

An International Survey to Understand Infection Control Practices for Spinal Cord Stimulation

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Objectives: Surgical site infections (SSIs) are associated with significant healthcare costs and morbidity. Limited research exists specific to the prevention of spinal cord stimulation (SCS) SSIs. The objectives of this international survey were to examine current infection control practices for SCS trials and implants and to compare reported responses with evidence-based recommendations.

Materials and Methods: A 33-question survey was developed based on an extensive literature review for infection control policies. The survey was hosted on the Internet. Dispersion of the survey occurred through professional associations and device manufacturers. Responses to 15 questions directly related to defined CDC, NICE, and SCIP evidence-based infection control practice recommendations were classified as either compliant or noncompliant. The survey was open for 20 days. Responses also were grouped and analyzed based on geographic location, practice location, and procedural volumes.

Results: Five hundred six physicians responded to the survey. Compliance rates for CDC, NICE, SCIP infection control practice recommendations were low with only four of the 15 questions having compliance rates $\geq 80\%$. Areas associated with high levels of noncompliance included weight-based antibiotic dosing, hair removal strategies, double gloving, surgical dressing, skin antiseptic agent selection, and postoperative continuation of antibiotics. Geographic and practice type variations existed for particular infection control practices. Procedural volume influenced operative implant times with low physician procedural volumes associated with extended operative times.

Conclusions: The survey provided significant insight into current practices and will assist in the development of specific SCS infection control policies. Based on the survey, further education is warranted on infection control strategies for physicians performing spinal cord stimulator trials and implants.

Keywords: Infection, infection control, spinal cord stimulation, surgical site infection

Conflict of Interest: Dr. Provenzano is a consultant for Halyard Health, Medtronic, St. Jude Medical, and Trevena. Dr. Deer is a consultant, researcher, and speaker for Axonics, Bioness, Medtronic, St. Jude Medical, Spinal Modulation, Nevro, and Globus. Dr. Thomson is a consultant, researcher, and speaker for Boston scientific and consultant for Axonics. Dr. Hayek is a member of the medical advisory board for Boston Scientific, Flowonix, Mallinckrodt, and Neuro, and a consultant for Greatbatch and Globus. Dr. Narouze is a consultant for St. Jude Medical and researcher for Medtronic. Dr. Rana receives research support from St. Jude Medical and Boston Scientific. Zachary Drennen, Tyler Watson, and Dr. Phelps have no disclosures. Dr. Buvanendran is a consultant for St. Jude Medical and Medtronic.

INTRODUCTION

Surgical site infections (SSIs), which represent approximately 22% of all healthcare associated infections, are linked to significant healthcare costs, humanistic consequences, and morbidity (1–3). In the USA and England, SSIs are the second and third most commonly reported infections, respectively (4,5). Recently, significant attention has been placed on the occurrence and prevention of SSIs and the current level of poor compliance with evidence-based guidelines (2). For spinal cord stimulation (SCS), the placement of an implantable device with neuraxis communication makes infection control practices a particularly relevant issue. Although not specific to the field of SCS, evidence-based guidelines have been developed both in the USA and Europe to provide education on methods to prevent SSIs (6,7).

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Infection rates for SCS have been reported in the range of 1–10% (8). Two large systematic reviews on SCS have reported infection rates ranging from 3.4% to 4.6% (9,10). Furthermore, Kumar et al. (11) in a multicenter randomized clinical trial comparing SCS with conventional medical management reported an 8% infection rate that was inclusive of wound breakdown. The infection rates reported for SCS are often higher than those associated with other devices such as total joint replacement surgery which has an average rate of infection of 2% (12). SCS infections can have significant consequences including epidural abscess and the ultimate removal of the implantable device (13).

Unfortunately, limited research specific to SCS exists to help guide and improve evidence-based infection control practices to reduce the occurrence of SSIs. Currently, infection control practices are extrapolated from well-developed practices from other surgical fields. Approximately 14,000 SCS implants are performed worldwide each year for a growing range of indications (14). This accelerated interest in the field has led to the need to better understand common practices among SCS proceduralists and to develop neuromodulation-specific infection control guidance.

The purpose of this study was to examine current infection control practices for SCS trials and implants through the use of an international survey. A second purpose was to compare the results with current evidence-based recommendations.

MATERIALS AND METHODS

A 33-question web-based survey (Appendix 1) on perioperative infection control practices (preoperative, intraoperative, and postoperative stages) for SCS was developed based on an extensive literature review through PubMed used to identify relevant journal articles published from 1967 to June 2013. Key search terms included SCS, SSIs, antibiotic prophylaxis, antimicrobial prophylaxis, implant infections, total joint arthroplasty infections, spine surgery infections, SCS system infections, methicillin-sensitive *Staphylococcus aureus* (MSSA) decolonization, methicillin-resistant *Staphylococcus aureus* (MRSA) decolonization, preoperative antiseptic showering, preoperative hair removal, skin antiseptic preparations, surgical gloves, wound irrigation, surgical closure, and incision care. The literature review consisted of defining key recommended areas for implementation of evidence-based infection control interventions from both standard surgical guidelines including the Centers for Disease Control and Prevention (CDC) (6), National Institute for Health and Care Excellence (NICE) (7) in the United Kingdom, Surgical Care Improvement Project (SCIP) (15,16), and other surgical subspecialties recommendations (17,18). Manuscript authors refined survey questions to allow for the investigation of important surgical infection control practices. Six of the 33 questions gathered demographic and practice pattern data, while the remaining 27 questions investigated infection control practices.

Following Institutional Review Board approval (Robert Morris University), the survey was hosted on the Internet. A link to the online survey was dispersed with the help of various professional organizations including the American Academy of Pain Medicine (AAPM), American Society of Regional Anesthesia and Pain Medicine (ASRA), The European Society of Regional Anaesthesia and Pain Therapy (ESRA), International Neuromodulation Society (INS), and device manufacturers (Boston Scientific, Medtronic, and St. Jude Medical). The survey was carried out for 20 days (October 17, 2013, to November 5, 2013).

The 27 questions investigating infection control practices were divided into four areas: 1) preoperative practices; 2) intraoperative

practices; 3) postoperative practices; and 4) infection control practices requiring further research. In order to highlight areas of compliance and noncompliance with the defined practice recommendations (CDC, NICE, and SCIP), the responses to 15 questions (questions 1, 2, 3, 4, 5, 6, 14, 17, 22, 23, 24, 25, 26, 27, and 28) were identified as either compliant (correct response according to recommendations) or noncompliant (incorrect response according to recommendations). Areas of compliance were defined by $\geq 80\%$ participant compliance rate for the defined practice question, and areas of noncompliance were defined by $< 80\%$ participant compliance rate for the defined practice question.

In order to assist with analysis, the demographic group data were refined and organized. Physician yearly procedural volumes for spinal cord stimulator trials and implants were classified into the following groups: 1) low volume, ≤ 10 trials or implants; 2) medium volume, > 10 and ≤ 40 trials or implants; and 3) high volume > 40 trials or implants. Geographic location organization was defined as USA, Europe, or other, which included data from North America—Other, South America, Africa, Asia, and Australia. The other group classification was created because of the low response rates ($\leq 1.63\%$ for each group) in each of these geographic subsets. Practice location organization was defined as academic practice, hospital-based program, and private practice that consisted of the private solo practice and private group practice groups. Operative times were classified as follows: ≤ 60 min, > 60 min and ≤ 90 min, and > 90 min (combining responses from > 90 - and ≤ 120 - and > 120 -min selection categories).

Statistical Analysis

The data were analyzed descriptively and expressed as percentages of the total number of returned valid responses for each question. All confidence interval estimates were calculated using a 95% level of confidence. Sample sizes related to each of the 33 questions are recorded in parenthesis either alone or with a corresponding confidence interval. For the identified 15 questions specifically addressing compliance with defined practice recommendations, compliance rates between geographic location, practice type, and procedural volume were analyzed using a chi-squared test for independence for questions resulting in an adequate number of responses in each category. A chi-squared test also was used to investigate a significant relationship between operative times and procedural volume. For questions resulting in low cell count, categories were combined, and a Fisher's Exact test was performed. All tests assumed a 0.05 significance level. Given that a statistically significant result between three groups (practice type, geographic location, or procedural volume) was observed, post-hoc analyses to compare pairwise significant group difference used a 0.02 level of significance to adjust for multiple comparisons. All descriptive statistics, tables, and pie and bar charts were calculated and constructed in Excel (Microsoft, Redmond, WA, USA). All chi-squared tests of independence, Fisher's Exact tests, and confidence intervals were performed in StatCrunch™ (Integrated Analytics LLC/Pearson, Boston, MA, USA).

RESULTS

Demographic and Practice Description Data

A total of 14,819 survey links were dispersed to physicians through an introductory statement by either email or mailed letter (only for Boston Scientific) with the following breakdown: AAPM, 1616; ASRA, 2841; and INS, 1391. The device manufacturers distributed 8971 surveys. ERSA assisted with notification of the survey link through its website (<http://esraeurope.org/>). Because of overlapping distribution lists, an accurate response rate could not

Table 1. Demographics of Responders.*

	Count (%)
Country, <i>N</i> = 490	
Africa	3 (0.61)
Asia	1 (0.20)
Australia	5 (1.02)
Europe	57 (11.63)
North America—USA	410 (83.67)
North America—Other	8 (1.63)
South America	6 (1.22)
Type of practice, <i>N</i> = 489	
Academic practice	99 (20.25)
Hospital-based practice	106 (21.68)
Private group practice	182 (37.22)
Private solo practice	102 (20.86)
Number of spinal cord simulator trials, <i>N</i> = 479	
≤5 trials	48 (10.02)
>5 trials to ≤10 trials	69 (14.41)
>10 trials to ≤20 trials	132 (27.56)
>20 trials to ≤40 trials	129 (26.93)
>40 trials	101 (21.09)
Number of spinal cord simulator implants, <i>N</i> = 470	
≤5 implants	75 (15.96)
>5 implants to ≤10 implants	87 (18.51)
>10 implants to ≤20 implants	118 (25.11)
>20 implants to ≤40 implants	111 (23.62)
>40 implants	79 (16.81)
Trial and implant pathway, <i>N</i> = 492	
Separate trial and separate full implant	450 (91.46)
Staged trial and completion implant	42 (8.54)
Operative time implants, <i>N</i> = 478	
≤60 min	163 (34.10)
>60 min and ≤90 min	218 (45.61)
>90 min and ≤120 min	75 (15.69)
>120 min	22 (4.60)

*Not all physicians responded to all the questions. *N* = Total respondents for each question.

be calculated. When available, the open rate (number of survey emails opened divided by the number of delivered emails) for the survey email was 36.0% for ASRA, 35.8% for INS, and 29.0% for AAPM.

A total of 506 physicians responded to the survey (Table 1); although, all of the respondents did not answer each question. A majority of the respondents were from the USA (83.7%) with greater than 50% of the responders practicing in a private practice setting. A majority of respondents followed a separate trial and implant pathway, 91.5% (CI: 89.0–94.0%, 492). While nearly all of the respondents from the USA reported they use a separate trial and separate implant pathway (96.8%, 410), only 61.4% of 57 European respondents reported using a separate implant pathway, leaving 38.6% performing a staged trial completion implant pathway. For practitioners that employed the separate trial and implant pathway, 75.2% (CI: 71.2–79.3%, 479) of respondents waited greater than two weeks from the conclusion of the trial to the implantation stage. The breakdown for the wait for the implantation procedure was as follows: 6.1%, ≤one week; 22.1%, >one week and ≤2 weeks; 38.4% >2 weeks and ≤3 weeks; and 33.4%, >3 weeks. When these surgeries were performed, 95.4% (CI: 93.5–97.3%, 478) of responders reported surgery times <2 hours (Table 1).

Compliance With Evidence-Based Infection Control Practice Recommendations

The results of the survey were analyzed and compared with current evidence-based recommendations (CDC, NICE, SCIP). Table 2 isolates compliance rates for recommended practices outlined in the survey that are specifically addressed by CDC, SCIP, and NICE. Of the 15 questions specifically investigating defined practices, only 26.7% (4/15) were associated with a compliance rate of ≥80%.

Only 8.35% (CI: 5.8–10.9%, 467) of respondents correctly chose the maximum time criteria of 365 days for defining a deep SSI (an infection extending into the muscle and fascia layers) for an implantable device as defined by the CDC. Of question respondents, 82.9% selected a time frame of ≤90 days after surgery. Geographic location, practice type, and procedural volume did not influence definition selection.

Preoperative Practices

Although greater than 80% of individuals reported utilizing antibiotics for both trials and implantation stages, the utilization of weight-based dosing was closer to 50% (Table 2). The use of preoperative antibiotics for trials was 86.1% (CI: 83.0–89.1%, 495), while only 44.8% (CI: 40.1–49.5%, 426) reported utilization of weight-based dosing. Similarly, the use of preoperative antibiotics for implants was 96.0% (CI: 94.2–97.7%, 494), while only 47.7% (CI: 42.6–51.4%, 493) reported utilization of weight-based dosing. Geographic location, practice type, and procedural volume did not influence the use of antibiotics prior to SCS trials and implants. However, the employment of weight-based dosing for trials and implants did vary based on practice type. Academic practices were significantly more likely to weight-based dose preoperative antibiotics in comparison to private practice and hospital settings for both trials and implants. For the trial stage, 61.25% of academic physicians used weight-based dosing compared with 37.7% of private practice physicians and 44.1% of hospital-based physicians ($p < 0.001$, $p = 0.011$, respectively). For the implant stage, 63.2% of academic physicians used weight-based dosing for preoperative antibiotics in comparison with 43.9% of private practice physicians and 48.5% of hospital-based physicians ($p < 0.001$, $p = 0.018$, respectively).

Of physicians that used preoperative antibiotics for implants (excluding vancomycin), 97.9% (CI: 96.9–99.2%, $N = 470$ Fig. 1 and Table 2) administered antibiotics within 60 min prior to surgical incision. Although practice type and procedural volume did not influence the time frame for administrative preoperative antibiotics (excluding vancomycin), geographic location did with a larger percentage of responders from the USA (98.0%) in comparison with Europe (92.9%) administering antibiotics within 60 min prior to surgical incision ($p = 0.046$).

When vancomycin is administered ($N = 496$), 92.3% of respondents selected an appropriate consideration for utilization including patients colonized with MRSA, patients with history of infection with MRSA, institutionalized patients, inpatient hospitalizations within the past year, and patients with proven beta-lactam allergy. Only 7.7% of respondents utilized vancomycin for all patients. Only 11.8% of respondents ($N = 490$) used prophylactic intravenous teicoplanin and +/- gentamicin for antimicrobial prophylaxis.

Figure 2 illustrates preoperative skin preparation procedures. When hair removal is required for a surgical operation, only 73.6% (CI: 69.6–77.6%, 469) of respondents selected a procedure involving electrical clippers immediately before the operation (Fig. 2a and

Table 2. Results of Survey Identifying Key Areas of Compliance and Noncompliance with CDC, NICE, and SCIP Infection Control Guidelines.

Recommended practice	Percent compliance (95% CI), n	Origin of recommended practice	Pertinent references and comments
Preoperative practices			
Utilization of preoperative antibiotics for SCS trials	86.1% (83.0–89.1%), 495	CDC IA and NICE	Bowater et al. (19) demonstrated that antibiotic prophylaxis is effective for reducing the risk of wound infection for all types of surgery.
Utilization of preoperative weight-based antibiotic dosing for SCS trials	44.8% (40.1–49.5%), 426	CDC IA and NICE	Weight-based dosing of antibiotics is required to achieve therapeutically effective drug concentrations (17,20).
Utilization of preoperative antibiotics for SCS implants	96.0% (94.2–97.7%), 494	CDC IA and NICE	Bowater et al. (19) demonstrated that antibiotic prophylaxis is effective for reducing the risk of wound infection for all types of surgery.
Utilization of preoperative weight-based antibiotic dosing for SCS implants	47.7% (42.6–51.4%), 493	CDC IA	Weight-based dosing of antibiotics is required to achieve therapeutically effective drug concentrations (17,20).
Appropriate preoperative timing (within one hour prior to surgical incision excluding vancomycin) of prophylactic antimicrobial administration for SCS implants	97.9% (96.9–99.2%), 470	CDC IA, NICE, SCIP	
Hair removal (when required) with electric clippers immediately before the surgical procedure	73.6% (69.6–77.6%), 469	CDC IA and NICE	
Intraoperative practices			
Utilization of double gloving	47.8% (43.4–52.2%), 494	CDC II and NICE	Tanner and Parkinson (21) concluded that the addition of a second pair of surgical gloves reduces perforations to the innermost gloves. Although there is insufficient evidence that double gloving reduces the risk of SSIs. NICE recommends wearing two pairs of sterile gloves when there is a high risk of glove perforation and the consequences of contamination may be serious (7).
Utilization of chlorhexidine gluconate for preoperative skin antiseptic agent	67.7% (63.6–71.8%), 499	CDC IB and NICE	CDC and NICE recommend the use of an appropriate antiseptic agent (povidone–iodine or chlorhexidine containing products). Darouiche et al. (22) demonstrated that preoperative skin preparation with chlorhexidine-alcohol is superior to povidone–iodine for preventing surgical site infection.
Postoperative practices			
Application of an occlusive dressing following a spinal cord stimulator trial	79.7% (76.1–83.3%), 478	CDC IB and NICE	CDC recommends applying a sterile dressing for 24–48 hours postoperatively (category IB). NICE recommends interactive dressings. Hutchinson and McGuckin demonstrate lower rates of infection with occlusive dressings (23).
Application of an occlusive dressing following a spinal cord stimulator implant	68.4% (64.2–72.6%), 469	CDC IB and NICE	CDC recommends applying a sterile dressing for 24–48 hours postoperatively (category IB). NICE recommends interactive dressings. Hutchinson and McGuckin (23) demonstrate lower rates of infection with occlusive dressings.
Understanding maximum time criterion for defining a deep surgical site infection of an implantable device (one year)	8.35% (5.8–10.9%), 467	CDC	Infection occurs within one year if an implant is in place and the infection appears related to the operation.
No continuation of antibiotics into the post-operative period for spinal cord stimulator trials beyond 24 hours*	54.5% (50.0–58.9%), 483	SCIP	SCIP recommends the discontinuation of antibiotics within 24 hours after surgery.
No continuation of antibiotics into the postoperative period for spinal cord stimulator implants beyond 24 hours†	52.8% (48.4–57.3%), 477	SCIP	SCIP recommends the discontinuation of antibiotics within 24 hours after surgery.
<p>Areas of compliance were defined by ≥80% participant compliance rate for the defined practice. Areas of noncompliance were defined by <80% participant compliance rate for the defined practice. N = Total number of respondents for that answered each question. *Examination of survey questions 22 and 23. †Examination of survey questions 24 and 25. CDC recommendations. IA: Strongly recommended for implementation and supported by well-designed experimental, clinical, or epidemiological studies. IB: Strongly recommended for implementation and supported by some experimental, clinical, or epidemiological studies and strong theoretical rationale. II: Suggested for implementation and supported by suggestive clinical or epidemiological studies or theoretical rationale.</p>			

Table 2). Practice type and procedural volume did not influence the hair strategy removal. Respondents from Europe only used electrical clippers immediately before surgery 42.6% of the time when hair removal is required which was statistically different than respon-

dents from the USA (77.3%) and other (73.9%) geographic location categories ($p < 0.001$, $p = 0.003$, respectively).

Chlorhexidine and povidone–iodine based solutions are used by 94.6% of respondents ($N = 499$) as the skin antiseptic agent (Fig. 2b).

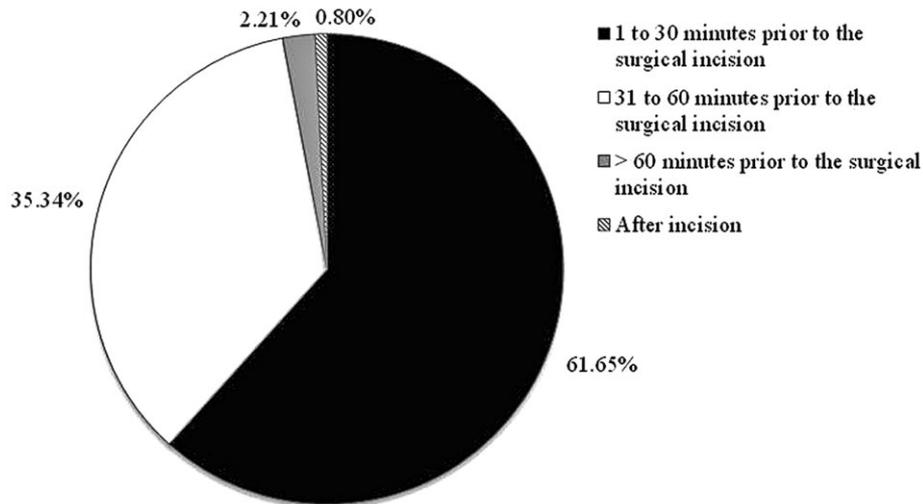


Figure 1. Timing of antibiotic administration for SCS implants ($N = 470$).

Only 67.7% (CI: 63.6–71.8, 499) of respondents used a chlorhexidine gluconate-based product (Table 2). Geographic location and practice type significantly influenced preoperative skin antiseptic agent selection but not procedural volume. A greater number of respondents from the USA (73.5%) in comparison to Europe (49.1%, $p = 0.001$) but not the other (65.2%) geographical category selected chlorhexidine-based solutions. Respondents from academic institutions (84.7%) also were more likely to use chlorhexidine-based solutions in comparison to private (65.1%, $p < 0.001$) and hospital-based practices (70.5%, $p = 0.007$).

Intraoperative Practices

Of the surveyed physicians, 80.5% (CI: 63.9–72.1%, 497) placed an incise adhesive drape with 68.2% (CI: 63.9–72.1%, 497) specifically using an iodophor impregnated plastic incise adhesive drape.

During the operative procedure, 47.8% of respondents (CI 43.4%–52.2%, 494) wear two pairs of gloves (Table 2). Double gloving was more common in the USA (49.6%) in comparison to Europe (32.1%, $p = 0.005$). Practice type also influenced gloving practices with academic physicians (61.6%) double gloving more often than private practice (44.2%, $p = 0.001$) and hospital-based physicians (43.8%, $p = 0.005$). Procedural volume did not significantly influence gloving technique.

For irrigation practices, 86.5% of respondents (CI, 83.5–89.5%, 483) irrigated the surgical wound prior to closure with 67.5% (CI, 63.3–71.7%, 480) of respondents adding antibiotics to the irrigation solution. Geographic location, practice type, and procedural volume all influenced surgical field irrigation practices. Individuals from the USA (91.7%) were more likely to irrigate the surgical wound in comparison with Europe (57.9%) and the other (69.6%) geographical categories ($p \leq 0.001$, $p = 0.011$, respectively). Academic (92.9%) and private practice (88.8%)-based physicians were more likely to irrigate the surgical wound when compared with hospital-based physicians (75.5%; $p < 0.001$, $p = 0.002$, respectively). High-volume SCS trial responders (93%) irrigated the surgical wound following an implant more frequently than medium volume responders (82.3%) but not low-volume (90.1%) responders ($p = 0.013$). Irrigation practices were not significantly influenced by implant procedural volumes. Respondents from the USA (83.2%) and the other (62.5%)

geographical category added antibiotics to the irrigation solution more frequently than respondents from Europe (18.2%; $p \leq 0.001$, $p < 0.001$, respectively). Private practice physicians (82%) utilized antibiotics in the irrigation solution more frequently than hospital-based (62.3%; $p = 0.002$) but not academic-based physicians (76.9%).

For wound closure, 478 participants described their practices with the following breakdown: 29.5% absorbable sutures and liquid skin adhesive, 29.3% absorbable sutures, 27.4% surgical staples, and 13.8% nonabsorbable sutures.

Postoperative Practices

Generally, about 50% of respondents continued antibiotics into the postoperative period; 50.5% (CI: 46.0–55.0%, 483) for spinal cord stimulator trials; and 57.4% (95% CI: 53.0–61.8%, 477) for implants. Geographic location, practice type, and procedural volume did not significantly influence the decision to continue antibiotics into the postoperative period for spinal cord stimulator trials or implants. For the respondents that continued antibiotics postoperatively, a large proportion continued antibiotics for greater than 24 hours, 90.2% (CI: 86.4–93.9%, 244) for trials (Fig. 3a), and 82.1% (CI: 77.6–86.7%, 274) for implants (Fig. 3b). Although practice type and procedural volume did not significantly influence the number of respondents that continued antibiotics for greater than 24 hours, geographic location did significantly influence this practice. For both spinal cord stimulator trials ($p = 0.007$) and implants ($p < 0.001$), respondents from Europe (25.0%) continued antibiotics for greater than 24 hours significantly more than respondents from USA (6.9%).

Occlusive dressings were utilized extensively for both spinal cord stimulator trials: 79.7% (CI: 76.1–83.3%, 478) and implants 68.4% (CI: 64.2–72.6%, 469). Practice type and procedural volume did not influence the use of occlusive dressings for both trials and implants. However, geographic location was found to influence the use of occlusive dressing with more individuals from USA (81.6% for trials and 70.3% for implants) placing an occlusive dressing than Europe (67.3% for trials and 51.8% for implants) for both spinal cord stimulator trials ($p = 0.033$) and implants ($p = 0.012$).

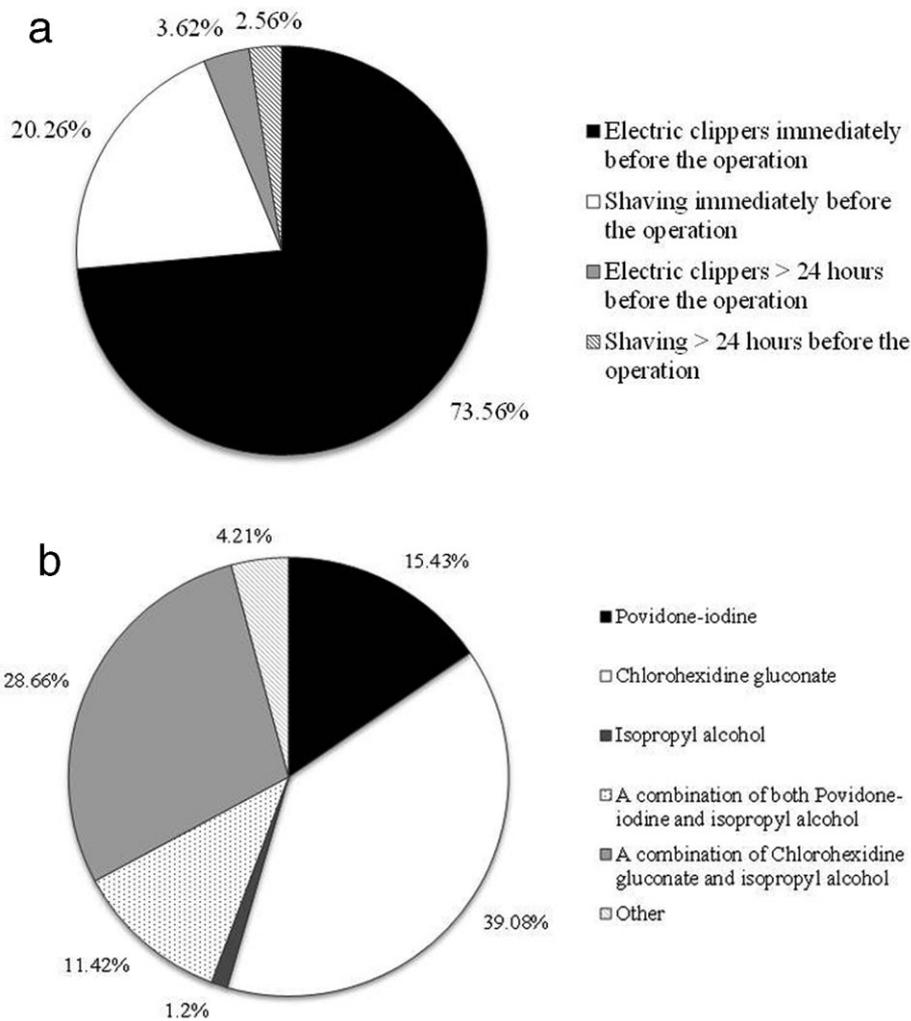


Figure 2. Preoperative skin preparation procedures. a. Hair removal strategies (N = 469). b. Skin antiseptic agent selection (N = 499).

Areas for Future Research for Infection Control Practices

Colonization with *Staphylococcus aureus*, both MSSA and methicillin-resistant MSRA, has been shown to be an independent risk factor for SSIs (24). Participants were surveyed regarding decolonization practices; 6.6% of respondents used mupirocin, and 37.8% of respondents used chlorhexidine baths independently of a preoperative test result for *Staphylococcus* species. A limited number of respondents routinely tested preoperatively for MRSA (25.1%) and MSSA (10.8%). Figure 4 displays preoperative decolonization practices for patients with a positive screening test for both MRSA (Fig. 4a) and MSSA (Fig. 4b). When patients had a positive screening test for MSSA, 44.0% of respondents did not make any clinical changes based on the test on finding. Whereas, when a positive screening test exists for MRSA only, 14.4% did not make any clinical changes based on the test finding.

Low procedural volumes and extended operative time have been suggested as possible risk factors for SSIs (25–28). Figure 5a (trials) and b (implants) illustrates the significant relationship between volume of trial and implant procedures performed and reported length of the implantation surgery. The number of performed trials (Fig. 5a, $p < 0.0001$) and implants (Fig. 5b, $p < 0.0001$) did significantly influence operative times with higher procedural volumes being associated with lower surgical times. Operative times increased for those physicians performing less than 10 SCS trial or

implant procedures per year. Figure 5a shows that approximately 57% of those reporting high procedural volumes (greater than 40 procedures) complete an SCS implant within 60 min. Conversely, about 75% of those reporting low procedural volumes (less than 10 procedures) for trials report operative SCS implant times in excess of 60 min. This significant trend is also observed for those performing high and low volume procedures for the placement of an implantable device (Fig. 5b).

DISCUSSION

To our knowledge, this is the first international survey investigating infection control practices for SCS. The results of greater than 500 practicing neuromodulation physicians presented here provide insight into current infection control practices for both SCS trials and implants. The main findings of our survey are 1) low compliance rates for the defined practice recommendations from the CDC (6), NICE (7), and SCIP (15,16); 2) areas for improvement in infection control practices exist for the preoperative, intraoperative, and postoperative periods; 3) significant geographic and practice type variations exist for particular infection control practices; and 4) future research for neuromodulation infection control practices is warranted.

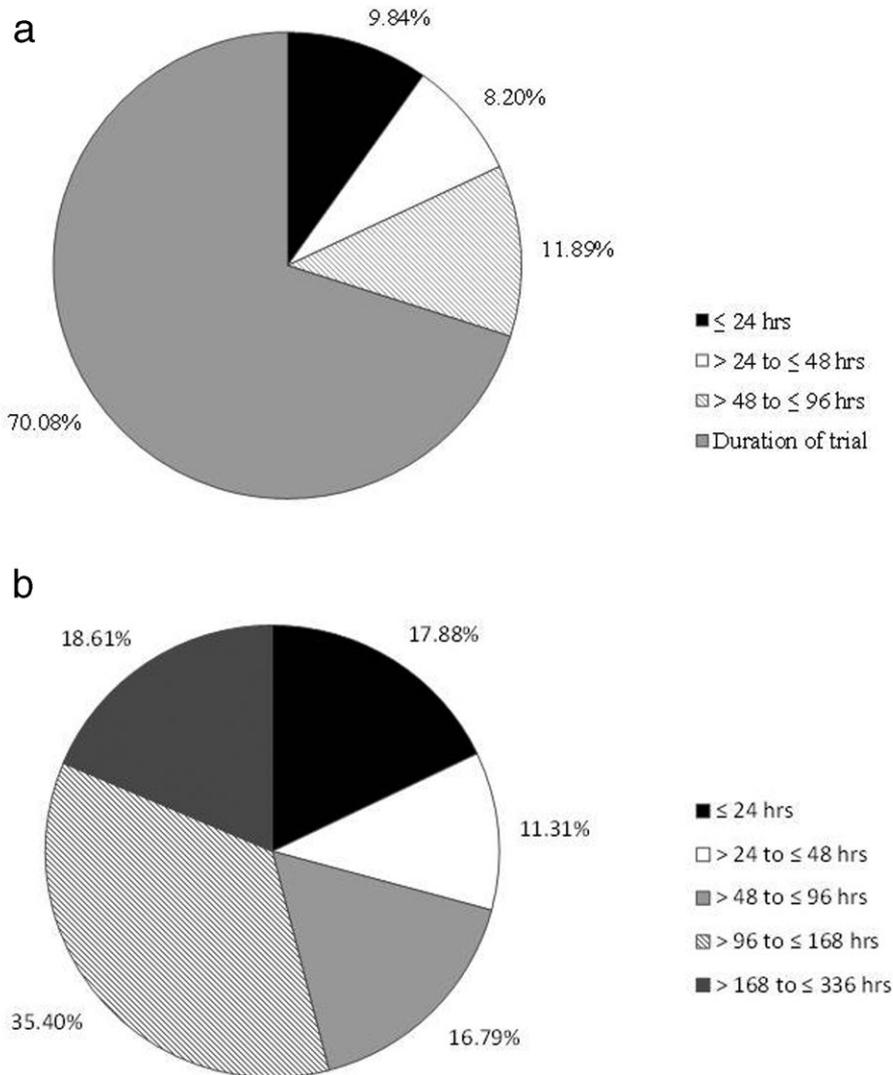


Figure 3. Postoperative practice patterns for antibiotic administration for respondents that continued postoperative antibiotics. a. Duration of use for trials ($N = 244$). b. Duration of use for implants ($N = 274$).

As with any survey, limitations exist. In this survey, the absolute response rate could not be calculated because of the overlapping distribution lists. Although absolute response rate cannot be calculated, the approximate response rate can be inferred from the available survey email open rates which were between 29% and 36%. These rates would be comparable to response rates (8% to 44%) reported for other web-only surveys using probability samples and consensus data (29). In addition, previous interventional pain web-based surveys on anticoagulation and prescription patterns demonstrated a response rate of 14% and 13%, respectively (29,30). A majority of the respondents were from the USA; therefore, additional surveys will be needed to further understand international infection control practice patterns. Since infection rates for practitioners were not collected, the direct relationship between practice patterns and infection rates cannot be inferred. Even though the survey has limitations, the significant response of greater than 500 practicing physicians from different demographic settings does provide a broad overview for current infection control practices for neuromodulation.

Our data indicate, for physicians performing both SCS trials and implants, low compliance rates currently exist with the defined CDC- (6), NICE- (7), and SCIP- (15,16) recommended infection control practices. Only four out of the 15 (26.7%) questions examining specific practices recommend by these guidelines were associated with a compliance rate of $\geq 80\%$. Areas that require further improvement exist in all portions of the surgical care continuum. The CDC through a four-tier ranking system (definitions provided in Table 2) published guidelines for the prevention of SSIs in 1999 which were updated in 2002 to include hand hygiene (31). In the survey presented here, low compliance rates existed for both IA and IB recommendations. In addition, only 8% understood the criteria for defining a deep incisional SSI (i.e. infection occurring within one year of an implant and appearing related to the operation). A superficial SSI, in contrast to a deep SSI, occurs within 30 days after the operation and involves only the skin and subcutaneous tissues of the incision. In 2006, the SCIP was implemented through a national quality partnership in the USA emphasizing 20 measures of which six specifically focused on postoperative infection (32). Three of the

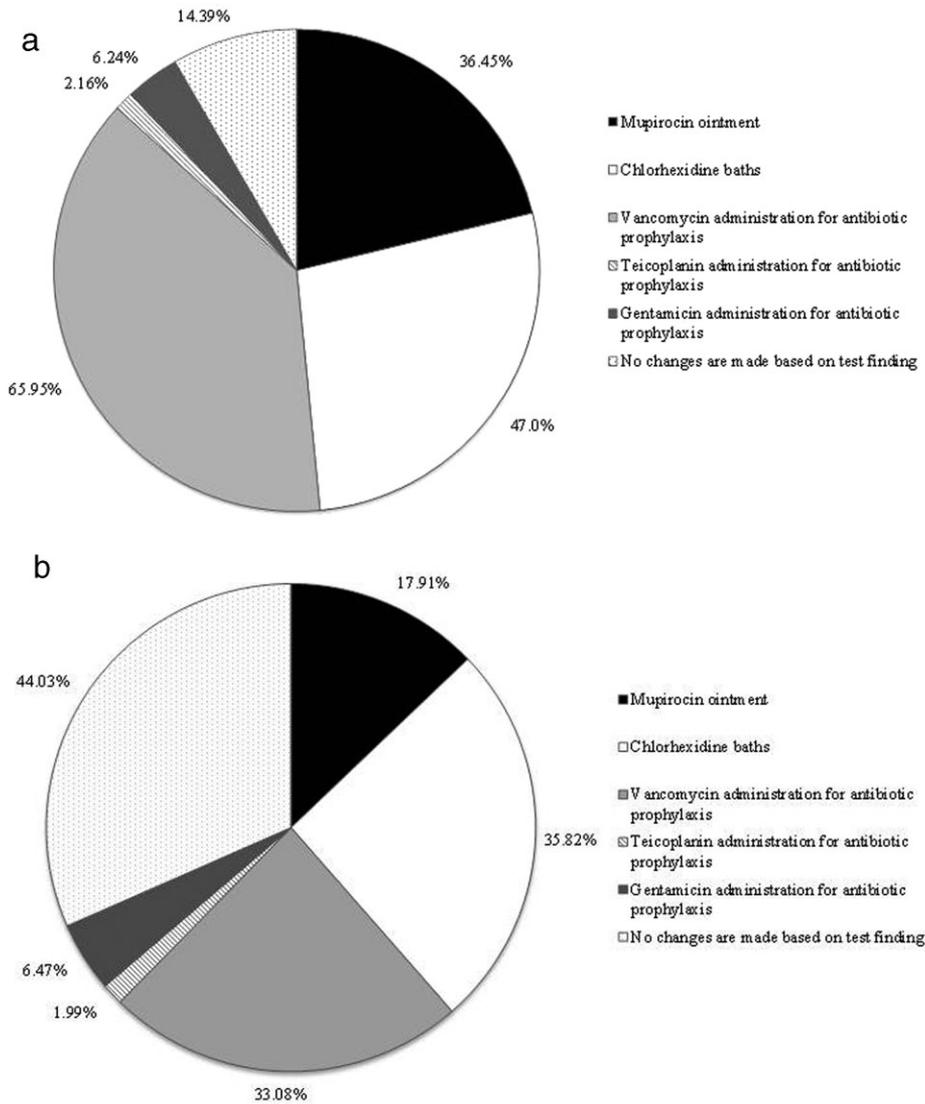


Figure 4. Preoperative decolonization protocols for *Staphylococcus aureus*. a. MRSA (N = 417). b. MSSA (N = 402). For these questions, participants were allowed to choose all answers that applied to their practice.

SCIP infection prevention measures were examined here including administration of prophylactic antibiotics within one hour of surgical procedure (two hours for vancomycin), discontinuing prophylactic antibiotics within 24 hours after surgery (48 hours after cardiac surgeries), and hair removal at the site of surgery with clippers or depilatory. Only one of the three SCIP measures in this survey was associated with a compliance rate of $\geq 80\%$ (i.e. appropriate timing of antibiotic administration).

Although it may be expected that physicians participating in the survey in areas outside of the USA may not be as aware of evidence-based guidelines recommendations by the CDC and SCIP, it should be noted that more than 80% of the survey responders were from the USA, and many of the NICE recommendations are similar to the CDC and SCIP recommendations. Nine of the 15 recommended practices examined here are recommended by NICE, and only four of the nine were associated with compliance rates $\geq 80\%$. In addition, although SSI rates for each respondent were not provided, it is concerning that compliance rates for evidence-based practices were not higher. Adherence to evidence-based guidelines has been

shown to be associated with a lower probability of developing a SSI (32).

Our data indicate that simple measures could be taken to improve infection control practices in the preoperative, intraoperative, and postoperative periods. Specifically in the preoperative period, further education on the importance of weight-based dosing of antibiotic prophylaxis and hair removal strategy is warranted. Antibiotic prophylaxis has been shown to be an effective intervention for preventing postoperative wound infection, independent of surgery type, resulting in an approximately 50% reduction in the incidence of wound infections (19). Furthermore, failure to optimize antimicrobial therapy has been shown to increase infection risk by two- to six-fold (33). In order for antimicrobial prophylaxis to be effective in the prevention of SSIs, serum and tissue levels must exceed the minimum inhibitory concentrations for the organisms likely to be encountered during the operation (17,20). Unfortunately, in this survey less than 50% of respondents weight-based dose antibiotics for spinal cord stimulator trials and implants. For hair removal, removal by electric clipper has been shown to be

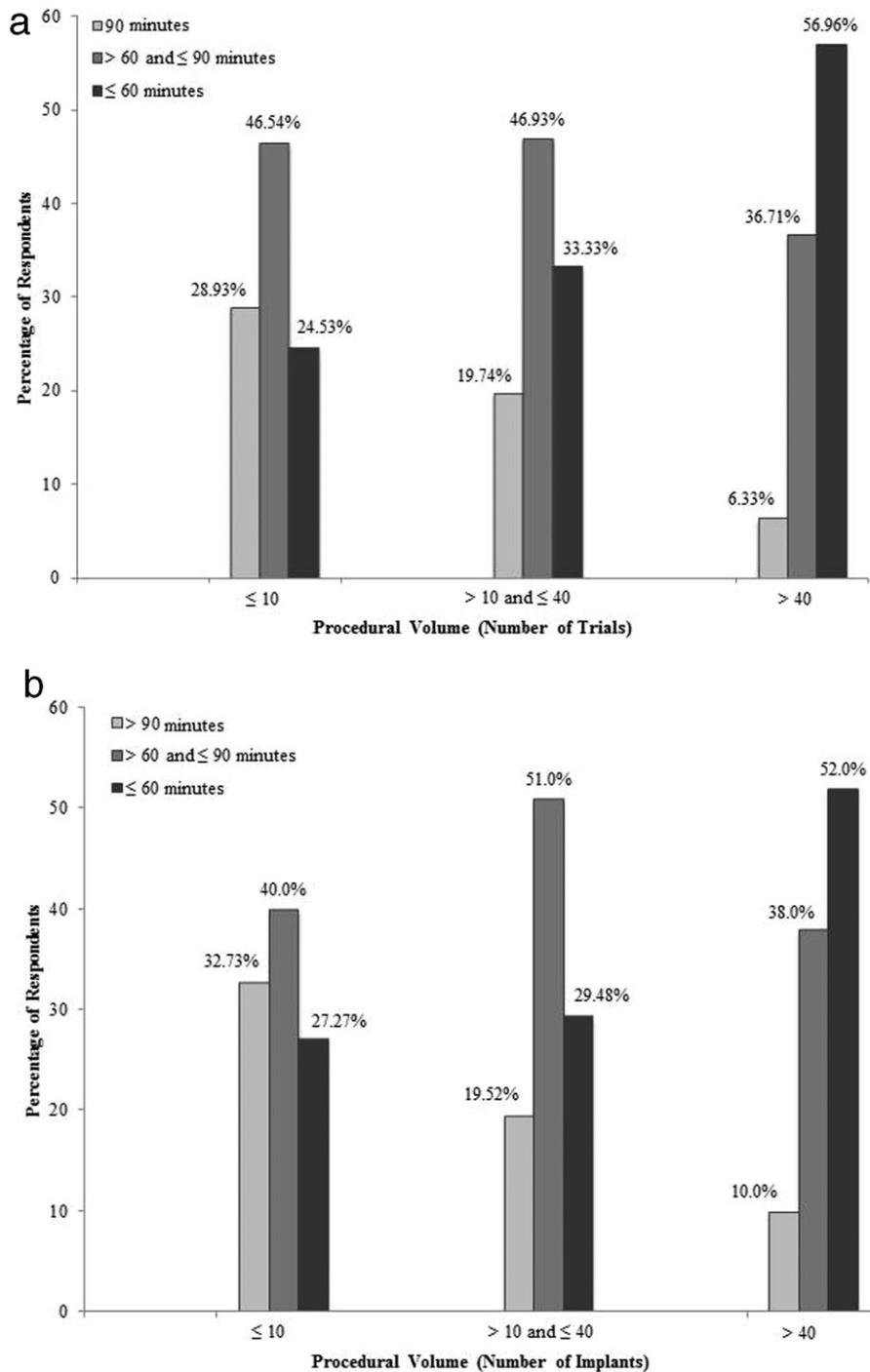


Figure 5. Procedural volume and surgical time a. Relationship between trial volumes and surgical implant operative times (N = 461). b. Relationship between implant volumes and surgical implant operative times (N = 466).

superior in reducing SSI in comparison with removal by a razor (34,35). The survey data here indicate that approximately 20% of responders are still shaving.

During the intraoperative period, areas for practice improvement include double gloving and the selection of a preoperative skin antiseptic agent. A second pair of surgical gloves has been recommended when there is a risk of glove perforation, and the consequences of contamination may be serious (7). Both of these situations exist when performing a neuromodulation technique.

Although there is insufficient evidence to definitively conclude that double gloving reduces the risk of SSIs, it can be concluded that the addition of a second pair surgical gloves reduces perforations to the innermost gloves. In addition, 83% of glove perforations are unnoticed, and risk of infection is two times higher when comparing perforated with not perforated surgical gloves (21,36). Both povidone-iodine and chlorhexidine-based products are used as skin antiseptic agents. In multiple clinical studies, chlorhexidine-based products have been shown to be superior for reducing and

eliminating bacteria and reducing SSIs (22,37,38). Darouiche et al. (22) demonstrated that the overall rate of SSIs was significantly lower in the chlorhexidine–alcohol group than the povidone–iodine group, 9.5% vs. 16.1%, respectively.

In the postoperative period, areas for improvement include the use of occlusive dressing and the continuation of antibiotics into the postoperative period. Hutchinson et al. in a systematic review showed a substantial decrease in the rate of infections when an occlusive dressing was used postoperatively in comparison to a nonocclusive dressing (2.6% vs. 7.1%) (23). It has been proposed that occlusive dressings allow for faster rates of re-epithelialization and collagen synthesis. In addition, the dressings create both a hypoxic environment and a physical barrier to impede and limit bacterial growth. Rudiger and Thomson (39), also suggested that surgical postoperative dressings may specifically influence the infection rates of spinal cord stimulators. Consistent evidence has been demonstrated for limiting the duration of postoperative antibiotics for spine surgery, orthopedic, and cardiac surgery. In addition, postoperative continuation of antibiotics following spine surgery inhibited normalization of body temperature and elevated C-reactive protein levels (40).

Differing needs may exist for educational optimization of infection control practice in diverse demographics settings. Compliance rates significantly differed between academic, hospital-based, and private practices for specific interventions including weight-based dosing of antibiotics, skin antiseptic preparation agent selection, irrigation practices, and double gloving. In addition, practice patterns were different between participants from USA and Europe for specific interventions including antibiotic timing, hair removal, skin antiseptic preparation agent selection, double gloving, irrigation, and postoperative antibiotic continuation. Future studies are warranted to further define the educational needs of practicing physicians based on geographic location and practice type. Furthermore, the relationship between the adherence to best practices for infection control and SSI rates between different demographics settings deserves future consideration.

Best practices from other surgical fields were examined in this survey that have been shown to significantly reduce SSI rates. One of those areas is preoperative decolonization of nasal carriers of both MRSA and MSSA (41). Greater than 80% of healthcare-associated *Staphylococcus aureus* infections originate from endogenous sources (41). Decolonization of MRSA and MSSA carriers with mupirocin nasal ointment and chlorhexidine washings has been shown to significantly reduce SSI with other implantable surgeries including total joint arthroplasty (42). Our survey indicates a currently limited use of preoperative testing for both and MSSA and MRSA and decolonization protocols. The ability of decolonization protocols to influence SSIs in neuromodulation should be examined.

Recently, the Neuromodulation Appropriateness Consensus Committee (NACC) has called for improvements in neuromodulation education and training. In other surgical fields, low procedural volumes and extended operative time have been suggested as possible risk factors for SSI (25–28). Recently, a retrospective review on intrathecal drug delivery and SCS implants for cancer patients suggested that extended operative times may be a risk factor for SSIs (43). Our data indicate a significant relationship between procedural volume and operative times. If the relationship between infection rates and procedural volumes and extended operative time holds for the field of neuromodulation, then efforts should be placed on methods to reduce operative time and improve procedural proficiency.

In conclusion, evidence-based infection control policies are critical for the field of neuromodulation. The large international survey presented here provides significant insight into current practices and will assist in the development of specific neuromodulation infection control policies. Based on the survey results, further education is warranted on infection control strategies for physicians performing SCS trials and implants to improve practice deficiencies. Future research and consensus are needed specifically for SCS infection control practices to improve patient safety and the clinical impact of this important therapy. The data presented here will help guide this development process.

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Authorship Statements

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REFERENCES

- Uckay I, Harbarth S, Peter R, Lew D, Hoffmeyer P, Pittet D. Preventing surgical site infections. *Expert Rev Anti Infect Ther* 2010;8:657–670.
- Leaper DJ, Tanner J, Kiernan M, Assadian O, Edmiston CE Jr. Surgical site infection: poor compliance with guidelines and care bundles. *Int Wound J* 2014;12:357–362.
- American Academy of Orthopaedic Surgeons. Patient Safety C, Evans RP: Surgical site infection prevention and control: an emerging paradigm. *J Bone Joint Surg Am* 2009;91 (Suppl. 6):2–9.
- Leaper D, Burman-Roy S, Palanca A et al. Prevention and treatment of surgical site infection: summary of NICE guidance. *BMJ* 2008;337:a1924.
- Thompson KM, Oldenburg WA, Deschamps C, Rupp WC, Smith CD. Chasing zero: the drive to eliminate surgical site infections. *Ann Surg* 2011;254:430–436, discussion 436–7.
- Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR. Guideline for prevention of surgical site infection, 1999. Hospital Infection Control Practices Advisory Committee. *Infect Control Hosp Epidemiol* 1999;20:250–278.
- Excellence NICE. *Surgical site infection: prevention and treatment of surgical site infection, Clinical guideline 74*. Manchester, United Kingdom: National Institute for Health and Clinical Excellence, 2008.
- Deer TR, Mekhail N, Provenzano D et al. The appropriate use of neurostimulation: avoidance of complications of neurostimulation therapies for the treatment of chronic pain. *Neuromodulation* 2014;17:571–598.

9. Cameron T. Safety and efficacy of spinal cord stimulation for the treatment of chronic pain: a 20-year literature review. *J Neurosurg* 2004;100:254–267.
10. Turner JA, Loeser JD, Deyo RA, Sanders SB. Spinal cord stimulation for patients with failed back surgery syndrome or complex regional pain syndrome: a systematic review of effectiveness and complications. *Pain* 2004;108:137–147.
11. Kumar K, Taylor RS, Jacques L et al. Spinal cord stimulation versus conventional medical management for neuropathic pain: a multicentre randomised controlled trial in patients with failed back surgery syndrome. *Pain* 2007;132:179–188.
12. Darouiche RO. Treatment of infections associated with surgical implants. *N Engl J Med* 2004;350:1422–1429.
13. Rauchwerger JJ, Zoarski GH, Waghmarae R et al. Epidural abscess due to spinal cord stimulator trial. *Pain Pract* 2008;8:324–328.
14. Atkinson L, Sundaraj SR, Brooker C et al. Recommendations for patient selection in spinal cord stimulation. *J Clin Neurosci* 2011;18:1295–1302.
15. Bratzler DW. The surgical infection prevention and surgical care improvement projects: promises and pitfalls. *Am Surg* 2006;72:1010–1016, discussion 1021–30, 1133–48.
16. Bratzler DW, Hunt DR. The surgical infection prevention and surgical care improvement projects: national initiatives to improve outcomes for patients having surgery. *Clin Infect Dis* 2006;43:322–330.
17. Alexander JW, Solomkin JS, Edwards MJ. Updated recommendations for control of surgical site infections. *Ann Surg* 2011;253:1082–1093.
18. Matar WY, Jafari SM, Restrepo C, Austin M, Purtill JJ, Parvizi J. Preventing infection in total joint arthroplasty. *J Bone Joint Surg Am* 2010;92 (Suppl. 2):36–46.
19. Bowater RJ, Stirling SA, Lilford RJ. Is antibiotic prophylaxis in surgery a generally effective intervention? Testing a generic hypothesis over a set of meta-analyses. *Ann Surg* 2009;249:551–556.
20. Forse RA, Karam B, MacLean LD, Christou NV. Antibiotic prophylaxis for surgery in morbidly obese patients. *Surgery* 1989;106:750–756, discussion 756–7.
21. Tanner J, Parkinson H. Double gloving to reduce surgical cross-infection. *Cochrane Database Syst Rev* 2006;CD003087.
22. Darouiche RO, Wall MJ Jr, Itani KM et al. Chlorhexidine-alcohol versus povidone-iodine for surgical-site antisepsis. *N Engl J Med* 2010;362:18–26.
23. Hutchinson JJ, McGuckin M. Occlusive dressings: a microbiologic and clinical review. *Am J Infect Control* 1990;18:257–268.
24. Rao N, Cannella B, Crossett LS, Yates AJ Jr, McGough R 3rd. A preoperative decolonization protocol for staphylococcus aureus prevents orthopaedic infections. *Clin Orthop Relat Res* 2008;466:1343–1348.
25. Akins PT, Harris J, Alvarez JL et al. Risk factors associated with 30-day readmissions after instrumented spine surgery in 14,939 patients. *Spine* 2015;40:1022–32.
26. Kim BD, Hsu WK, De Oliveira GS Jr, Saha S, Kim JY. Operative duration as an independent risk factor for postoperative complications in single-level lumbar fusion: an analysis of 4588 surgical cases. *Spine* 2014;39:510–520.
27. Lau RL, Perruccio AV, Gandhi R, Mahomed NN. The role of surgeon volume on patient outcome in total knee arthroplasty: a systematic review of the literature. *BMC Musculoskelet Disord* 2012;13:250.
28. Al-Khatib SM, Lucas FL, Jollis JG, Malenka DJ, Wennberg DE. The relation between patients' outcomes and the volume of cardioverter-defibrillator implantation procedures performed by physicians treating Medicare beneficiaries. *J Am Coll Cardiol* 2005;46:1536–1540.
29. Manchikanti L, Benyamin RM, Swicegood JR et al. Assessment of practice patterns of perioperative management of antiplatelet and anticoagulant therapy in interventional pain management. *Pain Physician* 2012;15:E955–E968.
30. Benzon HT, Kendall MC, Katz JA et al. Prescription patterns of pain medicine physicians. *Pain Pract* 2013;13:440–450.
31. Woods A. Key points in the CDC's surgical site infection guideline. *Adv Skin Wound Care* 2005;18:215–220.
32. Stulberg JJ, Delaney CP, Neuhauser DV, Aron DC, Fu P, Koroukian SM. Adherence to surgical care improvement project measures and the association with postoperative infections. *JAMA* 2010;303:2479–2485.
33. Burke JP. Maximizing appropriate antibiotic prophylaxis for surgical patients: an update from LDS Hospital, Salt Lake City. *Clin Infect Dis* 2001;33 (Suppl. 2): S78–S83.
34. Tanner J, Norrie P, Melen K. Preoperative hair removal to reduce surgical site infection. *Cochrane Database Syst Rev* 2011;(11):CD004122.
35. Niel-Weise BS, Wille JC, van den Broek PJ. Hair removal policies in clean surgery: systematic review of randomized, controlled trials. *Infect Control Hosp Epidemiol* 2005;26:923–928.
36. Thomas S, Agarwal M, Mehta G. Intraoperative glove perforation—single versus double gloving in protection against skin contamination. *Postgrad Med J* 2001;77:458–460.
37. 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.
38. Ostrander RV, Botte MJ, Brage ME. Efficacy of surgical preparation solutions in foot and ankle surgery. *J Bone Joint Surg Am* 2005;87:980–985.
39. Rudiger J, Thomson S. Infection rate of spinal cord stimulators after a screening trial period. A 53-month third party follow-up. *Neuromodulation* 2011;14: 136–141.
40. Ohtori S, Inoue G, Koshi T et al. Long-term intravenous administration of antibiotics for lumbar spinal surgery prolongs the duration of hospital stay and time to normalize body temperature after surgery. *Spine* 2008;33:2935–2937.
41. Bode LG, Kluytmans JA, Wertheim HF et al. Preventing surgical-site infections in nasal carriers of *Staphylococcus aureus*. *N Engl J Med* 2010;362:9–17.
42. Rao N, Cannella BA, Crossett LS, Yates AJ Jr, McGough RL 3rd, Hamilton CW. Preoperative screening/decolonization for staphylococcus aureus to prevent orthopedic surgical site infection prospective cohort study with 2-year follow-up. *J Arthroplasty* 2011;26:1501–7.
43. Engle MP, Vinh BP, Harun N, Koyyalagunta D. Infectious complications related to intrathecal drug delivery system and spinal cord stimulator system implantations at a Comprehensive Cancer Pain Center. *Pain Physician* 2013;16:251–257.

APPENDIX

Appendix 1: Survey Questionnaire

- 1: Do you utilize preoperative antibiotics for spinal cord stimulator trials?
- 1) Yes
 - 2) No
- 2: If yes to question 1, do you utilize weight base dosing? If no to question 1, please select not applicable.
- 1) Yes
 - 2) No
 - 3) Not applicable
- 3: Do you utilize preoperative antibiotics for spinal cord stimulator implants?
- 1) Yes
 - 2) No
- 4: If yes to question 3, do you utilize weight base dosing? If no to question 3, please select not applicable.
- 1) Yes
 - 2) No
 - 3) Not applicable
- 5: What is your time frame for administering perioperative antibiotics (excluding vancomycin)?
- 1) 1–30 min prior to the surgical incision
 - 2) 31–60 min prior to the surgical incision
 - 3) >60 min prior to the surgical incision
 - 4) After incision
- 6: If hair removal is required prior to surgical intervention, how and when do you primarily choose to remove the hair?
- 1) Shaving >24 hours before the operation
 - 2) Electric clippers >24 hours before the operation
 - 3) Shaving immediately before the operation
 - 4) Electric clippers immediately before the operation
- 7: Is it your routine practice to preoperatively test for methicillin-resistant *Staphylococcus aureus* (MRSA) colonization via nasal swab?
- 1) Yes
 - 2) No
- 8: Is it your routine practice to preoperatively test for methicillin-sensitive *Staphylococcus aureus* (MSSA) colonization via nasal swab?
- 1) Yes
 - 2) No
- 9: If you have a positive test for MRSA in a patient without a beta-lactam allergy, how do you manage? Choose all that apply.
- 1) Mupirocin ointment
 - 2) Chlorhexidine baths
 - 3) Vancomycin administration for antibiotic prophylaxis
 - 4) Teicoplanin administration for antibiotic prophylaxis
 - 5) Gentamicin administration for antibiotic prophylaxis
 - 6) No changes are made based on test finding
- 10: If you have a positive test for MSSA in a patient without a beta-lactam allergy, how do you manage? Choose all that apply.
- 1) Mupirocin ointment
 - 2) Chlorhexidine baths
 - 3) Vancomycin administration for antibiotic prophylaxis
 - 4) Teicoplanin administration for antibiotic prophylaxis
 - 5) Gentamicin administration for antibiotic prophylaxis
 - 6) No changes are made based on test finding
- 11: Do you use any of the following routinely, independently of a preoperative positive test result for *Staphylococcus* species? Choose all that apply.
- 1) Mupirocin ointment
 - 2) Chlorhexidine baths
 - 3) Vancomycin administration
 - 4) None of the above
- 12: What are your indications for the use of prophylactic intravenous vancomycin? If this question does not apply to you, choose not applicable and proceed to the next question. Choose all that apply.
- 1) Patients colonized with MRSA (detected during screening)
 - 2) Patients with history of infection with MRSA
 - 3) Institutionalized patients (nursing home, dialysis, etc.)
 - 4) Inpatient hospitalization within the last year
 - 5) Patients with proven beta-lactam allergy
 - 6) All patients
 - 7) Not applicable
- 13: What are your indications for the use of prophylactic intravenous teicoplanin and +/- gentamicin? If this question does not apply to you, choose not applicable and proceed to the next question. Choose all that apply.
- 1) Patients colonized with MRSA (detected during screening)
 - 2) Patients with history of infection with MRSA
 - 3) Institutionalized patients (nursing home, dialysis, etc.)
 - 4) Inpatient hospitalization within the last year
 - 5) Patients with proven beta-lactam allergy
 - 6) All patients
 - 7) Not applicable
- 14: Which preoperative skin antiseptic agent do you most commonly utilize prior to surgery?
- 1) Povidone-iodine
 - 2) Chlorhexidine gluconate
 - 3) Isopropyl alcohol
 - 4) A combination of both Povidone-iodine and isopropyl alcohol
 - 5) A combination of both Chlorhexidine gluconate and isopropyl alcohol
 - 6) Other (please specify)
- 15: Which of the following steps do you perform following skin antisepsis to cover the surgical field?
- 1) Placement of an iodophor impregnated incise adhesive drape
 - 2) Placement of a non-impregnated plastic incise adhesive drape
 - 3) An incise adhesive drape is not placed
- 16: What type of trialing and implantation pathway do you most commonly follow?
- 1) Separate trial and separate full implant
 - 2) Staged trial and completion implant
- 17: For surgical gloving, do you utilize?
- 1) Single gloving
 - 2) Double gloving
- 18: Do you irrigate the surgical wounds prior to closure?
- 1) Yes
 - 2) No
- 19: If yes to question 18, do you add antibiotics to the irrigation solution? If no to question 18, please select not applicable.
- 1) Yes
 - 2) No
 - 3) Not applicable

- 20: For skin wound closure, do you utilize?
- 1) Surgical staples
 - 2) Absorbable sutures
 - 3) Nonabsorbable sutures
 - 4) Absorbable sutures and liquid skin adhesive
- 21: What is the typical operative time associated with the implantation stage?
- 1) ≤ 60 min
 - 2) >60 and ≤ 90 min
 - 3) >90 and ≤ 120 min
 - 4) >120 min
- 22: Do you continue antibiotics into the postoperative period for spinal cord stimulator trials?
- 1) Yes
 - 2) No
- 23: If yes to question 22, during what time frame do you typically administer the antibiotics? If no to question 22, please select not applicable.
- 1) ≤ 24 hours
 - 2) >24 to ≤ 48 hours
 - 3) >48 to ≤ 96 hours
 - 4) Entire duration of trial
 - 5) Not applicable
 - 6) Other (please specify)
- 24: Do you continue antibiotics into the postoperative period for spinal cord stimulator implants?
- 1) Yes
 - 2) No
- 25: If yes to question 24, during what time frame do you typically administer the antibiotics? If not to question 24, please select not applicable.
- 1) ≤ 24 hours
 - 2) >24 to ≤ 48 hours
 - 3) >48 to ≤ 96 hours
 - 4) >96 to ≤ 168 hours
 - 5) >168 to ≤ 336 hours
 - 6) Not applicable
 - 7) Other (please specify)
- 26: What type of dressing do you apply to the surgical incision following a spinal cord stimulator trial?
- 1) Occlusive
 - 2) Nonocclusive
- 27: What type of dressing do you apply to the surgical incision following a spinal cord stimulator implant?
- 1) Occlusive
 - 2) Nonocclusive
- 28: What is the maximum time criterion for defining a deep surgical site infection (an infection extending into the muscle and fascia layers) for an implantable device?
- 1) 30 days after surgery
 - 2) 90 days after surgery
 - 3) 180 days after surgery
 - 4) 365 days after surgery
- 29: How long do you wait to progress forward to a permanent implantation following the removal of the trial lead?
- 1) ≤ 1 week
 - 2) >1 week to ≤ 2 weeks
 - 3) >2 weeks to ≤ 3 weeks
 - 4) >3 weeks
- 30: What type of practice are you in?
- 1) Private solo practice
 - 2) Private group practice
 - 3) Academic practice
 - 4) Hospital based program
- 31: How many spinal cord stimulator trials for you personally perform per year?
- 1) ≤ 5 trials
 - 2) >5 trials to ≤ 10 trials
 - 3) >10 trials to ≤ 20 trials
 - 4) >20 trials to ≤ 40 trials
 - 5) >40 trials
- 32: How many spinal cord stimulator implants do you personally perform per year?
- 1) ≤ 5 implants
 - 2) >5 implants to ≤ 10 implants
 - 3) >10 implants to ≤ 20 implants
 - 4) >20 implants to ≤ 40 implants
 - 5) >40 implants
- 33: What is your practice geographic location?
- 1) North America—USA
 - 2) North America—Other
 - 3) South America
 - 4) Europe
 - 5) Africa
 - 6) Asia
 - 7) Australia