of shaving, and the reduced use of clipping should begin to decrease the overall risk for SSIs in neurosurgery. The combination of these with the standard use of pre-operative antibiotics and good sterile techniques should make neurosurgery less infection-prone. This will reduce patient morbidity, improve outcomes, and reduce costs for the healthcare system. ■

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