Incidence and risk factors of surgical site infection in abdominal surgeries: A scoping review of cohort and case–control studies

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Abstract

Background

Abdominal surgery is considered a high-risk surgery for the development of surgical site infection. Few studies have evaluated the relative importance of its risk factors. Therefore, in this paper we mapped and summarized the evidence aimed to determine the relative importance of the risk factors and incidence of surgical site infections in abdominal surgery.

Methods

We searched SCOPUS, PubMed, and Web of Science databases up to March 16, 2023. Using the methodology of the Joanna Briggs Institute, we used both univariate and multivariate analysis results to evaluate the relative importance of the risk factors.

Results

Of 14,237 identified records, 107 articles were included in the review. The National Nosocomial Infection Surveillance (NNIS) risk index, operative time, and higher wound class were strong risk factors for surgical site infection incidence. Patients' educational status, malnutrition, functional status, and history of neurological/psychiatric disorders were also the risk factors, but there is a need for more evidence to reach a conclusion. The pooled incidence of surgical site infections was 10.6% (95% CI 9.02–12.55) in abdominal surgery, and the type of surgical procedures accounted for 31.5% of the heterogeneity.

Conclusion

Our findings show that surgical site infection in abdominal surgery is a multifactorial phenomenon with a considerable risk and has different risk factors with various relative importance. Determining the relative importance of the risk factors for prevention and control of surgical site infection is strongly recommended. We provide some recommendations for future research.

Background

An increasingly large number of global populations are at risk of surgical site infection (SSI) and its negative consequences. Weiser and his colleagues estimated that 312.9 million operations took place in the world in 2012(1). As the world population ages, the number of surgeries can increase. Liu et al. have indicated that the rates of general surgery increase with age. They revealed that 65-year-old individuals had three times more surgery than 15- to 44-year-old ones and 1.6 times more often than 45- to 64-year-old ones(2). About 9·4% and 23·2% of surgical patients worldwide develop a surgical site infection(3), and 38 percent of the patients who develop SSI die due to the infection(4). Surgical site infection affects the patients' safety(5), their physical and mental health (6), longer hospital stay, reoperation, readmission, and elevated healthcare cost for patients and hospitals (6–12), and it is a quality issue for health care systems(13).

Abdominal surgery represents a diverse group of procedures that form the core of general and paediatric surgical practice and a variety of surgical training programs. Abdominal operations are not limited to the practice of general surgeons, but urologists and gynaecologists may also perform it for a wide variety of indications (14). Abdominal surgeries are more likely to have bacterial contamination than others and are at a higher risk of surgical site infection than other surgeries (15–17). Previous reviews have estimated the incidence of surgical site infection in general(18–20) or specific types of abdominal surgery such as appendectomy(21), and hepatopancreatobiliary surgery (22) or patients undergoing general surgery(23); this study aimed to focus on the incidence of surgical site infection in abdominal surgery in general.

The relative importance of risk factors in development of SSI in the term of consistency is unknown. Traditionally, these risk factors are considered as the surrogate of underlying cause although they are also used for prediction purposes. The strength of the association of risk factors with the outcome is important because the more the strength of association, the more likely the relationship is thought to be causal. The epidemiologist commonly tries to quantify the strength of the association; however, consistency of the association is also of utmost importance to consider. Risk factors that can consistently predict the surgical site infection are more likely to have causal relationship or to be a good predictor. Such strong risk factors can help us to develop prevention strategies for surgical site infection or use it for standardizing the rates of surgical site infection among the patients for comparison purposes as the focus of quality improvement programs. To the best of our knowledge, no study has investigated the relative importance of the risk factors for SSI in real world settings in terms of consistency in abdominal surgery.

To find consistent risk factors and identify their relative importance, it is imperative to see how many times a risk factor predicts an outcome of interest in the same direction. Ignoring the univariate analysis; compiling meta-analyses of adjusted statistical tests results like adjusted odds ratio, or adjusted risk ratio and so on; and giving a pooled estimate of the parameter of interest as a criterion of strength of the association may introduce bias to the results of such studies. Because one variable may be insignificant in univariate analysis and as result not included in adjusted multivariate analysis in one study and be significant and included in multivariate analysis in another study, if we include only multivariate analysis results in meta-analysis, we have ignored the first study results.

In this review, we included both univariate and multivariate analysis results to see the consistency of risk factors in predicting surgical site infection without concerning about the strength of association. A better understanding of these risk factors helps to design interventions for SSI prevention, and risk adjustment for surveillance. One of the major purposes of conducting scoping reviews is to identify the key characteristics or factors related to a concept (24) Furthermore, this helps to identify research gaps in the existing literature. The objective of our scoping review was mapping and summarizing the evidence to understand relative importance of the risk factors and estimate global incidence of surgical site infection in abdominal surgery.

Methods

This scoping review was done based on JBI methodology for scoping guideline (25). We followed the PRISMA extension for scoping reviews (PRISMA-ScR) statement (26)

Search strategy: The search strategy consisted of three elements: (1) risk factor, (2) surgical site infection, (3) abdominal surgery. Search strategy in PubMed was developed by an experienced librarian and one principal investigator using mesh term and text words for these elements and adopted for each database. An initial search of PubMed and Web of Science was done to identify the related articles on the topic; then, we considered the text words and index terms in these articles to develop the search strategy for Scopus, Web of Science, and PubMed. The search strategy was adapted for each included database. The primary search strategy for these databases is presented in Additional file 1. Studies which were published in any language were considered.

Study/Source of Evidence selection

We searched the literature in SCOPUS, PubMed, and Web of Science. All identified citations were entered and combined into one file in the reference manager software (27), and the duplicates were removed. The titles and abstracts were screened, and the full texts of the selected articles were assessed in detail considering the inclusion criteria. PRISMA flowchart (28) was used to report the selection process.

Eligibility criteria

Participants

We included original peer-reviewed articles which reported surgical site infection in any type of abdominal surgery; we included the articles when the definition of surgical site infection met the CDC criteria. In studies with multiple procedures including non-abdominal surgeries, we reported the result of only the abdominal surgery. To avoid including the articles with likely misclassification bias, we selected the articles when all types of surgical site infections were considered. To reflect the real-world incidence of surgical site infection, we excluded the studies that were primarily conducted to evaluate one or more types of interventions. We defined the intervention as any action, treatment, or procedure to change the surgical outcome of patients. Non-human studies, studies which focused on specific pathogens, prevalence studies, nonabdominal surgeries, studies with inadequate or longer than 30-day follow up were excluded. Revision surgeries were excluded.

Concept

In this scoping review, we categorized the identified risk factors into two main categories, including patient-related risk factors and operation-related risk factors. In this review, surgical site infections (SSI) were defined as infections of the tissues, organs or spaces exposed during surgical procedure and categorized as incisional surgical site infections which were further classified as superficial incisional surgical site infections, affecting only the skin and subcutaneous tissues, and deep surgical site infections, affecting the deep soft tissues of the incision, including fascia and muscle layers. Infection of organs or spaces was defined as infection of any part of the anatomy other than the incision that was opened or manipulated during the surgical procedure. (29).

Context

The current scoping review considered all related articles irrespective of their geographical area, language, age group, or gender preferences.

Types of Sources

The current scoping review included retrospective or prospective cohort, case-control, case-cohort, and nested case-control. We excluded the case reports, letters to the editor, commentaries, conference abstracts, short communication, qualitative studies, randomized controlled trials, non-randomized controlled trials, before and after studies, prevalence or cross-sectional studies, ecological studies, and diagnostic studies or other procedures that did not report the risk factors for SSI.

Data Extraction

One reviewer extracted data in Excel using data extraction tool, which is presented in Additional file 2. The other reviewer checked the accuracy of data. Potential disagreements were resolved through discussion. The data extraction tool was modified in the data extraction phase to include all relevant risk factors. The key information extracted included author (year), data collection time, mid-year data collected, country, definition, study design, name of surgery procedure, population(N), number of SSIs, risk factors reported, and the length of follow-up. To assess the methodological quality of each study, two reviewers used the Critical Appraisal Skills Program (CASP) checklist for cohort and case-control studies(30)

Data Analysis and Presentation:

In this review, all case-control and cohort studies were used in a file to evaluate the risk factors. We enumerated and tabulated the scores of risk factors using pivot table tool from Microsoft Excel 2016. The scores for each factor in the study ranged from − 2 to 2 based on its role in surgical site infection development as follows: if the variable decreased the risk of surgical site infection in multivariate analysis (-2), if the variable decreased the risk of surgical site infection in univariate analysis (-1), if the relationship between the variable and surgical site infection was not significant (0), if the variable increased the risk in univariate analysis (+ 1), and if the variable increased the risk in multivariate analysis (+ 2).Then, we enumerated the number of times each factor was protective (scores of -1 and − 2), was a risk factor (scores of + 1 and + 2), and had no effect (score = 0) in multivariate and univariate analysis of studies. We first looked at the multivariate analysis; if it was significant in $p \leq 0.05$ level, the score of + 2 or -2 was allocated to it. Otherwise, we looked at univariate analysis result. To avoid the influence of the borderline significant results, we decided to consider $p \leq 0.05$ as significant (but not p-value = 0.051). We calculated the consistency scores for each factor as follows:

$$\text{Consistencyscore} = Nr - Np\text{Relative consistency} = \frac{Nr - Np}{Nr + Np + Nnull}$$

Total number of studies reported factor=$Nr + Np + Nnull$

Nr = number of times each factor was reported as risk factor in multivariate and univariate analysis

Np: number of times each factor was reported as protective factor in multivariate and univariate analysis

Null = number of times each factor was reported as not significant in the articles.

The risk factors were categorised as patient or operation-related factor. The relative importance of the risk factors was determined based on the consistency scores obtained and the total number of studies that reported the factor, as shown in Table 2.

The variables that were reported at least twice as risk factors in the multivariate analysis of the included studies were also included in our report.

Table 2
Categorizing the evidence based on consistency and relative consistency scores

Relative consistency	Number of studies reported variable			
	<5	(5–14)	(15–29)	>=30
Low (0-0.44)	Probable unimportant factor (Insufficient evidence)	Less important needs more evidence to confirmed	Less important	Unimportant
Moderate (0.45–0.74)	Probable Moderate risk factor with Insufficient evidence	Moderate risk factor needs more evidence to confirmed	Moderate risk factor	Moderate risk factor
High (> 0.75)	Probable strong risk factor with Insufficient evidence	Strong risk factor needs more evidence to confirmed	Strong risk factor	Very strong risk factor

Cohort studies were used in different files to report the incidence of surgical site infection. Meta-analysis was done with meta- package using R software version 4.2.0. Random effects model was used for meta-analysis of the incidence. Inverse variance method, especially restricted maximum-likelihood estimator for tau^2 and logit transformation, was used for meta-analysis of incidence proportion.

Results

Overall, 14237 records were identified. After exclusion of the duplicates and irrelevant studies by screening of the study titles and abstracts, 530 studies were assessed for eligibility. All eligible studies (107) were used to evaluate the risk factors of surgical site infection, and 81 eligible cohorts were used to estimate the global incidence of surgical site infection in abdominal surgery. The study selection process is presented in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram (Fig. 1).

107 studies that were included in this review were from different regions of the world. There were 22 studies from the USA(31–52), 12 from Spain(53–64), eight from China (65–72), seven from Japan (73–79), seven from Brazil (80–85), four from Korea (86–89), four from Canada (90–93), three from the UK (94–96), three from Germany (97–99), five international studies (100–104), two from each of Sierra Leone (105, 106), Israel (16, 107), Tanzania (108, 109), Norway (110, 111), Poland (112, 113) and Ethiopia (114, 115), and one from each of Thailand (116), Croatia (117), Vietnam (118), Taiwan (119), Mexico (120), Egypt (121), South Africa (122), Nepal (123), Switzerland (124), Netherlands (125), Italy (126), Ireland (127), India (128), France (129), Ghana (130), Saudi Arabia (15), Myanmar (131), Kosovo (132), Belgium (133) and Turkey (134) (Fig. 2). The full list of the included studies and related quality assessment is presented in Supplementary Table 1, Additional file 2.

Importance of risk factors

The importance of risk factors evaluated based on criteria is presented in Table 2. Patient-related factors are shown in Table 3 and operation-related factors in Table 4. Among patient-related factors, the National Nosocomial Infection Surveillance (NNIS) System Risk Index was a strong risk factor in development of surgical site infection. Educational status of patients, functional status, malnutrition, and history of Neurological/Psychiatric Disease were categorized as probable strong risk factors with insufficient evidence. Albumin or pre-albumin level, blood glucose level, male gender, remote infection, abnormal BMI, and ASA class were moderate risk factors. Other variables were less important or unimportant (Table 3).

Table III. Consistency and relative importance of patient related variables in studies								
Variables	**-2**	**-1**	**0**	**1**	**2**	**Total (N=107)**	**Relative consistency**	**Relative importance**
NNIS risk index			2	13	5	20	0.90	Strong risk factor
infection			5	2	6	13	0.62	Moderate risk factor needs more evidence
Albumin/prealbumin			6	3	7	16	0.63	Moderate risk factor
blood glucose level			8	4	7	19	0.58	Moderate risk factor
ASA class			26	17	15	58	0.55	Moderate risk factor
Abnormal BMI			33	7	25	65	0.49	Moderate risk factor
Sex(male)	4		27	10	17	58	0.40	Moderate risk factor
Hypertension			14	2	5	21	0.33	Less important
Cardiovascular disease			11	4	2	17	0.35	Less important
Malignancy			10	4	2	16	0.38	Less important
Previous surgery			11	4	4	19	0.42	Less important
Respiratory disease			9	2	4	15	0.40	Less important
Immunosuppression			14	5	5	24	0.42	Less important
Blood loss			15	8	2	24	0.38	Less important
Low hemoglobin			13	5	3	21	0.38	Less important
Education			1	1	2	4	0.75	Probable strong risk factor with insufficient evidence
Functional status			1	1	2	4	0.75	Probable strong risk factor with insufficient evidence
Malnutrition			1		3	4	0.75	Insufficient evidence
Neurological/Psychiatric Disease			1	1	2	4	0.75	Probable strong risk factor with insufficient evidence
Renal disease			10	1	2	13	0.23	Less important needs more evidence to confirmed
Radiotherapy			9	2	4	15	0.40	Less important needs

Hematocrit			3			3	0.00	Probable unimportant factor (Insufficient evidence)
Smoking			28	6	3	37	0.24	Unimportant
Diabetes			30	15	6	51	0.41	Unimportant
Age	3	2	56	11	9	81	0.19	Unimportant
Chemotherapy			8	2	2	12	0.33	Less important needs more evidence to confirmed
Comorbidities (yes VS no)			6	2	2	10	0.40	Less important needs more evidence to confirmed

Among operation-related factors, the length of operation and higher wound class were very strong risk factors. Surgeon’s low experience/grade was categorized as a strong risk factor, but it needs more evidence to be confirmed. Hair removal with razor and non-use of prophylaxis (oral) were categorized as probable strong risk factors with Insufficient evidence to have a conclusion. Bowel preparation, use or non-use of prophylaxis, pre-operative hospital stays, and stoma use were less important factors (Table 4).

Overall Incidence

Pooled incidence of surgical site infection in cohort studies was 10.6 (95% CI 9.02–12.55) per 100 patients. Heterogeneity was substantial (I^2 = 99%, t^2 = 0.68), and there was no significant difference between prospective and retrospective cohort studies (X^2 = 0.01, df = 1, P = 0.92), among WHO regions (X^2 = 7.88, df = 3, P = 0.05) and income group (X^2 = 3.89, df = 3, P = 0.27) of countries (Table 6).

Table IV. Consistency and relative importance of operation-related variables in studies								
Variables	**-2**	**-1**	**0**	**1**	**2**	**Total (N=101)**	**Relative consistency**	**Relative importance**
Length of operation			17	25	35	77	0.78	Very strong risk factor
Higher wound class			9	12	15	36	0.75	Very strong risk factor
Low surgeon experience/grade			2	4	3	9	0.78	Strong risk factor needs more evidence
Hair removal with razor					2	2	1.00	Probable risk factor with Insufficient evidence
Prophylaxis(oral)	2					2	-1.00	Probable protective factor with Insufficient evidence
Hair removal			5			5	0.00	Probable unimportant factor (Insufficient evidence)
Opens VS Minimally invasive			9	4	20	33	0.73	Moderate risk factor
Emergency/elective			21	10	11	42	0.50	Moderate risk factor
Blood transfusion			8	8	7	23	0.65	Moderate risk factor
Diagnosis			11	8	6	25	0.56	Moderate risk factor
Drains			9	7	5	21	0.57	Moderate risk factor
Bowel preparation			9	3	3	15	0.40	less important
Prophylaxis(pre-op)		2	14	3	5	24	0.25	Less important
Pre-operative hospital stays			14	3	6	23	0.39	Less important
Stoma			10	1	6	17	0.41	Less important
Type of surgery procedure			6	6	4	16	0.63	Moderate risk factor
Prophylaxis(type)			5	5	3	13	0.62	Moderate risk factor needs more evidence
Prophylaxis(time)			6	5	2	13	0.54	Moderate risk factor needs more evidence
Additional procedure			5	2	3	10	0.50	Moderate risk factor

							needs more evidence
Anesthesia		6	3	2	11	0.45	Moderate risk factor needs more evidence
Prophylaxis(dose)	1	3		3	7	0.29	Less important needs more evidence

Table VI. Summary statistics of meta- analysis of the incidence of surgical site infections after abdominal operations						
factor	subgroup	Study(n)	Incidence per 100 surgical procedures (95% CI)	I^2%	t2	Test for subgroup differences
Global		81	10.66(9.02–12.55)	99	0.69	
Design	Retrospective	25	10.52(7.78–14.07)	100	0.69	X2 = 0.01, df = 1(P = 0.92)
	Prospective	56	10.72(8.75–13.06)	99	0.70	
Who region	European Region	27	10.71(8.12-14.00)	100	0.61	X2 = 7.88, df = 3(P = 0.05)
	African Region	7	16.01(12.19–20.75)	89	0.13	
	Region of the Americas	26	12.13(8.98–16.19)	99	0.74	
	Western Pacific Region	15	8.77(6.04–12.56)	99	0.61	
Income level	High income	54	9.94(8.11–12.13)	100	067	X2 = 3.89, df = 3(P = 0.27)
	Upper-middle-income	16	11.91(7.34–18.73)	99	1.16	
	Lower-middle-income	5	10.47(7.35–14.70)	97	0.18	
	low-income	3	16.82(10.21–26.45)	92	0.23	
Surgical procedure	Caesarean and gynaecological	15	8.71(6.18–12.15)	99	0.51	X2 = 79.81, df = 7(P < 0.01)
	Bowel surgery (small bowel, colon and rectum)	22	13.65(10.62–17.37)	99	0.44	
	Mixed abdominal	17	12.18(9.41–15.61)	99	0.34	
	Appendectomy	8	7.57(3.90-14.17)	99	1.01	
	Gastric surgery	4	4.66(3.19–6.77)	74	0.11	
	Pancreatic surgery	3	16.45(5.41–40.39)	99	1.17	
	Liver transplantation	5	27.44(20.76–35.31)	91	0.14	
	Cholecystectomy	3	2.50(1.18–5.25)	94	0.42	
Operation	Operation time > t	23	14.08(10.0-18.64)	96	0.63	-

Table VI. Summary statistics of meta- analysis of the incidence of surgical site infections after abdominal operations

time						
	Operation time < t	23	7.24(5.04–10.30)	98	0.86	-
Wound class	Clean or clean-contaminated	24	7.83(6.00-10.16)	98	0.48	-
	Contaminated or dirty	24	20.69(15.63–26.85)	96	0.62	-
ASA class	ASA < 3	28	8.70(6.75–11.14)	98	0.52	-
	ASA ≥ 3	28	14.84(11.88–18.38)	93	0.41	-

Sources of heterogeneity

There were differences in the pooled incidence of surgical site infections based on the type of surgical procedure, from a lower range of 2.5 (95% CI 1.18–5.25) for cholecystectomy to a higher range of 27.4 (95% CI 20.76–35.31) for liver transplantation (Additional file 3). The meta-regression results showed that the type of surgery procedures accounted for 31.17% of the heterogeneity Additional file 4. Pooled incidence of surgical site infection was up to 14.1 (95% CI 10.0–18.64) during longer operation (surgical time ≥ T) compared to 7.2 (95% CI 5.04–10.30) at normal operation time (surgical time < T); it was 20.7 which is higher in dirty/contaminated wound class (95% CI 15.63–26.85) compared to 7.8 in clean/clean-contaminated wound class (95% CI 6.00-10.16). The pooled incidences were 14.8 (95% CI 11.88–18.38) for ASA Class ≥ 3 and 8.7 (95% CI 6.75–11.14) for ASA Class < 3 (Table 6).

All the data that was used in the analysis is presented in Additional File 5.

Discussion

Our study indicated that the NNIS Risk Index was a strong risk factor in development of surgical site infection. This is not surprising because this index was created to predict the risk of developing surgical wound infection among surgical patients; NNIS index consisted of three factors, and each was given 1 point: duration of the procedure > T (T is defined as the 75th percentile of the average time for a surgical procedure), wound class of contaminated or dirty, and the American Society of Anaesthesiologists Physical Status Classification (ASA) score greater than 2 (135, 136). Two of these three factors (length of operation and higher wound class) were categorised in our study as very strong risk factors, and ASA was classified as a moderate risk factor. A new approach based on the standardized incidence rate (SIR) has been proposed because the NNIS index uses a limited set of factors to predict surgical site infection (137). However, our study found that the NNIS index consistently predicted the surgical site infection and that new methods should consider its components. Such strong risk factors should be used in prevention and prediction purposes.

Some risk factors are categorized as moderate ones. They are frequently presented in the studies but have lower relative consistency than the strong risk factors. Moderate risk factors may in some cases have null effect, or their effects may be masked by other factors. For example, inherently, emergency surgery may have no effect on the incidence of surgical site infection. However, because emergency surgery is usually accompanied with dirtier and more contaminated wounds (higher wound class), it may have greater risk to develop surgical site infection than the elective surgery (138). Abnormal BMI may be accompanied with higher blood glucose and hypertension and has stronger effects in a study; without these factors, it has no effect on development of surgical site infection in another study.

Some factors in our study were categorized as less important factors. These factors have no effect in most of the situations, and researcher may assume that there is no effect of these factors and quit further investigation of these risk factors. However, it is important to consider that to find an association between SSI and a factor, there is a need for sufficient variability in the proportion of variables in the study population. For example, if all surgical patients had received the antibiotic prophylaxes before surgery, we couldn't find an association between prophylaxis use and subsequent surgical site infection after surgery. We should also consider that observational studies might have limitations to explore these types of factors.

Other factors are categorized as strong or moderate risk factors with insufficient evidence. Educational status of patients, functional status, malnutrition and history of Neurological/Psychiatric Disease, surgeon's low experience/grade, hair removal with razor, and non-use of prophylaxis (oral) were categorized as probable strong risk factors with Insufficient evidence to have a conclusive result. These risk factors should be investigated in future studies.

Pooled incidence of surgical site infection in our study was 10.6 (95% CI 9.02–12.55) per 100 patients in abdominal surgery. Our finding is in line with the international cohort study done by Bhangu et al. (2018) (100); they indicated that the surgical site infection in gastrointestinal surgery was 12.3% and it was similar to the systematic review conducted by Gillespie and his colleges that indicated that pooled 30-day cumulative incidence of SSI was 11% (95% CI 10–13%) in general surgery patients(23). Subgroup analysis in our study revealed that the incidence of surgical site infection in appendectomy patients was 7.5(95% CI 3.9–14.2) .This result is similar to that of a previous review and meta-analysis in surgical site infection incidence after appendectomy that was 7.0 (95% CI 6.4 to 7.7) per 100 cases (21). The high incidence of surgical site infections in this study suggests that SSI after abdominal surgery remains a global public health problem.

Our study showed significant heterogeneity in the incidence of surgical site infections, and the meta-regression results showed that the type of surgical intervention explained 31.5% of this heterogeneity. Most of the previous meta-analyses done in surgical site infection incidence revealed a high to substantial heterogeneity (6, 21). Surgical site infection is a multifactorial phenomenon. In line with previous reviews, we indicated that the incidence of surgical site infection was different based on the categorise of operation time duration (139), wound class (140), and ASA class. Thus, distribution of these or other important factors may be different in various countries. Therefore, a limited number of studies which were included in this meta-analysis from each country could not be the representative of that nation. This may also explain why we could not find a significant difference in the incidence of surgical site infection between WHO regions, nor between income groups of countries.

The other limitation of our study is the cut points that we used to determine the relative importance categories of factors. These cutoff points are arbitrary, and changing the cut points can change the status of factors. Future studies can explore optimal cutoff points to categorize the evidence based on relative importance.

Despite these limitations, we used a simple and practical approach to evaluate the evidence. This assessment is useful in identifying more important risk factors for developing a surgical site infection. Therefore, we can prioritize our efforts to change these factors, or use these factors to identify high-risk patients when they could not be changed. This assessment also helped us to identify research gaps and areas that need more evidence to ascertain about the role of risk factors.

The strengths of this study included relevant exclusion criteria. We included articles only when the definition of surgical site infection met CDC criteria. Today's CDC definition of surgical site infection is globally accepted; this helped us to find papers that identified the outcomes that are measured in the same way, which is essential for meta-analysis of studies(141). We included the articles if they considered all types of surgical site infections. This criterion limits the likely misclassification bias that can occur when classifying an infected individual as uninfected and vice versa. We excluded the studies that primarily developed to evaluate one or more types of interventions. All of these eligibility criteria helped us estimate an incidence rate that reflected the real situation, which has received less attention in previous reviews.

Conclusion

A counterplay of agents, environmental and patients' factors contributes to development of surgical site infection. In this review, for the first time, we have thoroughly examined the relative importance of the risk factors for surgical site infection in abdominal surgery and identified the important factors in development of surgical site infection. Risk factors that gain high relative importance can be used in standardizing the rates of surgical site infection. These factors can be prioritized in surgical site infection prevention and control programs. We have shown that the evidence is not sufficient to make a conclusive judgment about the role of some factors in the occurrence of surgical site infection. Future studies should investigate these factors.

Abbreviations

NNIS: National Nosocomial Infections Surveillance; CDC**:** Centers for disease control and prevention; SSI: surgical site infection

Declarations

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All contributors are listed as authors.

Authors' contributions

Fereidoun Jahangir: Conceptualization, Methodology, Formal analysis, Writing- Original draft preparation, Visualization, Investigation, quality assessment, Development of search strategy. Maryam Okhovati.: Investigation, Development of search strategy. Hossein Moameri: Investigation, quality assessment. *AliAkbar Haghdoost:* Supervision, Writing- Reviewing and Editing,

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Availability of data and materials

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Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Conflicts of interest:

Authors declare there is no conflict of interest in this article

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Figures

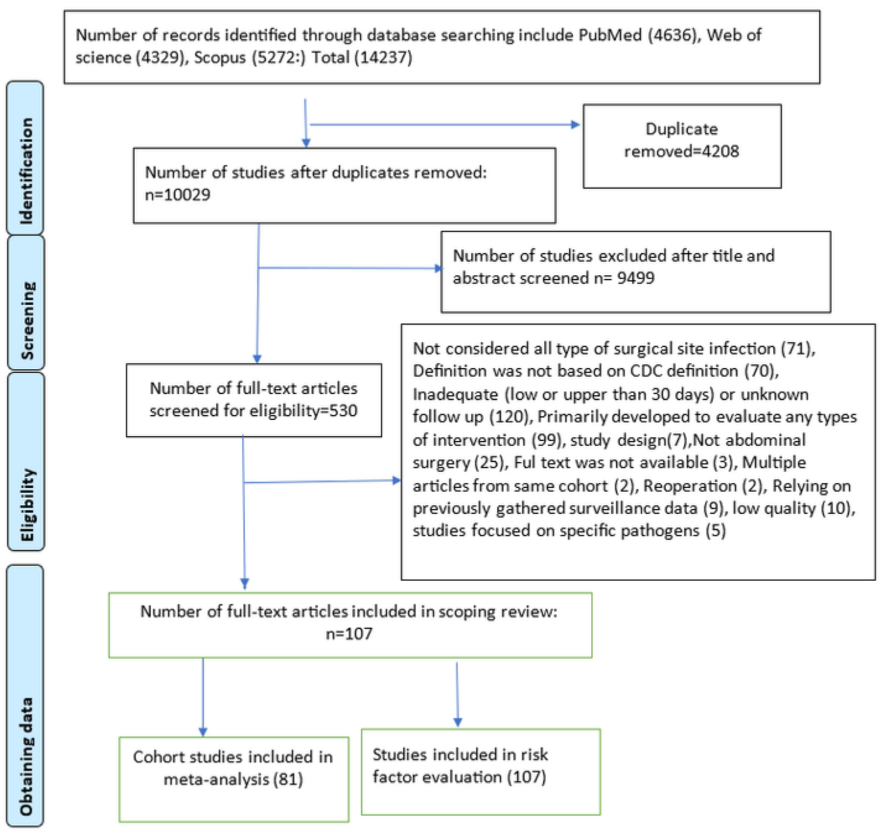

Figure 1

Prisma Flow Diagram

Figure 2

Number of studies included in scoping review by country

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