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RESEARCH ARTICLE

ISOLATION AND CHARACTERIZATION OF METHICILLIN-RESISTANT STAPHYLOCOCCUS AUREUS STRAIN FROM NWBORN AND HOSPITAL STAFF IN MATERNITY AND CHILDREN HOSPITAL IN MAKKAH

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Abstract

This study investigates methicillin-resistant Staphylococcus aureus colonization among newborns and hospital staff at the Maternity and Children's Hospital in Makkah. MRSA exhibits resistant features to beta-lactam antibiotics and, therefore, has become a big challenge to public health. Nasal swabs were cultured on selective media, and methicillin resistance was confirmed by molecular methods such as PCR. It resulted in the following resistance patterns: Benzylpenicillin-70% and Oxacillin-30%. The isolate is sensitive to Gentamicin, Linezolid, and Vancomycin among other classes. Different MRSA types from the neonates and staff isolate call for targeted infection control approaches. MRSA colonization in babies was related to the period of stay and an increased incidence of mortality, again the demand for continuous vigil through epidemiological surveillance and enforcing rigorous infection prevention practices towards changing clinical practice.

Introduction:-

Methicillin-resistant Staphylococcus aureus (MRSA) is a group of gram-positive bacteria known for their resistance to beta-lactam antibiotics, including penicillin derivatives and cephalosporins (Gardner, 2023; Lade and Kim, 2021; Hashmi et al., 2023). MRSA causes challenging infections, particularly in hospitals, prisons, and nursing homes, but has also become community- and livestock-acquired (Siddiqui and Koirala, 2023). Symptoms vary based on infection site and can include skin sores, swollen red bumps, fever, and severe headaches (Bush and Charles, 2023). Treatments involve strong antibiotics like Trimethoprim-sulfamethoxazole, Clindamycin, Minocycline, and Doxycycline (Choo and Chambers, 2016). Isolation of MRSA involves collecting clinical samples (e.g., wound swabs, blood cultures) or environmental samples from healthcare settings (Francois et al., 2023). Samples are cultured on agar plates, with Staphylococcus aureus identified through morphological and biochemical tests (Taylor and Unakal, 2023). Antibiotic susceptibility testing determines MRSA sensitivity to various antibiotics, aiding treatment (Bæk et al., 2014). Molecular techniques such as PCR and DNA sequencing identify resistance genes, while molecular typing methods track MRSA spread and outbreaks (Xing et al., 2022). Characterizing MRSA's virulence factors provides insights into their pathogenic potential and guides treatment (Watkins et al., 2012). Surveillance programs monitor MRSA prevalence and distribution, informing infection control and public health interventions (Immergluck et al., 2019). Understanding MRSA through microbiological, molecular, and

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epidemiological techniques is essential for effective infection control and management strategies (Silva et al., 2020). MRSA poses major challenges in healthcare due to its antibiotic resistance, ease of transmission, and severe impact on patient outcomes and resources. Effective control requires infection control measures, antimicrobial stewardship, surveillance, and research (Samuel et al., 2023). Resistant to multiple antibiotics, MRSA complicates treatment and increases illness duration, healthcare costs, and mortality (Gajdács, 2019). It causes severe infections like bloodstream infections and pneumonia, particularly in immunocompromised patients (Sikora and Zahra, 2023). MRSA spreads easily in healthcare settings due to close contact, poor hand hygiene, and contaminated surfaces (Collins, 2008). It is a leading cause of healthcare-associated infections (HAIs), prolonging hospital stays and increasing costs and morbidity (Dadi et al., 2021). Strict infection control measures are essential but variably implemented, leading to persistent outbreaks (Hughes et al., 2013). Community-acquired MRSA infections are also rising, affecting healthy individuals (DeLeo et al., 2010). MRSA infections burden healthcare resources with increased admissions, longer stays, and higher costs, including direct medical expenses and productivity losses (Zhen et al., 2020). Isolation and characterization of MRSA strains are crucial for understanding the bacteria, informing treatment, and preventing infections (Turner et al., 2019). Stringent hospital infection control measures, such as regular screening, thorough cleaning, and proper use of personal protective equipment, are essential to reduce MRSA spread and protect newborns and staff (Habboush et al., 2024). Newborns, especially pre-term, are vulnerable due to their underdeveloped immune systems and can acquire MRSA from the mother or hospital environment (James et al., 2008). Hospital staff, frequently exposed to patients, risk contracting and spreading MRSA (OAHPP and PIDAC, 2013). MRSA infections threaten patient safety, particularly in newborns and hospitalized individuals. Understanding MRSA colonization and transmission is critical, but limited data in Makkah hinders effective prevention and management. This research aims to isolate and characterize MRSA in newborns and staff, informing strategies to prevent and manage MRSA, and improve healthcare outcomes in KSA.

Background

MRSA is a major public health threat due to its resistance to beta-lactam antibiotics and its ability to cause various diseases (Gordon, 2008; Grundmann, 2006). Prevalence varies globally, with 12.6% in European long-term care facilities and 33.9% in North America (Szabó, 2016). Resistance to multiple antibiotics complicates treatment and requires new antimicrobials (Brumfitt, 1989; Rubin, 1971; Deresinski, 2005). MRSA's antibiotic resistance has persisted since the 1940s (Brumfitt, 1989). Its prevalence in hospitals increased significantly from 35.9% to 64.4% between 1992 and 2003 (Klevens, 2006). Transmission factors include staff shortages, overcrowding, and medical device use (Grundmann, 2002; Onorato, 1999; Sadoyama, 2000). MRSA causes severe infections with high mortality rates, requiring effective screening and surveillance (Diekema, 2001; Peacock, 1980; Deresinski, 2005). MRSA poses a significant threat in neonatal units, causing high infection rates and mortality (Regev-Yochay, 2005). Nosocomial transmission, staff colonization, and antibiotic resistance are key factors (Farrington, 1990; Millar, 1987). Effective infection control measures are essential to protect vulnerable newborns (Carey, 2010; Marcinak, 2003). Healthcare workers have varying MRSA colonization rates, with nurses at higher risk (Elie-Turenne, 2010). They significantly contribute to MRSA transmission in hospitals (Mulligan, 1993; Haley, 1982). The emergence of community-associated MRSA strains complicates its epidemiology (David, 2010). Makkah hospitals need improved disaster preparedness, infection control, and work environments (Al-Shareef, 2016; El-Nagger, 2013; Alkorbi, 2022). Despite control efforts, MRSA infections have increased, necessitating new treatments (Boyce, 2004; Brumfitt, 1994; Stryjewski, 2014). This research aims to isolate and characterize MRSA strains, assess risk factors, and evaluate colonization impacts on hospital stays and mortality, informing targeted interventions and enhancing infection control practices.

Methodology:-

The Maternity and Children Hospital in Makkah is a modern medical institution with state-of-the-art facilities and skilled manpower. Its main orientation is toward maternity care and pediatric services, making the institution indispensable for expectant mothers and families with infants and toddlers in the region. The hospital encompasses various departments and units dedicated to prenatal care, labor and delivery, neonatal intensive care, pediatric wards, and specialized clinics. These facilities are designed to provide comprehensive healthcare services, ranging from routine check-ups to advanced medical treatments, ensuring the health and safety of both mothers and newborns. Moreover, the hospital's strategic location in Makkah holds significant cultural and religious importance, attracting patients not only from the local community but also from different parts of Saudi Arabia and beyond. This influx of diverse patient populations contributes to the hospital's rich healthcare ecosystem, fostering collaboration, research, and the exchange of medical knowledge.

Study Design
This study is adopting a cross-sectional observation strategy in the investigation of MRSA strains among newborns and hospital staff at the Maternity and Children Hospital in Makkah.

Inclusion and Exclusion Criteria
Inclusion Criteria
- Newborns aged 0-28 days, admitted to the hospital's maternity ward, and no history of antibiotic treatment prior to admission.
- Healthcare workers directly involved in patient care (e.g., nurses, physicians, midwives), and working in the maternity and pediatric wards of the hospital.

Exclusion Criteria
- Newborn with congenital abnormalities or pre-existing medical conditions, and those born outside the hospital or transferred from other healthcare facilities.
- Staff not directly involved in patient care within the specified wards.

Data Collection Methods:-
Nasal swabs are collected from newborns (upon admission to the maternity ward) and hospital staff members using sterile swabs. Swabs are immediately transferred to the hospital's microbiology laboratory for culture and MRSA identification. Newborns demographic data (e.g., age, gender), clinical information (e.g., birth weight, gestational age), and relevant medical history are extracted from the medical records. Also h**ospital staff members a**dditional data such as job role, years of experience, adherence to infection control practices, and history of MRSA colonization or infection, are collected through self-reported questionnaires or electronic surveys.

Ethical Considerations
Informed consent is a well-established ethical consideration for this study. The parents or guardians of newborns, as well as hospital personnel, are thoroughly informed of the purpose of the study, the procedures that will be used, possible risks, and benefits accruable from the study. Sufficient time is accorded to the participants to go through the information provided and ask questions before giving an informed decision on participating in the study. Then consent forms are written in a clear and understandable language, ensuring that participants are fully aware of their rights and responsibilities. For newborns, consent is obtained from their parents or legal guardians, while hospital staff members provide voluntary consent for their participation. The study protocol undergoes thorough review and approval by the Maternity and Children Hospital's Board and Ethics Committee. This step is important, as it evaluates the design of the study in terms of participant recruitment, informed consent, data collection, confidentiality, and privacy of respondents. The approval ensures that the study adheres to ethical guidelines and regulations, safeguarding the rights and welfare of participants.

Measurement:-
Nasal samples are collected using sterile cotton swabs from both newborns (10 samples) and healthcare workers (40 samples). Demographic data including age, gender, and employment status are recorded for each participant. Then Sampling is conducted weekly over a period of 7 days. Nasal swabs are streaked onto selective media specific for Staphylococcus aureus, such as Mannitol Salt Agar (MSA) or Chromogenic agar supplemented with selective agents like cefoxitin or oxacillin. Plates are then incubated aerobically at 35-37°C for 24-48 hours. Microscopic examination and assessment of cultural characteristics are performed to identify colonies consistent with Staphylococcus aureus. Biochemical tests including catalase and coagulase assays are conducted to confirm the presence of Staphylococcus aureus. Once confirmed, isolates undergos further identification using automated systems such as Microscan and Vitec. The identification process is completed within two weeks from the initial sample collection.

Presumptive identification of Staphylococcus aureus colonies is based on characteristic colony morphology, hemolysis patterns, and positive coagulase test results. Confirmation of methicillin resistance is performed using molecular method such as Polymerase Chain Reaction (PCR) assays that target the mecA or mecC gene, and encodes methicillin resistance. Susceptibility testing is conducted using standardized methods such as automated systems (e.g., Vitek or MicroScan). Antibiotics commonly tested include oxacillin, cefoxitin, vancomycin, clindamycin, erythromycin, and trimethoprim-sulfamethoxazole. Molecular typing methods are employed to characterize MRSA strains and assess their relatedness. These methods can accurately isolate and characterize MRSA strains, providing valuable insights into their epidemiology, antimicrobial resistance profiles, and genetic diversity. This information is essential for guiding infection control measures and therapeutic interventions in healthcare settings.

Results:-

These results in table 1 provide a breakdown of the gender, age, and names of the newborns, along with the number of MRSA isolates obtained from each. This information will be instrumental in further analyzing the prevalence and distribution of MRSA colonization among newborns.

Table 1:- Names, age, and gender of the newborns of MRSA isolates.

Number of baby isolate	Name	Age	Gender
1	Baby g rawan	1 day	Girl
2	Baby g hilali	5 days	Girl
3	Baby b qefais	3 days	Boy
4	Baby b Ayesha	2 days	Boy
5	Osama	1 month	Boy
6	Baby b meshael	5 days	Boy
7	Baby b hoor	2 days	Boy
8	Baby b fahdah	2 days	Boy
9	Baby b shahad	2 days	Boy
10	Baby b nor	2 days	Boy

The proportions or percentages of MRSA colonization among newborns by gender and age group are shown in figures 1.

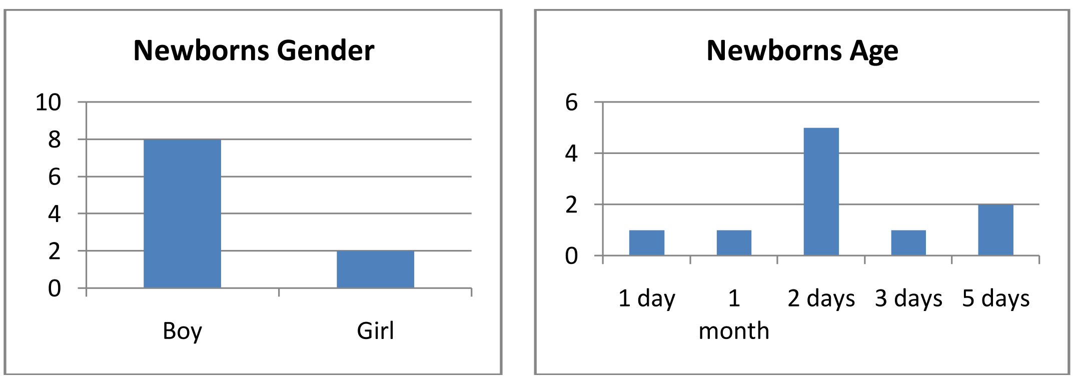


Figure 1:- Gender and Age distribution in the newborns isolates.

The results in table 2 show the antibiotic resistance profiles of the MRSA isolates to give insight into their potential impacts on treatment efficacy and patients' outcomes, such that "R" indicates resistance, "S" sensitivity, "POS" for positive, and "NEG" for negative. Correspondingly, figures 2 to 11 present the antibiotic resistance profile in newborns of MRSA-isolated babies.

The MRSA isolates from newborns showed a varied degree of resistance to different antibiotics. Three isolates were positive for cefoxitin resistance and thus confirmed as MRSA. Seven isolates were resistant to Benzylpenicillin, while three were sensitive. Similarly, three isolates were resistant to Oxacillin, while seven were sensitive. All the isolates were sensitive to Gentamicin. Two were resistant to Tobramycin, while eight were sensitive. One isolate showed resistance to both Levofloxacin and Moxifloxacin, while nine were sensitive. Three showed positive for inducible clindamycin resistance. Four isolates were resistant to Erythromycin, while six were sensitive. Three were resistant to Clindamycin, while seven were sensitive. All the isolates were sensitive to Linezolid, Teicoplanin, Vancomycin, Tigecycline, Nitrofurantoin, Rifampicin, and Trimethoprim/Sulfamethoxazole. One was resistant to Tetracycline, while nine were sensitive. Five were resistant to Fusidic Acid and five sensitive.

This indicates a varying degree of antibiotic resistance among the MRSA isolates. Antibiotic resistance can impact treatment efficacy, and understanding the resistance profile of MRSA isolates can guide effective treatment strategies.

Table 2:- Antibiotic resistance in the newborns of MRSA isolates.

Antimicrobial	isolate 1	isolate 2	isolate 3	isolate 4	isolate 5	isolate 6	isolate 7	isolate 8	isolate 9	isolate 10
Cefoxitin Screen	NEG	NEG	POS	NEG	POS	NEG	NEG	NEG	POS	NEG
Benzylpenicillin	R	S	R	R	R	R	R	S	R	R
Oxacillin	S	S	R	S	R	S	S	S	R	S
Gentamicin	S	S	S	S	S	S	S	S	S	S
Tobramycin	S	R	S	S	S	S	R	S	S	S
Levofloxacin	S	S	S	S	S	S	S	S	R	S
Moxifloxacin	S	S	S	S	S	S	S	S	R	S
Inducible Clindamycin Resistance	NEG	NEG	POS	NEG	NEG	NEG	NEG	NEG	POS	NEG
Erythromycin	S	R	R	S	S	S	R	S	R	S
Clindamycin	S	S	R	S	S	S	S	S	R	S
Linezolid	S	S	S	S	S	S	S	S	S	S
Teicoplanin	S	S	S	S	S	S	S	S	S	S
Vancomycin	S	S	S	S	S	S	S	S	S	S
Tetracycline	S	S	S	S	S	R	S	S	S	S
Tigecycline	S	S	S	S	S	S	S	S	S	S
Nitrofurantoin	S	S	S	S	S	S	S	S	S	S
Fusidic Acid	R	R	S	S	R	R	R	S	S	R
Rifampicin	S	S	S	S	S	S	S	S	S	S
Trimethoprim/ Sulfamethoxazole	S	S	S	S	S	S	S	S	S	S

R=resistance. S=sensitive. POS=positive. NEG= negative.

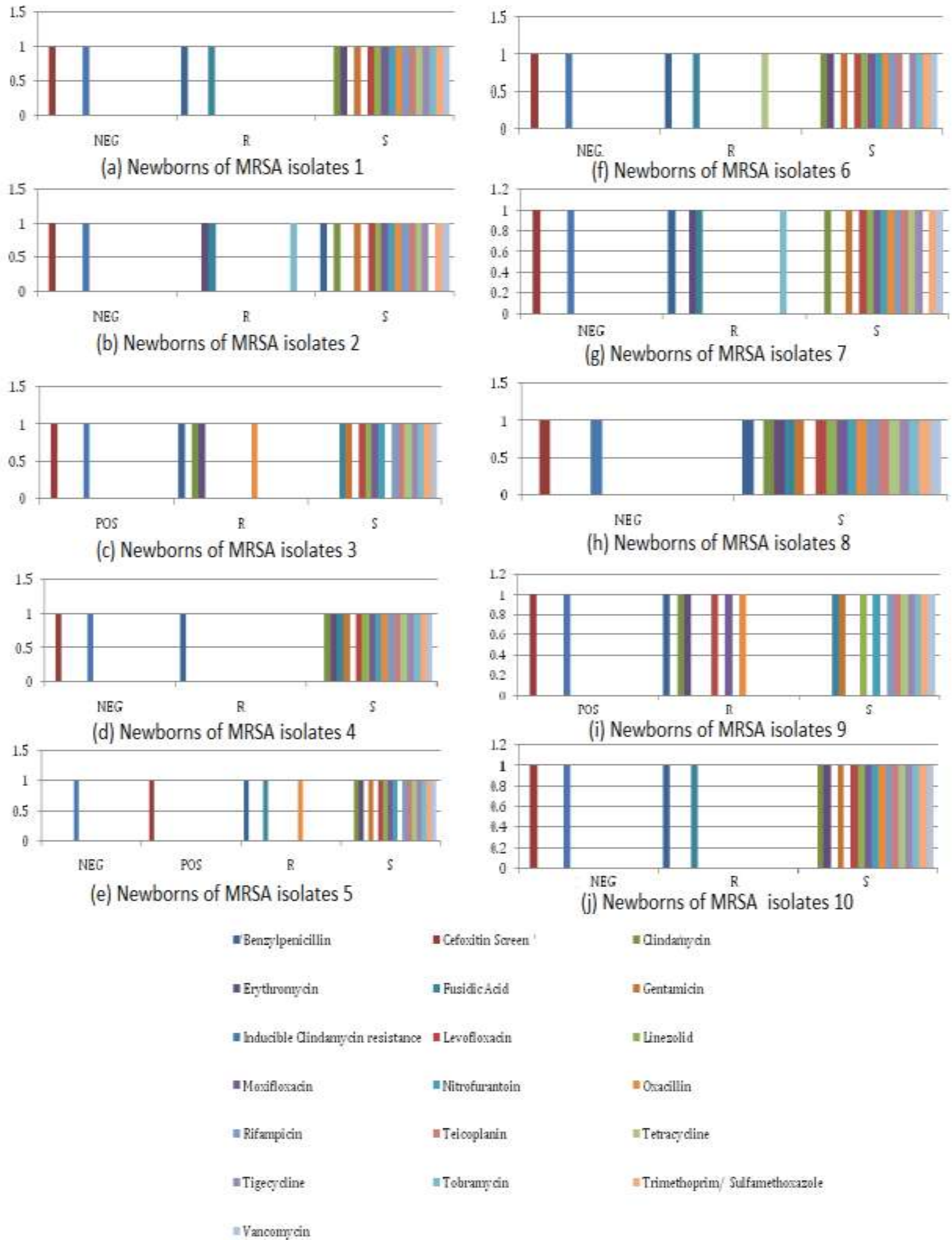


Figure 2:- Antibiotic resistance profile in the newborns of MRSA isolates.

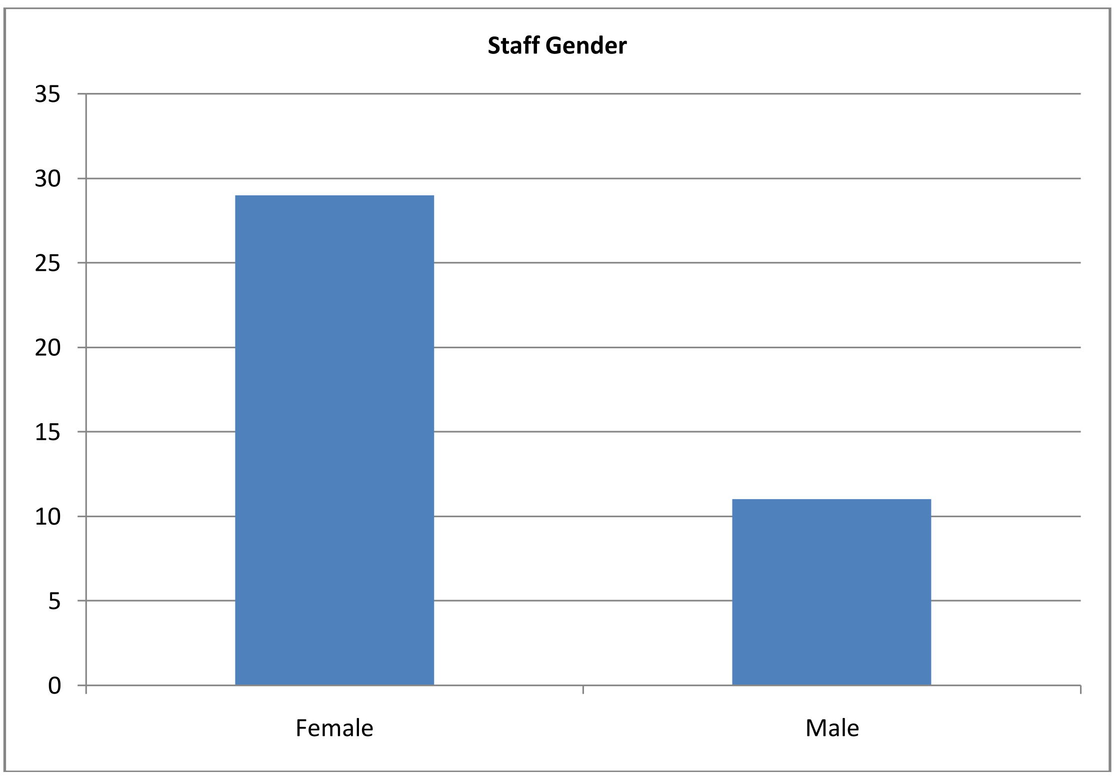
The results in table 3 provide a breakdown of the gender, age, and names of the healthcare staff, along with the number of MRSA isolates obtained from each. This information will be instrumental in further analyzing the prevalence and distribution of MRSA colonization among healthcare staff.

Table 3:- Names, age, and gender of the healthcare staff of MRSA isolates.

Number of helthcare isolate	Name	Age	Gender
1	Maryam kabbe	40	Female
2	Latifah husine	35	Female
3	Jaweedhahmmad	45	Female
4	Ahlam ali	30	Female
5	Shrooq saleh	33	Female
6	Nosaibatif	32	Female
7	Mohibanooraldin	36	Female
8	Noorhanahmmad	28	Female
9	Noor	28	Female
10	Farhana	44	Female
11	Fatimah	48	Female
12	Abdullah	34	Male
13	Abdulmajeed saleh	37	Male
14	Mohammed a	36	Male
15	Khaled alsubhi	33	Male
16	Ghadeeramin	34	Female
17	Ghada	30	Female
18	Ammarsindi	29	Male
19	Tahanialmaliki	27	Female
20	Hebashakir	30	Female
21	Waheed	48	Male
22	Waelalhazmi	46	Male
23	Tayssernoor	48	Female
24	Shahad	28	Female
25	Shrooq s	29	Female
26	Amal m	36	Female
27	Mashael	33	Female
28	Mnar	34	Female
29	Sawarahmmad	34	Female

Number of helthcare isolate	Name	Age	Gender
30	Akter	32	Female
31	Hannanfaisal	30	Female
32	Ola	38	Female
33	Alya	38	Female
34	Osama	26	Male
35	Alla	27	Male
36	Samah	29	Female
37	Sara	30	Female
38	Loayyamani	31	Male
39	Moaaz	31	Male
40	Moznnah	37	Female

The proportions or percentages of MRSA colonization among healthcare staff by gender and age group are shown in figures 12.



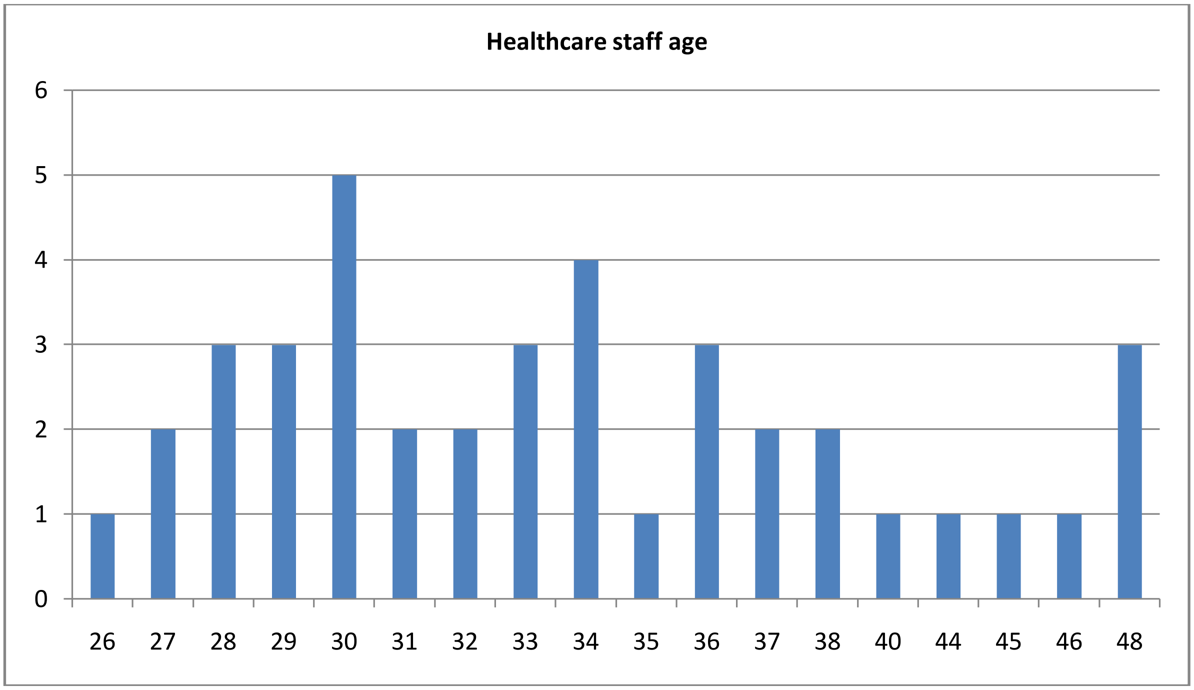


Figure 3:- Gender and age distribution in the healthcare staff of MRSA isolates.

The results in table 4, 5, 6, and 7 provide insight into the antibiotic resistance profiles of the MRSA isolates in healthcare staff, which is crucial for understanding their potential impact on treatment efficacy and patient outcomes such that "R" indicates resistance, "S" indicates sensitivity, "POS" indicates positive, and "NEG" indicates negative. Correspondingly, figures 4 to 7 show the antibiotic resistance profile in the healthcare staff of MRSA isolates.

Based on the provided data, it can be observed that all isolates were negative for Cefoxitin Screen except for isolate 5 and isolate 38 which were positive. This indicates that these two isolates may be resistant to cefoxitin. For Benzylpenicillin, most isolates were resistant except for isolates 3, 6, 8, 12, 17, and 31 which were sensitive. In the case of Oxacillin, all isolates were sensitive except for isolate 5, 13, and 38 which were resistant. This indicates that these three isolates may be resistant to oxacillin.

For Gentamicin, most isolates were sensitive except for isolate 5 and 15 which were resistant. In the case of Tobramycin, most isolates were sensitive except for isolate 5, 7, 10, 11, 15, 16, 17, 34, 35, and 36 which were resistant. For Levofloxacin, most isolates were sensitive except for isolate 5, 8, 12, 23, 25, 28, and 33 which were resistant. In the case of Moxifloxacin, most isolates were sensitive except for isolate 8, 12, 23, and 28 which were resistant.

All isolates were negative for Inducible Clindamycin Resistance indicating no resistance. For Erythromycin, most isolates were sensitive except for isolate 7, 13, 19, 23, 25, 28, 33, 34, 35, and 36 which were resistant. All isolates were sensitive for Clindamycin, Linezolid, Teicoplanin, Tigecycline, Nitrofurantoin, and Rifampicin.

For Tetracycline, most isolates were sensitive except for isolate 1, 5, 25, 29, and 33 which were resistant. In the case of Fusidic Acid, most isolates were sensitive except for isolate 1, 2, 4, 5, 6, 7, 10, 11, 13, 14, 15, 16, 23, 25, 27, 29, 32, 33, 34, 35, 36, and 39 which were resistant. For Trimethoprim/ Sulfamethoxazole, most isolates were sensitive except for isolate 23, 29, and 33 which were resistant.

Table 4:- Antibiotic resistance in the healthcare staff of MRSA isolates from 1 to 10.

Antimicrobial	isolate 1	isolate 2	isolate 3	isolate 4	isolate 5	isolate 6	isolate 7	isolate 8	isolate 9	isolate 10
Cefoxitin Screen	NEG	NEG	NEG	NEG	POS	NEG	NEG	NEG	NEG	NEG
Benzylpenicillin	R	R	S	R	R	S	R	S	R	R
Oxacillin	S	S	S	S	R	S	S	S	S	S
Gentamicin	S	S	S	S	R	S	S	S	S	S
Tobramycin	S	S	S	S	R	S	R	S	S	R
Levofloxacin	S	S	S	S	S	R	S	R	S	S
Moxifloxacin	S	S	S	S	S	S	S	R	S	S
Inducible Clindamycin Resistance	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG
Erythromycin	S	S	S	S	S	S	R	S	S	R
Clindamycin	S	S	S	S	S	S	S	S	S	S
Linezolid	S	S	S	S	S	S	S	S	S	S
Teicoplanin	S	S	S	S	S	S	S	S	S	S
Vancomycin	S	S	S	S	S	S	S	S	S	S
Tetracycline	R	S	S	S	S	S	S	S	S	S
Tigecycline	S	S	S	S	S	S	S	S	S	S
Nitrofurantoin	S	S	S	S	S	S	S	S	S	S
Fusidic Acid	R	R	S	R	R	R	R	S	S	R
Rifampicin	S	S	S	S	S	S	S	S	S	S
Trimethoprim/ Sulfamethoxazole	S	S	S	S	S	S	S	S	S	S

Table 5:- Antibiotic resistance in the healthcare staff of MRSA isolates from 11 to 20.

Antimicrobial	isolate 11	isolate 12	isolate 13	isolate 14	isolate 15	isolate 16	isolate 17	isolate 18	isolate 19	isolate 20
Cefoxitin Screen	NEG	NEG	POS	NEG	NEG	NEG	NEG	NEG	NEG	NEG
Benzylpenicillin	R	S	R	R	R	R	S	R	R	R
Oxacillin	S	S	R	S	S	S	S	S	S	S
Gentamicin	S	S	S	S	S	S	S	S	S	S

Tobramycin	R	S	S	S	R	S	S	S	S	S
Levofloxacin	S	R	S	S	S	S	S	S	R	S
Moxifloxacin	S	R	S	S	S	S	S	S	R	S
Inducible Clindamycin Resistance	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG
Erythromycin	R	S	R	S	R	S	S	S	S	S
Clindamycin	S	S	S	S	S	S	S	S	S	S
Linezolid	S	S	S	S	S	S	S	S	S	S
Teicoplanin	S	S	S	S	S	S	S	S	S	S
Vancomycin	S	S	S	S	S	S	S	S	S	S
Tetracycline	S	S	S	S	S	S	S	S	S	S
Tigecycline	S	S	S	S	S	S	S	S	S	S
Nitrofurantoin	S	S	S	S	S	S	S	S	S	S
Fusidic Acid	R	S	R	R	R	R	S	S	R	S
Rifampicin	S	S	S	S	S	S	S	S	S	S
Trimethoprim/ Sulfamethoxazole	S	S	S	S	S	S	S	S	S	S

Table 6:- Antibiotic resistance in the healthcare staff of MRSA isolates from 21 to 30.

Antimicrobial	isolate 21	isolate 22	isolate 23	isolate 24	isolate 25	isolate 26	isolate 27	isolate 28	isolate 29	isolate 30
Cefoxitin Screen	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG
Benzylpenicillin	R	R	R	R	R	R	R	R	R	R
Oxacillin	S	S	S	S	S	S	S	S	S	S
Gentamicin	S	S	S	S	S	S	S	S	S	S
Tobramycin	S	S	S	S	S	S	S	S	S	S
Levofloxacin	S	S	R	S	R	S	S	S	S	S
Moxifloxacin	S	S	R	S	S	S	S	S	S	S
Inducible Clindamycin Resistance	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG
Erythromycin	S	S	R	S	R	S	S	R	S	S
Clindamycin	S	S	R	S	S	S	S	S	S	S
Linezolid	S	S	S	S	S	S	S	S	S	S
Teicoplanin	S	S	S	S	S	S	S	S	S	S

Vancomycin	S	S	S	S	S	S	S	S	S	S
Tetracycline	S	S	S	S	S	R	S	S	R	S
Tigecycline	S	S	S	S	S	S	S	S	S	S
Nitrofurantoin	S	S	S	S	S	S	S	S	S	S
Fusidic Acid	S	S	R	S	R	R	R	S	S	R
Rifampicin	S	S	S	S	S	S	S	S	S	S
Trimethoprim/ Sulfamethoxazole	S	S	R	S	S	S	S	S	S	S

Table 7:- Antibiotic resistance in the healthcare staff of MRSA isolates from 31 to 40.

Antimicrobial	isolate 31	isolate 32	isolate 33	isolate 34	isolate 35	isolate 36	isolate 37	isolate 38	isolate 39	isolate 40
Cefoxitin Screen	NEG	NEG	NEG	NEG	NEG	NEG	NEG	POS	NEG	NEG
Benzylpenicillin	S	R	R	R	R	R	R	R	R	R
Oxacillin	S	S	S	S	S	S	S	R	S	S
Gentamicin	S	S	S	S	S	S	S	S	S	S
Tobramycin	S	S	S	R	R	R	S	S	S	S
Levofloxacin	S	S	S	S	S	S	S	S	S	S
Moxifloxacin	S	S	S	S	S	S	S	S	S	S
Inducible Clindamycin Resistance	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG
Erythromycin	S	S	R	R	R	R	S	S	S	S
Clindamycin	S	S	S	S	S	S	S	S	S	S
Linezolid	S	S	S	S	S	S	S	S	S	S
Teicoplanin	S	S	S	S	S	S	S	S	S	S
Vancomycin	S	S	S	S	S	S	S	S	S	S
Tetracycline	S	S	S	S	S	S	S	S	S	S
Tigecycline	S	S	S	S	S	S	S	S	S	S
Nitrofurantoin	S	S	S	S	S	S	S	S	S	S
Fusidic Acid	S	R	R	R	R	R	R	S	R	S
Rifampicin	S	S	S	S	S	S	S	S	S	S
Trimethoprim/ Sulfamethoxazole	S	S	S	S	S	S	S	S	S	S

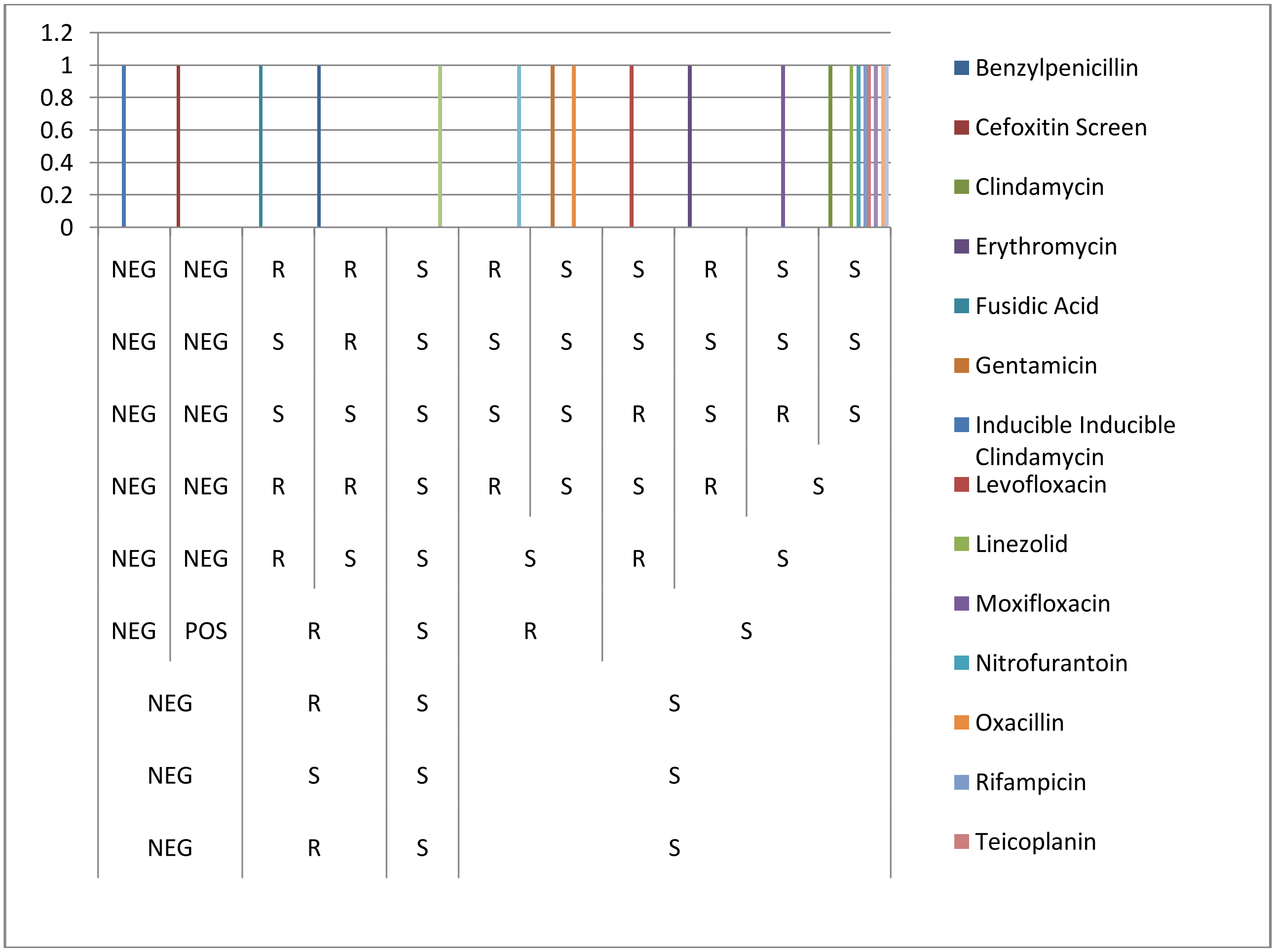


Figure 4:- Antibiotic resistance profile in the healthcare staff of MRSA isolates from 1 to 10.

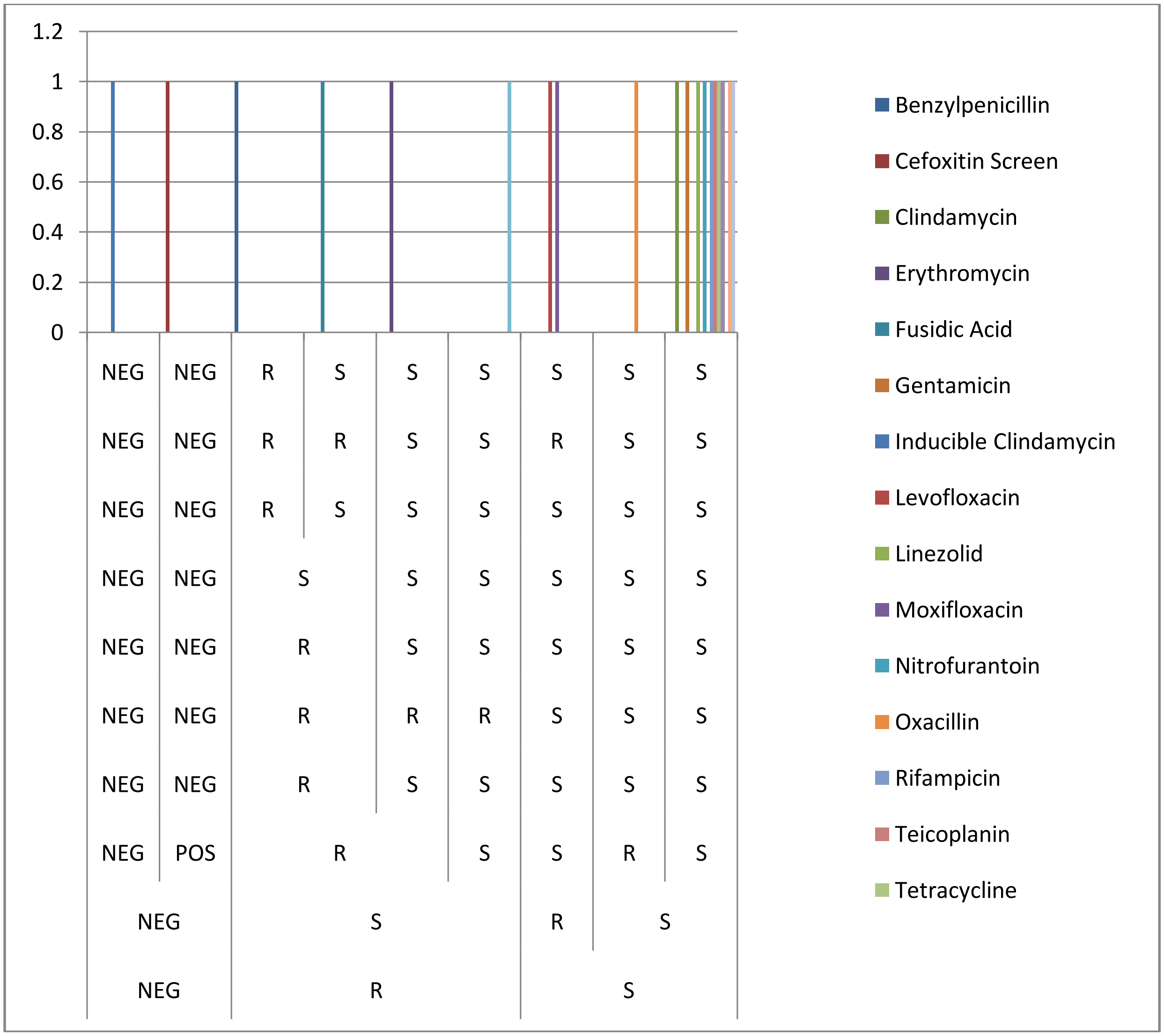


Figure 5:- Antibiotic resistance profile in the healthcare staff of MRSA isolates from 11 to 20.

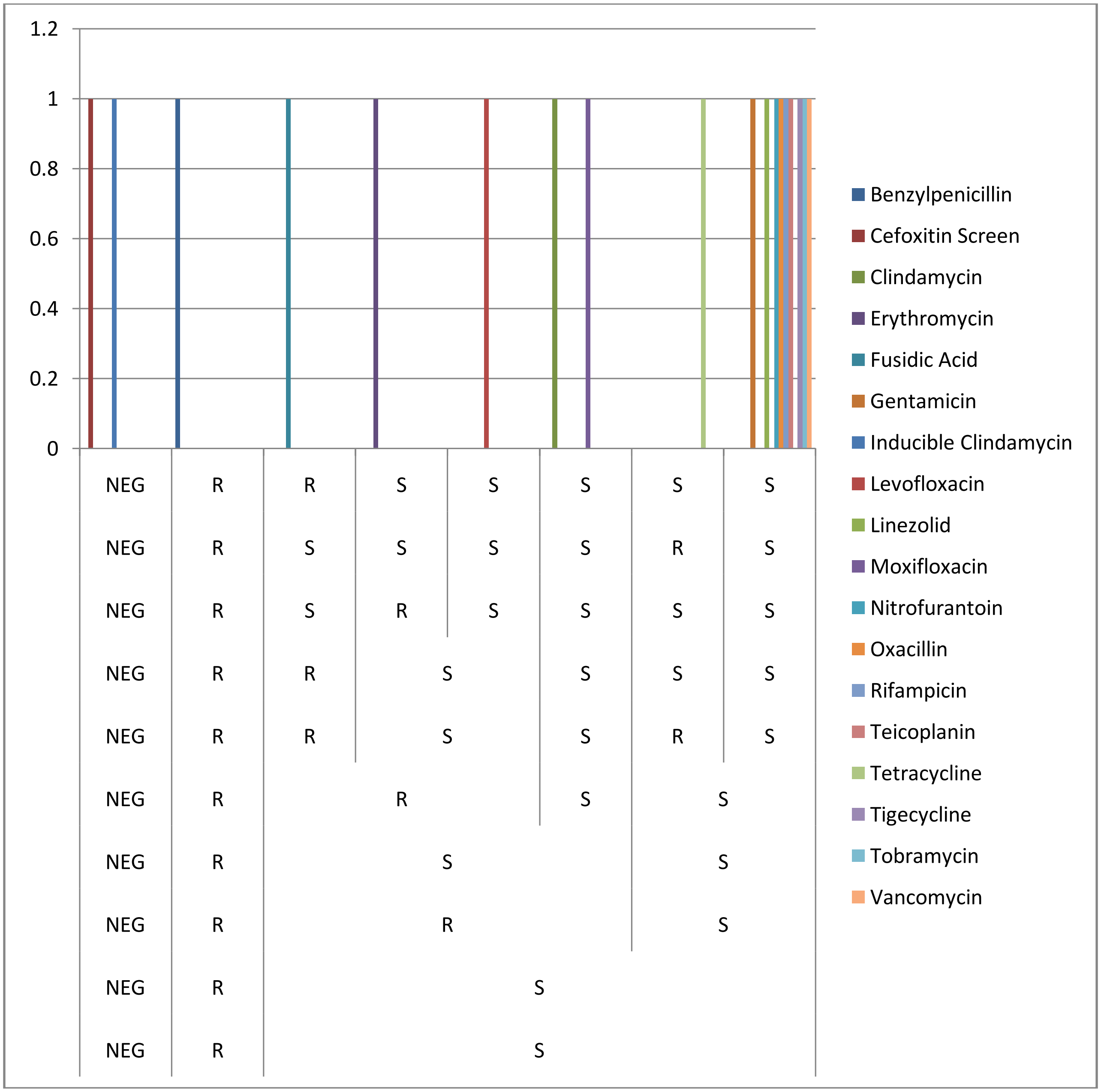
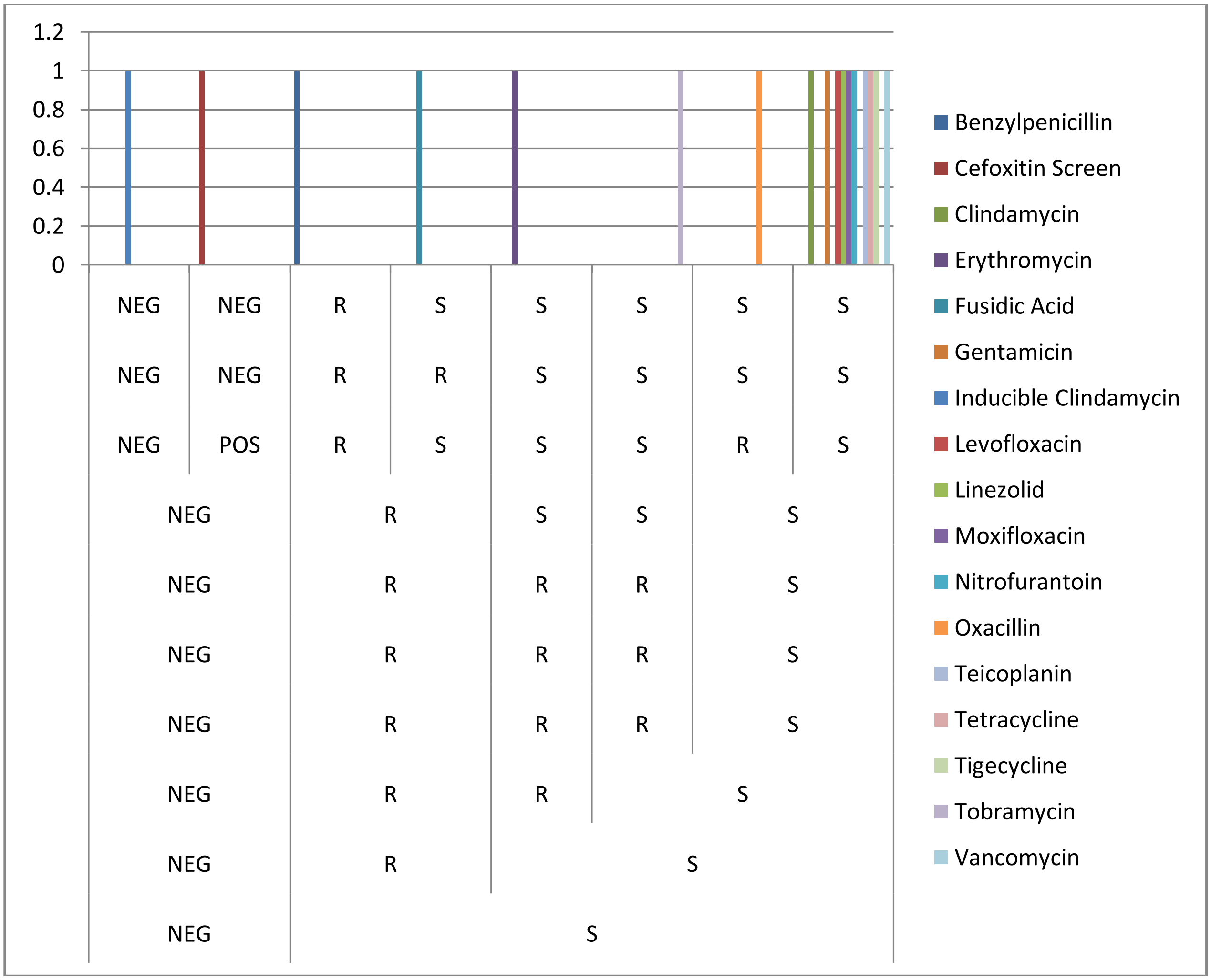


Figure 6:- Antibiotic resistance profile in the healthcare staff of MRSA isolates from 21 to 30.



Figures 7:- Antibiotic resistance profile in the healthcare staff of MRSA isolates from 31 to 40.

Discussion:-

To compare the antibiotic resistance profiles of MRSA isolates from newborns and health care staff, some statistical analysis such as Descriptive Statistics and Inferential Statistics are performed.

Descriptive analysis

Based on the newborns isolates data in the results, it can be seen that for the newborns, 30% of the isolates were positive for Cefoxitin Screen, 70% resistant to Benzylpenicillin and 30% resistant to Oxacillin. All isolates showed sensitivity to Gentamicin. Resistance of the 20% of isolates to Tobramycin, 10% to Levofloxacin, and Moxifloxacin was noted; 30% were positive for Inducible Clindamycin Resistance. 30% of the isolates showed resistance to Erythromycin while 10% were resistant to Clindamycin. All the isolates showed sensitivity to Linezolid, Teicoplanin, Vancomycin, Tigecycline, Nitrofurantoin, Rifampicin, and Trimethoprim/ Sulfamethoxazole. Resistance rates to Tetracycline were 10% and Fusidic Acid, 40%.

For the data of the isolates taken from the health care staff, 5% of the results showed positive Cefoxitin Screen; 70% were resistant to Benzylpenicillin, while 5% were resistant to Oxacillin. All were sensitive to Gentamicin. 7.5% of the isolates were resistant to Tobramycin, 5% were resistant to Levofloxacin and Moxifloxacin, and all were negative for Inducible Clindamycin Resistance. 15% of the isolates showed resistance to Erythromycin. All the isolates were sensitive to Clindamycin, Linezolid, Teicoplanin, Vancomycin, Tigecycline, Nitrofurantoin, Rifampicin, and Trimethoprim/ Sulfamethoxazole. All the isolates were sensitive to Tetracycline, and 22.5% were resistant to Fusidic Acid. This gives an overview of the resistance pattern in each group.

Results for the resistance pattern of the newborns' MRSA to different antibiotics are varied. This agrees with literature evidence showing that antibiotic resistance among MRSA isolates has usually varied (Wu et al., 2023; Wu et al., 2023).

In the study, 30% of the newborn isolates were positive for Cefoxitin Screen, an indirect test for the detection of the mecA gene, a determinant of methicillin resistance. This agrees with another study that reported all MRSA isolates from newborns to be resistant to penicillin (Wu et al., 2023).

The study also found that 70% of the isolates were resistant to Benzylpenicillin and 30% were resistant to Oxacillin. This is also consistent with the literature, since MRSA is resistant to most beta-lactam antibiotics, including penicillins and cephalosporins (Vestergaard et al., 2019).

All the isolates under study were sensitive to Gentamicin, an aminoglycoside antibiotic. This is somewhat in variance with a study from Wu et al. 2023, which reported a very small percentage of its isolates resistant to Gentamicin.

Resistance to Tobramycin, Levofloxacin, and Moxifloxacin was 20%, 10%, and 10%, respectively, in the study. Fluoroquinolones such as Levofloxacin and Moxifloxacin are among the common antibiotic classes that are usually employed against MRSA; however, it can easily develop resistance to them (Vestergaard et al., 2019).

In addition, the study found that 30% of the isolates were positive for Inducible Clindamycin Resistance. Clindamycin is a lincosamide antibiotic, and inducible resistance can occur through a mechanism known as the MLSb phenotype (Vestergaard et al., 2019).

The resistance rate to Erythromycin in this study was 30%, lower than reported in (Wu et al., 2023). All the isolates in this study were susceptible to Linezolid, Teicoplanin, Vancomycin, Tigecycline, Nitrofurantoin, Rifampicin, and Trimethoprim/ Sulfamethoxazole. This agreed with the report from (Vestergaard et al., 2019) since these antibiotics have been found to be very effective for MRSA.

Finally, the study found that 10% of the isolates were resistant to Tetracycline and 40% were resistant to Fusidic Acid. Tetracycline resistance is not uncommon in MRSA (Vestergaard et al., 2019), and Fusidic Acid resistance can occur, especially in hospital settings (Vestergaard et al., 2019).

Inferential statistics

To perform a chi-square test comparing the resistance profiles between the newborns and healthcare staff groups, the data is organized into contingency tables based on table 8.

Table 8:- Data organized based on their resistance to Antimicrobial.

Antimicrobial	Resistance	Newborns	Healthcare
Cefoxitin Screen	POS	4	1
Cefoxitin Screen	NEG	6	39
Benzylpenicillin	R	8	29
Benzylpenicillin	S	2	11
Oxacillin	R	5	6
Oxacillin	S	5	34
Gentamicin	S	10	27
Gentamicin	R	0	13
Tobramycin	S	7	27
Tobramycin	R	3	13
Levofloxacin	R	1	8
Levofloxacin	S	9	32
Moxifloxacin	R	1	9
Moxifloxacin	S	9	32
Inducible Clindamycin Resistance	POS	2	0
Inducible Clindamycin Resistance	NEG	8	40
Erythromycin	R	3	13
Erythromycin	S	7	27

Clindamycin	R	1	10
Clindamycin	S	9	30
Linezolid	S	10	40
Teicoplanin	S	10	40
Vancomycin	S	10	40
Tetracycline	R	1	9
Tetracycline	S	9	31
Tigecycline	S	10	40
Nitrofurantoin	S	10	40
Fusidic Acid	R	5	12
Fusidic Acid	S	5	28
Rifampicin	S	10	40
Trimethoprim/ Sulfamethoxazole	S	10	40

The chi-square test is performed to compare the resistance profiles between the newborns and healthcare staff groups as in table 5.2 In this table, "X_2" represents the chi-square statistic, "p" represents the p-value, "df" represents the degrees of freedom. In the case of a p-value being less than 0.05, it is concluded that there is a significant difference between the two groups for that antibiotic in resistance proportions. Otherwise, there is no significant difference between the resistance proportions if its p-value is greater than 0.05.

Table 9:- Chi-square test to compare the resistance profiles between newborns and healthcare staff.

Antibiotic	X^2 statistic	p-value	df –Degrees of freedom	Significance
Cefoxitin Screen	12.5	p = 0.0004	1	significant
Benzylpenicillin	0.233	p = 0.628	1	Not significant
Oxacillin	5.7	p = 0.016	1	Significant
Gentamicin	7.043	p = 0.008	1	Significant
Tobramycin	0.022	p = 0.879	1	Not significant
Levofloxacin	0.542	p = 0.461	1	Not significant
Moxifloxacin	0.728	p = 0.393	1	Not significant
Inducible Clindamycin Resistance	8.333	p = 0.003	1	Significant
Erythromycin	0.022	p = 0.879	1	Not significant
Clindamycin	1.048	p = 0.305	1	Not significant
Tetracycline	0.781	p = 0.376	1	Not significant
Fusidic Acid	1.426	p = 0.232	1	Not significant
Trimethoprim/ Sulfamethoxazole	0.0	p = 1	1	Not significant

The Linezolid, Teicoplanin, Vancomycin, Tigecycline, Nitrofurantoin, Rifampicin antibiotics do not have any resistance in the newborns group and are excluded from further analysis. The chi-square test results show significant differences in the resistance patterns of MRSA isolates between newborns and healthcare staff for certain antibiotics. A p-value of 0.0004 was observed for the Cefoxitin Screen, which points to a significant difference in resistance patterns between the two groups. This finding aligns with (Boswihi et al., 2020) that suggests variability in the mecA gene, which is detected by the Cefoxitin Screen and is a determinant of methicillin resistance.

For Oxacillin, the p-value is 0.016, which indicates a significant difference. This result agrees with the works of (Boswihi et al., 2020) that have reported variable resistance to Oxacillin among MRSA isolates.

In the case of Gentamicin, it is significant with a p-value of 0.008. This is, to some extent, different from a study by (Boswihi et al., 2020) that stated a small percentage of the isolate had developed resistance to Gentamicin.

For Inducible Clindamycin Resistance, the p-value of 0.003 indicates a significant difference. Resistance to clindamycin can be mediated through a mechanism known as the MLSb phenotype.

These findings underscore the need for an understanding of the antibiotic resistance profiles of MRSA isolates in different populations, as this information will guide infection prevention and control.

Conclusion:-

These results successfully attained the aims of this study, which was the isolation and characterization of MRSA strains from newborns and hospital staff in the Maternity and Children Hospital in Makkah. This study confirms the prevalence of MRSA colonization among newborns and health staff in the Maternity and Children Hospital in Makkah, resistance pattern of different antibiotics. The colonization rate of newborns for MRSA was 30% positive for Cefoxitin Screen, 70% resistant to Benzylpenicillin, and 30% resistant to Oxacillin. All the isolates were sensitive to Gentamicin, while resistance rates to other antibiotics were variable. The resistance patterns of MRSA isolates show variation among the newborns and health staff. Of note, all the isolates were sensitive to Linezolid, Teicoplanin, Vancomycin, Tigecycline, Nitrofurantoin, Rifampicin, and Trimethoprim/ Sulfamethoxazole. However, resistance rates for the remaining antibiotics were variable, and local resistance data should guide therapy. Highly significant differences in resistance patterns between neonates and healthcare workers suggest that MRSA strains may also vary between these populations, with implications for infection control policies.

This may have impacts on the length of stay in the hospital and mortality, as suggested, and hence calls for effective prevention and management. Further research is necessary to explore these impacts in detail. Several implications for clinical practice and public health can be derived from the results of the study. These point out the importance of conducting surveillance for MRSA colonization among healthcare settings, particularly for vulnerable populations like newborns. This study also highlights the effective infection control measures that are required to prevent the spread of MRSA in healthcare institutions. Moreover, the diversity in resistance patterns among the MRSA isolates reflects the importance of implementing effective antibiotic stewardship programs to ensure the appropriate use of antibiotics. Thus, the present study gives an overview of the prevalence, characteristics, and impact of MRSA colonization among newborns and hospital staff in Makkah. By addressing the research objectives, this study contributes to the existing knowledge on MRSA epidemiology and can be used to inform the development of targeted interventions to prevent and manage MRSA infections, thus improving patient safety and healthcare outcomes.

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