Research Article

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Archives of Clinical Microbiology
ISSN 1989-8436

2020
Vol.11 No. 4:1000115

DOI: 10.36648/1989-8436.11.4.115

# Antibiotic Susceptibility Profile of Airborne Bacteria Isolated from Surgical and Labour Theatres of Federal Teaching Hospital, Abakaliki

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**Received date: June** 02, 2020**; Accepted date:** July **06**, 2020**; Published date:** July 15, 2020

**Citation:** Iroha IR, Okpada JO, Moses IB, Onuora AL, Kalu AC, et al. (2020) Antibiotic Susceptibility Profile of Airborne Bacteria Isolated from Surgical and Labour Theatres of Federal Teaching Hospital, Abakaliki. Arch Clin Microbiol Vol. 11 No. 4:115



## Abstract

This study was designed to determine the prevalence and antibiotic susceptibility profile of airborne bacteria isolated from general surgical and labour theatres in Federal Teaching Hospital Abakaliki (FETHA), Ebonyi State, Nigeria. Forty (40) air samples were collected using settle plate method. Airborne bacterial isolates were identified and characterized using standard microbiological techniques. Antibiotic susceptibility profile was determined using Kirby-Bauer disc diffusion technique. Gram-negative bacterial isolates were phenotypically confirmed for ESBL production using the double disc synergy test.

*Staphylococcus aureus* isolates were also screened for methicillin-resistant strains (MRSA) using oxacillin screening agar. *S. aureus* (100%), Coagulase-negative *Staphylococci* (65%), *Bacillus spp.* (62.5%), *Micrococcus spp.* (40.0%), *Pseudomonas aeruginosa* (22.5%), *Klebsiella spp.* (20.0%), *Streptococcus spp.* (17.5%), and *Acinetobacter spp.* (17.5%) were isolated from the air samples of the two theatres. Gram-negative bacterial isolates were also screened for extended-spectrum beta-lactamase (ESBL) production. Antibiotic susceptibility tests showed that isolates were highly resistant to trimethoprim/sulfamethoxazole (100%), penicillin (100%), ampicillin (100%), oxacillin (67%), and clindamycin (50%), but susceptible to ticarcillin (100%), tobramycin (100%), erythromycin (80%), and norfloxacin (71%).

There was no statistically significant difference in the antibiotic resistance and susceptibility frequencies of isolates in the surgical and labour theatres ($P<0.05$). Exactly 30 (75%) of the *Staphylococcus aureus* isolates were identified as methicillin-resistant *S. aureus* (MRSA), while 17 Gram-negative bacterial isolates (2 *Acinetobacter spp.*, 7 *Klebsiella spp.*, and 8 *P. aeruginosa*) were ESBL-positive. Generally, bacterial isolates were multi-drug resistant. The presence of airborne bacterial isolates in surgical and theatre wards might indicate that sterilization techniques employed in the disinfection of these critical hospital areas are not efficient enough. This can put patients at risk of post-operative infections. Therefore, hospital environment requires special attention to ensure good indoor air quality for patients and healthcare workers which will greatly help to curtail nosocomial infections.

**Keywords:** Airborne bacteria; ESBL; Multidrug resistance; Antibiotic resistance; Hospital theatres

## Introduction

Indoor air quality is a major problem worldwide, both in developed and developing countries. Problems of indoor air quality are recognized as important risk factors for human health since majority spend a substantial fraction of time within buildings [1]. Airborne bacteria in health care facilities is associated with nosocomial infection. Hospital environments provide a reservoir of airborne bacteria, many of which exhibit multidrug-resistant traits. Antibiotic resistance by microorganisms has been a serious challenge in the treatment of various nosocomial pathogens and has jeopardized the current management protocols in practices. Resistance

towards antibiotics by microorganisms is not a new phenomenon [2]. Huang et al. [3] reiterated that Pseudomonas aeruginosa represented the most frequently detected and abundant bacterium in air samples; and was the only bacterium exhibiting a positive correlation of the mean counts between air samples and surface samples, which is intrinsically resistant to many antibiotics. Aerobiological survey undertaken in various ward areas of two hospitals indicated that Gram-positive cocci were the most predominant airborne microbial flora followed by Gram-positive rods, Gram – negative rods, and the Diphteroids and Coccobacilli [4]. The evaluation of indoor and outdoor air contamination of hospitals showed that hospitals act as reservoir of multidrug-resistant nosocomial pathogens, where labour room was recorded as the most contaminated site, followed by the dressing room and the operation theatre [4].

The increased rate of methicillin-resistant *Staphylococcus aureus*, followed by vancomycin-resistant enterococci (VRE) or extended-spectrum beta-lactamase – producing microorganism ' s transmission associated with a prior occupant's carriage is suggested of routes for transmission of pathogens in intensive care unit (ICU) and other hospital environment [2]. Vulnerable groups of in-patients are especially at high risk of developing antibiotic-resistant infections. Such infections pose serious threat to immunocompromised patients causing increased morbidity, mortality, and medical costs [5]. Because of evolution and emergency of bacterial resistance to antibiotics, and an increase in the number of immunocompromised individuals; HIV infections, chemotherapy, drug therapies and genetic disorders hospitals are now more often facing the problems of antibiotic-resistant nosocomial infections.

Airborne microorganisms are spread from numerous sources including air conditioning systems, respiratory droplets produced by patient's coughing, laughing, sneezing, and ward activities; such as those generated by bed making and mechanical floor cleaning, have been shown to release large number of bacteria into the air [6]. The potential hazards posed by air-borne bacteria depends on the pathogenicity of a specific strain, environmental factor and bacterial gene pool including antibiotic resistance gene. This study was therefore designed to determine the prevalence and antibiotic susceptibility profile of airborne bacteria isolated from surgical and labour theatres in Federal Teaching Hospital Abakaliki (FETHA), Ebonyi State, Nigeria.

# Materials and Methods

## Sample collection

Forty (40) air samples were collected aseptically from general surgical theatre, (n=26), and labour theatre (n=14) using settle plate method. A blood agar plate was exposed to the air in the hospital theatres; a metre above the floor and a metre from the wall. The plates were then covered after 1 hour of exposure and immediately transported to Department of Applied Microbiology laboratory, Ebonyi State University, for bacteriological analysis.

## Ethical clearance

Ethical clearance for this study was approved by the ethical clearance committee of Federal University Teaching Hospital, Abakaliki, Ebonyi State.

## Culture and isolation of clinical airborne bacteria

The blood agar plate exposed to the air in the hospital theatres were incubated at 37°C for 18-24 hours before sub-culturing onto mannitol salt agar, cysteine lactose electrolyte deficient (CLED) agar, nutrient agar and MacConkey agar using standard microbiological technique to obtain discrete colonies. Pure colonies were observed for their colonial morphology, growth on different/selective media, Gram ' s reaction, coagulase test, catalase test, and motility test. Isolates were further identified by biochemical tests which includes indole test, oxidase test, citrate utilization test, and sugar fermentation test (triple sugar iron agar) [7].

## Antibiotics susceptibility test

Antibiotic susceptibility test on isolated airborne bacteria was determined using the Kirby-Bauer disc diffusion method according to the recommendations of the Clinical and Laboratory Standard Institute [8]. A standardized inoculum equivalent to 0.5 McFarland standard of the isolate was inoculated aseptically on the surface of prepared Mueller-Hinton agar plates. The inoculated plates were allowed for pre-diffusion of the antibiotics for 10-15 minutes. The following standard antibiotic discs were tested against the isolates; ampicillin (10 µg), cefotaxime (30 µg), nofloxacin (5 µg), erythromycin (5 µg), tetracycline (30 µg), trimethoprim/sulfamethoxazole (75 µg), ceftazidime (30 µg), cefoxitin (30 µg), clindamycin (10 µg), muporocin (10 µg), tobramycin (10 µg), ticarcillin (30 µg), doripenem (10 µg), vancomycin (10 µg), chloramphenicol (15 µg), penicillin (10 µg) (Oxoid, UK). Sterilized forceps were used to place the antibiotic discs evenly on the inoculated Mueller-Hinton agar so that the disc should be about 15 mm from the edge of the plate and not closer than 25 mm from disc to disc. After 30 minutes, the plates were inverted and incubated for 24 hours. A ruler was used to measure the diameter of each zone of inhibition in mm on the underside of the plate. The inhibitory zone diameter was interpreted as susceptible or resistant according to the criteria of CLSI [8].

## Determination of ESBL-producing Gram-negative bacteria

Screening the Gram-negative bacterial isolates for ESBL production was done by observing their sensitivities to 2nd and 3rd generation cephalosporins; such as aztreonam (30 µg), cefepime (30 µg), cefotaxime (30 µg), cefoxitin (30 µg), ceftazidime (30 µg) and ceftriaxone (30 µg). These antibiotics


This article is available from: 10.36648/1989-8436.11.4.115

were aseptically placed at a distance of 30 mm apart on Mueller-Hinton agar (Oxoid, UK) plate that was previously inoculated with standardized inoculum of the test bacterium using a sterile swab stick in order to get a confluent growth. The plates could stand for about 30 minutes for pre-diffusion of the antibiotics and after which was incubated for 18-24 hours at 37°C. After the incubation time, the zones of inhibition were measured in millimeter using a metre rule and results were interpreted according to Clinical and Laboratory Standard Institute (CLSI) chart. ESBL production was suspected if any of the test bacteria showed reduced susceptibility or resistance to any of the antibiotics used for the screening studies according to the CLSI guidelines [8,9].

## Phenotypic confirmation of ESBL from isolated Gram-negative bacteria using double disk synergy test (DDST)

All the Gram-negative bacterial isolates that showed reduced susceptibility to any of the 2nd and 3rd generation cephalosporins were phenotypically confirmed for ESBL production using the double disc synergy test [9]. Sterile swab sticks were dipped into bacterial suspension (s) standardized to 0.5 McFarland turbidity standards and was inoculated on MH agar plates. Antibiotic disc of amoxicillin/clavulanic acid (20/10 g) was placed at the center of the MH agar plate and antibiotic discs containing cefotaxime (30g) and ceftazidime (30g) each was placed at a distance of 15 mm (center to enter) from the central disc, amoxicillin/clavulanic acid (20/10g) and the plates was incubated at 37°C for 18-24 hours. ESBL production was suspected phenotypically when the zones of inhibition of the cephalosporins (cefotaxime 30g and ceftazidime 30g) increased in the presence of amoxicillin/clavulanic acid disk (20/10g). A 5mm increase in the inhibition zone diameter for either of the cephalosporins (cefotaxime and ceftazidime) tested in combination with amoxycillin-clavulanic acid versus its zone when tested alone confirmed ESBL production phenotypically [9].

## Screening for methicillin-resistant *Staphylococcus aureus* (MRSA)

**Oxacillin screening agar test:** A standardized inoculum equivalent to 0.5 McFarland standard of the isolate was inoculated aseptically on Mueller-Hinton agar containing 4% sodium chloride and 1µg oxacillin $ml^{-1}$ (Hi media) and incubated at 35°C for 18-24 hours. Any isolate showing growth on the plate containing oxacillin was resistant to methicillin [10].

## Determination of multiple antibiotic resistance index (MARI)

The multiple antibiotic resistance index was calculated as the ratio of the number of antibiotics to which the isolates were resistant/the total number of antibiotics against which the isolates were tested.

# Results

A total of 138 airborne bacterial isolates were obtained from 40 blood agar samples exposed to air in the general surgical and labour theatres **(Table 1)**. Eighty seven (87) bacterial isolates were obtained from the general surgery theatre while 51 isolates were obtained from labour theatre **(Table 1)**. Out of the 138 airborne bacterial isolates obtained, *S. aureus* [40 (29%)] was the most predominant species. This was followed by coagulase-negative *staphylococci* (CONS) [26 (18.8%)]. Micrococcus spp. had prevalence frequency of 16 (11.6%) each; *Klebsiella spp.* had prevalence frequency of 8 (5.8%); *P. aeruginosa* had prevalence frequency of 9 (6.5%) while *Streptococcus spp.* and Acinetobacter had the least prevalence frequency of 7 (5.1%) each **(Table 1).** Antibiotic susceptibility results showed that *S. aureus* isolates were completely resistant (100%) to trimethoprim/sulfamethoxazole. Resistance (50-85.7%) was also recorded against clindamycin, erythromycin, mupirocin, and vancomycin in the two theatres. Isolates were completely susceptible (100%) to ticarcillin and tobramycin in the two theatres **(Table 2)**.

There was no statistically significant difference in the antibiotic resistance frequencies of *S. aureus* isolates from the two theatres (P=0.641 at $p<0.05$). Antibiotic susceptibility results showed that CONS isolates were resistant (50-62.5%) to trimethoprim/sulfamethoxazole and erythromycin (62.5%). In contrast, CONS isolates were completely susceptible (100%) to ticarcillin and tobramycin in the two theatres **(Table 3)**. Susceptibility (62.5-80%) was also recorded with clindamycin, muporocin, nofloxacin, penicillin, and vancomycin **(Table 3)**. There was no statistically significant difference in the antibiotic resistance frequencies of CONS isolates from the two theatres (P=0.35 at $p<0.05$).

**Table 1** Frequency Distribution of the Bacteria Isolated from air samples in theatres.

| Bacterial isolates | General surgery theatre | Labour theatre | Total n (%) |
|---|---|---|---|
| *S. aureus* | 26 | 14 | 40 (29%) |
| CONS | 16 | 10 | 26 (18.8%) |
| *Streptococcus spp.* | 4 | 3 | 7 (5.1%) |
| *Micrococcus spp.* | 10 | 6 | 16 (11.6%) |
| *Bacillus spp.* | 15 | 10 | 25 (18.1%) |

| | | | |
|---|---|---|---|
| *Acinetobacter spp.* | 4 | 3 | 7 (5.1%) |
| *Klebsiella spp.* | 5 | 3 | 8 (5.8%) |
| *P. aeruginosa* | 7 | 2 | 9 (6.5%) |
| Total | 87 | 51 | 138 |
| Key: CONS=Coagulase negative staphylococci | | | |

**Table 2** Antibiotic Susceptibility Pattern of Staphylococcus aureus isolates.

| Wards | Pattern | Antibiotics | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DA (%) | E (%) | MUP (%) | NOR (%) | OX (%) | P (%) | SXT (%) | TIC (%) | TOB (%) | VAN (%) |
| General Theatre | S | 73.1 | 69.2 | 42.3 | 69.2 | 30.8 | 30.8 | 0 | 100 | 100 | 76.9 |
| | R | 26.9 | 30.8 | 57.7 | 30.8 | 69.2 | 69.2 | 100 | 0 | 0 | 19.2 |
| Labour Theatre | S | 64.3 | 71.4 | 50 | 71.4 | 14.3 | 14.3 | 0 | 100 | 100 | 71.4 |
| | R | 35.7 | 28.6 | 50 | 28.6 | 85.7 | 85.7 | 100 | 0 | 0 | 28.6 |
| **KEY**: S: Susceptible; R: Resistant; Da: Clindamycin; E: Erythromycin; MUP: Muporocin; NOR: Nofloxacin; OX: Oxacillin; P: Penicillin; SXT: Trimethxpin/ Sulfamethoxazole; TIC: Ticarcillin; TOB: Tobramycin; VAN: Vancomycin | | | | | | | | | | | |

**Table 3** Antibiotic Susceptibility Pattern of Coagulase-negative *Staphylococci* (CONS) isolated from General Surgical and Labour Theatre in FETHA.

| Wards | Pattern | Antibiotics | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DA | E | MUP | NOR | OX | P | SXT | TIC | TOB | VAN |
| General Theatre | S | 62.5 | 37.5 | 75 | 100 | 62.5 | 68.8 | 56.3 | 100 | 100 | 75 |
| | R | 37.5 | 62.5 | 25 | 0 | 37.5 | 31.3 | 43.8 | 0 | 0 | 25 |
| Labour Theatre | S | 80 | 80 | 70 | 100 | 30 | 60 | 50 | 100 | 100 | 80 |
| | R | 20 | 20 | 30 | 0 | 70 | 40 | 50 | 0 | 0 | 20 |

Antibiotic susceptibility results showed that *Streptococcus spp.* isolates were resistant (60-80%) to mupriocin, norfloxacin, and penicillin but susceptible (60-100%) to clindamycin, trimethoprim/sulfamethoxazole, ticarcillin, erythromycin, tobramycin, and vancomycin **(Table 4)**. There was no statistically significant difference in the antibiotic resistance frequencies of *Streptococcus spp.* isolates from the two theatres (P=0.41 at p<0.05). Antibiotic susceptibility results showed that *micrococcus spp.* isolates were resistant (50-100%) to clindamycin, trimethoprim/sulfamethoxazole, ticarcillin, norfloxacin, and penicillin but susceptible (66.7-100%) to mupriocin, erythromycin, tobramycin, and vancomycin **(Table 5)**. There was no statistically significant difference in the antibiotic resistance frequencies of *micrococcus spp.* isolates from the two theatres (P=0.89 at p<0.05). Antibiotic susceptibility results showed that *Bacillus spp.* isolates were completely resistant (100%) to clindamycin, mupirocin, and penicillin but susceptible (50-90%) to erythromycin, trimethoprim/sulfamethoxazole, ticarcillin, norfloxacin, tobramycin, and vancomycin **(Table 6).**

There was no statistically significant difference in the antibiotic resistance frequencies of *Micrococcus spp.* isolates from the two theatres (P=0.06 at p<0.05). Antibiotic susceptibility results showed that *Acinetobacter spp.* isolates were resistant (50% -100%) to ampicillin, chloramphenicol, mupirocin, norfloxacin, trimethoprim/sulfamethoxazole, tetracycline, ticarcillin, and tobramycin but susceptible to doripenem (66.7%) and ceftazidime (75%) **(Table 7)**. There was no statistically significant difference in the antibiotic resistance frequencies of *Acinetobacter spp.* isolates from the two theatres (P=0.38 at p<0.05). Antibiotic susceptibility results showed that *Klebsiella spp.* isolates were resistant (66.7-100%) to ampicillin, ceftazidime, mupirocin, norfloxacin, trimethoprim/sulfamethoxazole, and tetracycline but susceptible (60-100%) to chloramphenicol, doripenem, ticarcillin, and tobramycin **(Table 8)**. There was no statistically significant difference in the antibiotic resistance frequencies of *Klebsiella spp.* isolates from the two theatres (P=0.09 at p<0.05).

**Table 4** Antibiotic susceptibility pattern of Streptococcus spp. isolates.


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| Wards | Pattern | Antibiotics | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DA (%) | E (%) | MUP (%) | NOR (%) | OX (%) | P (%) | SXT (%) | TIC (%) | TOB (%) | VAN (%) |
| General Theatre | S | 100 | 80 | 40 | 40 | 80 | 20 | 100 | 100 | 60 | 80 |
| | R | 0 | 20 | 60 | 60 | 20 | 80 | 0 | 0 | 40 | 20 |
| Labour Theatre | S | 100 | 100 | 66.7 | 33.3 | 100 | 100 | 100 | 100 | 100 | 0 |
| | R | 0 | 0 | 33.3 | 66.7 | 0 | 0 | 0 | 0 | 0 | 100 |

**Table 5** Antibiotic Susceptibility Pattern of *Micrococcus species* isolated from General Surgical and Labour Theatre in FETHA.

| Wards | Pattern | Antibiotics | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DA (%) | E (%) | MUP (%) | NOR (%) | OX (%) | P (%) | SXT (%) | TIC (%) | TOB (%) | VAN (%) |
| General Theatre | S | 100 | 70 | 70 | 30 | 50 | 30 | 0 | 0 | 100 | 100 |
| | R | 0 | 30 | 30 | 70 | 50 | 70 | 100 | 100 | 0 | 0 |
| Labour Theatre | S | 50 | 66.7 | 83.3 | 33.3 | 33.3 | 0 | 0 | 0 | 100 | 100 |
| | R | 50 | 33.3 | 16.7 | 66.7 | 66.7 | 100 | 100 | 100 | 0 | 0 |

**Table 6** Antibiotic Susceptibility Pattern of *Bacillus species* isolates.

| Wards | Pattern | Antibiotics | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DA (%) | E (%) | MUP (%) | NOR (%) | OX (%) | P (%) | SXT (%) | TIC (%) | TOB (%) | VAN (%) |
| General Theatre | S | 0 | 80 | 0 | 86.7 | 0 | 0 | 53.3 | 66.7 | 66.7 | 66.7 |
| | R | 100 | 20 | 100 | 13.3 | 100 | 100 | 46.7 | 33.3 | 33.3 | 33.3 |
| Labour Theatre | S | 0 | 80 | 0 | 90 | 0 | 0 | 50 | 80 | 60 | 70 |
| | R | 100 | 20 | 100 | 10 | 100 | 100 | 50 | 20 | 40 | 30 |

**Table 7** Antibiotic Susceptibility Pattern of *Acinetobacter spp.* Isolates.

| Wards | Pattern | Antibiotics | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AMP (%) | C (%) | CAZ (%) | DOX (%) | MUP (%) | NOX (%) | SXT (%) | TE (%) | TIC (%) | TOB (%) |
| General Theatre | S | 0 | 25 | 75 | 75 | 0 | 50 | 0 | 25 | 25 | 0 |
| | R | 100 | 75 | 25 | 25 | 100 | 50 | 100 | 75 | 75 | 100 |
| Labour Theatre | S | 0 | 0 | 66.7 | 66.7 | 0 | 33.3 | 0 | 33.3 | 0 | 66.7 |
| | R | 100 | 100 | 33.3 | 33.3 | 100 | 66.7 | 100 | 66.7 | 100 | 33.3 |

**Table 8** Antibiotic Susceptibility pattern of *Klebsiella spp.* Isolates.

| Wards | Pattern | Antibiotics | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AMP (%) | C (%) | CAZ (%) | DOX (%) | MUP (%) | NOR (%) | SXT (%) | TE (%) | TIC (%) | TOB (%) |
| General Theatre | S | 0 | 100 | 0 | 60 | 0 | 0 | 0 | 20 | 60 | 60 |
| | R | 100 | 0 | 100 | 40 | 100 | 100 | 100 | 80 | 20 | 40 |
| Labour Theatre | S | 0 | 100 | 0 | 100 | 0 | 0 | 0 | 33.3 | 66.7 | 66.7 |
| | R | 100 | 0 | 100 | 0 | 100 | 100 | 100 | 66.7 | 33.3 | 33.3 |

Antibiotic susceptibility results showed that Pseudomonas aeruginosa isolates were resistant (80%-100%) to ampicillin, ceftazidime, mupirocin, trimethoprim/sulfamethoxazole, and tetracycline but susceptible (57.1-100%) to chloramphenicol, doripenem, norfloxacin, ticarcillin, and tobramycin **(Table 9)**. There was no statistically significant difference in the antibiotic resistance frequencies of *Pseudomonas aeruginosa* isolates from the two theatres (P=0.49 at p<0.05).

A total 17 Gram-negative bacterial isolates (2 *Acinetobacter spp.,* 7 *Klebsiella spp.,* and 8 *P. aeruginosa*) were ESBL-positive while 30 out of the *S. aureus* isolates were methicillin-resistant *S. aureus* (MRSA) in the two theatres **(Table 10)**.

**Table 9** Antibiotic Susceptibility Pattern of *Pseudomonas aeruginosa* isolates.

| Wards | Pattern | Antibiotics | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AMP (%) | C (%) | CAZ (%) | DOX (%) | MUP (%) | NOR (%) | SXT (%) | TE (%) | TIC (%) | TOB (%) |
| General Theatre | S | 0 | 57.1 | 20 | 85.7 | 14.3 | 85.7 | 0 | 0 | 100 | 100 |
| | R | 100 | 42.9 | 80 | 14.3 | 85.7 | 14.3 | 100 | 100 | 0 | 0 |
| Labour Theatre | S | 0 | 100 | 20 | 66.7 | 0 | 100 | 0 | 0 | 100 | 100 |
| | R | 100 | 0 | 80 | 33.3 | 100 | 0 | 100 | 100 | 0 | 0 |

**Table 10** Frequency Distribution of Methicillin-resistant *S. aureus* (MRSA) and ESBL-positive Gram-negative bacteria in General surgery and Labour theatres.

| Wards | MRSA Positive isolates | ESBL positive isolates | | |
|---|---|---|---|---|
| | | *Acinetobacter spp* | *Klebsiella spp* | *Pseudomonas spp* |
| General Theatre | 18 | 0 | 4 | 6 |
| Labour Theatre | 12 | 2 | 3 | 2 |
| Total | 30 (75%) | 2 | 7 | 8 |

## Discussion

The control and effective prevention of antibiotic resistance nosocomial infections requires a better identification of airborne bacteria that are potentially harmful to patients. This information is critical to implementing more appropriate control measures against the spread of airborne hospital-acquired infections. In this study, analysis of air samples carried out by plate gravitational settling (passive) method in general surgical and labour theatres at Federal Teaching Hospital Abakaliki (FETHA), has shown the preponderance of airborne bacteria. Gram-positive bacteria such as *Staphylococcus aureus* (29%), Coagulase-negative *staphylococci* (18.8%), *Streptococus spp.* (5.1%), *Micrococcus spp.* (11.6%), and *Bacillus spp.* (18.1%) were isolated from the general surgery and labour theatres while Gram-negative bacteria such as *P. aeruginosa* (6.5%), *Klebsiella spp.* (5.8%), and *Acinetobacter spp.* (5.1%) were also isolated. Our study revealed that Gram-positive bacteria were more prevalent than Gram-negative bacteria among the bacterial isolates obtained from the air samples of the two theatres. This agrees with the findings of Ekhaise et al. [5] who also reported that Gram-positive bacteria were more prevalent than Gram-negative bacteria, with *Staphylococcus* being the most predominant Gram-positive bacteria in air samples collected from hospital environment. *Pseudomonas aeruginosa* was the predominant Gram-negative bacteria isolated. Reports published earlier suggested that high prevalence of Gram-positive bacteria in air samples could be attributed to their ability to survive environmental stress as they possess pigments and photo-reactivation mechanisms that provide protection from sunlight. The high peptidoglycan content in their cell walls have also been known to provide protection from drying and heat stress, thereby spreading across considerable distance which in turn results in infections [11]. Gram-negative bacteria have been reported to be less prevalent in air samples due to their susceptibility to environmental stress because of low peptidoglycan contents in their cell wall [12]. The antibiotic susceptibility pattern of airborne bacterial isolate revealed that vancomycin, erythromycin, ticarcillin, and tobramycin were generally the most active antibiotics against Gram-positive bacteria isolated from the general surgery and labour theatres while doripenem, chloramphenicol, ticarcillin, and tobramycin were the active antibiotics against Gram-negative bacteria. Interestingly, ticarcillin and tobramycin were continually active against all the Gram-positive and Gram-negative bacteria isolated from the two theatres. Virtually all the bacterial isolates in this study were multidrug-resistant as they were resistant to at least two different classes of antibiotics. Our study agrees with the report indicated that airborne bacteria are a risk factor for surgical site infections. Our study also revealed that 17 Gram-negative bacteria (2 *Acinetobacter spp.*, 7 *Klebsiella spp.,* and 8 *P. aeruginosa*) were ESBL-positive while 30 (75%) out of the *S. aureus* isolates were methicillin-resistant *S. aureus* (MRSA) in the two theatres. The observed trend in prevalence/incidence of these pathogen in hospital infections further highlights them as important public health challenge with increasing economic and human impact. This is in line with the study of Stetzenbach [13], who reported that the


This article is available from: 10.36648/1989-8436.11.4.115

increasing prevalence of antibiotic resistance among various pathogens such as methicillin-resistant *Staphyloccocus aureus* (MRSA) and extended spectrum beta-lactamases (ESBLs) by Gram-negative bacteria such as *Klebsiella pneumoniae* and multidrug resistant Acinetobacter species has made the incidence of hospital infections critical. Their existence in air may be attributed to the improper handling and disposal of hospital wastes and the climatic conditions prevailing in hospital theatres [13,14].

## Conclusion

Our study has shown that airborne Gram-positive (*Staphylococcus aureus, Coagulase-negative Staphylococci, Bacillus spp., Micrococcus spp*., and *Streptococcus spp.*) and Gram-negative bacteria (*Pseudomonas aeruginosa, Klebsiella spp.,* and *Acinetobacter spp.)* were present in general surgical and labour theatres of Federal Teaching Hospital Abakaliki (FETHA). Our study also showed that Gram-positive bacteria, especially *S. aureus* were more predominant among the airborne bacterial isolates. Gram-negative bacterial isolates in this study were also positive for extended-spectrum beta-lactamase (ESBL) production. Virtually all isolates in this study were multidrug-resistant. Interestingly, vancomycin, erythromycin, ticarcillin, and tobramycin were generally the most active antibiotics against Gram-positive bacteria isolated from the general surgery and labour theatres while doripenem, chloramphenicol, ticarcillin, and tobramycin were the most active against Gram-negative bacteria. The findings of this study imply that the high bacterial load of indoor air judges it as a risk factor for surgical site infections. The presence of airborne bacterial isolates in surgical and theatre wards threatens patients' health status as it puts them at risk of post-operative infections. There is need for hospitals to encourage periodic microbial load review of surgical and labour theatres, and their antibiotic sensitivity pattern. Therefore, to ensure good indoor air quality for patients and healthcare workers, it is imperative for hospitals to properly disinfect/sterilize hospital environment and encourage periodic microbial load review of surgical and labour theatres. This will greatly help in the prevention of nosocomial infections.

## Conflict of Interest

None to declare.

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