Risk factors for surgical site infection in minor dermatological surgery: A systematic review

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Abstract

Objective: Antibiotics can be prescribed as prophylaxis against surgical site infection (SSI) in dermatological surgery. In accordance with antibiotic stewardship, clinical evidence should inform judicious antibiotic prescribing. This review aimed to identify patient and procedure related risk factors for SSI following minor dermatological surgery.

Data sources: MEDLINE, CINAHL, Informit and Scopus databases were searched for relevant literature on patient populations receiving minor surgery, where risk factors for SSI were explicitly stated.

Study Selection: Studies involving major dermatological surgery were excluded. The preliminary search yielded 820 studies after removing duplicates. 210 abstracts were screened, and 42 full texts were assessed for eligibility. A total of 13 papers were included. Studies were appraised using the Newcastle-Ottawa Quality Assessment Scale.

Data Extraction: An electronic data collection tool was constructed to extract information from the eligible studies, and distributed to participating authors.

Data synthesis: Risk factors identified included age, sex, diabetes mellitus, chronic obstructive pulmonary disease (COPD), anti-hypertensive and corticosteroid use, smoking, surgery on the lower or upper extremities, excision of non-melanocytic skin cancers (NMSC), large skin excisions and complex surgical techniques. A maximum of two studies agreed on any one risk factor and there were insufficient studies for meta-analysis.

Conclusions: Re-excision of skin cancer, below knee excisions and intra-operative haemorrhagic complications were predictive for infection in more than one study. More high-quality studies are required to accurately identify risk factors so they can be reliably used in clinical guidelines.

Introduction

Surgical site infection (SSI) following dermatological surgery is associated with prolonged wound healing, lengthened recovery time, poor cosmesis and overall increased costs to the health system.[1] Both patient and clinician concerns regarding these adverse outcomes result in an anticipatory safety net of inappropriate antibiotic prophylaxis, which promotes undesirable antibiotic resistance.[2] A key recommendation from the antibiotic stewardship guidelines from the Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America is that antibiotic therapy should be based on patient specific factors,[3] hence an awareness of patients who are at higher risk of SSI is necessary to encourage more judicious antibiotic prescribing.

To accurately define patient groups predisposed to developing a SSI, a comprehensive understanding of patient, procedural and physician related risk factors is necessary. Extensive clinical studies have investigated these risk factors in small to large cohorts, however to our knowledge few studies have presented a large systematic review of all possible risk factors which contribute to an individual's overall risk of infection.

This review aims to systematically appraise the current evidence of risk factors for SSI in minor dermatological surgery, and identify where further research may be required.

Methods

Protocol/registration

The systematic review was registered in the PROSPERO international prospective register of systematic reviews (ID CRD42016045830).

Eligibility criteria

Two eligibility criteria were applied in this review. The first was based on a population, intervention, comparison and outcome (PICO) strategy (**Table 1**). Eligible papers examined

populations of patients undergoing minor dermatological surgical procedures (from 1990 to date), and described relevant risk factors for SSI in sufficient detail for data extraction. Minor dermatological surgery was defined as any small surgical procedure carried out on the skin, in an outpatient setting. The definition did not account for the size of the lesion excised. Although skin flaps could be considered to be a more complex surgery, they were included as they are often carried out in a primary care outpatient setting in Australia. Graft and Mohs procedures were included if they were a component of a study which included simple skin excisions but data on individual procedures could not be extracted. Major surgeries (which were excluded) were defined as larger plastic surgery procedures such as mammoplasties, abdominoplasties and gluteoplasties, as well as burns, graft procedures, and major oncological surgeries involving structures other than the skin (e.g. removal of head and neck cancer).

[TABLE 1]

The second eligibility criteria regarded the study design. Only cohort or case control studies in the English language were eligible for inclusion. Interventional studies, case studies, commentaries, letters, editorials and reviews were excluded. Randomised controlled trials were only included when the authors performed a secondary data analysis to define risk factors for surgical site infection.

Information sources

Ovid MEDLINE, CINAHL, Scopus and Informit were searched to identify relevant literature, from January 1, 1990 to the date of search. The search was conducted in May 2016, and repeated in August 2017. Reference lists of identified papers were also searched for additional studies.

Search

A search strategy based on the 'PICO' format described in **Table 1** was employed, using the search terms "Dermatological surgical procedures", "minor surgical procedures", "surgical wound infection", "skin neoplasms", "plastic surgery", and variations (as suggested by the MESH headings), combined with Boolean search terms 'AND' and 'OR' as appropriate. Specifiers within each term's subject tree were used to narrow down the search. The MESH terms and their alternative terms were used in databases which could not be searched using subject headings. Full electronic search strategies for each database can be found in the appendix.

Study selection

Following removal of duplicates, title scanning for relevance resulted in removal of a number of papers from consideration, while titles that were ambiguous were included for abstract screening. The remaining abstracts were then perused to identify articles relevant to the topic, followed by full text screening, using the PICO criteria described in **Table 1**. The author (MD) and two independent assessors (MP and PD) screened all papers.

Data collection process

A data collection tool was constructed to extract information from the eligible studies. This tool comprised the following fields: 'author', 'year', 'country', 'study type', 'population', 'setting', 'sample size', 'methods used', 'surgical procedures done', 'definition of infection', 'infections', 'risk factors for infection', 'secondary outcomes', 'key conclusions' and 'source of funding'. Infections were expressed as absolute and relative frequencies.

Risk of bias in individual studies

Papers were evaluated with the Newcastle-Ottawa Quality Assessment Scales to determine the quality of each study. Papers found to be of low quality were interpreted with caution.

Summary measures

The ideal summary measure for this review was relative risk. If relative risk was not available, then odds ratios were presented. If neither were available, proportions of infection in each risk factor group were presented, with confidence intervals and statistical significance if available.

Synthesis of results

The risk factors identified were highly variable and expressed via different summary measures, therefore a meta-analysis was not performed due to the heterogeneity of the data.

Results

Study selection

The literature search retrieved 892 articles. Following elimination of 72 duplicates, 610 articles were excluded after title screening. Abstracts of the remaining 210 eligible articles were reviewed, and 42 full texts were screened. A total of 13 studies were included. This screening process is presented in the context of the '*Preferred Reporting Items for Systematic Reviews and Meta-Analyses' (PRISMA)* flow chart, in **Fig. 1**.

Figure 1. Screening process of eligible articles as per the PRISMA guidelines.

[FIG 1 HERE]

Characteristics

Study characteristics and results of individual studies have been combined into one single section below.

Risk of bias within studies

The quality of the studies per the '*Newcastle-Ottawa Quality Assessment*' is presented in **Table 2**. Only one quality assessment scale was required. Most studies were representative of the 'true exposed cohort', as they followed all patients from the start of the study until its endpoint,

and only excluded patients if they significantly altered the results (i.e. already taking antibiotics). The main source of bias arose from assessment of the primary outcome. The diagnosis of surgical site infection is subjective, and while several different definitions exist, there is a need for more validated, reliable and standardised definition of SSI.[4] We decided to employ the Centres for Disease Control (CDC) criteria as it is currently considered to be the gold standard, although is still prone to subjectivity.[5] The time period involved for definition of infection varied between studies from time of discharge from hospital, to time of removal of sutures or 30 days post-operatively (The CDC guidelines use up to 30 days). Further, in all but one study the outcomes were self-reported either by the investigators or a separate clinician. The study which did not self-report outcomes enlisted a pathologist to blindly report whether infection was present or not in lab results.[6]

Results of individual studies

Results of individual studies are summarised in **Table 3.** Two of the 14 studies were performed in a general practice setting,[7-8] with the remainder in private clinic rooms, operating theatres or a combination. Studies were based in Australia, North America or Europe. Two studies consisted of total procedures rather than total patients, which raised the issue of having multiple wounds per patient. These studies are marked accordingly in **Table 3**. Infection rates ranged from 1.3%-27.0%, however the overall incidence of infection was low. Exceptions were studies carried out in general practice settings in Australia, and another study with a small sample size.[7-9] Demographic, social/environmental, medical, preoperative and intraoperative risk factors were described in the studies. Only two papers reported their results with a relative risk. Due to non-homogeneity of results across the papers identified, the risk information was collectively presented under the column 'Risk measure', as either relative risk, odds ratio, proportion of the exposure group that developed the outcome versus the proportion without.

[TABLE 2 HERE]

[TABLE 3 HERE]

Demographic factors

Only one study of 1000 patients reported older age (>50 years) as a risk factor (OR 5.5, 95% CI 1.9-16.0).[10] Men had a higher risk of infection than women in the same study (OR 5.1, 95% CI 1.7-15.9) and in another large prospective study when reconstructive procedures were involved (OR 5.46, 95% CI 1.12-26.54, p=0.04).[10,11]

Patient medical comorbidities

A large hospital study found diabetes mellitus (OR 2.54, 95% CI 1.10-5.87, p=0.03) and chronic obstructive pulmonary disease (COPD) (OR 2.52, 95% CI 1.06-5.97, p=0.04) were significantly associated with infection.[12] A smaller general practice study in Australia also found that diabetes mellitus predisposed to infection (RR 1.7, 95% CI 1.4-2.2, p<0.001).[7]

Medication/treatment related factors

Use of anti-hypertensives were associated with infection (OR 2.5, 95% CI 1.4-4.2, p-0.006) in a large Australian study. A small British study (with a high infection rate) found 63% of patients on corticosteroids developed an infection compared to 21% who were not taking the medication (95% CI difference 19%-66%, p<0.001).[9]

Smoking

Ex-smokers were found to have a higher risk of infection in a general practice setting (RR 1.7, 95% CI 1.1-2.6, p=0.02).[8] In a small prospective hospital study, 63% of smokers developed an infection compared to 12% of non-smokers (95% CI difference 34%-70%, p<0.001).[9]

Location of lesion and surgical site

Procedures below the waist were associated with an increased risk of surgical site infection. In one study 48% of patients who had a ‘below waist’ procedure developed an infection, compared to 23% in those who received their procedure above the waist (95% CI difference

4%-47%).[9] Another study also reported that 17.6% of their total excisions occurred on the lower limb (p<0.001).[13] In general practice, there was a higher risk of infection in procedures on the thighs (RR 2.2, 95% CI 1.3-3.6, p=0.002) and legs/feet (RR 1.9, 95% CI 1.1-3.1, p=0.02) in one study,[7] and 'lower extremities' (RR 3.7, 95% CI 1.9-6.9, p<0.001) in the other.[8] A private hospital study reported similar findings, as 6.92% of their surgical wounds below the knee (p<0.001), and 10% around the groin (p=0.03) became infected.[14] An American study supported these findings, with procedures on the leg having increased odds of infection (OR 4.28, p=0.03).[6]

The trunk (OR 4.49, p=0.005), scalp (OR 4.33, p=0.01),[6] and upper extremities (RR 3.2, 95% CI 2.3-4.4, p<0.001) were high risk surgical sites for infection.[8] A smaller study also found 6.5% of patients receiving surgery on the nose and 5.2% on the ear developed an infection, with no statistical inference.

Surgical factors – complexity and size of procedure

The type of procedure was reported to be a significant risk factor. In a private surgery setting, 8.57% of patients receiving wedge resections (lip/ear), and 8.7% of patients receiving graft procedures developed an infection (p<0.001).[14] Flap repairs had the highest proportion of infections (15.5%, p<0.001) in another private surgery based study in Australia.[13] This finding was supported by a small German study (p=0.009), however this result was not quantified.[15] 'Complex surgical wounds' (flap and graft procedures) were also risk factors for infection in a British study.[16]

The same study found excisions larger than 20mm in length conferred an increased risk of infection (RR 2.4, 95% CI 1.7-3.4, p<0.001). In a small study of 100 patients, 7.5% of patients who had an excision larger than the median defect length (>30mm) developed an infection, compared to 1.4% in the group without this exposure.

Histology of lesion

Excision of non-melanocytic skin cancers (NMSC), specifically squamous cell carcinomas (SCC) and basal cell carcinomas (BCC) were risk factors. This finding was demonstrated in general practice, with the earlier study reporting a higher risk of infection if a BCC (RR 2.1, 95% CI 1.3-3.4, p=0.004) or SCC (RR 1.8, 95% CI 1.3-2.6, p<0.001) was excised.[7] The more recent study found that conversely, SCC excisions (RR 2.3, 95% CI 1.1-4.6) held a higher risk of infection compared to BCC excision (RR 2.1, 95% CI 1.4-3.2, p=0.001), both posing a significant risk compared to those who were not having a NMSC excised.[8] Another study reported a 12.0% infection rate in a population undergoing skin cancer removal, compared to 0.8% in those that underwent non-cancerous procedures.[16] Re-excision of skin cancer was also strongly predictive of infection (RR 14.8, 95% CI 4.5-28.5, p<0.001).[8]

Haemorrhagic and anaesthetic complications

A haemorrhagic complication was uncontrolled bleeding around the time of surgery or development of a haematoma shortly after, and an anaesthetic complication was vaso-vagal syncope, clinical signs of drug reaction or neurological signs of overdose. One study found both haemorrhagic (OR 7.59, 95% 3.95-14.61, p<0.001) and anaesthetic complications (OR 4.58, 95% CI 1.61-13.00, p<0.004) had increased odds of infection.[17] Another study carried out separate analyses for reconstructive procedures and simple excisions, and haemorrhagic complication was a risk factor for infection in both (OR 11.29, 95% CI 3.43-37.16, p<0.001), (OR 6.6, 95% CI 2.52-17.30. p<0.001).[11]

Other

Receiving preoperative radiotherapy (OR 20.35, 95% CI 5.37-77.17, p<0.001) and the insertion of a surgical drain (OR 3.02, 95% CI 1.64-5.57, p<0.001) were associated with increased odds of developing an infection in one Italian study.[12] In an audit paper, 28.5% of patients whose surgery involved the cartilage developed an infection, compared to 5.9% of the

group where the surgery was above the level of the cartilage. Mohs surgery on the ear was also a risk factor, (12.5% vs.1.45% in the 'non-ear' group).[18] One of the studies carried out in a private surgical setting in Australia found ulceration of the wound/lesion was a risk factor (OR 3.15, 95% CI 1.8-5.7, p=0.008), as was keeping the wound dry (OR 2.1, 95% CI 1.1-3.8, p-0.018).[13] A small British study reported that location of the operation (53% infected in ward vs. 17% in operating theatre, 95% CI difference 17%-55%, p<0.001), and experience of the surgeon were associated with infection (33% infected in patients operated on by senior house officer, and 14% operated on by a specialist registrar and consultant (95% CI difference 2%-37%, p=0.03).[9]

Aseptic technique

The use of non-sterile gloves was identified as a risk factor for infection (OR 0.18, 95% CI 0.05-0.65, p=0.009), in a French study with the odds ratio in favour of sterile gloves, but only in a subgroup of more complex procedures.[11]

Discussion

This systematic review identified 13 papers which measured risk factors for SSI in minor dermatological surgery. Two studies were assessed to be high quality, two were moderate-high, two moderate, four low-moderate and three studies were of low-quality.

Although setting of the studies varied from outpatient clinics/examination rooms to hospital operating theatres, it is difficult to assess whether this had an impact, as heterogeneity did not allow us to analyse infection by setting. The one study which formally assessed this was underpowered and of poor quality.[9]

Whilst no restrictions were placed on the country of origin, all included papers were published in developed western countries. Surgical site infection is low after dermatological surgery as evidenced in this review, and associated with low rates of morbidity and mortality. Indeed, the applications of this study are more concerned with improving outcomes relevant in western setting, such as costs to the health system, maintaining cosmetic appearance and antibiotic resistance. Such issues are minor in comparison to the more pressing public health concerns in developing countries.

Infection rates in most studies were between 1%-5%, consistent with the CDC accepted rate of infection following clean minor surgery (<5%).[19] Exceptions were three Australian studies, conducted in a tropical setting, reporting infection rates between 7.25%-8.70%.

Only one study identified age>50 as a risk factor on multivariate analysis, however a direct relationship is unlikely due to the number of confounding factors associated with older age which might lead to vascular compromise, poorer wound healing and greater risk of infection. Male sex was a risk factor in two low-moderate quality studies with large sample sizes.[10,11] This relationship has been identified in non-dermatological studies,[20] and is likely due to inherent health behaviours and practices of males regarding wound care and post-surgical management.

While two large studies demonstrated that Diabetes mellitus was a risk factor, the authors of the latter study confirmed that this parameter was under recorded.[7,12] Diabetes mellitus may be associated with infection due to its immunological and vascular complications.[21] However, the sparsity and poor level of evidence across the dermatological literature makes it difficult to draw any definite conclusions in this population. COPD is a plausible risk factor as affected patients have impaired innate immunity.[22] It is also possible that COPD is associated with infection due to the inherent risks of smoking (see below) and concomitant steroid use.

Anti-hypertensive and corticosteroid use were risk also factors. The immunosuppressive effects of corticosteroid use are well recognised in the medical literature; why anti-hypertensive medication predisposes to wound infection is less clear. As the authors of this study did not control for medical-comorbidities it is possible that underlying vascular defects (causing hypertension) were responsible for impaired wound healing. Hypertension itself (rather than the use of anti-hypertensives) has been purported as a risk factor in non-dermatological surgery populations.[23]

The effect of smoking on SSI is contentious. While generally believed to be a contributor to infection due to its adverse effects on perfusion, coagulation, capillary oxygen transfer and collagenesis,[24] only two studies reported an association. One study had poor methodology, and the other claimed that the status of ‘ex-smoker’ rather than ‘current-smoker’ conferred an increased risk. This result should be appreciated with caution however, as time between quitting smoking and involvement in the study was not specified and it is unclear how having previously smoked would impart a greater risk of infection than being a current smoker.

Several studies identified an increased incidence of infection when procedures were performed on the extremities of the upper and lower limbs but particularly below the knee. Procedures on the ear and nose were also more likely to become infected. Although facial

wounds have a lower infection rate due to high vascularity,[16] sites such as the ear and nose have been previously noted as high risk areas for infection, due to increased moisture and higher concentrations of local flora and sebaceous glands.[25] It is likely that the higher risk of infection in the extremities is also due to the reduced perfusion at these locations, implying a substandard healing process compared to a wound with ample perfusion.

The impact of the type of the procedure was similarly well documented. The high rates of infection after flap and graft procedures are plausible due to the degree of skin damage inflicted. Flap surgery is a larger and more complex procedure compared to a simple skin incision, and although designed to reduce wound tension, still has a higher overall tension compared to smaller closures, deeming it more susceptible to breakage and opening.[26] Skin grafts are required for wounds too large to be closed by simple techniques, however unlike flap surgery, grafted skin lacks adequate blood supply. We postulate that with more complex wound closure and compromised blood flow, comes higher risk of wound reopening and poor vascular access, creating a portal for infection as well as an ideal environment for bacterial growth. This may clarify why wound size was also a significant risk factor for infection.

Excision of SCCs and BCCs were risk factors for infection in several studies.[7,8,16] As non-melanocytic skin cancers are often excised from the nose and ear,[27] it is possible that it is the location on which non-melanocytic skin cancers arise that have a higher risk of developing wound infection, rather than the lesion itself. However, BCC and SCC were still a risk factor when body site was controlled on multivariate analysis, and it is likely that oncological surgery is itself a risk factor, possibly because of the increased risk of ulceration and the viability of surrounding skin.

Haemorrhagic complications were associated with developing an infection in two studies, as was an anaesthetic complication. Haemorrhagic complications during surgery might indicate a deeper underlying pathology causing abnormal bleeding, and this may be the indirect

cause of increased risk. Haemostasis comprises the first of the four stages of wound healing,[28] – without this crucial step, the remaining components of tissue repair cannot take place, or occur improperly which ultimately results in impaired wound healing. Failure to execute a normal inflammatory response followed by rapid tissue remodelling following a surgical injury could therefore provide ideal environmental conditions for bacterial colonisation and subsequent SSI. Why anaesthetic complications increase infection risk is unclear, but could be due to changes in surgical procedure that may occur, favouring resuscitative/supportive action over asepsis in such a situation. However, such risk factors are not relevant in the outpatient setting in which minor dermatological surgery is typically performed.

This review had several limitations. Wound infection is a subjective diagnosis and subject to intra- and inter-observer variability.[29] Standardised diagnostic criteria exist,[5] however many studies did not use them. Secondly, few studies examined the same risk factors. This also meant that a meta-analysis was not possible due to the heterogeneity of the data collected. Ideally we would have preferred to study more risk factors pertaining to the patient and staff, pre-operative skin preparation and other intra-operative variables, however we were limited by the variables presented in the studies collected. Lastly, although we limited this review to English language, including non-English language articles would have only increased findings by one.

Conclusion

Identifying risk factors for surgical site infection guides evidence based, judicious antibiotic prophylaxis. This systematic review aimed to comprehensively present the current known risk factors for SSI following minor dermatological surgery.

The risk factors identified were re-excision of skin cancer, below knee excisions, lesion histology, developing a haemorrhagic complication during surgery and receiving preoperative radiotherapy, however the latter two of these risk factors may not be relevant to the outpatient setting in which most minor dermatological surgery is performed.

The results of this review study highlight the contribution of patient risk factors for SSI when considering potential candidates for prophylaxis, however the low power of the studies involved highlights the need for larger and adequately powered studies in this field. We hope that the results of this study will encourage further research regarding risk factors for SSI, to contribute to clinical practice guidelines regarding antibiotic prophylaxis, ideally leading to more judicious and evidence based antibiotic prescription.

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Tables

Table 1. 'PICO' search strategy.

'PICO' terms	Description
Population	All patients undergoing a minor dermatological surgical procedure worldwide (1990-onwards)
Intervention	The presence of a risk factor which increase or decreases the likelihood of developing a surgical site infection, including but not limited to - Age >65 - Tobacco smoking - Diabetes mellitus/other medical comorbidities - Wound size - Wound location - Complexity of surgery - Use of corticosteroids - Use of immunomodulatory drugs
Comparison	Absence of the risk factor in that same population
Outcome	Primary - Surgical site infection Secondary - Scarring/cosmesis - Cellulitis, deeper infection, sepsis - Death - Length of stay

Table 2. Quality assessment of included studies with the Newcastle-Ottawa Quality Assessment Scale.

Author & year	Country and setting	Study design	Selection	Comparability	Outcome	Outcome of quality assessment
Amici 2003	France Examination rooms, dedicated private clinic treatment rooms, hospital operating theatre	Prospective cohort	All patients receiving surgical procedures in the study period (2002-2003) by the volunteer members of the dermatological surgical society. Non-exposed/exposed arising from same community. Source of ascertainment of exposure not described. Demonstrated outcome was not present before starting study by excluding those suspected.	Controlled for significant associated variables with multivariate analysis.	Outcome based on self-reported subjective/objective classification. Follow-up period not specified, but appeared to capture outcome specified in all cases. No patients lost to follow-up.	Moderate
Bordeaux 2007	USA Private dermatology clinic rooms	Prospective cohort	All patients presenting to a dermatology clinic (2006-2007). Non-exposed/exposed arising from same community. Ascertainment of exposure from either structured questionnaire or secure record. Did not demonstrate that outcome was not present before study.	Controlled for significant associated variables with multivariate analysis (but not for infection outcome)	Outcome objectively and blindly confirmed by pathologist (cultures required to confirm infection). Did not specify period of follow-up, although suture removal was used as a marker, and follow-up prompted by investigators. No patients lost to follow-up.	Moderate-high
Dixon 2005	Australia Private dermatology clinic operating theatre, private	Prospective cohort	All patients managed at a private clinic (2002-2005) by one surgeon. Non-exposed/exposed arising from same community. Source of ascertainment of exposure not described but presumably from patient, staff and self-reporting. Avoided	Not controlled for variables, did not perform multivariate analysis.	Outcome assessed subjectively through predetermined categories. Not specified who assessed but likely self-reported. Strong adherence to follow-up. Follow up period to	Low-moderate

	hospital operating theatre		including those with outcome before study by excluding those who had the outcome until they were treated.		suture removal, appropriate for outcome. No patients lost to follow-up.	
Drapeau 2005	Italy Day surgery theatre or in hospital surgery wards	Prospective cohort	All patients from 23 hospitals (2004-2005) undergoing plastic and reconstructive surgery. Non-exposed/exposed arising from same community. Source of ascertainment of exposure not described. Did not demonstrate that outcome was not present before study.	Controlled for significant associated variables with multivariate analysis.	Outcome assessed using a standardised criterion (CDC), not specified whether this was blinded. Appropriate follow-up period of entire hospital stay or 30 days post discharge via clinics. No patients lost to follow-up.	Moderate-high
Futoryan 1995	USA Outpatient clinic surgery room	Retrospective chart review	Random patients from a surgical logbook obtained chronologically. Non-exposed/exposed arising from same community. Ascertained exposure from medical records, and patients if information was missing. Did not demonstrate that outcome was not present before study.	Not controlled for any variables. Did not perform multivariate analysis. Audit style study.	Outcome assessed subjectively using clinical features or objectively based on a clinician's decision to prescribe antibiotics. Did not specify who made this assessment or if was blinded. No patients lost to follow-up.	Low
Gabrielli 1996	Italy Setting not specified	Prospective cohort	All outpatients receiving plastic surgery (1995-1996). Non-exposed/exposed arising from same community. Source of ascertainment of exposure not described. Partially avoided including those with outcome before study by excluding those with abnormal blood results. Infection is often present without abnormal blood findings however.	Controlled for significant associated variables with multivariate analysis.	Outcome assessed subjectively by medical staff at varying time intervals, using clinical features. Follow-up intervals appropriate to assess outcome. No patients lost to follow-up.	Low-moderate
Heal 2006	Australia General practice treatment rooms	Prospective study of patients invited to participate in a trial	All patients presenting for minor skin excisions at four general practices (2004-2005), invited to participate in a trial, performed by 19 general practitioners. Non-exposed/exposed arising from same community. Ascertained exposure from general practice	Controlled for significant associated variables with	Outcome assessed with a standardised criterion (CDC) by a nurse/doctor who was not an investigator. Follow-up period was until suture removal, appropriate for the	High

			medical records from practice nurses. Demonstrated outcome was not present prior to study via exclusion criteria.	multivariate analysis.	outcome, and no patients were lost to follow up.	
Heal 2012	Australia General practice treatment rooms, skin cancer clinic treatment rooms	Prospective study of patients invited to participate in a trial	All patients presenting for minor skin excisions at three general practices, invited to participate in a trial, performed by 16 general practitioners. Non-exposed/exposed arising from same community. Ascertained exposure from general practice medical records from practice nurses. Demonstrated outcome was not present prior to study via exclusion criteria.	Controlled for significant associated variables with multivariate analysis.	Outcome assessed with a standardised criterion (CDC) by a nurse/doctor who was not an investigator. Follow-up period was until suture removal, appropriate for the outcome, and no patients were lost to follow up.	High
Penington 2010	Australia Private hospital procedure room	Prospective cohort	All consecutive patients receiving skin excisions by a single surgeon at a private hospital. Non-exposed/exposed arising from same community. Ascertained exposure from a standardised data collection form. Did not demonstrate that outcome was not present before study.	Controlled for significant associated variables with multivariate analysis.	Outcome assessed by surgeon subjectively, self-reported by patient, or objectively based on antibiotic prescription. Follow-up period not specified but not patients lost to follow-up.	Moderate
Rogues 2007	France Private office treatment rooms, examination rooms, specially designed procedure rooms and hospital operating theatres	Prospective cohort	All patients receiving surgical procedures in the study period (2002-2003) by the volunteer members of the dermatological surgical society. Non-exposed/exposed arising from same community. Source of ascertainment of exposure not described. Demonstrated outcome was not present before starting study by excluding those with suspected outcome.	Controlled for significant associated variables with multivariate analysis.	Not specified who assessed outcome, but this was done by a non-reported classification procedure. Follow-up period was until suture removal. No patients lost to follow-up.	Low-moderate
Schliephake 1994	Germany Not specified	Retrospective cohort	Patients who had received resection of skin tumours around the head and neck area. Non-exposed/exposed arising from same community. Non-exposed/exposed arising from same	Controlled for significant associated variables	Did not specific how outcome was assessed or by whom. Did not specify follow-up period. No patients lost to follow up.	Low

			community. Source of ascertainment of exposure not described. Did not demonstrate that outcome was not present before study.	with multivariate analysis.		
Sylaidis 1995	UK Hospital operating theatre	Prospective cohort	All patients attending plastic surgical unit (1995-1995) for clean elective facial surgery. Non-exposed/exposed arising from same community. Ascertained exposure from a standardised questionnaire. Demonstrated outcome was not present before starting study by excluding those with suspected outcome.	Not controlled for variables. Only univariate analysis performed. Audit style research.	Outcome assessed blindly but subjectively by non-investigating clinicians. Graded outcome based on a surrogate criterion. Objectively classified on a pathological basis.	Low
Wahie 2006	UK Hospital dermatology ward and examination rooms	Prospective cohort	All patients who underwent incisional and excision skin biopsies during admission in a 9-month period in 2006. Non-exposed/exposed arising from same community. Exposure data ascertained by records, notes, microbiology reports and charts. Did not demonstrate that outcome was not present before study.	Controlled for significant associated variables, with multivariate analysis. but none found. Low positive events (29)	Outcome assessed by investigator, subjectively using clinical features. Follow - up was until discharge, appropriate for outcome, and occurred at regular intervals.	Low-moderate

Table 3. Risk factors for surgical site infection in dermatological surgery. [a] Presented as relative risk (RR), odds ratio (OR) or proportions of the exposed vs. unexposed populations with infection. [1]No significant risk factors were found on univariate analysis. When looking at surgical site alone in logistic regression, the mentioned locations were found to be significantly associated with increased infection. [2]Odds ratios were not presented for variables which had more than one category; proportions presented for these variables. $_p$ Indicates a sample size of procedures/excisions rather than the number of patients. [3] Univariate results presented as no significant risk factors came out of multivariate analysis. Likely due to small sample size and number of infections. 95% confidence intervals are for the difference in measures. All studies which present confidence intervals conducted multivariate analysis. COPD – chronic obstructive pulmonary disease. BCC – basal cell carcinoma. SCC – squamous cell carcinoma.

Author, year, (country)	**Sample size**	**Incidence of infection**	**Risk factors for infection**	**Risk measure[a]**	**95% confidence interval, (p value)**
Amici 2003 (France)	3788	2.1%	Haemorrhagic complication	OR 7.59	3.95-14.61, (p<0.001)
			Anaesthetic complication	OR 4.58	1.61-13.00 (p<0.004)
Bordeaux 2007 (USA)[1]	1911	1.3%	Trunk	OR 4.49	Not provided (p=0.005)
			Scalp	OR 4.33	Not provided (p=0.01)
			Leg	OR 4.28	Not provided (p=0.03)
Dixon 2005 (Australia)	5091_p	1.47%	Groin	10.00%	Not provided p=0.03
			Skin grafts	8.70%	Not provided p<0.001
			Wedge resections (of lip/ear)	8.57%	Not provided

			Below knee	6.92%	P<0.001 Not provided p<0.001
Drapeau 2005 (Italy)	2806	3.0%	Preoperative radiotherapy	OR 20.35	5.37-77.17 (p<0.001)
			Use of surgical drain	OR 3.02	1.64-5.57 (p<0.001)
			Diabetes mellitus	OR 2.54	1.10-5.87 (p=0.03)
			COPD	OR 2.52	1.06-5.97 (p=0.04)
Futoryan 1995 (USA)	1047	2.3%	Involvement of cartilage	28.5% v 5.9%	Not provided
			Mohs surgery on ear v non-ear	12.5% v 1.45%	Not provided
Gabrielli 1996 (Italy)	1000	1.7%	Older age (>50 years)	OR 5.6	1.9-16.0 (not provided)
			Male sex	OR 5.1	1.7-15.9 (not provided)
Heal 2006 (Australia)	857	8.6%	Thighs	RR 2.2	1.3-3.6 (p=0.002)
			BCC	RR 2.1	1.3-3.4 (p=0.004)
			Legs, feet	RR 1.9	1.1-3.1 (p=0.02)
			SCC	RR 1.8	1.3-2.6 (p<0.001)
			Diabetes mellitus	RR 1.7	1.4-2.2 (p<0.001)
Heal 2012 (Australia)	972	8.7%	Re-excision of skin cancer	RR 14.8	4.5-28.5 (p<0.001)
			Lower extremities	RR 3.7	1.9-6.9 (p<0.001)
			Upper extremities	RR 3.2	2.3-4.4

					(p<0.001)
			Excision >20mm	RR 2.4	1.7-3.4
					(p<0.001)
			SCC	RR 2.3	1.1-4.6
					(p=0.02)
			BCC	RR 2.1	1.4-3.2
					(p=0.001)
			Ex-smoker	RR 1.7	1.1-2.6
					(p=0.02)
Penington 2010 (Australia)	924_p	7.25%	Ulceration	OR 3.15	1.8-5.7
					(p=0.008)
			Anti-hypertensives	OR 2.5	1.4-4.2
					(p=0.006)
			Kept wound dry	OR 2.1	1.1-3.8
					(p=0.02)
			Site[2]	Lower limb (17.6%)	Not provided
					(p<0.001)
			Closure[2]	Flap repairs (15.5%)	Not provided
					(p<0.001)
Rogues 2007 (France)	3491	1.90%	*Reconstructive procedures*		
			Haemorrhagic complication	OR 11.29	3.43-37.16
					(p<0.001)
			Immunosuppressive treatment	OR 9.99	1.83-54.30
					(p=0.008)
			Male gender	OR 5.46	1.12-26.54
					(p=0.04)
			Wearing sterile gloves	OR 0.18	0.05-0.65
					(p=0.009)
			Simple excision		
			Haemorrhagic complication	OR 6.6	(2.52-17.30)
					(p<0.001)
Schliephake 1994	273	5.13%	Defect larger than median v defect smaller than median	7.5% v 1.4%	Not specified (p=0.01)

(Germany)			Flap procedures	Not specified	Not specified (p=0.009)
Sylaidis 1995 (UK)	464	2.80%	Oncological surgery v non-oncological surgery	12.0% v 0.8%	Not specified (p<0.001)
			Complex surgical wounds (flaps/grafts)	Not specified (variable depending on surgical site)	Not specified (p value variable depending on site)
			Nasal area	6.5%	Not specified (p=0.01)
			Auricular area	5.2%	Not specified (p=0.03)
Wahie 2006 (UK)[3]	100	27%	Below waist v above waist	48% v 23%	4%-47% (p=0.02)
			In ward v in operating theatre	53% v 17%	17%-55% (p<0.001)
			Senior house officer v specialist registrar & consultant	33% v 14%	2%-37% (p=0.03)
			Smoker v non-smoker	64% v 12%	34%-70% (p<0.001)
			Corticosteroids v none	63% v 21%	19%-66% (p<0.001)