An Update on Antibiotic Prophylaxis in Dermatologic Surgery

Helena Rosengren · Clare Heal · Samuel Smith

Published online: 14 April 2012
© Springer Science+Business Media, LLC 2012

Abstract Antibiotic prophylaxis can be given to prevent surgical site infection or to avoid bacterial infective endocarditis and prosthetic joint infections as a result of bacteremia following surgery. Although prophylactic antibiotics are rarely warranted for clean dermatologic surgery, there is increasing support in the literature for their judicious use for selected high-risk cases. This article discusses the host co-morbidities, wound characteristics, body sites, and complex surgical procedures associated with increased dermatologic surgical site infection and goes on to review the evidence for and against antibiotic prophylaxis in its various forms. Updated guidelines for prevention of infective endocarditis and prosthetic joint infection following dermatologic surgery are also outlined.

Keywords Antibiotic prophylaxis · Dermatological surgical site infection · Infective endocarditis · Prosthetic joint infection

Introduction

In dermatologic surgery, prophylactic antibiotics are used to prevent either bacteremia or surgical site infection (SSI).

H. Rosengren (✉)
School of Medicine and Dentistry, James Cook University,
James Cook Drive, Douglas,
Townsville, QLD 4814, Australia
e-mail: helenarosengren@gmail.com

C. Heal · S. Smith
School of Medicine and Dentistry, James Cook University,
Level 1, Building K, Mackay Base Hospital, Bridge Rd,
Mackay, QLD 4740, Australia

C. Heal
e-mail: clare.heal@jcu.edu.au

S. Smith
e-mail: Samuel.smith@my.jcu.edu.au

Bacteremia can result in infective endocarditis (IE) and prosthetic joint infection (PJI) in vulnerable patients, and recently updated guidelines clearly stipulate when prophylactic antibiotics are to be used [1, 2]. The use of antibiotics to prevent dermatologic surgical site infection (DSSI) remains controversial, however.

Antibiotic prophylaxis (AP) is usually not recommended for clean dermatologic surgery as infection rates are generally very low. Furthermore, indiscriminate antibiotic use can cause emergence of resistant pathogens, unpleasant side effects, allergic reactions, and rarely *Clostridium difficile* enterotoxaemia [3–8, 9, 10, 11]. Observational studies have shown that certain host factors, wound characteristics, body sites, and complex skin closures increase DSSI rates [4–6, 9, 12••].

Though there are no current official guidelines for AP in dermatological surgery, many review articles advocate prophylaxis for selected higher-risk cases [4, 5, 9, 12••, 13]. Wound infection delays healing and is associated with discomfort, increased follow-up visits, and poorer cosmetic outcome [14••, 15]. Furthermore, failure to complete antibiotics as prescribed may promote antibiotic resistance.

This review focuses on causes and prevention of SSI, IE, and PJI in relation to dermatologic surgery. Having analyzed relevant retrospective studies, prospective studies, and meta-analyses as well as review articles, we hope to bring the reader up to date with current evidence and guidelines.

Definition of Superficial Incisional Surgical Site Infection

Most DSSIs result from resident flora present on epidermal or mucosal surfaces at the time of incision [7]. Whether such contamination results in infection depends on a complex interaction between host and microbe [16, 17]. When this

inoculating dose exceeds 10^5 organisms per gram of tissue, frank infection generally ensues [14, 15].

There is no universal agreement on the definition of wound infection and whether quantitative microbiological studies are useful [18]. The most widely accepted description for dermatologic surgical site infection however is based on the 1992 US Center for Disease Control (CDC) classification [9, 15], in which infection must occur within 30 days of surgery and involve skin or deep tissue at the incision site [19]. In addition, one of the following must apply: 1) purulent discharge from the incisional wound; 2) organisms are isolated on culture of aseptically obtained wound fluid or tissue; 3) one or more of the following is present: pain, tenderness, localized swelling, redness, heat, or the surgeon has deliberately re-opened wound (unless culture of the incision is negative); 4) the treating doctor diagnoses a superficial incisional surgical site infection. Stitch abscess are not defined as infection.

Incidence of Dermatologic Surgical Site Infection

Review articles scrutinizing data from large observational studies report low wound infection rates (1–3%) for simple cutaneous surgery, Mohs micrographic surgery (MMS), and secondary intention healing [5, 9, 12, 14, 16]. This is consistent with more recent studies (DSSI < 1.4%) [20–22]. There are however a number of factors that may increase DSSI rates and this will be discussed in more detail below.

It is clear from the literature that many clinicians may be using antibiotics excessively to help prevent SSI. A retrospective plastic surgery department review revealed overprescribing of AP in 27.5% of breast, 61.8% of head and neck, and 19.4% of hand and upper limb surgery patients [23]. In dermatological surgery, published studies acknowledge that antibiotics are often given at the surgeon's discretion without reference to any predetermined protocol [10, 24]. In a retrospective review of 8850 elective hand surgery cases, the infection rate was only 0.35% yet 31% received AP [10]. Other recent studies, however, have shown judicious AP use [22, 25].

Risk Factors for Dermatologic Surgical Site Infection

Risk factors for DSSI (Fig. 1) relate to aseptic practices, host co-morbidities, wound characteristics, body site, surgical technique, and complexity of the surgical procedure [4, 6, 26].

Routine hand washing and good patient preparation have significantly reduced DSSI [6, 27]. A Cochrane review confirmed that shaving body hair at the surgical site is associated with more infections than clipping or use of

depilatory creams [28]. Infection rates were the same whether hair was shaved or not removed at all. Use of one non-sterile marker on multiple patients prior to antiseptic preparation does not affect incisional site sterility [29]. If the marker inadvertently becomes contaminated with blood it must of course be thrown away. Evidence suggests that chlorhexidine is probably the most effective antiseptic [16].

A number of studies dispute the need for sterile gloves in dermatologic surgery and though we would not advocate this practice, further randomized controlled trials (RCTs) may be warranted. A large prospective observational study in which only clean non-sterile gloves were used for 1000 MMS cases had infection rates equivalent to other studies (0.78% for simple elliptical repair; 2.4% for flap repair) [20]. A retrospective study of 1400 MMS cases found no difference in infection rates with sterile or clean gloves [30]. Infection rates were the same for excision and repair procedures regardless of whether sterile or clean surgical gloves were worn in a prospective randomized trial involving 60 MMS cases [31]. In a large prospective study involving 3491 dermatologic surgical cases, though infection rates were not influenced by sterility of gloves for elliptical closures, there were significantly fewer infections if sterile gloves were worn for complex cases. (3.4 vs 14.7%) [32].

Host Factors

Diabetes, smoking, malnutrition, obesity, chronic renal failure, and immunocompromising illness have variably been shown to increase the risk of DSSI [4–6, 9, 16, 33, 34].

There has been conflicting evidence regarding the association between diabetes, the most prevalent of these risk factors, and DSSI. Three recent large studies have found diabetes to be an independent risk factor for DSSI [10, 35, 36]. Although other recent studies may not have confirmed this association [22, 37–39], under-reporting of diabetes might be an explanation. Of note, none of these studies attempted to assess glycemic control. A significant association between both pre- and postoperative glycemic control and incidence of SSI has been found in a number of studies [40–46]. The relevance of this association in dermatological surgery may be an interesting area for future research.

Infection has correlated positively with smoking in some recent studies [10, 23]. Smoking has been shown to reduce cutaneous blood flow and tissue oxygen tension in humans [47] and viability of skin flaps in rats [48]. In contrast smoking was not found to be a risk factor for DSSI in two recent prospective observational studies [36, 37].

A number of studies have shown that infection rates are significantly higher for excision of skin neoplasm than for excision of benign lesions [30, 35, 37, 49, 50].

Studies have shown that *Staphylococcus aureus* nasal carriers develop more SSI than non-carriers [51–53].

Fig. 1 Risk factors for dermatologic surgical site infection

Evidence suggests that this also applies to dermatologic surgery [54].

Wound Characteristics

Wound classification (I to IV) based on the 1985 CDC guidelines [55] have historically been used to help determine the need for prophylactic antibiotics [4, 5, 7]. Closure of incisions on clean non-contaminated skin under sterile conditions (class I wounds) generally does not need AP. Surgery involving oral/nasal mucosa or the axillary/anogenital areas (class II wounds) should receive antibiotic prophylaxis if the patient is immunocompromised. In the case of a major break in sterile surgical technique or a frankly inflamed or infected wound (class III and IV wounds), therapeutic antibiotics are required [55]. Wounds contaminated with oil and crush injuries should also receive AP [33].

Two large prospective studies taking place in subtropical Australia found much higher infection rates for simple dermatologic surgery than would normally be expected (8.7% in 972 patients [13], 8.6% in 857 patients [25]). The reasons for this are unclear but we postulate that high ambient temperature and humidity may improve conditions for bacterial colonization. A recent study has confirmed higher post-operative bacterial wound counts to be associated with increased DSSI [15].

Body Site

The incidence of DSSI is influenced by body site [4, 9, 12, 14], with lower limb surgery most consistently complicated by infection [21, 35–39, 56, 57]. The reasons for this are unclear but reduced perfusion pressure in the distal limbs [35], higher tension closures, as well as the frequent

necessity for complex graft/ flap surgery are postulated reasons. When compared to overall infection rates, dermatologic surgery below the knee is associated with a 1.7- to 4.7-fold increase in infection rate [13–15, 21, 29]. With surgery on the thigh, a 1.6- to 1.9-fold increase in infection rate has been observed [35, 37]. The groin has been associated with a 6.8-fold [38] and the genitalia with a 10.8-fold [21] increase in infection rate.

Auricular and nasal surgery are also reported to have higher infection rates, perhaps in part because complex closures are more likely at these sites. The increase in DSSI at these sites has however been found to be independent of surgical complexity, with the authors postulating that high concentration of sebaceous glands and other anatomical features that may favor greater bacterial colonization on the nose and ear may play a role [49]. On the ear, a 1.9- to 5.5-fold increase in infection has been observed [38, 49, 58], and with cartilage involved the increase was 12.4-fold [58]. On the nose, infection rates were 2.3 to 2.4 times greater than overall infection rates [38, 59].

Surgical Repair

Longer duration of procedure increases the incidence of DSSI [10, 22, 32, 60]. Increased length of scar also correlates positively with DSSI [37, 61]. Large observational prospective studies have shown that flap repair will increase the likelihood of infection by 2 to 15 times compared to simple elliptical closure [4, 20, 32, 36, 39, 49, 59, 60, 62]. Graft repair has also been linked to much higher infection rates [36, 38, 49, 58, 60, 61]. Given the increased risk of infection associated with complex procedures, simple dermatologic reconstruction is preferable wherever possible.

Multivariate analysis has confirmed that hematoma is an independent risk factor for DSSI [20, 32, 60]. This emphasizes the need for meticulous inter-operative hemostasis, particularly where there are risk factors for bleeding post-operatively. Risk factors include prescribed warfarin [21, 37, 63, 64] and clopidogrel [21], as well as age above 67 years, having auricular surgery, and complex repairs [64].

Prophylactic Regimes for Preventing Dermatologic Surgical Site Infection

Antimicrobial Agents

Concerns regarding antibiotic toxicity and resistance have prompted the use of other antimicrobials to help prevent DSSI. Though outside the scope of this article, the results for silver alginate and honey impregnated dressings are encouraging and warrant prospective randomized trials to verify their effectiveness as prophylactic agents against wound infection [9•]. Both silver alginate dressings and medical grade honey have shown broad antimicrobial activity with high sensitivity and low resistance [65, 66]. The use of sterile maggots to ingest bacteria and devitalized tissue is also recognized to help prevent infection following dermatologic surgery [67].

Nasal Antibiotic Ointment

A Cochrane review has confirmed that prescribing mupirocin nasal ointment in *Staphylococcus aureus* nasal carriers pre-operatively results in significantly fewer *S. aureus* SSIs [68]. General use of intranasal mupirocin prior to elective surgery is not advocated, but in *S. aureus* and particularly methicillin-resistant *S. aureus* (MRSA) carriers it is recommended [69].

Treatment of MRSA carriers with intranasal mupirocin and a course of oral antibiotics significantly reduced post-operative MRSA infection in a controlled study involving MMS cases [54]. None of the treated MRSA nasal carriers (22 of 963 participants screened) developed DSSI. Although one confirmed nasal carrier, who failed to have antibiotic treatment, developed an MRSA wound infection, there were no other MRSA infections.

Topical Antibiotics

Given that most DSSIs originate from skin flora at the surgical site, one might expect a topical antibiotic applied to the post-operative wound to reduce the likelihood of infection. Evidence from RCTs however suggests that the use of topical antibiotics in dermatological surgery is not effective [14••, 18, 34, 70]. Although an adequately powered RCT found a statistically significant reduction in

infection rate from use of chloramphenicol ointment, its use was still felt not to be clinically significant, and best reserved for high-risk wounds only [71]. In addition, the routine use of topical antibiotics has been hypothesized to contribute to the emergence of resistant antibacterial strains and can cause allergic contact dermatitis [14••, 70].

Oral Antibiotics

Limited evidence is available for the role of oral antibiotic prophylaxis in the prevention of DSSI. Sub-analysis of 60 reconstructive dermatologic flap procedures conducted as part of a plastic surgery RCT found that 1 g of oral azithromycin given the evening before surgery resulted in significantly fewer DSSIs [72]. In a small, non-randomized observational study involving 18 patients having facial graft surgery for non-melanoma skin cancer (NMSC), 1.5 g of flucloxacillin prescribed orally usually 2 h or less following surgery and for the next 1 days in 9 patients with diabetes or tumor ulceration resulted in significantly less infection, graft loss, and graft necrosis [15].

Conversely, an RCT with 82 patients undergoing secondary intention healing following auricular MMS found no significant difference in infection rates with a post-operative course of once daily 500 mg of oral levofloxacin [73]. AP was started on the day of surgery but it is not clear how long after surgery it was commenced. DSSI is usually caused by wound contamination with adjacent skin commensals, which reside and multiply in the wound coagulum, a medium that is relatively impenetrable to antibiotics. To be effective, prophylactic antibiotics must therefore ideally be present in the wound well before the wound coagulum forms [74, 75].

As *S. aureus* and streptococci are the most prevalent bacteria causing DSSI, first-generation cephalosporins or penicillinase-resistant penicillins are generally recommended for prophylaxis [4, 12, 76]. Oral cephalexin or dicloxacillin given as a large 2-g dose 30 to 60 min before the procedure is generally recommended (Table 1) [4, 12, 77]. For those with penicillin allergy, clindamycin, azithromycin, or clarithromycin are the antibiotics of choice. If unable to take medication by mouth, cefazolin, ceftriaxone or (in the case of penicillin allergy) clindamycin is given intravenously or intramuscularly. For procedures involving the groin, axilla or oral or nasal mucosa, a broad spectrum penicillin, such as amoxicillin, is preferred to give greater gram-negative coverage [8, 12].

Intra-incisional Antibiotics

In the 1960s and 1970s, several studies showed that spraying pressurized antibiotic into open post-operative wounds significantly reduced infection rates [14••]. Sterile cefazolin

Table 1 Oral antibiotic prophylaxis regimes for DSSI, IE and PJI

	Incision of keratinized skin	Incision of oral mucosa	Penicillin allergy (any body site)	Timing
DSSI	Cephalexin (2 g) Dicloxacillin (2 g)	Amoxicillin (2 g)	Clindamycin (600 mg) Azithromycin (500 mg) Clarithromycin (500 mg)	30–60 min before surgery
IE	Cephalexin (2 g) Dicloxacillin (2 g)	Amoxicillin (2 g)	Clindamycin (600 mg) Azithromycin (500 mg) Clarithromycin (500 mg)	30–60 min before surgery
PJI	Cephalexin (2 g) Cephadrine (2 g)	Amoxicillin (2 g)	Clindamycin (600 mg)	1 h before surgery

DSSI dermatologic surgical site infection; *IE* infective endocarditis; *PJI* prosthetic joint infection

powder sprinkled into the wound prior to closure has also been shown to significantly reduce infection [78]. Two prospective, blinded, randomized, placebo-controlled trials have shown that the administration of intra-incisional antibiotics (clindamycin/nafeicillin) with the pre-operative local anesthetic significantly reduced infection rates in MMS (0.2% vs 2.5% [79] and 0.7% vs 2.4% [80]).

The high antibiotic concentration at the surgical site, where the formation of wound coagulum may reduce the effectiveness of systemic antibiotics, is a potential advantage of this route of administration. In addition, there are no systemic and bowel side effects and possibly less antibiotic resistance as the gut is bypassed [18, 34]. A theoretical problem with intra-incisional antibiotics is contact dermatitis, though this was not reported in these studies.

Intramuscular Antibiotics

Though this may no longer be a preferred route for AP, two large RCTs have shown intramuscular cephazolin to significantly reduce DSSI [78, 81]. Prophylaxis was more effective for subgroups commenced on antibiotics pre- rather than post-operatively.

Intravenous Antibiotics

We found two double-blinded RCTs that studied the impact of intravenous AP on DSSI. In the first, the administration of perioperative intravenous cephalothin to 127 burns victims requiring skin grafts resulted in significantly less infection (0.8% vs 5.7%), reduced graft loss, and shortened hospital stay compared to 122 controls [82].

Though not strictly dermatologic surgery, the other RCT involving 1340 hand surgery patients (including 400 who had superficial soft tissue surgery only), found that 2 g of intravenous cefazolin given pre-operatively and then every 4 h for 24 h made no difference to infection rates (3.13% v 3.43%) [83].

In a recent retrospective review of 8850 elective hand surgery cases, the low (0.35%) SSI rate was not further improved by AP even in higher-risk patient groups [10]. E-mail contact with the corresponding author established that preferred AP was cephazolin injected intravenously 30 to 60 min pre-operatively. Given the low infection rate and relatively small patient numbers in subgroups, the effectiveness of AP cannot be discounted for specific risk factors associated with DSSI.

An observational prospective study for 85 skin grafts (performed for skin cancer or trauma on all body sites) found that those who received intravenous cephazolin, flucloxacillin, or amoxicillin/clavulanate at induction had a reduced risk of infection and graft failure [24]. The use of prophylactic antibiotics was the only predictor of successful graft take.

It has been shown that the ideal time to give intravenous antibiotic prophylaxis is 30 to 60 min prior to the surgical procedure [84].

Prophylaxis Against Infective Endocarditis

Major changes in the most recent 2007 American Heart Association (AHA) guidelines [1] have eliminated about 90% of people previously given prophylaxis for infective endocarditis (IE) [16]. After careful review of 56 years of published articles, the AHA committee concluded that even if AP were 100% effective, only a very small number of cases of IE would be prevented.

Dermatologic surgery rarely causes bacteraemia [1, 7], and AP is therefore not indicated even in patients at highest risk of adverse outcome from IE unless the surgical site is already infected or involves incision of the oral mucosa. High-risk conditions (Table 2) are a prosthetic cardiac valve, history of IE, cardiac transplant with valvulopathy, or an unrepaired congenital heart defect that causes cyanosis or that has been repaired in the past 6 months. Conditions such

Table 2 Risk factors for IE and PJI that require antibiotic prophylaxis if dermatological surgery involves infected skin or incision of oral mucosa

IE risk factors	PJI risk factors
Previous IE	Previous PJI
Prosthetic heart valves	All patients within 2 years of joint replacement
Transplanted heart valve with valvulopathy	Inflammatory arthropathies (ie, rheumatoid arthritis/systemic lupus erythematosus)
Unrepaired congenital heart defect that causes cyanosis	Drug- or radiation-induced immunosuppression
Within 6 months of surgery for congenital heart disease	Co-morbidities including HIV, malignancy, malnourishment, type 1 diabetes, hemophilia

IE infective endocarditis; PJI prosthetic joint infection

as valvular heart disease, aortic stenosis, and stable congenital heart disease no longer require AP.

The AHA has clarified that simply injecting local anaesthetic via the oral mucosa does not require prophylaxis [1]. Optimal oral health and hygiene is more important than AP for a dental procedure to reduce the risk of IE [16].

Despite new AHA guidelines being evidence-based, there has been resistance among dentists, cardiologists, and patients to comply with the changes [85–87]. Barriers to implementation include difficulty explaining to patients previously requiring AP for IE that this recommendation is now obsolete for future procedures [86, 87]; fear of criticism from colleagues and lack of trust in the evidence also prevents compliance [85]. Patients habituated to taking AP before certain procedures expressed concern that the updated guidelines were incorrect [86, 87]. Our own experience mirrors this with many patients remaining on AP to prevent IE following dermatologic surgery because their cardiologists still recommend it.

Where prophylaxis is required, a penicillin or cephalosporin is recommended for procedures involving infected keratinized skin (Table 1). Vancomycin or clindamycin can also be given. For breaches of the oral mucosa, amoxicillin (2 g) is the antibiotic of choice. For those with penicillin allergy, azithromycin, clindamycin, or clarithromycin are now advocated. A single dose should be taken orally 30 to 60 min pre-operatively [1].

Prophylaxis Against Prosthetic Joint Infections

Total hip and knee replacements are common, and though prosthetic joint infection (PJI) is a rare complication (<2.5%), the consequences can be disastrous for the patient and expensive for the health system [3, 88–90].

The American Dental Association (ADA) and the American Academy of Orthopedic Surgeons created the latest guidelines for PJI prevention in 2003 [2]. The data showed that most late onset PJI was related to bacteraemia. Consequently, patients susceptible for PJI should receive AP for incision of infected skin or the oral mucosa. AP is not indicated for patients with pins, plates, or screws [2].

Patients at high risk of PJI (Table 2) include anyone who has had a total joint replacement within 2 years. Additionally, a previous prosthetic joint infection, being immunocompromised, or having certain co-morbidities warrant AP for PJI regardless of when the joint was replaced. High risk co-morbidities include insulin-dependent (type 1) diabetes, malignancy, HIV infection, malnourishment, and hemophilia.

The administration of a mucosal anesthetic is deemed a lower-risk bacteremic procedure [2], and as such the cutaneous surgeon should consider AP in high-risk patients when administering a nerve block by the intra-oral route [9].

The recommended prophylactic antibiotic regime (Table 1) is 2 g of cephalexin or cephadrine for infected keratinized surgery and 2 g of amoxicillin for oral mucosal surgery. For patients with penicillin allergy, 600 mg of clindamycin is advocated. Antibiotics are given orally 1 h prior to surgery [2].

Conclusions

Many host- and procedure-related factors influence the risk of DSSI, and in the absence of clear updated guidelines reflecting emerging evidence, the decision to give prophylactic antibiotics should be on a case-by-case basis with systematic attention to multiple risk factors.

Prophylactic prescribing of antibiotics could result in unnecessary troublesome side effects, allergy, anaphylaxis, and drug resistance. Evidence confirms re-emergence of more antibiotic sensitive bacteria and development of fewer resistant pathogens with cautious prescribing of antibiotics [14•]. On the other hand, a high-risk, complex dermatological procedure complicated by infection can result in delayed healing and poor cosmesis. In such a case, a single oral pre-operative antibiotic dosage may prevent a prolonged course of antibiotics as well as significant morbidity and expense.

Even Henry Flemming himself noticed that resistant bacteria emerged if sufficient doses of penicillin were not given [14•]. The recommended single dose of prophylactic antibiotic is equivalent to a 24 h total dosage for established infection. Given that it is the antibiotic concentration during treatment rather than the antibiotic itself that promotes resistance, we postulate that the risk of emergence of resistant bacteria following a single, large prophylactic antibiotic dose may be less than that for treating established infection, where doses may be forgotten or the treatment stopped prematurely.

RCTs have shown that topical antibiotics applied immediately after dermatologic surgery do not prevent infection and they should therefore not be used. Two studies have shown oral AP significantly reduced DSSI [15, 72]. Large RCTs have confirmed the effectiveness of intra-incisional [78, 80] and intramuscular [78, 81] AP against DSSI. Intravenous AP has been found to reduce infection rates following skin grafts [24, 82] but not hand surgery.

We know of no RCT that has specifically studied the effect of intranasal mupirocin alone in dermatological surgery, but as the impact on SSI has been universally beneficial in other studies we would recommend checking for and treating *S. aureus* nasal carriage for dermatologic surgical cases at higher risk of infection. It might be prudent to check for *S. aureus* nasal carriage in patients with a history of recurrent DSSI. In addition, regular screening of staff assisting during surgery might be advisable.

Updated guidelines for IE and PJI are very clear that AP need only be considered in dermatologic surgery for high-risk patients having surgery involving infected skin or breach of the oral mucosa. The recent guidelines have radically revised the definition for high-risk patients, and dermatologic surgeons should familiarize themselves with the changes to prevent over-prescribing of AP.

Having reviewed the evidence, we believe that where multiple risk factors for DSSI exist, antibiotic prophylaxis should be considered. Further RCTs are needed to help establish the effectiveness of oral and intranasal antibiotic prophylaxis.

Disclosure No conflicts of interest relevant to this article were reported.

References

Recent papers of particular interest have been highlighted as follows:

- Of importance
- Of particular importance

1. Wilson W, Taubert KA, Gewitz M, Lockhart PB, Baddour LM, Levison M, Bolger A, Cabell CH, Takahashi M, Baltimore RS, Newburger JW, Strom BL, Tani LY, Gerber M, Bonow RO, Pallasch T, Shulman ST, Rowley AH, Burns JC, Ferrieri P, Gardner T, Goff D, Durack DT. Prevention of infective endocarditis: guidelines from the American Heart Association: a guideline from the American Heart Association Rheumatic Fever, Endocarditis, and Kawasaki Disease Committee, Council on Cardiovascular Disease in the Young, and the Council on Clinical Cardiology, Council on Cardiovascular Surgery and Anesthesia, and the Quality of Care and Outcomes Research Interdisciplinary Working Group. *Circulation*. 2007;116:1736–54.
2. Antibiotic prophylaxis for dental patients with total joint replacements. *J Am Dent Assoc* 2003;134:895–9.

3. Enzler MJ, Berbari E, Osmon DR. Antimicrobial prophylaxis in adults. *Mayo Clin Proc*; 86:686–701.
4. Maragh SL, Otley CC, Roenigk RK, Phillips PK. Antibiotic prophylaxis in dermatologic surgery: updated guidelines. *Dermatol Surg*. 2005;31:83–91.
5. Messingham MJ, Arpey CJ. Update on the use of antibiotics in cutaneous surgery. *Dermatol Surg*. 2005;31:1068–78.
6. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR. Guideline for Prevention of Surgical Site Infection, 1999. Centers for Disease Control and Prevention (CDC) Hospital Infection Control Practices Advisory Committee. *Am J Infect Control*. 1999;27:97–132. quiz 133–4; discussion 96.
7. Hirschmann JV. Antimicrobial prophylaxis in dermatology. *Semin Cutan Med Surg*. 2000;19:2–9.
8. Moorhead C, Torres A. I PREVENT bacterial resistance. an update on the use of antibiotics in dermatologic surgery. *Dermatologic surgery: official publication for American Society for Dermatologic Surgery* [et al.] 2009;35:1532–8.
9. • Rosengren H, Dixon A. Antibacterial prophylaxis in dermatologic surgery: an evidence-based review. *Am J Clin Dermatol*; 11:35–44. *This review article summarizes the evidence for and against antibiotic prophylaxis for dermatologic surgical site infection. It also outlines relevant aspects of the updated guidelines for prevention of infective endocarditis and prosthetic joint infection.*
10. Bykowski MR, Sivak WN, Cray J, Buterbaugh G, Imbriglia JE, Lee WP. Assessing the impact of antibiotic prophylaxis in outpatient elective hand surgery: a single-center, retrospective review of 8,850 cases. *J Hand Surg Am*; 36:1741–7.
11. Carignan A, Allard C, Pepin J, Cossette B, Nault V, Valiquette L. Risk of *Clostridium difficile* infection after perioperative antibacterial prophylaxis before and during an outbreak of infection due to a hypervirulent strain. *Clin Infect Dis*. 2008;46:1838–43.
12. •• Wright TI, Baddour LM, Berbari EF, Roenigk RK, Phillips PK, Jacobs MA, Otley CC. Antibiotic prophylaxis in dermatologic surgery: advisory statement 2008. *J Am Acad Dermatol* 2008;59:464–73. *This comprehensive review article evaluates the indications for prevention of infective endocarditis, prosthetic joint infection, and wound infection following dermatologic surgery.*
13. 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;249:551–6.
14. •• Del Rosso JQ. Wound care in the dermatology office: where are we in 2011? *J Am Acad Dermatol* 2011;64:S1–7. *This article gives an interesting historical background on antibacterial prophylaxis in dermatologic surgery, outlining the dangers of antibiotic resistance.*
15. Saleh K, Sonesson A, Persson B, Riesbeck K, Schmidtchen A. A descriptive study of bacterial load of full-thickness surgical wounds in dermatologic surgery. *Dermatol Surg*; 37:1014–22.
16. • Shurman DL, Benedetto AV. Antimicrobials in dermatologic surgery: facts and controversies. *Clin Dermatol*;28:505–10. *This review article gives a comprehensive update on infective endocarditis and prosthetic joint infection prevention guidelines relevant to dermatologic surgery.*
17. Anderson DJ, Kaye KS, Classen D, Arias KM, Podgorny K, Burstin H, Calfee DP, Coffin SE, Dubberke ER, Fraser V, Gerding DN, Griffin FA, Gross P, Klompas M, Lo E, Marschall J, Mermel LA, Nicolle L, Pegues DA, Perl TM, Saint S, Salgado CD, Weinstein RA, Wise R, Yokoe DS. Strategies to prevent surgical site infections in acute care hospitals. *Infection control and hospital epidemiology: the official journal of the Society of Hospital Epidemiologists of America* 2008;29 Suppl 1:S51–61.
18. Lipsky BA, Hoey C. Topical antimicrobial therapy for treating chronic wounds. *Clin Infect Dis*. 2009;49:1541–9.
19. Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG. CDC definitions of nosocomial surgical site infections, 1992: a

- modification of CDC definitions of surgical wound infections. *Infect Control Hosp Epidemiol*. 1992;13:606–8.
20. Rogers HD, Desciak EB, Marcus RP, Wang S, MacKay-Wiggan J, Eliezri YD. Prospective study of wound infections in Mohs micrographic surgery using clean surgical technique in the absence of prophylactic antibiotics. *J Am Acad Dermatol*; 63:842–51.
 21. Bordeaux JS, Martires KJ, Goldberg D, Pattee SF, Fu P, Maloney ME. Prospective evaluation of dermatologic surgery complications including patients on multiple antiplatelet and anticoagulant medications. *J Am Acad Dermatol*; 65:576–83.
 22. Toia F, D'Arpa S, Massenti MF, Amodio E, Pirrello R, Moschella F. Perioperative antibiotic prophylaxis in plastic surgery: A prospective study of 1100 adult patients. *J Plast Reconstr Aesthet Surg*.
 23. Landes G, Harris PG, Lemaine V, Perreault I, Sampalis JS, Brutus JP, Lessard L, Dionyssopoulos A, Nikolis A. Prevention of surgical site infection and appropriateness of antibiotic prescribing habits in plastic surgery. *J Plast Reconstr Aesthet Surg*. 2008;61:1347–56.
 24. Henderson NJ, Fancourt M, Gilkison W, Kyle S, Mosquera D. Skin grafts: a rural general surgical perspective. *ANZ J Surg*. 2009;79:362–6.
 25. Chan BC, Patel DC. Perioperative management and the associated rate of adverse events in dermatological procedures performed by dermatologists in New Zealand. *Australas J Dermatol*. 2009;50:23–8.
 26. Owens CD, Stoessel K. Surgical site infections: epidemiology, microbiology and prevention. *J Hosp Infect*. 2008;70 Suppl 2:3–10.
 27. Franz MG, Steed DL, Robson MC. Optimizing healing of the acute wound by minimizing complications. *Curr Probl Surg*. 2007;44:691–763.
 28. Tanner J, Khan D. Surgical site infection, preoperative body washing and hair removal. *J Perioper Pract*. 2008;18(232):237–43.
 29. Zhao X, Chen J, Fang XQ, Fan SW. Surgical site marking will not affect sterility of the surgical field. *Med Hypotheses*. 2009;73:319–20.
 30. Rhinehart MB, Murphy MM, Farley MF, Albertini JG. Sterile versus nonsterile gloves during Mohs micrographic surgery: infection rate is not affected. *Dermatol Surg*. 2006;32:170–6.
 31. Xia Y, Cho S, Greenway HT, Zelac DE, Kelley B. Infection rates of wound repairs during Mohs micrographic surgery using sterile versus nonsterile gloves: a prospective randomized pilot study. *Dermatol Surg*; 37:651–6.
 32. Rogues AM, Lasheras A, Amici JM, Guillot P, Beylot C, Taieb A, Gachie JP. Infection control practices and infectious complications in dermatological surgery. *J Hosp Infect*. 2007;65:258–63.
 33. Abubaker AO. Use of prophylactic antibiotics in preventing infection of traumatic injuries. *Oral Maxillofac Surg Clin North Am*. 2009;21:259–64. vii.
 34. McHugh SM, Collins CJ, Corrigan MA, Hill AD, Humphreys H. The role of topical antibiotics used as prophylaxis in surgical site infection prevention. *J Antimicrob Chemother*; 66:693–701.
 35. Heal C, Buettner P, Browning S. Risk factors for wound infection after minor surgery in general practice. *The Medical journal of Australia*. 2006;185:255–8.
 36. Dixon AJ, Dixon MP, Dixon JB. Prospective study of skin surgery in patients with and without known diabetes. *Dermatologic surgery : official publication for American Society for Dermatologic Surgery [et al.]* 2009;35:1035–40.
 37. Heal C, Buettner P, Drobetz H. Risk factors for surgical site infection after dermatological surgery. *International journal of dermatology In press*.
 38. Dixon AJ, Dixon MP, Askew DA, Wilkinson D. Prospective study of wound infections in dermatologic surgery in the absence of prophylactic antibiotics. *Dermatologic surgery: official publication for American Society for Dermatologic Surgery [et al.]* 2006;32:819–26; discussion 826–7.
 39. Penington A. Ulceration and antihypertensive use are risk factors for infection after skin lesion excision. *ANZ J Surg*. 2010;80:642–5.
 40. Sehgal R, Berg A, Figueroa R, Poritz LS, McKenna KJ, Stewart DB, Koltun WA. Risk factors for surgical site infections after colorectal resection in diabetic patients. *J Am Coll Surg*; 212:29–34.
 41. McConnell YJ, Johnson PM, Porter GA. Surgical site infections following colorectal surgery in patients with diabetes: association with postoperative hyperglycemia. *J Gastrointest Surg*. 2009;13:508–15.
 42. Lamloum SM, Mobasher LA, Karar AH, Basony L, Abdallah TH, Al-Saleh AI, Al-Shamali NA. Relationship between postoperative infectious complications and glycemic control for diabetic patients in an orthopedic hospital in Kuwait. *Med Princ Pract*. 2009;18:447–52.
 43. Dronge AS, Perkal MF, Kancir S, Concato J, Aslan M, Rosenthal RA. Long-term glycemic control and postoperative infectious complications. *Arch Surg*. 2006;141:375–80. discussion 380.
 44. O'Sullivan CJ, Hynes N, Mahendran B, Andrews EJ, Avalos G, Tawfik S, Lowery A, Sultan S. Haemoglobin A1c (HbA1C) in non-diabetic and diabetic vascular patients. Is HbA1C an independent risk factor and predictor of adverse outcome? *Eur J Vasc Endovasc Surg*. 2006;32:188–97.
 45. Latham R, Lancaster AD, Covington JF, Pirolo JS, Thomas CS. The association of diabetes and glucose control with surgical-site infections among cardiothoracic surgery patients. *Infect Control Hosp Epidemiol*. 2001;22:607–12.
 46. Zerr KJ, Furnary AP, Grunkemeier GL, Bookin S, Kanhere V, Starr A. Glucose control lowers the risk of wound infection in diabetics after open heart operations. *Ann Thorac Surg*. 1997;63:356–61.
 47. Sorensen LT, Jorgensen S, Petersen LJ, Hemmingsen U, Bulow J, Loft S, Gottrup F. Acute effects of nicotine and smoking on blood flow, tissue oxygen, and aerobic metabolism of the skin and subcutis. *J Surg Res*. 2009;152:224–30.
 48. Tosun Z, Bite U. A comparative study of the influence of smoking on skin flap survival in pregnant rats. *Br J Plast Surg*. 2005;58:812–6.
 49. Sylaidis P, Wood S, Murray DS. Postoperative infection following clean facial surgery. *Ann Plast Surg*. 1997;39:342–6.
 50. Dettenkofer M, Wilson C, Ebner W, Norgauer J, Ruden H, Daschner FD. Surveillance of nosocomial infections in dermatology patients in a German university hospital. *Br J Dermatol*. 2003;149:620–3.
 51. Perl TM. Prevention of *Staphylococcus aureus* infections among surgical patients: beyond traditional perioperative prophylaxis. *Surgery*. 2003;134:S10–7.
 52. Wenzel RP, Perl TM. The significance of nasal carriage of *Staphylococcus aureus* and the incidence of postoperative wound infection. *J Hosp Infect*. 1995;31:13–24.
 53. Kluytmans J, van Belkum A, Verbrugh H. Nasal carriage of *Staphylococcus aureus*: epidemiology, underlying mechanisms, and associated risks. *Clin Microbiol Rev*. 1997;10:505–20.
 54. Cordova KB, Grenier N, Chang KH, Dufresne R, Jr. Preoperative methicillin-resistant *Staphylococcus aureus* screening in Mohs surgery appears to decrease postoperative infections. *Dermatol Surg*; 36:1537–40.
 55. Garner JS, Jarvis WR, Emori TG, Horan TC, Hughes JM. CDC definitions for nosocomial infections, 1988. *Am J Infect Control*. 1988;16:128–40.
 56. Wahie S, Lawrence CM. Wound complications following diagnostic skin biopsies in dermatology inpatients. *Arch Dermatol*. 2007;143:1267–71.
 57. Lathlean S. Skin cancer in general practice in South Australia. A 5 year study. *Australian family physician* 1999;28 Suppl 1:S28–31.

58. Futoryan T, Grande D. Postoperative wound infection rates in dermatologic surgery. *Dermatol Surg.* 1995;21:509–14.
59. Maragh SL, Brown MD. Prospective evaluation of surgical site infection rate among patients with Mohs micrographic surgery without the use of prophylactic antibiotics. *J Am Acad Dermatol.* 2008;59:275–8.
60. Amici JM, Rogues AM, Lasheras A, Gachie JP, Guillot P, Beylot C, Thomas L, Taieb A. A prospective study of the incidence of complications associated with dermatological surgery. *Br J Dermatol.* 2005;153:967–71.
61. Paradela S, Pita-Fernandez S, Pena C, Fernandez-Jorge B, Garcia-Silva J, Mazaira M, Fonseca E. Complications of ambulatory major dermatological surgery in patients older than 85 years. *J Eur Acad Dermatol Venereol.* 24:1207–13.
62. Dixon AJ, Dixon MP, Askew DA, Wilkinson D. Prospective study of wound infections in dermatologic surgery in the absence of prophylactic antibiotics. *Dermatol Surg.* 2006;32:819–26. discussion 826–7.
63. Lewis KG, Dufresne Jr RG. A meta-analysis of complications attributed to anticoagulation among patients following cutaneous surgery. *Dermatol Surg.* 2008;34:160–4. discussion 164–5.
64. Dixon AJ, Dixon MP, Dixon JB. Bleeding complications in skin cancer surgery are associated with warfarin but not aspirin therapy. *Br J Surg.* 2007;94:1356–60.
65. Percival SL, Slone W, Linton S, Okel T, Corum L, Thomas JG. The antimicrobial efficacy of a silver alginate dressing against a broad spectrum of clinically relevant wound isolates. *Int Wound J.* 8:237–43.
66. Blair SE, Cokcetin NN, Harry EJ, Carter DA. The unusual antibacterial activity of medical-grade *Leptospermum* honey: antibacterial spectrum, resistance and transcriptome analysis. *Eur J Clin Microbiol Infect Dis.* 2009;28:1199–208.
67. White R. Wound dressings and other topical treatment modalities in bioburden control. *J Wound Care.* 20:431–9.
68. van Rijen M, Bonten M, Wenzel R, Kluytmans J. Mupirocin ointment for preventing *Staphylococcus aureus* infections in nasal carriers. *Cochrane Database Syst Rev* 2008:CD006216.
69. Trautmann M, Stecher J, Hemmer W, Luz K, Panknin HT. Intranasal mupirocin prophylaxis in elective surgery. A review of published studies. *Chemotherapy.* 2008;54:9–16.
70. Sheth VM, Weitzel S. Postoperative topical antimicrobial use. *Dermatitis.* 2008;19:181–9.
71. Heal CF, Buettner PG, Cruickshank R, Graham D, Browning S, Pendergast J, Drobetz H, Gluer R, Lise C. Does single application of topical chloramphenicol to high risk sutured wounds reduce incidence of wound infection after minor surgery? Prospective randomised placebo controlled double blind trial. *BMJ.* 2009;338:a2812.
72. Amland PF, Andenaes K, Samdal F, Lingaas E, Sandsmark M, Abyholm F, Giercksky KE. A prospective, double-blind, placebo-controlled trial of a single dose of azithromycin on postoperative wound infections in plastic surgery. *Plast Reconstr Surg.* 1995;96:1378–83.
73. Mailler-Savage EA, Neal KW, Jr., Godsey T, Adams BB, Gloster HM, Jr. Is levofloxacin necessary to prevent postoperative infections of auricular second-intention wounds? *Dermatologic surgery* : official publication for American Society for Dermatologic Surgery [et al.] 2008;34:26–30; discussion 30–1.
74. 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.
75. Classen DC, Evans RS, Pestotnik SL, Horn SD, Menlove RL, Burke JP. The timing of prophylactic administration of antibiotics and the risk of surgical-wound infection. *N Engl J Med.* 1992;326:281–6.
76. Scheinfeld N, Struach S, Ross B. Antibiotic prophylaxis guideline awareness and antibiotic prophylaxis use among New York State dermatologic surgeons. *Dermatol Surg.* 2002;28:841–4.
77. Hirschmann JV. Antimicrobial prophylaxis in dermatologic surgery. *Cutis.* 2007;79:43–51.
78. Bencini PL, Galimberti M, Signorini M, Crosti C. Antibiotic prophylaxis of wound infections in skin surgery. *Arch Dermatol.* 1991;127:1357–60.
79. Griego RD, Zitelli JA. Intra-incisional prophylactic antibiotics for dermatologic surgery. *Arch Dermatol.* 1998;134:688–92.
80. Huether MJ, Griego RD, Brodland DG, Zitelli JA. Clindamycin for intra-incisional antibiotic prophylaxis in dermatologic surgery. *Arch Dermatol.* 2002;138:1145–8.
81. Bencini PL, Signorini M, Galimberti M, Cavicchini S, Caputo R. Preoperative antibiotic prophylaxis in flexural surgery of difficult contamination-prone areas of the skin: the utility of a single dose of antibiotic. *J Dermatological Treatment.* 1994;5:17–9.
82. Alexander JW, MacMillan BG, Law EJ, Krummel R. Prophylactic antibiotics as an adjunct for skin grafting in clean reconstructive surgery following burn injury. *J Trauma.* 1982;22:687–90.
83. Aydin N, Uraloglu M, Yilmaz Burhanoglu AD, Sensoz O. A prospective trial on the use of antibiotics in hand surgery. *Plast Reconstr Surg.* 126:1617–23.
84. Weber WP, Marti WR, Zwahlen M, Misteli H, Rosenthal R, Reck S, Fueglistaler P, Bolli M, Trampuz A, Oertli D, Widmer AF. The timing of surgical antimicrobial prophylaxis. *Ann Surg.* 2008;247:918–26.
85. Spallek H, Song M, Polk DE, Bekhuis T, Frantsve-Hawley J, Aravamudhan K. Barriers to implementing evidence-based clinical guidelines: a survey of early adopters. *J Evid Based Dent Pract.* 10:195–206.
86. Soheilipour S, Scambler S, Dickinson C, Dunne SM, Burke M, Jabbarifar SE, Newton JT. Antibiotic prophylaxis in dentistry: part I. A qualitative study of professionals' views on the NICE guideline. *Br Dent J.* 211:E1.
87. Soheilipour S, Scambler S, Dickinson C, Dunne SM, Burke M, Jabbarifar SE, Newton JT. Antibiotic prophylaxis in dentistry: part II. A qualitative study of patient perspectives and understanding of the NICE guideline. *Br Dent J.* 211:E2.
88. Lindsay W, Bigsby E, Bannister G. Prevention of infection in orthopaedic joint replacement. *J Perioper Pract.* 21:206–9.
89. Shuman EK, Malani PN. Prevention and management of prosthetic joint infection in older adults. *Drugs Aging.* 28:13–26.
90. Cataldo MA, Petrosillo N, Cipriani M, Cauda R, Tacconelli E. Prosthetic joint infection: recent developments in diagnosis and management. *J Infect.* 61:443–8.