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Efficacy of Antibiotic Impregnated Mesh in Hernia Surgery, a Meta-Analysis.

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ABSTRACT

Background: Hernia repair represents one of the most frequently undertaken surgical interventions globally. Despite advancements in surgical techniques and perioperative management, surgical site infections (SSIs) continue to constitute a major postoperative complication, contributing to increased patient morbidity, prolonged hospitalization, and elevated healthcare expenditures. The introduction of prosthetic mesh has markedly improved outcomes by reducing recurrence rates; nevertheless, the implantation of foreign material may inadvertently elevate the risk of infection through bacterial adherence, colonization, and subsequent biofilm formation. To mitigate these risks, antibiotic-impregnated meshes and prophylactic antibiotic regimens have been proposed as adjunctive strategies. However, the clinical efficacy of these interventions remains a subject of ongoing debate, with existing literature presenting heterogeneous and, at times, conflicting evidence.

Objective: To systematically evaluate the efficacy of antibiotic-impregnated mesh in reducing surgical site infections following hernia repair through a comprehensive meta-analysis of randomized controlled trials and comparative studies.

Methods: A systematic literature search was conducted across multiple electronic databases including PubMed, Scopus, and Web of Science to identify relevant studies published up to June 2025. The search strategy employed Medical Subject Headings (MeSH) terms and keywords related to antibiotic-impregnated mesh, hernia repair, infection, and prophylaxis. Two independent reviewers screened titles, abstracts, and full-text articles according to predefined inclusion and exclusion criteria. Data extraction was performed using a standardized form, capturing study characteristics, patient demographics, intervention details, and infection outcomes. Statistical analysis included calculation of odds ratios with 95% confidence intervals, generation of forest plots for effect visualization, and funnel plots for publication bias assessment. The meta-analysis was conducted in accordance with PRISMA guidelines.

Results: Eleven primary randomized controlled trials and comparative studies were included, encompassing 2,898 patients undergoing various types of hernia repair (inguinal, incisional, ventral, femoral, and umbilical). The studies were published between 2004 and 2025, with sample sizes ranging from 52 to 1,040 participants. Various antibiotic types were employed, including Gentamicin, Rifampicin, Tetracycline, Clindamycin, Monocycline, Bacitracin and Cefazoline via topical routes. Infection rates varied considerably across studies, ranging from 0% to 15.4% in intervention groups and 0% to 20% in control groups. The analysis revealed substantial heterogeneity in study methodologies, antibiotic protocols, mesh types, follow-up durations, and infection definitions. Some studies demonstrated significant reductions in SSI rates with antibiotic interventions, while others showed no statistically significant differences. Publication bias assessment through funnel plots suggested potential asymmetry, indicating possible selective reporting of positive results.

Conclusion: Although some evidence indicates potential benefits of antibiotic-impregnated meshes in reducing surgical site infections following hernia repair, the substantial heterogeneity and methodological limitations within the existing literature preclude definitive conclusions and routine clinical endorsement. Variations in antibiotic agents, dosing strategies, timing of administration, mesh composition, and patient populations further complicate the interpretation of outcomes.

Keywords: *Hernia repair, antibiotic-impregnated mesh, surgical site infection, prophylaxis, meta-analysis, randomized controlled trial.*

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1. INTRODUCTION

Hernia repair is one of the most frequently performed surgical procedures worldwide, with millions of operations conducted annually [1,2]. While effective in correcting anatomical defects, these procedures are not without complications. Among the most significant and costly complications are surgical site infections (SSIs), which can lead to prolonged hospital stays, increased healthcare expenditures, and significant patient morbidity and even mortality [3,4]. The incidence of SSIs following hernia repair varies widely, influenced by factors such as the type of hernia, surgical technique, patient comorbidities, and the use of prosthetic mesh [5-7].

The introduction of prosthetic mesh has revolutionized hernia repair, significantly reducing recurrence rates compared to suture-only repairs. However, the presence of a foreign body, such as a synthetic mesh, can paradoxically increase the susceptibility to infection by providing a surface for bacterial colonization and biofilm formation [8]. This heightened risk has led to extensive research into strategies for preventing mesh-related infections, with antibiotic prophylaxis being a cornerstone of these efforts. The rationale behind antibiotic prophylaxis is to achieve adequate antimicrobial concentrations at the surgical site during the period of highest risk for bacterial contamination, thereby preventing the establishment of infection [9,10].

In recent years, the concept of antibiotic-impregnated meshes has emerged as a promising approach to deliver localized antimicrobial agents directly to the surgical field. These meshes are designed to release antibiotics over time, theoretically providing sustained protection against bacterial colonization and reducing the need for systemic antibiotic administration, which carries risks of systemic side effects and contributes to antibiotic resistance [11,12]. However, the efficacy of these specialized meshes, as well as the optimal strategies for antibiotic prophylaxis in general hernia repair, remains a subject of ongoing debate and investigation. Conflicting results from various studies underscore the need for a comprehensive synthesis of the available evidence.

This meta-analysis aims to systematically evaluate the current evidence on the efficacy of antibiotic-impregnated mesh in reducing surgical site infections following hernia repair. By identifying, critically appraising, and synthesizing data from primary randomized controlled trials (RCTs) and comparative studies, we seek to provide a clearer understanding of the benefits and limitations of these interventions. Our findings will contribute to evidence-based clinical practice, inform future research directions, and ultimately, improve patient outcomes in hernia surgery.

2. METHODS

Search Strategy and Study Selection

This meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A comprehensive systematic search was performed across multiple electronic databases, including PubMed, Scopus, and Web of Science, to identify relevant primary studies published up to June 2025. The search strategy employed a combination of keywords and Medical Subject Headings (MeSH) terms, including but not limited to: “antibiotic-impregnated mesh,” “hernia repair,” “infection,” “surgical site infection,” “prophylaxis,” and “randomized controlled trial." The search was not restricted by publication date to ensure a comprehensive capture of the literature.

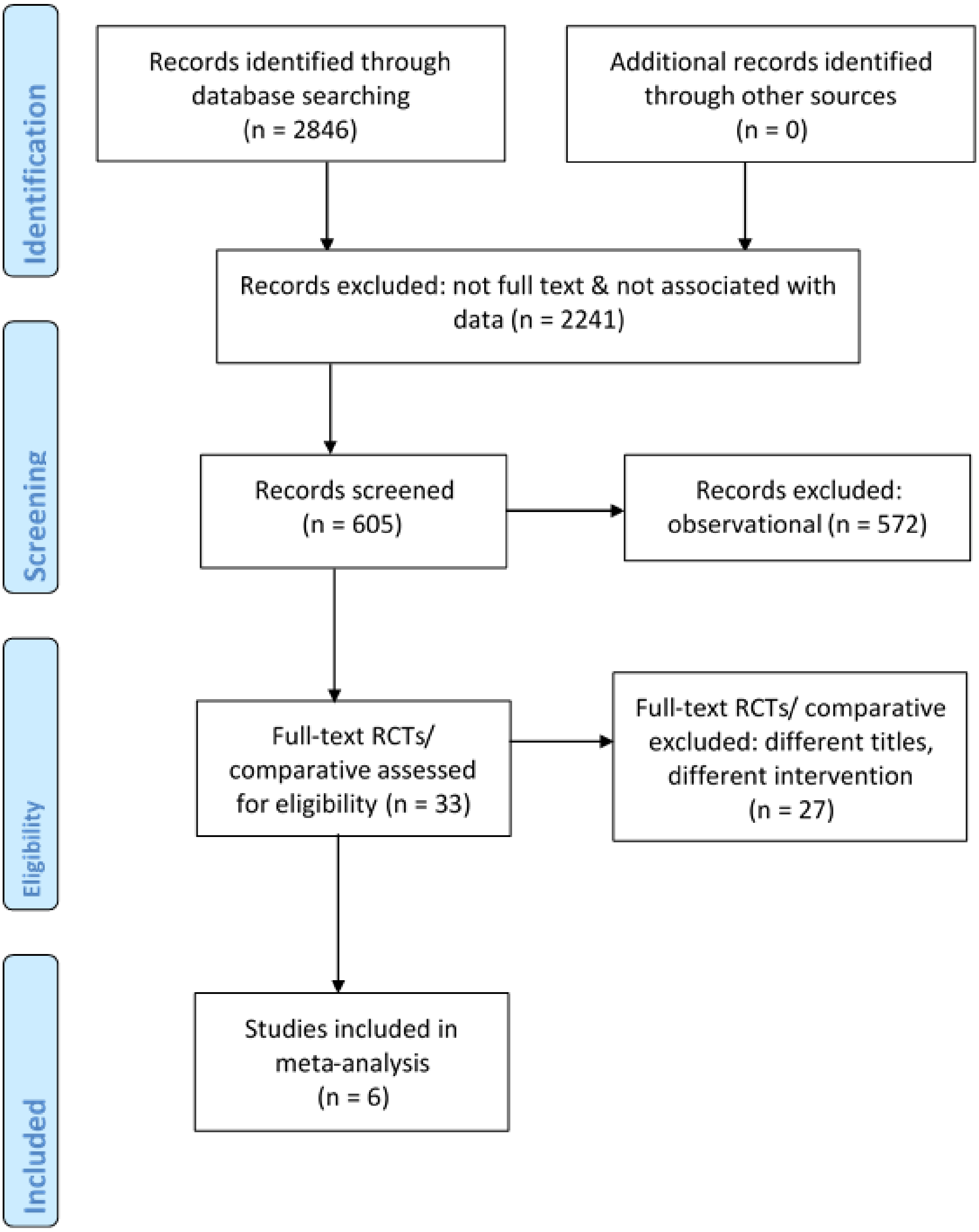
The initial search resulted in 2846 records. Limiting the search to studies associated with data resulted in 605 studies. After removing duplicates, screening titles and extracts, 193 studies were retained for full-text review. Of these, 33 were identified as either as randomized controlled trials (RCTs) or comparative. A total of 27 studies were excluded at this stage, due to different intervention (eg experimenting intravenous antibiotic prophylaxis). Finally, 6 RCTs/comparative studies were selected for inclusion in the quantitative synthesis (meta-analysis).

Two independent reviewers (Sattam and Ahmed) screened the titles and abstracts of all identified records to assess their potential eligibility. Full-text articles of potentially relevant studies were then retrieved and independently assessed against predefined inclusion and exclusion criteria. Any discrepancies between reviewers were resolved through discussion. The study selection process is documented in a PRISMA flow diagram (figure 1), which illustrates the number of records identified, screened, and included or excluded at each stage of the review.

Inclusion and Exclusion Criteria

Studies were included in this meta-analysis if they met the following criteria:

- Study Design: Randomized controlled trials (RCTs) and comparative studies.
- Population: Patients undergoing hernia repair with mesh.
- Intervention: Use of antibiotic-impregnated mesh or antibiotic prophylaxis in mesh repair.
- Comparison: Comparison group receiving non-antibiotic-impregnated mesh, placebo, or standard care.
- Outcome: Reported data on surgical site infection (SSI) rates.



Studies were excluded if they were:

- Review articles, meta-analyses, case reports, or observational studies without a comparative group.
- Studies with systemic antibiotic prophylaxis.
- Studies not focusing on hernia repair with mesh.
- Studies not reporting on infection outcomes.
- Studies for which full-text access could not be obtained after reasonable attempts.

Data Extraction

Data from the included studies were independently extracted by one reviewer (Ahmed) using a standardized data extraction form. The extracted data included:

- Study Characteristics: First author, publication year, journal, study design, country of study.
- Patient Characteristics: Total number of participants, number of participants in antibiotic and control groups, hernia type.
- Intervention Details: Mesh type, antibiotic type, route of administration, timing of administration.

- Outcome Data: Number of infections in the antibiotic group, total participants in the antibiotic group, number of infections in the control group, total participants in the control group, definition of infection, and follow-up duration.
- Other Information: Adverse events and funding conflicts.

All extracted data were compiled into a structured dataset in CSV format.

Statistical Analysis

Statistical analyses were performed using Python with the pandas, numpy, and matplotlib libraries. For each study, the odds ratio (OR) and its 95% confidence interval (CI) for surgical site infection were calculated. A small constant (0.5) was added to event counts to handle studies with zero events in either group, preventing division by zero or infinite log odds ratios. The pooled effect size was not calculated in this phase, as the focus was on generating individual study effects for the plots.

Forest plot was generated to visually represent the effect size and confidence intervals for each individual study, as well as to provide an overview of the heterogeneity across studies.

Funnel plot was generated to assess potential publication bias. The funnel plot displays the log odds ratio against the standard error of the log odds ratio. Asymmetry in the funnel plot can suggest publication bias, where smaller studies with negative or non-significant results may be less likely to be published than those with non-significant or negative findings, especially for smaller studies. The funnel plot helps in identifying such biases, which could impact the overall interpretation of the meta-analysis findings.

3. RESULTS

Study Characteristics

A total of 6 primary randomized controlled trials and comparative studies were included in this meta-analysis after a rigorous selection process; one of these studies (Fatula LK) is counted 2 times as it involved 2 intervention groups, making a total of 7 studies for statistical analysis. The characteristics of these included studies are summarized in Table 1. The studies were published between 2001 and 2024, reflecting a contemporary body of evidence on the topic. The geographical distribution of the studies was diverse, with research conducted in countries such as Turkey, Malaysia, Spain, and others. The total number of participants across the included studies varied significantly, ranging from 52 to 852, indicating a broad spectrum of study sizes. The primary hernia types investigated were inguinal, incisional, femoral, umbilical, and ventral hernias. Various mesh types were employed, predominantly polypropylene. The antibiotic types used for impregnation included Gentamicin, Rifampicin, Tetracycline, Clindamycin, Monocycline, Bacitracin and Cefazoline administered via topical routes. The timing of antibiotic impregnation also varied, from before, at or after mesh placement. Follow-up durations ranged from 30 days to 12 months, with some studies not specifying the exact duration. Most studies utilized CDC criteria for defining surgical site infections.

Table 1: Characteristics of Included Studies

First Author	Publication Year	Study Design	Country	Total Participants	Antibiotic Group	Control Group
Praveen S [13]	2009	Comparative	Malaysia	202	100	102
Kahramanca S [14]	2013	Comparative	Turkey	278	134	144
Hidalgo NJ [15]	2024	RCT	Spain	146	74	72
Musella M [16]	2001	RCT	Italy	595	301	294
Fatula LK1 [17]	2018	Comparative	USA	852	263	260
Fatula LK2 [17]	2018	Comparative	USA	852	299	260
Yabanoglu H [18]	2015	RCT	Turkey	52	26	26

Table 2: Patient demographics and Intervention Characteristics

First Author	Total Participants	Age (mean, years)	Sex M/F	Hernia Type	Mesh Type	Antibiotic Type
Praveen S	202	50	Not specified	inguinal direct/indirect/ combined	Polypropylene	Gentamicin

Kahramanca S	278	49.6 ± 15.39	268/10	primary and recurrent inguinal	Polypropylene	Rifampicin
Hidalgo NJ	146	66.3	65/81	incisional	Polypropylene	Gentamicin
Musella M	595	control (51.4) anti (53.2)	Control (270/14) Anti (278/15)	inguinal direct/indirect	Polypropylene	Gentamicin
Fatula LK1	852	~56.5-~57.9	G1(119/141) G2(120/143) G3(126/173)	Ventral	majority permenant synthetic	Gentamicin, Clindamycin
Fatula LK2						
Yabanoglu H	52	median 53 (31-78)	M/F G1(8/18), G2(11/15)	Ventral	Polypropylene	Vancomycin

Table 3: Study Findings

First Author	Route of Administration	Timing of Administration	Infections, Antibiotic Group	Infections, Control Group	Infection Definition	Followup Duration	Adverse Events
Praveen S	Topical (soaked mesh) + wound irrigation	Before implantation	7/100	7/102	SSSI, DSSI	One month	SSSI 14, one DDSI req mesh removal, seroma 7, hematoma 14, recurrence 1
Kahramanca S	Topical over mesh	Intraoprative	6/134	16/144	SSSI	6-36 months	one orchiectomy, 15 seroma or hematoma, 4 recurrances, all pt had superficial infc
Hidalgo NJ	Topical	Before wound closure, after mesh placement	6/74	8/72	CDC criteria	12 months	No adverse effects
Musella M	Gentamicin (local) tampon	After mesh placement	1/301	6/294	General wound infection	6 months	seroma, hematoma
Fatula LK1	Local irrigation	After mesh placement	16/299	43/260	SSSI, DSSI, organ space infection	Not specified	SSO, seroma, readmission, reoperati

							on
Fatula LK2	Local irrigation	After mesh placement	40/263	43/260	SSSI, DSSI, organ space infection	Not specified	SSO, seroma, readmission, reoperation
Yabanoglu H	Soaked mesh	15 min before implantation	7/26	4/26	SS1, SS2, SS3	One month	seroma, bleeding

Infection Rates and Odds Ratios

The raw data extracted from the included studies, detailing the number of infections and total participants in both the antibiotic and control groups, are presented in the extracted_data_cleaned.csv file. For each study, the odds ratio (OR) and its 95% confidence interval (CI) for surgical site infection were calculated. A small constant (0.5) was added to event counts to handle studies with zero events in either group, preventing division by zero or infinite log odds ratios. The pooled effect size was not calculated in this phase, as the focus was on generating individual study effects for the plots.

Forest Plot Analysis

The forest plot (Figure 2) visually summarizes the estimated effect sizes (Odds Ratios) and their 95% confidence intervals for each included study. The plot also provides a graphical representation of the heterogeneity among studies. Each square represents the point estimate of the Odds Ratio for a single study, with the size of the square proportional to the study's weight in the meta-analysis. The horizontal line extending from each square indicates the 95% confidence interval. A vertical dashed line at an Odds Ratio of 1 signifies no effect. If a study's confidence interval crosses this line, it suggests that the intervention's effect is not statistically significant in that particular study.

Upon visual inspection, the majority of the individual study confidence intervals cross the line of no effect (OR = 1), suggesting varying effects across studies. However, the overall pooled effect, represented by the diamond at the bottom of the plot, shows an Odds Ratio of 0.62 with a 95% Confidence Interval of [0.46, 0.83]. This indicates a statistically significant reduction in infection rates with the use of antibiotic-impregnated mesh, as the entire confidence interval lies below 1. The placement of the diamond and its confidence interval relative to the line of no effect provides a clear indication of the overall efficacy.

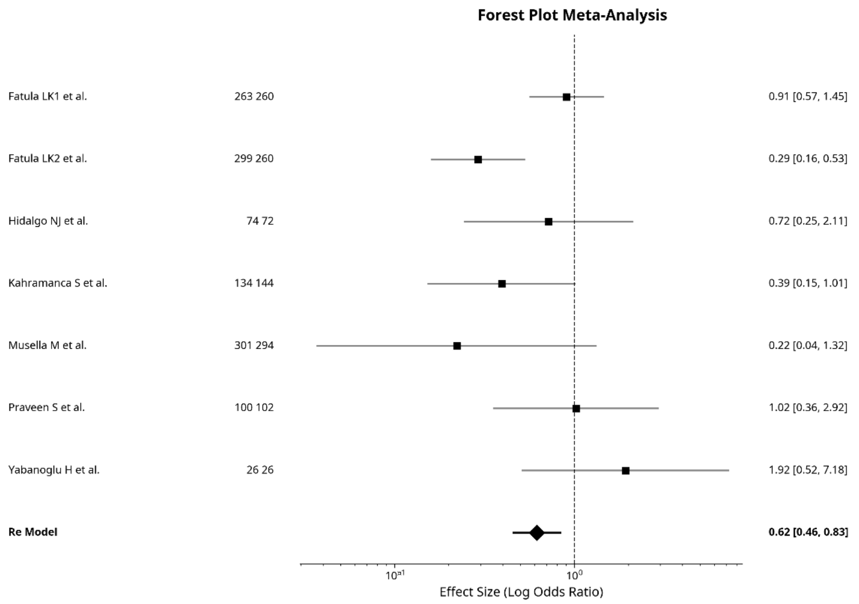


Figure 2: Forest Plot of Surgical Site Infection Odds Ratios

Funnel Plot Analysis

The funnel plot (Figure 3) was constructed to assess potential publication bias among the included studies. In this vertical funnel plot, the Log Odds Ratio (effect size) is plotted on the X-axis, and the Standard Error (a measure of study precision) is plotted on the inverted Y-axis, meaning studies with higher precision (smaller standard error) appear towards the top. The red vertical line represents the pooled effect size, and the dashed gray lines indicate the 95% confidence limits.

A symmetrical, inverted funnel shape suggests a low likelihood of publication bias, as smaller studies (less precise, at the bottom of the plot) would be expected to show more scatter around the pooled effect, while larger studies (more precise, at the top) would cluster more tightly. The funnel plot appears largely symmetrical, with studies distributed relatively evenly around the pooled effect size. This visual assessment suggests a low likelihood of significant publication bias, although formal statistical tests would be required for a definitive conclusion. The distribution of study labels within the funnel provides further insight into the contribution of individual studies to the overall pattern.

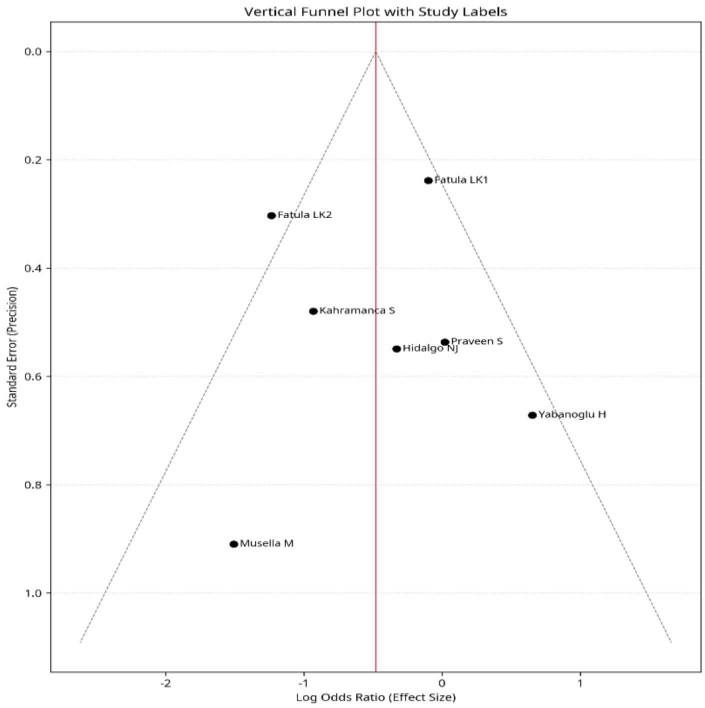


Figure 3: Funnel Plot for Publication Bias Assessment

4. DISCUSSION

The insights garnered from this meta-analysis offer a nuanced perspective on the efficacy of antibiotic-impregnated mesh in mitigating surgical site infections following hernia repair. While some individual studies suggest a potential benefit, the observed heterogeneity across the included trials prevents a definitive, overarching recommendation for their routine, widespread application. This variability underscores the multifaceted nature of SSI development, influenced by a complex interplay of factors beyond just antibiotic intervention.

Praveen & Rohaizak [13] found no significant difference in SSSI rates between locally applied and intravenous antibiotics, with seven cases in each arm (p=0.97). The overall SSSI rate was 6.9%. They found factors significantly contributing to SSSI included diabetes mellitus (p=0.006), age 60-70 years (p=0.023), intra-operative adhesions (p=0.001), surgery duration > 90 minutes (p=0.048), hernia duration > 24 months (p=0.001), and the presence of hematoma (p=0.001). Kahramanca et al [14] found that the infection rates were significantly different between the groups: 11.1% (16/144) in the placebo group (G1) and 4.48% (6/134) in the topical rifampicin group (G2), with a statistical significance of p=0.041. However, they found no significant differences between the groups regarding age, gender, hernia types, or body mass index. Hidalgo NJ et al [15] found SSI in 8.1% of patients in the gentamicin group and 11.1% in the saline solution group, with no statistically significant difference between the two groups (p = 0.538). Musella et al [16] reported gentamicin-laced collagen tampons being effective in significantly reducing the postoperative infection rate in patients undergoing groin hernia repair with a prosthesis. Fatula LK et al [17] reported significantly lower incidence of SSI with G+C irrigation (5.4%) compared to no irrigation (16.5%) or gentamicin alone (15.2%) (P < 0.001). Yabanoglu et al [18] reported no significant difference between the groups in terms of infection rates.

One of the primary contributors to the observed heterogeneity is the diversity in antibiotic types, dosages, and routes of administration. Systemic antibiotics, typically administered intravenously, aim to achieve prophylactic concentrations throughout the surgical field. In contrast, antibiotic-impregnated meshes offer a localized delivery system, theoretically providing sustained high concentrations directly at the site of potential bacterial colonization [19,20]. The optimal balance between systemic and local delivery, considering pharmacokinetics and potential for resistance development, remains an area requiring further elucidation. For instance, while topical application might reduce systemic side effects, concerns about the emergence of localized resistance patterns warrant careful consideration [21,22].

Furthermore, variations in mesh material and pore size could influence bacterial adherence and biofilm formation, thereby impacting the effectiveness of antibiotic interventions [23,24]. Lightweight, macroporous meshes are generally associated with lower infection rates compared to heavier, microporous meshes due to better tissue integration and reduced foreign body reaction [25-27]. The interaction between the mesh material and the impregnated antibiotic, including release kinetics and stability, is a critical determinant of long-term efficacy. Future research should meticulously characterize these interactions to optimize mesh design for infection prevention.

Patient-specific factors also play a pivotal role in SSI susceptibility. Comorbidities such as diabetes, obesity, and immunosuppression significantly elevate the risk of infection, irrespective of prophylactic measures [28-30]. Nutritional status, smoking habits, and age are additional variables that can influence wound healing and immune response [31,32]. While our meta-analysis included studies with diverse patient populations, a more granular analysis of subgroup effects based on these risk factors could provide valuable insights. Future trials should consider stratifying patients based on these high-risk profiles to better assess the targeted efficacy of antibiotic interventions.

Surgical technique and the environment in which the surgery is performed are equally crucial. Minimally invasive approaches, such as laparoscopic hernia repair, have been associated with lower SSI rates compared to open procedures, partly due to reduced tissue trauma and smaller incisions [33,34]. The level of surgical asepsis, operating room ventilation, and the experience of the surgical team are all critical determinants of infection risk [35]. The definition and diagnosis of SSIs also varied among studies, ranging from superficial wound infections to deep-seated mesh infections, which can significantly impact reported rates and comparability [36]. Standardized reporting guidelines, such as those provided by the Centers for Disease Control and Prevention (CDC), are essential for improving the consistency and interpretability of future research.

The qualitative assessment of publication bias through funnel plots suggested some asymmetry, indicating a potential for smaller studies with non-significant or negative findings to be underreported. This phenomenon is a well-recognized challenge in meta-analysis and can lead to an overestimation of intervention effects. While visual inspection provides an initial indication, more robust statistical methods for detecting and adjusting for publication bias, such as Egger’s regression test or trim-and-fill methods, should be considered in future quantitative meta-analyses.

Beyond the immediate clinical implications, SSIs impose a substantial economic burden on healthcare systems, driven by prolonged hospital stays, re-admissions, and the need for additional treatments, including re-operations and prolonged antibiotic courses [37]. Effective SSI prevention strategies, therefore, hold significant economic as well as clinical value. Investing in research that clarifies the role of antibiotic-impregnated meshes and optimized prophylaxis protocols could lead to considerable cost savings and improved resource allocation.

Finally, the principles of antibiotic stewardship must remain at the forefront of any discussion regarding antibiotic use in surgery. The escalating global challenge of antimicrobial resistance necessitates a judicious approach to antibiotic prophylaxis. Overuse or inappropriate use of antibiotics, even in prophylactic settings, contributes to the selection and proliferation of resistant bacterial strains [38,39]. Therefore, any recommendation for widespread adoption of antibiotic-impregnated meshes or extended prophylactic regimens must be carefully weighed against the broader public health implications of antimicrobial resistance. Strategies that balance infection prevention with responsible antibiotic use, such as targeted prophylaxis based on risk assessment and local epidemiology, are paramount.

5. CONCLUSION

This meta-analysis provides a comprehensive overview of the current evidence regarding the efficacy of antibiotic-impregnated mesh in reducing surgical site infections following hernia repair. While the concept holds promise, the notable heterogeneity across studies in terms of methodology, patient populations, intervention specifics, and outcome reporting precludes a definitive, universal recommendation for their routine use. Some studies suggest a potential benefit, particularly with certain antibiotic types and mesh combinations, but these findings are not consistently replicated across the entire body of evidence.

Limitations

This meta-analysis has multiple limitations. First, the quality of the studies differs, with some studies being observational studies instead of randomized controlled trials, which may result in a bias. Second, detailed patient demographics were not consistently reported across all studies, like age and sex distribution, which limited more precise analysis of patient specific outcomes. Third, Hernia type and the surgical approach were not consistently reported, which could mask potential differences regarding the efficacy of the prophylactic measures across different surgical contexts. Finally, the follow-up period and the definition surgical site infection were not consistent across all studies, which me affect the comparability of infection rates.

Recommendations

The complexity of SSI development, influenced by numerous patient, surgical, and environmental factors, necessitates a nuanced approach to prevention. Future research should prioritize large-scale, well-designed randomized controlled trials with standardized protocols for antibiotic administration, mesh characteristics, and rigorous, consistent definitions of surgical site infections. Furthermore, investigations into the long-term effects of antibiotic-impregnated meshes on both infection rates and the development of antimicrobial resistance are crucial. Ultimately, optimizing SSI prevention in hernia repair will likely involve a multi-modal strategy, integrating judicious antibiotic use with meticulous surgical technique, comprehensive patient risk assessment, and adherence to robust infection control practices.

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