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A COMPARATIVE STUDY ON THE ROLE OF VANCOMYCIN IN INFECTION PREVENTION DURING SPINAL FIXATION SURGERIES: A SYSTEMATIC REVIEW

Systematic Review

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ABSTRACT

Background: Surgical site infections (SSIs) remain among the most serious complications following spinal fixation surgeries, contributing to increased morbidity, prolonged hospitalization, repeated surgical interventions, and substantial healthcare costs. Implant-associated infections are particularly challenging due to biofilm formation and the predominance of Gram-positive organisms, especially *Staphylococcus aureus* and methicillin-resistant *Staphylococcus aureus* (MRSA). Vancomycin, a glycopeptide antibiotic with potent Gram-positive coverage, has gained attention as an adjunct prophylactic strategy, particularly in intrawound form.

Objective: To evaluate the efficacy and safety of systemic and intrawound vancomycin in preventing SSIs in spinal fixation and instrumentation surgeries.

Methods: A systematic search of PubMed, Scopus, Web of Science, and Google Scholar was conducted from database inception to the latest available year. Eligible studies included randomized controlled trials, cohort studies, and meta-analyses assessing vancomycin prophylaxis in spinal instrumentation. Primary outcomes included overall SSI rates, deep and superficial infections, and pathogen distribution. Secondary outcomes included adverse effects and subgroup analyses in trauma and high-risk populations. Data were narratively synthesized due to heterogeneity in study design and dosing protocols.

Results: Twenty-seven studies comprising more than 30,000 patients were included. Intrawound vancomycin (1–2 g) reduced SSI rates from 13–20% in control groups to 0–5% in treated cohorts in several randomized and retrospective studies. Large thoracolumbar fusion cohorts reported infection rates of 0.2% versus 2.6% with adjunctive vancomycin. Meta-analyses demonstrated pooled odds ratios approximating 0.31, indicating significant reduction in postoperative infections. Protective effects were most pronounced in trauma patients, individuals with diabetes or obesity, and institutions with high MRSA prevalence. Reported systemic toxicity was minimal, with no consistent increase in nephrotoxicity. Occasional sterile seromas were noted. Some studies observed a proportional rise in Gram-negative infections.

Conclusion: Intrawound vancomycin appeared to be an effective adjunct to standard systemic prophylaxis in high-risk spinal fixation surgeries, particularly against Gram-positive pathogens including MRSA. A selective, risk-based approach was supported, while further multicenter randomized trials with standardized protocols and long-term resistance monitoring remain essential.

Keywords: Anti-Bacterial Agents, Anti-Infective Agents, Local; Orthopedic Procedures, Surgical Wound Infection, Spinal Fusion, Staphylococcus aureus; Vancomycin.

INTRODUCTION

Spinal fixation surgery has become a cornerstone in the management of diverse spinal pathologies, including traumatic injuries, degenerative disorders, spinal deformities, and neoplastic conditions. These procedures commonly involve the implantation of metallic hardware—such as rods, screws, and plates—to restore spinal stability and structural alignment (1). Over the past decades, advances in surgical techniques, instrumentation design, and perioperative care have significantly improved operative outcomes. Nevertheless, surgical site infections (SSIs) remain among the most serious and challenging complications following spinal instrumentation. These infections are associated with substantial patient morbidity, prolonged hospitalization, repeated surgical interventions, and increased healthcare expenditure, thereby posing a considerable burden on both patients and healthcare systems (2). The reported incidence of postoperative infections after spinal surgery varies widely, ranging from approximately 0.5% to 12%, depending on patient-related factors, procedural complexity, and institutional infection-control practices (3). The presence of implanted hardware further complicates infection management. Bacterial adhesion to metallic surfaces facilitates biofilm formation, a structured microbial community that confers protection against host immune responses and systemic antibiotic therapy (4). Once established, implant-associated infections often necessitate prolonged antimicrobial therapy, revision procedures, and, in severe cases, removal of instrumentation—compromising spinal stability and adversely affecting long-term functional outcomes (5). Such consequences underscore the critical importance of optimizing preventive strategies in spinal fixation surgery. Gram-positive organisms, particularly *Staphylococcus aureus* and *Staphylococcus epidermidis*, account for the majority of spinal SSIs (6). The rising prevalence of methicillin-resistant *Staphylococcus aureus* (MRSA) has further complicated prophylactic approaches, as conventional β-lactam antibiotics may be inadequate in high-risk settings. This evolving antimicrobial resistance landscape has intensified interest in more targeted and effective prophylactic regimens to reduce postoperative infection rates. Vancomycin, a glycopeptide antibiotic with potent activity against Gram-positive organisms including MRSA, has emerged as a key agent in this context. Traditionally administered intravenously as part of perioperative prophylaxis, vancomycin is increasingly being applied locally in powdered form directly into the surgical wound prior to closure (7,8).

This strategy aims to achieve high local antibiotic concentrations at the surgical site while minimizing systemic exposure and toxicity (9). Experimental and clinical studies suggest that intrawound vancomycin may inhibit early bacterial colonization of implants, disrupt biofilm formation, and reduce postoperative infection rates without significantly altering systemic microbial flora. Despite promising findings, concerns persist regarding the routine use of vancomycin in spinal fixation procedures. Potential adverse effects include impaired wound healing, nephrotoxicity when administered systemically, and the theoretical risk of promoting antimicrobial resistance or shifting infection patterns toward Gram-negative or vancomycin-resistant organisms (10). Moreover, heterogeneity across studies—with variations in dosing regimens, routes of administration, surgical techniques, and patient populations—has resulted in inconsistent conclusions regarding its overall efficacy and safety (11). While some investigators advocate for routine adjunctive use of vancomycin in high-risk cases, others caution against widespread implementation in the absence of standardized guidelines and robust long-term safety data. Given the clinical and economic implications of SSIs in spinal instrumentation, a comprehensive and critical appraisal of available evidence is warranted. Clarifying whether vancomycin—administered systemically, locally, or in combination—provides superior prophylactic benefit compared with conventional regimens is essential for evidence-based surgical practice. Furthermore, understanding its effectiveness against predominant pathogens, particularly MRSA, and evaluating its safety profile are crucial in balancing infection prevention with antimicrobial stewardship principles (12). Accordingly, this review seeks to address the following research question: Does vancomycin, administered systemically or locally, effectively and safely reduce surgical site infections in spinal fixation surgeries compared with standard prophylactic antibiotics? The objective of this review is to critically evaluate and compare existing evidence on the efficacy and safety of vancomycin in spinal instrumentation procedures, examine its impact across different patient risk profiles and surgical contexts, and identify current gaps in the literature to inform future research and optimize antibiotic prophylaxis strategies in spinal surgery.

METHODS

An inductive narrative literature review was conducted to critically evaluate existing evidence regarding the prophylactic use of vancomycin in spinal fixation and spinal instrumentation surgeries. A comprehensive and systematic search of electronic databases,

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including PubMed, Scopus, Web of Science, and Google Scholar, was performed from database inception to the most recent available year to ensure contemporary relevance (5). The search strategy incorporated both Medical Subject Headings (MeSH) and free-text keywords, including "vancomycin," "spinal fixation surgery," "spinal instrumentation," "surgical site infection," "infection prevention," and "antibiotic prophylaxis." Boolean operators (AND, OR) were applied to refine search combinations and enhance retrieval sensitivity and specificity (13). Reference lists of included studies were also manually screened to identify additional relevant publications. Eligibility criteria were predefined to enhance methodological transparency. Studies were included if they were randomized controlled trials, prospective or retrospective cohort studies, case–control studies, or systematic reviews evaluating the prophylactic use of vancomycin—administered either intravenously or locally as intrawound powder—in patients undergoing spinal fixation or instrumentation procedures. The population of interest comprised patients of any age or gender undergoing spinal instrumentation for traumatic, degenerative, deformity-related, or neoplastic spinal conditions. Studies were required to report clearly defined postoperative infection outcomes, including overall surgical site infection rates, deep or superficial infections, or implant-associated infections. Where applicable, reported adverse outcomes such as nephrotoxicity, impaired wound healing, antimicrobial resistance patterns, or shifts in microbial flora were also extracted. Studies were excluded if they focused exclusively on non-spinal orthopedic procedures, involved animal models, were limited to case reports or small case series without comparative data, or evaluated antibiotics unrelated to vancomycin prophylaxis (14). Articles lacking clearly defined infection-related outcome measures or insufficient methodological detail were also excluded. Non-English language publications, conference abstracts without full texts, unpublished data, and grey literature were excluded to maintain consistency in data quality and interpretability.

All identified citations were exported into reference management software (EndNote, Clarivate Analytics) to facilitate systematic organization and removal of duplicate records. Following deduplication, titles and abstracts were screened independently by two reviewers to assess relevance against predefined inclusion criteria. Discrepancies were resolved through discussion and consensus. Potentially eligible studies underwent full-text review to confirm eligibility. The study selection process was documented using a PRISMA flow diagram to ensure transparency and reproducibility in reporting. Data extraction was performed using a standardized data collection form. Extracted variables included study design, sample size, patient demographics, indication for surgery, type of spinal procedure, route and dosage of vancomycin administration, comparator antibiotic regimens, duration of follow-up, reported infection rates, and documented adverse events (15). Methodological quality and risk of bias were assessed according to study design. Randomized controlled trials were appraised using established risk-of-bias domains, including allocation concealment, blinding, and completeness of outcome reporting. Observational studies were evaluated for selection bias, confounding, and clarity of outcome definition. The rigor of methodology, transparency in reporting, and consistency of outcome measures were considered in assessing overall study quality (7). Given the anticipated heterogeneity in study designs, dosing regimens, surgical techniques, and patient populations, a quantitative meta-analysis was not uniformly feasible. Therefore, findings were synthesized narratively and comparatively, with emphasis placed on infection reduction efficacy, safety outcomes, and contextual factors influencing clinical applicability. This structured methodological approach aimed to provide a comprehensive and balanced appraisal of the current evidence base regarding the role of vancomycin in preventing surgical site infections in spinal fixation surgeries.

Effectiveness of Vancomycin in Reducing Surgical Site Infections

Across randomized controlled trials and large retrospective cohorts, intrawound vancomycin was consistently associated with reduced SSI rates. In thoracolumbar instrumentation procedures, SSI incidence decreased from 20.5% in control groups to 5.2% in patients receiving intrawound vancomycin. Similarly, posterior stabilization studies reported reductions from 13% to 0% in trauma populations. Large-scale analyses of instrumented thoracolumbar fusions demonstrated infection rates of 0.2% with vancomycin compared to 2.6% with systemic prophylaxis alone. Meta-analytic pooling of 27 studies (n=17,321) yielded a combined odds ratio of approximately 0.31, indicating a statistically significant reduction in postoperative infections favoring vancomycin prophylaxis. These findings collectively support a protective effect, particularly in implant-based procedures where biofilm formation risk is elevated.

Comparative Efficacy with Standard Antibiotic Prophylaxis

Comparative analyses demonstrated that adjunctive intrawound vancomycin, when added to standard systemic prophylaxis, resulted in lower infection rates than systemic antibiotics alone. While first-generation cephalosporins reduced bacteremia and early contamination, intrawound vancomycin provided higher localized concentrations at implant interfaces. In most comparative cohorts, combination prophylaxis was associated with statistically significant reductions in SSI incidence. However, certain elective low-risk populations

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showed minimal incremental benefit, and heterogeneity in surgical complexity and patient comorbidity contributed to variability in effect magnitude.

Spectrum of Pathogens and Targeted Protection

The microbiological profile across studies consistently identified Gram-positive cocci—particularly *Staphylococcus aureus* and *Staphylococcus epidermidis*—as predominant pathogens. Vancomycin prophylaxis significantly reduced rates of MRSA-related infections in institutions with elevated baseline prevalence. Meta-analytic data confirmed a marked decline in Gram-positive and MRSA infections among vancomycin-treated groups. Nevertheless, a few studies reported a relative proportional increase in Gram-negative infections, although absolute rates remained low. These findings suggested a targeted protective effect primarily against staphylococcal pathogens.

Safety Profile and Adverse Effects

Most studies reported favorable safety outcomes with intrawound vancomycin. Serum vancomycin levels following topical application remained below nephrotoxic thresholds, and no consistent association with renal dysfunction was observed. Isolated cases of sterile seroma formation, delayed wound healing, or local irritation were documented but occurred infrequently. No statistically significant increase in wound dehiscence or systemic toxicity was reported. However, concerns regarding antimicrobial resistance patterns were raised, particularly in contexts of widespread prophylactic use, underscoring the need for continued microbiological surveillance.

Dose-Dependent Effects and Method of Administration

Dosing strategies varied between 1 g and 2 g of vancomycin powder applied directly to the surgical wound prior to closure. While higher doses appeared to achieve stronger local antibacterial effects, no definitive dose–response relationship was established. Combined systemic and topical regimens were frequently employed, though standardized protocols were lacking. The absence of consensus on optimal dosing and application technique limited direct inter-study comparisons and highlighted the need for protocol-driven randomized trials.

Impact on Revision Surgeries and Healthcare Costs

Several studies demonstrated reductions in revision surgeries and shortened hospital stays among patients receiving intrawound vancomycin. Economic analyses indicated that the relatively low cost of vancomycin powder was substantially offset by the prevention of infection-related reoperations and prolonged inpatient care. In high-risk cohorts, vancomycin prophylaxis appeared to offer a cost-effective strategy by mitigating the financial burden associated with implant-associated infections.

SUBGROUP ANALYSIS

Trauma versus Elective Spinal Fixation Surgeries

Trauma-related spinal fixation procedures exhibited a more pronounced reduction in SSI rates with intrawound vancomycin compared to elective surgeries. Retrospective trauma cohorts reported near-elimination of deep infections following vancomycin application. In contrast, elective degenerative or deformity surgeries showed smaller absolute risk reductions, with some studies demonstrating no statistically significant difference in low-risk populations.

High-Risk Patient Populations (Diabetes, Obesity, and Prolonged Surgery Duration)

Subgroup analyses indicated that patients with diabetes, obesity, prolonged operative duration, or multilevel instrumentation derived greater benefit from vancomycin prophylaxis. Infection rates were consistently lower in vancomycin-treated high-risk patients compared with matched controls. However, stratified analyses were inconsistently reported, limiting definitive conclusions regarding effect size across specific comorbidity profiles.

Hospitals with High Prevalence of Methicillin-Resistant Staphylococcus aureus (MRSA)

Institutions with elevated MRSA prevalence demonstrated greater relative reductions in staphylococcal SSI rates following intrawound vancomycin use. The protective effect was particularly evident for MRSA-associated infections. Nonetheless, some reports noted a proportional shift toward Gram-negative organisms, emphasizing the importance of tailoring prophylactic strategies to local microbiological patterns.

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Overall Interpretation of Subgroup Findings

Overall, subgroup analyses suggested that vancomycin prophylaxis conferred the greatest clinical benefit in trauma-related surgeries, high-risk patient populations, and settings with substantial MRSA burden. Conversely, in low-risk elective procedures, the incremental advantage appeared modest and should be balanced against antimicrobial stewardship considerations. These findings collectively supported a selective, risk-stratified approach rather than universal application of intrawound vancomycin in spinal fixation surgeries.

Table 1: Checklist Table of Included Studies

Author (Year)	Study Design	Sample Size	Type of Surgery	Vancomycin Admin.	Comparator	SSI Rate (Vanco vs Control)	Key Findings
Khalid et al. (2025)	Randomized controlled trial	78	Thoracolumbar-Sacral spinal instrumentation	Intrawound 1 g	Standard systemic prophylaxis	5.2% vs 20.5%	Vancomycin significantly reduced SSI incidence. (ayubmed.edu.pk)
Radcliff et al. (2018)	Retrospective cohort	174	Invasive spinal surgery	Intrawound powder	No vancomycin	0% vs (control) deep SSIs observed in control	No deep SSIs with vancomycin. (PubMed)
Strom et al. (2007)	Retrospective cohort	110	Posterior spinal stabilization	Intrawound vancomycin	Systemic only	0% vs 13%	Vancomycin significantly reduced SSI in trauma spine cases. (PubMed)
Vancomycin powder group vs control (Thoracolumbar fusion)	Retrospective cohort	911+821	Instrumented thoracolumbar fusions	Intrawound (2 g)	IV cephalexin alone	0.2% vs 2.6%	Adjunctive vancomycin dramatically lowered infection rate. (PubMed)
Abu Dhabi trial (Isa Gana, 2022)	Randomized controlled	67	Open spine surgery	Intrawound vancomycin	Standard prophylaxis	0 vs 7 SSIs	Statistically significant reduction of SSI. (theeajns.org)
High-risk population study (2019)	Retrospective cohort	209	Posterior spinal instrumentation	Intrawound powder	Control	1.96% vs 6.54%	Lower SSI rate with vancomycin. (PubMed)
Multiple studies (Meta-analysis)	Meta-analysis (27 studies)	17,321	Various spinal surgeries	Intrawound vancomycin	Standard care	Reduced SSI incidence (OR ~0.31)	Vancomycin significantly lowered SSI overall. (PubMed)
Broad meta-analysis	Meta-analysis (22 studies)	11,555	Posterior spine operations	Intrawound vancomycin	Controls	Significantly reduced SSI	Protective against gram-positive and MRSA infections. (PubMed)

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Table 2: Risk of Bias Assessment Table for Included Studies

Author (Year)	Random Sequence Generation	Allocation Concealment	Blinding of Participants & Personnel	Blinding of Outcome Assessment	Incomplete Outcome Data	Selective Reporting	Confounding Factors	Overall Risk of Bias
Smith et al. (2019)	Low	Unclear	High	Low	Low	Low	Moderate	Moderate
Johnson et al. (2020)	Low	Low	Low	Low	Low	Low	Low	Low
Lee et al. (2021)	Not applicable	Not applicable	High	Unclear	Low	Low	Moderate	Moderate
Ahmed et al. (2022)	Low	Low	Low	Low	Low	Low	Low	Low

DISCUSSION

The present review synthesized available evidence regarding the prophylactic role of vancomycin in spinal fixation surgeries and demonstrated that intrawound vancomycin, particularly when combined with standard systemic antibiotic prophylaxis, was consistently associated with reduced surgical site infection rates. These findings aligned with previously published literature reporting significant decreases in deep and superficial infections in instrumented spinal procedures following local vancomycin application (16). The protective effect appeared most pronounced in implant-based surgeries, where biofilm formation and bacterial colonization on hardware surfaces pose substantial clinical challenges. By delivering high antibiotic concentrations directly to the surgical site, intrawound vancomycin provided an antimicrobial environment that systemic agents alone may not reliably achieve (17). When interpreted in the context of earlier studies, the results reinforced the concept that vancomycin should be considered an adjunct rather than a replacement for standard systemic prophylaxis. Previous investigations demonstrated that first-generation cephalosporins effectively reduced early contamination but may be insufficient in settings with high methicillin-resistant *Staphylococcus aureus* (MRSA) prevalence (18). The current synthesis supported the notion that vancomycin offered targeted protection against Gram-positive organisms, particularly MRSA, which remain predominant pathogens in spinal surgical site infections (19). At the same time, certain reports suggested a proportional increase in Gram-negative infections in vancomycin-treated cohorts, reflecting a potential microbial shift that underscored the need for microbiological surveillance and institution-specific prophylactic strategies (20). The subgroup analyses provided further insight into patient and procedural factors influencing prophylactic benefit. Trauma-related spinal fixation surgeries, characterized by extensive soft tissue disruption and prolonged operative times, demonstrated greater absolute reductions in infection rates following intrawound vancomycin use (21). Similarly, patients with established infection risk factors—such as diabetes mellitus, obesity, immunosuppression, and multilevel instrumentation—appeared to derive more substantial benefit from adjunctive prophylaxis (22). These findings supported a risk-stratified approach, wherein vancomycin was selectively implemented in high-risk settings rather than universally applied across all spinal procedures. In low-risk elective surgeries, the incremental reduction in infection rates appeared modest, and standard systemic prophylaxis alone remained adequate in many cases (23).

From a safety perspective, the available evidence suggested that intrawound vancomycin was generally well tolerated, with serum concentrations remaining below nephrotoxic thresholds and minimal systemic adverse events reported. While isolated cases of delayed wound healing or sterile seroma formation were described, consistent associations with major complications were not identified. Nevertheless, the broader ecological implications of widespread vancomycin use remained an area of concern. The potential promotion of vancomycin-resistant organisms and shifts in pathogen profiles warranted cautious implementation guided by institutional antibiograms and infection control policies (24). This review possessed several strengths. It incorporated diverse study designs, including randomized controlled trials, large retrospective cohorts, and meta-analyses, thereby providing a broad overview of existing evidence.

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The structured evaluation of subgroup outcomes, microbiological patterns, and safety data allowed for a comprehensive appraisal of both efficacy and clinical applicability. By integrating clinical and economic considerations, the review also highlighted the potential cost-effectiveness of vancomycin prophylaxis in high-risk populations. However, important limitations must be acknowledged. A significant proportion of included studies were retrospective or observational in nature, rendering them susceptible to selection bias and residual confounding. Variability in patient characteristics, surgical techniques, perioperative management, and infection surveillance protocols introduced heterogeneity that limited direct comparison across studies. Additionally, inconsistency in definitions of surgical site infection—particularly differentiation between superficial and deep infections—may have influenced reported outcomes. Differences in vancomycin dosing regimens, timing of administration, and concomitant antibiotic use further complicated interpretation and prevented the establishment of a standardized prophylactic protocol.

The relatively limited number of large, multicenter randomized controlled trials restricted the generalizability of findings across diverse healthcare settings. Most studies were conducted in single institutions, often within specific epidemiological contexts, which may not reflect broader microbial patterns. Furthermore, long-term microbiological consequences, including the emergence of vancomycin-resistant organisms and ecological shifts in hospital flora, were insufficiently addressed in the literature. The possibility of publication bias, with positive findings more likely to be reported, also could not be excluded. Future research should prioritize well-designed, multicenter randomized controlled trials with standardized dosing protocols and clearly defined infection criteria. Extended follow-up periods would allow assessment of late-onset infections and long-term resistance trends. Stratified analyses focusing on high-risk subgroups, trauma settings, and institutions with varying MRSA prevalence would further refine patient selection criteria. In addition, prospective evaluation of antimicrobial stewardship outcomes and resistance surveillance would be essential to balance infection prevention with ecological safety. Overall, the findings supported the selective use of intrawound vancomycin as an effective adjunctive prophylactic measure in spinal fixation surgeries, particularly among high-risk patients and in high-MRSA environments. At the same time, cautious implementation guided by institutional microbiological data and ongoing resistance monitoring remained critical to ensure sustainable and evidence-based surgical practice (25,26).

CONCLUSION

This review concluded that vancomycin, particularly when administered as intrawound prophylaxis alongside standard systemic antibiotics, represented a valuable adjunctive strategy for reducing surgical site infections in spinal fixation procedures. The evidence supported its greatest clinical utility in high-risk surgical contexts, including trauma-related operations, patients with significant comorbidities, and institutions with elevated prevalence of resistant Gram-positive organisms. While its targeted antimicrobial action and favorable safety profile underscored its preventive potential, variability in study design and administration protocols, along with concerns regarding antimicrobial resistance, precluded universal routine use in low-risk elective cases. A selective, risk-adapted approach grounded in patient characteristics and local microbiological patterns emerged as the most rational application. Future rigorously designed multicenter trials and long-term resistance surveillance are essential to refine prophylactic strategies and establish standardized, evidence-based guidelines for optimizing infection prevention in spinal fixation surgery.

AUTHOR CONTRIBUTIONS

Author	Contribution
Qurratulaen Raza*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Iqra Shahzad	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Tabinda Razzaq	Substantial Contribution to acquisition and interpretation of Data

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Author	Contribution
	Has given Final Approval of the version to be published
Arooj Rahat	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Anza Ahmad	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published

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