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Frequency Of *Staphylococcus Aureus* In Wound Infections Among Patients In District Okara

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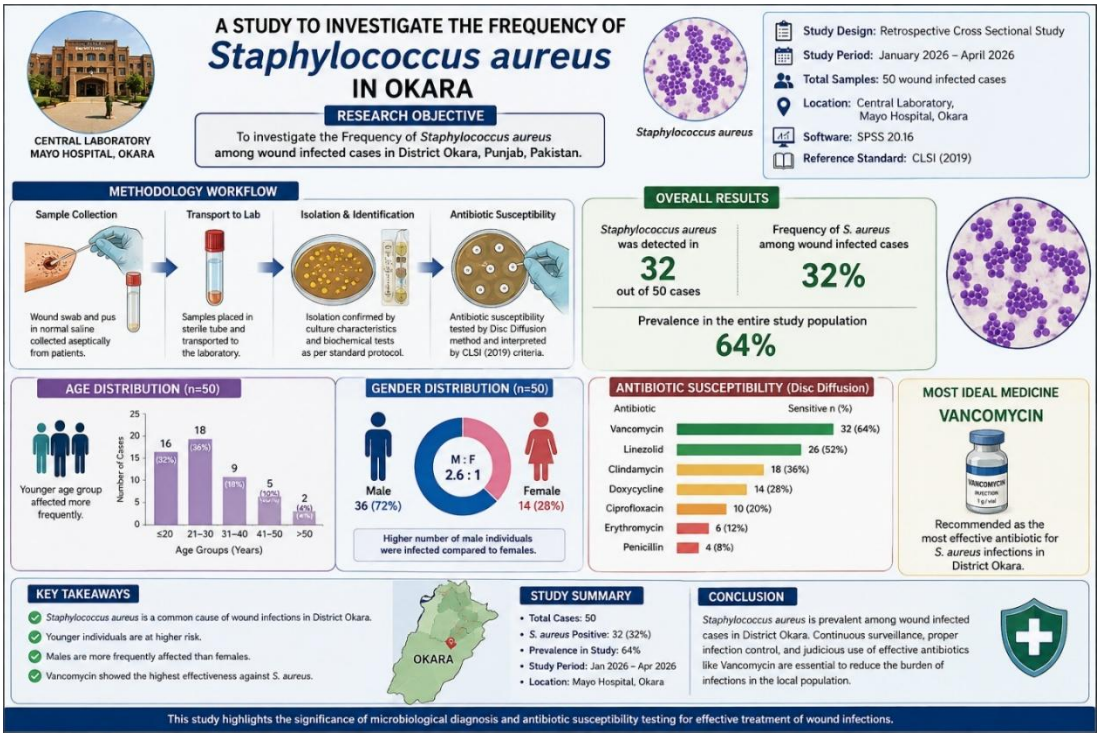
Abstract

A study to investigate the frequency of *Staphylococcus aureus* in Okara conducted at the Central laboratory of Mayo Hospital. The information provided here includes both their age, gender and their antibiotic resistance, and the most ideal Medicine for individuals around Okara. As such: Research objective, to investigate the Frequency of *Staphylococcus aureus* among wound infected cases in District Okara, Punjab, Pakistan. This was a retrospective cross sectional study that used a total of 50 cases conducted at a prestigious institute between January 2026 and April 2026. Samples taken are wound swab and pus in normal saline from cases and put in tube & then moved to laboratory, all taken under aseptic conditions and the isolation is confirmed onthe bases of culture and biochemical test and antibiotic susceptibilities were tested by standard criteria disc diffusion and also results confirmed by CLSI (2019),results taken through SPSS 20.16. Total results is about; *Staphylococcus aureus* infection occurs among, the thirty two cases of which about 32% out of the 50 have this result indicating *Staphylococcus aureus* to be present in the patient to a total population of 64% in the entire study about wound infected infection at District Okara. Patients aged younger are infected more than others and that age at risk seems like, so with regards to gender there was greater number of people suffering in to make a decision of the antibiotic and it turned out to be Vancomycin in this study for thirty two (32) out of the fifty (50) in each case but there was more male individuals with infection than female and it was proved by this, The research that has come to close have come up with the finding that *S.aureus* can be held a cause to prevalent for many injuries among locals in Okara.

Graphical Abstract



Objectives

1. To isolate and to identify *Staphylococcus aureus* from the wound samples
2. To ascertain the frequency of *Staphylococcus aureus* among infected patients
3. To analyze the distribution of infection based on age and gender
4. To access the antimicrobial susceptibility patterns of *Staphylococcus aureus*

Introduction

Staphylococcus aureus ,Gram positive bacterium, is classified in Staphylococcaceae family, catalase and coagulase positive coccus. First identified in 1880 by Alexander Ogston as an etiology causing wound's infections; it is currently one of leading etiology creating Community acquired infections (CAIs) as well as Hospital acquired infections (HAIs). The most important bacteria to the healthy mankind by nature resides on the skin and mucous membranes of animals and individuals and invades any damage tissue so as can cause diseases from simple skin's infections, such as cellulitis and boils; upto invasive disease including but not limited to Pneumonia, osteomyelitis, endocarditis, Bacteremia and Septic Shock. Virulence Factors of this organism like exotoxins, adhesives, surface protein and biofilm formation plays significant role during its survival and infection. Increasing resistance in *Staphylococcus aureus* has greatly challenge therapeutic options worldwide due to acquisition of resistance including against the important antibiotic-methicillin as such Methicillin-Resistant *Staphylococcus aureus* (MRSA). There are many published and reported articles regarding frequent identification of *S. aureus* and MRSA from patients admitted to hospital of various parts of Pakistan , specially wound patients that produces biofilm and with high degree of anti-microbial resistance, which lead to poor outcomes, however limited study performed by many researcher from Pakistan but no one specifically from District Okara on such subject. This study focus to assess prevalence of *S.aureus* in wound.

Methodology

A retrospective cross-sectional study was carried out at Central Diagnostic Laboratory, Mayo Hospital, Lahore, Pakistan from 01-August-2025 to 25-January-2026 by undergraduates of Department of Medical Laboratory Technology, University of Okara. The study population comprised 50 wound specimens which were collected from male and female patients of all age groups from District Okara with history of wound infections based on clinical diagnosis. Ethics approval was granted by Ethics committee, Mayo Hospital, Lahore. No clinical intervention was required, only laboratory analysis was done on these specimens. Wound swabs & pus samples were obtained in sterile cotton swabs and immediately transported to the microbiology laboratory in saline. The samples were cultured in Blood agar and Macconkey agar mediums then were incubated in appropriate conditions at 37 degree Celcius over 24 hours. Isolates of *Staphylococcus aureus* were characterized by colony morphology on nutrient and blood agar media, Gram stain, and then confirmed by performing catalytic activity, coagulase activity, oxidase activity (conventional biochemical tests). Susceptibility to different antibiotic was performed by disk diffusion technique as described by the Clinical and Laboratory Standards Institute (CLSI guidelines). Kirby Bauer method on Muller-Hinton agar (MH) media and results interpreted based on diameter of inhibition zones. The following antibiotics included in the antimicrobial susceptibility testing are Penicillin, Oxacillin, Erythromycin, Ceftazidime, Gentamicin, Ciprofloxacin, Vancomycin. After collection of data by laboratory, the results were analyzed by using appropriate statistical tool for reporting frequency of *Staphylococcus aureus* isolates from wound samples and their pattern of resistance against antibiotics.

Findings

In Gram staining, Staphylococcus aureus appears to be a Gram-positive cocci, which is observed primarily in clusters that resemble bunches of grapes, although single

cells, pairs, and short chains also exist. The microorganism is a rod, which is immobile, non-endospore-forming, and produces positive catalase and coagulase. SPSS analysis was performed using SPSS version 20 in Central Diagnostic laboratory at Lahore against 50 wound samples isolated from Mayo hospital Lahore, which consisted of 25 male and 25 female subject samples respectively; 32 isolates of *S.aureus* were separated among 50 samples(64%), whereas 18 samples did not show any outgrowth(36%). Among the cases examined, *Staphylococcus aureus* most often occured in adults(19 of 32). In the investigation among sex it was found that more (20 samples) of *S.aureus* cases occur among men than women(12 samples), therefore, it was concluded that *S. aureus* is the most commonly occurring agent in wound infections of patients of the Okara district.

Table #4.1 Distribution of *Staphylococcus aureus* isolated samples according to gender. A greater percentage of *Staphylococcus aureus* positive samples occur among men than women. Thus, higher predominance amongst the sex groups is reported here;

Table #4.1: Frequency of *S. aureus* isolated cases on the basis of Gender

Gender	Total number of Collected Samples	*S. aureus* isolated cases	Percentage%
Male	25	20	80
Female	25	12	48

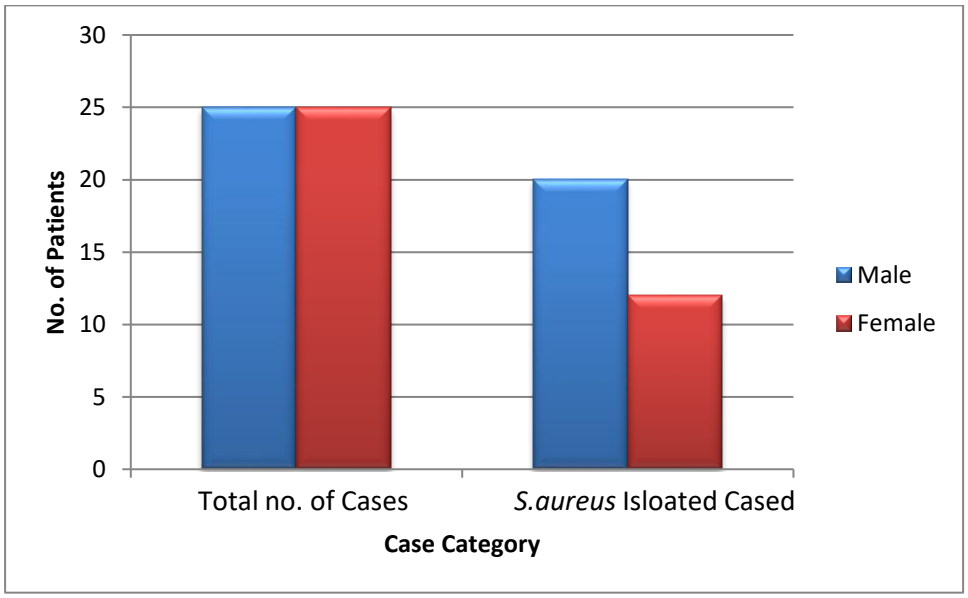


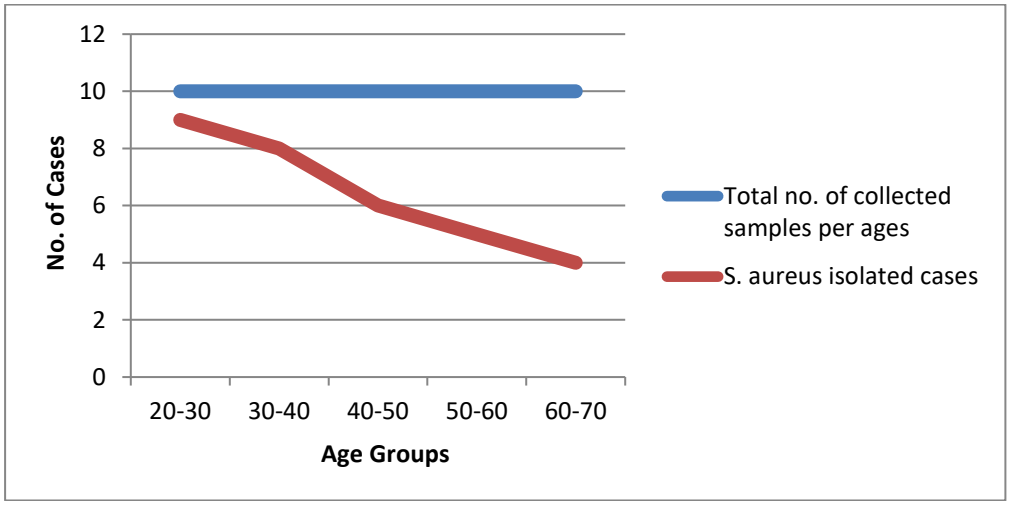
Figure # 4.1: Frequency of *S. aureus* isolated cases on the based of Gender

The above bar chat, figure 4.1, illustrates the distribution of *Staphylococcus aureus* isolates among male and female patients. A higher frequency of isolates was observed in males than in females, indicating greater prevalence in the male study population.

Table #4.2 summarizes the age-wise distribution of *Staphylococcus aureus* isolates among the study participants. The highest frequency was observed in younger adults, while the prevalence gradually decreased with increasing age.

Table # 4.2: Frequency of *S. aureus* isolated cases on the basis of age

Age	Total no. of collected samples	*S. aureus* isolated cases	Percentage%
20-30	10	09	90
30-40	10	08	80
40-50	10	06	60
50-60	10	05	50
60-70	10	04	40



Figure# 4.2: Line graph of frequency of *S. aureus* isolated cases based on Age

The line graph figure. 4.2 shows the distribution of age groups for *S.aureus* isolates. The peak of incidence was found among age group 20-30 years the highest frequency, thereafter age related decreases occurred for all higher age groups.

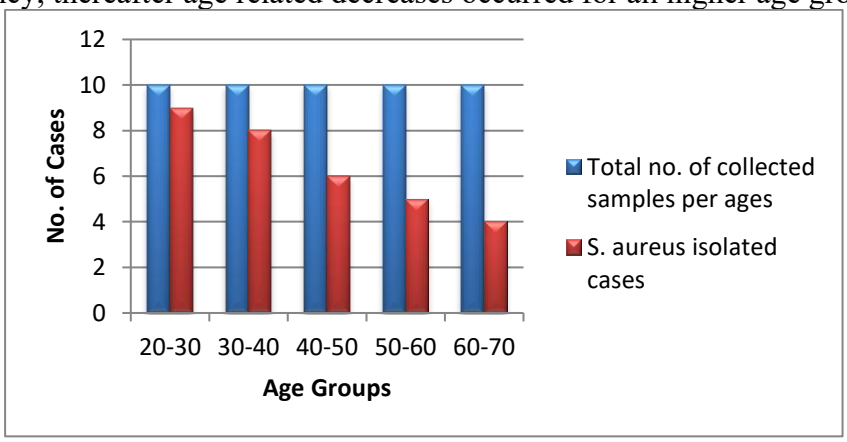


Figure # 4.3: Bar Chart of *S. aureus* Isolated Cases Based on Age

The above bar chart, figure 4.3, shows comparisons in number of *S.aureus* isolated between various age-bands. It is clear from the results that infections were more frequent among younger adults rather than older individuals.

Table 4.3 depicts the antimicrobial susceptibility profile of the MRSA isolates towards the antibiotics under investigation. We noted higher resistance towards penicillin (100%) and ceftazidine (75%), with vancomycin showing higher sensitivity among the isolates (87.5%) of tested strains.

Table # 4.3: Antimicrobial Resistance Pattern of MRSA Isolates

Antibiotic	Resistant (n)	Resistance (%)	Sensitive (n)	Sensitive (%)
Pencillin	32	100	0	0
Methicillin	16	50	16	50
Ciproflox acin	20	66.6	12	37.5
Vancomycin	04	12.5	28	87.5
Erythromycin	18	60	14	43.7
Oxacillin	17	53.1	15	46.8
Gentamicin	17	53.1	15	46.8
Ceftazidime	24	75	08	25

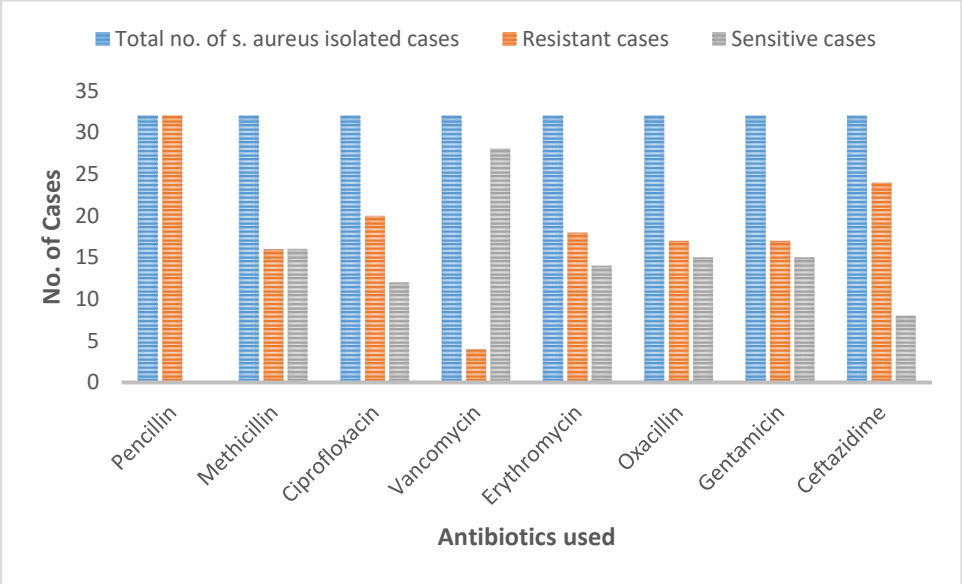


Figure 4.4: Bar Chart of Antimicrobial Resistance Pattern of MRSA Isolates

The above graph depicts the overall antimicrobial resistance patterns of MRSA isolates to different antibiotics used. Both penicillin and ceftazidime showed high resistance rates, and vancomycin continued to be the most active antibacterial drugs for MRSA isolates tested herein.

Discussion

64% of all the wound swabs yielded *Staphylococcus aureus* and proved that *S. aureus* is the most common cause of the wounds infection in the studied population. The yield is consistent with that of many local reports, stating *S.aureus* as the most dominant pathogen of wound infections with varying frequency according to the site and method of sampling.

The higher yield in males and tendency to concentrate more in young adults might be attributed to the increased possibility of trauma, occupational hazards or habit that causes higher probability of breach of the skin and subsequent inoculation by this organism. The gender and age differences might be related to sociocultural and occupational differences in the region and might warrant large scale epidemiological

surveys. The results for antimicrobial susceptibility showed alarming results of resistance shown by the MRSA strains to different antibiotics. Penicillin showed a predictable resistance with the presence of universal betalactamase in *S. aureus*, but the resistance to ceftazidime(75%), ciprofloxacin(66.6%) and moderate resistance shown by gentamicin and oxacillin gives us few options to use them for empirical therapy. The maintained susceptibility (87.5%) toward vancomycin is consistent with the pattern reported worldwide where glycopeptide remains most effective in the management of many MRSA strains; but the dependency on vancomycin poses other health hazards like toxicity, expense and emerging vancomycin reduced susceptibility. These results indicate that local antibiogram for empirical therapy should be regularly updated and stewardship program be utilized to judiciously utilize antibiotics. Strengths of the study are prospectivity of sampling and culture-confirmation by means of identification using standardized biochemical tests; however many limitation temper the results and discussion. A sample size of 50 wound swabs with single center design leads to limited generalization over the entire District Okara or other areas. MRSA were classified by phenotype as revealed in this study. Molecular detection of mecA/mecC was not carried out and was would have better defined characterization of the isolates. Clinical details like previous history of antibiotics administration, coexisting morbidities, wound characteristics, length of hospitalization and prognosis were not documented and hence we failed to relate either the use of antibiotic or resistance with such data. The implications of the findings on practice include; culture and antibiotic susceptibility testing in wound infections for proper treatment, establishment of guidelines for empirical treatment of wound infections based on local antibiograms and strict infection control protocol. Prospective studies with multi-center studies, include molecular assays for confirming resistance mechanisms and collect clinical and epidemiological details will help identify factors predicting MRSA colonization and infection, thus contributing to preventive strategies.

Future Perspectives and Integration With Other Domains

Future Perspectives

The present study provides an important preliminary epidemiological baseline for *Staphylococcus aureus* wound infections among patients from District Okara. The recovery of *S. aureus* from 64% of the examined wound specimens, together with its greater occurrence among male and younger patients and the substantial antimicrobial resistance observed among the tested isolates, highlights the need for future investigations that extend beyond simple prevalence estimation. Future research should incorporate molecular characterization, longitudinal surveillance, clinical risk assessment, nutritional and metabolic profiling, artificial intelligence, microbiome analysis, environmental surveillance, and One Health approaches. The integration of these domains could provide a more comprehensive understanding of why particular individuals develop *S. aureus* wound infections and why some infections become persistent or difficult to treat.

Future studies should employ larger multicentre and longitudinal designs involving hospitals, diagnostic laboratories, primary-care facilities, and community populations throughout Okara and neighbouring districts. Detailed information should be collected regarding age, gender, occupation, wound type, previous antimicrobial exposure, hospitalization, nutritional status, metabolic conditions, wound duration, and treatment outcomes. Such datasets could subsequently be linked with computational prediction systems and clinical decision-support models. AI-based approaches have already been explored for complex decision-making and predictive systems in other domains [37,47,52,53], providing methodological concepts that could be adapted for antimicrobial-resistance surveillance.

A major priority should be molecular and genomic characterization of *S. aureus*. The present investigation relied primarily on conventional microbiological identification and antimicrobial susceptibility testing. Future work should incorporate

mecA and *mecC* detection, resistance-associated genes, toxin genes, virulence determinants, biofilm-associated genes, and whole-genome sequencing where resources permit. The increasing use of genome-editing and molecular technologies in biological research demonstrates the rapidly expanding capacity for precise genetic investigation [33,34]. Although the cited CRISPR studies concern other biological systems, their technological principles provide a potential framework for future molecular diagnostic and functional-genomics investigations of antimicrobial resistance.

Future studies should also investigate virulence, biofilm formation, and wound microbiome interactions. Rather than examining *S. aureus* as an isolated organism, researchers could characterize the entire microbial community of infected wounds using sequencing-based approaches. Such work could be combined with metabolomic, proteomic, and transcriptomic analyses. Multi-omics research in other biological systems demonstrates the value of integrating multiple molecular levels to understand complex biological responses [49]. This approach could potentially identify bacterial and host biomarkers associated with persistent infection, treatment failure, or delayed wound healing.

Another promising direction is the integration of host nutritional and metabolic information. Nutritional status can influence immune function, tissue repair, and recovery. Research investigating zinc supplementation and IGF-1 expression demonstrates relationships between nutritional factors and physiological pathways [31], while studies of dietary recovery strategies illustrate the relationship between nutrition, metabolism, and physiological recovery [41]. Future *S. aureus* wound studies could therefore investigate micronutrient status, body composition, metabolic health, and dietary adequacy alongside microbiological findings.

The emerging field of nutrigenomics may provide additional opportunities. Research examining phytochemical-rich diets and epigenetic markers demonstrates how dietary components may interact with molecular pathways [32]. Similarly, AI-assisted nutrigenomic modeling has investigated interactions between dietary anthocyanins, the gut microbiome, butyrate production, and insulin sensitivity [48]. Although these studies do not directly establish nutritional interventions for *S. aureus* infection, they support the broader concept of investigating interactions among diet, host biology, microbiota, inflammation, and disease outcomes.

Integration With Other Domains

1. Artificial Intelligence and Machine Learning

Artificial intelligence represents one of the most promising domains for integration with future *S. aureus* surveillance. AI systems could combine demographic variables, wound characteristics, microbiological results, antimicrobial susceptibility profiles, previous antibiotic exposure, and clinical biomarkers to estimate the probability of *S. aureus* infection and resistance.

Recent interdisciplinary research has demonstrated the potential of AI to integrate laboratory biomarkers, medical imaging, and molecular information for clinical diagnostics [45]. A similar multimodal framework could be developed for wound infections by combining microbiological and clinical information. AI could potentially assist in identifying high-risk patients, predicting antimicrobial resistance, and supporting laboratory-based clinical decision-making.

Machine-learning approaches developed for anomaly and fraud detection provide another transferable methodological concept [53]. In an antimicrobial-resistance setting, similar algorithms could be trained to identify unusual clusters of resistant *S. aureus* isolates, detect changes in local resistance patterns, and generate alerts for infection-control teams.

AI automation may additionally improve laboratory workflow and organizational efficiency. Research examining AI automation and employee productivity indicates that intelligent automation can influence workflow design and

organizational performance [52]. In microbiology laboratories, related approaches could support automated antibiogram generation, data quality monitoring, laboratory reporting, and resistance-trend analysis.

2. Precision Medicine and Personalized Infection Management

The future of wound-infection treatment could increasingly move toward patient-specific antimicrobial and supportive management. Rather than relying exclusively on population-level resistance patterns, future systems could combine individual clinical characteristics with microbiological and molecular data.

Nutritional and metabolic research provides an indirect foundation for such approaches. Studies examining zinc supplementation and IGF-1 [31], dietary recovery and lean-mass preservation [41], and nutrigenomic interactions [48] demonstrate the importance of individual biological variation. Future *S. aureus* studies could investigate whether nutritional, metabolic, inflammatory, and molecular characteristics modify susceptibility to infection or treatment response.

3. Gut Microbiome and Systemic Inflammation

The gut microbiome represents another potential domain of integration. Research on functional foods and gut microbiota has examined the relationship between microbial communities and chronic low-grade inflammation [60]. Similarly, research examining gut microbiome diversity in severe acute malnutrition emphasizes the relationship between nutritional vulnerability and microbial ecology [64].

These findings do not directly establish that gut microbiota determine *S. aureus* wound infection. However, they support future investigations examining whether gut microbial composition, nutritional status, systemic inflammation, and wound microbiota collectively influence wound healing and infection persistence.

4. Food Microbiology and One Health

The One Health approach provides a particularly relevant framework for Pakistan because antimicrobial resistance can circulate among humans, animals, food systems, and environmental reservoirs. Research on microbiological safety and health risks in raw cow and buffalo milk from Punjab provides a regional example of the importance of food-associated microbial surveillance [35]. Similarly, research on beef quality and safety demonstrates the importance of systematic microbiological assessment of animal-derived foods [24].

Future research could compare *S. aureus* isolates obtained from human wound infections with isolates from livestock, milk, meat, food-processing environments, and healthcare environments. Molecular typing and genomic sequencing could then be used to investigate whether genetically related strains circulate between these reservoirs.

5. Probiotics and Functional Foods

The study of beneficial microorganisms provides another indirect connection. Research utilizing *Lactobacillus rhamnosus* as a probiotic adjunct culture demonstrates the potential health applications of beneficial microorganisms [23]. Future laboratory research could investigate whether selected probiotic organisms or their metabolites influence *S. aureus* colonization, biofilm formation, or inflammatory responses.

Similarly, research on plant-based functional foods [36], pomegranate-peel polyphenols [50], and watermelon-peel flavonoids [58] provides potential starting points for screening natural bioactive compounds for antibacterial, anti-biofilm, antioxidant, or wound-healing activity.

These compounds should not be presented as established treatments for *S. aureus* on the basis of their nutritional or antioxidant properties alone. Rather, they represent candidate research directions requiring laboratory screening, toxicity assessment, pharmacological evaluation, animal studies, and ultimately clinical trials.

6. Biomaterials and Advanced Wound Dressings

Protein and food-material research may also contribute to future advanced wound-care technologies. Research involving soy-whey hybrid proteins and microbial

transglutaminase crosslinking [25], sustainable whey-corn hybrid protein systems [26], protein-based food structures [27], and ultrasound-assisted soy-protein modification [59] demonstrates how biological materials can be structurally modified to achieve desired functional properties.

These concepts could potentially be transferred to biomedical-material research. Future studies could investigate protein-based films, hydrogels, biodegradable matrices, or controlled-release wound dressings incorporating antimicrobial compounds. Such applications would require independent evaluation of mechanical properties, biocompatibility, antimicrobial activity, degradation, toxicity, and clinical performance.

7. Antioxidants and Oxidative Stress

Oxidative stress provides another bridge between nutritional science and wound biology. Research investigating olive oil and flaxseed oil in relation to drug-induced hepatotoxicity provides evidence concerning dietary lipids and biological stress responses [22]. Studies of pomegranate polyphenols [50] and watermelon-peel flavonoids [58] similarly highlight the biological relevance of antioxidant compounds.

Future wound research could measure oxidative-stress biomarkers alongside bacterial load, inflammatory markers, wound-healing progression, and treatment response. This could help determine whether oxidative balance is associated with recovery and whether specific bioactive compounds deserve further investigation.

8. CRISPR, Genome Editing, and Molecular Diagnostics

CRISPR-based technologies represent another promising area for future research. CRISPR-Cas12a-mediated epigenome editing has demonstrated targeted modification of biological pathways [33], while CRISPR-Cas-mediated genome editing has been explored for disease resistance in crops [34].

Although these references concern agricultural applications, the underlying technological principles could inform future *S. aureus* research. Potential applications include rapid molecular detection of resistance genes, functional analysis of virulence determinants, investigation of bacterial regulatory pathways, and development of highly specific diagnostic assays.

9. Multi-Omics and Systems Biology

The integration of genomics, transcriptomics, proteomics, metabolomics, and microbiomics represents an important future direction. Multi-omics research has been used to investigate biological responses to environmental contaminants [49], demonstrating how different molecular levels can be combined to provide a more comprehensive biological interpretation.

A comparable framework could be applied to *S. aureus* wound infections by integrating bacterial genome characteristics, resistance determinants, virulence profiles, wound microbiome composition, host inflammatory markers, nutritional status, and treatment outcomes.

10. Environmental Health and Antimicrobial Resistance

Environmental surveillance should become an integral part of future antimicrobial-resistance research. Research on microplastic and nanoplastic exposure demonstrates how environmental stressors can be associated with oxidative stress and biological alterations [51]. Although this research does not directly demonstrate effects on *S. aureus*, it reinforces the importance of considering environmental exposures within broader health frameworks.

Future studies in Okara could investigate hospital wastewater, sewage, agricultural runoff, antimicrobial residues, and environmental water sources for antimicrobial-resistant organisms. This would help determine whether environmental reservoirs contribute to the circulation of resistant *S. aureus*.

Research examining trehalose-mediated responses to salinity stress in plants further illustrates how biological systems respond to environmental stress [61]. While the organism and context are different, the systems-level concept could encourage

investigation of environmental conditions affecting bacterial persistence and survival.

11. Sustainable Healthcare and Environmental Stewardship

Antimicrobial-resistance control should also be integrated with **healthcare sustainability**. Research on sustainable protein development emphasizes environmental stewardship alongside technological innovation [26], while research examining the social dimensions of sustainability performance emphasizes that sustainability extends beyond environmental metrics [40].

Future antimicrobial-stewardship programs should therefore consider antimicrobial consumption, laboratory waste, disposable materials, wastewater management, resource requirements, and long-term environmental effects while maintaining patient safety.

12. Healthcare Management and Risk Governance

Laboratory findings become clinically useful only when supported by effective healthcare systems. Research on risk governance and strategic control mechanisms provides a conceptual framework for managing complex and uncertain risks [42]. This can be applied to antimicrobial resistance through structured surveillance systems, infection-control policies, antimicrobial-stewardship committees, laboratory quality assurance, and outbreak-response mechanisms.

Healthcare workforce sustainability is equally important. Research on wellbeing-oriented human-resource management in healthcare organizations emphasizes the relationship between workforce sustainability and healthcare performance [56]. Future antimicrobial-resistance programs should therefore incorporate workforce training, adequate staffing, professional wellbeing, and institutional support.

13. Digital Surveillance and Data Governance

As microbiological surveillance becomes increasingly digital, electronic laboratory systems could integrate patient information, culture results, antimicrobial susceptibility patterns, molecular data, and treatment outcomes.

Research on machine-learning-based fraud detection demonstrates how large datasets can be analyzed for abnormal patterns [53]. Similar approaches could potentially identify unusual clusters of resistant *S. aureus* isolates.

AI-enhanced decision systems also demonstrate how computational simulations can support decision-making under uncertainty [37]. Similar modeling could be used to evaluate alternative antimicrobial-stewardship strategies, estimate resistance trajectories, and assess potential outbreak-control interventions.

14. Education and Professional Training

AI-assisted educational systems could contribute to antimicrobial-resistance education. Research on AI-assisted learning has examined academic performance and critical-thinking outcomes [57], while adaptive learning platforms have explored personalized learning outcomes [66].

These approaches could be adapted to develop interactive microbiology-training modules involving *S. aureus* identification, MRSA recognition, susceptibility interpretation, wound-culture analysis, and antimicrobial-stewardship decisions.

AI-supported language-learning research also provides a transferable model for personalized digital communication [29]. Such approaches could potentially support multilingual antimicrobial-resistance education for healthcare workers and communities.

15. Nutrition, Socioeconomic Factors, and Health Equity

Future *S. aureus* studies should incorporate social determinants of health. Research examining dietary habits, nutritional status, and socioeconomic factors among university students in Punjab demonstrates the value of combining nutritional and social variables [55]. Research on migration, displacement, and healthcare inequities further demonstrates how structural factors can influence healthcare access [54].

Accordingly, future Okara studies should consider occupation, socioeconomic

status, healthcare accessibility, education, nutritional status, treatment affordability, and healthcare-seeking behaviour. This would help determine whether particular groups experience higher infection risk or delayed access to microbiological diagnosis.

16. Physical Recovery and Functional Outcomes

Research involving long-term gait changes following ACL reconstruction demonstrates the importance of evaluating functional recovery after injury rather than focusing exclusively on the initial clinical event [30]. Although this research concerns orthopaedic rehabilitation, the principle could be transferred to wound-infection studies.

Future investigations could therefore record not only microbiological clearance but also healing time, recurrence, functional limitations, return to work, and quality of life.

Similarly, nutritional recovery studies in physically active populations [41] could provide conceptual guidance for evaluating nutritional status and tissue recovery following wound infection.

17. Dentistry and Biofilm-Associated Infections

Dental research provides another indirect but relevant connection. Research examining orthodontic treatment and periodontal health highlights relationships among tissue integrity, patient-specific risk factors, and microbial disease [38]. Research on silver diamine fluoride demonstrates the use of antimicrobial approaches for controlling dental caries [39].

These studies can inform comparative investigations of biofilm-associated disease across oral and wound environments. Future research could explore whether shared mechanisms of biofilm persistence exist across different tissues and whether anti-biofilm strategies developed in one field have potential applications in another.

18. Diagnostic Accuracy and Molecular Confirmation

Diagnostic research provides another important methodological connection. Comparative evaluation of HCV screening tests and confirmatory PCR demonstrates the value of combining screening and molecular confirmation to improve diagnostic accuracy [63].

A similar principle could be explored in *S. aureus* diagnostics. Rapid screening methods could potentially be combined with culture and molecular confirmation to reduce diagnostic delays and identify resistance determinants earlier.

19. Social and Cultural Dimensions

Social-science research examining gendered subjectivities, language, power, and identity demonstrates the importance of social and cultural context in human behaviour [65]. Although not a microbiological study, this perspective may be relevant when interpreting differences in infection frequency between males and females.

The higher proportion of male infections in the present study should not automatically be attributed to biological sex. Future studies should investigate occupational exposure, trauma, healthcare-seeking behaviour, cultural practices, and socioeconomic differences before concluding that sex itself is the primary explanation.

20. Agricultural and Environmental Biotechnology

Agricultural biotechnology provides additional methodological perspectives. CRISPR-mediated disease-resistance research [34] and CRISPR-Cas12a epigenome editing [33] demonstrate the growing capacity to manipulate biological systems precisely. Such technologies could indirectly contribute to future infectious-disease research through improved molecular diagnostics and functional genomics.

Environmental stress research [61] likewise demonstrates the value of investigating biological responses under changing environmental conditions. Similar systems-level approaches could be used to investigate how environmental conditions affect bacterial survival and transmission.

21. Integrated Future Research Framework

Based on these interdisciplinary connections, future *S. aureus* research in

District Okara could be organized into six interconnected levels:

Level 1 – Clinical surveillance: age, gender, occupation, wound characteristics, comorbidities, treatment history, nutritional status, socioeconomic factors, healing time, recurrence, and clinical outcomes [31,41,54,55].

Level 2 – Microbiological surveillance: culture, biochemical identification, antimicrobial susceptibility testing, biofilm assessment, virulence profiling, and regional antibiograms [1–21].

Level 3 – Molecular and genomic surveillance: resistance determinants, virulence genes, toxin profiles, genome sequencing, CRISPR-based diagnostics, and strain tracking [33,34].

Level 4 – Host and systems biology: inflammatory biomarkers, nutritional status, metabolic health, epigenetic factors, gut microbiome, wound microbiome, and multi-omics profiles [31,32,48,49,60,64].

Level 5 – Environmental and One Health surveillance: livestock, food products, hospital wastewater, environmental reservoirs, antimicrobial residues, and community transmission [24,35,36,51,61].

Level 6 – Digital and implementation systems: AI-assisted diagnosis, predictive analytics, electronic surveillance, cybersecurity, professional education, healthcare workforce sustainability, risk governance, adaptive learning, and equitable implementation [29,37,40,42,45,52,53,54,56,57,66].

Overall Future Perspective

The future of *S. aureus* wound-infection research in Okara should not be limited to determining how frequently the organism occurs. Future research should investigate why particular patients become infected, which bacterial lineages and virulence determinants are responsible, how antimicrobial resistance develops and spreads, how wound and gut microbiomes influence persistence, how nutritional and metabolic factors affect healing, how environmental and food-associated reservoirs contribute to transmission, and how computational technologies can support earlier and more precise intervention.

The additional interdisciplinary references 22–66 provide multiple avenues for this progression. Food science and functional-food research can contribute knowledge concerning bioactive compounds, probiotics, nutrition, protein materials, food safety, and microbial systems [22–28,35,36,50,58,59]. Molecular biology and biotechnology can contribute genome-editing and molecular-diagnostic approaches [33,34]. Nutrition and metabolic research can contribute perspectives on physiological recovery, micronutrients, endocrine responses, and individualized health [31,32,41,48]. Microbiome research can support investigation of host-microbial interactions and systemic inflammation [48,49,60,64]. AI and computational sciences can support diagnostic prediction, surveillance, automation, decision-making, and personalized systems [29,37,45,47,52,53,57,66]. Environmental and sustainability research can broaden surveillance toward environmental reservoirs and sustainable healthcare systems [40,49,51,61]. Social science, healthcare management, and education can facilitate equitable implementation, workforce development, risk governance, and antimicrobial-resistance awareness [42,54–57,65,66].

Even references with a relatively distant primary research area can provide transferable concepts. For example, computational plasma modeling [44] illustrates advanced computational approaches to complex systems; AI-based adaptive energy protection [47] illustrates real-time predictive decision-making; AI-enhanced venture modeling [37] demonstrates simulation-based decision support; and adaptive educational technologies [66] illustrate personalized learning. These principles can potentially be adapted to antimicrobial-resistance surveillance when validated specifically for clinical microbiology.

Ultimately, the long-term objective should be the development of a District Okara integrated antimicrobial-resistance surveillance platform connecting clinical

laboratories, hospitals, pharmacies, public-health authorities, environmental monitoring systems, veterinary services, food-safety laboratories, and academic research groups.

Such a platform could continuously generate local antibiograms, identify emerging resistance patterns, map potential transmission pathways, integrate clinical and molecular information, support antimicrobial stewardship, and provide early warning of unusual resistance patterns. The future therefore lies in moving from descriptive prevalence studies toward integrated, predictive, precision-oriented, and One Health antimicrobial-resistance research.

For District Okara and the wider Punjab region, this integrated approach could ultimately improve early diagnosis, rational antimicrobial selection, infection prevention, wound healing, resistance surveillance, and long-term public-health preparedness.

Conclusion

Overall Staphylococcus aureus was the leading cause of wound infection in the cohort, recovered from 64% of isolates; it was more prevalent in males and younger patients. Isolates of MRSA were characterized by the presence of 100% penicillin resistance and significant ceftazidime resistance rates; vancomycin displayed better in-vitro efficacy. These results highlight the importance of cultural diagnosis and regional antibiotic guidelines when initiating empiric treatment and controlling resistance propagation.

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