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Review Article

Incidence and Risk Factors of Surgical Site Infection in Abdominal Surgeries: A Scoping Review of Cohort and Case-Control Studies

Fereidoun Jahangir[1,2], PhD candidate;
AliAkbar Haghdoost[1,3], MD, PhD;
Hossein Moameri[4], PhD candidate;
Maryam Okhovati[5], PhD

[1]Department of Epidemiology and Biostatistics, School of Public Health, Kerman University of Medical Sciences, Kerman, Iran;
[2]Department of Nursing, Hazrat Zahra (P.B.U.H) Abadeh School of Nursing, Shiraz University of Medical Sciences, Shiraz, Iran;
[3]Modeling in Health Research Center, Institute for Futures Studies in Health, Kerman University of Medical Sciences, Kerman, Iran;
[4]HIV/STI Surveillance Research Center, and WHO Collaborating Center for HIV Surveillance, Institute for Futures Studies in Health, Kerman University of Medical Sciences, Kerman, Iran;
[5]Department of Health Management, Policy and Economics, School of Medical Management and Information, Kerman University of Medical Sciences, Kerman, Iran

Correspondence:
AliAkbar Haghdoost, MD, PhD;
Institute for Futures Studies in Health, Kerman University of Medical Sciences, Haft Bagh-e-Alavi Highway,
Postal code: 76169-13555, Kerman, Iran
Tel: +98 34 31325409
Email: ahaghdoost@gmail.com
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What's Known

- An increasingly large number of global populations are at risk of surgical site infection.
- Abdominal surgeries have a higher risk of bacterial contamination and surgical site infection than other surgeries. Few studies have evaluated the relative consistency of surgical site infection risk factors in abdominal surgeries.

What's New

- This study indicated that surgical site infection occurred in every 10.6% of patients undergoing abdominal surgery.
- Risk factors of abdominal surgery vary in relative consistency. Highly consistent risk factors, such as operative time and higher wound class, should be used in standardizing risks in prevention and control strategies.

Abstract

Background: Abdominal surgery is considered a high-risk procedure for the development of surgical site infection (SSI). Few studies have evaluated the relative importance of surgical site infection risk factors in terms of consistency in abdominal surgery. Therefore, this comprehensive review article mapped and summarized the evidence aimed to determine the relative importance of the risk factors and incidence of SSIs in abdominal surgery.

Methods: A literature review was conducted using electronic databases and search engines such as Scopus, PubMed, and Web of Science up to March 16, 2023. There was no language restriction for the papers to be included in the study. The relative consistency of the risk factors was measured and evaluated using the methodology of the Joanna Briggs Institute. Original peer-reviewed cohort and case-control studies were included if all types of SSIs were included. Meta-analysis was performed to determine the pooled estimates of SSI incidences.

Results: Of 14,237 identified records, 107 articles were included in the review. The pooled incidence of SSI was 10.6% (95% CI: 9.02–12.55%, χ^2=12986.44, P<0.001). Operative time and higher wound class were both significant consistent risk factors for SSI incidence. Patients' educational status, malnutrition, functional status, and history of neurological/psychiatric disorders were all candidates for consistent risk factors, with insufficient evidence.

Conclusion: The findings of the present study indicated that SSI in abdominal surgery was a multifactorial phenomenon with a considerable risk and had different risk factors with various relative importance. Determining the relative importance of the risk factors for the prevention and control of SSI is strongly recommended.

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Keywords ● Surgical wound infection ● Risk factors ● Cohort studies ● Case-control studies ● Abdomen

Introduction

An increasingly large number of global populations are at risk of surgical site infection (SSI) and its associated complications. Weiser and his colleagues estimated that 312.9 million surgeries were performed all over the world in 2012.[1] Liu and others indicated that the rates of general surgery increased with age.

Approximately 9.4% to 23.2% of surgical patients worldwide develop a surgical site infection,[2] and 38% of these patients die due to the infection.[3] SSI affects the patients' safety,[4] physical and mental health,[5] prolonged hospital stays, reoperation, readmission, and elevated healthcare cost for patients and hospitals,[5-9] which is a quality issue for healthcare systems.[9]

Abdominal surgery refers to a wide range of procedures that are fundamental to general and pediatric surgical practice, as well as a variety of surgical training programs. Abdominal procedures are not limited to the practice of general surgeons; urologists and gynecologists may also perform them for a wide variety of indications.[10] Abdominal surgeries are more prone to bacterial contamination and therefore more likely to result in SSI than other surgeries.[11, 12] Previous reviews estimated the incidence of SSI in certain types of abdominal surgery, such as appendectomy,[13] and hepatopancreatobiliary surgery,[14] or patients undergoing general surgery,[15] but not the overall incidence of SSI in abdominal surgery.

The relative importance of risk factors in the development of SSI in terms of consistency is unknown. Traditionally, these risk factors are considered as the surrogate of underlying cause, although they are also used to predict outcomes. The degree of the association between risk factors and outcomes is important because the more the strength of the association, the more likely the relationship is assumed to be causal. The epidemiologist frequently attempts to quantify the strength of the association. However, the consistency of the association is also of utmost importance to consider. Risk factors that can consistently predict the SSI are more likely to have a causal relationship or to be a good predictor. Such consistent risk factors can assist us in developing prevention strategies for SSI or use them for standardizing the rates of SSI among patients for comparative purposes as part of quality improvement initiatives. Previous studies proposed different models for standardization of the SSI by incorporating various risk factors into the models.[16, 17] However, to the best of our knowledge, neither these studies nor the earlier ones investigated the consistency of these risk factors.

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 test results; such as adjusted odds ratios, adjusted risk ratios, and so on; and using a pooled estimate of the parameter of interest as a criterion of strength of the association may introduce bias into the results of such studies. Since one variable might be insignificant in univariate analysis and as a result not included in adjusted multivariate analysis in one study while being significant and included in multivariate analysis in another study, if we included only multivariate analysis results in a meta-analysis, we would ignore the first study's results.

In this review, we included both univariate and multivariate analysis results to assess the consistency of risk factors in predicting SSI without concerning the strength of association. A better understanding of these risk factors aids in the development of SSI prevention programs, as well as risk adjustment for surveillance.

One of the major purposes of conducting this scoping review was to determine the key characteristics or factors related to this concept.[18] Furthermore, it could help to identify research gaps in the existing literature. In this way, the objective of this scoping review was to map and summarize the data to identify the relative importance of the risk factors in terms of consistency, as well as to estimate the global incidence of SSI in abdominal surgery.

Materials and Methods

This scoping review was conducted based on the Joanna Briggs Institute (JBI) methodology for scoping reviews.[19] The Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for scoping reviews (PRISMA-ScR) statement were followed for reporting this manuscript.[20]

Search Strategy

The search strategy included three components: (1) risk factor, (2) surgical site infection, and (3) abdominal surgery. The search strategy in PubMed was developed by an experienced librarian and one principal investigator, using mesh terms and text words for these elements, which was then used in Scopus, and Web of Science.

An initial search of PubMed and Web of Science was done to identify the related articles on the topic. Then, the text words and index terms in these articles were considered to develop a search strategy for Scopus, Web of Science, and PubMed. The search strategy was tailored to each incorporated database. The primary search strategy for these databases is presented in supplementary file 1. There were no language restrictions for the articles to be included in the study. That is, if the full text of the article was not in English, it was translated into Persian and evaluated using an online translator (https://www.onlinedoctranslator.com/en/translationform).

Study/Source of Evidence Selection

We searched the literature in SCOPUS, PubMed, and Web of Science databases up to March 16, 2023. All identified citations were entered and integrated into a single file in EndNote software (version: 20, Clarivate Philadelphia, USA), and the duplicates were removed. Then, the titles and abstracts of the selected publications were screened, and the full texts were assessed in detail considering the inclusion criteria. The PRISMA flow diagram was used to report the selection process.

Eligibility Criteria

Participants: The original peer-reviewed articles, where the definition of SSI met the Centers for Disease Control and Prevention (CDC) criteria, were included in this study.[21, 22] In studies with multiple procedures, including non-abdominal surgeries, only the outcome of abdominal surgery was reported. To avoid including studies with a high likelihood of misclassification bias, the articles that addressed all types of surgical site infections were considered. To better reflect the real-world incidence of surgical site infection, the studies that were primarily designed to evaluate one or more types of interventions were excluded. The intervention was defined as any activity, treatment, or procedure to change the surgical outcome of patients.

Concept: In this scoping review, the identified risk factors were categorized into two main categories, including patient-related risk factors and operation-related risk factors. In this review, SSI was defined as infections of the tissues, organs, or spaces exposed during a surgical procedure. These infections were further divided into two categories: superficial incisional surgical site infections, which affected only the skin and subcutaneous tissues, and deep surgical site infections, which affected 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.[23]

Context: The present scoping review included all related articles, irrespective of their geographical area, language, age group, or sex preferences.

Types of Sources: The present scoping review included retrospective or prospective cohort, case-control, case-cohort, and nested case-studies. Other types of study were excluded.

Data Extraction: One reviewer (J.F) extracted data from Microsoft Excel software 2016 (Microsoft Corporation, USA) using a data extraction tool, which is presented in supplementary file 2. The other reviewer (M.H.) reviewed the data for accuracy. Potential disagreements were addressed through discussion. The data extraction tool was modified during the data extraction process to include all relevant risk factors. To assess the methodological quality of each study, two reviewers used the Critical Appraisal Skills Program (CASP) checklist for cohort and case-control studies.[24]

Data Analysis and Presentation

In this review, the scores of risk factors were enumerated and tabulated, using the pivot table tool from Microsoft Office Excel software (2016). The scores for each factor in the study ranged from -2 to 2 based on its role in SSI development as follows: if the variable decreased the risk of SSI in multivariate analysis (-2), if the variable decreased the risk of SSI in univariate analysis (-1), if the relationship between the variable and SSI 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 that 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 analyses of studies. At first, we first examined the multivariate analysis. If it was significant at the $P \leq 0.05$ level, it received a score of +2 or -2. Otherwise, we examined univariate analysis results. To eliminate the impact of the borderline significant results, we considered $P \leq 0.05$ as significant (not $P=0.051$). We calculated the consistency scores for each factor as follows:
Consistency score=Nr-Np

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

The total number of studies reported factor=Nr+Np+Nnull

Nr: Number of times each factor was reported as a risk factor in both multivariate and univariate analysis

Np: Number of times each factor was reported as a protective factor in both multivariate and univariate analysis

Null: Number of times each factor was reported as not significant in the articles.

The relative importance of the risk factors was determined based on the consistency scores obtained and the total number of studies reporting a factor, as shown in table 1.

Table 1: Categorizing the evidence reported SSI based on the number of studies and relative consistency scores

		Number of studies reported variable			
		<5	(5-14)	(15-29)	≥30
Relative consistency	Low (0-0.44)	Candidate to be an inconsistent factor (Insufficient evidence)	Less consistent risk factors need more evidence to be confirmed.	Less consistent	Inconsistent
	Moderately Consistent (0.45-0.74)	Candidate to be a moderately Consistent risk factor with Insufficient evidence	Moderately Consistent risk factors need more evidence to be confirmed.	Moderately Consistent risk factors	Moderately Consistent risk factors
	High (≥0.75)	Candidate to be a consistent risk factor with Insufficient evidence	Consistent risk factors need more evidence to be confirmed.	Consistent risk factors	Highly Consistent risk factors

The variables that were reported at least twice as risk factors in the multivariate analysis of the included studies were also included in this report. Cohort studies were used to report the incidence of surgical site infection. Meta-analysis was done with meta-package using R software version 4.2.0 (R Foundation for Statistical Computing, Vienna, Austria). The random effects model was used for meta-analysis of the incidence. The meta-analysis of incidence proportion was conducted using the inverse variance method, namely the restricted maximum-likelihood estimator for tau^2 and logit transformation.

Results

Overall, 14237 records were identified. After removing the duplicates and irrelevant studies by screening the study titles and abstracts, 530 studies were assessed for eligibility. All eligible studies (107) were used to determine the risk factors of surgical site infection, and 81 eligible cohorts were used to estimate the global incidence of SSI in abdominal surgery. The study selection process is presented in the PRISMA flow diagram (figure 1).

This review article comprised 107 studies from different regions of the world.

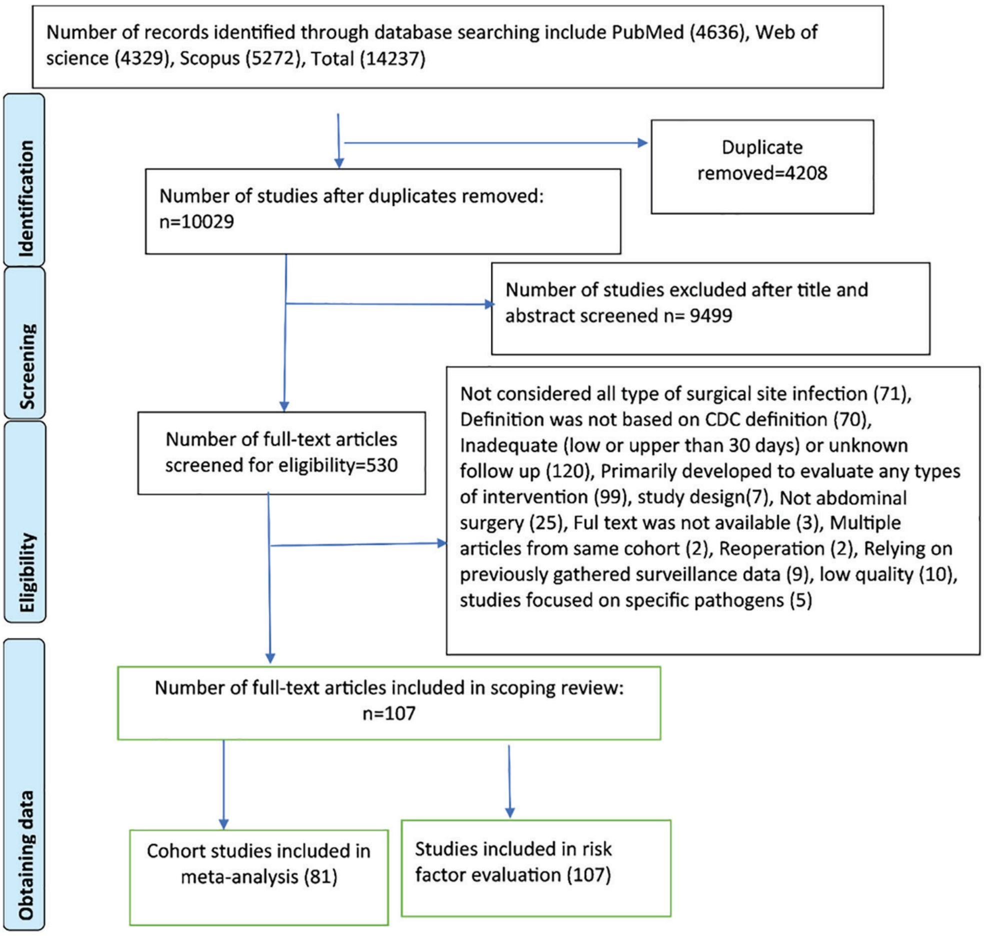

Figure 1: PRISMA Flow diagram displays details of the studies selected throughout the scoping review.

There were 22 studies from the USA, 12 from Spain, eight from China, seven from Japan, seven from Brazil, four from Korea, four from Canada, three from the UK, three from Germany, five international studies, two from each of Sierra Leone, Israel, Tanzania, Norway, Poland, and Ethiopia, and one from each of Thailand, Croatia, Vietnam, Taiwan, Mexico, Egypt, South Africa, Nepal, Switzerland, Netherlands, Italy, Ireland, India, France, Ghana, Saudi Arabia, Myanmar, Kosovo, Belgium, and Turkey (figure 2). The full list of the included studies and related quality assessments is presented in supplementary file 2.

Importance of Risk Factors

The importance of risk factors that were evaluated based on criteria is presented in table 1. Among patient-related factors, the National Nosocomial Infections Surveillance System (NNIS) risk index was a consistent risk factor in the development of surgical site infection. The NNIS risk index consisted of three factors, each of which was assigned one point, including duration of the procedure>T (T is defined as the 75^{th} percentile of the average time for a surgical procedure), wound class of contaminated or dirty, and the ASA score greater than 3.[25] The patient's Educational status, functional status, malnutrition, and history of neurological/psychiatric diseases were categorized as potential consistent risk factors with insufficient evidence. Albumin or pre-albumin level, blood glucose level, male sex, remote infection, abnormal BMI, and the American Society of Anaesthesiologists Physical Status Classification (ASA) score were all relatively consistent risk factors. Other variables were either less consistent or inconsistent (table 2).

Among operation-related parameters, the length of operation and higher wound class were highly consistent risk factors. The surgeon's low experience/grade was categorized as a consistent risk factor, although further research is required to validate this. Hair removal with a razor and non-use of prophylaxis (oral) were categorized as potential consistent risk factors, with insufficient evidence to draw a conclusion. Bowel preparation, use or non-use of prophylaxis, pre-operative hospital stays, and stoma use were less consistent factors (table 3).

Overall Incidence

The pooled incidence of SSI 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 (χ^2=0.01, df=1, P=0.92), among WHO regions (χ^2=7.88, df=3, P=0.05), and income group (χ^2=3.89, df=3, P=0.27) of countries (table 4).

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 (supplementary file 3). The meta-regression results indicated that the type of surgery procedures accounted for 31.17% of the heterogeneity (supplementary file 4). The pooled incidence of SSI 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).

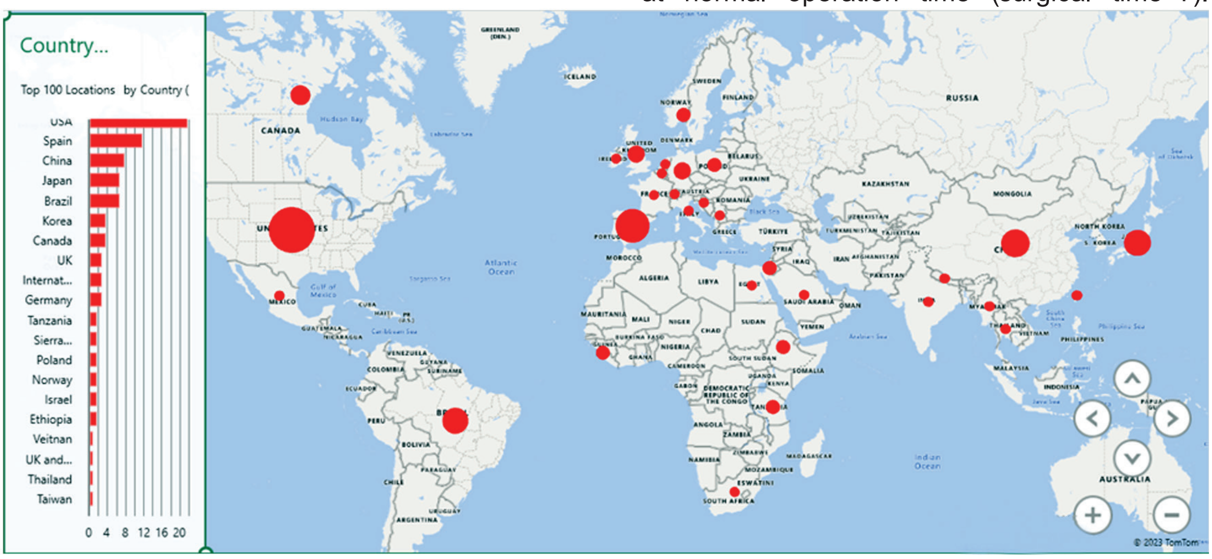

Figure 2: The figure shows the number of studies included in the scoping review from different countries of the world. The larger circles indicate the greather number of articles from that country.

Table 2: Consistency and relative importance of patient-related variables in the development of SSI reported in the studies

Variables	-2	-1	0	1	2	Total (N=107)	Relative consistency	Relative importance
NNIS risk index			2	13	5	20	0.90	Consistent risk factor
Infection			5	2	6	13	0.62	Moderately Consistent risk factor needs more evidence
Albumin/prealbumin			6	3	7	16	0.63	Moderately Consistent risk factor
Blood glucose level			8	4	7	19	0.58	Moderately Consistent risk factor
ASA class			26	17	15	58	0.55	Moderately Consistent risk factor
Abnormal BMI			33	7	25	65	0.49	Moderately Consistent risk factor
Sex (male)	4		27	10	17	58	0.40	Moderately Consistent risk factor
Hypertension			14	2	5	21	0.33	Less consistent
Cardiovascular disease			11	4	2	17	0.35	Less consistent
Malignancy			10	4	2	16	0.38	Less consistent
Previous surgery			11	4	4	19	0.42	Less consistent
Respiratory disease			9	2	4	15	0.40	Less consistent
Immunosuppression			14	5	5	24	0.42	Less consistent
Blood loss			15	7	2	24	0.38	Less consistent
Low hemoglobin			13	5	3	21	0.38	Less consistent
Education			1	1	2	4	0.75	Candidate to be a consistent risk factor with insufficient evidence
Functional status			1	1	2	4	0.75	Candidate to be a consistent risk factor with insufficient evidence
Malnutrition			1		3	4	0.75	Insufficient evidence
Neurological/Psychiatric Disease			1	1	2	4	0.75	Candidate to be a consistent risk factor with insufficient evidence
Renal disease			10	1	2	13	0.23	Less consistent needs more evidence to be confirmed
Radiotherapy			4		2	6	0.33	Less consistent needs more evidence to be confirmed
Hematocrit			3			3	0.00	Candidate to be inconsistent factor (Insufficient evidence)
Smoking			28	6	3	37	0.24	Inconsistent
Diabetes			30	15	6	51	0.41	Inconsistent
Age	3	2	56	11	9	81	0.19	Inconsistent
Chemotherapy			8	2	2	12	0.33	Less consistent needs more evidence to be confirmed
Comorbidities (yes *vs.* no)			6	2	2	10	0.40	Less consistent needs more evidence to be confirmed

ASA: American Society of Anaesthesiologists Physical Status Classification; NNIS: National Nosocomial Infections Surveillance System

It was 20.7, which was higher in the dirty/contaminated wound class (95% CI: 15.63-26.85) than 7.8 in the 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 4).

Discussion

The findings of the present study indicated that the NNIS risk index was a consistent risk factor in the development of surgical site infection. It is not surprising because this index was created to predict the risk of developing surgical wound infection among surgical patients, and it consisted of three factors.[25] In the present study, two of these three factors (length of operation and higher wound class) were categorized as highly consistent risk factors, and the third, ASA class, was classified as a moderately consistent risk factor. Since the NNIS risk index uses a limited set of factors to predict SSI, an approach based on the standardized incidence ratio (SIR) has been proposed.[26] However, the present study found that the NNIS risk index consistently predicted the SSI, implying that new methods should consider its components. Such consistent risk factors should be used for prevention and prediction purposes.

Moderately consistent risk factors might, in some cases, have null or limited effects, or their effects might be masked by other factors. For example, inherently, emergency surgery might not affect the incidence of surgical site infection. However, since emergency surgery is usually accompanied by dirtier and more contaminated wounds (higher wound class), there may be a

Table 3: Consistency and relative importance of operation-related variables in the development of SSI reported in the studies

Variables	-2	-1	0	1	2	Total (N=101)	Relative consistency	Relative importance
Length of operation			17	25	35	77	0.78	Highly consistent risk factor
Higher wound class			9	12	15	36	0.75	Highly consistent risk factor
Low surgeon experience/ grade			2	4	3	9	0.78	Consistent risk factor needs more evidence
Hair removal with a razor					2	2	1.00	Candidate to be a risk factor with Insufficient evidence
Prophylaxis (oral)	2		0			2	-1.00	Candidate to be a protective factor with Insufficient evidence
Hair removal			5			5	0.00	Candidate to be inconsistent factor (Insufficient evidence)
Opens *vs*. Minimally invasive			9	4	20	33	0.73	Moderately Consistent risk factor
Emergency *vs*. Elective			21	10	11	42	0.50	Moderately Consistent risk factor
Blood transfusion			8	8	7	23	0.65	Moderately Consistent risk factor
Diagnosis			11	8	6	25	0.56	Moderately Consistent risk factor
Drains			8	7	3	18	0.56	Moderately Consistent risk factor
Bowel preparation			9	3	3	15	0.40	less consistent
Prophylaxis (pre-op)		1	20	8	5	23	0.39	Less consistent
Pre-operative hospital stays			14	3	6	23	0.39	Less consistent
Stoma			10	1	6	17	0.41	Less consistent
Type of surgery procedure			6	6	4	16	0.63	Moderately Consistent risk factor
Prophylaxis (type)			5	5	3	13	0.62	Moderately Consistent risk factor needs more evidence
Prophylaxis (time)			6	5	2	13	0.54	Moderately Consistent risk factor needs more evidence
Additional procedure			5	2	3	10	0.50	Moderately Consistent risk factor needs more evidence
Anesthesia			6	3	2	11	0.45	Moderately Consistent risk factor needs more evidence
Prophylaxis (dose)	1		3		3	7	0.29	Less consistent needs more evidence

greater risk of developing SSI than elective surgery.[27] Abnormal BMI was categorized as a moderately consistent risk factor in our study. This finding was consistent with the previous systematic review conducted by Cai and others,[28] which indicated that obesity was an independent risk factor for surgical site infection in colorectal surgery. Since most of the studies included in these reviews investigated multiple risk factors in one study,[27, 28] the power of such included studies to evaluate these factors might be questionable. Future powerful studies focusing on these risk factors are recommended.

Some risk factors were categorized as potential consistent risk factors. However, there was insufficient evidence to draw a definitive conclusion. These risk factors should be investigated in future studies.

Smoking and diabetes were both categorized as inconsistent risk factors. Because these elements are biologically plausible in the development of surgical site infection. Future studies with higher power, which primarily developed to address these factors, are strongly recommended. Previous systematic reviews conducted by Martin and colleagues[29] and kong[30] showed that diabetes and smoking were independent risk factors for SSIs for multiple surgical procedure types, respectively. When in a specific type of surgery, such as abdominal surgery, there is insufficient evidence regarding the relationship between a risk factor and SSI, researchers might benefit from combining the results of research in other surgeries or other types of study designs. However, this should not affect the importance of conducting exploratory research in that type of surgery, as risk factors for SSI might differ between each type of surgery. In a systematic review, Cai and others found that both smoking and diabetes were independent risk factors for SSI development in colorectal surgery.[28] When the P value was less than 0.05, they pooled the influence of the risk factor by combining odds ratio values of the same factor from different studies. This approach might underestimate the significance of non-significant studies.

According to the findings of the present study, the pooled SSI incidence was 10.6 (95% CI: 9.02-12.55) per 100 abdominal surgery patients. This finding was in line with the international cohort study conducted by GlobalSurg and

Table 4: Summary statistics of meta-analysis of the incidences of SSI after abdominal operations

Factor	Subgroup	Study (n)	Incidence per 100 surgical procedures (95% CI)	I²%	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	χ^2=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	χ^2=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	χ^2=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	χ^2=79.81, df=7, (P=0.001)
	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 time	Operation time>T	23	14.08 (10.0-18.64)	96	0.63	-
	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	

colleagues,[31] who reported that the SSI in gastrointestinal surgery was 12.3%. Similarly, another systematic review by Gillespie and others indicated that pooled 30-day cumulative incidence of SSI was 11% (95% CI: 10%–13%) in general surgery patients.[15] Subgroup analysis in the present study revealed that the incidence of SSI in appendectomy patients was 7.5 (95% CI: 3.9-14.2). This finding was similar to that of a previous review and meta-analysis of SSI incidence after appendectomy, which was 7.0 (95% CI: 6.4 to 7.7) per 100 patients.[13] The high incidence of surgical site infections in this study suggested that SSI after abdominal surgery is still a global patient safety concern.

The present 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 on SSI incidence revealed a high to substantial heterogeneity.[13, 32] In line with previous reviews, it was indicated that the incidence of SSI was different based on the categorization of operation time duration,[33] wound class,[34] and ASA class.[28] Thus, the distribution of these or other important factors might be different in various countries. Therefore, a limited number of studies that were included in this meta-analysis from each country could not be representative of that nation. It may also explain why we could not find a significant difference in the incidence of SSI between WHO regions, or between income groups of countries.

Despite these limitations, we used a simple and practical approach to evaluate the evidence. This screening could be useful in identifying highly consistent risk factors for developing a surgical site infection. Therefore, we can prioritize our efforts to change these factors or use them to identify high-risk patients when they cannot be changed. This assessment also assisted us in identifying research gaps and areas that require additional data to determine the significant role of risk factors.

The strengths of this study included relevant exclusion criteria. We included articles only when the definition of SSI met CDC criteria. Today's CDC definition of SSI is globally accepted, which helped us to find papers that identified outcomes measured in the same way, which is essential for meta-analysis of studies.[35] The articles were included if they addressed all types of surgical site infections. This criterion reduces the likelihood of misclassification bias when classifying an infected individual as uninfected, and vice versa. The studies that were primarily designed to evaluate one or more types of interventions were removed. All of these eligibility criteria assisted us in estimating an incidence rate that accurately reflected the real situation, which has received little attention in previous reviews.

Finally, although the strength of the association is critical when considering risk factors, future research should focus on the relative consistency of risk factors.

Conclusion

The development of surgical site infection is influenced by a complex interaction of agents, environmental factors, and patient characteristics. This scoping review comprehensively analyzed the relative consistency of the risk factors for SSI in abdominal surgery and identified the consistent factors that contribute to the development of surgical site infections. Risk factors with high relative importance can be utilized to standardize the rates of surgical site infection. These factors might be prioritized in SSI prevention and control programs. Moreover, it was found that the evidence was insufficient to make a definitive conclusion about the role of certain factors in the occurrence of surgical site infection. Future studies should investigate these factors.

This article evaluated risk factors based on the consistency of reporting within the literature. The more consistent the risk factors, the more valuable they will be for standardizing clinical SSI surveillance practice. Since the existing guidelines are based on both existing evidence and expert opinion, clinicians should follow them for other preventive practices. This article could provide a guide for researchers to identify areas that require further investigation in future studies.

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Authors' Contribution

F.J: Conceptualization, Methodology, Formal analysis, Writing- Original draft preparation, Visualization, Investigation, quality assessment, Development of search strategy; M.O: Investigation, Development of search strategy, Reviewing and Editing; H.M: Investigation, quality assessment, Reviewing and Editing; A.H: Supervision, Writing- Reviewing and Editing. All authors have read and approved the final manuscript and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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