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Short report

Evaluation of droplet production by a new design of clinical handwash basin for the healthcare environment

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SUMMARY

Splashing from handwash basins may be a source of bacteria in the healthcare environment. A novel splash-reducing basin was assessed for its ability to reduce droplet formation during simulated handwashing. The basin was compared to two conventional basins commonly used in healthcare. Basins were mounted in a test system and tap flushed for 30-s with and without handwashing. Droplets were visualized with fluorescent dye. With conventional basins, >1000 droplets were formed during 30-s flushes and found to spread further than 2-m. The novel basin significantly reduced the number of droplets formed during handwashing and reduced the distance spread.

Introduction

Basins and taps are recognised as reservoirs of bacteria in the healthcare environment. Organisms such as *Pseudomonas aeruginosa* and *Legionella pneumophila* are important causes of healthcare-associated infections, particularly among patients in augmented care units [1]. Outbreaks of *P. aeruginosa* have been attributed to contaminated hospital water systems; for example, those that occurred in neonatal units in Northern Ireland in 2011–2012 [2].

Basin surfaces may become contaminated during handwashing or if biological waste is discarded. In a recent study, 40% of drains were found to contain extended-spectrum β-lactamase (ESBL)-producing Gram-negative bacteria [3]. Splashes formed during handwashing may be a source of dissemination of organisms from contaminated water systems and from basin surfaces and drains [4]. Water flowing directly on to a drain below the outlet causes greater splashback than water that hits a basin surface [4].

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P. aeruginosa is a common cause of nosocomial infections [1]. Patients, such as burns patients, may be particularly susceptible to splashes of water containing bacteria if near to basins.

Single-bore outlet fittings without flow straighteners are increasingly used in an effort to reduce biofilm formation [5]. These fittings reduce the surface area available in the tap for biofilm attachment; however, may increase the risk of splashing as the water hits the basin surface due to more turbulent water flow.

In this study the droplet production of a novel basin designed to reduce splashing during handwashing was compared to two commonly used basins in healthcare.

Method

Basins

Three ceramic handwash basins were tested for the formation of splashes. The basins tested were designated A, B and C (Figure 1). Basin A incorporates a hydrophilic glaze and a moulded ceramic fin designed to reduce splashing by creating shallower angles at which water hits the basin. The uppermost rims at the edges and back of the basin were thinned and rounded compared to conventional basins. This allows for a greater surface area within the basin bowl and reduced flat surfaces at the top of the basin on which stagnant water may form. Basin B was of similar shape to Basin A; however, it had a smaller surface area in the basin bowl and more flat surfaces at the top rims of the basin. Basin C was of a rounder design with the smallest surface area in the basin bowl and greatest surface area at the top rims of the basin. All three basins had drains located at the back of the basin and not directly under the flow of water.

Test system

The study was conducted in a 2 × 2-m test chamber lined with polythene sheeting on the floor and walls. The test system consisted of a Markwik21+ (Ideal Standard, UK) mixer tap with a single-bore outlet fitting. The tap was mounted 20 cm above the top surface of each test basin in accordance with the maximum recommended height in Health Building Note (HBN) 00–10 Part C [6]. The tap thermostatic mixer valve was set to midpoint and water was circulated at room temperature using a pump at a flow rate of ~8 L/min. The basin and tap rig was placed in the test system chamber to allow a distance of 2-m to the front and one side of the basin.

Splash testing

Tap water was dyed with fluorescein (10 ppm) (Cole-Parmer, UK) to allow visualization of splashes. The surrounding floor was covered with absorbent paper to capture splashes from test cycles. No bacteria were used to inoculate the water.

Basins were tested with and without handwashing. For tests without handwashing, the tap was flushed for 30-s with water flow uninterrupted. With handwashing, a nurse wearing protective overalls, gloves and a visor washed their hands following the World Health Organisation (WHO) seven-step handwashing guidelines commonly used in healthcare [7].

After each test, upon closing the tap, a fallout period of 1 min allowed droplets to settle on floor surfaces. Each basin was tested three times with and without handwashing. The basins were wiped dry and the paper was changed between cycles to ensure no fluorescence from previous cycles remained.

Water droplets settling on the floor were visualized with ultraviolet light (wavelength: 365nm). Droplets were photographed immediately after each test cycle to prevent diffusion and fading of fluorescence. Droplets were counted and categorized by size (<1 mm, 1–5 mm and >5 mm diameter) and distances travelled, measured from the centre front of each test basin. Counting and sizing was automated by Photoshop CC Pro, Adobe Systems (CA, USA) and manually verified.

Data analysis

Means were compared by one-way analysis of variance (ANOVA) performed using RStudio software (Boston, MA, USA) and differences were considered statistically significant when $P<0.05$.

Results

Floor droplets after flush

Droplets were evenly distributed on the floor to the front and sides with all three basins (Figure 2a–c). Small droplets (<1 mm) were predominant with all basins (73–86% of droplets) (Table I). The number of droplets <1 mm decreased with

Figure 1. Basins A (with fin), B and C.

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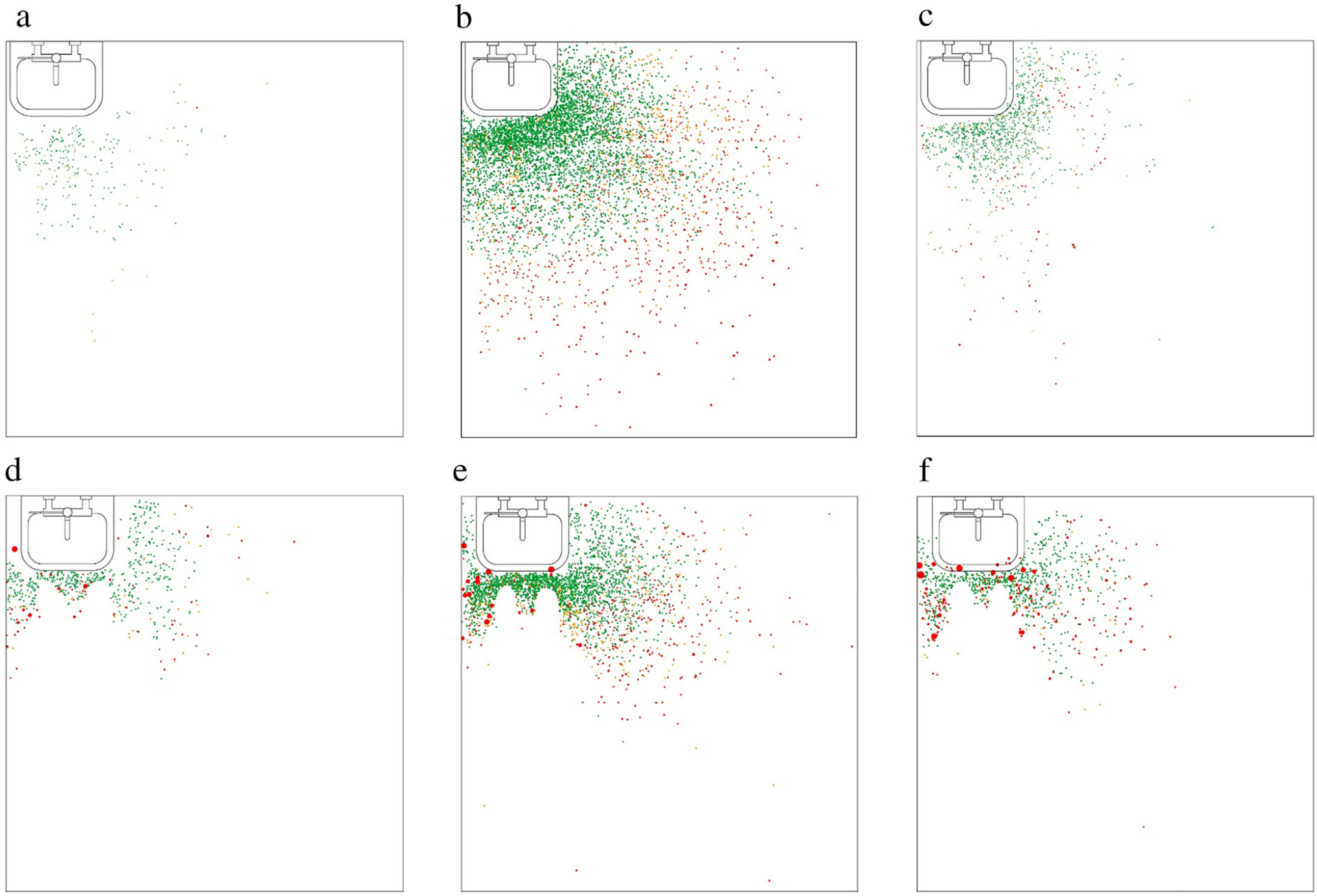

Figure 2. (a–c) Basins A, B and C following flush only. (d–f) Basins A, B and C following handwashing. Droplets observed on the floor during single replicate. Green dots represent droplets of <1 mm, orange dots represent droplets of 1–5 mm and red dots represent droplets of >5 mm.

Table I
Average number of droplets on floor surfaces ± standard deviation following handwashing and flushes with each basin ($N = 3$)

Droplet size	Flush (30-s without handwashing)				With handwashing			
	Distance travelled from basin			Total	Distance travelled from basin			Total
	0–50 cm	50–100 cm	>100 cm		0–50 cm	50–100 cm	>100 cm	
Basin A								
<1 mm	145 ± 83	49 ± 27	15 ± 25	209 ± 91	310 ± 97	48 ± 18	0 ± 0	358 ± 99
1–5 mm	23 ± 11	17 ± 3	13 ±16	53 ± 20	29 ± 10	26 ± 18	0 ± 0	54 ± 20
>5 mm	0 ± 0	0 ± 1	1 ± 1	1 ± 1	30 ± 11	21 ± 15	1 ± 2	53 ± 19
Total	168 ± 84	67 ± 27	29 ± 30	263 ± 93	369 ± 98	95 ± 29	1 ± 2	465 ± 102
Basin B								
<1 mm	3446 ± 376	1101 ± 356	197 ± 133	4744 ± 535	1649 ± 174	387 ± 57	7 ± 2	2043 ± 183
1–5 mm	121 ± 36	250 ± 56	192 ± 225	563 ± 235	100 ± 53	102 ± 23	7 ± 4	210 ± 58
>5 mm	31 ± 19	198 ± 131	330 ± 185	559 ± 227	95 ± 18	121 ± 48	38 ± 19	254 ± 55
Total	3598 ± 378	1549 ± 383	718 ± 320	5865 ± 627	1845 ± 183	610 ± 79	52 ± 19	2507 ± 200
Basin C								
<1 mm	852 ± 360	122 ± 33	7 ± 3	980 ± 361	561 ± 95	79 ± 14	2 ± 1	642 ± 96
1–5 mm	85 ± 75	69 ± 34	5 ± 8	160 ± 82	52 ± 12	19 ± 4	0 ± 1	71 ± 13
>5 mm	28 ± 5	47 ± 30	12 ± 6	87 ± 31	89 ± 24	35 ± 17	2 ± 0	126 ± 29
Total	965 ± 368	238 ± 56	24 ± 10	1227 ± 372	702 ± 99	134 ± 22	4 ± 1	839 ± 102

The distance travelled was measured from the front centre of each basin.

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distance with all basins whilst droplets of >5 mm were found to spread further ($P<0.01$).

Basin B produced the highest number of droplets of all sizes which spread furthest of the basins tested. High numbers of large droplets (>5 mm) were produced and the furthest droplet spread up to 202 cm from the front of the basin. Basin C produced significantly fewer droplets than Basin B ($P<0.01$) with the furthest droplet from Basin C found 172 cm from the front of the basin. Basin A reduced the total number of droplets on the floor by 95% when compared with Basin B ($P<0.01$); however, the difference from Basin C was not significant. The furthest distance a droplet travelled from Basin A was the least of all basins (129 cm).

Floor droplets after handwashing

The mean handwashing time was 28-s (range: 25–30-s, σ: 1.8). With all basins tested, splashes were found on the nurse's overalls; however, they could not be quantified due to their high number. Two droplets were found on the nurse's visor in two of three tests with Basin C.

The presence of the nurse blocked splashes from reaching the floor directly in front of the basins (Figure 2d–f). As with flushing only, small droplets (<1 mm) were most predominant with all basins (77–81% of droplets). Fewer droplets were found on the floor with Basins B and C with handwashing when compared to flushing ($P<0.01$); however, no significant difference was found with Basin A ($P>0.05$). With Basin A, more large droplets (>5 mm) were observed with handwashing than with a flush only (11% vs 0% of droplets, respectively) ($P<0.01$).

As with flushing only, Basin B produced the highest number of observed droplets ($P<0.01$). Fewer droplets were observed with Basin A when compared with Basins B (mean 81% fewer) and C (mean 45% fewer) ($P=0.01$).

With all basins, aerosols may have been formed that remained suspended in air or droplets may have formed that were too small to visualize by the methods used. These were not quantified and may have travelled further than the 2-m test parameters. A continuous column of water with the same tap, flow rate and pressure was used in each test; however, droplets may have been formed directly from the outlet. A proportion of detected droplets may not be influenced by basin design.

Discussion

With commonly used handwash basins in healthcare, high numbers of droplets may be formed during a flush or a typical handwashing cycle. Droplets travelled over 100 cm with all basins and up to 202 cm with Basin B during flushing. With Basin A, there was reduction in total number of droplets observed during a 30-s flush when compared with Basin B. The number of droplets of all sizes were fewer than with Basins B and C and few large droplets were produced. The furthest distance that droplets were observed was shortest with Basin A.

Fewer droplets were observed on the floor after handwashing with Basin A than with Basins B and C. Compared with flushing only, there were fewer observed droplets with Basins B and C after handwashing and no significant difference with Basin A. This may be attributed to splashing on the nurse's overalls, suggesting that high numbers of splashes may land on basin users during handwashing.

Hydrophobic surfaces are increasingly used in healthcare in an effort to prevent adherence of bacteria and formation of biofilms. However, hydrophobic surfaces increase splashing [8]. The inclusion of a hydrophilic glaze in Basin A may have aided in the reduction of splashes forming. The disadvantages of hydrophilic surfaces being used in a basin are that water may be retained on the surface and in the drain allowing formation of biofilms. Retention of bacteria on the basin surface immediately under the flow of water may result in dispersal from droplet formation.

Reducing the formation of splashes may reduce the spread of bacteria from contaminated water systems. *L. pneumophila* has been found at 1.8×10^6 cfu/L in hospital tap water [5]. The Health Technical Memorandum (HTM) 04-01 Part C advises flushing of taps for 2 min to collect post-flush samples following positive *P. aeruginosa* water samples [9]. With high levels of bacteria, small droplets formed during flushing or handwashing may contain sufficient quantities of bacteria to contaminate surrounding surfaces or cause infection in patients. Small droplets may have the ability to travel further; stay suspended in air longer and are more likely to be inhaled into the lung [10].

Despite reducing splashing, >250 droplets per 30-s flush and >460 droplets per handwash were formed with the novel basin design. Regular screening for waterborne bacteria such as *P. aeruginosa* and *L. pneumophila* is an important infection-prevention measure in healthcare as a contaminated tap may cause potentially harmful pathogens to spread through splashing. Equipment and patient beds that are within 2-m of basins may be at risk of splashing. The use of partitions or placement of basins further away may reduce the risk of contamination [4]. The high number of splashes found on the nurse's overalls with all basins tested suggests a risk of cross-contamination from water to staff clothing during handwashing. Additionally, the design requires the flow of water to hit the fin and splash reduction properties would be compromised if the tap and basin were not properly aligned or with taps with movable spouts.

Microbiological aspects should be considered when designing products for use in healthcare. The model used in this study may be used to test future basin designs. Evaluation of hydrophilic and hydrophobic glazes may be beneficial in the design of future sanitary ware for use in healthcare.

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Conflict of interest statement

None.

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