Antibiotic Prophylaxis against Surgical Site Infection after Open Hernia Surgery: A Systematic Review and Meta-Analysis

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Keywords

Prophylactic antibiotics · Hernia repair · Surgical site infection · Systematic review · Meta-analysis

Abstract

Objective: The role of antibiotic prophylaxis (AP) in the prevention of surgical site infection (SSI) after hernia repair is debated. We conducted this systematic review and meta-analysis to assess the evidence on the value of prophylactic antibiotics in reducing the risks of SSI after open hernia surgery. **Methods:** We ran an online and manual search to identify relevant randomized controlled trials that compared prophylactic antibiotics to nonantibiotic controls in patients undergoing open surgical hernia repair. Data on SSI risk were extracted and pooled as risk ratios (RRs) with 95% confidence intervals (95% CIs), using RevMan software. We further used the Cochrane risk of bias tool and GRADE assessment to evaluate the quality of generated evidence. **Results:** Twenty-nine studies ($N = 8,616$ patients) were included in the current analysis. Antibiotic prophylaxis reduced the risk of SSI in open

hernia repair patients ($RR = 0.65$, 95% CI = 0.53, 0.79). Subgroup analysis showed a significant benefit for antibiotics in mesh repair patients ($RR = 0.60$, 95% CI = 0.48, 0.76) yet no significant difference in SSI risk after herniorrhaphy ($RR = 0.86$, 95% CI = 0.54, 1.36). In addition, AP was associated with a significant reduction in superficial SSI risk ($RR = 0.56$, 95% CI = 0.43, 0.72) but not deep SSI ($RR = 0.70$, 95% CI = 0.30, 1.62). Further analysis showed a significant reduction in SSI risk with amoxicillin/clavulanic acid and cefazolin but not with cefuroxime. **Conclusion:** The present meta-analysis suggests that AP is beneficial prior to open mesh hernia repair. However, the quality of evidence was low, and further well-designed trials are needed.

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Introduction

Worldwide, almost 20 million hernia surgeries are performed each year. Most of these procedures are to repair inguinal hernias (IH) [1], and mesh repair (hernio-

plasty) is used in 90% of these cases [2]. Hernia surgery is generally considered to be a clean procedure. The rate of surgical site infections (SSIs) after hernia repair varies widely according to the type of center, type of hernia, and surgical technique but can be as low as 1–2% [3]. Among other factors, SSI after hernia repair may predispose patients to hernia recurrence [4].

The appropriateness of the use of antibiotic prophylaxis (AP) before hernia surgery is debated. Earlier retrospective and prospective datasets have reported different practices and results [5–7]. The European Hernia Society does not recommend the routine use of AP in low-risk patients [8]. Several prospective randomized trials have explored the effectiveness of AP prior to hernia repair surgery. Some of these studies reported significant benefits for antibiotic use before surgery, while other studies failed to find such benefit [9–37].

In this meta-analysis, we analyzed the best available evidence examining the role of AP in preventing SSI after hernia repair. To that end, we compared the incidence of SSI in patients undergoing open hernia repair receiving prophylactic antibiotics versus nonantibiotic controls.

Methods

We performed this systematic review in compliance with the Cochrane handbook for systematic reviews of intervention [38] and reported it in compliance with the PRISMA checklist (see online suppl. Table 1; for all online suppl. material, see www.karger.com/doi/10.1159/000517404) [39].

Literature Search

We searched the following online databases to find randomized controlled trials (RCTs): Medline, Cochrane central library, EMBASE, CINAHL, ClinicalTrials.gov, and the World Health Organization search engines with no language restriction. The initial search was performed in May 2017; another updated search was performed in August 2020. We also screened the references lists of the included studies and published systematic reviews for all relevant studies that evaluated the benefits of prophylactic antibiotics in patients undergoing hernia repair operations. The search terms used were ["Hernia OR, Herniation OR, Herniotomy OR, Hernia repair" AND "Antibacterial agents OR, Antibiotic OR, Anti-bacterial OR, Clindamycin OR, Cefuroxime OR, Ceftazidime OR, Ofloxacin OR, Levofloxacin OR, Azithromycin OR, Sulbactam OR, Ampicillin OR, Mezlocillin OR, Oxacillin OR, Vancomycin OR, Tobramycin OR, Ciprofloxacin OR, Cefazolin OR, Gentamicin OR, Metronidazole OR, Neomycin OR, Doxycycline" AND, "Surgical site infection OR, Surgical wound infection OR, Surgical wound dehiscence OR, Infection control OR, Wound complication"]. MeSH terms and text key words were used.

Eligibility Criteria and Screening

We included RCTs that matched the following criteria: (1) population: adult patients undergoing open IH surgery, regardless

elective or emergency, (2) intervention: prophylactic antibiotics, (3) control: patients may have received placebo, saline, multivitamins, or other nonantibiotic controls, (4) outcome: SSI (both superficial and deep SSI). Two reviewers (A.A. and N.F.) independently evaluated the title, abstract, and (if needed) full text of relevant studies for inclusion and exclusion criteria. Any discrepancies were resolved by consensus.

Data Extraction and ROB Assessment

Two researchers (W.M. and N.F.) independently extracted data using a special extraction form, and any discrepancies were resolved by discussion. The extracted data included the following: inclusion and exclusion criteria, setting, type of repair, type of antibiotic, SSI definition, and incidence. Two authors (M.F. and A.A.) independently assessed the relevant articles for the risk of bias (ROB) using the Cochrane Collaboration Criteria (to assess for selection bias, performance bias, reporting bias, attrition bias, and other sources of bias) [40]. We then used the GRADE quality of evidence assessment to assess the certainty of evidence of analyzed outcomes [41].

Statistical Analysis

The statistical analysis was performed using Review Manager software (RevMan version 5.3, Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2012). Meta-analysis was conducted to assess the primary outcome of SSI. Risk ratios (RRs) and 95% confidence intervals (95% CIs) were calculated for pooling up the results of different studies, using Mantel-Haenszel fixed effects model analysis. Heterogeneity was explored using conventional Cochrane's *Q* test and *I*² test. The *p* value of the *Q* test was considered significant when it was ≤0.10. Publication bias was assessed by visually inspecting the funnel plot produced using Review Manager. We performed subgroup analyses by type of antibiotic and type of SSI.

Results

Literature Search Results

The initial search identified 5,629 related articles. The study selection process is shown in Figure 1, including the justification for exclusion. Only 29 RCTs met our inclusion criteria in which 8,616 patients participated (shown in Fig. 1) [9–37]. Of these participants, 4,718 patients received AP before surgery, compared with 3,898 patients who did not. Two studies [17, 26] compared different classes of antibiotics. Table 1 shows the characteristics of the included studies.

Characteristics of the Included Studies Surgical Procedures

Nineteen studies included only patients who underwent open mesh repair of their IH. Two studies included patients who underwent only anatomic groin (femoral and inguinal) herniorrhaphy, both studies excluded mesh

Fig. 1. PRISMA flow diagram showing the study selection process.

repair. The study by Taylor et al. included patients who had groin (inguinal and femoral) hernias repaired either by mesh or herniorrhaphy.

Antibiotic Prophylaxis

The included studies assessed 12 antibiotics belonging to 4 different classes (penicillins, cephalosporins, quinolones, and macrolides). Participants in all control groups took identically shaped placebos.

ROB Assessment

The risk of selection bias was high/unclear in about half of the included studies. Only 12 studies performed adequate blinding of the participants, and only 11 studies performed adequate blinding of outcome assessors. The majority of included studies had low risks of attrition and reporting biases. Figure 2 shows ROB items for each study. The results of GRADE assessment are illustrated in online suppl. Table 2.

Overall SSI Rate

The overall rate of SSI after hernia surgery was 4.27%. Antibiotic prophylaxis was associated with an overall significant reduction in the SSI rate (RR = 0.65, 95% CI = 0.53, 0.79, $p < 0.0001$; 28 studies; $N = 8,221$; low quality of evidence) compared to the control group. Subgroup analysis based on hernia surgery type showed that in hernio-

plasty, AP was associated with significantly reduced SSI risk (RR = 0.60, 95% CI = 0.48, 0.76, $p < 0.0001$; 25 studies; $N = 6,896$; low quality of evidence) compared to control group. The same result was not observed in patients who underwent herniorrhaphy (RR = 0.86, 95% CI = 0.54, 1.36, $p = 0.25$; 3 studies; $N = 1,325$; very low quality of evidence). No significant heterogeneity was observed in overall and subgroup analyses (shown in Fig. 3). Further, the symmetrical funnel plot indicated no evidence of significant publication bias.

Subgroups Based on SSI Type

Data analysis showed that AP was associated with a significant reduction in the risk of superficial SSI (RR = 0.56, 95% CI = 0.43, 0.72, $p < 0.0001$; 23 studies; $N = 6,658$; low quality of evidence) compared to control group. However, in terms of deep SSI, no significant difference was observed (RR = 0.70, 95% CI = 0.30, 1.62, $p = 0.40$; 14 studies; $N = 4,638$; low quality of evidence) between AP and control groups. No significant heterogeneity was observed for both outcomes. Funnel plots for both outcomes were symmetrical, indicating no evidence of significant publication bias.

Subgroups Based on Antibiotic Type

Subgroup analysis showed that AP using amoxicillin plus clavulanic acid (RR = 0.55, 95% CI = 0.35, 0.88, $p =$

Table 1. Characteristics of included studies

Author, reference	Inclusion criteria	Exclusion criteria	Setting	Type of repair	AP	Follow-up	SSI definition	Rate of SSI, %	Antibiotic event/total (%)	Control event/total (%)	p value
Abd Al-Fatah [28]	IH Age >15 years	Allergy to antibiotics Antibiotic use <5 days before surgery Pregnancy or lactation Existing indication for AP Liver or renal impairment	IP	Mesh IH repair	IV amoxicillin + clavulanic acid 1.2 g	4 weeks	Preset criteria by the study group	4	3/100 (3)	5/100 (5)	0.4
Razack et al. [31]	Unilateral/ bilateral IH	Allergic to antibiotic Complicated hernia Recurrent hernia DM Pregnancy or lactation Immunosuppression	IP	Mesh IH repair	IV cefazolin 1 g	4 weeks	ASEPSIS criteria	8.3	7/94 (7.4)	8/86 (9.3)	0.351
Aufenacker et al. [13]	Unilateral/ bilateral IH	Age <35 years Recurrent hernia Need for antibiotics for other reasons Immunosuppression Patient on cortisone Allergy to antibiotics	NM	Mesh IH repair	IV cefuroxime 1.5 g	3 months	CDC criteria	1.6	8/503 (1.6)	9/505 (1.8)	0.82
Celdrán et al. [14]*	IH ASA classes I and II	NM	OP	Mesh IH repair	IV cefazolin 1g	3 months	CDC criteria	4	0/50	4/49 (8)	0.059
Ergul et al. [24]	Unilateral IH	Age <18 years Complicated hernia Recurrent hernia Bilateral repair Coagulopathy and anticoagulant drugs Advance systemic disease Immune suppression Allergy to cephalosporin Antibiotics use <72 h before surgery Pregnancy and lactation VHD that require AP Patient on cortisone Giant scrotal hernia Prostatic valve or joint Insertion of drain	IP	Mesh IH repair	IV cefazolin 1g	1 month	CDC criteria	6	5/100 (5)	7/100 (7)	0.4
Goyal et al. [22]	IH	Complicated hernia Local skin infection systemic infection DM Antibiotic use <1 week before surgery	IP	Mesh IH repair	IV amoxicillin + clavulanic acid 1.2 g	8 days	NM	1.3	1/100 (1)	2/100 (2)	0.33

Table 1 (continued)

Author, reference	Inclusion criteria	Exclusion criteria	Setting	Type of repair	AP	Follow-up	SSI definition	Rate of SSI, %	Antibiotic event/total (%)	Control event/total (%)	p value
Jain et al. [19]	Unilateral IH	Complicated hernia Advanced systemic diseases Immunosuppression ASA scores higher than 11 Patient on cortisone Age <18 or >60 years Local skin infections or disease at the site of incision Allergic to antibiotics Antibiotics use <1 week before surgery	IP	Mesh IH repair	IV amoxicillin + clavulanic acid 1.2 g	1 month	CDC criteria	1.6	1/60 (1.6)	1/60 (1.6)	0.5
Kochhar et al. [29]	IH Age 15–70 years	Allergy to antibiotics Complicated hernia Recurrent hernia Pregnancy or lactation Immune suppression Existing indication for AP Antibiotic use <5 days before surgery	IP	Mesh IH repair	IV amoxicillin + clavulanic acid 1.2 g	4 weeks	ASEPSIS criteria	4.2	4/106 (3.7)	5/106 (4.7)	0.7
Mazaki et al. [27]*	Unilateral/ bilateral IH	OP procedure Age <18 years Complicated hernia Recurrent hernia Advance systemic disease ASA > IV Immune suppression Allergy to β-lactam Antibiotics use <48 h before surgery Pregnancy and lactation Presence of infection at the time of surgery	IP	Mesh IH repair	IV cefazolin 1 g	3 months	CDC criteria	7.5	2/100 (2)	13/100 (13)	0.006
Morales et al. [11]	Inguinal and femoral hernia	Emergency surgery Patient on cortisone AIDS and HIV patients Patient with malignancy Patient noncompliant to the allocation Patient did not follow the postoperative protocol Insertion of drain	IP/OP	Mesh repair	IV cefazolin 2g IV erythromycin 1 g if patient is allergic to β-lactam	1 month	Preset criteria by the study group	1.9	4/237 (1.7)	6/287 (2.1)	0.7
Oteiza et al. [15]	Uncomplicated unilateral IH	Recurrent hernia Allergy to penicillin ASA class IV Patient who needs admission	OP	Mesh IH repair	IV amoxicillin + clavulanic acid 2 g	1 month	NM	0.4	1/124 (0.8)	0/123 (0)	NS

Table 1 (continued)

Author, reference	Inclusion criteria	Exclusion criteria	Setting	Type of repair	AP	Follow-up	SSI definition	Rate of SSI, %	Antibiotic event/total (%)	Control event/total (%)	p value
Othman et al. [23]	Unilateral/ bilateral IH	Complicated IH Patient on cortisone Antibiotic use <48 h before surgery VHD or patient with prosthetic heart valve	IP	Mesh IH repair	IV amoxicillin + clavulanic acid 1.2 g	1 month	CDC criteria	10	4/50 (8)	6/48 (12.5)	0.47
Perez et al. [16]	Unilateral IH	Age <18 or >70 years ASA class II Patient at increased risk of infection because of systemic disease Presence of infection at the time of surgery Allergic to β -lactam Antibiotic use <48 h before surgery VHD Prosthetic valve or joints	NM	Mesh IH repair	IV cefazolin 1 g	1 month	CDC criteria	3	4/180 (2.2)	7/180(3.9)	0.55
Shankar et al. [20]	Unilateral/ bilateral IH	Recurrent hernia Immunosuppression DM	IP	Mesh IH repair	IV cefazolin 1 g	1 month	CDC criteria	8.7	12/172 (7)	17/162 (10.5)	0.344
Thakur et al. [21]	Unilateral/ bilateral IH	Complicated hernia Patient on cortisone Patient on chemotherapy Antibiotics use <1 week before surgery VHD Prosthetic valve or joint	IP	Mesh IH repair	IV cefuroxime 1.5 g	1 month	NM	12.7	3/29 (10.3)	4/26 (15.3)	0.01
Tzovaras et al. [18]	IH Age >15 years	Allergy to antibiotics Antibiotic use <5 days before surgery Pregnancy or lactation Bilateral hernia repair Existing indication for AP Liver or renal impairment	IP	Mesh IH repair	IV amoxicillin + clavulanic acid 1.2 g	1 month	Preset criteria by the study group	3.7	5/190 (2.6)	9/189 (4.7)	0.4

Table 1 (continued)

Author, reference	Inclusion criteria	Exclusion criteria	Setting	Type of repair	AP	Follow-up	SSI definition	Rate of SSI, %	Antibiotic event/total (%)	Control event/total (%)	p value
Ullah et al. [25]	Unilateral IH Age >18 years Male	Complicated hernia Recurrent hernia FBS >126 mg/dL Immune suppression ASA scores higher than 11 Cortisone intake in the last 2 weeks BMI ≥29 Chronic liver disease Impaired renal function	IP	Mesh IH repair	IV amoxicillin + clavulanic acid 1 g	2 weeks	NM	12.7	6/83 (7.2)	15/83 (18.1)	0.036
Wang et al. [26]	IH Age: 16–81 years BMI 18–32 kg/m ²	Patient with malignancy Immune system disease Allergy to β-lactam Use of cortisone or immune suppression <1 month before surgery Antibiotic use <3 days before surgery Pregnancy and lactation	IP	Mesh IH repair	IV cefazolin 1g IV levofloxacin 200 mg	1 month	CDC criteria	4.48	Cefazolin = 15/385 (3.92) Levofloxacin = 17/383 (4.42)	20/392 (5.1) Cefazolin = 0.438 Levofloxacin = 0.803	
Yerdel et al. [12]*	Unilateral IH	Complicated hernia Recurrent hernia Large hernia defect Advance systemic disease ASA > II Patient on cortisone Allergy to antibiotics Age <18 years Pregnancy and lactation Antibiotics use <1 week before surgery	IP	Mesh IH repair	IV ampicillin + sulbactam 1.5 g	1 year	CDC criteria	4.8	1/136 (0.7)	12/133 (9)	0.001
Akhtar et al. [30]	IH Age 15–50 years Male	DM Tuberculosis Anemia Jaundice Immune suppression Systemic disease	NM	Inguinal herniorrhaphy	IV cloxacillin 1 g	1 month	Preset criteria by the study group	4.6	2/75 (2.7)	5/75 (6.7)	0.246
Platt et al. [9]**	Inguinal/femoral hernia Age >18 years Speak English Live within 35 miles of hospital	Insertion of prosthetic material Second incision Pregnancy or lactation Antibiotic use <1 week before surgery Allergy to β-lactam Some hospitals excluded OP cases	IP/OP	Inguinal femoral herniorrhaphy	IV cefonicid 1 g	3 months	Preset criteria by the study group	0.16	4/301 (1.3)	6/311 (1.9)	RR: 0.55 95% CI: (0.2–1.38)

Table 1 (continued)

Author, reference	Inclusion criteria	Exclusion criteria	Setting	Type of repair	AP	Follow-up	SSI definition	Rate of SSI, %	Antibiotic event/total (%)	Control event/total (%)	p value
Taylor et al. [10]	Inguinal or femoral hernia Age >18 years	Allergy to β -lactam Bilateral hernia Pregnancy or lactation Renal or liver impairment Existing indication for AP	IP/OP	Inguinal femoral herniorrhaphy 33 patients had mesh repair	Amoxicillin + clavulanic acid 1.2 g	4–6 weeks	Preset criteria by the study group	8.9	25/283 (8.8)	25/280 (8.9)	0.97
Terzi et al. [17]	Unilateral/bilateral IH Recurrent hernia Age <18 years	Complicated hernia Pregnancy or lactation Allergy to antibiotics Antibiotic use <1 week before surgery Morbid obesity Liver or renal impairment Neutropenia Immune suppression Significant GI disease	IP	Mesh IH repair	PO ciprofloxacin 500 mg IV cefazolin 1 g	1 year	CDC criteria	2	4/199 (2) cefazolin	4/196 (2) ciprofloxacin	0.59
Rahmani et al. [33]	Unilateral IH, age: 25–84	Emergency hernia repair Allergy to cefalotin or penicillin Taking antibiotics because of other situations like infectious disease Cardiac valve disease Immune deficiency Taking medications (immunosuppressant and corticosteroids)	OP	Mesh IH repair	IV cefalotin 1 g for 1 dose, 30 min before surgery	12 weeks	CDC criteria	4.6	4/141 (2.8)	9/141 (6.4)	>0.05
Bidar et al. [36]	Primary IH, age >18 years	Recurrent, strangulated, bilateral hernia femoral hernia Allergy to cefuroxime Systemic advanced diseases like DM, liver, or renal impairment Patients on steroids or antibiotic within a week before surgery Pregnant or lactating women	NA	Mesh IH repair	IV cefuroxime 1,500 mg before incision	42 days	CDC criteria	1.6	0/30 (0)	1/30 (3.3)	>0.05
Siddiqui et al. [35]	Uni/bilateral IH	Local skin/systemic infection and DM Being on immunosuppressive drugs Receiving antibiotic within 1 week	IP	Mesh IH repair	IV cefuroxime 1.5 g before surgery	A	Preset criteria by the study group	17.5	2/20 (10)	5/20 (25)	>0.05

Table 1 (continued)

Author, reference	Inclusion criteria	Exclusion criteria	Setting	Type of repair	AP	Follow-up	SSI definition	Rate of SSI, %	Antibiotic event/total (%)	Control event/total (%)	p value
Bahar et al. [32]	Uni/bilateral IH, age > 18 years	Emergency operations Immunocompromised patients and those on immunosuppressive drugs Using antibiotics 1 week before surgery Allergy to antibiotics	NA	Mesh IH repair	IV cefazolin 1 g before surgery	12 months	Preset criteria by the study group	2	6/237 (2.5)	2/158 (1.3)	0.36
Vinoth et al. [34]	IH	Emergency hernia repair Allergy to cefotaxime Systemic advanced diseases Immune deficiencies	NA	Mesh IH repair	IV cefotaxime 1 g 30 min before surgery	NA	CDC criteria	11.6	2/30 (6.6)	5/30 (16.6)	0.59
Kahla et al. [37]	IH, age: 18–65 years	Strangulated hernia Immunosuppressive disease Allergy to the antibiotic	NA	Mesh IH repair	IV cefazolin 1 g at induction	42 days	Preset criteria by the study group	7.5	1/20 (5)	2/20 (10)	0.54

ASA, American Society of Anesthesiologists; BMI, body mass index; DM, diabetes mellitus; FBS, fasting blood sugar; GI, gastrointestinal disease; GP, general practitioner; IH, inguinal hernia; IP, inpatient procedures; NS, not significant; NM, not mentioned; OP, outpatient procedure; RR, risk ratio; VHD, valvular heart disease; AP, antibiotic prophylaxis; SSI, surgical site infection; CI, confidence interval. * Stopped early because of high event rate in the control arm. ** The study investigated SSI in hernia and breast surgery. Therefore, the sample size was not calculated to measure the difference in SSI in hernia patients.

0.01; 9 studies; $N = 1,899$; low quality of evidence) or cefazolin ($RR = 0.67$, 95% $CI = 0.48, 0.95$, $p = 0.02$; 8 studies; $N = 2553$; low quality of evidence) were associated with significant reductions in SSI risk, while prophylaxis using cefuroxime ($RR = 0.68$, 95% $CI = 0.35, 1.33$, $p = 0.26$; 4 studies; $N = 1,163$; low quality of evidence) was associated with a comparable SSI risk compared to control group. No significant heterogeneity was observed across all subgroups. An exploratory comparative analysis based on only 2 studies showed comparable risks of SSI in patients who received cephalosporins versus quinolones ($RR = 0.90$, 95% $CI = 0.49, 1.66$, $p = 0.74$; 2 studies; $N = 1,169$; very low quality of evidence) [17, 26].

Discussion

Our meta-analysis showed that the use of AP prior to hernia surgery reduces the risk of SSI. The pooled incidence rate of SSI in the AP group was 3.5% and 5.2% in the no-AP group. However, subgroup analysis showed that the benefit of AP was mainly in procedures where mesh was used. The rate of SSI was not affected by choice of quinolone versus cephalosporin.

Meta-analyses exploring the same subject have reported different results [42–48]. A 2012 Cochrane review examined the role of systemic and local antibiotics in preventing SSI after hernia repair, regardless of the hernia type or procedural technique. The review demonstrated that antibiotics significantly reduced the rate of post-hernia repair SSI by 36% compared with controls but only in cases of mesh repair. However, the number needed to treat was too high to justify the regular use of AP in cases of mesh repair (NNT, 70; 95% $CI: 43–183$) [43]. Evidence provided by Aufenacker et al. [46] did not support the use of AP to prevent SSI prior to mesh hernia repair.

Six other meta-analyses looked at the effects of AP prior to IH mesh repair. Those reviews [42–44, 48, 49] with one exception [47] showed AP to be beneficial in this procedure. Other factors could be related to the skill level and expertise of the performing surgeon, the procedural technique, the definition of SSI, follow-up modalities and duration, and the presence or absence of comorbidities in the study populations.

The results of observational studies looking at the use of AP prior to hernia repair are contradictory. In a single-arm prospective study that included 2002 mesh repairs of IHS, Just et al. [50] found that AP reduced the rate of SSI from 1.2 to 0.2% [50]. A similar finding was noted by Taylor et al. [51] who surveyed 2,665 IH repair

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Abd Al-Fatah 2011	+	+	+	?	+	+	+
Abdul Razack 2015	?	+	?	+	+	+	+
Akhtar 2014	+	?	?	-	+	+	+
Aufenacker 2004	+	?	+	+	+	+	+
Bahar 2015	-	-	-	-	+	+	?
Bidhur 2013	+	?	+	?	+	+	+
Celdran 2004	+	?	+	?	+	+	+
Ergul 2012	?	+	+	+	+	+	+
Goyal 2011	+	-	?	-	+	+	+
Jain 2008	+	?	-	?	+	+	+
Kahla 2019	?	?	-	-	+	+	?
Kochhara2014	?	?	?	+	+	+	+
Mazaki 2014	+	?	+	+	+	+	+
Morales 2000	?	-	-	-	+	+	+
Oteiza 2003	+	-	-	?	+	+	+
Othman 2011	+	?	+	?	+	+	+
Perez 2005	+	+	+	+	+	+	+
Platt 1990	?	+	+	+	-	+	+
Rahmani 2012	?	?	+	?	+	-	+
Shankar 2010	?	+	?	+	+	+	+
Siddiqui 2017	-	-	-	-	+	?	?
Taylor 1997	+	?	?	?	?	+	+
Terzi 2005	+	?	?	+	+	+	+
Thakur 2010	?	?	-	-	+	+	+
Tzovaras 2006	+	+	+	+	+	+	+
Ulah 2013	?	?	?	-	+	+	+
Vinoth 2015	?	?	?	?	+	?	?
Wang 2013	+	+	?	?	+	+	+
Yerdel 2001	+	+	+	+	+	+	+

Fig. 2. ROB items for each study.

patients and found an overall rate of SSI of 5.3%. Patients who received AP had less of a risk of SSI than those who did not receive AP (4.2 vs. 7.6%, respectively; $p = 0.002$). On the other hand, retrospective data did not support the use of AP prior to primary hernia surgery without or with mesh insertion. A series of retrospective review by Gilbert et al. [6] reported the results of 2,492 IH repairs, 74% of the patient had mesh repair, and almost half of them received AP. The group found that AP provided no additional protection against SSI in primary hernia repair irrespective of the technique. However, there was a difference in recurrent hernia mesh repair (0.43 vs. 2.2%).

After hernia repair surgery, SSI is usually managed with antibiotics and rarely requires surgical intervention or removal of the mesh which is most likely related to the fact that most SSIs are superficial [5, 52]. However, post-repair SSI has been linked to hernia recurrence. Glassow et al. [53] described the outcome of 26,000 herniorrhaphy. They found that SSI increases the recurrence rate 4 times.

No other study linked SSI to hernia recurrence. Therefore, SSI might predispose the patient to hernia recurrence, but its role in recurrence is minor. Another factor that influences the decision to use AP is the lack of formal cost-benefit analysis. Theoretically, the use of a single dose of AP is more economical than the treatment of SSI and its possible consequences including recurrence [9, 54]. In hernia repair like other surgery, the choice of AP is usually driven by the micro-organism likely to have caused the infection; if there is no visceral violation, it is usually Gram-positive cocci and skin flora [52, 55], and the use of cephalosporins and penicillins appears safe. Prospective studies (were included in this analysis) comparing the use of cephalosporin versus quinolones showed no significant differences in the rate of post-hernia repair SSI [17, 26].

Limitations

Meta-analyses provide an assessment of the best available evidence; however, they are always limited by their primary studies. The clinical trials included in our analysis, which investigated AP prior to the use of mesh to repair uncomplicated IH, mostly involved healthy patients and excluded patients with comorbidities. This affects the generalizability of our findings to recurrent, nonelective, or other hernia types. Other limitations of this meta-analysis are lack of unified definition for SSI and differ-

Fig. 3. Overall and subgroup analyses.

ent follow-up period/modality, which might influence the rate of SSI. Some of the studies included in our analysis had a very short follow-up; in fact, only 2 studies had 1 year follow-up: according to the WHO definition, SSI can occur up to 1 year after mesh surgery [56]. The use of different antibiotics is another constraint of our review.

Conclusion

We have demonstrated a beneficial role for systemic AP in preventing SSI after open mesh hernia repair. Our findings do not support the use of AP in cases of herniorrhaphy; however, these results should be interpreted carefully due to the low quality of available evidence, and

further well-designed RCTs are still needed. Further, a large clinical trial is required to address issues such as cost-effectiveness, hernia recurrence, and quality of life.

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Statement of Ethics

The King Abdullah International medical Research (KAIMRC) IRB has exempted this study from review because there was non-human intervention.

Conflict of Interest Statement

All the authors declare no conflicts of interest.

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Author Contributions

L.A.R., W.M., and N.F.: contributed to article screening, data extraction, and risk of bias assessment; H.B. data analysis; M.F. and A.A.: idea conception and supervision. All the authors revised the final version of the manuscript and approved it for publication.

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