A study on hospital solid waste - quantification and microbial analysis in a hospital near kanyakumari district

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ABSTRACT: Studies of waste management in Indian hospitals are very low. Too much of biomedical wastes production increase the risk of dangerous diseases which may be transmitted to humans. These wastes treated as general waste and mixed with general waste. This infectious wastes decay and mix with the soil. During rainy season, such dangerous wastes mix with the rain water leading to epidemics such as cholera. Fecal coli forms have been found to be higher even in bore wells near hospitals. In this study quantity of solid waste generated from the hospital was estimated six times at an interval of 3 months (January 2010 to June 2011). During the study period, the solid waste produced in the hospital (from 267 beds) ranged between 490.12±72.63 and 643.53±66.13 kg day⁻¹. The mean healthcare waste generation rate estimated in the present study was 0.48±0.05 to 4.38±0.36 kg bed⁻¹ day⁻¹. Total coliforms were found to be in the range of 4±1×10³ CFU mL⁻¹ and staphylococcal count (3.67±0.58×10⁷ CFU mL⁻¹). Fecal enterococcal count was recorded 5±1.73×10⁶ CFU mL⁻¹ and Pseudomonas colonies were present numbers 3.67±1.53×10⁶ CFU mL⁻¹. Concerning Vibrio spp, recorded the value of 3.33±0.58×10⁷ CFU mL⁻¹.

Key Words: Municipal solid waste management, Infectious waste, Bio-hazardous waste, Studies of waste management in Indian hospitals.

Introduction
Municipal solid waste management is among the biggest challenges faced throughout the world. In developing countries, sometimes biomedical waste is treated as general waste and mixed with general waste, leading to the spread of dangerous diseases which may be transmitted to humans. Illegal repacking and resale of contaminated hospital utensils lead to hospital-inflicted diseases some of which are HIV/AIDS, hepatitis, etc.

But with judicious planning and management, the risk can be reduced. Studies have shown that healthcare waste consists of 5% hazardous waste and 10% infectious waste and the remaining 85% is noninfectious waste. Handling the 15% waste properly will lead to reduction in such risks (Katoch, 2007). At present, solid wastes generated by hospitals, research centres, community centres, public places, etc. need immediate proper disposal policy.

The World Health Organization estimates that each year there are about 8 to 16 million new cases of hepatitis B virus (HBV), 2.3 to 4.7 million cases of hepatitis C virus (HCV) and 80,000 to 160,000 cases of human immune deficiency virus (HIV) due to unsafe injections and mostly due to very poor waste management systems (WHO, 1999).

Biomedical wastes in hospitals fall under two major categories: non-infectious and bio-hazardous. Constituents of non-infectious waste are non-infected plastic, cardboard, packaging material, paper, etc. Bio-hazardous again falls into two types: (a) Infectious waste - sharps, non-sharps, plastics, disposables, liquid waste, etc.; (b) non-infectious waste radioactive waste, discarded glass, chemical waste, cytotoxic waste, incinerated waste, etc. The most appropriate way of identifying the categories of biomedical waste is by sorting the waste into colour-coded plastic bags or containers (Rao et al., 2004).

Studies of waste management in Indian hospitals are very low (Lakshmi, 2003; Patil and Pokhrel, 2005). In India, in view of the serious situation of biomedical waste management, the Ministry of Environment and Forests, within the Government of India, ratified the Biomedical Waste (Management and Handling) Rules, in July 1998. Inappropriate managed wastes dumping yards, sludge collecting/disposing sites, and regions meant for storing/packaging of highly infectious wastes are virtual store houses of different microbes. Untreated infectious wastes decay and mix with the soil. During the monsoon, such
dangerous wastes mix with the rain water leading to epidemics such as cholera. Fecal coli forms have been found to be higher even in bore wells near hospitals.

**Materials and methods**

**Study Area**

The hospital from where samples were collected is situated in south India. J S Medical Trust Hospital situated in Nagercoil, Kanyakumari district. A 267 bed hospital, it has various departments which including general medicine, general gynecology, general surgery, ENT, pediatrics, and psychiatry. In addition to this, the hospital offers super specialty services in cardiology, urology, neurology, laparoscopic surgery, pediatric surgery, neonatology as well as gastroenterology.

A general survey of the total solid bio-medical waste produced from each ward from this multi-specialty hospital and number of selective bacteria present in each sample was done and samples were collected. The quantitative analysis of the solid waste in between January 2010 and June 2011 in six quarters, and the microbiological parameters were analyzed between January 2010 and December 2010 in four quarters. During each quarter, samples were collected continuously for a 5-day period. Samples were collected from each sampling unit in different sterilized bottles for further analyses. Per-bed and per-day volume of solid waste generated was assessed.

**Sample Collection**

In the hospital colour coded high-density polyethylene bags are used for easy identification and segregation of wastes. The samples were transported to the laboratory within 2 h in ice jackets. Solid waste samples were collected from each wards in a sterile zip lock high-quality polythene bags and sealed immediately. During collection, sterile gloves and masks were used. This was conducted in accordance with the United States Environment Protection agency (US EPA) -approved Quality Assurance Project Plan. Each site was sampled five times at 3-month interval, during the period from January 2010 to June 2011. The wastes were quantified and recorded for five continuous days in an interval of 3 months. Wet wastes generated in the hospital kitchen, Children’s Park, laundry, rest room and office were also included in this study. Part of these non-infectious general wastes is used for biogas production in the hospital.

**Selective bacterial count**

Soil samples were collected from waste dumping site and sludge disposal area; selective bacterial analyses were done. MacKonkey agar (Hi-Media, India) was prepared and diluted samples were spread in plates and incubated for estimating of coliforms and fecal enterococci; shigella salmonella agar (SS) for Salmonella spp., mannitol salt agar for Staphylococcus spp.; cetrimide agar (or Pseudomonas agar) for Pseudomonas colonies; and thiosulphate citrate bile salt (TCBS) agar for Vibrio spp. The inoculated media were incubated in an aerobic environment for 24 to 48 at 37°C.

**Result and discussion**

The mean healthcare waste generation rate estimated in the present study was 0.48±0.05 to 4.38±0.36 kg bed⁻¹ day⁻¹. In the first quarter the highest quantity was recorded in the E-block (ICU, semi-private, cardiology, private and hemodialysis) private (3.38±0.42 kg bed⁻¹ day⁻¹) and the lowest (0.61±0.11 kg bed⁻¹ day⁻¹) in the urology section. In the second quarter the highest value was recorded (3.43±0.45 kg bed⁻¹ day⁻¹) in NICU and the lowest in the urology division (0.71±0.1 kg bed⁻¹ day⁻¹); in the third quarter the highest (3.52±0.33 kg bed⁻¹ day⁻¹) in E-block private and the lowest in the urology division (0.5±0.08 kg bed⁻¹ day⁻¹). In the fourth quarter the highest volume (2.92±0.45 kg bed⁻¹ day⁻¹) was again recorded in NICU and the lowest (0.16±0.03 kg bed⁻¹ day⁻¹) in the urology section and in the fifth quarter the highest (4.38±0.36 kg bed⁻¹ day⁻¹) in NICU and H-block (MICU, SICU and private) private wards and the lowest (0.73±0.07 kg bed⁻¹ day⁻¹) in the haemodialysis section. In the sixth quarter the highest amount was recorded (3.75±0.25 kg bed⁻¹ day⁻¹) in NICU and lowest (0.5±0.06 kg bed⁻¹ day⁻¹) in the haemodialysis unit. In middle- and low-income
countries the quantum of solid waste generated from hospitals is 0.5-6 and 0.5-3 kg bed⁻¹ day⁻¹ (WHO, 1999). Altin et al. (2003) and Ahmed et al. (2014) implied that the quantity of waste produced in a hospital depends on the national income and the type of facility concerned. In high-income countries hospitals produce wastes up to 4-9 kg bed⁻¹ day⁻¹ and general hospitals up to 1-4 kg bed⁻¹ day⁻¹. Tabasi and Marthandan (2013) and Thirumala (2013) also reported that the quantum of waste generation not only depends on the type of hospitals but also on the income of the country. It may also differ based on the management of hospital, i.e. in India, hospital management can be government, semi-government or private. A study conducted in one of the districts of South India showed that government and private hospitals generate wastes around 5-7 and 2-4 kg bed⁻¹ day⁻¹, respectively and another study conducted in one of the districts in western India revealed that both private and government hospitals generate around 1-3 kg bed⁻¹ day⁻¹. The values reported are extremely high compared to those of the present study. This implies that the hospital studied has a carefully planned system, which leads to the production of minimal wastes.

The mean healthcare waste generation rate estimate in present study is 0.48±0.05 to 4.38±0.36 kg bed⁻¹ day⁻¹. These values are higher than those reported in Saudi Arabian health centres, the mean waste generated being 0.07 kg bed⁻¹ day⁻¹ (Al-Zahrani et al., 2000). Babu et al. (2009) reported that the waste generation rate ranges between 0.5 and 2.0 kg bed⁻¹ day⁻¹ in Indian hospitals. The lower value of the above-mentioned range is similar to that of this study.

The total amount of non-hospital waste generated from the hospital compound (hospital surroundings such as laundry, canteen, restroom, waiting shed, kitchen, office, playground and others) was estimated. The highest volume was recorded in the fifth quarter (January to March 2011) (330.75±21.53 kg day⁻¹) and the lowest in the second quarter (April to June 2010) (217.8±24.5 kg day⁻¹). Estimating the total quantum of waste including those generated from the wards and surroundings revealed that the highest volume was recorded in the sixth (April to June 2011) quarter (966.53±90.3 kg day⁻¹), followed by the fifth (January to March 2011) quarter (953.2±73.18 kg day⁻¹).

Taskona (2007) reported that in a 450-bed hospital in Greece, 650 kg of infectious waste and 3250 kg of non-infectious waste are being produced each day; the quantities corresponded to 1.4 kg bed⁻¹ day⁻¹ of infectious waste, 7 kg bed⁻¹ day⁻¹ of non-infectious waste and thus 8.4 kg bed⁻¹ day⁻¹ of total waste. According to WHO report in 1999, average generation rate of hospital waste was 4.1-8.7 kg bed⁻¹ day⁻¹. The amount of hospital waste generated in kilogram per bed per day was 2.5 kg in UK, 4.5 kg in USA, 2.3 kg in France, 3 kg in Spain and 1.5 kg in India. These findings are very closely related to the results of this study. In the data of the United States Environmental Protection Agency (US EPA) of America and Japan, Ministry of Health suggested a volume of 1 to 1.5 kg bed⁻¹ day⁻¹ for hospitals is normal quantity. But waste production has been quoted up to 5.24 kg in developed countries. The average quantity of hospital solid waste produced in India ranges from 1.5 to 2.2 kg bed⁻¹ day⁻¹ (Manasi, 2017).

Solid waste from hospitals includes bandages, linen and other infectious waste (30-35%), plastics (7-10%), disposable syringes (0.3-0.5%), glass (3-5%) and other general wastes including food (40-45%). The percentage of similarity in the quantum of solid waste generated from wards between different periods (quarters) was analyzed by using the Bray-Curtis Similarity Index (Primer-6 software). The highest similarity (95.5%) was found to be between the third (July to September 2010) and sixth (April to June 2011) quarters and the lowest (79.69%) between the fifth (January to March 2010) and sixth (April to June 2011) quarters. Proper segregation is the best method suggested to reduce the production of more infectious solid wastes. The variation in the volume of waste generated could be due to the differences in resource inputs to health facilities, linearity between visitors and waste generation rate season of the year, availability of different facilities, social status of the patients, waste management, legislative system of the country, and the economic strengths of the country.

The percentage of similarity in the quantity of the solid waste generated per bed per day between different wards and periods (quarters) was analyzed by using the Bray-Curtis Similarity Index (Primer-6 software). The highest similarity of waste produced per bed per day was 95.59% between G-block private and I-block private wards, followed by G-block private and E-block private (95.35%). The lowest similarity (54.51%) was recorded between urology and hemodialysis sections, considering solid waste other than hospital ward wastes, the highest similarity (98.18%) was noted between kitchen and canteen and the lowest (88.12%) between playground and canteen (Figure 5).

As regards the per-bed, per-day samples, the quarter-wise similarity analysis revealed the highest (97.52%) similarity between the first (January to March 2010) and third (July to September 2010) quarters and lowest similarity (92.02%) between the second (April to June 2010) and sixth (April to June 2011) quarters (Table 1). Concerning the other wastes produced, the highest similarity (99.06%) was found between the first (January to March 2010) and third (July to September 2001) quarters and lowest
The data distribution of the waste quantity was analysed using ProUCL software.

**Bacteriological studies**

Bacteria (total coliforms, fecal enterococci, staphylococci, *Pseudomonas* sp, *Salmonella* sp. and *Vibrio* sp.) were isolated by using selective bacterial media (Figure 2 and 3). Total coliforms were found to be in the range of 4±1×10⁶ CFU mL⁻¹ in the sludge dumping site-3 to 5.67±1.53×10⁷ CFU mL⁻¹ in the sludge disposing site 3 and waste processing/packaging area. Fecal enterococcal count was recorded to be the highest in the waste dumping area-1 (5±1.73×10⁷ CFU mL⁻¹) and the lowest (0.67±0.58×10⁷ CFU mL⁻¹) in liquid sludge-3. The highest staphylococcal count (3.67±0.58×10⁷ CFU mL⁻¹) was recorded in the waste packing area 1 and the lowest (0.03±0.58×10⁷ CFU mL⁻¹) in the liquid sludge 3. *Pseudomonas* colonies were present in higher numbers (3.67±1.53×10⁷ CFU mL⁻¹) in the waste packing area 1. In the case of *Salmonella* sp. the highest number (3±1.73×10⁷ CFU mL⁻¹) was recorded in the waste packing area 1 and the lowest (0.67±0.58×10⁷ CFU mL⁻¹) in the liquid sludge 3. Concerning *Vibrio* sp., waste packing area 1 recorded the highest value (3.33±0.58×10⁷ CFU mL⁻¹) and liquid sludge disposing area 1, liquid sludge 3 and waste packing area 2 (Figure 6) recorded the lowest value (1.33±1.1×10⁷ CFU mL⁻¹).

High count of tested bacterial species (total coliforms, staphylococci, *Pseudomonas* sp., *Salmonella* sp. and *Vibrio* sp.) was noted in the waste-packing area 1, except fecal enterococci. The liquid sludge disposing area 1 recorded higher counts of fecal enterococci. Of all the bacterial species studied, the lowest counts were reported from the liquid sludge-disposing area 3. In the hospital studied, highly infectious waste such as blood samples, operation wastes; human sputum, etc. are kept in a separate area for packing and final disposal (incineration). Medical Council of India regulations imply that the infectious waste should not be dumped in the open. They should not be stored more than 48 hours. This may be the reason why the selective bacterial count was higher in this area. The sludge-disposing area 3 recorded the lowest count. This is because of the fact that sludge is the end product of a long process of wastewater treatment. Various disinfectants and chemicals are added to the wastewater leading to the reduced survival of many bacteria. Coliform bacteria thrive in wet areas. The population of these microbes have also been found to be higher in samples after treatment. *Staphylococcus* sp., *Salmonella* sp. and *Enterococcus* sp. are associated with significant infection in clinical areas or with serious disease outbreaks. The presence of these organisms should generate immediate attention towards cleaning/disinfection practices. Risk assessment would determine a review of existing practices leading to additional cleaning or even closure of a clinical area for deep cleaning if thought appropriate (Vishal et al., 2011). *Pseudomonas aeruginosa* is an opportunistic pathogen and is resistant to many antibiotics; it leads to respiratory infection in patients with cystic fibrosis. *Pseudomonas* can spread by contaminated equipment and can be incorporated into piped portable water. It also affects the intestine, eyes and the urinary tract (Hadault et al., 2001; Fathi et al., 2014).

*Escherichia coli*, the human pathogen, presents a serious risk of disease. It is present high counts in hospital wastewater and in intestine of living organisms (Guardabassi et al., 1998). *Vibrio* sp. is a Gram-negative bacteria causing food-borne infection and is associated with under-cooked foods. This facultative anaerobe leads to gastroenteritis and causes septicemia. *V. cholerae* causes cholera and is transmitted through contaminated water (Faruque et al., 2008). *V. parahaemolyticus* is a human pathogen, and causes human diarrhoea or extra-intestinal infections. *Salmonella* spp. are pathogens of humans, and warm- and cold-blooded animals. It causes typhoid and enteric infections. *Salmonella* and *Shigella* sp. have also been isolated from hospital wastes (Tsai et al., 1998). *Staphylococcus* sp. is commonly found in the environment and also found in skin, intestine and nasal passages. *S. aureus* is a pathogen of external ear and eye. Coliforms are found in soil, water and influence surface water and is the general indicator of sanitary condition (Tan et al., 2008).

Fecal coliforms are present in the gut and feces of warm-blooded animals and are an indicator of animal or human waste. *E. coli* is the major fecal coliform and best indicator of fecal pollution and presence of pathogens. It is present in under-cooked foods and drinking water and affects humans and animals, causing urinary tract and intestinal infections (Tan et al., 2008).

Symptomless carriers carry enteropathogens such as *Salmonella* sp., and other bacteria such as *Streptococcus pyogenes*, *Corynebacterium diptheriae*, Neisseria meningitidis, hepatitis B virus, and cytomegalovirus. Contamination of patients by carriers can give rise to an outbreak of disease. In developing countries *Vibrio* is one of disease agents associated with the mixing of sewage and drinking water (Pereira et al., 2007). *Salmonella enterica* sv. Typhimurium remains the most frequently isolated in human, swine, avian, and bovine salmonellosis (Popoff and Minor, 2013).

The similarity in the bacterial counts present in the sampling sites was analyzed by the Bray Curtis similarity index.
Similarity Index. The highest similarity (94.26%) was noted between liquid sludge disposing area 2 and waste dumping area 3. The lowest similarity (79.16%) was recorded between waste dumping area 1 and waste packing area 2. Similarity was high (92.61%) between fecal enterococci and coliform numbers. These species were most predominant in the samples. The lowest (34.01%) similarity was noted between coliforms and *Pseudomonas*. The distribution of the bacterial species was analyzed and graphically represented (Figure 2) by using ProUCL.

Figure 1. Distribution of quantity of solid hospital waste collected from different wards.

![Figure 1](image1.png)

Figure 2. Cluster analysis on the quantity of selective bacterial counts.

![Figure 2](image2.png)

Figure 3. Selective bacterial count in hospital solid waste.
Figure 4. Similarity index of quantity of solid hospital waste collected from different wards.

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<tbody>
<tr>
<td>Quantity</td>
<td>97.24</td>
<td>96.85</td>
<td>96.78</td>
<td>96.81</td>
<td>96.60</td>
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<td>96.79</td>
<td>96.58</td>
<td>96.82</td>
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<td>96.80</td>
<td>96.84</td>
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</tbody>
</table>

Figure 5. Similarity index of quantity of solid hospital waste collected other than wards.

<table>
<thead>
<tr>
<th>WASTE OTHER THAN WARDS</th>
<th>LAUNDRY</th>
<th>CANTEEN</th>
<th>REST ROOM</th>
<th>PHARMACY</th>
<th>W. SHEAD</th>
<th>KITCHEN</th>
<th>OFFICE</th>
<th>PLAY GROU</th>
<th>SURROUND</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIMILARITY (0 to 100)</td>
<td>98.06</td>
<td>95.85</td>
<td>96.49</td>
<td>94.45</td>
<td>91.02</td>
<td>90.046</td>
<td>90.80</td>
<td>98.21</td>
<td>98.34</td>
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Figure 6. Selective bacterial count in hospital solid waste collected from different sample collection sites.

<table>
<thead>
<tr>
<th>SAMPLING AREAS</th>
<th>Waste dump-1</th>
<th>Waste dump-2</th>
<th>Waste dump-3</th>
<th>Liquid sludge-1</th>
<th>Liquid sludge-2</th>
<th>Liquid sludge-3</th>
<th>Waste packing are</th>
<th>Waste packing are</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIMILARITY (0 to 100)</td>
<td>92.353</td>
<td>85.547</td>
<td>85.547</td>
<td>85.264</td>
<td>85.264</td>
<td>83.584</td>
<td>93.6</td>
<td>91.334</td>
</tr>
</tbody>
</table>

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Table 1. Total quantity of solid waste generated in hospital wards (kg bed⁻¹ day⁻¹).

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</tr>
</thead>
<tbody>
<tr>
<td>ICU</td>
<td>12</td>
<td>1.42±0.35</td>
<td>1.13±0.22</td>
<td>1.41±0.22</td>
<td>1.71±0.25</td>
<td>2.02±0.26</td>
<td>3.02±0.22</td>
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<tr>
<td>E.S. Priv</td>
<td>14</td>
<td>2.41±0.30</td>
<td>1.77±0.23</td>
<td>2.19±0.27</td>
<td>1.90±0.24</td>
<td>2.42±0.19</td>
<td>2.39±0.21</td>
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<td>Cardio</td>
<td>15</td>
<td>1.91±0.22</td>
<td>1.31±0.15</td>
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<td>1.90±0.24</td>
<td>2.42±0.19</td>
<td>2.35±0.16</td>
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<tr>
<td>E. Priv</td>
<td>8</td>
<td>4.38±0.42</td>
<td>4.10±0.73</td>
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<td>3.28±0.70</td>
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</tr>
<tr>
<td>Hem dyl</td>
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<td>0.75±0.11</td>
<td>0.83±0.14</td>
<td>0.81±0.06</td>
<td>0.49±0.05</td>
<td>0.74±0.07</td>
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<tr>
<td>F. Surgi</td>
<td>18</td>
<td>1.90±0.19</td>
<td>1.73±0.24</td>
<td>1.75±0.12</td>
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<td>1.54±0.17</td>
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<td>3.34±0.38</td>
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<td>2.60±0.25</td>
<td>2.28±0.33</td>
<td>2.80±0.59</td>
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<td>NICU</td>
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<td>4.27±0.64</td>
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<td>3.92±0.45</td>
<td>5.83±0.25</td>
<td>4.75±0.25</td>
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<tr>
<td>L.G Priv</td>
<td>17</td>
<td>1.62±0.37</td>
<td>1.31±0.17</td>
<td>1.69±0.26</td>
<td>1.74±0.28</td>
<td>1.75±0.06</td>
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<tr>
<td>Casual</td>
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<td>2.04±0.66</td>
<td>1.76±0.18</td>
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<td>2.43±0.13</td>
<td>2.32±0.39</td>
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<td>1.66±0.09</td>
<td>1.15±0.19</td>
<td>1.94±0.14</td>
<td>1.73±0.12</td>
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<tr>
<td>ICU</td>
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<td>2.31±0.39</td>
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<td>G. S.Priv</td>
<td>20</td>
<td>1.32±0.22</td>
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<td>1.40±0.10</td>
<td>1.19±0.17</td>
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<td>1.70±0.15</td>
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<td>G. Priv</td>
<td>8</td>
<td>3.95±0.65</td>
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<td>4.25±0.42</td>
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<td>MICU</td>
<td>11</td>
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<td>2.66±0.08</td>
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<td>H. Priv</td>
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<td>3.43±0.89</td>
<td>3.47±0.63</td>
<td>3.11±0.39</td>
<td>3.79±0.48</td>
<td>5.38±0.36</td>
<td>4.71±0.32</td>
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<td>M. Medi</td>
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<td>1.31±0.38</td>
<td>2.30±0.20</td>
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<td>I. Priv</td>
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<td>3.03±0.50</td>
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<td>Uro</td>
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<td>0.60±0.08</td>
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<tr>
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<td>22</td>
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<td>0.98±0.13</td>
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<td>1.50±0.12</td>
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Bibliography


