Effects of aerators, filters and chlorination on contamination of water samples: a nine years study in a Southern University Hospital

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Abstract

Objectives. The aim of our study was to evaluate the microbiological contamination by Pseudomonas aeruginosa in the water system of the University Hospital “G. Martino” in Messina over a period of nine years, in order to a) clarify possible relationship between the presence of aerators and contamination, b) to highlight the presence of a yearly variation and c) to verify the statistical difference between microbiological contamination of taps with and without filters.

Materials and Methods. We carried out our study between January 2010 and December 2018 through the collection of water samples that were analysed for total bacteria count and Pseudomonas aeruginosa. The differences between the results recorded over the nine-year study period were analysed using variance analysis. P values of <0.05 were considered statistically significant. Software R was used for statistical assessment.

Results. We analysed a total of 6168 samples with a positive rate of 9.31% and a decreasing trend over the years to a value of 2.44% (p<0.001), due to the elimination of the aerators of taps without filters and also to the introduction of filters in taps of high-risk wards and surgical rooms. We found statistical difference between taps with or without filter (p<0.001) and a higher positive rate during the summer season compared to the other months.

Conclusions. These results reveal a high level of contamination of taps by opportunistic bacteria with severe implications especially for high-risk settings and therefore, the need to improve the management of these devices. Clin Ter 2019; 170(4):e262-266. doi: 10.7417/CT.2019.2145

Key words: aerators, contamination, filters, Pseudomonas, taps, water

Introduction

The water distribution system in hospitals may constitute a source of healthcare-associated infections (HAIs) (1). Understanding the means of acquisition, sources and reservoirs of nosocomial pathogens is crucial for developing methods to reduce the incidence of nosocomial infections (2). Several non-coliform bacteria can replicate in relatively pure water, including Pseudomonas aeruginosa, Burkholderia cepacia, Serratia marcescens, Acinetobacter calcoaceticus, Flavobacterium meningosepticum, Aeromonas hydrophila, and certain nontuberculous mycobacteria. (3-4) Pseudomonas aeruginosa can persist in hospital water for long periods (5) and it thrives best in the distal elements of plumbing and waste-water systems, such as taps, sinks, U-bends, and toilets (6); it is considered one of the emerging microorganisms most frequently involved in pathologies such as bacteraemia, pneumopathy and meningitis (1). The infection of immunocompromised individuals by P. aeruginosa carries a risk of fatality but the incidence and mortality rate of infections are unknown (7). Retrograde contamination could occur in a number of different ways, many resulting from human behaviour. Outlet fitting may become contaminated via splashback from a contaminated waste trap or surface (e.g. while rinsing contaminated equipment) or through inappropriate disposal and/or splashing of patient fluids (8-10). Water contamination in hospitals is monitored by immediate filtration and culture on agar media (11). Various practical designs of water systems/appliances are described, during and after building construction, together with monitoring methods and outcomes. These include disinfection treatment options, taps, circulation systems, thermal control, filters, mixing devices etc.; design and construction considerations, such as safe plumbing systems (not necessarily cost-effective), pipework material and corrosion/leakage issues are also dealt with. Despite this, a systematic approach is fundamental with regular monitoring, maintenance and trouble-shooting within the context of a water safety plan managed by competent and responsible professionals (12).

The aim of our study was to evaluate the microbiological contamination by Pseudomonas aeruginosa in the water system of the University Hospital “G. Martino” di Messina over a period of nine years, in order to a) clarify possible relationship with the presence of aerators, b) to highlight the presence of yearly variation and c) to verify statistical difference between taps with and without filters.
Water: valuable asset and means of infection

Materials and methods

We carried out our study between January 2010 and December 2018.

1) Collection from the tap without filter

The collection was carried out in a sterile, leak-proof 500 ml plastic container, containing sodium thiosulfate in a concentration suitable for inhibiting the action of the disinfectant (chlorine). The metallic tap was disinfected externally and internally with the flaming procedure, first removing the aerator if present. At this point, the sample was collected after running the water for about 1 minute from the tap, opening the bottle without touching the inside of the cap and closing it immediately after collection.

2) Collection from the tap with filter

The collection was carried out in a sterile, leak-proof 500 ml plastic container, containing sodium thiosulfate in a concentration suitable for inhibiting the action of the disinfectant. The metal faucet was not disinfected due to the presence of the antibacterial filter and the sample was collected directly, opening the bottle without touching the inside of the cap and closing it immediately after collection.

3) Bacteriological examination procedure

The water samples collected from the different dispensing points were subjected to bacteriological investigations. In particular, we analysed the total bacteria count and the presence of *Pseudomonas aeruginosa*, as a possible cause of hospital infection. This operation is carried out on sterile cellulose acetate membranes with a 45µm porosity placed on the special support of the graduated funnels using sterile pliers, arranged in series on a ramp connected to a suction pump. We used an Agar Cetrimide plate for the analysis of *Pseudomonas aeruginosa* and Plate Count Agar for the count of the total bacterial load. After filtering 100 ml of sample for the identification of *Pseudomonas aeruginosa* we incubated the plate at 37 °C ±2 for 48 h ±2, while for the bacterial count we incubated two plates respectively at 37 °C ±2 for 24 h ±2 and at 22 °C ±2 for 72 h ±2 after filtration of 1 ml of sample. After the specific incubation time, we proceeded with the identification of colonies eventually present (based on their morphological, nutritional and colour characteristics) and to their count. In the case of suspicious colonies for the confirmation of *Pseudomonas aeruginosa*, according to Law Decree 31/2001(13) the membrane was transferred to a sterile plate with 1-2 ml of sterile distilled water and laid on an oxidase strip, which turned blue after 20-30 seconds.

Statistical analysis

Differences between the results recorded over the nine-year study period were evaluated using variance analysis. P values of <0.05 were considered statistically significant. Software R was used for statistical assessment.

Hospital facility and water distribution

The “Gaetano Martino” University Hospital is a structure of about 310,000 m² and it is distributed into 11 pavilions and a congress centre (as described in Fig. 1); every building has four to six floors in total.

The water distribution supplied to the hospital is provided by the municipality across a pipeline. According to Law Decree 31/01 (13), the water is first disinfected with chlorine dioxide and stored in a centralized tank, where an additional chlorination occurs with free chlorine (0.6%). The water is distributed to each pavilion by electric-motor pumps (first a boiler produces heated water) on each floor.

Results

We analysed a total of 6168 samples, which included 2776 with a filter and 3392 without a filter. The positive rate was 9.31% for the total samples collected (6.23% positive rate in samples with a filter and 11.82% in samples without a filter).

Evaluating the trend of positive samples, we could observe a decrease over time especially from January 2013 to a value of 2.44%, due to the elimination of the aerators of taps without filters (Fig. 2), as well as to the introduction of filters in taps of high-risk wards and surgical rooms. In 2016, the small number of samples was due to a change in the Health management policy. Also, an increasing of the positivity rate was detected in 2016 due to the lack of monthly replacement of the filter. Also, we observed a higher positive rate every year during the summer months, as indicated in Figure 2 for the 2012-2013 periods.

Bacterial contamination decreased over the nine-year period with statistically significant variation (p<0.001). The lowest value was detected in 2018, while the highest value was measured in 2010 and 2011 (Tab. 1).

We found statistical difference between taps with or without filter both on the total samples and also on the samples by years in the period 2010-2013 (Tab.1).

<table>
<thead>
<tr>
<th>Year</th>
<th>Samples with filter</th>
<th>Samples without filter</th>
<th>Mean count of total positive sample</th>
<th>SD</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>54</td>
<td>495</td>
<td>94.73</td>
<td>79.23</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>2011</td>
<td>378</td>
<td>384</td>
<td>83.29</td>
<td>56.72</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>2012</td>
<td>640</td>
<td>521</td>
<td>70.62</td>
<td>74.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>2013</td>
<td>501</td>
<td>436</td>
<td>33.41</td>
<td>13.1</td>
<td>n.s.</td>
</tr>
<tr>
<td>2014</td>
<td>493</td>
<td>451</td>
<td>26.52</td>
<td>19.2</td>
<td>n.s.</td>
</tr>
<tr>
<td>2016</td>
<td>65</td>
<td>240</td>
<td>21.42</td>
<td>7.28</td>
<td>n.s.</td>
</tr>
<tr>
<td>2017</td>
<td>201</td>
<td>358</td>
<td>20.15</td>
<td>12.3</td>
<td>n.s.</td>
</tr>
<tr>
<td>2018</td>
<td>127</td>
<td>200</td>
<td>19.75</td>
<td>11.25</td>
<td>n.s.</td>
</tr>
</tbody>
</table>
Table 2 shows that the highest positive rates were detected in pavilion G and B, with a difference between taps with or without filter. Also, we first observed the highest positive rate for every pavilion in 2013. Successively, due the elimination of aerators from taps without filters, the positive rate dropped to a maximum value of 6.34% for pavilion G.

In 2016, the contamination rate dropped to a value of 3.31% in pavilion H, due to the presence of a centralized sterilization tank and chlorination with free chlorine, achieving better microbiological quality of water.

**Discussion and conclusion**

In our study we found that the use of aerators contributes to water contamination, as described in Figure 2 and Table 2: in fact, an important reduction of the positive rate was detected after their elimination in 2013. These data confirm findings of other authors that described a possible contamination of aerators by gram-negative bacteria and

<table>
<thead>
<tr>
<th>Pavillon</th>
<th>Total positive samples 2010-2018 (a)</th>
<th>Positive with filter 2010-2018</th>
<th>Positive without filter 2010-2018</th>
<th>Positive samples first 2013 (b)</th>
<th>Positive samples after 2013 (c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAV. A</td>
<td>7.13%</td>
<td>5.43%</td>
<td>10.10%</td>
<td>14.77%</td>
<td>3.64%</td>
</tr>
<tr>
<td>PAV. B</td>
<td>14.93%</td>
<td>7.14%</td>
<td>15.49%</td>
<td>26.94%</td>
<td>5.68%</td>
</tr>
<tr>
<td>PAV. C</td>
<td>8.91%</td>
<td>5.33%</td>
<td>9.61%</td>
<td>29.13%</td>
<td>3.08%</td>
</tr>
<tr>
<td>PAV. D</td>
<td>7.68%</td>
<td>7.25%</td>
<td>8.22%</td>
<td>10.78%</td>
<td>2.98%</td>
</tr>
<tr>
<td>PAV. E</td>
<td>8.66%</td>
<td>6.63%</td>
<td>11.78%</td>
<td>11.99%</td>
<td>5.87%</td>
</tr>
<tr>
<td>PAV. F</td>
<td>8.24%</td>
<td>2.98%</td>
<td>10.87%</td>
<td>18.57%</td>
<td>5.67%</td>
</tr>
<tr>
<td>PAV. G</td>
<td>16.52%</td>
<td>9.00%</td>
<td>23.38%</td>
<td>21.33%</td>
<td>6.34%</td>
</tr>
<tr>
<td>PAV. H</td>
<td>8.46%</td>
<td>6.28%</td>
<td>11.02%</td>
<td>15.70%</td>
<td>3.31%</td>
</tr>
<tr>
<td>PAV. NI</td>
<td>6.59%</td>
<td>5.68%</td>
<td>7.17%</td>
<td>17.35%</td>
<td>3.64%</td>
</tr>
</tbody>
</table>
in particular with *P. aeruginosa* or *Pseudomonas spp.* with highly significant association between these contaminations and colonization/infection of patients (1,14-16). Also, we obtained higher contamination rates after 2015 for the lack of monthly substitution of filters. We wanted to state that filters may have been contaminated via splashback from a contaminated waste trap or surface, so it is important to monitor and effectively sanitize all surfaces in hospital settings, as well as to eliminate contaminated filters (8-10,17-22). In fact, in our study a statistical difference between taps with or without filter was obtained, and these results highlighted the importance of correct preventive measures, as well as correct application of guidelines (23-25). Another finding that we obtained was the severe contamination during summer months compared to the other months: these differences were interpreted as a result of differences in water temperature (26) and, also, in behaviour of healthcare workers, because many of them go on vacation during this season (27). An additional action that was taken in order to achieve better quality was the chlorination with free chlorine in some pavilions where the chlorination with free chlorine in some pavilions was not taken for waterborne pathogen control . Ann Agric Environ Med. 2012;19(4):619–624

At the end of our study, bacterial contamination decreased over the nine-year period with statistically significant variation thanks to the application of the described preventive measures. Today, in fact, correct application of prevention measures (such as sanitation, use of disposable devices, correct handwashing and vaccination of population and healthcare workers, etc…) remains the most cost-effective intervention against the fight of HAIs and antimicrobial resistance (23,24,31-44). Limitation of the study are the lack of monthly substitution of filters. We wanted to state that contaminated waste trap or surface, so it is important to monitor and effectively sanitize all surfaces in hospital settings (29,30).

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