Syahniar et al | Article 8957
J Pure Appl Microbiol. 2024;18(2):1319-1325. doi: 10.22207/JPAM.18.2.54
Received: 31 August 2023 | Accepted: 30 April 2024
Published Online: 02 June 2024

P-ISSN: 0973-7510; E-ISSN: 2581-690X

RESEARCH ARTICLE OPEN ACCESS

Nasal Carriage and Antimicrobial Susceptibility Pattern of *Staphylococcus aureus* among Breastfeeding Mothers and their Infants

Rike Syahniar[1]*, Adinta Anandani[1], Aning Subiyatin[2] and Hanif Ahmad Mubarok[3]

[1]Department of Microbiology, Faculty of Medicine and Health, Universitas Muhammadiyah Jakarta, Jakarta, Indonesia.
[2]Department of Midwifery, Faculty of Medicine and Health, Universitas Muhammadiyah Jakarta, Jakarta, Indonesia.
[3]Medical Study Program, Faculty of Medicine and Health, Universitas Muhammadiyah Jakarta, Jakarta, Indonesia.

Abstract

Most *S. aureus* infections are multidrug resistant. *S. aureus* infections often occur with prolonged conditions, causing increased treatment costs and mortality rates. There is a need to understand the antibiotic susceptibility pattern to *S. aureus* in mothers and infants because the burden of *S. aureus* infection in infants is high. This study aims to determine the prevalence of nasal carriers of *S. aureus* in lactating mothers and their infants and their antibiotic susceptibility patterns. This cross-sectional study involved 59 pairs of breastfeeding mothers and infants aged 0 to 6 months. The research was conducted in the work area of the South Tangerang City Health Office. We take a nasal swab of the mother and the baby. We used Vitek-2 to determine antibiotic resistance against *S. aureus*. Overall, we found 22/59 (37%) *S. aureus* in infants' noses, 18% of whom were MRSA. In mothers, we found 18/59 (30%) *S. aureus* isolates and 17% were MRSA. The majority of *S. aureus* isolates from infants were sensitive to cefoxitin (82%), gentamicin (86%), ciprofloxacin (91%), levofloxacin (95%), moxifloxacin (91%), vancomycin (100%), clindamycin (82%), erythromycin (86%), nitrofurantoin (100%), linezolid (100%) and tetracycline (77%). The majority of *S. aureus* isolates from mothers are sensitive to cefoxitin (83%), gentamicin (94%), ciprofloxacin (89%), levofloxacin (89%), moxifloxacin (89%), vancomycin (100%), clindamycin (89%), erythromycin (89%), nitrofurantoin (100%), linezolid (100%) and tetracycline (83%). MRSA monitoring of mothers and babies in the community needs to be done to prevent and control the spread.

Keywords: Antibiotics, Infant, MRSA, *Staphylococcus aureus,* Lactating Mothers

***Correspondence:** ri.syahniar@umj.ac.id

Citation: Syahniar R, Anandani A, Subiyatin A, Mubarok HA. Nasal Carriage and Antimicrobial Susceptibility Pattern of *Staphylococcus aureus* among Breastfeeding Mothers and their Infants. *J Pure Appl Microbiol.* 2024;18(2):1319-1325. doi: 10.22207/JPAM.18.2.54

INTRODUCTION

Staphylococcus aureus infections range from soft tissue infections to bacteremia, which causes morbidity or mortality in hospital and community settings.[1] *S. aureus* infections that should be treated with antibiotics have been found to have *S. aureus* strains resistant to several antibiotics.[2] Infants appear especially susceptible to colonization and infection with Methicillin-Resistant *Staphylococcus aureus* (MRSA). Colonization or MRSA infection in neonates is associated with significant morbidity, causing a burden of medical care costs for affected infants.[3] MRSA colonization rates in neonatal infections range from 3.9% to 32%. This is of particular concern among important pathogens causing infections in hospitals.[4] MRSA transmission is most likely through the birth canal and/or through contact with surrounding people, namely parents, health workers, visitors, or a contaminated hospital environment.[4]

The prevalence of *S. aureus* resistance in Asia, both methicillin resistance acquired in healthcare and the community, is the highest in the world.[2] The systematic review study that we have done has found the prevalence of MRSA 0.3%-52% from various clinical isolates in Indonesia.[5] The results of a meta-analysis study found that infants who were colonized with MRSA were approximately five times more likely to develop MRSA infection than infants who were not colonized.[4]

In recent decades, the prevalence of infections caused by MRSA has increased among healthy people, especially children.[1] *S. aureus* carried maternally was identified as a risk factor for early colonization in postnatal infants.[6] Newborns acquire *S. aureus*, including MRSA, from adult sources because many healthy individuals can carry it as part of their normal microflora. There are few studies on the pattern of *S. aureus* sensitivity to antibiotics in nursing mothers and infants. The aim of this study was to determine the prevalence of nasal carriers of *S. aureus* in lactating mothers and their infants and their pattern of antibiotic susceptibility.

MATERIALS AND METHODS

Study design and research subject

This research was a cross-sectional study involving infants who were taken in the South Tangerang City. We took samples from June 2022 to July 2023. The inclusion criteria for breastfeeding mothers are not suffering from mastitis or breast abscess infections and not taking antibiotics for the last two weeks. Inclusion criteria for infants are aged 0-6 months in good health, and not taking antibiotics for the previous two weeks. Exclusion criteria for breastfeeding mothers were experiencing severe infection and suffering from flu, and samples were not met from the mother's nasal swab. Exclusion criteria for infants included severe infection, flu, and samples from the baby's nasal swab were not met. Using a questionnaire, we interviewed respondents to obtain information on demographic characteristics and birth history.

Specimen collection

We took baby and mother nasal swabs using a sterile cotton swab by inserting it into the nose about 2 cm deep and then rotating it 360° for about 3 seconds. Nasal swabs are moistened with sterile phosphate buffered saline before being inserted into the nostrils. The swab was inserted into the Amies transport medium. All specimens were brought to the FMH UMJ laboratory for culture.

Isolation, identification, and antibiotic sensitivity test

All specimens were grown on mannitol Salt Agar (MSA). All media were incubated at 37°C for 24-48 hours under aerobic conditions—initial identification by observation of colonies and gram staining. *S. aureus* identification and sensitivity test using the VITEK®2 System (BioMérieux, Marcy-l' Etoile, France) with GP cartridges according to the manufacturer's instructions. The results were based on the antimicrobial susceptibility guidelines of the Clinical Laboratory Standards Institute (CLSI)—determination of MRSA based on cefoxitin antibiotic resistance. The antibiotics tested included cefoxitin, linezolid, ciprofloxacin, clindamycin, erythromycin, moxifloxacin, vancomycin, tetracycline, benzylpenicillin, levofloxacin, gentamicin, and nitrofurantoin.

Table 1. Characteristics of participants and their relationship to *S. aureus* carriers

Characteristic	Range	Mean (SD)	Frequency	*S. aureus* Infant Carrier (n=59)		p-value
				Yes	No	
Mother's Age	16-42	29.76 (5.97)				
Baby's Age (mo)[a]	1-5	2.6 (1.39)				
≤ 2			29 (49%)	13	16	0.239
> 2			30 (51%)	9	21	
Baby's Gender[a]						
Female			36 (61%)	15	21	0.384
Male			23 (39%)	7	16	
Get fully breastfed[a]						
Yes			54 (91.5%)	19	35	0.272
No			5 (8.5%)	3	2	
Delivery Type[a]						
Vaginal			26 (44%)	9	17	0.706
Cesarean			33 (56%)	13	20	
Birthweight (gram)[a]						
<2500			5 (8.5%)	3	2	0.272
≥2500			54 (91.5%)	19	35	
Primiparity[a]						
Yes			22 (37%)	7	15	0.503
No			37 (63%)	15	22	
Total			58 (100%)	22 (37%)	37 (63%)	

Data analysis

Data was entered into Microsoft Excel and presented as tables and graphs. Chi-square test or Fisher's exact test was used for analysis data on characteristics with *S. aureus* carriage in infants using the Statistical Package for the Social Sciences (version 22.0; SPSS). The determination of statistical significance used is p<0.05.

RESULTS

A total of 59 pairs of mothers and babies became the subject of this study. The babies' ages range from 1 to 5 months, with an average of 2.6±1.39 months. Maternal age ranged from 16 to 42 years, averaging 29.76±5.97 years. In this study, 49% of infants aged less than two months and more than two months were the same at 51%. Thirty-six (61%) babies were girls, and 23 (39%) were boys. Most of the babies (91.5 %) were fully breastfed, and the rest received formula or mixed breast milk and formula. Thirty-three (56%) were delivered by cesarean section, and the remainder by vaginal delivery. A total of 54 (91.5%) babies were born normally (≥2500 grams). Twenty-two (37%) mothers had primiparity, and thirty-seven (63%) had no primiparity. Table 1 shows that all characteristics have no relationship with *S. aureus* carrier in infants (p<0.05).

Overall, we found 22/59 (37%) *S. aureus* in the noses of the babies and 18/59 (30%) mothers. Table 2 shows that the pattern of antibiotic susceptibility showed that of the 18 maternal *S. aureus* isolates, 15/18 (83%) were Methicillin Sensitive *Staphylococcus aureus* (MSSA), and the remaining 3/18 (17%) were MRSA. The majority of *S. aureus* isolates from mothers are sensitive to cefoxitin (83%), gentamicin (94%), ciprofloxacin (89%), levofloxacin (89%), moxifloxacin (89%), vancomycin (100%), clindamycin (89%), erythromycin (89%), nitrofurantoin (100%), linezolid (100%) and tetracycline (83%). Most

Table 2. Antibiotic Susceptibility Pattern of *S. aureus* Isolated from Mother's Nasal Swab

Antibiotic Agent	Susceptible n (%)	Intermediate n (%)	Resistant n (%)
Cefoxitin	15 (83)	0 (0)	3 (17)
Gentamicin	17 (94)	1 (6)	0 (0)
Benzylpenicillin	4 (22)	0 (0)	14 (78)
Ciprofloxacin	16 (89)	0 (0)	2 (11)
Levofloxacin	16 (89)	0 (0)	2 (11)
Moxifloxacin	16 (89)	0 (0)	2 (11)
Vancomycin	18 (100)	0 (0)	0 (0)
Clindamycin	16 (89)	0 (0)	2 (11)
Erythromycin	16 (89)	0 (0)	2 (11)
Nitrofurantoin	18 (100)	0 (0)	0 (0)
Linezolid	18 (100)	0 (0)	0 (0)
Tetracycline	15 (83)	0 (0)	3 (17)

Table 3. Antibiotic Susceptibility Pattern of *S. aureus* Isolated from Baby's Nasal Swab

Antibiotic Agent	Susceptible n (%)	Intermediate n (%)	Resistant n (%)
Cefoxitin	18 (82)	0 (0)	4 (18)
Gentamicin	19 (86)	1 (5)	2 (9)
Benzylpenicillin	4 (18)	0 (0)	18 (82)
Ciprofloxacin	20 (91)	1 (5)	1 (5)
Levofloxacin	21 (95)	0 (0)	1 (5)
Moxifloxacin	20 (91)	0 (0)	2 (9)
Vancomycin	22 (100)	0 (0)	0 (0)
Clindamycin	18 (82)	0 (0)	4 (18)
Erythromycin	19 (86)	0 (0)	3 (14)
Nitrofurantoin	22 (100)	0 (0)	0 (0)
Linezolid	22 (100)	0 (0)	0 (0)
Tetracycline	17 (77)	0 (0)	5 (23)

of the isolates were resistant to benzylpenicillin (78%).

The results of antibiotic susceptibility patterns showed that of the 22 infant *S. aureus* isolates, 18/22 (82%) were Methicillin Sensitive *Staphylococcus aureus* (MSSA), and the remaining 4/22 (18%) were MRSA. The majority of *S. aureus* isolates from infants were sensitive to cefoxitin (82%), gentamicin (86%), ciprofloxacin (91%), levofloxacin (95%), moxifloxacin (91%), vancomycin (100%), clindamycin (82%), erythromycin (86%), nitrofurantoin (100%), linezolid (100%) and tetracycline (77%). Most of the isolates were resistant to benzylpenicillin (82%) (Table 3).

Of the seven pairs of mothers and babies, four pairs of mothers and babies had the same pattern of antibiotic sensitivity (Table 4). In sample 22, there were differences in the susceptibility pattern to gentamicin and tetracyclin antibiotics, sample 32 to benzylpenicillin antibiotics, and sample 56 to the antibiotics moxifloxacin and clindamycin.

DISCUSSION

Studies estimate that at least 70-90% of the general population are intermittent carriers of *S. aureus*.[7] About 20% of the people are persistent carriers, and about 60% of colonization occurs intermittently, with a high level of colonization in children.[7,8] Only about 20-30% of the population are not carriers and have never hosted *S. aureus*.[7]

In this study, we obtained nasal carriage of *S. aureus* in mothers (30%) and infants (37%). This result was lower than the Schaumburg study,[9] which got 41.7%, and Accorsi EK[10] got 56% *S. aureus* from nasal swabs in infants. In mothers, the results of this study were higher than those of Aylana et al. Getting *S. aureus* in healthy mothers is 19.3%. The anterior nares are the main reservoir of *S. aureus* and a significant risk factor for developing a patent staphylococcal infection, either community-acquired or health-care-acquired.[11] When *S. aureus* begins to enter the host and the host's defenses are overcome, *S. aureus* begins to spread and settle into the anterior nose so that the host becomes a nasal carrier of *S. aureus*.[12]

The infant's age is in the range of 1 to 5 months. In this study, 49% of infants aged less than two months and more than two months were the same at 51%. The average carriage rate in the first eight weeks of life is around 40-50%, after which it drops to 21% at six months.[11] Colonization of *S. aureus* generally peaks in newborns until 1-2 months of age and then declines at six months of age.[13] In contrast to this study, there was more *S. aureus* in babies more than 2 months old. In addition, we found no difference in infant age in *S. aureus* carriers (p=0.412). This can be caused by environmental influences, including interference from pathogenic flora and other non-pathogenic NPs.[13] Additionally, the hygiene practices of better mothers or caregivers can lead to decreased bacterial clearance. Most of the babies (62%) were

Table 4. Antimicrobial Susceptibility Pattern of *S. aureus* Isolated from Mother and Baby's Nasal Swab

Sample Number	Participant	FOX	GEN	BEN	CIP	LEV	MOX	VAN	CLIN	ERY	NIT	Lin	TET
22	Mother/ Baby	S/S	S/R	R/R	S/S	S/S	S/S	S/S	S/S	S/S	S/S	S/S	R/S
27	Mother/ Baby	R/R	S/S	R/R	R/R	R/R	R/R	S/S	R/R	R/R	S/S	S/S	S/S
30	Mother/ Baby	S/S	S/S	R/R	S/S	S/S	S/S	S/S	S/S	S/S	S/S	S/S	S/S
32	Mother/ Baby	S/S	S/S	R/S	S/S	S/S	S/S	S/S	S/S	S/S	S/S	S/S	S/S
36	Mother/ Baby	S/S	S/S	R/R	S/S	S/S	S/S	S/S	S/S	S/S	S/S	S/S	S/S
53	Mother/ Baby	S/S	S/S	R/R	S/S	S/S	S/S	S/S	S/S	S/S	S/S	S/S	R/R
56	Mother/ Baby	S/S	S/S	S/S	S/S	S/S	S/R	S/S	S/R	S/S	S/S	S/S	S/S

Abbreviations: Cefoxitin (FOX); Gentamicin (GEN); Benzylpenicillin (BEN); Ciprofloxacin (CIP); Levofloxacin (LEV); Moxifloxacin (MOX); Vancomycin (VAN); Clindamycin (CLIN); Erythromycin (ERY); Nitrofurantoin (NIT); Linezolid (LIN); Tetracycline (TET)

female. Studies found that the female sex was a risk factor for MSSA and MRSA colonization,[14] but in this study, we found no difference (p=0.587).

Most of the babies (93%) were fully breastfed, and the rest received formula or mixed breast milk and formula. This study did not show the effect of full breastfeeding on the presence of *S. aureus* in the infant's nose. Most babies (55%) have been born by cesarean section, and the rest through the vaginal process. In this study, we found no difference between vaginal and cesarean delivery in the presence of *S. aureus* in the baby's nasal passages (p=0.437). This result is similar to another study.[12] Although vertical transmission via the vaginal route of the mother concomitantly and early infant colonization may occur, horizontal transmission in early neonatal life appears to be more common.[6] Another study found vaginal delivery to be a risk factor for MSSA but not for MRSA colonization.[14]

In this study, most isolates were sensitive to almost all antibiotics. However, we found MRSA isolates in mothers (17%) and infants (18%). This result is similar to a study in Ethiopia in healthy children, namely 18.8%.[15] However, this result is higher than Denmark at 0.11%[16] and Taiwan, which found that the rate of nasal MRSA carriage was 10.2% in children aged 2-6 months, significantly associated with MRSA carriage.[17] Differences in MRSA detection results may be caused by differences in diagnostic methods used to confirm/detect MRSA other than the cefoxitin disc detection method, differences in geographic distribution, study population characteristics, sampling quality, and culture techniques.

More than 50% of maternal and infant *S. aureus* isolates in this study were sensitive to cefoxitin (82%), gentamicin (86%), ciprofloxacin (91%), levofloxacin (95%), moxifloxacin (91%), vancomycin (100%), clindamycin (82%), erythromycin (86%), nitrofurantoin (100%), linezolid (100%) and tetracycline (77%). However, benzylpenicillin has a resistance of 83%. These results are in line with many studies on healthy people in Ethiopia (99.3%), China (87.5%), Nigeria (100%), and Ghana (95%).[8,18-20] This may be observed because penicillin and ampicillin have been on the market for a long time, are cheap, and easy to obtain without a prescription (despite being prescription drugs). Therefore, penicillin may have been widely abused.

Tetracycline, clindamycin, and erythromycin are commonly prescribed antibiotics in the community. The emergence of resistance to other essential antimicrobials, such as clindamycin, has a meaningful impact on clinical outcomes and treatment choices. Clindamycin is associated with reduced relapse rates and a lower risk of treatment failure for *S. aureus* and other types of skin & soft tissue infections (SSTIs). Clindamycin is usually used to treat uncomplicated infections in the pediatric population. Given the increasing prevalence of clindamycin resistance in MSSA isolates from clinically significant infections, it is necessary to encourage clinicians to re-evaluate this prescribing practice. In addition, it should be a concern, especially if local data shows that clindamycin is not routinely active against *S. aureus* isolates.[21]

The high-risk population of newborns generally receives broad-spectrum antimicrobial

agents as empiric therapy. The initial administration of antimicrobials by the clinician is based on initial clinical suspicion because microbiological examination evidence takes time. Identification results from culture results usually only come out 24 to 72 hours later. Vancomycin can be used as both empirical and definitive therapy because it is still susceptible to most MRSA infections. Newer agents, such as linezolid, may also be used as alternative oral regimens if available and considered cost-effective.[22] This research is limited to only taking samples from one site. Therefore, we may miss MRSA colonies in the axillae, throat, perineum, and anal areas, although the anterior nose is the site of the highest colonization. In addition, this study did not identify cohort factors that influence carriers of *S. aureus*.

CONCLUSION

We found MRSA in mothers (17%) and their babies (18%). Although most antibiotics are still susceptible to *S. aureus*, some antibiotics are resistant, such as benzylpenicillin, tetracycline, clindamycin, erythromycin, oxacillin, moxifloxacin, gentamicin, ciprofloxacin, and levofloxacin. Education, ongoing surveillance, and decolonization of carriers are essential to prevent transmission in the community.

ACKNOWLEDGMENTS

The authors would like to the thank the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia, LLDIKTI Region 3, and LPPM Universitas Muhammadiyah Jakarta for their funding and facilitation. Authors are also thankful the South Tangerang City Health Office for granting permission for the research location.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORS' CONTRIBUTION

RS conceptualized the study. RS, AA, AS and HAM collected the data and organized the samples. RS and AA performed laboratory analysis. RS performed data analysis. RS wrote the manuscript. All authors reviewed and approved the final manuscript for publication.

FUNDING

This research was supported by a PDUPT grant with reference number 179/E5/PG.02.00/PL/2023 from the Ministry of Education, Culture, Research and Technology of the Republic of Indonesia, a derivative contract LLDIKTI Region 3, and UMJ Number: 454/LL3/AL.04/2023, Researcher UMJ Derivative Contract Number: 429/R-UMJ/VI/2023.

DATA AVAILABILITY

All datasets generated or analyzed during this study are included in the manuscript.

ETHICS STATEMENT

The study protocol involved humans was performed in accordance with the Declaration of Helsinki and approved by the Commission of Health Research Ethics, Faculty of Medicine and Health, Universitas Muhammadiyah Jakarta (No.113/PE/KE/FKK-UMJ/VI/2022).

INFORMED CONSENT

Written informed consent was obtained from the participants before enrolling in the study.

REFERENCES

1. Tsai MH, Chiu CY, Su KW, et al. Community-Associated Methicillin-Resistant *Staphylococcus aureus* Colonization in a Birth Cohort of Early Childhood: The Role of Maternal Carriage. *Front Med* (Lausanne). 2021;8:1957. doi: 10.3389/fmed.2021.738724
2. Siddiqui AH, Koirala J. Methicillin Resistant *Staphylococcus Aureus*. StatPearls. 2021.
3. Nelson MU, Gallagher PG. Methicillin-Resistant *Staphylococcus aureus* in the Neonatal Intensive Care Unit. *Semin Perinatol.* 2012;36(6):424-430. doi: 10.1053/j.semperi.2012.06.004
4. Chew CH, Yeo CC, Che Hamzah AM, et al. Multidrug-Resistant Methicillin-Resistant *Staphylococcus aureus* Associated with Hospitalized Newborn Infants. *Diagnostics.* 2023;13(6):1050. doi: 10.3390/diagnostics13061050
5. Syahniar R, Rayhana, Kharisma DS, Khatami M, Duarsa DBB. Methicillin-resistant *staphylococcus aureus* among clinical isolates in Indonesia: A systematic review. *Biomed Pharmacol J.* 2020;13(4):1871-1878. doi: 10.13005/bpj/2062
6. Jimenez-Truque N, Tedeschi S, Saye EJ, et al. Relationship Between Maternal and Neonatal

Staphylococcus aureus Colonization. Pediatrics. 2012;129(5):e1252. doi: 10.1542/PEDS.2011-2308

7. Chmielowiec-Korzeniowska A, Tymczyna L, Wlazlo L, Nowakowicz-Debek B, Trawinska B. *Staphylococcus aureus* carriage state in healthy adult population and phenotypic and genotypic properties of isolated strains. *Postepy Dermatol Alergol.* 2020;37(2):184-189. doi: 10.5114/ada.2020.94837
8. Tigabu A, Tiruneh M, Mekonnen F. Nasal Carriage Rate, Antimicrobial Susceptibility Pattern, and Associated Factors of *Staphylococcus aureus* with Special Emphasis on MRSA among Urban and Rural Elementary School Children in Gondar, Northwest Ethiopia: A Comparative Cross-Sectional Study. *Adv Prev Med*. 2018;9364757. doi: 10.1155/2018/9364757
9. Schaumburg F, Alabi AS, Mombo-Ngoma G, et al. Transmission of *Staphylococcus aureus* between mothers and infants in an African setting. *Clin Microbiol Infect.* 2014;20(6):O390-O396. doi: 10.1111/1469-0691.12417
10. Accorsi EK, Franzosa EA, Hsu T, et al. Determinants of *Staphylococcus aureus* carriage in the developing infant nasal microbiome. *Genome Biol*. 2020;21(1):301. doi: 10.1186/s13059-020-02209-7
11. Sakr A, Bregeon F, Mege JL, Rolain JM, Blin O. *Staphylococcus aureus* nasal colonization: An update on mechanisms, epidemiology, risk factors, and subsequent infections. *Front Microbiol.* 2018;9:2419. doi: 10.3389/fmicb.2018.02419
12. Maayan-Metzger A, Strauss T, Rubin C, et al. Clinical evaluation of early acquisition of *Staphylococcus aureus* carriage by newborns. *Int J Infect Dis.* 2017;64:9-14. doi: 10.1016/j.ijid.2017.08.013
13. Patel JA, Alvarez-Fernandez P, Jennings K, Loeffelholz M, Mccormick D, Chonmaitree T. Factors affecting *staphylococcus aureus* colonization of the nasopharynx in the first 6 months of life. *Pediatr Infect Dis J.* 2015;34(8):826-830. doi: 10.1097/INF.0000000000000744
14. Geng W, Qi Y, Li W, et al. Epidemiology of *Staphylococcus aureus* in neonates on admission to a Chinese neonatal intensive care unit. *PLoS One.* 2020;15(2):e0211845. doi: 10.1371/journal.pone.0211845
15. Best N, Fraser JD, Rainey PB, Roberts SA, Thomas MG, Ritchie SR. Nasal carriage of *staphylococcus aureus* in healthy aucklanders. *N Z Med J.* 2011;124(1332):31-39.
16. Katrine M, Holmid A, Nordmann Winther T, et al. Prevalence of MRSA nasal carriage among pregnant women in Copenhagen. *PLoS One*. 2021;16(1):e0246343. doi:10.1371/journal.pone.0246343
17. Tsai MS, Chen CJ, Lin TY, Huang YC. Nasal methicillin-resistant *Staphylococcus aureus* colonization among otherwise healthy children aged between 2 months and 5 years in northern Taiwan, 2005-2010. *J Microbiol Immunol Infect.* 2018;51(6):756-762. doi: 10.1016/j.jmii.2017.07.014
18. Deng JJ, Xiao GG, Zhu Y, Zhou W, Wan CM. *Staphylococcus Aureus* Nasal Carriage and Its Antibiotic Resistance Profiles in Tibetan School Children in Southwest China. *HK J Paediatr* (new series) 2014;19:75-78.
19. Okwu M, Bamgbala S, Aborisade W. Prevalence of Nasal Carriage of Community-Associated Methicillin-Resistant *Staphylococcus Aureus*(CA-MRSA) among Healthy Primary School Children in Okada, Nigeria. *Journal of Natural Sciences Research.* 2012;2(4):61-65. www.iiste.org
20. Eibach D, Nagel M, Hogan B, et al. Nasal carriage of *staphylococcus aureus* among children in the Ashanti region of Ghana. *PLoS One.* 2017;12(1):e0170320. doi: 10.1371/journal.pone.0170320
21. Carrel M, Goto M, Schweizer ML, David MZ, Livorsi D, Perencevich EN. Diffusion of clindamycin-resistant and erythromycin-resistant methicillin-susceptible *Staphylococcus aureus* (MSSA), potential ST398, in United States Veterans Health Administration Hospitals, 2003-2014. *Antimicrob Resist Infect Control.* 2017;6:55. doi: 10.1186/s13756-017-0212-1
22. Siddiqui AH, Koirala J. Methicillin-Resistant *Staphylococcus aureus*. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022.