Original article

Effect of silver nanoparticles on biofilm-forming *Pseudomonas aeruginosa* isolates from Menoufia University Hospitals

Amal F. Makled¹, Sahar A. Mohamed¹, Ahmed A. Teima², Dalia N. Shaban¹, Amal M. Dawoud¹

1- Department of Medical Microbiology and Immunology, Faculty of Medicine, Menoufia University, Egypt
2- Department of Tropical medicine, Faculty of Medicine, Menoufia University, Egypt.

**ABSTRACT**

**Background:** Numerous infections can be caused by *Pseudomonas aeruginosa*, particularly in hospitalized patients. The aim of the study was to estimate the antibacterial and biofilm inhibition effects of Silver nanoparticles (AgNPs) on *P.aeruginosa* isolates.

**Methodology:** A total of 283 samples were taken from hospitalized patients at Menoufia University Hospitals. *P. aeruginosa* isolates were identified by standard microbiological methods and VITEK 2 system. Antibiogram and biofilm formation were assessed by disk diffusion and modified congo red agar methods respectively. PslA and lasR genes were detected by conventional PCR. The antibacterial and anti-biofilm effects of AgNPs were also tested.

**Results:** *P. aeruginosa* isolates represented 16.7% of isolates, 92% of them were resistant to piperacillin and ciprofloxacin. Resistance to aztreonam, piperacillin/tazobactam, cefepime, ceftazidime, and gentamicin were 74%, 72%, 72%, 62%, and 52% respectively. *P. aeruginosa* isolates were sensitive to meropenem (68%) and imipenem (60%). Approximately 54% and 44% of the isolates were ESβL and biofilm producers respectively. PslA and lasR genes were found among 52% and 48% of *P. aeruginosa* isolates respectively. The MIC and MBC of AgNPs ranged from (6.25 to 50 μg/mL), inhibiting 40.9% of biofilms at 6.25 μg/mL and further inhibiting 40.9% of biofilms at 12.5 μg/mL.

**Conclusion:** *P. aeruginosa* are serious nosocomial pathogens due to high antimicrobial resistance that is mainly due to ESβLs production and biofilm formation. AgNPs exert potent antibacterial and anti-biofilm effects at concentrations of 6.25–50 μg/ml.
the host’s immune system and create an antibiotic resistance barrier (3).

The pslA and lasR genes are involved in the synthesis and regulation of components of biofilm matrix including exopolysaccharides and extracellular DNA. The pslA gene encodes a glycosyltransferase enzyme that catalyzes the polymerization of Psl polysaccharide, which is important in initial adhesion and aggregation of P. aeruginosa cells on surfaces. The lasR gene encodes a transcriptional regulator in the quorum sensing system that controls the expression of numerous genes that mediate communication of bacterial cells and trigger synthesis of extracellular matrix relevant to biofilm formation (4, 5).

Biofilm-producing P. aeruginosa causes severe infections, especially in immunocompromised patients. These infections are difficult to be treated because extracellular matrix of biofilm is one of the main elements that reduce the penetration of antibiotics and the emergence of resistance (5).

Therefore, other therapeutic agents (non-antibiotic) alone or in combination with antibiotics would be quite effective in the treatment of infections with multi-drug resistant P. aeruginosa. These strategies include the usage of phage therapy, iron chelation, nanoparticles, vaccination, electrochemical scaffolds, and antimicrobial peptides, as well as quorum sensing and bacterial lectins inhibition (6).

Recently, nanoparticles have been viewed as a strong substitute for antibiotics and have a good chance of addressing the issue of bacterial multidrug resistance. In addition to penetrating bacterial cell walls and causing the bacterial cells to be destroyed by the production of free radicals, AgNPs can also produce silver ions that can form bonds with important organelles and cause those organelles to malfunction (2).

Some studies have considered that the fundamental mechanisms of AgNPs in biofilm eradication are their binding to the exopolysaccharide matrix, which disrupts biofilm integrity by identifying the peptidoglycan in the bacterial cell wall, leading to physical damage and also, electrostatic interactions between AgNPs and bacterial membranes lead to membrane rupture, allowing penetration of AgNPs through the mature biofilm (7).

Nowadays, Wound dressings, medical device coatings, and AgNPs-impregnated textile fabrics are further examples of AgNPs uses. The benefit of using AgNPs for impregnation is that silver ions are continuously released, and the devices could be coated on both the interior and exterior, enhancing their antibacterial efficacy. Burn injuries treated with AgNPs have better cosmoses and scar-free healing. More research is needed to establish the interactions between AgNPs and antibiotics. (7).

The aim of this study was to assess the antibacterial and anti-biofilm activity of AgNPs on isolated P. aeruginosa.

Patients and Methods
Study design and patients:
This analytical cross-sectional study was conducted from January 2021 to August 2022. It included 283 clinical specimens (sputum, urine, pus, wound swab, blood and burn swabs) collected from patients at different departments (ICU, burn unit, surgery, urology, pediatrics and internal medicine), who developed symptoms and signs of HAIs which are infections affecting the patient as a result of admission and were not present at admission time. For the majority of patients, HAIs appear 48 hours or more after admission (9). All the selected patients were subjected to detailed history taking (including exposure to invasive procedures like surgery, urinary catheters, central venous lines or endotracheal tubes) and comprehensive clinical examinations. The Menoufia University Local Ethics Committee (11/2020MICR-17) approved the study protocol. Before involvement in this study, written consent was taken from each patient or his/her legal guardians. Inclusion criteria included patients who had HAIs. Exclusion criteria were patients who refused participation in the study, those with good response to antibiotic therapy or were colonized without signs of infections.

Sample size calculation:
According to Karimipour and Tanomand, (8) with power 80% and confidence level 95%. Sample size was calculated and found to be 40 subjects.

Identification of P. aeruginosa:
Samples were processed at Medical Microbiology and Immunology Department, Faculty of Medicine, Menoufia University. Identification of obtained colonies up to species level occurred via conventional techniques
including Gram stain, culture using various bacteriological media (nutrient agar, blood agar, macConkey's, sabouraud's dextrose agar, mannitol salt agar, and cetrimide agar) (Oxoid, UK) then incubated aerobically at 37°C for 24 hours, followed by biochemical reactions (TSI, urease, MIO, oxidase, and catalase)(2). Identification was then confirmed using VITEK2 compact device system (Biomeriux, France) using GN ID cards. Confirmed P. aeruginosa isolates were preserved at -80°C in the suspension of the brain heart infusion with 20% glycerol for subsequent gene analysis by PCR.

**Antimicrobial susceptibility test:**

Antimicrobial susceptibility for P. aeruginosa isolates was performed using Kirby-Bauer disk diffusion method against different antimicrobial agents (Oxoid, UK) and interpreted according to Clinical Laboratory Standard Institute 2022 CLSI (12). The tested antimicrobial agents included piperacillin/tazobactam (TZP, 100/10 μg), aztreonam (ATM, 30 μg), ceftazidime (CAZ, 30 μg), piperacillin (PPL, 100 μg), imipenem (IPM, 10 μg), meropenem (MEM, 10 μg), levofloxacin (LEV, 5 μg), ciprofloxacin (CIP, 5 μg), ofloxacin (OFLX, 5 μg), gentamicin (CN, 10 μg), tobramycin (TOB, 10 μg), amikacin (AK, 30 μg).

Multidrug-resistant P. aeruginosa included isolates that were resistant to at least one agent in three or more antimicrobial groups, whereas extensively drug-resistant isolates were those that were susceptible to only one or two categories and pandrug-resistant P. aeruginosa included those with resistance to all agents in all antimicrobial categories (13).

**Detection of ESβL production:**

Screening and phenotypic confirmation of ESβLs producers were performed using ceftazidime (30 μg), cefotaxime (30 μg), and ceftriaxone (30 μg). If the diameter of inhibition zone was less than 22 mm for ceftazidime, less than 27 mm for cefotaxime and less than 25 mm for ceftriaxone, the strain was regarded as suspicious for ESβL production. For confirmation, ceftazidime (30 μg) and ceftazidime/clavulanic acid (30/10 μg) discs were put 20 mm apart on MHA plate and incubated aerobically at 37°C for 18-24 hrs. ESβL producing isolate was considered when the diameter of the ceftazidime/clavulanic acid disk was 5 mm or more than that of ceftazidime disk alone (12, 14).

**Phenotypic identification of biofilm development:**

Modified congo red agar (MCRA) was used. Inoculated agar was incubated at 37°C for 48 h and then for 2-4 days at room temperature. Dry black color was interpreted as strong positive biofilm. Weak biofilm producer gave occasional darkening only in the center while red colonies was interpreted as negative biofilm producers (5).

**Genotypic detection of biofilm associated genes (pslA, lasR) by conventional PCR:**

**DNA extraction:**

Pure P. aeruginosa colonies were obtained by culturing on cetrimide agar (HI MEDIA) after multiple streaking plate method. According to the instructions of the manufacturer, bacterial DNA was extracted and purified from 50 isolated P. aeruginosa using the QIAamp DNA Mini Kit (Germany) (QIAamp® DNA Mini and Blood Mini Handbook, Fifth Edition, 2016). Table 1 lists the primers that were used. After DNA extraction, its concentration and purity were evaluated by spectrophotometer using the Nanodrop (Implen, Germany). The ratio of the readings at 260 nm and 280 nm (A260 / A280) ranged from 1.7 to 1.9.

**PCR amplification:**

For lasR gene and pslA gene, the following components were added to a thin-walled 25-μl PCR tube: 12.5 μl MyTaq PCRTM Master Mix (2x), 1 μl forward primer, 1 μl reverse primer, 0.5 μl Water nuclease–free and 10 μl DNA Extract. For the pslA gene amplification, initial denaturation at 94°C for 5 min, followed by 35 cycles of DNA denaturation for 30s at 94°C, primer annealing for 40s at 52°C and final extension for 50s at 72°C (15).

For the lasR gene, initial denaturation at 94°C for 5 min followed by 30 cycles of DNA denaturation for 30s at 94°C, primer annealing for 40s at 52°C and final extension for 50s at 72°C (16).

Electrophoresis was carried out on agarose gel 1.5% (EGY technology) stained with ethidium bromide (Sigma, USA) for 20 minutes. UV transilluminator was used to visualize the products using DNA molecular weight (MW) marker: (Ladder 50 bp ladder) (Bioline, UK) (code BIO-33056) for detection of pslA and lasR genes.

**Testing of the anti-bacterial effect of AgNPs**

NanoTech, Egypt provided a stock solution of 200 μg/ml spherical, water soluble AgNPs (20±5
nm). AgNPs were prepared by chemical reduction as reported by the manufacturer. Serial two-fold dilutions were used to create different concentrations of AgNPs from the stock solution, ranging from 100 µg/ml to 3.125 µg/ml. The bacterial suspension turbidity was adjusted to 0.5 McFarland Standard. 100µl of each concentration and 100 µl of diluted cultures of each isolate were added to the wells of the 96-well micro dilution flat bottom plate, which had been labeled with different AgNPs concentrations. The lowest AgNPs concentration at which no visible growth can be seen was identified as minimal inhibitory concentration (MIC). After a further 24 hours of incubation, a minimal bactericidal concentration (MBC) was determined as the maximum dilution of AgNPs that still prevented bacteria growth on agar plates (17).

Assessment of the anti-biofilm effect of AgNPs

About 2 ml of sterile Trypticase soy broth was poured into labeled tubes. 50 µl of freshly cultured strain was then added to each test tube. Then AgNPs at two-fold dilutions from 100 µg/ml to 3.125 µg/ml were added. Then, each labeled individual MCRA was inoculated, and the mixture was incubated aerobically at 37 °C for 24 hours. The color of the colonies was checked and interpreted - as mentioned before-under the heading “Phenotypic identification of biofilm development”

Statistical Analysis

Using SPSS version 23, data were gathered, tabulated and analyzed. The Chi-square (χ2) test was used for comparison of categorical variables. The p-value cut-off for statistical significance was at < 0.05.

Results

About 299 isolates were obtained from 283 clinical samples obtained from different hospital departments. The Gram-negative bacilli, Gram-positive cocci and Candida were identified in 74.6% (223/299), 24.4% (73/299) and 1% (3/299) respectively. Out of 50 P. aeruginosa isolates, 44% (22/50) were found to be biofilm producers using the MCRA method. Biofilm-forming isolates were 100% resistant to ceftazidime, 95.5% to ciprofloxacin, and 90.9% to piperacillin, aztreonam and ofloxacin. About 86.4% of biofilm-producing isolates were resistant to piperacillin/tazobactam and cefepime but lower resistance occurred with meropenem (50%), imipenem (59.1%) and gentamicin (68.2%). Biofilm production was detected among 31/50 (62%) by screening disk diffusion method and only 27/50 (54%) of them were confirmed by cephalosporin/clavulanate combined test with statistically significant difference (P-value <0.05). Except for tobramycin and ofloxacin, ESβLs producing P. aeruginosa showed higher rates of antibiotic resistance than non-ESβL producers. (Table-3).

Out of 50 P. aeruginosa isolates, 44% (22/50) and 48 % (24/50) were positive for the pslA and lasR genes respectively. About 36% (18/50) of isolates had both pslA and lasR genes (figure -1a and figure -1b).

Among biofilm producers, pslA and lasR genes were detected in 20/22(90.9%) and 18/22(81.8%) respectively (P-value <0.001), Among ESβL producing isolates, pslA and lasR positive isolates represented 16/27 (59.3%) and 14/27(51.9%) respectively with no statistically significant difference [Table -4].

All pslA positive P. aeruginosa isolates were resistant to quinolones group (ciprofloxacin, levofloxacin and ofloxacin), 92.3% (24/26) were resistant to each of piperacillin and ceftazidime, 88.5 % (23/26) were resistant to aztreonam and 80.8% (21/26) of isolates were resistant to gentamicin and piperacillin/tazobactam.

The majority of P.aeruginosa isolates were resistant to piperacillin (92%), ciprofloxacin (92%), levofloxacin (78%), ofloxacin (78%), aztreonam (74%), cefepime (72%), and piperacillin-tazobactam (72%). On the other hand, P. aeruginosa isolates were sensitive to meropenem (68%) and imipenem (60%) (Table-3). About 44% of P. aeruginosa isolates were Multi-drug resistant, 12% were extensively-drug resistant and 6% were Pan-drug resistant.

ESβL production was detected among 31/50 (62%) by screening disk diffusion method and only 27/50 (54%) of them were confirmed by cephalosporin/clavulanate combined test with statistically significant difference (P-value <0.05). Except for tobramycin and ofloxacin, ESβLs producing P. aeruginosa showed higher rates of antibiotic resistance than non- ESβL producers. (Table-3).
Among lasR positive P. aeruginosa isolates, 100% (24/24) were resistant to piperacillin, ceftazidime, ciprofloxacin, and levofloxacin, 95.8% (23/24) were resistant to ceftazidime, aztreonam and piperacillin/tazobactam, 91.7% (22/24) were resistant to ofloxacin and 83.3% (20/24) were resistant to tobramycin.

Regarding the antibacterial effect of AgNPs, higher concentrations were needed for bacterial growth inhibition in biofilm-producing isolates. MIC in biofilm producers ranged from 6.25 to 25 µg/ml, of which 36.4% had MIC of 25 µg/ml. On the other hand, the range of MIC in non-biofilm producers was (6.25 - 25 µg/ml), and 75% of them had MIC of 6.25 µg/ml [Table 5].

The MIC of AgNPs was 6.25 µg/mL in 81.6% (14/19) of antibiotic-susceptible P. aeruginosa isolates, MIC for inhibition of 55% of antibiotic resistant strains ranged from 12.5 to 25µg/ml, with statistically significant difference (P<0.05). This result suggests that higher concentrations of AgNPs are required for inhibition of antibiotic-resistant strains.

Regarding anti-biofilm effect of AgNPs, the biofilm formation was inhibited in 40.9% (9/22) of isolates at concentration were 6.25 µg/mL of AgNPs, while 12.5 µg/mL of AgNPs inhibited formation of biofilm in 81.8% (18/22) and at concentration 25 µg/mL, biofilm formation was inhibited in all isolates [figures- 2a and figure -2b].

**Table 1. Primers sequences of pslA and lasR genes.**

<table>
<thead>
<tr>
<th>Gene</th>
<th>Primer sequence 5’—–3’</th>
<th>Annealing temperature</th>
<th>Amplicon size (bp)</th>
<th>References</th>
</tr>
</thead>
</table>
| **pslA** | Forward  
TGGGTCTTCAAGTTCCGCTC  
Reverse  
ATGCTGGTCTTTGCGGATGA | 52°C | 119 | *(Maita and Boonbumrung, (15)*) |
| **lasR** | Forward  
AAGTGAAAAATTGGAGTGAG  
Reverse  
GTAGTTGCCGACGACGATGAAG | 52°C | 130 | *Lima et al., (16)* |
<table>
<thead>
<tr>
<th>Isolated organisms</th>
<th>Total (n=299)</th>
<th>Burn unit</th>
<th>Surgery</th>
<th>Urology</th>
<th>ICU</th>
<th>Pediatrics</th>
<th>Internal medicine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. (%)</td>
<td>No. (%)</td>
<td>No. (%)</td>
<td>No. (%)</td>
<td>No. (%)</td>
<td>No. (%)</td>
<td>No. (%)</td>
</tr>
<tr>
<td>Staph aureus</td>
<td>62 (20.7%)</td>
<td>10 (16.1%)</td>
<td>2 (3.2%)</td>
<td>6 (9.7%)</td>
<td>40 (64.5%)</td>
<td>3 (1.0%)</td>
<td>1 (1.6%)</td>
</tr>
<tr>
<td>Coagulase-negative Staphylococci</td>
<td>6 (2.0%)</td>
<td>-</td>
<td>1 (16.7%)</td>
<td>1 (16.7%)</td>
<td>4 (66.7%)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Strept.pneumoniae</td>
<td>5 (1.7%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4 (80%)</td>
<td>-</td>
<td>1 (20%)</td>
</tr>
<tr>
<td>Klebsella spp</td>
<td>84 (28.1%)</td>
<td>30 (35.7%)</td>
<td>2 (2.4%)</td>
<td>18 (21.4%)</td>
<td>32 (38%)</td>
<td>1 (1.2%)</td>
<td>1 (1.2%)</td>
</tr>
<tr>
<td>E. coli</td>
<td>69 (23.1%)</td>
<td>-</td>
<td>4 (5.8%)</td>
<td>34 (49.3%)</td>
<td>23 (33.3%)</td>
<td>3 (4.3%)</td>
<td>5 (7.2%)</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>50 (16.7%)</td>
<td>30 (60%)</td>
<td>1 (2%)</td>
<td>6 (12%)</td>
<td>12 (24%)</td>
<td>1 (2%)</td>
<td>-</td>
</tr>
<tr>
<td>Acinetobacter spp</td>
<td>9 (3.0%)</td>
<td>-</td>
<td>1 (11.1%)</td>
<td>3 (33.3%)</td>
<td>4 (44.4%)</td>
<td>1 (11.1%)</td>
<td>-</td>
</tr>
<tr>
<td>Proteus spp</td>
<td>5 (1.7%)</td>
<td>-</td>
<td>1 (20%)</td>
<td>1 (20%)</td>
<td>3 (60%)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Enterobacter spp</td>
<td>5 (1.7%)</td>
<td>-</td>
<td>-</td>
<td>2 (40%)</td>
<td>3 (60%)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Citrobacter spp</td>
<td>1 (0.3%)</td>
<td>-</td>
<td>-</td>
<td>1 (100%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Candida spp</td>
<td>3 (1.0%)</td>
<td>-</td>
<td>1 (33.3%)</td>
<td>1 (33.3%)</td>
<td>1 (33.3%)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 3. Antibiotic resistance of Pseudomonas aeruginosa in relation to ESβL production

<table>
<thead>
<tr>
<th>Resistant antimicrobial agents</th>
<th>Antimicrobial resistance</th>
<th>ESβL (No =27)</th>
<th>Non-ESβL (No =23)</th>
<th>X2</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piperacillin</td>
<td>46 (92%)</td>
<td>27 (58.7)</td>
<td>19 (41.3)</td>
<td>5.104*</td>
<td>0.038*</td>
</tr>
<tr>
<td>Piperacillin/tazobactam</td>
<td>36 (72%)</td>
<td>15 (41.7)</td>
<td>21 (58.3)</td>
<td>7.873*</td>
<td>0.005*</td>
</tr>
<tr>
<td>Ceftazidime</td>
<td>31 (62%)</td>
<td>27 (87.1)</td>
<td>4 (12.9)</td>
<td>35.975**</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>Cefepime</td>
<td>36 (72%)</td>
<td>27 (75.0)</td>
<td>9 (25.0)</td>
<td>22.826**</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>Aztreonam</td>
<td>37 (74%)</td>
<td>27 (73.0)</td>
<td>10 (27.0)</td>
<td>20.623**</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>Imipenem</td>
<td>16 (32%)</td>
<td>14 (87.5)</td>
<td>2 (12.5)</td>
<td>10.630*</td>
<td>0.001*</td>
</tr>
<tr>
<td>Meropenem</td>
<td>13 (26%)</td>
<td>13 (100)</td>
<td>0 (0.0)</td>
<td>14.965**</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>Gentamicin</td>
<td>26 (52%)</td>
<td>16 (61.5)</td>
<td>10 (38.5)</td>
<td>1.239</td>
<td>0.266</td>
</tr>
<tr>
<td>Tobramycin</td>
<td>24 (48%)</td>
<td>10 (41.7)</td>
<td>14 (58.3)</td>
<td>2.826</td>
<td>0.093</td>
</tr>
<tr>
<td>Amikacin</td>
<td>24 (48%)</td>
<td>10 (41.7)</td>
<td>14 (58.3)</td>
<td>2.826</td>
<td>0.093</td>
</tr>
<tr>
<td>Ciprofloxacin</td>
<td>46 (92%)</td>
<td>25 (54.3)</td>
<td>21 (45.7)</td>
<td>0.028</td>
<td>1.000</td>
</tr>
<tr>
<td>Levofloxacin</td>
<td>39 (78%)</td>
<td>24 (61.5)</td>
<td>15 (38.5)</td>
<td>4.056*</td>
<td>0.044*</td>
</tr>
<tr>
<td>Ofloxacin</td>
<td>39 (78%)</td>
<td>19 (48.7)</td>
<td>20 (51.3)</td>
<td>1.991</td>
<td>0.158</td>
</tr>
</tbody>
</table>

X2: Chi square test  p: p value for comparing between ESβL was detected by cephalosporin/clavulanate combined test and Non-ESβL in Pseudomonas

Table 4. Prevalence of biofilm genes (pslA, lasR) among biofilm and ESβL producing Pseudomonas aeruginosa isolates.

<table>
<thead>
<tr>
<th>Variable data</th>
<th>PslA gene</th>
<th>Total</th>
<th>lasR gene</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive</td>
<td>Negative</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Production of biofilm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biofilm producers</td>
<td>20</td>
<td>90.9</td>
<td>2</td>
<td>9.1</td>
</tr>
<tr>
<td>Non biofilm producers</td>
<td>6</td>
<td>21.4</td>
<td>22</td>
<td>78.6</td>
</tr>
<tr>
<td>X2 (p)</td>
<td>23.828*</td>
<td>(&lt;0.001*)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production of ESβL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESβL producers</td>
<td>16</td>
<td>59.3</td>
<td>11</td>
<td>40.7</td>
</tr>
<tr>
<td>Non ESβL producers</td>
<td>10</td>
<td>43.5</td>
<td>13</td>
<td>56.5</td>
</tr>
<tr>
<td>X2 (p)</td>
<td>1.239 (0.266)</td>
<td></td>
<td>0.349 (0.555)</td>
<td></td>
</tr>
</tbody>
</table>
Table 5. Concordance of Minimal inhibitory and Minimal bactericidal concentrations of Silver Nano particles between biofilm producers and non-biofilm producers

<table>
<thead>
<tr>
<th>Concentration of silver nano particles</th>
<th>Total (n=50)</th>
<th>Biofilm producers (n=22)</th>
<th>Non-biofilm producers (n=28)</th>
<th>$\chi^2$</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>MIC=MBC</td>
<td>34</td>
<td>68.0</td>
<td>10</td>
<td>45.5</td>
<td>24</td>
</tr>
<tr>
<td>6.25µg/ml</td>
<td>18</td>
<td>36.0</td>
<td>0</td>
<td>0.0</td>
<td>18</td>
</tr>
<tr>
<td>12.5 µg/ml</td>
<td>10</td>
<td>20.0</td>
<td>4</td>
<td>18.2</td>
<td>6</td>
</tr>
<tr>
<td>25 µg/ml</td>
<td>6</td>
<td>12.0</td>
<td>6</td>
<td>27.3</td>
<td>0</td>
</tr>
<tr>
<td>MIC&lt;MBC</td>
<td>16</td>
<td>32.0</td>
<td>12</td>
<td>54.5</td>
<td>4</td>
</tr>
<tr>
<td>MIC (6.25 µg/ml) &lt; MBC (12.5 µg/ml)</td>
<td>10</td>
<td>20.0</td>
<td>7</td>
<td>31.8</td>
<td>3</td>
</tr>
<tr>
<td>MIC (12.5 µg/ml) &lt; MBC (25 µg/ml)</td>
<td>4</td>
<td>8.0</td>
<td>3</td>
<td>13.6</td>
<td>1</td>
</tr>
<tr>
<td>MIC (25 µg/ml) &lt; MBC (50 µg/ml)</td>
<td>2</td>
<td>4.0</td>
<td>2</td>
<td>9.1</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure (1a): Agarose gel electrophoresis for the PCR amplified products of Pseudomonas aeruginosa pslA gene.

Lane M: DNA molecular size marker (50-550 bp).
Lanes 1, 2, 3, 4, 6, 7, 8 and 9 were positive for pslA gene (119 bp).
Lanes 5 was negative for pslA gene (119 bp).
Figure (1b): Agarose gel electrophoresis for the PCR amplified products of lasR gene.

Lane M: DNA molecular size marker (50-550bp).
Lanes 1, 2, 4, 5, 6, 7 and 8 were positive for lasR gene (130 bp).
Lanes 3 and 9 were negative for lasR gene (130 bp).

Figure (2a): Effect of different concentrations of AgNPS on biofilm forming P. aeruginosa.
Figure (2b) Anti-biofilm concentration of AgNPs on biofilm forming isolates on MCRA that show there is a biofilm at 6.25 and 12.5 µg/ml and absence of biofilm and growth of organism at concentration of 25 and 50 µg/ml.

Discussion

The Centers for Disease Control and Prevention (CDC) have considered multidrug-resistant P. aeruginosa as a serious threat for the past ten years (19).

P. aeruginosa were isolated from 16.7% of clinical samples. This result was similar to Mahmoud et al., (20) study performed in Egypt that found 19%; (54/283) of all specimens were P. aeruginosa. On the other hand, a higher percentage (33.3%) was reported by Abd El-Baky et al., (21) in Egypt. In contrast, a very low percentage (6.67%) was found by Khan et al., (22) in Pakistan. These differences may be due to differences in adherence to infection control measures and variable resistance to antibiotics (22).

P. aeruginosa was mostly isolated from burn wounds (60%). This was consistent with Roshani et al., (23) findings, which demonstrated that burn samples accounted for a significant source proportion of the isolates (58%). This high prevalence may be due to that P. aeruginosa can colonize the skin and mucous membranes of burn patients and form biofilms that protect the bacteria from host defenses and antibiotics (24).

About 62% of the isolates in this study were ceftazidime resistant. A similar result (61.4%) was obtained by Kos et al., (25) in China. Resistance to aminoglycosides in our study was similar to the study conducted by Asghar and Ahmed, (26) in KSA which found resistance rate ranged from 46% to 52%. Resistance to Quinolones (ciprofloxacin, levofloxacin, and ofloxacin) varied from (78% to 92%) in our study. Similarly, a study performed in Iran by Arabameri et al. (27) revealed that 78% of isolates were resistant to levofloxacin and 80% were resistant to the ciprofloxacin. For meropenem and imipenem respectively about 68% and 60% of P. aeruginosa isolates showed sensitivity. A comparable result was obtained by Pokharel et al., (28) in Nepal in which 65% of isolates were susceptible to both imipenem and meropenem.

In the current study, screening of ESβL production showed that 62% of isolated P. aeruginosa were ESβL producers, whereas the combined disk test detected 54%. Woodford et al. (29) in the United Kingdom reported near findings, where 47% of P. aeruginosa isolates were ESβL positive.

In this study, 22/50 (44%) of P. aeruginosa isolates were biofilm producers of which 20/22 (90.9%) formed strong biofilms and 2/22 (9.1%) formed weak biofilms. Heydari & Eftekhar, (30) in Iran published that 43.5% of isolates were biofilm producers of which 66.7% produced strong biofilms.
and 33.3% formed weak biofilms. A higher rate of biofilm production among P. aeruginosa isolates was reported by El-Khashaab et al., (31) in Egypt (91.4%). In contrast, lower rates of biofilm production among P. aeruginosa isolates were reported by Abootaleb et al., (4) in Iran (24%). The variance could be explained by the various types and numbers of samples used in each study and the isolates’ capacity to form a biofilm (32).

In the present study, pslA gene was detected in 20/22 (90.9%) of biofilm-producing P. aeruginosa isolates. Nader et al. (33) observed a higher rate in Iraq, where 31/31 (100%) of biofilm-forming isolates had the pslA gene. As for lasR gene, it was found in 18/22 (81.8%) of biofilm-producing P. aeruginosa isolates. Similarly, Abdelraheem et al., (32) in Egypt documented that lasR was detected in 20/27 (74.1%) of biofilm-forming isolates. Higher result (84%) was found by Elnegery et al., (34), while lower rates (40%) was noted by Abousheleib et al., (35) in Egypt.

When evaluating the anti-bacterial activity of AgNPs, the MIC of AgNPs ranged from 6.25 to 25 µg/ml with a better antibacterial activity as compared to the earlier work of Singh et al. (36), who observed that the MIC of AgNPs ranged from 6.25 to 200 µg/ml. On contrast, Liao et al., (37) in China reported lower MIC range (2.812-5.624 µg/mL) of AgNPs.

The major application of AgNPs is as a biofilm inhibiting agent against P. aeruginosa isolates. AgNPs were most effective in biofilm prevention among P. aeruginosa at a concentration of 25 µg/ml, with a 100% inhibition rate. However, Kalishwaralal et al., (38) revealed that the maximal inhibition of biofilm was achieved at concentration 100 µg/mL. According to Singh et al., (39) in Denmark, 50 µg/mL of AgNPs had accepted anti-biofilm effect against P. aeruginosa. Moreover, Palanisamy et al. (40) in Malaysia found that the maximal activity of AgNPs against biofilm development occurred at a concentration of 25 µg/ml with an inhibition rate of 67%.

Conclusion and Recommendations

Recently frequent serious nosocomial infections could result from multi-drug resistant P. aeruginosa isolates which positively correlated with biofilm-forming capacity of the isolate. There is a high prevalence of the pslA and lasR genes among biofilm forming isolates. The synthesized AgNPs showed both antibacterial and anti-biofilm activity. More studies must be performed to show the safety and antimicrobial activity of AgNPs.

Limitation

The inability to cultivate the samples anaerobically due to financial constraints was one of the study’s limitations.

Acknowledgment

Great thanks from writers to personnel at Menoufia University Hospitals in Egypt for their invaluable assistance.

Financial disclosure. None.

Conflict of interest. No hidden conflicts of interest for the writers to mention.

References


5- Ansari MA, Khan HM, Khan AA, Cameotra SS, Pal R. Antibiofilm efficacy of silver nanoparticles against biofilm of extended spectrum β-lactamase isolates of...


11- Tille MB. Daily and scott,s diagnostic microbiology 2017 ED, mosby 2: 307-333

12- Clinical and Laboratory Standards Institute (CLSI) performance standards for antimicrobial susceptibility testing 32th ed. 2022; CLSI supplement M100.


20- Mahmoud AB, Zahran WA, Hindawi GR, Labib AZ, Galal R. Prevalence of multidrug-


38-Kalishwaralal K, BarathManiKanth S, Pandian SRK, Deepak V, Gurunathan S. Silver nanoparticles impede the biofilm formation by *P. aeruginosa* and *Staphylococcus epidermidis*. Colloids Surf B Bio Interfaces. 2010; 79(2) 340-344.
