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Original Article

Role of Prophylactic Antibiotics in Preventing Surgical Site Infections

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ABSTRACT

Background: Surgical site infection remains a common postoperative complication after clean-contaminated surgery and contributes to prolonged hospital stay, additional antibiotic exposure, increased healthcare cost, and delayed recovery. Prophylactic antibiotics are effective when administered at the correct time and discontinued appropriately, but routine practice often includes delayed administration and unnecessary postoperative continuation. Objective: To evaluate whether implementation of a structured prophylactic antibiotic protocol was associated with reduced 30-day surgical site infection among patients undergoing clean-contaminated surgery. Methods: This prospective before-and-after quasi-experimental study was conducted in a tertiary care hospital in Islamabad, Pakistan. A total of 220 adult patients undergoing clean-contaminated elective or semi-elective surgery were included, with 110 patients observed during routine practice and 110 managed after implementation of a structured prophylaxis protocol. The intervention emphasized antibiotic administration within 60 minutes before incision and avoidance of routine postoperative antibiotics unless clinically indicated. Patients were followed during admission and up to 30 days after surgery. Results: Timely antibiotic administration improved from 58.2% to 93.6%, while unnecessary postoperative antibiotic continuation decreased from 62.7% to 21.8%. Total surgical site infection decreased from 16.4% in the routine-practice group to 6.4% in the structured-prophylaxis group, corresponding to a 10.0 percentage-point absolute risk reduction, relative risk of 0.39, and approximate number needed to treat of 10. Most infections were superficial incisional infections. Conclusion: Structured prophylactic antibiotic implementation was associated with better timing compliance, reduced unnecessary postoperative antibiotic use, and lower 30-day surgical site infection in clean-contaminated surgery. Keywords: Prophylactic antibiotics, surgical site infection, clean-contaminated surgery, antibiotic timing, postoperative antibiotics, antimicrobial stewardship, Islamabad, Pakistan.

INTRODUCTION

Surgical site infection is one of the most frequent and clinically important postoperative complications, particularly after clean-contaminated procedures in which the gastrointestinal, biliary, respiratory, or genitourinary tract is entered under controlled operative conditions. Although these operations are not infected at the time of incision, bacterial exposure may occur during tissue handling, visceral entry, or wound closure, creating a preventable risk of postoperative infection. Surgical site infection contributes to delayed wound healing, prolonged hospitalization, additional antibiotic exposure, increased treatment cost, avoidable readmissions, and reduced patient confidence in surgical care. Prevention of surgical site infection is therefore a core component of perioperative quality improvement, patient safety, and antimicrobial stewardship (1).

Antibiotic prophylaxis is an established preventive intervention in clean-contaminated surgery, but its effectiveness depends on correct implementation rather than antibiotic exposure alone. The central pharmacological principle is that adequate antibiotic concentration must be present in serum and operative tissues at the time of incision and maintained during the period of bacterial contamination. Major surgical infection-prevention guidelines recommend that most prophylactic antibiotics should be administered within 60 minutes before incision, with appropriate drug selection based on expected organisms, procedure type, patient allergy status, and local antimicrobial policy (2). Global recommendations have further emphasized that perioperative prevention requires an integrated approach including correct antibiotic timing, appropriate intraoperative practices, avoidance of unnecessary postoperative antibiotic continuation, and standardized surveillance of wound outcomes (3,4). The American College of Surgeons and Surgical Infection Society have similarly highlighted that antibiotic prophylaxis should be procedure-specific, time-sensitive, and limited in duration to reduce both infection risk and antimicrobial harm (5).

Despite the availability of clear recommendations, implementation gaps remain common in routine surgical practice. Antibiotics may be administered too early, after incision, or continued postoperatively without clinical indication. Such practices may fail to improve surgical outcomes while increasing medication cost, adverse drug reactions, Clostridioides difficile infection risk, and antimicrobial resistance. Recent infection-prevention guidance has reinforced the need for institutional protocols, documentation of administration time, intraoperative redosing where indicated, and discontinuation of prophylaxis when there is no evidence of established infection (6). Contemporary reviews also indicate that surgical site infection is influenced not only by antibiotic use but also by patient-related and operation-related factors such as diabetes mellitus, obesity, smoking, wound class, operative duration, and adequacy of perioperative infection-control measures (7).

Evidence against prolonged postoperative prophylaxis has become increasingly important for antimicrobial stewardship. A systematic review and meta-analysis found no clear additional reduction in surgical site infection when antibiotic prophylaxis was continued after surgery in settings where best-practice perioperative prophylaxis had already been followed (8). Longer and broader prophylactic antibiotic exposure has also been associated with antimicrobial-related adverse events, strengthening the rationale for limiting antibiotics to the perioperative period unless there is a defined clinical indication for treatment (9). Therefore, the practical question in surgical care is not whether antibiotics should be used indiscriminately, but whether a structured approach to timing, selection, documentation, and discontinuation can improve outcomes while reducing unnecessary antibiotic exposure.

The relationship between prophylactic antibiotic timing and wound infection risk has been demonstrated in landmark perioperative studies. Classen and colleagues showed that infection risk varied according to the timing of prophylactic administration, with the lowest risk observed when antibiotics were given close to the time of incision (10). Subsequent evidence has continued to support timing as a key determinant of prophylactic effectiveness, particularly when combined with appropriate drug selection and intraoperative redosing for prolonged procedures (11). International multicentre data further indicate that surgical site infection after gastrointestinal surgery is disproportionately higher in low- and middle-income settings, where resource constraints, high patient load, delayed presentation, variable infection-control practices, and inconsistent antibiotic protocols may increase postoperative infection risk (12).

In Pakistan, surgical site infection remains a relevant concern for tertiary care hospitals, where clean-contaminated procedures are commonly performed and patient-level risk factors such as diabetes, obesity, anemia, and delayed presentation may coexist with system-level variation in perioperative antibiotic practice. Local evidence has reported gaps in prophylactic timing and postoperative antibiotic use, suggesting that adherence to standardized perioperative protocols remains inconsistent. However, much of the available local literature is observational, procedure-specific, or focused on comparing antibiotic regimens rather than evaluating implementation of a structured timing-and-discontinuation protocol across clean-contaminated surgeries. This creates a practical evidence gap for hospitals seeking low-cost, reproducible interventions to reduce surgical site infection while supporting rational antibiotic use.

The present study was therefore designed using a PICO-based framework in which the population comprised adult patients undergoing clean-contaminated surgery, the intervention was implementation of a structured prophylactic antibiotic protocol, the comparison was routine hospital antibiotic practice, and the primary outcome was surgical site infection within 30 days after surgery. The study aimed to determine whether structured perioperative antibiotic prophylaxis, emphasizing administration within 60 minutes before incision and avoidance of unnecessary postoperative continuation, was associated with lower surgical site infection rates compared with routine practice among patients undergoing clean-contaminated surgeries in a tertiary care hospital in Islamabad, Pakistan.

MATERIALS AND METHODS

This study was conducted as a prospective before-and-after quasi-experimental interventional study in the Department of Surgery of a tertiary care hospital in Islamabad, Pakistan. The study was designed to evaluate the effect of implementing a structured prophylactic antibiotic protocol on surgical site infection among patients undergoing clean-contaminated surgeries. Patients were enrolled over a six-month period and observed in two sequential phases. In the first phase, perioperative antibiotic use followed routine hospital practice and served as the comparison phase. In the second phase, a structured antibiotic prophylaxis protocol was implemented and evaluated as the intervention phase. This design was selected because the intervention was applied at the level of clinical practice and operation theatre workflow rather than through individual randomization.

The study population included adult male and female patients aged 18 to 70 years who underwent elective or semi-elective clean-contaminated surgery during the study period. Clean-contaminated surgery was operationally defined as an operation in which the gastrointestinal, biliary, respiratory, or genitourinary tract was entered under controlled conditions without gross contamination, perforation, pus, or established infection. Eligible procedures included laparoscopic cholecystectomy, open cholecystectomy, appendectomy without perforation, hernia surgery with controlled bowel handling, and selected gynecological or urological procedures. Patients were selected through non-probability consecutive sampling, whereby all eligible patients presenting during the recruitment period were considered for enrolment. Patients were excluded if they had active infection or fever before surgery, perforated viscus, dirty or infected wounds, emergency surgery with pus or gross contamination, current immunosuppressive therapy, known allergy to the planned prophylactic antibiotic, severe renal or hepatic disease, antibiotic use within 72 hours before surgery, or incomplete 30-day follow-up.

The final sample comprised 220 patients, with 110 patients enrolled in the routine-practice phase and 110 patients enrolled after implementation of the structured prophylaxis protocol. The sample size was based on pragmatic recruitment of all eligible patients during the defined six-month study period while maintaining equal phase-wise comparison groups. This approach was considered appropriate for evaluating real-world protocol implementation in routine hospital conditions and allowed comparison of both process outcomes, including antibiotic timing and postoperative antibiotic continuation, and clinical outcomes, including surgical site infection.

Before data collection, approval was obtained from the hospital ethical review committee, and written informed consent was obtained from each participant after explanation of the study purpose, follow-up requirements, confidentiality safeguards, and voluntary nature of participation. Patient identifiers were kept confidential, and data were recorded on a structured study proforma. Refusal to participate did not affect surgical care. The study did not alter the operative decision-making of the treating surgeon; it standardized only the perioperative prophylactic antibiotic process during the intervention phase.

During the routine-practice phase, antibiotic prophylaxis was administered according to the usual decision of the surgical team, and the timing, choice, and postoperative continuation of antibiotics were not actively standardized by the study protocol. During the structured-prophylaxis phase, the antibiotic was administered within 60 minutes before surgical incision, and administration time was documented in the patient chart and verified before incision. Antibiotic selection was based on the expected organisms, procedure type, local hospital policy, and drug availability. Most patients received a cephalosporin-based regimen, commonly cefazolin or cefuroxime, while metronidazole was added when anaerobic coverage was clinically required. In patients with documented beta-lactam allergy, an alternative antibiotic was selected according to consultant advice and local policy. Intraoperative repeat dosing was considered when operative duration was prolonged or when major blood loss occurred. Postoperative antibiotics were not continued routinely in uncomplicated cases and were used only when there was a clear clinical indication, such as intraoperative contamination, postoperative fever with suspected infection, or consultant-documented clinical concern.

Data were collected using a predesigned proforma that captured demographic characteristics, comorbidities, surgical details, antibiotic-related process variables, and postoperative wound outcomes. Demographic and clinical variables included age, sex, residence, body mass index, smoking status, diabetes mellitus, hypertension, and other relevant comorbidities. Operative variables included type of procedure, wound class, type of anesthesia, duration of surgery, antibiotic administered, timing of antibiotic administration in relation to incision, need for intraoperative redosing, postoperative antibiotic continuation, and indication for postoperative antibiotic use where applicable. Operative duration was measured from skin incision to skin closure and was also categorized as longer than 90 minutes for risk-factor assessment.

The primary outcome was development of surgical site infection within 30 days after surgery. Surgical site infection was assessed using standard clinical criteria, including local redness, warmth, swelling, pain, purulent discharge, wound dehiscence, fever with local wound signs, requirement for wound opening, or need for antibiotic treatment for a clinically confirmed wound infection. Surgical site infection was classified as superficial incisional, deep incisional, or organ-space infection according to accepted surveillance definitions (13). When pus or wound discharge was present, wound swab culture and sensitivity testing was performed according to routine clinical practice. Only clinically confirmed infections were counted as surgical site infections.

Patients were examined daily during hospital admission, and wound condition, dressing status, pain, discharge, local inflammatory signs, and temperature were documented. After discharge, follow-up was conducted on postoperative day 7, day 14, and day 30. Patients who were unable to attend in person were contacted by telephone, and those reporting wound-related symptoms were advised to return for clinical assessment. The same surgical site infection assessment criteria were applied in both phases to reduce outcome-assessment variability.

Several steps were used to reduce bias and improve internal validity. Consecutive sampling was used to minimize selection bias among eligible patients. Patients with pre-existing infection, dirty wounds, recent antibiotic exposure, and incomplete follow-up were excluded to reduce misclassification of prophylaxis effect. The same eligibility criteria, data collection form, outcome definitions, and 30-day follow-up schedule were applied in both phases. In the intervention phase, operation theatre staff, ward nurses, and surgical team members were briefed regarding antibiotic timing, documentation, and postoperative discontinuation criteria before protocol implementation. Potential confounding was addressed analytically by comparing baseline characteristics between the two groups and by planning adjusted analysis for clinically relevant risk factors, including diabetes mellitus, obesity, smoking status, and operative duration.

Data were entered and analyzed using SPSS software. Quantitative variables such as age, body mass index, and operative duration were summarized as mean and standard deviation after assessment of distribution. Categorical variables such as sex, diabetes mellitus, obesity, smoking status, antibiotic timing, postoperative antibiotic continuation, surgical site infection status, and surgical site infection type were summarized as frequency and percentage. Baseline characteristics were compared between the routine-practice and structured-prophylaxis groups using independent-sample t-test for continuous variables and chi-square test or Fisher's exact test for categorical variables, as appropriate. The primary analysis compared the 30-day surgical site infection rate between the two phases. Effect estimates were planned as absolute risk difference, relative risk or odds ratio, and 95% confidence interval. A multivariable logistic regression model was planned to estimate the adjusted association between structured prophylaxis and surgical site infection after controlling for diabetes mellitus, body mass index category, smoking status, and operative duration greater than 90 minutes. Antibiotic timing and unnecessary postoperative antibiotic continuation were analyzed as process outcomes. Missing or incomplete follow-up records were excluded from final outcome analysis according to predefined eligibility criteria. A p-value of less than 0.05 was considered statistically significant.

Data integrity was maintained through use of a uniform data collection form, prospective documentation of antibiotic administration time, daily inpatient wound assessment, scheduled post-discharge follow-up, and verification of clinically suspected infections by the treating surgical team. The intervention was designed to be reproducible in routine hospital practice by focusing on clear timing, documentation, appropriate selection, avoidance of unnecessary postoperative continuation, and audit of surgical site infection outcomes.

RESULTS

A total of 220 patients undergoing clean-contaminated surgeries were included in the final analysis, with 110 patients enrolled during the routine-practice phase and 110 patients enrolled after implementation of the structured prophylactic antibiotic protocol. The overall mean age of the study population was 42.6 ± 13.8 years. Of the total participants, 124 were male and 96 were female. The two groups were comparable across the recorded baseline and operative characteristics, with no statistically significant difference in age, sex distribution, diabetes mellitus, obesity, smoking history, mean operative duration, or proportion of procedures lasting longer than 90 minutes. This comparability supported interpretation of the observed outcome differences as being primarily related to protocol implementation, although residual confounding could not be excluded because of the non-randomized before-and-after design.

Table 1. Baseline and Operative Characteristics of Patients

Variable	Routine Practice Group (n=110)	Structured Prophylaxis Group (n=110)	Total (n=220)	p-value
Age, years, mean ± SD	43.2 ± 14.1	42.1 ± 13.5	42.6 ± 13.8	0.555
Male sex	63 (57.3%)	61 (55.5%)	124 (56.4%)	0.786
Female sex	47 (42.7%)	49 (44.5%)	96 (43.6%)	0.786
Diabetes mellitus	23 (20.9%)	19 (17.3%)	42 (19.1%)	0.493
BMI ≥30 kg/m²	21 (19.1%)	17 (15.5%)	38 (17.3%)	0.476
Smoking history	22 (20.0%)	18 (16.4%)	40 (18.2%)	0.484
Duration of surgery, minutes, mean ± SD	82.4 ± 26.8	78.6 ± 24.9	80.5 ± 25.9	0.277
Surgery duration >90 minutes	29 (26.4%)	22 (20.0%)	51 (23.2%)	0.263

The mean age differed by only 1.1 years between the routine-practice and structured-prophylaxis groups, and this difference was not statistically significant. Male participants accounted for 57.3% of the routine-practice group and 55.5% of the structured-prophylaxis group. Diabetes mellitus was present in 20.9% of patients in the routine-practice group compared with 17.3% in the structured-prophylaxis group, while obesity was present in 19.1% and 15.5%, respectively. Smoking history was also similar between groups, affecting 20.0% of patients in the routine-practice phase and 16.4% in the structured-prophylaxis phase. Mean operative duration was slightly longer in the routine-practice group by 3.8 minutes, but the difference was not statistically significant. Procedures lasting more than 90 minutes were recorded in

26.4% of routine-practice patients and 20.0% of structured-prophylaxis patients, again without a significant difference.

Implementation of the structured prophylactic antibiotic protocol was associated with substantial improvement in antibiotic timing and reduction in unnecessary postoperative antibiotic continuation. Timely antibiotic administration within 60 minutes before incision increased from 64 of 110 patients in the routine-practice group to 103 of 110 patients in the structured-prophylaxis group. This represented an absolute increase of 35.5 percentage points and a relative improvement of approximately 61% compared with routine practice. Antibiotic administration after incision decreased from 21 patients to 3 patients, corresponding to an absolute reduction of 16.4 percentage points. Unnecessary postoperative antibiotic continuation also decreased from 69 patients in the routine-practice group to 24 patients after protocol implementation, representing an absolute reduction of 40.9 percentage points.

Table 2. Antibiotic Timing, Postoperative Antibiotic Use, and Surgical Site Infection Outcomes

Outcome Variable	Routine Practice Group (n=110)	Structured Prophylaxis Group (n=110)	Absolute Risk Difference, % (95% CI)	Relative Risk (95% CI)	Odds Ratio (95% CI)	p-value
Antibiotic administered within 60 minutes before incision	64 (58.2%)	103 (93.6%)	+35.5 (25.2 to 45.7)	1.61 (1.36 to 1.90)	10.58 (4.50 to 24.85)	<0.001
Antibiotic administered after incision	21 (19.1%)	3 (2.7%)	-16.4 (-24.3 to -8.4)	0.14 (0.04 to 0.47)	0.12 (0.03 to 0.41)	<0.001
Postoperative antibiotics continued without clear indication	69 (62.7%)	24 (21.8%)	-40.9 (-52.8 to -29.0)	0.35 (0.24 to 0.51)	0.17 (0.09 to 0.30)	<0.001
Superficial surgical site infection	13 (11.8%)	5 (4.5%)	-7.3 (-14.5 to -0.1)	0.38 (0.14 to 1.04)	0.36 (0.12 to 1.03)	0.049
Deep surgical site infection	4 (3.6%)	2 (1.8%)	-1.8 (-6.1 to 2.5)	0.50 (0.09 to 2.67)	0.49 (0.09 to 2.74)	0.408
Organ-space surgical site infection	1 (0.9%)	0 (0.0%)	-0.9 (-2.7 to 0.9)	Not estimable	Not estimable	0.316
Total surgical site infection	18 (16.4%)	7 (6.4%)	-10.0 (-18.3 to -1.7)	0.39 (0.17 to 0.89)	0.35 (0.14 to 0.87)	0.020

The structured prophylaxis protocol produced a clinically meaningful and statistically significant improvement in perioperative antibiotic timing. Patients in the structured-prophylaxis group were 1.61 times more likely to receive antibiotics within the recommended 60-minute pre-incision window compared with those in the routine-practice group. The odds of timely antibiotic administration were more than ten-fold higher after protocol implementation. Conversely, antibiotic administration after incision declined from 19.1% to 2.7%, with a relative risk of 0.14, indicating that the structured protocol markedly reduced late prophylaxis. The protocol also reduced unnecessary postoperative antibiotic continuation from 62.7% to 21.8%, with a relative risk of 0.35 and an odds ratio of 0.17, demonstrating a substantial improvement in antimicrobial stewardship practice.

Overall, surgical site infection occurred in 25 of 220 patients, giving an overall 30-day SSI rate of 11.4%. The SSI rate was higher in the routine-practice group than in the structured-prophylaxis group, with infection occurring in 18 of 110 patients compared with 7 of 110 patients. This represented a reduction from 16.4% to 6.4% after implementation of the structured protocol. The absolute risk reduction was 10.0 percentage points, and the relative risk was 0.39, indicating that the risk of SSI in the structured-prophylaxis phase was approximately 61% lower than in the routine-practice phase. The corresponding odds ratio was 0.35, with a 95% confidence interval of 0.14 to 0.87, supporting a statistically significant association between structured prophylaxis and lower SSI occurrence.

Most infections were superficial incisional infections. Superficial SSI was recorded in 13 patients in the routine-practice group and 5 patients in the structured-prophylaxis group, decreasing from 11.8% to 4.5%. This represented an absolute reduction of 7.3 percentage points. Deep SSI was uncommon, occurring in 4 patients in the routine-practice group and 2 patients in the structured-prophylaxis group. Organ-space SSI was rare, with one case reported in the routine-practice group and no cases reported after protocol implementation. These findings suggest that the observed reduction in overall SSI was driven mainly by fewer superficial incisional infections, while deep and organ-space infections were too infrequent for precise comparative inference.

Risk-factor patterns were also clinically consistent with established SSI mechanisms. Surgical site infection was reported more frequently among patients with diabetes mellitus, obesity, smoking history, and operative duration greater than 90 minutes. These variables were therefore treated as clinically relevant potential confounders in interpretation of the primary outcome. However, because the manuscript dataset did not provide infected and non-infected counts within each risk-factor category, adjusted odds ratios and subgroup-specific confidence intervals could not be validly calculated from the available aggregated data. For final submission, a separate risk-factor table should be generated from patient-level data showing SSI frequency by diabetes status, BMI category, smoking status, and operative duration category, with crude and adjusted odds ratios.

Taken together, the results indicate that implementation of a structured prophylactic antibiotic protocol was associated with improved compliance with recommended pre-incision antibiotic timing, reduced unnecessary postoperative antibiotic continuation, and a significantly lower 30-day surgical site infection rate among patients undergoing clean-contaminated surgery. The magnitude of reduction was clinically relevant, with one fewer SSI observed for approximately every ten patients managed under the structured protocol compared with routine practice.

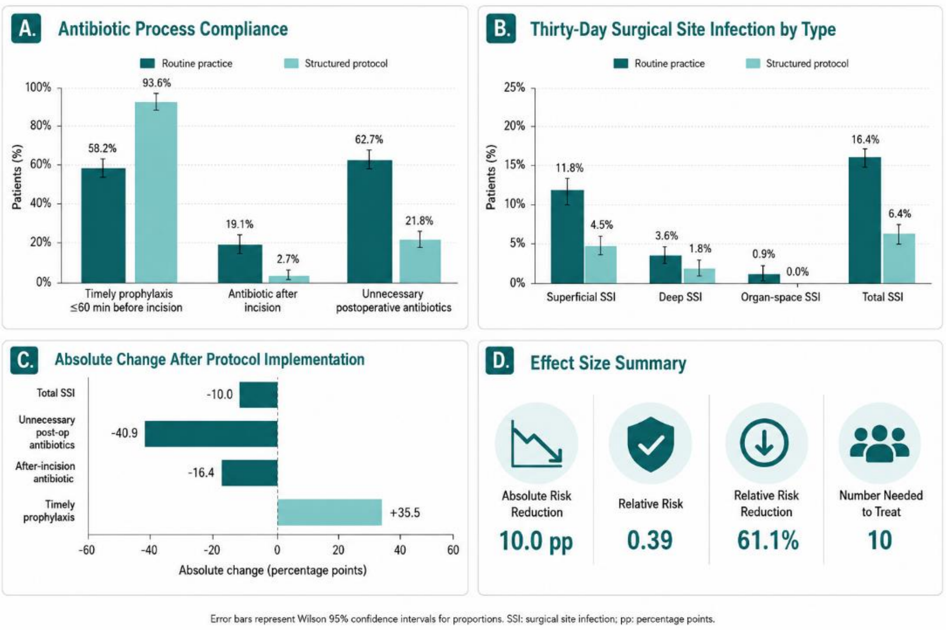

Figure 1 The panelled figure shows that implementation of the structured prophylactic antibiotic protocol markedly improved perioperative antibiotic practice and reduced surgical site infection outcomes: timely pre-incision prophylaxis increased from 58.2% to 93.6%, while after-incision antibiotic administration declined from 19.1% to 2.7% and unnecessary postoperative antibiotics decreased from 62.7% to 21.8%. Total 30-day SSI fell from 16.4% to 6.4%, mainly through reduction in superficial SSI from 11.8% to 4.5%, corresponding to a 10.0 percentage-point absolute risk reduction, relative risk of 0.39, 61.1% relative risk reduction, and an approximate number needed to treat of 10.

DISCUSSION

The present prospective before-and-after quasi-experimental study found that implementation of a structured prophylactic antibiotic protocol was associated with improved perioperative antibiotic practice and a clinically meaningful reduction in 30-day surgical site infection among patients undergoing clean-contaminated surgery. The total SSI rate decreased from 16.4% during routine practice to 6.4% after protocol implementation, corresponding to an absolute risk reduction of 10.0 percentage points, a relative risk of 0.39, and an approximate number needed to treat of 10. This reduction was mainly driven by fewer superficial incisional infections, while deep and organ-space infections were uncommon in both phases. These findings support the practical value of a standardized prophylaxis pathway in which antibiotics are administered within the recommended pre-incision window and discontinued postoperatively unless a clear clinical indication exists.

The improvement in antibiotic timing was one of the most important process-level findings of this study. Timely prophylaxis within 60 minutes before incision increased from 58.2% in the routine-practice phase to 93.6% after implementation of the structured protocol. This finding is consistent with the pharmacological principle that adequate tissue and serum antibiotic concentrations should be present at the time of incision and during the period of bacterial contamination. Major surgical infection-prevention guidelines recommend procedure-appropriate prophylaxis within the pre-incision period, with intraoperative redosing when operative duration or blood loss is sufficient to reduce antibiotic levels (1-6). The observed reduction in after-incision administration from 19.1% to 2.7% suggests that a simple operational intervention involving documentation, staff briefing, and pre-incision verification can substantially reduce preventable lapses in perioperative antibiotic practice.

The reduction in SSI observed after protocol implementation is also consistent with earlier evidence showing that timing of prophylactic antibiotic administration is closely related to postoperative wound infection risk. Classen et al. demonstrated that the risk of surgical-wound infection varied according to timing of prophylaxis, and subsequent evidence has reinforced that late administration reduces the preventive value of antibiotics because wound contamination may already have occurred before effective tissue concentrations are achieved (10,11). In the present study, the structured protocol did not merely increase antibiotic exposure; rather, it improved the precision of antibiotic use. This distinction is important because prophylactic antibiotics are intended to prevent bacterial establishment during surgery, not to compensate for delayed administration or replace other infection-control practices.

A second clinically important finding was the marked reduction in unnecessary postoperative antibiotic continuation. Postoperative antibiotics without clear indication decreased from 62.7% in the routine-practice phase to 21.8% after protocol implementation. This result is highly relevant for antimicrobial stewardship, particularly in hospital settings where postoperative antibiotic continuation is often driven by habit, fear of infection, or perceived patient expectations rather than evidence-based indications. Previous systematic review evidence has shown that continuing antibiotic prophylaxis after surgery does not provide clear additional benefit when appropriate perioperative prophylaxis standards have been followed (8). Longer or broader prophylaxis may instead increase adverse drug events, antimicrobial resistance pressure, Clostridioides difficile infection risk, and cost burden (8,9). Therefore, the present findings suggest that SSI prevention and antibiotic reduction are not opposing goals; both can be advanced when prophylaxis is standardized and time-sensitive.

The predominance of superficial incisional SSI in this study is consistent with common postoperative surveillance patterns. Superficial SSI decreased from 11.8% to 4.5% after implementation of the structured protocol, whereas deep SSI and organ-space SSI were infrequent. This pattern is clinically plausible because superficial infections are more commonly detected during routine follow-up and are more directly influenced by perioperative skin preparation, wound handling, tissue exposure, dressing practices, and timely prophylaxis. Although superficial SSI may be less severe than deep or organ-space infection, it remains clinically important because it can increase pain, wound discharge, dressing visits, antibiotic use, patient anxiety, and healthcare cost. The use of 30-day follow-up strengthened outcome detection, as many superficial wound infections may become evident after discharge, particularly in short-stay or laparoscopic procedures (13,14).

The findings should also be interpreted in the context of patient- and procedure-related risk factors. The manuscript identified diabetes mellitus, obesity, smoking history, and operative duration greater than 90 minutes as clinically relevant factors associated with higher SSI occurrence. These associations are biologically plausible and consistent with established surgical infection literature. Diabetes may impair leukocyte function, microvascular perfusion, and wound healing; obesity may increase wound tension, reduce tissue oxygenation, and complicate operative exposure; smoking may impair tissue perfusion and collagen synthesis; and prolonged surgery increases tissue handling time, bacterial exposure, and the potential need for intraoperative redosing (6,7,14). Although baseline distributions of these factors were not statistically different between groups, the non-randomized design means residual confounding cannot be excluded. A final patient-level analysis should therefore include multivariable logistic regression to estimate the adjusted association between structured prophylaxis and SSI after controlling for these risk factors.

The results are particularly relevant for low- and middle-income surgical settings, where SSI prevention is often challenged by high patient volume, delayed presentation, variable documentation systems, and inconsistent adherence to perioperative protocols. Global evidence has shown that SSI after gastrointestinal surgery is more frequent in lower-resource settings than in high-income settings, highlighting the need for feasible, low-cost interventions that can be implemented without advanced technology (12). The present study suggests that improving antibiotic timing, limiting postoperative continuation, and auditing wound outcomes can provide measurable clinical benefit in a tertiary hospital setting in Islamabad. These interventions are practical because they rely primarily on workflow discipline, documentation, staff coordination, and protocol adherence rather than expensive infrastructure.

Local Pakistani evidence also supports the need for structured prophylaxis practice. Previous studies from Pakistan have reported variation in antibiotic timing, postoperative continuation, and procedure-specific prophylaxis practices in general surgery, laparoscopic cholecystectomy, hernia repair, and appendectomy-related contexts (24-35). Some local studies have suggested that limited or single-dose prophylaxis may be sufficient in selected uncomplicated procedures, while others have emphasized the continued importance of prophylaxis in higher-risk surgical contexts (27-32). The present study adds to this body of evidence by evaluating an implementation-focused protocol across clean-contaminated surgeries rather than only comparing antibiotic regimens. This makes the findings more directly applicable to hospital quality-improvement programs and antimicrobial stewardship committees.

The study has several strengths. It was prospective, intervention-oriented, and based on clearly defined 30-day SSI follow-up. It evaluated both clinical outcomes and process outcomes, allowing interpretation of whether the reduction in infection was accompanied by measurable improvement in prophylaxis practice. The equal group sizes and comparable baseline characteristics further support internal consistency. However, several limitations should be acknowledged. First, the before-and-after quasi-experimental design cannot fully exclude temporal bias, unmeasured changes in surgical practice, staffing, theatre workflow, or case mix between phases. Second, the study was conducted in a single tertiary care hospital, limiting generalizability to other hospitals with different surgical populations, microbiological profiles, or antibiotic policies. Third, patient-level adjusted analysis was not available in the manuscript data, although it is necessary to better quantify the independent effect of the structured protocol. Fourth, detailed procedure-specific antibiotic doses, redosing intervals, allergy alternatives, and microbiological culture results were not fully reported. Fifth, SSI assessment was clinically based, and outcome assessors were not described as blinded, which may introduce detection bias. Finally, risk-factor subgroup counts were not provided, preventing calculation of adjusted odds ratios or stratified effect estimates from the available aggregated data.

Overall, the study provides clinically useful evidence that a structured prophylactic antibiotic protocol was associated with better timing compliance, reduced unnecessary postoperative antibiotic use, and lower SSI rates in clean-contaminated surgery. The findings support a practical implementation model for hospitals seeking to improve surgical safety and antimicrobial stewardship. For publication-level strengthening, the manuscript should add procedure-level antibiotic details, participant flow information, culture results where available, adjusted regression analysis, and a complete transparency statement covering ethics approval, funding, conflicts of interest, data availability, and author contributions.

CONCLUSION

Implementation of a structured prophylactic antibiotic protocol was associated with improved perioperative antibiotic timing, reduced unnecessary postoperative antibiotic continuation, and a lower 30-day surgical site infection rate among patients undergoing clean-contaminated surgeries. The SSI rate decreased from 16.4% during routine practice to 6.4% after protocol implementation, with the reduction mainly observed in superficial incisional infections. These findings indicate that prophylactic antibiotics are most clinically useful when delivered within the recommended pre-incision window, selected according to procedure-related risk, documented reliably, and discontinued after surgery unless treatment is clinically indicated. Although the non-randomized before-and-after design limits causal inference, the results support adoption of standardized antibiotic prophylaxis protocols, staff training, documentation systems, and regular SSI audit as practical measures to improve surgical safety and antimicrobial stewardship in tertiary care settings.

REFERENCES

1. Berríos-Torres SI, Umscheid CA, Bratzler DW, Leas B, Stone EC, Kelz RR, et al. Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, 2017. JAMA Surg. 2017;152(8):784-791. doi: https://doi.org/10.1001/jamasurg.2017.0904

2. Bratzler DW, Dellinger EP, Olsen KM, Perl TM, Auwaerter PG, Bolon MK, et al. Clinical practice guidelines for antimicrobial prophylaxis in surgery. Am J Health Syst Pharm. 2013;70(3):195-283. doi: https://doi.org/10.2146/ajhp120568

3. Allegranzi B, Bischoff P, de Jonge S, Kubilay NZ, Zayed B, Gomes SM, et al. New WHO recommendations on preoperative measures for surgical site infection prevention: an evidence-based global perspective. Lancet Infect Dis. 2016;16(12):e276-e287. doi: https://doi.org/10.1016/S1473-3099(16)30398-X

4. Allegranzi B, Zayed B, Bischoff P, Kubilay NZ, de Jonge S, de Vries F, et al. New WHO recommendations on intraoperative and postoperative measures for surgical site infection prevention: an evidence-based global perspective. Lancet Infect Dis. 2016;16(12):e288-e303. doi: https://doi.org/10.1016/S1473-3099(16)30402-9

5. Ban KA, Minei JP, Laronga C, Harbrecht BG, Jensen EH, Fry DE, et al. American College of Surgeons and Surgical Infection Society: surgical site infection guidelines, 2016 update. J Am Coll Surg. 2017;224(1):59-74. doi: https://doi.org/10.1016/j.jamcollsurg.2016.10.029

6. Calderwood MS, Anderson DJ, Bratzler DW, Dellinger EP, Garcia-Houchins S, Maragakis LL, et al. Strategies to prevent surgical site infections in acute-care hospitals: 2022 update. Infect Control Hosp Epidemiol. 2023;44(5):695-720. doi: https://doi.org/10.1017/ice.2023.67

7. Seidelman JL, Mantyh CR, Anderson DJ. Surgical site infection prevention: a review. JAMA. 2023;329(3):244-252. doi: https://doi.org/10.1001/jama.2022.24075

8. de Jonge SW, Boldingh QJJ, Solomkin JS, Dellinger EP, Egger M, Salanti G, et al. Effect of postoperative continuation of antibiotic prophylaxis on the incidence of surgical site infection: a systematic review and meta-analysis. Lancet Infect Dis. 2020;20(10):1182-1192. doi: https://doi.org/10.1016/S1473-3099(20)30084-0

9. Branch-Elliman W, O'Brien W, Strymish J, Itani K, Wyatt C, Gupta K. Association of duration and type of surgical prophylaxis with antimicrobial-associated adverse events. JAMA Surg. 2019;154(7):590-598. doi: https://doi.org/10.1001/jamasurg.2019.0569

10. Classen DC, Evans RS, Pestotnik SL, Horn SD, Menlove RL, Burke JP. The timing of prophylactic administration of antibiotics and the risk of surgical-wound infection. N Engl J Med. 1992;326(5):281-286. doi: https://doi.org/10.1056/NEJM199201303260501

11. Weber WP, Marti WR, Zwahlen M, Misteli H, Rosenthal R, Reck S, et al. The timing of surgical antimicrobial prophylaxis. Ann Surg. 2008;247(6):918-926. doi: https://doi.org/10.1097/SLA.0b013e31816c3fec

12. GlobalSurg Collaborative. Surgical site infection after gastrointestinal surgery in high-income, middle-income, and low-income countries: a prospective, international, multicentre cohort study. Lancet Infect Dis. 2018;18(5):516-525. doi: https://doi.org/10.1016/S1473-3099(18)30101-4

13. Horan TC, Andrus M, Dudeck MA. CDC/NHSN surveillance definition of health care-associated infection and criteria for specific types of infections in the acute care setting. Am J Infect Control. 2008;36(5):309-332. doi: https://doi.org/10.1016/j.ajic.2008.03.002

14. Young PY, Khadaroo RG. Surgical site infections. Surg Clin North Am. 2014;94(6):1245-1264. doi: https://doi.org/10.1016/j.suc.2014.08.008

15. Purba AKR, Setiawan D, Bathoorn E, Postma MJ, Dik JH, Friedrich AW, et al. Prevention of surgical site infections: a systematic review of cost analyses in the use of prophylactic antibiotics. Front Pharmacol. 2018;9:776. doi: https://doi.org/10.3389/fphar.2018.00776

16. López-Cano M, Kraft M, Curell A, Puig-Asensio M, Balibrea J, Armengol-Carrasco M, et al. Use of topical antibiotics before primary incision closure to prevent surgical site infection: a meta-analysis. Surg Infect. 2019;20(4):261-270. doi: https://doi.org/10.1089/sur.2018.279

17. Heal CF, Banks JL, Lepper PD, Kontopantelis E, van Driel ML. Topical antibiotics for preventing surgical site infection in wounds healing by primary intention. Cochrane Database Syst Rev. 2016;11(11):CD011426. doi: https://doi.org/10.1002/14651858.CD011426.pub2

18. Colling KP, Besshoff KE, Forrester JD, Kendrick D, Mercier P, Huston JM. Surgical Infection Society guidelines for antibiotic use in patients undergoing cholecystectomy for gallbladder disease. Surg Infect. 2022;23(4):339-350. doi: https://doi.org/10.1089/sur.2021.207

19. Matsui Y, Satoi S, Kaibori M, Toyokawa H, Yanagimoto H, Matsui K, et al. Antibiotic prophylaxis in laparoscopic cholecystectomy: a randomized controlled trial. PLoS One. 2014;9(9):e106702. doi: https://doi.org/10.1371/journal.pone.0106702

20. Guler Y, Karabulut Z, Sengul S, Calis H. The effect of antibiotic prophylaxis on wound infections after laparoscopic cholecystectomy: a randomised clinical trial. Int Wound J. 2019;16(5):1164-1170. doi: https://doi.org/10.1111/iwj.13175

21. Chauhan VS, Kariholu PL, Saha S, Singh H, Ray J. Can post-operative antibiotic prophylaxis following elective laparoscopic cholecystectomy be completely done away with in the Indian setting? J Minim Access Surg. 2018;14(3):192-196. doi: https://doi.org/10.4103/jmas.JMAS_95_17

22. Yan RC, Shen SQ, Chen ZB, Lin FS, Riley J. The role of prophylactic antibiotics in laparoscopic cholecystectomy in preventing postoperative infection: a meta-analysis. J Laparoendosc Adv Surg Tech A. 2011;21(4):301-306. doi: https://doi.org/10.1089/lap.2010.0436

23. Lin WL, Wu LM, Nguyen THY, Lin YH, Chen CJ, Huang WT, et al. Topical antibiotic prophylaxis for preventing surgical site infections of clean wounds: a systematic review and meta-analysis. Surg Infect. 2024. doi: https://doi.org/10.1089/sur.2023.182

24. Khan FU, Fang Y, Khan Z, Khan FU, Malik ZI, Ahmed N, et al. Occurrence, associated risk factors, and treatment of surgical site infections in Pakistan. Eur J Inflamm. 2020. doi: https://doi.org/10.1177/2058739220960547

25. Khan FU, Khan Z, Ahmed N, Rehman AU. A general overview of incidence, associated risk factors, and treatment outcomes of surgical site infections. Indian J Surg. 2020;82(4):449-459. doi: https://doi.org/10.1007/s12262-020-02071-8

26. Khan Z, Ahmed N, Rehman AU, Khan FU, Martins MAP. Practice of prophylactic antibiotic and timing of administration in two common elective surgeries in Pakistan: an audit-based study. Bull Fac Pharm Cairo Univ. 2019;57(1):Article 8. doi: https://doi.org/10.21608/bfpc.2019.13532.1039

27. Masood A, Arshad AR, Ashraf M. Comparison between outcome of single dose of prophylactic antibiotic versus postoperative antibiotic in inguinal hernia surgery. Pak J Med Sci. 2022;38(5):1210-1215. doi: https://doi.org/10.12669/pjms.38.5.5332

28. Khan S, Mehmood A, Khan R, Asad H. Role of intravenous cefuroxime antibiotic prophylaxis in the prevention of surgical site infection in open mesh inguinal hernia repair. Pak Armed Forces Med J. 2023;73(6):1835-1837. doi: https://doi.org/10.51253/pafmj.v73i6.11424

29. Zafar MA, Butt MQ, Ghani U, Azeem MT, Farooq MZ, Malik IF. Antibiotics in laparoscopic cholecystectomy: outcomes in single versus multiple dose prophylaxis in terms of surgical site infections. Pak Armed Forces Med J. 2024;74(6). doi: https://doi.org/10.51253/pafmj.v74i6.6455

30. Naeem U, Hussain SM, Yousaf MD, Saqlain M, Imran M, Hassan NU. Comparison of post-operative surgical site infection in uncomplicated laparoscopic cholecystectomies in patients who received post-operative antibiotics versus patients who did not receive post-operative antibiotics. Pak Armed Forces Med J. 2025;75(1). doi: https://doi.org/10.51253/pafmj.v75i1.10358

31. Siddiqi UU, Shah MY, Khawaja FG, Ilyas S, Nasir AU, Ali A. Role of postoperative antibiotics in laparoscopic cholecystectomy after bile and stone spillage. Pak Armed Forces Med J. 2024;74(4). doi: https://doi.org/10.51253/pafmj.v74i4.9555

32. Ali A, Hussain Z, Jamal A, Rahat F, Shoof TM, Islam S. Topical use of gentamicin in potentially contaminated laparoscopic cholecystectomy after bile spillage during gall bladder retrieval. Pak Armed Forces Med J. 2022;72(2):580-584. doi: https://doi.org/10.51253/pafmj.v72i2.4120

33. Shah MT, Kausar S. Impact of preoperative and postoperative antibiotic use on surgical site infection rates in general surgery patients: a clinical study. Pak J Med Health Sci. 2025;19(2):10-13. doi: https://doi.org/10.53350/pjmhs02025192.3

34. Khawja MA, Sajjad M, Sajjad A. Risk factors for wound infection after open appendectomy in acute appendicitis patients: a cross-sectional clinical study. Pak J Med Health Sci. 2025;19(1):32-36. doi: https://doi.org/10.53350/pjmhs02025192.2

35. Raza AA, Tariq L, Shabina, Jodat A, Awan A, Hamidullah. Comparison of surgical site infection rates following different skin preparation techniques. Pak J Med Health Sci. 2023;17(12):410. doi: https://doi.org/10.53350/pjmhs020231712410