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Antimicrobial resistance in children's upper respiratory tract infections: A scoping review

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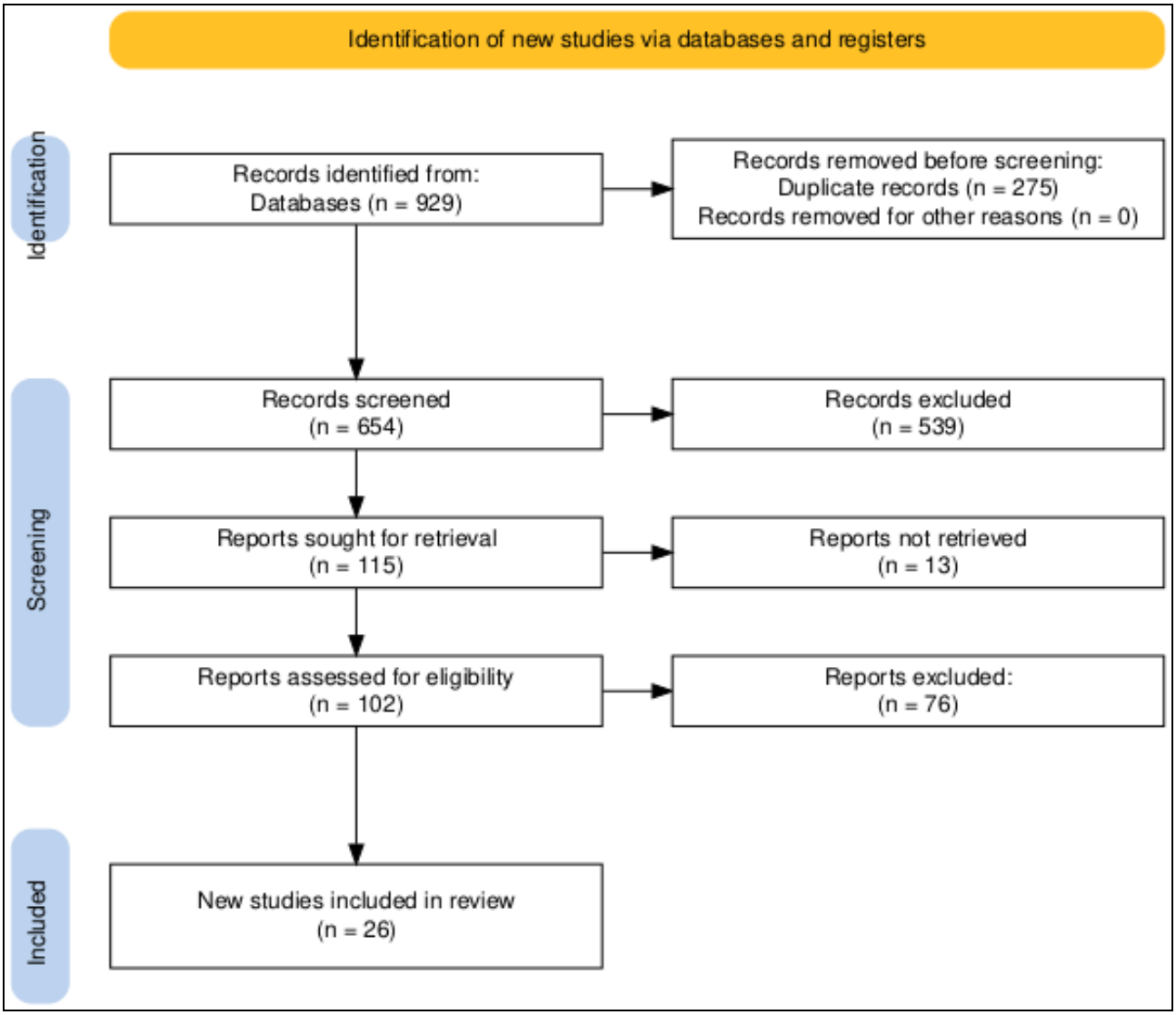
Abstract
Antimicrobial resistance in pediatric upper respiratory tract infections is a big concern around the world mainly due to the inappropriate and excessive use of antibiotics for largely viral conditions. This scoping review aimed to synthesize evidence on antimicrobial resistance patterns, evaluate the impact of antibiotic prescribing, and explore alternative strategies, including Homoeopathy. Studies published from 2013-2025 were reviewed. Findings showed that penicillin remains effective against Streptococcus pyogenes, but macrolide resistance shows concerning geographical variations. These results showed Homeopathic interventions as a potential to significantly reduce antibiotic consumption in pediatric upper respiratory tract infections, showing comparable clinical outcomes, improved symptom relief, and a favorable safety profile. This suggest that Homoeopathy can serve as a complementary strategy to conventional antibiotic stewardship programs, contributing to antimicrobial resistance mitigation.

Keywords: Drug resistance, infection upper respiratory, homoeopathy, children

Introduction
Upper respiratory tract infections a broad category which include several clinical syndromes such as rhinitis, pharyngitis, tonsillitis, laryngitis, sinusitis, otitis media and common cold. These infections represent a significant burden on health-care systems globally, largely due to their high incidence and prevalence in both adult and pediatric populations [1]. Upper Respiratory Tract Infections (URTI) are predominantly self-limiting conditions and most of these infections are of viral origin. Despite their predominantly viral etiology, antibiotics are frequently prescribed for these conditions in clinical practice [2].
Antimicrobial resistance (AMR) the ability of microorganisms to withstand the effects of antimicrobial drugs, leading to persistent infections and treatment failures has emerged as a major global public health threat, driven in part by inappropriate and excessive use of antibiotics in community infections such as URTI especially in pediatric cases [3]. In clinical practice, antibiotics are frequently prescribed for URTI's in children despite proper guideline recommendations to avoid their use in uncomplicated viral infections [4-6]. This inappropriate use of antibiotics has lead to the development of antimicrobial resistance over the years. This widespread practice contributes substantially to the global health crisis of antibiotic resistance, diminishing the effectiveness of these crucial medications for treating bacterial infections [7, 8]. An alternative system of medicine such as Homoeopathy can be an effective alternative, particularly for self-limiting viral URTIs, thereby reducing use of antibiotics and lessen the progression of antimicrobial resistance [9]. This scoping review aims to synthesize current evidence on the prevalence and patterns of antimicrobial resistance in URIs, evaluate the impact of antibiotic prescribing practices on this resistance, and explore potential strategies, including the role of alternative therapies like Homoeopathy.

Methods
This scoping review was done according to the Preferred Reporting Items Systematic Reviews and Meta-Analysis extension for Scoping Reviews (PRISMA-ScR) checklist. This review included studies for antimicrobial resistance pattern and its burden and homeopathic interventions in pediatric populations presenting with upper respiratory tract infections. Eligible studies includes RCTS, Cohort studies, observational studies, surveillance studies etc. published from 2013-2025.

To get relevant studies for this review a search strategy and eligibility criteria gas been developed. The search was conducted in different databases like PubMed, Research Gate, Google Scholar, HRI etc. An initial search was conducted in PubMed using MESH terms and later adapted to other databases.



Results

An overview of AMR papers showed that their is susceptibility of GAS isolates to penicillin, there by confirming the continued efficacy of penicillin based antibiotics as first line therapy for streptococcal pharyngitis. In the Ethiopian study all 22 of the recovered *S. Pyogenes* isolates showed susceptibility to both penicillin and amoxicillin [10]. This finding was constant in other countries like China, Greece, Iran as well as in those previous studies conducted within Ethiopia, suggesting that penicillin resistance in GAS remains uncommon in clinical practice (11-13). In a Greek surveillance study by analyzing 52 *S. Pyogenes* isolates recovered over a six year period (2015-2021), showed 100% susceptibility to both penicillin and cephalosporin compunds [12].

Beta-Lactam Resistance

A study conducted by Musser [14] showed a genome wide analysis of 7025 GAS strains globally, revealing that Penicillin Binding Proteins (PBP) 2x mutations are widespread and beta lactam resistance is emerging on a global scale. Vannice [15] in his study documented the first clinical cases demonstrating ppbx2 mutations associated with reduced penicillin and amoxicillin susceptibility in the USA. Sayyahfar [11] in his report showed 100% penicillin susceptibility in Iran.

Macrolide and lincosamide resistance

It is noted that Macrolide resistance emerged as a significant concern across multiple geographic regions, with substantial variation in resistance rates. In the Ethiopian study conducted by Gebre [10] the resistance rate to erythromycin was 27.3%, comparable to earlier investigations from other Ethiopian regions but lower than resistance rates seen in Asian populations. Iranian pediatric populations demonstrated concerning levels reporting about 57.6% azithromycin resistance and 33.9% erythromycin resistance among children aged 3-15 years with GAS pharyngitis, though penicillin remained 100% susceptible [11]. In contrast, Khademi [16] reported meta analytic estimate of 5.4% macrolide resistance in Iranian children, suggesting regional variation within country.

European studies revealed moderate resistance levels, with Meletis *et al.* [12] documenting 20.4% erythromycin reistance and tetracycline 40.8% and 17.4% in pediatric populations in Greece. Grivea *et al.* [17] from his study gave

evidence and linked these findings in Greek pediatric pharyngitis patients aged 3-18years, with certain resistance patterns to specific EMM types. Most variations is noted among Asian population, Li *et al*. [13] reported extreme macrolide resistance of 98.3% in china, showing marked geographic variation. Kwon & Kim [18] found only 3.2% macrolide resistance in south Korea, attributed to effective antimicrobial stewardship programs. Rafei [19] provided global systermic review documenting multiple macrolide resistance phenotypes and their worldwide distribution. A study conducted by Berbel [20] in Spain demonstrated the genetic elements by examining 1028 GAS isolates over a period of 21 years and identified 142 isolates demonstrating macrolide resistance.

Treatment Challenges

It is seen from the studies that highlighted clinical treatment limitations and mechanisims of treatment failure. Babiker [21] study showed GAS infections across different countries demonstrating adjunctive clindamycin improves outcomes in invasive infections, suggesting limitations of beta lactam monotherapy.

Reduction in Antibiotic prescribing and antimicrobial resistance burden

Homeopathic interventions showed significant possibility to reduce antibiotic consumption in pediatric URTI populations by directly addressing antimicrobial resistance concerns. The most important evidence comes from large scale cohort study conducted in Germany by taking 610,118 patients with acute URTI, where homoepathic treatment was associated with significantly fewer antibiotic prescriptions when compared to conventional cough and cold medicines and nasal medicines over a 12 month follow up. This study indicates a reduction in the antibiotic exposure at the population level, suggesting Homoeopathy as an effective antibiotic strategy [22].

An antibiotic stewardship pediatric RCT study assessed CalSuli-4-02 for recurrent URTI prevention, which showed decreased antibiotic use in both treatment groups, with the homeopathic intervention showing superior symptom improvement and higher treatment satisfaction [23].

A systematic review examining Homoeopathy's role in AMR mitigation concluded that homeopathic treatment can lower infection recurrence and reduce antibiotic reliance while demonstrating comparable clinical outcomes to conventional treatments, supporting integration within WHO's One Health framework. The policy analysis emphasized that with 1.27 million deaths annually from AMR and 30% of antibiotic prescriptions being inappropriate, Homoeopathy represents a viable complementary method to reduce resistant organisms [24].

Clinical effectiveness enabling antibiotic stewardship

A randomized double-blind placebo-controlled trail of homeopathic syrup for acute cough (N=80) showed reduced lower cough severity after 4days and 7 days with no treatment related adverse events [25]. Similarly an RCT of 261 preschool children found that homeopathic treatment produced significant improvement in sneezing, cough, and composite score during 1-2 days compared to placebo [26].

A case series of 5 children with chronic tonsillitis showed marked improvement with individualized homeopathic medicines and no adverse effects [27]. An invitro study of plant based homeopathic medicines showed antibacterial activity that could further reduce antibiotic needs [28].

The safety profile was consistently favourable across all studies with minimal adverse effects and higher parental satisfaction (75% vs 27% "very satisfied", P=0.0001), supporting acceptability as an antibiotic alternative [29]. These findings can eventually supports the homoeopathic interventions as an alternative for antimicrobial stewardship programs in pediatric primary care.

Discussion

Antimicrobial Resistance (AMR) poses a significant challenge in the management of upper respiratory tract infection, primarily due to the over prescription and inappropriate use of antibiotics. As a result the search of alternate solutions comes-up in the community and Homoeopathy emerges as a potential valuable alternative in such cases.

One of the fundamental concepts of Homoeopathy is its individualized treatment. This patient-centered approach serves as a cornerstone of homeopathic practice, embodying a philosophy that recognizes each individual as a distinct entity with specific physical, emotional, and psychological attributes. Homeopathic remedies are selected based on a comprehensive analysis of the patient's symptoms and constitution. This holistic and patient-centered method helps in understanding of health and illness, thereby facilitating more effective and compassionate care.

In treating URTIs, homoepathy uses individualized remedies for specific symptoms and overall health of the child. This avoids the unnecessary use of antibiotics which can lead or contribute to AMR.Homoeopathy promotes preventive measures through the use of constitutional remedies that aim to strengthen the child's overall health and immunity. By focusing on enhancing the childs vitality and resilience, Homoeopathy may lead to fewer infections and reduced antibiotic use-age.

A systemic review by Fixsen [1] of post-1994 clinical studies examining Homoeopathic treatment of URTI's and their complications found positive outcomes overall with results suggesting "at least equivalence between Homoeopathy and conventional treatment for uncomplicated URTI's with fewer adverse events and potential broader therapeutic outcomes" and critically, 'in the light of antimicrobial resistance Homoeopathy offers alternative strategies for minor infections and possible prevention of recurring URTI's. The HRI submission to a UK parliamentary AMR inquiry presented evidence that Homoeopathy could reduce antibiotic prescribing by comparing individualized Homoeopathy with conventional care in 81 children "the Homoeopathy group required no antibiotics" while achieving equivalent clinical outcomes with symptomatic improvement occuring more rapidly.

Conclusion

With the escalating utilization of antibiotics for the treatment of respiratory tract infections, even those of viral etiology, a concerning pattern of resistance has emerged over recent years. This inappropriate administration of antibiotics has rendered the management of respiratory infections, particularly in pediatric populations, increasingly challenging. To mitigate the prevalence of unwarranted antibiotic prescriptions, it is imperative to implement effective strategies that encompass the education of both

healthcare professionals and parents, alongside the establishment of stewardship programs. Furthermore, alternative medicinal approaches, such as Homoeopathy, may contribute to the reduction of antimicrobial resistance (AMR).

Conflict of Interest
Not available

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Not available

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