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Antibiotics for Spinal Cord Stimulation Trials and Implants: A Survey Analysis of Practice Patterns

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Abstract

Background: Spinal cord stimulation (SCS) is an established treatment modality for neuropathic pain. Published guidelines exist to aid physicians in proper antibiotic use during and after spinal cord stimulation trials and implants. In this brief review, we present and analyze the current antibiotic practice patterns of clinicians.

Methods: The study protocol was reviewed and granted an exemption by an Institutional Review Board. The survey queried practice parameters in regards to spinal cord stimulation therapy. The American Society of Regional Anesthesia and Pain Medicine (ASRA) and Society of Interventional Spine (SIS) distributed the survey to their active members by emails with a web link to the survey.

Results: Our results indicate that 82% and 69% of physicians do not utilize nasal swabs for methicillin-sensitive *Staphylococcus aureus* (MSSA) or methicillin-resistant *Staphylococcus aureus* (MRSA), respectively, prior to SCS trial and implantation. During trials, 47% providers administer a single dose of antibiotics, 35% administer antibiotics for the duration of the trial, and 17% do not administer antibiotics. During implantation, 44% of physicians administer a single dose during the procedure, 11% administer antibiotics up to 24 hours, 24% administer antibiotics between 3-5 days, 14% administer antibiotics for more than 5 days, and 4% do not administer antibiotics.

Conclusions: Our study suggests a portion of pain physicians do not adhere to the Neuromodulation Appropriateness Consensus Committee (NACC) guidelines in regards to antibiotic administration for SCS trial and implantation. Further analysis and surveys would allow insight into common practices. More information and education would be beneficial to optimize peri-procedure antibiotic use to reduce infection risk and decrease antimicrobial resistance.

Keywords: Spinal Cord Stimulation, Implantable Pulse Generator, Neuromodulation, Surgical Site Infections, Bacteria, Morbidity, Antibiotics, Nasal Swab

1. Background

Neuromodulation such as spinal cord stimulation (SCS), peripheral nerve stimulation (PNS), dorsal root ganglion stimulation (DRG), and intrathecal drug delivery (IDD) are common interventional and effective therapies for intractable neuropathic pain (1-5). Whereas the primary indications for spinal cord stimulation remain failed back surgery syndrome and complex regional pain syndrome, recent advances are widening indications of use including chronic intractable back pain without previous surgery where other treatments have failed (6-8). It is therefore likely that this treatment will be increasingly used in the future. Furthermore, several interventional and medical (opioids and non-opioids) approaches have been considered to target chronic and intractable pain (e.g. low back pain), with different efficacy and risks (9-17).

Surgical site infections (SSIs), which accounts for a significant portion of healthcare associated infections, are a common cause of morbidity, mortality, and increased healthcare costs (18-20). Infection rates associated with SCS vary in the literature from 1 - 10% and are relatively greater to those recorded for other implantable devices (21-23). The majority of SSIs are due to the patient's skin

flora, with *Staphylococcus aureus* and coagulase-negative staphylococci being the predominant bacteria. In addition, methicillin-resistant *Staphylococcus aureus* (MRSA) is becoming more prevalent, and increasingly more difficult to treat (22). The implantable pulse generator (IPG) site is the chief location for over 50% of infections related to SCS (22).

The Center for Disease Control and Prevention (CDC) recommends several measures to prevent surgical site infections (24). These measures include pre-operative measures, such as glycemic control, avoiding routine use of vancomycin, and intraoperative measures, including skin antisepsis, and limiting traffic within the operating room (24). The use of a prophylactic antibiotic therapy is categorized as a class IA, meaning it is strongly recommended for implementation and supported by well-designed studies (24). The Neuromodulation Appropriateness Consensus Committee (NACC) guidelines also recommend the use of pre-operative antibiotic prophylaxis as a strong and effective practice in preventing SSI, with up to 50% reduction in infections (22, 25). It is worth noting that antibiotic therapy should be tailored to the patient, such that it is weight based and appropriately formulated from the nasal swab. Without optimizing antibiotic therapy, the risk of wound infections is dramatically increased (22, 26).

In 2013, Provenzano et al. conducted a survey on perioperative infection control practices (27). The survey revealed that only 4 of 15 questions regarding infection control recommend practice had high compliance (27). The Neuromodulation Appropriateness Consensus Committee (NACC) Recommendations for Infection Prevention and Management were published in 2017 to improve patient care and reduce morbidity and mortality related to surgical site infections (22). Their recommendations include optimizing diabetes, smoking cessation, utilizing pre-procedural nasal swab testing, and weight-based antibiotics (22).

We designed a 31-item questionnaire regarding common and important topics for spinal cord stimulation to assess common practices in the neuromodulating community, including questions about antibiotic usage during trial and implant as well as screening for *Staphylococcus aureus* and MRSA. Given that SCS infection rates continue to be higher than other implantable devices, we have devoted this article to discuss and analyze the details pertaining to the use of antibiotics and detection of methicillin-sensitive *Staphylococcus aureus* (MSSA) and MRSA colonization.

2. Methods

A questionnaire was developed to inquire about practices around SCS. Questions were designed by the authors based upon perceived importance, and purposefully limited to prevent the survey becoming excessively long or burdensome. It was submitted and approved by the Institutional Review Board and, subsequently, approved by the Boards of American Society of Regional Anesthesia (ASRA) and Spine Intervention Society (SIS). The survey could not be sent to a dedicated neuromodulation society because of logistic issues.

A modified questionnaire, consisting of 31 questions related to various aspects of SCS practice, was translated into the Survey Monkey, Inc., Copyright 1999 - 2021, available at https://wwww.surveymonkey.com. The questionnaire was then distributed by the ASRA and SIS to all active members by email with the web link for anonymous participation. Given many pain physicians are members of both societies, recipients were asked to complete the survey only once. The response rate was calculated based on number of members who opened the email and assuming only 20% of the recipients were truly eligible because these are multidisciplinary societies. We did not make adjustment for overlapping membership because this information is also not available. This review presents the findings of the questions pertaining to the perioperative use of antibiotics during trial and permanent implants, and nares swabbing for MSSA and MRSA.

3. Results

The results for the questions regarding perioperative antibiotic use and nasal swabbing are presented below. The survey was delivered to 2967 members of SIS and 3169 members of ASRA with 1259 and 1477 members of each society opening the email. Of those which opened the email, a maximum of 195 responses were received. The survey responses were attained between 20th March 2020 and 26th June, 2020. Assuming 20% recipients were actively practicing SCS, the response rate for question 1 was 35.6%, question 2 was 33.1%, question 3 was 35.6% and question 4 was 35.5%.

There was significant heterogeneity among physicians on the use of antibiotics for the SCS procedure. As seen in Table 1, the majority of physicians use antibiotics for the trial (82.6%), with 47% using a single dose of antibiotics during the procedure and 35% using antibiotics for the duration of the trial. Approximately 17% of physicians do not administer any antibiotics during the procedure or the duration of the trial. For the use of antibiotics for the permanent implant, over 95% of pain physicians utilize antibiotics (refer to Table 2). This was further assessed by length of usage, with 44% utilizing a single dose during the procedure, 11% utilizing antibiotics for up to 24 hours, 24% utilizing antibiotics between 3 - 5 days, and 14% utilizing antibiotics for more than 5 days. A small portion of physi-

cians, 4%, do not administer antibiotics for the permanent implant.

The use of nasal swabs prior to undertaking any SCS procedure was low. Table 3 outlines the use of nasal swabs prior SCS trial or implantation. Approximately 69% and 82% of physicians do not incorporate MRSA and MSSA nasal swabs prior the procedure.

4. Discussion

The practice parameters for perioperative infection control vary among clinicians. The results of almost 200 practicing neuromodulation physicians presented here provide information on basic infection control practices for both SCS trials and implants. Compared to the survey by Provenzano et al, there has not been a substantial increase in the use of antibiotics among clinicians (> 80% vs > 82%) for SCS trials (27). Nonetheless, there continues to be a significant portion of physicians who do not adhere to the NACC guidelines. Our data suggest 47% and 56% of physicians utilize antibiotics for trials and implants, respectively, as a single dose or up to 24 hours, which is in compliance with NACC guidelines. Approximately 39% of providers extend antibiotic use up to more than 5 days for implants. As compared to Provenzano et al, the number of clinicians that continue antibiotics in the postoperative period has decreased to 35% from 50.5% for SCS trials and to 39% from 57% for implants (27). This decrease may reflect the NACC guidelines' recommendation to consider discontinuing antibiotics within 24 hours for implantation (22). Indeed, infections associated with SCS are the most common complication after implantation (23). This can lead to not only explantation and infection in the epidural space, but also increased morbidity, and increased healthcare costs (23, 28). However, studies indicate prolonged antibiotic use in the post-operative period does not improve outcomes and may contribute to multidrug-resistant bacteria, including MRSA, which can lead to increased morbidity and mortality (22, 29, 30). On the other hand, 17% (34/181) of clinicians do not use antibiotics prior to performing an SCS trial and 4% (8/195) prior to an SCS implant despite evidence that the preoperative use of antibiotics, independent of surgery type, results in a 50% decrease in the incidence of wound infections (23, 25).

NACC guidelines help establish standard practices in order to improve patient safety. For the purposes of antibiotic use, they recommend pre-procedure antibiotic use and discontinuation of antibiotics within 24 hours (22). NACC guidelines endorse tailoring antibiotics to community, hospital, and resistance patterns of organisms (22). They further recommend that for most SCS procedures, a single dose of a cephalosporin, such as cefazolin, is appropriate (22). Cefazolin is favorable in terms of having a high safety profile, low cost, and activity against common organisms, such as MSSA, that cause SSIs (28, 31). In patients with a beta-lactam allergy, clindamycin or vancomycin can be considered (22). However, vancomycin should be reserved for patients with MRSA colonization, as seen on nasal swab (22, 28, 32, 33). This is important to help limit multidrug resistant infections, including vancomycin-resistant strains (34). In addition, vancomycin is less effective than cefazolin in preventing MSSA related SSIs (28, 35). The antibiotic should be administered intravenously approximately 30 - 60 minutes prior to incision, with the exception of vancomycin which should be administered 120 minutes prior to incision (22, 28).

Our results also indicate that a large percentage of clinicians (82% and 69%) are not testing for MSSA or MRSA prior to a SCS trial or implant, despite level IA evidence from the NACC guidelines to decolonize MRSA prior to the procedure (22). This underutilized diagnostic test can help identify patients who are carriers of MSSA and MRSA and is recommended by the NACC guidelines (22). Because being either a MSSA or MRSA carrier is the most important risk factor of SSIs, these patients are at a significantly higher risk of developing an infection (22, 36-39). Both MSSA and MRSA are commonly located in the anterior nares, perianal, and groin regions (22). Pre-procedure nasal swab testing for both MSSA and MRSA, allows for the detection of these bacteria to not only signify when to decolonize the patient, but to administer appropriate antibiotics, such as vancomycin. Decolonization entails application of mupirocin nasal ointment and chlorhexidine wash prior the procedure (22). About to 1/3 of the population are carriers of S. aureus, illustrating that nasal swabs are cost effective manner to identify a large portion of patients who are at higher risk of infection (22, 40). Despite this, nasal screening may not detect up to 20% of patients with colonization (41). On the other hand, it is not clear if universal decolonization may be beneficial (41). Decolonization with mupirocin may also lead to mupirocin resistance S. aureus, which can potentially cause failure of decolonization (41). More information is needed to determine optimization of decolonization.

There continue to be obstacles in which ongoing education and NACC guidelines are not implemented by physicians. The duration of antibiotic use in SCS and nasal swab testing vary widely among practicing physicians. Provenzano et al published in 2013, and nearly 7 years later, our results remain comparable (27). The barriers to adoption of best antibiotic prophylaxis measures may include lack of accessibility of information and consensus guidelines, ongoing education regarding guidelines, and physicians'

Table 1. Antibiotic Prophylaxis Use During the Spinal Cord Stimulator Trial Phase

Question # 1	No	Yes-One Dose During Procedure	Yes-Through Duration of Trial
Do you use antibiotics for the period of the trial? (95% CI)	17.4 (12.1 - 22.8)	47.2 (40.2 - 54.2)	35.4 (28.7 - 42.1)
No.	34	92	69

Abbreviation: CI, confidence interval.

Table 2. Antibiotic Prophylaxis Use During the Permanent Spinal Cord Stimulator Implant Phase

Question # 2	No	Yes- One Time Within 60 Minutes of Skin Incision	Yes-Up to 24 Hours	Yes-For 3-5 Days	Yes-More Than 5 Days
Do you use antibiotics for the permanent implant? (95% CI)	4.4 (1.4 - 7.4)	44.8 (37.5 - 52.0)	11.6 (6.9 - 16.3)	24.3 (18.1 - 30.6)	14.9 (9.7 - 20.1)
No.	8	81	21	44	27

Abbreviation: CI, confidence interval.

Table 3. Use of Nasal Swabs for MSSA/MRSA Peri-procedurally

Question # 3 & 4	No	Yes
3. Do you use nasal swab for MRSA before trial/implant? (95%CI)	69.2 (62.8 - 75.7)	30.8 (24.3 - 37.2)
No.	135	60
4. Do you use nasal swab for MSSA before trial/implant? (95% CI)	82.5 (77.1 - 87.8)	17.5 (12.2 - 22.9)
No.	160	34

adherence to their routine practices.

4.1. Limitations

There are several limitations in our study. The survey link was emailed to over 6000 members with active general membership through the American Society of Regional Anesthesia and Spine Intervention Society. Membership through these societies included physicians with a variety of practices and, of which a small portion perform neuromodulation procedures, such as spinal cord stimulation. We were unable to send the survey to societies for neuromodulation due to logistical reasons. We estimated that 10-20% of the recipients were eligible to respond to the questionnaire. In addition, there are overlapping members between the two societies, making it difficult to account for the true number of interventional pain physicians who perform SCS within these groups. This may have influenced the response rate to be lower as the overlap was unknown. The questionnaire also did not investigate further details, including the class of antibiotics administered, timing of antibiotic administration, weight-based antibiotic dosing, and the reasoning behind physicians' common antibiotic administration practices. The study also did not assess the use of direct wound application of antibiotics (e. g. vancomycin powder). Ideally, a larger study would provide more information regarding antibiotic use and nasal swab use as typical practices for pain physicians.

4.2. Conclusions

The use of perioperative infection control practices continues to vary among neuromodulation clinicians. Surgical site infections are the most common complication for spinal cord stimulation and are associated with increased morbidity and mortality. The NACC provides guidelines to provide a consensus to improve patient safety and standardize practices. In regard to antibiotic administration, the NACC advocates that a single preoperative dose of antibiotics is largely sufficient. Antibiotic should be tailored to nasal swab testing, weight-based dosing, and discontinuation of antibiotics within 24 hours. More education is needed to continue to refine guidelines and recommendations, and more importantly, to disperse the information to practicing pain physicians. Our data suggest the majority of physicians do not utilize nasal swabs to determine MSSA and MRSA presence. Although most physicians administer antibiotics peri-procedurally for both trial and permanent phases, they administer them for typically longer durations than recommended by the NACC. There also continues to remain a significant portion of physicians who do not administer antibiotics. This review gives initial data regarding the use of antibiotics from a large group of interventional pain physicians, allowing providers to review how the majority of pain physicians

practice with regards to antibiotic usage. Further analysis and questionnaires should be performed to determine how physicians select antibiotics.

Footnotes

Authors' Contribution: Study concept and design: SS, JH, IU, OV, TS, JG, LK; Analysis and interpretation of data: SS, JH, TS, JG, LK; Drafting of the manuscript: SS, JH, IU, OV, KM, TS, JG, LK; Critical revision of the manuscript for important intellectual content: SS, JH, IU, OV, KM, TS, JG, LK; Statistical analysis: SS, JH, JG, LK.

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References

1. Kumar K, Taylor RS, Jacques L, Eldabe S, Meglio M, Molet J, et al. The effects of spinal cord stimulation in neuropathic pain are sustained: a 24-month follow-up of the prospective randomized controlled multicenter trial of the effectiveness of spinal cord stimulation. *Neurosurgery*. 2008;**63**(4):762–70. discussion 770. doi: 10.1227/01.NEU.0000325731.46702.D9. [PubMed: 18981888].
2. Berger AA, Liu Y, Possoit H, Rogers AC, Moore W, Gress K, et al. Dorsal Root Ganglion (DRG) and Chronic Pain. *Anesth Pain Med*. 2021;**11**(2). e113020. doi: 10.5812/aapm.113020. [PubMed: 34336621]. [PubMed Central: PMC8314073].
3. Amorizzo E, Colini-Baldeschi G. Peripheral Nerve Stimulation: Two Cases of Intractable Neuropathic Pain. *Anesth Pain Med*. 2021;**11**(2). e113162. doi: 10.5812/aapm.113162. [PubMed: 34336623]. [PubMed Central: PMC8314092].
4. Urits I, Schwartz R, Smoots D, Koop L, Veeravelli S, Orhurhu V, et al. Peripheral Neuromodulation for the Management of Headache. *Anesth Pain Med*. 2020;**10**(6). e110515. doi: 10.5812/aapm.110515. [PubMed: 34150578]. [PubMed Central: PMC8207880].
5. Sun C, Wang YT, Dai YJ, Liu ZH, Yang J, Cheng ZQ, et al. Programmable Pump for Intrathecal Morphine Delivery to Cisterna Magna: Clinical Implications in Novel Management of Refractory Pain Above Middle Thoracic Vertebrae Level Utilizing a Prospective Trial Protocol and Review. *Anesth Pain Med*. 2021;**11**(3). e115873. doi: 10.5812/aapm.115873. [PubMed: 34540643]. [PubMed Central: PMC8438709].
6. Al-Kaisy A, Van Buyten JP, Kapural L, Amirdelfan K, Gliner B, Caraway D, et al. 10 kHz spinal cord stimulation for the treatment of non-surgical refractory back pain: subanalysis of pooled data from two prospective studies. *Anaesthesia*. 2020;**75**(6):775–84. doi: 10.1111/anae.15036. [PubMed: 32383509]. [PubMed Central: PMC7384077].
7. Abejon D, Vancamp T, Monzon EM. A Cost-Consequence Analysis Examining the Differences Between Non-Rechargeable and Rechargeable Systems. *Anesth Pain Med*. 2020;**10**(1). e100308. doi: 10.5812/aapm.100308. [PubMed: 32337173]. [PubMed Central: PMC7158244].
8. Berger AA, Urits I, Hasoon J, Gill J, Aner M, Yazdi CA, et al. Improved Pain Control with Combination Spinal Cord Stimulator Therapy Utilizing Sub-perception and Traditional Paresthesia Based Waveforms: A Pilot Study. *Anesth Pain Med*. 2021;**11**(1). e113089. doi: 10.5812/aapm.113089. [PubMed: 34221951]. [PubMed Central: PMC8241823].
9. Patel VB, Wasserman R, Imani F. Interventional Therapies for Chronic Low Back Pain: A Focused Review (Efficacy and Outcomes). *Anesth Pain Med*. 2015;**5**(4). e29716. doi: 10.5812/aapm.29716. [PubMed: 26484298]. [PubMed Central: PMC4604560].
10. Imani F, Rahimzadeh P, Khademi H, Narimani Zamanabadi M, Sadegi K, Abolfazli A. Comparison of Transforaminal Triamcinolone and Dexmedetomidine in Radicular Low-Back Pain: A Randomized Double-Blind Clinical Trial. *Anesth Pain Med*. 2019;**9**(5). e96117. doi: 10.5812/aapm.96117. [PubMed: 31903335]. [PubMed Central: PMC6935293].
11. Rostami K, Sharif F, Zarshenas L, Ebadi A, Farbood A. Health Needs in Patients Suffering from Chronic Back Pain: A Qualitative Study. *Anesth Pain Med*. 2019;**9**(2). e85244. doi: 10.5812/aapm.85244. [PubMed: 31341823]. [PubMed Central: PMC6614852].
12. Edinoff AN, Girma B, Trettin KA, Horton CC, Kaye AJ, Cornett EM, et al. Novel Regional Nerve Blocks in Clinical Practice: Evolving Techniques for Pain Management. *Anesth Pain Med*. 2021;**11**(4). e118278. doi: 10.5812/aapm.118278.
13. Marliana A, Setyopranoto I, Setyaningsih I, Rhatomy S. The Effect of Pulsed Radiofrequency on Radicular Pain in Lumbal Herniated Nucleus Pulposus: A Systematic Review and Meta-analysis. *Anesth Pain Med*. 2021;**11**(2). e111420. doi: 10.5812/aapm.111420. [PubMed: 34336613]. [PubMed Central: PMC8314080].
14. Malik KM, Imani F, Beckerly R, Chovatiya R. Risk of Opioid Use Disorder from Exposure to Opioids in the Perioperative Period: A Systematic Review. *Anesth Pain Med*. 2020;**10**(1). e101339. doi: 10.5812/aapm.101339. [PubMed: 32337175]. [PubMed Central: PMC7158240].
15. Edinoff AN, Kaplan LA, Khan S, Petersen M, Sauce E, Causey CD, et al. Full Opioid Agonists and Tramadol: Pharmacological and Clinical Considerations. *Anesth Pain Med*. 2021;**11**(4). e119156. doi: 10.5812/aapm.119156.
16. Urits I, Jung JW, Amgalan A, Fortier L, Anya A, Wesp B, et al. Utilization of Magnesium for the Treatment of Chronic Pain. *Anesth Pain Med*. 2021;**11**(1). e112348. doi: 10.5812/aapm.112348. [PubMed: 34221945]. [PubMed Central: PMC8236839].
17. Tully J, Jung JW, Patel A, Tukan A, Kandula S, Doan A, et al. Utilization of Intravenous Lidocaine Infusion for the Treatment of Refractory Chronic Pain. *Anesth Pain Med*. 2020;**10**(6). e112290. doi: 10.5812/aapm.112290. [PubMed: 34150583]. [PubMed Central: PMC8207879].
18. Uckay I, Harbarth S, Peter R, Lew D, Hoffmeyer P, Pittet D. Preventing surgical site infections. *Expert Rev Anti Infect Ther*. 2010;**8**(6):657–70. doi: 10.1586/eri.10.41. [PubMed: 20521894].
19. Leaper DJ, Tanner J, Kiernan M, Assadian O, Edmiston CJ. Surgical site infection: poor compliance with guidelines and care bundles. *Int Wound J*. 2015;**12**(3):357–62. doi: 10.1111/iwj.12243. [PubMed: 24612792]. [PubMed Central: PMC7950697].
20. 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. doi: 10.2106/JBJS.I.00549. [PubMed: 19884406].
21. Deer TR, Mekhail N, Provenzano D, Pope J, Krames E, Thomson S, et al. The appropriate use of neurostimulation: avoidance and treatment of complications of neurostimulation therapies for the treatment of chronic pain. Neuromodulation Appropriateness Consensus Committee. *Neuromodulation*. 2014;**17**(6):571–97. discussion 597-8. doi: 10.1111/ner.12206. [PubMed: 25112891].
22. Deer TR, Provenzano DA, Hanes M, Pope JE, Thomson SJ, Russo MA, et al. The Neurostimulation Appropriateness Consensus Committee (NACC) Recommendations for Infection Prevention and Management. *Neuromodulation*. 2017;**20**(1):31–50. doi: 10.1111/ner.12565. [PubMed: 28042909].
23. 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**(2):136–41. discussion 141. doi: 10.1111/j.1525-1403.2010.00317.x. [PubMed: 21992200].
24. Center for Disease Control. *Guideline for Prevention of Surgical Site Infection*. 2017. Available from: https://www.cdc.gov/infectioncontrol/guidelines/ssi/index.html.
25. 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**(4):551–6. doi: 10.1097/SLA.0b013e318199f202. [PubMed: 19300236].
26. Burke JP. Maximizing appropriate antibiotic prophylaxis for surgical patients: an update from LDS Hospital, Salt Lake City. *Clin Infect Dis*. 2001;**33 Suppl 2**:S78–83. doi: 10.1086/321861. [PubMed: 11486303].
27. Provenzano DA, Deer T, Luginbuhl Phelps A, Drennen ZC, Thomson S, Hayek SM, et al. An International Survey to Understand Infection Control Practices for Spinal Cord Stimulation. *Neuromodulation*. 2016;**19**(1):71–84. doi: 10.1111/ner.12356. [PubMed: 26490243].
28. Anderson DJ, Sexton DJ, Post T. *Antimicrobial prophylaxis for prevention of surgical site infection in adults*. Waltham: UpToDate; 2020, [cited 4 February 2021]. Available from: https://www.uptodate.com/contents/antimicrobial-prophylaxis-for-prevention-of-surgical-site-infection-in-adults.
29. Nelson CL, Green TG, Porter RA, Warren RD. One day versus seven days of preventive antibiotic therapy in orthopedic surgery. *Clin Orthop Relat Res*. 1983;(176):258–63. [PubMed: 6851335].
30. Davies J, Davies D. Origins and evolution of antibiotic resistance. *Microbiol Mol Biol Rev*. 2010;**74**(3):417–33. doi: 10.1128/MMBR.00016-10. [PubMed: 20805405]. [PubMed Central: PMC2937522].
31. No authors listed. Antimicrobial prophylaxis for surgery. *Treat Guidel Med Lett*. 2012;**10**(122):73–8. quiz 79-80. [PubMed: 22996382].
32. Bratzler DW, Dellinger EP, Olsen KM, Perl TM, Auwaerter PG, Bolon MK, et al. Clinical practice guidelines for antimicrobial prophylaxis in surgery. *Surg Infect (Larchmt)*. 2013;**14**(1):73–156. doi: 10.1089/sur.2013.9999. [PubMed: 23461695].
33. 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. doi: 10.2106/JBJS.J.01046. [PubMed: 21123590].
34. Boneca IG, Chiosis G. Vancomycin resistance: occurrence, mechanisms and strategies to combat it. *Expert Opin Ther Targets*. 2003;**7**(3):311–28. doi: 10.1517/14728222.7.3.311. [PubMed: 12783569].
35. Bull AL, Worth LJ, Richards MJ. Impact of vancomycin surgical antibiotic prophylaxis on the development of methicillin-sensitive staphylococcus aureus surgical site infections: report from Australian Surveillance Data (VICNISS). *Ann Surg*. 2012;**256**(6):1089–92. doi: 10.1097/SLA.0b013e31825fa398. [PubMed: 22824854].
36. Perl TM, Cullen JJ, Wenzel RP, Zimmerman MB, Pfaller MA, Sheppard D, et al. Intranasal mupirocin to prevent postoperative Staphylococcus aureus infections. *N Engl J Med*. 2002;**346**(24):1871–7. doi: 10.1056/NEJMoa003069. [PubMed: 12063371].
37. Kluytmans J, van Belkum A, Verbrugh H. Nasal carriage of Staphylococcus aureus: epidemiology, underlying mechanisms, and associated risks. *Clin Microbiol Rev*. 1997;**10**(3):505–20. doi: 10.1128/CMR.10.3.505. [PubMed: 9227864]. [PubMed Central: PMC172932].
38. Wenzel RP, Perl TM. The significance of nasal carriage of Staphylococcus aureus and the incidence of postoperative wound infection. *J Hosp Infect*. 1995;**31**(1):13–24. doi: 10.1016/0195-6701(95)90079-9. [PubMed: 7499817].
39. Kalmeijer MD, van Nieuwland-Bollen E, Bogaers-Hofman D, de Baere GA. Nasal carriage of Staphylococcus aureus is a major risk factor for surgical-site infections in orthopedic surgery. *Infect Control Hosp Epidemiol*. 2000;**21**(5):319–23. doi: 10.1086/501763. [PubMed: 10823564].
40. Hutzschenreuter L, Flessa S, Dittmann K, Hubner NO. Costs of outpatient and inpatient MRSA screening and treatment strategies for patients at elective hospital admission - a decision tree analysis. *Antimicrob Resist Infect Control*. 2018;**7**:147. doi: 10.1186/s13756-018-0442-x. [PubMed: 30519461]. [PubMed Central: PMC6267031].
41. Anderson DJ, Sexton DJ, Cochran A, Collins KA. *Overview of control measures for prevention of surgical site infection in adults*. Massachusetts: UpToDate; 2017, [cited 16 February 2021]. Available from: https://www.uptodate.com/contents/overview-of-control-measures-for-prevention-of-surgical-site-infection-in-adults.