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Observation study of water outlet design from a cross-infection/user perspective: time for a radical re-think?

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SUMMARY

Background: Handwashing is a key barrier to cross-infection performed at a handwash station (HWS). Elbow-operated outlets, if used incorrectly (with hands), become highly touched objects, potentially providing a route for cross-infection.
Aim: To study how elbow-operated outlets were used by staff in this hospital, whether the correct type of HWS had been installed in the various ward areas according to the *Health Building Note (HBN) 00-10 Part C: Sanitary Assemblies* (hands-free outlets in clinical, food preparation and laboratory areas), and factors impinging on design/setup which may affect compliance with correct use.
Methods: Observation of outlet use was performed by mounting a video camera above four HWSs. Review of suitability of outlet was conducted by two of the authors by visiting ward areas and assessing compliance against HBN recommendations. Angle of elbow-operated lever setup was measured using a protractor and water temperature in relation to angle of movement of elbow lever was measured using a calibrated thermocouple.
Findings: Ninety-two percent of staff used hands to turn on the outlet and 68% used hands to turn the outlet off, potentially re-contaminating their hands. More than 70% of users moved the lever $\leq 45^{\circ}$. Almost half of elbow levers were set up incorrectly, being flush or within 3.5 cm of the rear panel, making elbow operation extremely difficult. Selection of outlet type according to HBN was most incorrect in the intensive treatment unit but also occurred in the newly built parts of the hospital.
Conclusions: Although handwashing is a key barrier to cross-infection, poor selection and incorrect use of outlet undermines its effectiveness. Design and incorrect instalment further compromise the intended means of operation of elbow levers. Of equal concern is that this risk mostly goes unrecognized. There is an opportunity to improve handwashing safety, but it requires engagement across a broad stratum from Government Departments of Health and manufacturers down to the user.

Introduction

Handwashing is one of the most effective barriers to cross-infection. Semmelweis, recognized as the first person to introduce the practice into healthcare, used a bowl, a jug

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containing a solution of calcium hypochlorite and a towel. The modern-day equivalent handwash station (HWS) is essentially a basin connected to the drainage system above which is an outlet connected to the building water supply, together with soap and hand towels.

Although HWSs function to reduce cross-infection, they can also act as a source. The neonatal outbreak in Belfast in 2011/2012 was a turning point in the UK, prompting recognition of the periphery of the water system as a source of infection, prompting the ensuing health technical memorandum (HTM 04-01 parts b/c).

Outlets may be manually (hand/elbow/knee/foot) or sensor operated. Concerns exist over the risk of biofilm formation in sensor-operated outlets due to the increased complexity (there is also a risk of contaminating the end of the outlet with hands when learning how to activate the sensor) [1]. Elbow-operated outlets are therefore often seen as the gold standard in clinical areas, even though liable to biofilm formation from thermostatic cartridges (often unnecessary if a scalding risk assessment had been performed). Knee-/foot-operated outlets have never gained widespread acceptance in healthcare within the UK.

Transmission of waterborne organisms from HWSs by either contaminated water or drain contents is well recognized [2,3]. An additional risk at HWSs is the potential to re-contaminate hands through operation of the outlet after handwashing. To address this risk, *Health Building Note (HBN) 00-10 Part C: Sanitary Assemblies* states on page 11, 2.37, 'Basin taps in clinical areas and food-preparation and laboratory areas are required to be operated without the use of hands' [4]. It gives the option of either a sensor or single-lever action (elbow-operated) tap. For other areas, such as 'non-clinical wash-hand basins' or 'hand-rinse basins', sink-mounted pillar taps which are hand operated can be used.

Elbow outlets could become highly touched objects if operated incorrectly with hands, thereby providing a route for cross-infection for not just waterborne organisms. Therefore, for this study it was decided to look at how elbow-operated outlets were used by staff in the authors' hospital, whether the correct type of HWS had been installed in the various ward areas according to the HBN, and factors impinging on design/setup which may affect compliance with correct use.

Materials and methods

Observation of use of elbow-operated outlets

Markwik 21 outlets (Ideal Standard, Kingston upon Hull, UK) are installed at most clinical HWSs within the newer hospital areas. According to the manufacturer's description, they are 'panel-mounted thermostatic basin mixers with single-lever operation. Single-lever sequential operation ensures both hot and cold water is drawn on each use. Long lever gives precise control'.

The elbow-operated lever rotates approximately 170°, changing water temperature (up to a maximum of 42°C) (Table I) but not altering the rate of flow once moved beyond the initial 10°.

A video camera with wide-angle lens (Sony FDR-X300R) was mounted above an HWS using a double-suction device (Delkin Fat Gecko camera mount). The angle of view allowed observation of the outlet and the handwashing process but precluded identifying the member of staff. A live-view remote made setting up the camera angle easier and could be used to turn the camera on and off.

Table I
Relationship between angle of movement of elbow lever and water temperature

Angle of movement of lever	10°	20°	45°	75°	90°	120°	150°	170°
Temperature (°C)	20.6	24	25	28	33	37	40.2	42

The video camera was set up as described above at four different HWSs located in acute medical and surgical wards. Staff were asked to wash their hands as normal and were assured beforehand that the angle of view excluded their faces and the purpose of the study was not to check on their technique but to help with HWS design. The video capture was then reviewed to obtain information on how the outlet was turned on/off and the angle of rotation of the elbow-operated lever.

Water temperature in relation to angle of movement of elbow lever

Moving the elbow lever across the full 170° changes water washing temperature. Using a calibrated thermocouple in the water stream, water temperature was measured against angle of operation at three HWSs.

Installation of outlets

The angle at which the elbow lever is set at in relation to the body of the outlet is adjustable. The manufacturer recommends the lever should be set at 20° in front of the main body of the outlet. It was noted that this was not always the case, making it difficult to operate if set flush with the inspection panel behind. The angle of the elbow-operated lever was measured when set to off in relation to the body of the outlet using a protractor. When at a negative angle, the distance between the end of the lever and the rear panel was measured.

A review of suitability of outlet/HWS

HBN 00-10 Part C: Sanitary Assemblies gives guidance on the types of basin and outlet that should be used for clinical handwash basins (incorporating elbow- or sensor-operated outlets to prevent hand contamination) and non-clinical handwash basins (no specific design feature of outlet to stop hand contamination). Two of the authors visited the critical care unit, emergency admission unit, neonatal unit and general ward to assess suitability of design of basin/outlet in relation to area/use and also whether an HWS station was necessary in a particular area.

Results

Observation of use of elbow-operated outlets/water temperature in relation to angle of movement of elbow lever

Thirty-seven handwashing episodes were recorded over a two-week period. The outlet was turned on using hands 34

times, wrist once and elbow twice. When turning off the outlet, hands were used on 21 occasions, wrist four times, forearm five times, elbow six times, and paper towel once.

The angle to which the elbow lever was rotated was ≤45° in 26 instances of handwashing, between 60° and 90° in five instances and ≥150° in six. The relationship between angle of movement of elbow lever and water temperature is shown in Table I. Turning the handle ≤45° gave a water temperature of 20—25°, at which individuals seemed comfortable washing their hands.

Installation of outlets

The angle of setup of the elbow lever relative to the main body of the outlet was recorded and the results are shown in Table II. At angles between −11° and −25° the maximum gap between the end of elbow lever was 3.5 cm, with no gap in 12 instances. A gap of 3.5 cm or less was, in practical terms, equivalent to being flush with the panel behind.

Suitability of outlet

General ward: The choice of outlet for all 14 clinical HWSs assessed was deemed correct. However, two HWSs were considered unnecessary (in a doctor's office and a drug preparation room). The latter HWS was difficult to access and was placed next to clean stored equipment, risking contamination from splashing. Kitchens (provided in other kitchen areas inspected apart from ITU/neonatal unit) had knee-operated handwash basins. In communal patient areas (toilets and bathrooms), non-clinical handwash basins were provided.

Emergency assessment unit (EAU): Of nine HWSs, the choice of outlet was correct apart from one of the main isolation rooms with a lobby. This outlet resembled a domestic tap, with a knob that could only be hand-operated. As one of two of only two isolation rooms with a lobby, it was designated for patients where the infection risk was highest. In two rooms (store room and clean utility) it was felt that an HWS was not necessary.

Intensive treatment unit (ITU): This area is of much older design than the other three areas. None of the 19 HWSs were deemed suitable in the acute area, being classed as hand rinse basins (sink-mounted single outlet with short lever). Two of the HWSs in the HDU were appropriate. An HWS in the clean utility was deemed unnecessary.

Neonatal unit: Of 12 clinical HWSs, hand rinse basins were present in one side room (used for insertion of long lines), the laboratory area (blood gases performed, etc.) and the kitchen (used for preparing baby feeds). These were deemed inappropriate, requiring either sensor- or elbow-operated outlets. An HWS in the clean utility with shelves in close vicinity either side stocked with clean equipment was categorized as unnecessary.

Table II
Angle of setup of elbow lever relative to main body of outlet (manufacturer recommends around 15—20°)

Angle	>10°	0° to ≤10°	−1° to −10°	−11° to −25°
Number of outlets	10	8	10	22

Discussion

Our findings show that 92% of staff turn on elbow-operated outlets with their hands and 68% use either their hands or wrist to turn the outlet off (use of wrists is deemed incorrect as it contravenes 'bare below the elbows' which advocates wrist washing). Our results are consistent with findings in a similar observation study at another hospital [5].

The patient environment may be linked to the transmission of nosocomial infections because many surfaces are frequently touched and mutually contacted by healthcare workers, patients, and visitors. This is unified in the World Health Organization (WHO)'s 'five moments for hand hygiene' combining a patient zone and healthcare zone containing other surfaces that may pose a risk, prompting hand hygiene. HWSs are not usually included in lists of highly touched surfaces of concern, presumably because either they are not perceived as a risk or they are outside of the immediate healthcare zone. In one study, using adenosine triphosphate (ATP) testing, tap handles were frequently found to be contaminated, affirming that these are highly touched surfaces [6]. High levels of contamination would be expected as use of an HWS over alcohol gel is required when hands are visibly soiled (heavily contaminated).

Handwash training/assessment using ultraviolet light with fluorescent powders/creams and handwashing instructions placed at HWSs tend to emphasize technique with little attention to the correct use of the HWS. Re-contamination of hands at clinical HWSs, and at the frequency observed, is cause for concern.

The greatest number of HWSs not meeting clinical standards were found in the ITU (old estate built in 1994 prior to Health Technical Memorandum: sanitary assemblies (DH 2006)/HBN), with staff using rinse basins with a single pillar tap with short hand-operated lever. Observation showed hands were used to turn the outlet both on and off with potential re-contamination (the inherent risk not being appreciated). Even in the more recently built neonatal unit, the incorrect type of handwashing facility was present in clinical areas. Ward kitchen areas run by domestic staff have knee-operated handwashing facilities (removing the risk of hand re-contamination from outlets), unlike the kitchen used for preparing neonatal feeds and on the ITU (hand rinse basin). (The HWSs in the ITU are in the process of being replaced as part of a package of measures in response to an outbreak of *Pseudomonas aeruginosa*. The neonatal side room HWS is also being replaced with HBN-compliant units.)

Handwashing facilities provided in clean utility/storage areas and drug preparation areas (room design often made access difficult): both are unnecessary and potentially dangerous (splashing on clean stored equipment). Hands should be clean before accessing such areas and provision of alcohol gel should be adequate. Indeed, nationally water services were removed from pharmacy sterile preparation areas after deaths from waterborne infections from a nearby sink.

The elbow-operated outlet used in the hospital (a popular design used in many hospitals) requires turning approximately 170° to achieve maximum temperature (42°C). Most users (>70%) moved the lever 45° or less, being comfortable to wash in water temperatures of lower-to mid-20s. The large turning arc necessitates that the lever is set back and to one side resulting in an unnatural movement by the user to reach back/across to operate with an elbow. It also means that

items such as towel dispensers, liquid soap dispensers placed above the outlet can interfere with operation. Most outlets were not installed in line with manufacturers' instructions (Figure 1). Forty-four percent of tap handles were either flush or within 3.5 cm of the panel behind, making it extremely difficult to turn on using the elbow. The angle of setup appeared random. Estates staff report that they are not given instructions on a specific angle on setup. Observation by one author suggests such practices are widespread, not limited to this hospital. The large turning arc may be compromising correct use and installation of this outlet. Handwashing does not require a range of water temperatures (i.e. fixed temperature of the sensor outlet would be better). Thus, an elbow lever with a narrow turning arc set up perpendicular to wall/user, with a sign saying 'use elbow' might engage better with users.

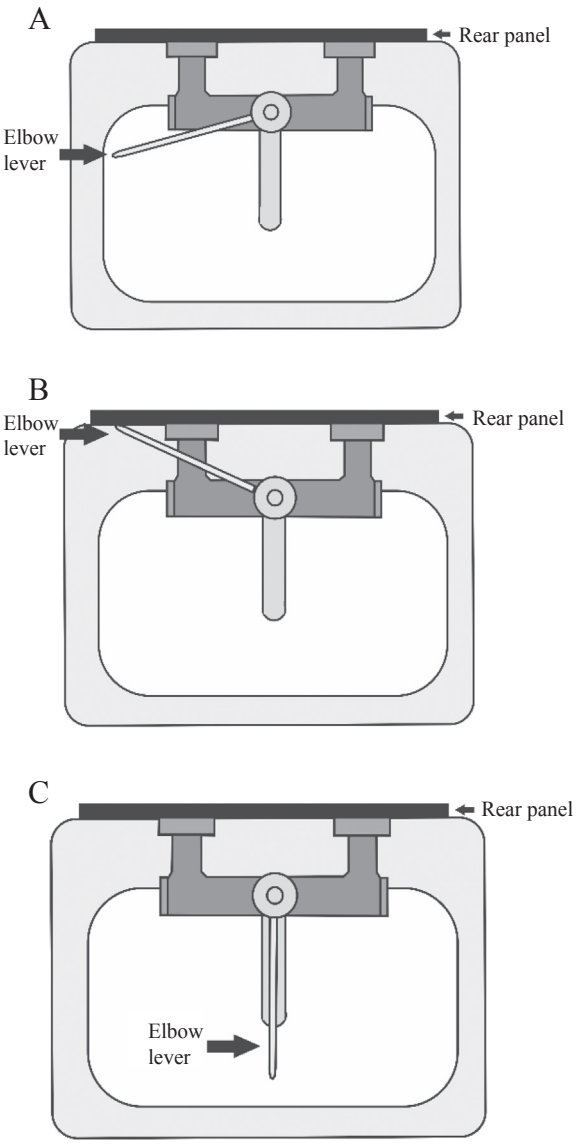

Figure 1. Bird's eye view from above outlet and sink. (A) Correct angle of setup of elbow lever according to manufacturer (+30°). (B) Forty-four percent of elbow levers were either installed flush or in close proximity with the rear panel making it difficult to operate with elbows (−11° to −25°). (C) Even with correct setup as in (A) the user has to reach somewhat awkwardly across the sink to operate. Locating the lever as shown in (C) is more ergonomic and feasible as most users only rotate the lever through 45° or less.

So how can the situation be improved? Foremost must be an appreciation by everyone including Government Departments of Health, manufacturers, hospital design teams and users of the risk associated with HWSs. Gaining almost saintly status following national campaigns to reduce infection, this now needs to be tempered by acknowledgement of the hazards, which are many. Apart from a few situations (visibly soiled hands, certain pathogens), alcohol gel is more effective, safer and better tolerated than water/soap and should be the primary mode of hand disinfection.

The primary focus of this paper is the risk around using hands to operate an outlet. WHO teaching mitigates the risk of turning a tap off using a paper towel (1/37 staff in this study; however, the staff member used the towel to turn off the outlet first then dried their hands, potentially re-contaminating them). Turning an outlet on with contaminated hands still represents a risk if handwashing technique by subsequent users is not adhered to 100%. Our results show compliance with correct technique using elbow-operated outlets is poor. Similar results might be expected with paper towel use (both methods are mentioned in training in our hospital). The HBN makes a divide in recommending sink-mounted outlets which are hand-operated for non-clinical areas — toilets (patients, visitors and staff) and bathrooms — despite our acknowledgement that bacteria do not observe boundaries. A healthcare worker in contact with a patient's faeces uses an elbow-operated or sensor-operated outlet to prevent cross-infection. The same patient requiring the toilet in a communal bathroom will operate and potentially contaminate the outlet handle with faecal organisms putting ensuing patients at risk. Patients are not taught how to operate HWSs safely. Even if they were, why should their compliance be better than health staff? The global threat of antimicrobial resistance comes from highly mobile resistance determinants within Gram-negative organisms which, with humans, reside principally in the bowel. The drive should be to install outlets minimizing the risk of hand re-contamination at all communal HWSs irrespective of whether they are for clinical use or in a toilet, etc.

There is a significant opportunity to improve the safety of handwashing by revisiting the design of outlets, but manufacturers must factor in the user's perspective. For example, with sensor-operated outlets, the placement and appearance of sensor may vary, yet users are somehow expected to know how to operate them; this is unacceptable and could lead to hands inadvertently contaminating the spout of the outlet. Standardized placement of sensor combined with visual cues (illumination of sensor or sign above) are simple potential solutions. The role of leg-/knee- or foot-operated outlets requires further exploration. The future of all elbow-operated outlets in their current form must be questioned (not just the design used in this hospital).

The high level of potential hand re-contamination from incorrect use of outlets is alarming, but equally so is the fact that it goes unrecognized. Following the Belfast neonatal incident, tap manufacturers improved design to minimize the risk of water contamination from the outlet. Now work on design is required to ensure that the purpose of handwashing is

not immediately negated through hand re-contamination. In developing new designs, manufacturers need to consider simplifying the interface to improve user compliance. Within infection control, greater emphasis needs to be placed on correct use of outlets. It is also suggested that, in the UK, *HBN 00-10 Part C: Sanitary Assemblies* is revised to include placing 'hands free' HWSs in all communal areas as the risk from hand re-contamination is not restricted to clinical staff. The end of the antibiotic era is becoming less of a threat and more of a reality. To preserve these precious agents, a reduction in the transmission of organisms is a necessary part of the strategy. Hand hygiene is the most important measure to avoid the transmission of harmful germs and prevent healthcare-associated infections [7]. There is no option other than to get it right.

Conflict of interest statement
The authors have no conflicts of interest to declare.

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