Section: Microbiology

Original Research Article

ANTIMICROBIAL ACTIVITY OF POTASSIUM PERMANGANATE AGAINST STAPHYLOCOCCAL ISOLATES FROM ATOPIC DERMATITIS LESIONS

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Received *: 08/05/2025*
Received in revised form *: 23/06/2025*
Accepted *: 12/07/2025*

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DOI: 10.70034/ijmedph.2025.3.280

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2025; 15 (3); 1527-1531

A B S T R A C T

Background: Atopic dermatitis (AD) is frequently complicated by secondary bacterial colonization, especially by Staphylococcus aureus and coagulase-negative staphylococci (CoNS), including methicillin-resistant and biofilm-forming strains. Potassium permanganate ($KMnO_4$), a low-cost topical antiseptic, has demonstrated potential antimicrobial activity. This study aimed to evaluate the in vitro effect of $KMnO_4$ at different concentrations on staphylococcal isolates from AD patients.

Materials and Methods: A cross-sectional study was conducted on 48 clinically diagnosed AD patients. Skin swabs were cultured, and staphylococcal isolates were identified. The antimicrobial activity of $KMnO_4$ (0.01%, 0.05%, 0.1%, and 0.2%) was tested using the agar well diffusion method. Biofilm production and methicillin resistance were assessed. Comparative analysis with vancomycin discs and correlation with EASI scores were also performed.

Results: A total of 54 isolates were recovered, including S. aureus (66.7%) and CoNS (33.3%), with 30.6% MRSA and 68.5% biofilm producers. $KMnO_4$ exhibited a dose-dependent effect, with 0.2% achieving mean inhibition zones of 12.8 ± 2.5 mm and inhibiting 94.4% of isolates effectively. CoNS showed slightly higher susceptibility than S. aureus. $KMnO_4$ activity was significantly lower than vancomycin ($p < 0.001$), but comparable in 9.3% of isolates. A moderate inverse correlation ($r = –0.32$, $p = 0.018$) was observed between EASI scores and antimicrobial response.

Conclusion: Potassium permanganate at 0.2% demonstrates significant in vitro antimicrobial activity against common staphylococcal pathogens in AD, including resistant and biofilm-forming strains. While not a substitute for systemic antibiotics, it may serve as a valuable adjunct topical agent in early or uncomplicated cases.

Keywords: Atopic dermatitis, Staphylococcus aureus, Coagulase-negative staphylococci, Potassium permanganate, Antimicrobial resistance.

INTRODUCTION

Atopic dermatitis (AD) is a chronic, relapsing inflammatory skin disorder affecting approximately 15–20% of children and 1–3% of adults worldwide, with higher prevalence rates observed in urbanized regions and developed nations.[1] In India, the prevalence among school-aged children ranges from 3% to 6%, with rising incidence attributed to changing environmental and lifestyle factors.[2] The disease is characterized by intense pruritus, eczematous lesions, and a compromised skin barrier, which facilitates microbial colonization and infection. Among the microbial agents implicated, Staphylococcus aureus plays a predominant role, colonizing lesional and non-lesional skin in up to 90% of AD patients, compared to 5–30% in healthy individuals.[3]

The presence of S. aureus in AD is not merely incidental; the organism contributes to disease exacerbation through the production of exotoxins such as alpha-toxin, superantigens, and biofilms, which enhance inflammation, disrupt epidermal integrity, and reduce the efficacy of topical

treatments.[4,5] Moreover, recurrent infections and colonization by methicillin-resistant strains have raised concerns about long-term antibiotic use and the emergence of resistance.[6]

Potassium permanganate ($KMnO_4$) is a strong oxidizing agent with established antimicrobial, antifungal, and deodorizing properties. In dermatology, it has traditionally been used in dilute concentrations (typically 0.01%) as a topical antiseptic for weeping skin lesions, ulcers, and infected eczema.[7] Its mechanism involves oxidation of bacterial cell walls and proteins, resulting in rapid bactericidal activity. Preliminary studies suggest its efficacy against a broad range of microorganisms, including Staphylococcus aureus, but specific investigations into its effectiveness on clinical isolates from AD patients remain sparse.[8]

Given the rising concern over antimicrobial resistance and the need for safe, inexpensive, and effective topical agents in AD management, this study aimed to evaluate the in vitro effect of potassium permanganate on Staphylococcus isolates derived from the skin of patients with atopic dermatitis. The findings could help assess its potential role as an adjunctive antimicrobial strategy in the dermatological care of AD.

MATERIALS AND METHODS

Study Design and Setting: This cross-sectional study was carried out in the Department of Microbiology in collaboration with the Department of Dermatology at a tertiary care teaching hospital located in North India. The study duration was twelve months, from October 2023 to October 2024. Institutional Ethical Committee approval was obtained prior to commencement, and written informed consent was secured from all participants or their guardians in the case of minors.

Study Population and Sample Collection: The study included patients aged 5 to 50 years who were clinically diagnosed with atopic dermatitis based on Hanifin and Rajka criteria and presented with active skin lesions [9]. Exclusion criteria included recent use (within the previous two weeks) of systemic or topical antibiotics, corticosteroids, or antiseptics. A total of 48 eligible patients were enrolled consecutively from the dermatology outpatient department. Lesional skin swabs were collected under aseptic precautions using sterile cotton swabs pre-moistened with normal saline. Swabs were placed in sterile containers and transported immediately to the microbiology laboratory for culture.

Microbiological Processing and Identification of Isolates: Each swab sample was inoculated onto blood agar and mannitol salt agar (HiMedia Laboratories, India) and incubated aerobically at 37°C for 24 to 48 hours. Colonies with morphological features suggestive of Staphylococcus spp.—such as golden yellow colonies with mannitol fermentation—were selected for further identification. Gram staining and catalase testing were performed, followed by slide and tube coagulase tests to differentiate Staphylococcus aureus from coagulase-negative staphylococci (CoNS). Species-level identification was confirmed using standard biochemical tests and, where required, automated identification via the VITEK 2 Compact system (bioMérieux).

Preparation of Potassium Permanganate Solutions: Potassium permanganate ($KMnO_4$) of analytical grade (Merck, India) was used for the study. A 1% stock solution was prepared by dissolving 1 gram of $KMnO_4$ in 100 mL of sterile distilled water. From this stock, working solutions of 0.01%, 0.05%, 0.1%, and 0.2% were freshly prepared prior to testing. These concentrations were selected based on their conventional clinical use in dermatology for antisepsis and wound management.

Antimicrobial Susceptibility Testing: The antimicrobial activity of $KMnO_4$ against the staphylococcal isolates was evaluated using the agar well diffusion method on Mueller-Hinton agar (HiMedia) as per CLSI guidelines.[10] A standardized bacterial suspension equivalent to 0.5 McFarland turbidity standard was prepared for each isolate. Using a sterile swab, the suspension was evenly spread to create a lawn culture. Wells of 6 mm diameter were punched into the agar and filled with 100 µL of each $KMnO_4$ concentration. Plates were incubated at 37°C for 24 hours. Zones of inhibition were measured in millimeters using a digital Vernier caliper. Each isolate was tested in triplicate to ensure consistency. Sterile distilled water served as the negative control, and vancomycin (30 µg) disc was used as the positive control for S. aureus.

Statistical Analysis: All data were compiled in Microsoft Excel and analyzed using SPSS version 20.0. Continuous variables were summarized as mean ± SD, and categorical variables as frequencies and percentages. Independent t-tests were used to compare mean inhibition zones between S. aureus and CoNS. Paired t-tests compared $KMnO_4$ (0.2%) and vancomycin inhibition zones. Pearson's correlation assessed the relationship between EASI scores and $KMnO_4$ response. Correlation was illustrated with a scatter plot and regression line. A p-value <0.05 was considered statistically significant.

RESULTS

Among the 48 patients with atopic dermatitis, the mean age was 21.8 ± 9.2 years, with the majority falling in the 15–30-year age group (41.7%). Males slightly outnumbered females (54.2% vs. 45.8%). The average disease duration was 13.6 ± 5.4 months. Subacute lesions were most common (41.7%), followed by chronic (33.3%) and acute types (25%). The mean body surface area involved was 11.4 ± 4.9%, and the average EASI score was 8.3 ± 2.7. Moisturizer use was reported by 81.3% of patients, while 68.8% had a history of secondary skin infections [Table 1].

Table 1: Demographic and Clinical Characteristics of Patients with Atopic Dermatitis (n = 50).

Variable	Frequency (%)/mean ± SD
Age (years)	21.8 ± 9.2
Age group	
5-14 years	18 (37.5%)
15-30 years	20 (41.7%)
>30 years	10 (20.8%)
Gender	
Male	26 (54.2%)
Female	22 (45.8%)
Duration of disease (months)	13.6 ± 5.4
Type of lesion	
Acute	12 (25%)
Subacute	20 (41.7%)
Chronic	16 (33.3%)
Body Surface Area involved (%)	11.4 ± 4.9
EASI Score	8.3 ± 2.7
Use of moisturizers in past 2 weeks	39 (81.3%)
History of secondary skin infection	33 (68.8%)

Out of 54 staphylococcal isolates recovered, Staphylococcus aureus was the predominant species (66.7%), followed by coagulase-negative staphylococci (CoNS) at 33.3%. Methicillin resistance was detected in 30.6% of S. aureus isolates. Biofilm production was observed in 75% of S. aureus and 55.6% of CoNS. Notably, 6 patients (12.5%) harbored both S. aureus and CoNS simultaneously from the same lesion [Table 2].

Table 2: Distribution of Staphylococcal Species and Resistance Patterns (n=54)#.

Organism Isolated	Frequency (%)	MRSA (%)	Biofilm Producers (%)
Staphylococcus aureus	36 (66.7%)	11 (30.6%)*	27 (75.0%)*
Coagulase-negative staphylococci (CoNS)	18 (33.3%)	NA	10 (55.6%)**

*n=36; **n=18; #6 patients yielded more than one isolate (e.g., S. aureus + CoNS).

The antimicrobial activity of potassium permanganate increased in a concentration-dependent manner. At 0.01%, the mean zone of inhibition was 4.3 ± 1.6 mm, with only 11.1% of isolates showing zones ≥10 mm. This increased progressively to 12.8 ± 2.5 mm at 0.2%, where 94.4% of isolates demonstrated effective inhibition (≥10 mm), indicating strong bactericidal activity at higher concentrations [Table 3].

Table 3: Zone of Inhibition (mm) of Potassium Permanganate at Different Concentrations Against All Staphylococcal Isolates (n = 54).

$KMnO_4$ Concentration (%)	Zone of Inhibition (mm)		Isolates with ≥10 mm Zone
	mean ± SD	Min–Max	Frequency (%)
0.01%	4.3 ± 1.6	2–7	6 (11.1%)
0.05%	6.8 ± 1.9	4–10	23 (42.6%)
0.10%	9.6 ± 2.2	6–14	38 (70.4%)
0.20%	12.8 ± 2.5	9–18	51 (94.4%)

When comparing species-specific responses, CoNS consistently exhibited slightly larger inhibition zones than S. aureus at all $KMnO_4$ concentrations, though the differences were not statistically significant ($p > 0.05$). At 0.2%, the mean zone for S. aureus was 12.4 ± 2.4 mm compared to 13.6 ± 2.7 mm for CoNS ($p = 0.067$) [Table 4].

Table 4: Comparison of Mean Zone of Inhibition Between S. aureus and CoNS at Different $KMnO_4$ Concentrations.

$KMnO_4$ (%)	S. aureus (n=36)	CoNS (n=18)	t value	p-value
	Mean ± SD (mm)			
0.01%	4.1 ± 1.5	4.7 ± 1.7	t = 1.20	0.235
0.05%	6.5 ± 1.8	7.4 ± 1.9	t = 1.88	0.065
0.10%	9.3 ± 2.1	10.1 ± 2.3	t = 1.31	0.195
0.20%	12.4 ± 2.4	13.6 ± 2.7	t = 1.86	0.067

The mean zone of inhibition with vancomycin was significantly greater than that of 0.2% $KMnO_4$ for both S. aureus (16.2 ± 2.1 mm vs. 12.4 ± 2.4 mm, $p < 0.001$) and CoNS (17.1 ± 1.8 mm vs. 13.6 ± 2.7 mm, $p < 0.001$). However, $KMnO_4$ still achieved inhibition comparable to vancomycin in 5.6% of S. aureus and 16.7% of CoNS isolates, suggesting potential as a topical adjunct [Table 5].

Table 5: Comparison of Inhibition Zone of $KMnO_4$ (0.2%) Versus Vancomycin Disc Among Staphylococcal Isolates.

Organism Isolated	$KMnO_4$ 0.2%	Vancomycin 30 µg	% $KMnO_4$ ≥ Vancomycin	t value	p-value
	Mean ± SD (mm)				
S. aureus (n=36)	12.4 ± 2.4	16.2 ± 2.1	2 (5.6%)	t = 7.38	<0.001
CoNS (n=18)	13.6 ± 2.7	17.1 ± 1.8	3 (16.7%)	t = 4.85	<0.001

A moderate inverse correlation (r = –0.32, p = 0.018) was observed between EASI scores and zone of inhibition at 0.2% $KMnO_4$ concentration. This suggests that higher clinical severity was associated with reduced antimicrobial response, possibly due to heavier bacterial colonization or biofilm presence in severe lesions [Figure 1].

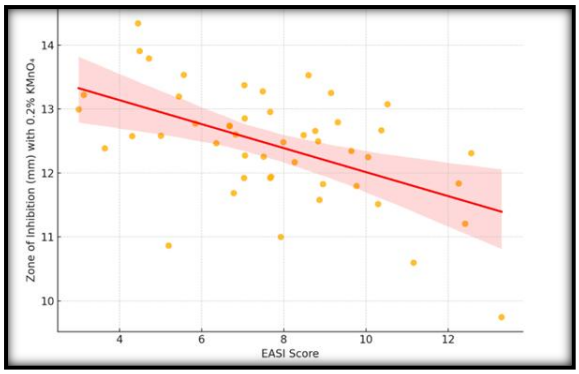

Figure 1: Correlation Between Clinical Severity (EASI Score) and Zone of Inhibition.

DISCUSSION

The present study aimed to evaluate the in vitro antimicrobial activity of potassium permanganate ($KMnO_4$) against Staphylococcus species isolated from the skin lesions of patients with atopic dermatitis (AD), a chronic, relapsing inflammatory skin condition frequently complicated by bacterial colonization and secondary infection. The demographic distribution of our sample revealed a predominance of younger individuals, with a mean age of 21.8 years and the majority in the 15–30-year age group. This reflects the epidemiologic trends observed in both Indian and global populations, where AD increasingly affects adolescents and young adults.[11,12] Male predominance (54.2%) and the mean EASI score of 8.3 ± 2.7 are also in line with studies reporting moderate disease severity and higher exposure to environmental risk factors among males in semi-urban settings.[13]

A striking 68.8% of our cohort had a history of secondary skin infections, emphasizing the high clinical relevance of microbial colonization in AD pathogenesis and exacerbations. Staphylococcus aureus was isolated in 66.7% of patients, consistent with reviews Ogonowska et al., and Demessant-Flavigny et al., reporting colonization rates between 60% and 90% in both lesional and non-lesional skin.[14,15] Coagulase-negative staphylococci (CoNS) were also identified in 33.3% of isolates, and 12.5% of patients yielded both organisms simultaneously. These findings are in agreement with the review Huang et al., who highlighted microbial dysbiosis with dominance of S. aureus over CoNS species, especially during active flares of AD.[16]

Of particular concern in our findings is the high prevalence (30.6%) of methicillin-resistant S. aureus (MRSA) among isolates, reinforcing global trends of antimicrobial resistance even in community settings. Narayan et al., reported MRSA colonization in 28% of children with AD, while study by Sangaphunchai et al., have found resistance rates ranging from 20–35%.[17,18] Furthermore, biofilm formation was observed in 75% of S. aureus and 55.6% of CoNS isolates. This aligns with reports from Datta et al., and Silva et al., indicating that biofilm-producing strains are more prevalent in chronic dermatological infections and are less susceptible to conventional antibiotics.[19,20] Biofilms not only protect bacteria from host immune responses and antimicrobials but also contribute to chronic inflammation and delayed healing in AD.

The antimicrobial efficacy of potassium permanganate increased proportionally with its concentration. At 0.2%, $KMnO_4$ achieved a mean zone of inhibition of 12.8 ± 2.5 mm, effectively inhibiting 94.4% of isolates with zones ≥10 mm. These findings are consistent with the study by Lundgren et al., who demonstrated dose-dependent bactericidal effects of $KMnO_4$ against S. aureus in chronic wound models.[21] In our study, lower concentrations (0.01% and 0.05%) showed limited activity (zones ≥10 mm in only 11.1% and 42.6% of isolates respectively), which corroborates prior study by Roy et al., that concentrations below 0.1% are often subtherapeutic.[22]

Notably, CoNS isolates demonstrated slightly higher mean zones of inhibition than S. aureus across all $KMnO_4$ concentrations, although the differences did not reach statistical significance ($p > 0.05$). This pattern may reflect the greater resistance associated with S. aureus due to thickened peptidoglycan layers, MRSA strains, and more robust biofilm architecture.[23] Similar trends were reported by Severn et al., who found that S. epidermidis (a common CoNS) was more susceptible to oxidizing agents compared to S. aureus, especially in vitro.[24]

When compared to vancomycin—a reference standard antibiotic—$KMnO_4$ at 0.2% showed significantly smaller inhibition zones in both S. aureus (12.4 ± 2.4 mm vs. 16.2 ± 2.1 mm, $p < 0.001$) and CoNS (13.6 ± 2.7 mm vs. 17.1 ± 1.8 mm, $p < 0.001$). Despite this, a subset of isolates (5.6% of S. aureus and 16.7% of CoNS) exhibited zones with $KMnO_4$ that were comparable to or greater than vancomycin. This highlights the potential of $KMnO_4$ as a supportive topical agent, especially in superficial or early-stage infections, where systemic antibiotics may be excessive or contraindicated. Study Ebadian et al., have reported favorable outcomes when

$KMnO_4$ soaks were used adjunctively in infected eczematous dermatoses.[25]

The correlation analysis revealed a moderate but statistically significant inverse correlation between EASI score and $KMnO_4$ response ($r = –0.32$, $p = 0.018$), indicating that greater clinical severity was associated with reduced antimicrobial sensitivity. This finding may be attributed to higher bacterial burden, thicker biofilm layers, and disrupted skin barrier in more severe cases, which collectively hinder antiseptic penetration.[26] Boparai et al., previously demonstrated that impaired innate immunity and reduced antimicrobial peptides in severe AD contribute to enhanced colonization and treatment resistance, further supporting our findings.[27]

In terms of practical application, $KMnO_4$ offers several advantages including low cost, availability, and broad-spectrum antiseptic action. However, its efficacy appears limited to topical application and surface decontamination. It does not replace systemic antibiotics in deeper or spreading infections but may serve as an effective adjunct or preventive intervention, especially in low-resource settings where MRSA is endemic.

CONCLUSION

Our study demonstrated that potassium permanganate exhibits a concentration-dependent antimicrobial effect against Staphylococcus aureus and coagulase-negative staphylococci isolated from the skin of patients with atopic dermatitis. At 0.2%, it achieved substantial inhibition in over 90% of isolates, including some methicillin-resistant and biofilm-forming strains. While its efficacy was inferior to vancomycin, its low cost, accessibility, and broad-spectrum action support its role as an adjunct topical antiseptic. The inverse correlation between clinical severity and response highlights its potential in early or moderate cases. Further in vivo and clinical studies are warranted to validate these promising findings.

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