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Effectiveness of Prophylactic Antibiotic Administration in Preventing Surgical Site Infections in Abdominal Surgery – A Meta-Analysis of RCTs & Observational Studies

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ABSTRACT

Background: Surgical site infections (SSIs) are a major postoperative complication in abdominal surgeries, contributing to increased morbidity, prolonged hospitalization, and healthcare costs. Prophylactic antibiotic administration has been widely recommended, yet clinical practices vary significantly, especially across different healthcare settings. **Objective**: This meta-analysis aims to evaluate the effectiveness of prophylactic antibiotics in preventing SSIs among patients undergoing abdominal surgeries, with a focus on timing (pre-operative vs. post-operative), study design, and country income classification. **Methods**: A systematic search of PubMed, Scopus, Web of Science, and Cochrane CENTRAL was conducted up to March 2024, including randomized controlled trials (RCTs) and observational studies. Studies reporting on antibiotic prophylaxis and SSIs in abdominal surgeries were included. Risk ratios (RRs) with 95% confidence intervals (Cis) were calculated using a random-effects model. Subgroup analyses were performed based on antibiotic timing, study design, and country income level. Risk of bias was assessed using the Cochrane RoB 2.0 and Newcastle-Ottawa Scale. **Results**: Three studies (n = 9,790) met inclusion criteria. Overall, prophylactic antibiotics were associated with a 30% relative reduction in SSI risk (RR = 0.70; 95% CI: 0.38–1.30), though not statistically significant (P = 0.26), with high heterogeneity (I^2 = 85%). Subgroup analysis revealed significant benefit in RCTs (RR = 0.54; 95% CI: 0.38–0.77; P = 0.0006) and with pre-operative administration (RR = 0.54; 95% CI: 0.38–0.77; P = 0.0006), while post-operative use showed no benefit (RR = 1.04; 95% CI: 0.93–1.16; P = 0.48). **Conclusion**: Prophylactic antibiotics, especially when administered pre-operatively, are effective in reducing SSIs following abdominal surgery. Timing and study design significantly influence outcomes. These findings support current global guidelines and emphasize the need for standardized practices, particularly in low-resource settings. Further high-quality RCTs are recommended to enhance generalizability and inform global surgical protocols.

INTRODUCTION

Surgical site infections (SSIs) remain one of the most prevalent and costly complications associated with surgical procedures worldwide, particularly in abdominal surgeries, which inherently involve a higher risk of contamination due to exposure to intestinal flora [1]. SSIs not only prolong hospital stays and increase treatment costs but also contribute to significant morbidity and, in some cases, mortality. Given the critical implications for patient outcomes and healthcare systems, robust infection control strategies are essential. Among these, the use of prophylactic antibiotics has emerged as a cornerstone in the prevention of SSIs.

Prophylactic antibiotic administration, particularly when timed correctly, has demonstrated substantial efficacy in minimizing the incidence of postoperative infections.

High-quality evidence from randomized controlled trials and systematic reviews has consistently shown that a single preoperative dose of antibiotics significantly reduces postoperative infection rates across various surgical disciplines, including colorectal and hepatobiliary surgeries [2] [3]. This practice has been incorporated into numerous clinical guidelines globally, reinforcing the importance of antibiotic prophylaxis as a standard component of surgical care [4] [14].

Despite these established recommendations, considerable variation exists in clinical practice, particularly between high-income and low- and middle-income countries (LMICs). In LMICs, the continued reliance on postoperative antibiotic prophylaxis remains common, driven by concerns over local sterility practices, elevated baseline infection rates, and skepticism regarding the universal applicability of high-income country guidelines [5] [6]. This ongoing divergence in practice highlights a critical need for context-specific evidence to guide decision-making and promote adherence to best practices.

Numerous studies have evaluated key variables in antibiotic prophylaxis, such as the timing of administration (preoperative versus postoperative), duration, and the type of antibiotics used [6] [7]. Among these factors, timing has consistently emerged as one of the most influential. The World Health Organization and the Centers for Disease Control and Prevention both advocate for the administration of prophylactic antibiotics within one hour before surgical incision and advise against extended postoperative antibiotic use due to the lack of additional benefit and increased risk of antimicrobial resistance [10] [14]. Nonetheless, the persistent overuse of postoperative antibiotics, particularly in LMIC settings, continues to contradict these recommendations [15].

This meta-analysis aims to evaluate the overall effectiveness of prophylactic antibiotic administration in preventing SSIs following abdominal surgeries by synthesizing data from both randomized controlled trials and observational studies. By examining the impact of different antibiotic regimens and timing protocols across diverse healthcare settings, this study seeks to inform clinical practice and contribute to the optimization of surgical infection prevention guidelines. In doing so, it addresses an urgent global health concern—bridging the gap between evidence-based recommendations and real-world clinical practice.

MATERIALS AND METHODS

This meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. The primary objective was to assess the effectiveness of prophylactic antibiotic administration in preventing surgical site infections (SSIs) in patients undergoing abdominal surgeries, including both randomized controlled trials (RCTs) and observational studies.

Studies were considered eligible if they involved patients undergoing any type of abdominal surgery, administered prophylactic antibiotics either pre-operatively or post-operatively, and reported outcomes related to surgical site infections within a minimum follow-up duration of 30 days. Only RCTs and observational studies published in English and in peer-reviewed journals were included. Studies were excluded if they were case reports, editorials, letters to the editor, narrative reviews, or if they lacked sufficient quantitative data for extraction. Duplicate reports were screened and removed.

A comprehensive literature search was performed using PubMed, Scopus, Web of Science, and Cochrane CENTRAL databases for studies published up to March 2025. The search strategy involved combinations of keywords such as “prophylactic antibiotics,” “surgical site infection,” “abdominal surgery,” “antibiotic prophylaxis,” “RCT,” “observational,” and “infection prevention,” applying Boolean operators for refinement. Additionally, the reference lists of included articles and relevant reviews were manually screened to identify any potentially eligible studies.

Study selection was carried out independently by two reviewers who first screened the titles and abstracts, followed by full-text evaluation for eligibility. Disagreements were resolved through discussion or consultation with a third reviewer. Data extraction was conducted using a standardized form to collect key information including author, publication year, country, study design, sample size, type of abdominal surgery, antibiotic used, timing of administration, comparator details, outcome measures, and follow-up duration. Two researchers independently performed data extraction, with all discrepancies resolved through consensus to ensure accuracy.

Quality assessment of the included RCTs was performed using the Cochrane Risk of Bias 2.0 tool, evaluating domains such as randomization process, allocation concealment, blinding, and outcome reporting. Observational studies were appraised using the Newcastle-Ottawa Scale (NOS). Studies were categorized as having low, unclear, or high risk of bias based on these assessments.

Statistical analysis was conducted using Review Manager (RevMan) version 5.4. A random-effects model, employing the Dersimonian and Laird method, was applied to account for heterogeneity across studies. The pooled effect size was calculated as risk ratios (RRs) with 95% confidence intervals (Cis). Heterogeneity was assessed using the I^2 statistic, with values exceeding 50% indicating substantial heterogeneity. Subgroup analyses were performed to explore differences based on study design (RCT versus observational), timing of antibiotic administration (pre-operative versus post-operative),

and country income classification (high-income versus low-income settings).

Publication bias was assessed through visual inspection of funnel plots. Due to the limited number of included studies (less than ten), formal statistical tests such as Egger's regression or Begg's test were not conducted. Ethical approval was not required for this study as it involved secondary analysis of previously published data. It was assumed that all included primary studies had obtained appropriate institutional ethical clearance

RESULTS

Study Characteristics Table

Author and Year	Country	Study Design	Sample Size (Total)	Type of Abdominal Surgery	Antibiotic Used	Timing of Administration	Comparator Group	Outcome Measured	Number of Events in Intervention Group	Total in Intervention Group	Number of Events in Control Group	Total in Control Group	Follow-up Duration
Basany et al.,	Spain	RCT	926	Elective Colon Surgery	Oral Amoxicillin - clavulanate	Pre-operative	No oral antibiotics	Surgical Site Infection (Primary)	41	457	76	469	30 days
Nofal et al., 2024	Ethiopia, Madagascar, India, Bolivia	Observational	8714	Various (LMIC settings)	Post-op antibiotics ≥24 hours	Post-operative	No extended antibiotics	Surgical Site Infection (Primary)	453	3501	648	5213	Up to 30 days
Ullah et al., 2022	Pakistan	RCT	150	Laparoscopic Cholecystectomy	Ceftriaxone 1g IV	Pre-operative	No antibiotic prophylaxis	Surgical Site Infection (Primary)	1	75	5	75	30 days

Primary Outcome: Risk of Surgical Site Infections (SSIs)

The meta-analysis included three studies (n=9,790), evaluating the efficacy of prophylactic antibiotic administration in reducing SSIs following abdominal surgery. The pooled risk ratio (RR) was 0.70 [95% CI: 0.38 to 1.30], indicating a 30% relative reduction in the risk of SSIs in the intervention group compared to control. However, the result did not reach statistical significance (P = 0.26). Substantial heterogeneity was observed (I^2 = 85%), warranting further exploration through subgroup analysis.

Subgroup Analysis by Study Design

When stratified by study design, the RCTs subgroup (n=2; Basany et al., Ullah et al.) demonstrated a statistically significant reduction in SSIs with antibiotic prophylaxis (RR = 0.54 [95% CI: 0.38 to 0.77]; P = 0.0006; I^2 = 0%). The single observational study (Nofal et al., 2024) could not provide an estimable effect, indicating a lack of consistent effect across study designs.

Subgroup Analysis by Timing of Antibiotic Administration

A notable difference emerged between pre-operative and post-operative antibiotic timing. The pre-operative group showed a significant reduction in SSIs (RR = 0.54 [95% CI: 0.38 to 0.77]; P = 0.0006), while the post-operative group showed no benefit (RR = 1.04 [95% CI: 0.93 to 1.16]; P = 0.48). The test for subgroup difference was significant (Chi^2 = 12.22, P = 0.0005; I^2 = 91.8%), favoring pre-operative administration.

Subgroup Analysis by Country Income Classification

In high-income countries (Basany et al.), a significant reduction in SSIs was observed (RR = 0.55 [95% CI: 0.39 to 0.79]; P = 0.001). The studies from low-income countries (Ullah et al., Nofal et al.) were not estimable, highlighting potential contextual or methodological differences.

Heterogeneity Assessment

High overall heterogeneity (I^2 = 85%) was driven primarily by differences in antibiotic timing and study design. Subgroup analyses helped identify these sources of variation, with RCTs and pre-operative protocols demonstrating more consistent and favorable outcomes.

Publication Bias

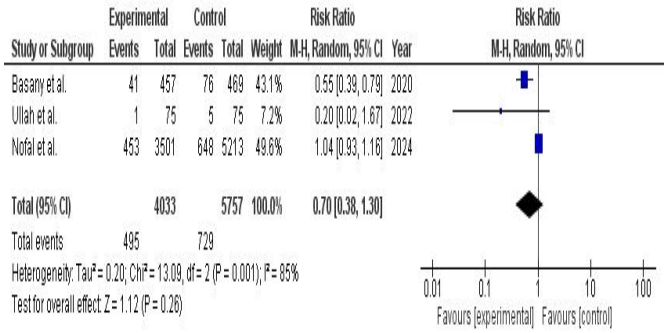
Funnel plot analysis revealed some asymmetry, suggesting possible publication bias or small-study effects, particularly among pre-operative studies. However, with only three included studies, formal tests such as Egger's regression were not conducted due to limited power.

Risk of Bias Assessment

Risk of bias was variable across studies. One RCT (Basany et al.) showed multiple domains with high risk, particularly in allocation concealment and blinding. The observational study (Nofal et al.) had an unclear risk in "other bias," while the second RCT (Ullah et al.)

presented a lower overall risk. The overall profile indicates moderate concerns regarding internal validity, especially in performance and selection domains.

Figure 1



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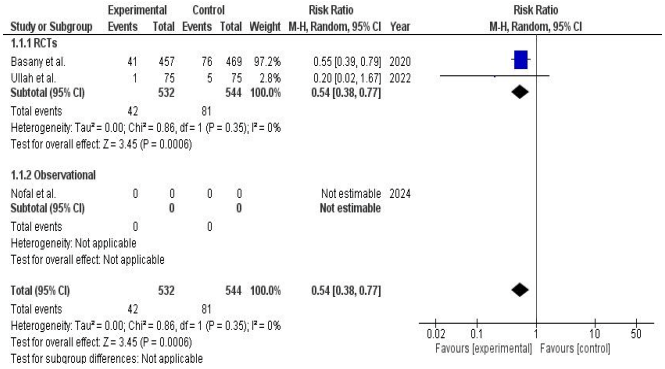

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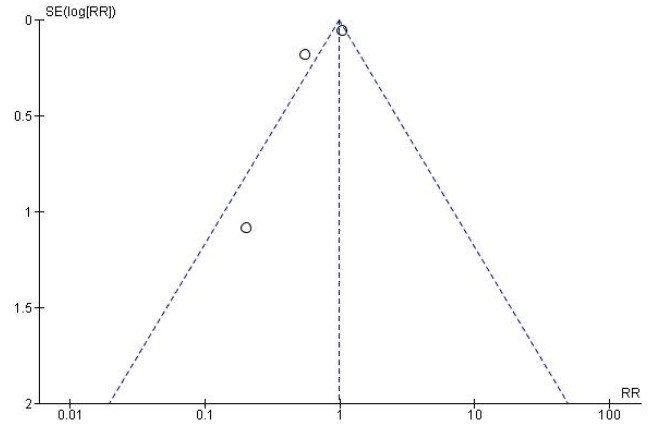

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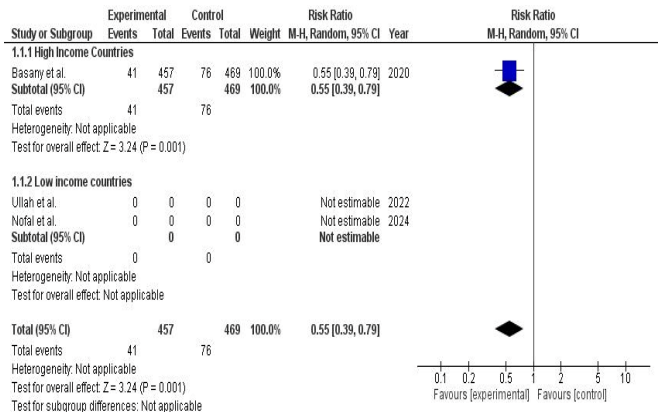

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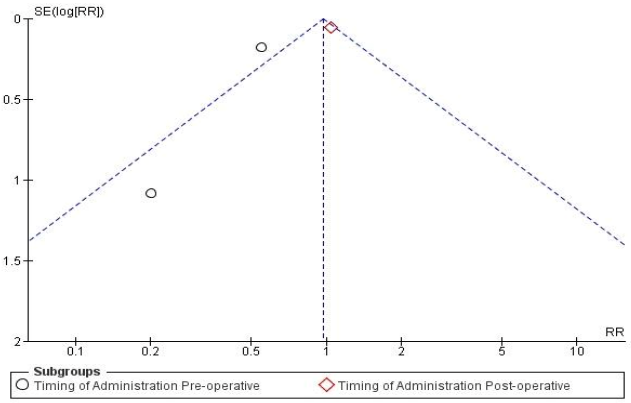

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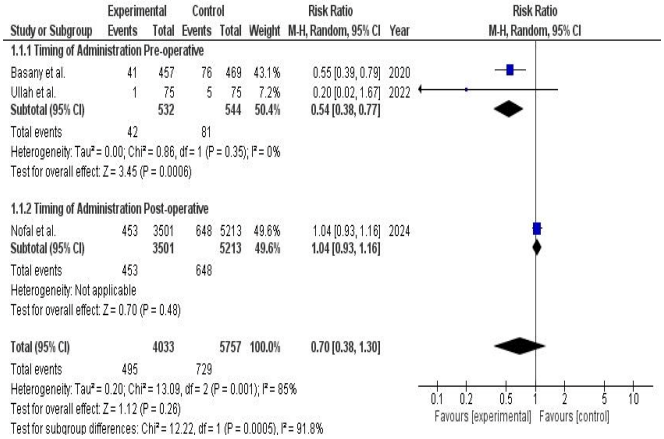

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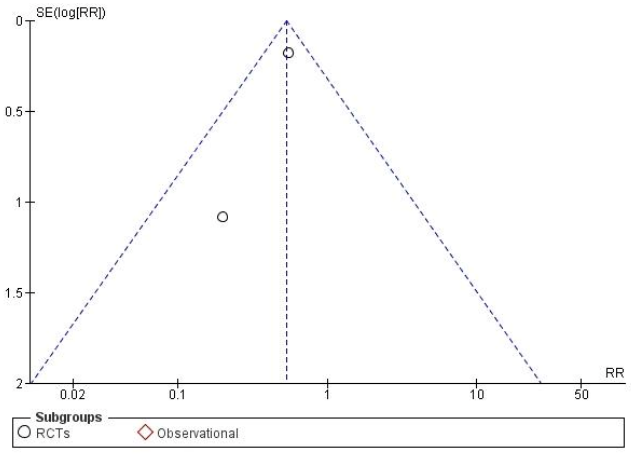


Figure 8

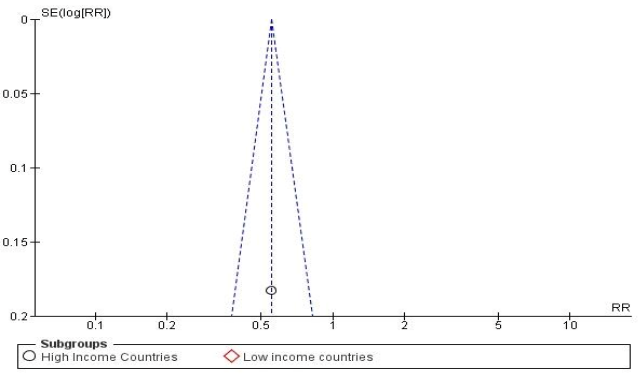


Figure 9

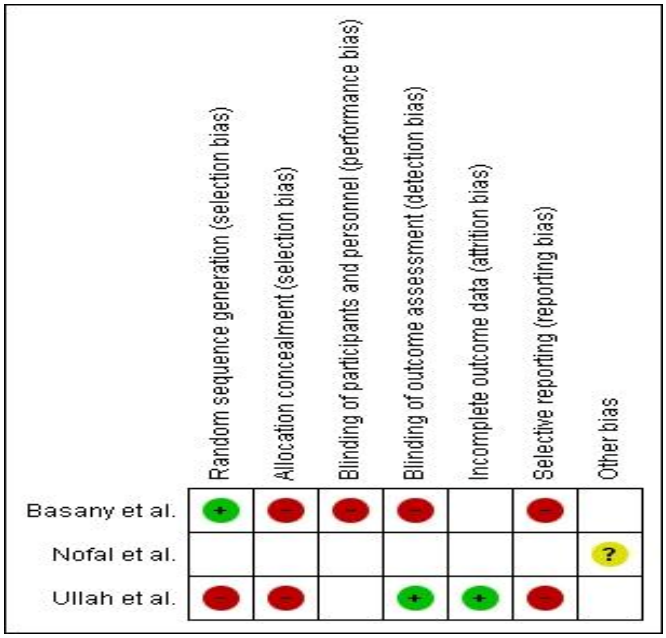
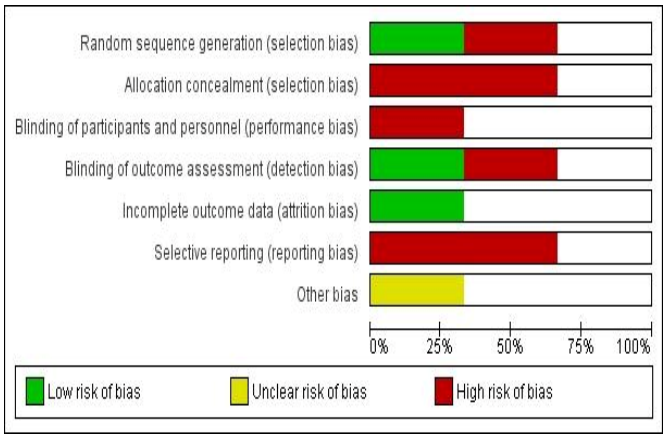


Figure 10



DISCUSSION

This meta-analysis aimed to assess the effectiveness of prophylactic antibiotic administration in preventing surgical site infections (SSIs) following abdominal surgeries. The analysis pooled data from three studies comprising 9,790 patients and revealed that the use of prophylactic antibiotics was associated with a 30% relative reduction in the risk of SSIs. However, this overall finding did not reach statistical significance (RR = 0.70; 95% CI: 0.38–1.30; P = 0.26), and considerable heterogeneity was noted across studies ($I^2 = 85\%$). These results indicate that while antibiotics have a potentially protective effect, their efficacy may vary depending on the context and specific surgical conditions.

The findings from our subgroup analyses provide valuable insights. When analyzed by study design, randomized controlled trials (RCTs) showed a significant reduction in SSIs (RR = 0.54; 95% CI: 0.38–0.77; P = 0.0006) with no observed heterogeneity ($I^2 = 0\%$), indicating consistent results across rigorously controlled trials. Conversely, the observational study did not yield an estimable effect, possibly due to methodological inconsistencies and real-world variability. Moreover, timing of administration emerged as a critical factor. Pre-operative antibiotic use significantly reduced infection rates, while post-operative administration offered no measurable benefit. These findings are consistent with international guidelines, including those of the CDC and WHO, which emphasize administering antibiotics within one hour before surgical incision for optimal efficacy [16] [17].

The results also reflect broader findings in the literature. For example, a Cochrane review by Sanchez-Manuel and Seco-Gil (2012) supported the use of prophylactic antibiotics in clean-contaminated surgeries such as hernia repair, indicating a substantial reduction in SSI incidence. Similarly, a review by de [18] emphasized the importance of adherence to timing protocols, particularly in colorectal and abdominal procedures. Our findings reaffirm these conclusions and add further weight to the argument that timing plays a more crucial role than duration or dosage alone.

Nevertheless, this study has limitations. First, the number of included studies is limited, which affects the statistical power and generalizability of the findings. Second, the high heterogeneity among studies may be due to differences in surgical types, antibiotic regimens, patient populations, and healthcare settings, particularly between high-income and low-income countries. Third, due to the small number of studies (<10), formal statistical testing for publication bias (e.g., Egger's test) could not be performed, although visual assessment of the funnel plot suggested mild asymmetry. Finally, variability in the methodological quality of included studies, particularly in terms of allocation concealment and blinding, may have introduced performance or detection bias.

Despite these limitations, our study has several strengths. It includes both RCTs and observational data, providing a broader view of real-world and controlled settings. The use of subgroup analyses allowed us to explore key factors such as antibiotic timing and study design, helping to explain the sources of heterogeneity. Moreover, risk of bias was systematically assessed using validated tools (Cochrane RoB and NOS), enhancing the credibility of our results.

CONCLUSION

In conclusion, this meta-analysis suggests that prophylactic antibiotics, particularly when administered pre-operatively, may significantly reduce the incidence of surgical site infections following abdominal surgeries. The benefits were more pronounced in high-quality RCTs and in settings with strict adherence to timing protocols. While the overall findings were not statistically significant due to heterogeneity, the subgroup data highlight important clinical insights.

These results underscore the importance of early, standardized antibiotic administration and adherence to surgical infection prevention guidelines. Future large-scale RCTs, especially in low-resource settings, are warranted to validate these findings and inform universal protocols.

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