

Comprehensive Preventive Approach to Surgical Site Infections (SSIs): A Review

Seyed Mansour Razavi^{1,2}, Leila Seddigh^{1,*}, and Farnaz Khatami¹

¹ Department of Community Medicine, Tehran University of Medical Sciences, Tehran, Iran

² Research Center for Rational Use of Drugs, Tehran University of Medical Sciences, Tehran, Iran

* **Corresponding author:** Leila Seddigh, Department of Community Medicine, Tehran University of Medical Sciences, Tehran, Iran.
Email: l-seddigh@tums.ac.ir

Received 2017 January 25; Accepted 2017 September 17.

Abstract

Context: To deal with health problems, using an approach, based on prevention perspective, consist of different types of prevention, can be a proper way to manage the health problems such as surgical site infections (SSIs).

Introducing an action plan from the perspective of "prevention" for dealing with surgical site infections (SSIs).

Evidence Acquisition: We have used 5 known prevention levels as a simple approach for dealing with surgical site infections. For gathering information, electronic databases, including Scopus, Medline, ISI, IranMedex, and Irandoc sites were used.

Results: For prevention of surgical site infection, a comprehensive evidence based instruction, consist of 75 related factors and 74 proposed measurable and operational preventive activities was developed.

Conclusion: We concluded that, to deal with surgical site infections use of the proposed action plan may be useful. Even we believe that, this approach can be used to deal with any health problems including diseases, disorders, accidents and events.

Keywords: Hospital Infection Control, Prevention Levels, Prevention, Risk Factors, Surgical Site Infection

1. Context

Surgical site infection defined as the presence of at least one of the following criteria: Pain or tenderness, localized swelling, erythema, localized heat, purulent drainage, accompanied by the fever and anorexia with a positive culture from the superficial incision or subcutaneous tissue which occurs within 30 days after the surgery (1). There has been estimated that, about 234 million operations performed annually throughout the world (2). Surgical site infection is the most common healthcare-associated infection, and 31% of all hospitalized patients experience this complication (3). Threatening and common direct and indirect complications of SSI which impose costs and readmissions are as follows: Delayed wound healing, scars and keloids (4), atelectasis is common during and after general anesthesia (5), pneumonia, hospital stay and significant economic burden and direct and indirect costs due to readmission (re-operation, extra nursing care and resource utilization) (4, 6), toxemia, septicemia, septic shock, thrombophlebitis and emboli, failure of vital organs, and extensive debridement. One-third of postoperative deaths are related to SSI. Patient dissatisfaction and litigation, and reduced quality of life, are also other complications (4). Despite many advances in the field of hospital infection control, including: Improved operating rooms ventilation, improved methods of sterilization, progress of safety equipment, improved surgical techniques and availability of antibiotics for prophylaxis, hospital infections are still, one of the main cause of

increasing morbidity, duration of hospitalization, and mortality (7). So, because the prevention of SSI requires a multidisciplinary approach (2) in this study, we have used a simple approach consists of, different levels of prevention, including: primordial, primary, secondary, tertiary, quaternary, as well as malpractice prevention. Short definitions for these levels are as follows:

Primordial prevention: Measures designed to risk factors reduction. Primary prevention: applying measures to avoid the occurrence of diseases. Secondary prevention: measures to early diagnosis of an existing disease and early treatment. Tertiary prevention: measures to reduce disabilities, through applying of rehabilitation modalities. Quaternary prevention: measures to mitigate or avoid results of unnecessary interventions in the health system (over medicalization) (8) and medical malpractice as a doctor's failure to practice. In present study, we have provided a guide for comprehensive preventive approach to surgical site infections (SSIs).

2. Evidence Acquisition

For gathering information related to prevention of surgical site infections (SSIs), electronic databases, including Scopus, Medline, ISI, IranMedex, and Irandoc sites were used. We used the following key words in national and international sources: surgical site infection, hospital infection control, surgical infection control, prevention levels and risk factors. According to this search, 50 articles related to our aims were found and reviewed.

3. Results

There were listed 75 risk and predisposing factors and 74 activities in different preventive areas. The results, regarding proposed approach, were as follows:

3.1. Risk Factors Predisposing and Conditions

3.1.1. Factors Associated with the Patient

Age increasing (1, 2, 9) and diabetes mellitus (2, 9, 10), (significant relationships have been demonstrated between increased level of HgA1c and SSI rates) (11), postoperative anemia (12), obesity (BMI > 30) and overweight (9, 10, 13, 14), malnutrition (defined as significant weight loss 6 months prior to surgery) (2, 10, 15), stress (eg. due to fear or delayed surgery), renal insufficiency (creatinine < 2 mg/dL) (10), cigarette smoking (10, 15, 16), (cigarette smoking leading to tissue hypovolemia and hypoxia) (11), alcohol overuse (14, 17), cirrhosis (10), hypothermia (18), hypoxemia, (oxygen saturation less than 50% was identified as an independent risk factor for SSI) (9), low serum albumin/ hypoproteinemia (12), necrosis of operated area, malignant disease (10, 12, 16), COPD (chronic obstructive pulmonary disease) (10), decreased immunity/ having immunological disorders (1, 16), use of corticosteroids (e.g. following gastrointestinal surgery) (19), history of broad- spectrum antibiotics, 3- months before the surgery, chemotherapy and radiotherapy (e.g. breast-reconstruction surgery) (15), postoperative transfusion (20), excessive blood loss (11), coexistent infections (e.g. Peritonitis) (2, 12), colonization of the surgical site with bacteria (11), super imposed infections on chronic skin diseases such as psoriasis, eczema, etc., patient flora, patient nasal carrier state of staphylococcus sp. (21, 22), poor patient's hygiene and low socioeconomic status (9).

3.1.2. Pre-Operative Factors

Durations of hospitalization before surgery (1), the quality of patient's preparation for surgery (10), proper showering (21), shaving (10) and prophylaxis with antibiotics (1).

3.1.3. Factors Related to Operating Room

Uncontrolled traffic of operating room (2), low quality of air ventilation (10), presence of laminar air flow (LAF) system from less sterile areas into more sterile ones (2), lack of safe water for scrub (2), high temperature and humidity of operating room (23), low quality of environmental cleaning and disinfection (2).

3.1.4. Factors Related to Surgery Equipment

Contaminated surgical equipment (2), types of sutures (plain, antimicrobial-impregnated or triclosan-coated sutures) (24), use of non-

absorbable suture (11), types of urinary and long-term central venous catheters for total parenteral nutrition at pre-operation time.

3.1.5. Factors Related to the Surgeon and Staff

Surgeon's experience and skills (1, 2), tiredness and hastiness of the surgeon and staff, nasal carriage of the surgeon and staff (22), behaviors and habits of the surgeon and staff such as: poor communication, improperly used equipment, unhealthy behavior, and cognitive errors due to stress or inattention (2).

3.1.6. Factors Related to Surgery

Dirty surgeries (25), surgeries on devitalized tissues, foreign bodies, contamination with feces, and perforated guts, are prone to infection (11), surgeries of contaminated areas (abdomen, perineum and lower limbs are usually more contaminated than the other sites) (21), emergent surgeries versus elective surgeries (1, 11, 16), extensive operation area, incomplete preparation of surgical area, inadequate duration of surgical scrub (2, 10), operation duration (risk of infection rises in the times more than 2 hours) (1, 2, 10, 16), incision length > 14.7 cm (26), surgery technique, simple or complex technique (1, 10, 21), open surgery versus laparoscopic methods (27, 28), extensive and repeated cauterization (copious use of subcutaneous electrocautery) (11), poor oxygenation and poor homeostasis action of operation area (7), increase of bleeding and hematoma formation (29), use of drains, especially in the abdominal surgeries (25), insertion of foreign material or implants (2, 10), inadequate sterilization of surgical equipment (1, 2, 10).

3.1.7. Factors Related to the Organism

The patient's skin flora (21), virulence factors: Adherence components, capsules, invasion enzymes (hyaluronidase - collagenase - fibrinolytic enzymes - coagulase - proteases - nucleases - lipases) and toxins (exotoxins - endotoxins) (30), infectivity and antimicrobial resistance.

3.1.8. Factors Related to After the Surgery

Postoperative serum glucose levels higher than 200 mg/ dL (especially in cardiac surgery populations) (11), postoperative pain (9), wound manipulation, fear of bathing, immobility, not changing or removing surgical wound dressings timely disruption of sutures in surgery site, oozing, hematoma and wound drainage (29).

4. Primordial Activities (by Health Managers)

- Developing hospital standards and monitoring of them
- Setting up appropriate surveillance system

- Equip the operating rooms and intensive wards with LAF system through HEPA and ULPA filters. HEPA filters display 99.97% efficiency in removing airborne particles (2). Not using conventional fan or cooler in operating rooms (2, 9)

- Provide appropriate ventilation (exchange of the air 15 - 20 times per hour), heating, ventilation, air-conditioning system (HVAC) (2), appropriate temperature (18 to 24 degree centigrade) and proper humidity (20 to 60%) (23) for the operating rooms

- Provide appropriate sutures and proper catheters. E.g. antimicrobial impregnated sutures, triclosan-coated sutures which are effective in preventing SSI in non-abdominal surgeries (24), or silicone sheath catheters impregnated with antimicrobial agents, which decrease the risk of colonization and infection (31)

- Provide access to inexpensive and standard devices and sanitation agents

- Control of operating room traffic (4)

- Strengthening of training of medical employees and public education

- Installation of warning boards and educational posters in appropriate places in the hospital

- Provide proper equipment sterilization setting and monitoring of sterilization process (proper sterilization of medical instruments is an essential action in removing all types of microbes and prevention of catastrophic consequences.) (32)

5. Primary Prevention

5.1. Physical Protective Measures

- Hand decontamination (hand hygiene probably is the most important SSI prevention strategy) (4, 9, 15, 33). Brushes are not recommended for surgical hand preparation (9). Some also recommend the use of disposable brushes (4). Hand rubbing with an alcohol-based formulation was considered as effective as scrubbing (9). Using hand hygiene monitoring system (34)

- Using the sterile surgical masks (questioned) (11), sterile gloves (the rate of SSI, may be increasing with perforated gloves, so, double gloving reduces inner glove perforation) (4, 11), apron, gown, hat (questioned) (32), glasses, face protective shields (in splashing conditions). Use of shoe covers have never been definitively demonstrated to reduce the rates of surgical infections (11)

- Shaving the surgical site with clipper with a disposable head (not to shave with blade or razor) just prior to surgical incision (4, 9-11, 21).

- Use of external heating procedures for operating room to prevent postoperative hypothermia (18)

- Proper environment cleaning and disinfection

- Use of dressing holders (bandage supporters) for special sites such as the head, shoulder, perineal, etc.)

- Use of compression stockings for DVT

prevention

- Use of safety box for sharp devices

5.2. Chemoprophylaxis

- Preoperative bath, using chlorhexidine soap or hexachlorophene (1, 4, 22). Of course, in some studies, the effect of chlorhexidine gluconate in SSI, compared with placebo or soap has not been shown (11). Operation site scrub with chlorhexidine or povidoneiodine or chlorhexidine plus alcohol or betadine alcohol (11, 25). Chlorhexidine gluconate is significantly more effective than povidone iodine (11).

- Bowel preparation with oral antibiotics (9)

- Using antibiotics just before the operation (the best time is between 0 - 60 minutes before incision) (4, 21). Antibiotic prophylaxis is recommended for placement of a prosthesis or implant, clean-contaminated and contaminated surgeries (4, 9). Ertapenem, cefotetan or cefoxitinare or cefazoline recommended as prophylactic antibiotics. If vancomycin or a fluoroquinolone are used, they should be administered within 120 minutes before incision (1, 10, 35).

- Use of mupirocin ointment for staphylococcus aureus nasal carriers (22). Not to use topical antimicrobial agents after the surgery (4).

- Administration of anticoagulants will reduce the risk of deep vein thrombosis (DVT) or venous thromboembolism (VTE) especially after the total joint replacement (29, 36). Of course, hematoma formation due to wound drainage can predispose patients towards infection and needs further studies (29).

- Maintaining blood sugar level around normal levels or less than 200 mg/dL with insulin or oral antidiabetic drugs (11).

5.3. Biological Prevention

- Using the foods with enough protein such as fish, poultry or red meat to early repair of the wound

- Complete patients and staff vaccination, including hepatitis, tetanus, pneumococcal vaccines (23-valent polysaccharide or as a 13-valent conjugate every 5 years) (36), etc., before or after the surgeries. For example, vaccination with pneumococcal vaccines for those who had splenectomy.

- Immune prophylaxis (e.g. Hepatitis B SIG) at the time of needle stick in non-immune staff

5.4. The Other Primary Prevention Comments

- Shower the night before surgery

- Smoking cessation (37) even, as short term as 4 weeks before the surgery (11)

- Correction of high blood sugar (< 200 mg/dL) (9), anemia, high creatinine and treatment of infectious diseases before the surgery

- Removing hand jewelry, artificial and polished nails before the operation by operating team

members (4)

- Correct the patient's prep and drep (4)
- Maintain body temperature level above 36°C during and immediately post-surgery (4, 9, 10, 21)
- Maintain adequate perfusion, oxygenation and hemoglobin saturation, more than 95% during surgery (4)
- Removal of devitalized tissues (9).
- Using absorbable suture materials (25). In some studies, use of staples versus sutures is recommended (9).
- Use an aseptic non-touch technique for dressing change by sterile saline (4).
- Moving up, as soon as possible after the operation
- No wound manipulation by the patient
- Advise patients to have bath 48 hours after the surgery with tap water and dressing the wound (4).
- Do not use diathermy for surgical incision (4).
- Training of patient about, moving as soon as possible, blood glucose control, wound care, bath and removing sutures time stitches, pay attention to warning signs and injection of vaccines needed, etc.

6. Secondary Prevention

6.1. Early Diagnosis

- Evaluation of clinical signs and symptoms and cells blood count, RBC indexes, ESR, CRP, FBS and 2 hour after meal, creatinine, albumin, protein, liver function tests, exudates culture and antibiogram, the site sonography or CT scan if required.
- Screening of patient's hemoglobin, fasting blood sugar, HbA1C and kidney failure, particularly for elective surgeries
- Screening for methicillin-resistant staphylococcus aureus of skin or nasal carriage on admission for all patients undergoing implants, cardiothoracic, orthopedic, or neurosurgical procedures (9, 21).

6.2. Early Treatment

- Using proper antibiotics, according to drug susceptibility testing results, type of the wound (especially for contaminated wounds) and surgeon decision (4).
- Control of diabetes and anemia
- Caring the wound (abscess drainage, debridement, washing with normal saline, dressing, etc.)
- Negative-pressure wound therapy (38)
- Amputation if necessary

7. Tertiary Prevention

7.1. Persistent Complications/ Rehabilitation Measures

- Mandatory amputations, ostomy (6)/ use of artificial limbs and prosthesis
- Scars and keloids (4)/ Skin grafts

- Sterility in PID (4)/ pelvic physiotherapy
- Limb atrophy/ Limbs physiotherapy
- Lung emphysema/ lung physiotherapy

8. Quaternary Prevention

8.1. Common Unnecessary Medicalizations

- Unnecessary keeping surgical patients in hospital
- Repeated and unnecessary sampling from environment
- Excessive use of disinfectants for the environment
- Administration of prophylactic antibiotics, more than recommended doses

8.2. Preventive Measures From Over Medicalization

- Telephone follow-up could be as a useful tool for the monitoring of operated patients and it can prevent the readmission to hospital and reducing the severe complications. (39)
- Observance of indications for doing surgical or procedural interventions
- Precise use of valid therapeutic guidelines
- Avoid excessive diagnostic methods such as CT scan or ultrasonography for confirmed cases like abscesses by clinical examination

9. Malpractices and Measures That Are Taken to Prevent Them

9.1. Possible Malpractices

- Not applying aseptic techniques
- Administration of inappropriate antibiotics
- places added stress on patient
- Surgery without a clear indication (e.g. unnecessary amputations)

9.2. Malpractice Preventive Measures

- Reducing the duration of hospitalization and operating time as much as possible
- Rational use of antibiotics
- Use of guidelines
- Counselling with experts

10. Discussion

In this study, we used 5 known prevention levels including: primordial, primary, secondary, tertiary and quaternary levels and proposed an action plan using this approach for prevention and control of SSIs. This approach is similar to biopsychosocial approach which in addition to emphasis on individual dimensions of health, it also focuses on social and environmental factors (33, 40).

As we know, the main goal in primordial level is to prevent the emergence and development of risk factors (41). This type of prevention emphasizes on social and environmental factors which can lead to

emersion of diseases (42). We found 75 risk factors and predisposing conditions for SSI.

To prevent the listed SSI related risk factors we have proposed 10 evidence-based activities for officials. Infection control committee (ICC) and infection control team (ICT) have an important role for carrying out all aspects of infection control in hospitals (43). Most of proposed activities are executable by ICC and some of them are related to the other managers outside the hospital.

To execute any action plan outside the hospital, usually, the main responsible are social officials, including legislators, policy makers, managers, and governmental or non-governmental organizations (8, 44). Most executive responsible individuals, and organizations for prevention and control of SSIs, out of the hospital (in Iran) which have been suggested by the participants were: Diseases management center of health ministry, training centers for continuing medical education, companies producing detergents, disinfectants, medical equipment providers and municipalities (for management of infectious wastes).

As well as, most executive responsible for the hospital were: Presidents and directors of the hospitals, heads of the operating rooms, ICC and affiliated units, infection control doctors and nurses, and hospital MIS system.

The other findings obtained from this study indicate that, most of the proposed preventive measures for SSI (40 practical actions) were related to primary prevention level. Primary prevention promotes health condition prior to development of diseases or injuries and more focuses on individuals (42). This suggests that, more emphasis should be placed on individual actions. In other words, most endogenous factors should be managed by the physicians and the patients themselves, but, managing of exogenous factors should be addressed by the hospital authorities.

Some recommendations listed in the literatures on prevention of SSI are contradictory. For example, some evidences clearly suggest that, not to use nasal decontamination with topical antimicrobial agents for eliminating staphylococcus aureus routinely, or not to use mechanical intestinal preparation routinely to reduce the risk of SSI, or not to use antibiotic prophylaxis for clean non-prosthetic and uncomplicated surgery routinely (4).

Because of the systemic nature of this approach, there is little chance of forgetting the important points.

11. Conclusion

We have proposed a plan of action for the prevention and control of SSI to the managers.

This approach can be used as a comprehensive method in dealing with Surgical Site Infections.

Even we believe that, to deal with any health problems including diseases, disorders, accidents and events, use of the proposed approach may be useful.

Acknowledgments

Hereby, we would like to appreciate sincerely all officials of the TUMS ICC for encouraging us to write this article.

References

1. Razavi SM, Ibrahimpoor M, Sabouri Kashani A, Jafarian A. Abdominal surgical site infections: incidence and risk factors at an Iranian teaching hospital. *BMC Surg.* 2005;5:2. doi: [10.1186/1471-2482-5-2](https://doi.org/10.1186/1471-2482-5-2). [PubMed: [15733323](https://pubmed.ncbi.nlm.nih.gov/15733323/)].
2. Spagnolo AM, Ottria G, Amicizia D, Perdeli F, Cristina ML. Operating theatre quality and prevention of surgical site infections. *J Prev Med Hyg.* 2013;54(3):131-7. [PubMed: [24783890](https://pubmed.ncbi.nlm.nih.gov/24783890/)].
3. Magill SS, Hellinger W, Cohen J, Kay R, Bailey C, Boland B, et al. Prevalence of healthcare-associated infections in acute care hospitals in Jacksonville, Florida. *Infect Control Hosp Epidemiol.* 2012;33(3):283-91. doi: [10.1086/664048](https://doi.org/10.1086/664048). [PubMed: [22314066](https://pubmed.ncbi.nlm.nih.gov/22314066/)].
4. National Collaborating Centre for Women's and Children's Health. Surgical site infection, prevention and treatment of surgical site infection. London: RCOG Press; 2008.
5. Edmark L, Auner U, Hallen J, Lassinantti-Olowsson L, Hedenstierna G, Enlund M. A ventilation strategy during general anaesthesia to reduce postoperative atelectasis. *Ups J Med Sci.* 2014;119(3):242-50. doi: [10.3109/03009734.2014.909546](https://doi.org/10.3109/03009734.2014.909546). [PubMed: [24758245](https://pubmed.ncbi.nlm.nih.gov/24758245/)].
6. Hopkins J. Complications from preventable surgical site infections leading to hospital readmissions after colon surgery. Manchester: News Medical. net, An AZoNetwork Site; 2011. Available from: <http://www.news-medical.net/news/20111117/Complications-from-preventable-surgical-site-infections-leading-to-hospital-readmissions-after-colon-surgery.aspx>.
7. Lubega A, Joel B, Justina Lucy N. Incidence and etiology of surgical site infections among emergency postoperative patients in Mbarara regional referral hospital, South Western Uganda. *Surg Res Pract.* 2017;2017:6365172. doi: [10.1155/2017/6365172](https://doi.org/10.1155/2017/6365172). [PubMed: [28168215](https://pubmed.ncbi.nlm.nih.gov/28168215/)].
8. Jamouille M. The four duties of family doctors, quaternary prevention, first, do no harm. Hong Kong: Hong Kong Practitioner; 2014. P. 36.
9. 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](https://doi.org/10.1586/eri.10.41). [PubMed: [20521894](https://pubmed.ncbi.nlm.nih.gov/20521894/)].
10. Poggio JL. Perioperative strategies to prevent surgical-site infection. *Clin Colon Rectal Surg.* 2013;26(3):168-73. doi: [10.1055/s-0033-1351133](https://doi.org/10.1055/s-0033-1351133). [PubMed: [24436669](https://pubmed.ncbi.nlm.nih.gov/24436669/)].
11. Reichman DE, Greenberg JA. Reducing surgical site infections: a review. *Rev Obstet Gynecol.* 2009;2(4):212-21. [PubMed: [20111657](https://pubmed.ncbi.nlm.nih.gov/20111657/)].
12. Aksamija G, Mulabdic A, Rasic I, Aksamija L. Evaluation of risk factors of surgical wound dehiscence in adults after laparotomy. *Med Arch.* 2016;70(5):369-72. doi: [10.5455/medarch.2016.70.369-372](https://doi.org/10.5455/medarch.2016.70.369-372). [PubMed: [27994299](https://pubmed.ncbi.nlm.nih.gov/27994299/)].
13. Kempegowda H, Richard R, Borade A, Tawari A, Graham J, Suk M, et al. Obesity is associated with high perioperative complications among surgically treated intertrochanteric fracture of the femur. *J Orthop Trauma.* 2017;31(7):352-7. doi: [10.1097/BOT.0000000000000825](https://doi.org/10.1097/BOT.0000000000000825). [PubMed: [28323791](https://pubmed.ncbi.nlm.nih.gov/28323791/)].
14. Olsen LL, Moller AM, Brorson S, Hasselager RB, Sort R. The impact of lifestyle risk factors on the rate of infection after surgery for a fracture of the ankle. *Bone Joint J.* 2017;99-B(2):225-30. doi: [10.1302/0301-620X.99B2.BJJ-2016-0344.R1](https://doi.org/10.1302/0301-620X.99B2.BJJ-2016-0344.R1). [PubMed: [28148665](https://pubmed.ncbi.nlm.nih.gov/28148665/)].

15. Ooi A, Song DH. Reducing infection risk in implant-based breast-reconstruction surgery: challenges and solutions. *Breast Cancer (Dove Med Press)*. 2016;**8**:161-72. doi: [10.2147/BCTT.S97764](https://doi.org/10.2147/BCTT.S97764). [PubMed: [27621667](https://pubmed.ncbi.nlm.nih.gov/27621667/)].
16. Hopkins J. Surgical site infections, health library Johns Hopkins medicine. USA: Johns Hopkins Medicine; 2017. Available from: http://www.hopkinsmedicine.org/healthlibrary/conditions/surgical_care/surgical_site_infections_134,144.
17. Shabanzadeh DM, Sorensen LT. Alcohol consumption increases post-operative infection but not mortality: a systematic review and meta-analysis. *Surg Infect (Larchmt)*. 2015;**16**(6):657-68. doi: [10.1089/sur.2015.009](https://doi.org/10.1089/sur.2015.009). [PubMed: [26244748](https://pubmed.ncbi.nlm.nih.gov/26244748/)].
18. Zeba S, Surbatovic M, Marjanovic M, Jevdjic J, Hajdukovic Z, Karkalic R, et al. Efficacy of external warming in attenuation of hypothermia in surgical patients. *Vojnosanit Pregl*. 2016;**73**(6):566-71. [PubMed: [27498449](https://pubmed.ncbi.nlm.nih.gov/27498449/)].
19. Shukuda H. Patient-related risk factors for surgical site infection following eight types of gastrointestinal surgery. *J Hosp Infect*. 2016;**93**(4):347-54. doi: [10.1016/j.jhin.2016.04.005](https://doi.org/10.1016/j.jhin.2016.04.005). [PubMed: [27209057](https://pubmed.ncbi.nlm.nih.gov/27209057/)].
20. Pulido L, Ghanem E, Joshi A, Purtill JJ, Parvizi J. Periprosthetic joint infection: the incidence, timing, and predisposing factors. *Clin Orthop Relat Res*. 2008;**466**(7):1710-5. doi: [10.1007/s11999-008-0209-4](https://doi.org/10.1007/s11999-008-0209-4). [PubMed: [18421542](https://pubmed.ncbi.nlm.nih.gov/18421542/)].
21. Harrington P. Surgical site infection, NICE quality standards, public health England. England: Public Health England; 2017.
22. Lefebvre J, Buffet Bataillon S, Henaux PL, Riffaud L, Morandi X, Haegelen C. Staphylococcus aureus screening and decolonization reduces the risk of surgical site infections in patients undergoing deep brain stimulation surgery. *J Hosp Infect*. 2017;**95**(2):144-7. doi: [10.1016/j.jhin.2016.11.019](https://doi.org/10.1016/j.jhin.2016.11.019). [PubMed: [28081909](https://pubmed.ncbi.nlm.nih.gov/28081909/)].
23. Murphy J. Temperature and humidity control in surgery rooms. *ASHRAE J*. 2006;**48**(6):H18.
24. Guo J, Pan LH, Li YX, Yang XD, Li LQ, Zhang CY, et al. Efficacy of triclosan-coated sutures for reducing risk of surgical site infection in adults: a meta-analysis of randomized clinical trials. *J Surg Res*. 2016;**201**(1):105-17. doi: [10.1016/j.jss.2015.10.015](https://doi.org/10.1016/j.jss.2015.10.015). [PubMed: [26850191](https://pubmed.ncbi.nlm.nih.gov/26850191/)].
25. Cheadle WG. Risk factors for surgical site infection. *Surg Infect (Larchmt)*. 2006;**7**(Suppl 1):7-11. doi: [10.1089/sur.2006.7.s1-7](https://doi.org/10.1089/sur.2006.7.s1-7). [PubMed: [16834549](https://pubmed.ncbi.nlm.nih.gov/16834549/)].
26. Nagaria T, Kujur A, Thakur N. Incision length, an emerging risk factors for surgical-site infection following cesarean section. *Int J Reprod Contracept Obstet Gynecol*. 2017;**6**(5):1829-33. doi: [10.18203/2320-1770.ijrcog20171566](https://doi.org/10.18203/2320-1770.ijrcog20171566).
27. Brathwaite S, Latchana N, Esemuede I, Harzman A, Husain S. Risk factors for surgical site infection in open and laparoscopic Hartmann closure, a multivariate analysis. *Surg Laparosc Endosc Percutan Tech*. 2017;**27**(1):51-3. doi: [10.1097/SLE.0000000000000365](https://doi.org/10.1097/SLE.0000000000000365). [PubMed: [28145967](https://pubmed.ncbi.nlm.nih.gov/28145967/)].
28. Sarkut P, Kilicurgay S, Aktas H, Ozen Y, Kaya E. Routine use of prophylactic antibiotics during laparoscopic cholecystectomy does not reduce the risk of surgical site infections. *Surg Infect (Larchmt)*. 2017;**18**(5):603-9. doi: [10.1089/sur.2016.265](https://doi.org/10.1089/sur.2016.265). [PubMed: [28375803](https://pubmed.ncbi.nlm.nih.gov/28375803/)].
29. Wang Z, Anderson FA Jr, Ward M, Bhattacharyya T. Surgical site infections and other postoperative complications following prophylactic anticoagulation in total joint arthroplasty. *PLoS One*. 2014;**9**(4):e91755. doi: [10.1371/journal.pone.0091755](https://doi.org/10.1371/journal.pone.0091755). [PubMed: [24717837](https://pubmed.ncbi.nlm.nih.gov/24717837/)].
30. Peterson JW. Medical microbiology. 4th ed. Galveston, Texas: University of Texas Medical Branch at Galveston; 1996.
31. Tcholakian RK, Raad II. Durability of anti-infective effect of long-term silicone sheath catheters impregnated with antimicrobial agents. *Antimicrob Agents Chemother*. 2001;**45**(7):1990-3. doi: [10.1128/AAC.45.7.1990-1993.2001](https://doi.org/10.1128/AAC.45.7.1990-1993.2001). [PubMed: [11408213](https://pubmed.ncbi.nlm.nih.gov/11408213/)].
32. Jabbari H, Alikhah H, Sahebkar Alamdari N, Behzad MN, Mehrabi E, Borzui L, et al. Developing the use of quality indicators in sterilization practices. *Iran J Public Health*. 2012;**41**(7):64-9. [PubMed: [23113212](https://pubmed.ncbi.nlm.nih.gov/23113212/)].
33. Lindau ST, Laumann EO, Levinson W, Waite LJ. Synthesis of scientific disciplines in pursuit of health, the interactive biopsychosocial model. *Perspect Biol Med*. 2003;**46**(3 Suppl):S74-86. [PubMed: [14563076](https://pubmed.ncbi.nlm.nih.gov/14563076/)].
34. Swoboda SM, Earsing K, Strauss K, Lane S, Lipsett PA. Electronic monitoring and voice prompts improve hand hygiene and decrease nosocomial infections in an intermediate care unit. *Crit Care Med*. 2004;**32**(2):358-63. doi: [10.1097/01.CCM.0000108866.48795.0F](https://doi.org/10.1097/01.CCM.0000108866.48795.0F). [PubMed: [14758148](https://pubmed.ncbi.nlm.nih.gov/14758148/)].
35. Leng XS, Zhao YJ, Qiu HZ, Cao YK, Zhu WH, Shen JF, et al. Ertapenem prophylaxis of surgical site infections in elective colorectal surgery in China: a multicentre, randomized, double-blind, active-controlled study. *J Antimicrob Chemother*. 2014;**69**(12):3379-86. doi: [10.1093/jac/dku302](https://doi.org/10.1093/jac/dku302). [PubMed: [25151205](https://pubmed.ncbi.nlm.nih.gov/25151205/)].
36. Boam T, Sellars P, Isherwood J, Hollobone C, Pollard C, Lloyd DM, et al. Adherence to vaccination guidelines post splenectomy, a five year follow up study. *J Infect Public Health*. 2017;**10**(6):803-8. doi: [10.1016/j.jiph.2017.01.006](https://doi.org/10.1016/j.jiph.2017.01.006). [PubMed: [28189514](https://pubmed.ncbi.nlm.nih.gov/28189514/)].
37. Zhu Y, Liu S, Zhang X, Chen W, Zhang Y. Incidence and risks for surgical site infection after adult tibial plateau fractures treated by ORIF, a prospective multicentre study. *Int Wound J*. 2017;**14**(6):982-8. doi: [10.1111/iwj.12743](https://doi.org/10.1111/iwj.12743). [PubMed: [28303656](https://pubmed.ncbi.nlm.nih.gov/28303656/)].
38. Li PY, Yang D, Liu D, Sun SJ, Zhang LY. Reducing surgical site infection with negative pressure wound therapy after open abdominal surgery, a prospective randomized controlled study. *Scand J Surg*. 2017;**106**(3):189-95. doi: [10.1177/1457496916668681](https://doi.org/10.1177/1457496916668681). [PubMed: [27609528](https://pubmed.ncbi.nlm.nih.gov/27609528/)].
39. da Mata LR, da Silva AC, Pereira Mda G, de Carvalho EC. Telephone follow-up of patients after radical prostatectomy: a systematic review. *Rev Lat Am Enfermagem*. 2014;**22**(2):337-45. doi: [10.1590/0104-1169.3314.2421](https://doi.org/10.1590/0104-1169.3314.2421). [PubMed: [26107844](https://pubmed.ncbi.nlm.nih.gov/26107844/)].
40. Cheattle MD. Biopsychosocial approach to assessing and managing patients with chronic pain. *Med Clin North Am*. 2016;**100**(1):43-53. doi: [10.1016/j.mcna.2015.08.007](https://doi.org/10.1016/j.mcna.2015.08.007). [PubMed: [26614718](https://pubmed.ncbi.nlm.nih.gov/26614718/)].
41. Claas SA, Arnett DK. The role of healthy lifestyle in the primordial prevention of cardiovascular disease. *Curr Cardiol Rep*. 2016;**18**(6):56. doi: [10.1007/s11886-016-0728-7](https://doi.org/10.1007/s11886-016-0728-7). [PubMed: [27142061](https://pubmed.ncbi.nlm.nih.gov/27142061/)].
42. Starfield B, Hyde J, Gervas J, Heath I. The concept of prevention: a good idea gone astray? *J Epidemiol Community Health*. 2008;**62**(7):580-3. doi: [10.1136/jech.2007.071027](https://doi.org/10.1136/jech.2007.071027). [PubMed: [18559439](https://pubmed.ncbi.nlm.nih.gov/18559439/)].
43. Sato T. Infection control in hospitals. *Masui*. 2010;**59**(1):56-63. [PubMed: [20077771](https://pubmed.ncbi.nlm.nih.gov/20077771/)].
44. Sheridan SL, Harris RP, Woolf SH; Shared Decision-Making Workgroup of the USTF. Shared decision making about screening and chemoprevention. A suggested approach from the U.S. Preventive Services Task Force. *Am J Prev Med*. 2004;**26**(1):56-66. [PubMed: [14700714](https://pubmed.ncbi.nlm.nih.gov/14700714/)].