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Comparison of cleaning efficacy between in-use disinfectant and electrolysed water in an English residential care home

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SUMMARY

Background: Infection control in hospitals and care homes remains a key issue. They are regularly inspected regarding standards of hygiene, but visual assessment does not necessarily correlate with microbial cleanliness. Pathogens can persist in the inanimate environment for extended periods of time.

Aim: This prospective study compared the effectiveness of a novel sanitizer containing electrolysed water, in which the active ingredient is stabilized hypochlorous acid (Aqualution™), with the effectiveness of the quaternary ammonium disinfectant in current use for microbial removal from hand-touch surfaces in a care home. The study had a two-period crossover design.

Methods: Five surfaces were cleaned daily over a four-week period, with screening swabs taken before and after cleaning. Swabs were cultured in order to compare levels of surface microbial contamination [colony-forming units (cfu)/cm^2] before and after cleaning with each product.

Findings: Cleaning with electrolysed water reduced the mean surface bacterial load from 2.6 [interquartile range (IQR) 0.30–30.40] cfu/cm^2 to 0.10 (IQR 0.10–1.40) cfu/cm^2 [mean $\log_{10}$ reduction factor 1.042, 95% confidence interval (CI) 0.79–1.30]. Cleaning with the in-use quaternary ammonium disinfectant increased the bacterial load from 0.90 (IQR 0.10–8.50) cfu/cm^2 to 93.30 (IQR 9.85–363.65) cfu/cm^2 (mean $\log_{10}$ reduction −1.499, 95% CI −1.87 to −1.12) ($P < 0.0001$). Using two proposed benchmark standards for surface microbial levels in hospitals, electrolysed water resulted in a higher 'pass rate' than the in-use quaternary ammonium disinfectant (80–86% vs 15–21%, $P < 0.0001$).

Conclusion: Electrolysed water exerts a more effective bacterial kill than the in-use quaternary ammonium disinfectant, which suggests that it may be useful as a surface sanitizer in environments such as care homes.

Introduction

Residential homes are subject to infection risks since frail elderly people are potentially more vulnerable to disease-causing pathogens than healthy adults.[1,2] Many care homes in

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the UK lack the infection control surveillance that exists in hospitals, and outbreaks of infection may significantly challenge workload capacity. Care homes may have sufficient single rooms for isolation purposes; however, unlike hospital wards, they cannot close beds to aid control. It is therefore imperative that cleaning and disinfection practices are optimal.

The first line of defence is a thorough and proper approach to patient and environmental hygiene.[3] Aesthetic cleanliness is reassuring but does not indicate the absence of potential pathogens. A previous hospital-based study showed that whilst 82% of areas were deemed visually clean, only 30% were of a microbiologically acceptable standard.[4] Unfortunately, visual appraisal forms the basis of National Health Service cleaning standards, with no concurrent microbiological analysis for validation.[5] There are no agreed standards for microbiological cleanliness, although maximum microbial levels of <2.5 colony-forming units (cfu)/cm^2 and <5 cfu/cm^2 have been suggested for hand-touch sites.[4,5] Hands are likely to pick up potential pathogens and transmit them between environmental sites and people.[5,6] Such transmission is compounded by the fact that some sites receive more cleaning attention than others, usually due to accessibility rather than contamination risk.[7] In addition, pathogens are able to persist in the environment for extended periods of time, posing increased risk for transmission of infection.[3,8]

One of the most significant factors affecting cleaning efficiency is time. Conventional biocides require a minimum contact time (usually >5 min) to produce a significant reduction in the number of micro-organisms.[9] This is not practical during daily cleaning, and in most cases, the biocides used do not receive the contact time required for them to be effective. Even if sufficient contact time was possible, there would be an additional risk of contact and ingestion by vulnerable people, such as care home residents with dementia.

Electrolysed water (also known as super-oxidized water) is produced by ion-exchange electrolysis of saline, and contains a significantly higher level of available hypochlorous acid than can be delivered via chemical formulation.[10] It is effective against a range of micro-organisms following contact times of <1 min.[11] To date, no studies have compared the effectiveness of electrolysed water with other disinfecting agents in a care home environment. This study was designed to compare a proprietary electrolysed water preparation with the disinfectant currently used for routine cleaning purposes in a care home using proposed microbiological standards.

Materials and methods

The care home in this study consists of four identical houses, each accommodating 30 residents in individual bedrooms, with communal areas and a satellite kitchen for preparation of snacks (set meals are prepared in a central kitchen). A two-period crossover study lasting for two weeks was undertaken. The home's usual proprietary disinfectant, a quaternary ammonium compound (alkyl-dimethyl benzyl ammonium chloride plus non-ionic surfactants, 0.04% following dilution), was used in the first week in two of the houses and electrolysed water was used in the second week. In the other two houses, the order of use of each disinfectant was reversed.

Aqualution™ (Aqualution Systems Ltd, Duns, UK) is a commercial product in which hypochlorous acid has been stabilized, allowing it to be bottled and stored for periods in excess of one year. Sensitivity and toxicology studies have demonstrated that the product is non-toxic for mammals and safe for the environment.[10] Compliance studies have demonstrated that electrolysed water is bactericidal for *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Salmonella* spp., *Escherichia coli* and *Campylobacter jejuni*, with a contact time <1 min being necessary to deliver the required $\log_{10}$ reduction factor of 5.[11–15] Aqualution is supplied ready to use in 1-L spray bottles and does not require any special instructions for use. The in-use quaternary ammonium disinfectant has to be diluted *in situ* into spray bottles, and requires personal protective equipment to be worn during the dilution procedure. Approximately 1.5 mL of product is dispensed per trigger spray for both electrolysed water and the in-use quaternary ammonium disinfectant.

Five surface areas were chosen in each house: sluice door handle; sink in lavatory; patient hoist; bedroom worktop (vanity unit top); and commode seat. The same surfaces were cleaned and screened before and after cleaning on four days per week (Monday–Thursday). Cleaning and screening in all four houses was undertaken by the same nurse throughout the study. The sites were sprayed with either electrolysed water or the in-use quaternary ammonium disinfectant and then wiped with a microfibre cloth. Screening was carried out immediately before and after cleaning.

During the two-week study period, a total of 320 swabs were obtained (eight days, four houses and five surface sites before and after cleaning). Pre- and post-cleaning swabs sampled a 100-cm^2 area of each test surface using a sterile template and swabs (Technical Service Consultants Ltd, Heywood, UK). For each sampling site, the area was swabbed using diagonal movements across the whole template area. Following the use of electrolysed water, the area was recleaned with the in-use quaternary ammonium disinfectant after the swabs had been taken.

Swabs were couriered to the laboratory daily and analysed for total aerobic colony counts (ACCs). Analyses were performed at the Scitech Laboratory, Craven Arms, Shropshire, using the pour-plate technique. Plates were incubated at 30 °C for 72 h, after which colonies were counted and ACCs were reported in cfus. No further identification was attempted.

Statistical methods

Levels of microbial contamination of the screened surfaces (cfu/cm^2) were derived from the reported ACC figures by dividing them by the area screened. For each pair of pre- and postcleaning figures, the $\log_{10}$ reduction was calculated as the logarithm (base 10) of the ratio of the precleaning level to the postcleaning level, such that a positive figure represented a decrease in microbial load after cleaning and a negative figure represented an increase. In order to facilitate this, if the pre- and/or postcleaning ACC was reported as zero, 1 cfu was assumed for the purpose of calculation of the $\log_{10}$ reduction.

Data for levels of surface contamination (microbial load), both before and after cleaning, had a highly positively skewed distribution, even after logarithmic transformation, with a small number of extreme outlying (high) values. For this reason, data were summarized in terms of median values and interquartile ranges (IQR). Data for microbial reduction following cleaning ($\log_{10}$ reduction figures) resembled a normal distribution. These data were therefore summarized as arithmetic means, together with standard errors of the mean and 95% confidence intervals

(CI). All data have been summarized overall (within each product group) and broken down into subgroups according to factors of potential interest (e.g. week, day of week, house, surface studied). Statistical analysis was undertaken using SAS/STAT Version 8 (SAS Institute, Cary, NC, USA).

Analysis of the reduction in microbial surface contamination following cleaning was undertaken on $\log_{10}$ reduction figures calculated for each pair of pre-/postcleaning swab results. An appropriate analysis of variance was performed within the framework of a generalized linear model which included product, week, day of week, house and surface site, and relevant interaction terms. Since the order of use of disinfectants was the same within a house but differed between houses, the factor 'house' effectively served as a 'treatment order' term.

Postcleaning 'pass rate' figures for surface microbial levels, according to two proposed criteria, were compared for the two cleaning products using Fisher's exact test. Although the primary analysis is the overall comparison of the two products, results of such tests have also been presented for subgroups relating to factors of potential interest (as per data summary); such additional tests should be regarded as exploratory in nature.

All available data were analysed and no attempt was made to impute values for the small number of missing data items. For hypothesis tests, actual *P*-values are presented, with values <0.05 being considered statistically significant.

Results

Of the 320 swabs scheduled during the study, 317 were obtained. During one day (Thursday) in the first week, swabs were not obtained before or after cleaning the sluice door handle with electrolysed water in one house, and a swab was not obtained before cleaning the bedroom worktop with the in-use quaternary ammonium disinfectant in a different house.

Median (and IQR) pre- and postcleaning surface microbial levels (expressed as cfu/cm^2 of screened surface) are summarized in Table I. For electrolysed water, overall median levels decreased from 2.60 (IQR 0.30–30.40) cfu/cm^2 before cleaning to 0.10 (IQR 0.10–1.40) cfu/cm^2 after cleaning. For the in-use quaternary ammonium disinfectant, overall median levels increased from 0.90 (IQR 0.10–8.50) cfu/cm^2 before cleaning to 93.30 (IQR 9.85–363.65) cfu/cm^2 after cleaning. Median levels reflected this overall pattern for all four houses, and all five surfaces studied for both disinfectants throughout the study. Marked reductions after cleaning with electrolysed water were seen at all sites, with median postcleaning levels generally below 0.2 cfu/cm^2, whereas higher median levels were found following cleaning with the in-use quaternary ammonium disinfectant. Precleaning microbial levels were considerably higher on Mondays than on other days of the week but, again, median levels decreased markedly following cleaning with electrolysed water and increased markedly following cleaning with the in-use quaternary ammonium disinfectant on all weekdays studied.

Table II summarizes the reduction in surface microbial levels following cleaning in terms of mean $\log_{10}$ reduction figures. Electrolysed water resulted in a mean $\log_{10}$ reduction factor of 1.042 (95% CI 0.79–1.30), which represented an ~11-fold mean decrease in ACCs after cleaning. The in-use quaternary ammonium disinfectant resulted in a mean $\log_{10}$ reduction factor of -1.499 (95% CI −1.87 to −1.12), which was a ~32-fold increase in mean $\log_{10}$ values as a result of cleaning ($P < 0.0001$). The patterns of these changes with both products were generally consistent across study weeks, all four houses and all five surfaces studied, but with some variation between the days of the week. There was no evidence of significant period ('week') or order (represented by 'house') effects.

No official standards are available for acceptable microbial colony counts in healthcare environments. Dancer and Griffith

Table I
Summary of surface microbial contamination levels

	Electrolysed water						In-use quaternary ammonium disinfectant					
	Preclean microbial level (cfu/cm^2)			Postclean microbial level (cfu/cm^2)			Preclean microbial level (cfu/cm^2)			Postclean microbial level (cfu/cm^2)		
	N	Median	IQR	*N*	Median	IQR	*N*	Median	IQR	*N*	Median	IQR
Week 1	39	1.00	0.10–30.40	40	0.10	0–1.40	39	2.50	0.10–28.00	40	82.80	7.90–158.40
Week 2	40	4.65	0.60–28.5	40	0.10	0.10–1.00	40	0.60	0.15–3.40	40	149.60	13.45–392.20
House 1	19	0.70	0.10–3.60	19	0.10	0–1.00	20	0.50	0.10–0.90	20	101.60	6.20–412.65
House 2	20	6.30	0.15–32.5	20	0.15	0–3.00	20	1.25	0.20–12.35	20	196.80	46.40–379.65
House 3	20	3.10	0.20–20.20	20	0.10	0.10–0.50	19	2.10	0.10–8.50	20	45.20	0.35–114.50
House 4	20	10.25	0.60–67.00	20	0.20	0.10–2.85	20	2.60	0.15–30.00	20	128.20	50.10–371.60
Monday	20	13.60	1.30–43.95	20	0.35	0.10–4.90	20	4.60	0.60–65.00	20	30.60	2.10–365.75
Tuesday	20	2.60	0.70–24.00	20	0.10	0.10–0.50	20	0.80	0.20–6.65	20	128.50	59.2–389.80
Wednesday	20	0.60	0.05–11.50	20	0.10	0.05–1.20	20	0.45	0.10–2.30	20	95.50	26.80–295.05
Thursday	19	1.80	0.20–33.60	19	0.10	0–0.50	19	0.50	0.10–3.80	20	79.60	1.90–275.20
Sluice door handle	15	0.60	0.10–5.20	15	0.10	0.10–0.20	16	0.20	0.10–0.60	16	59.20	3.00–283.65
Sink in lavatory	16	4.25	0.40–26.70	16	0.15	0.10–1.20	16	0.25	0.10–12.95	16	167.25	35.95–390.20
Patient hoist	16	17.80	2.70–58.75	16	2.40	0.25–6.80	16	4.30	0.55–36.60	16	63.60	6.75–133.20
Room vanity top	16	1.00	0.25–12.00	16	0.10	0–0.15	15	2.00	0.60–3.80	16	102.50	30.80–297.80
Commode seat	16	5.60	0.10–38.00	16	0.10	0.05–2.20	16	3.40	0.15–35.60	16	139.50	23.90–389.60
Overall	79	2.60	0.30–30.40	79	0.10	0.10–1.40	79	0.90	0.10–8.50	80	93.30	9.85–363.65

cfu, colony-forming unit; IQR, interquartile range.

Table II
Summary and analysis of reduction in surface microbial contamination following cleaning (log_{10} reduction figures)

	Log_{10} reduction in surface microbial level							
	Electrolysed water				In-use quaternary ammonium disinfectant			
	N	Mean	SEM	95% CI	*N*	Mean	SEM	95% CI
Week 1	39	1.011	0.206	0.59 to 1.43	39	−1.165	0.297	−1.77 to −0.57
Week 2	40	1.073	0.153	0.76 to 1.38	40	−1.824	0.226	−2.28 to −1.37
House 1	19	0.886	0.283	0.29 to 1.48	20	−2.129	0.236	−2.62 to −1.64
House 2	20	1.131	0.303	0.50 to 1.76	20	−1.519	0.378	−2.31 to −0.73
House 3	20	0.926	0.212	0.48 to 1.37	19	−0.730	0.424	−1.62 to 0.16
House 4	20	1.220	0.222	0.76 to 1.68	20	−1.579	0.404	−2.42 to −0.73
Monday	20	1.154	0.288	0.55 to 1.76	20	−0.320	0.448	−1.26 to 0.62
Tuesday	20	1.364	0.198	0.95 to 1.78	20	−2.063	0.192	−2.46 to −1.66
Wednesday	20	0.501	0.268	−0.06 to 1.06	20	−2.217	0.315	−2.88 to −1.56
Thursday	19	1.156	0.225	0.68 to 1.63	19	−1.391	0.365	−2.16 to −0.62
Sluice door handle	15	0.928	0.242	0.41 to 1.45	16	−1.784	0.424	−2.69 to −0.88
Sink in lavatory	16	1.014	0.395	0.17 to 1.86	16	−1.705	0.547	−2.87 to −0.54
Patient hoist	16	0.857	0.209	0.41 to 1.30	16	−0.998	0.382	−1.81 to −0.18
Room vanity top	16	1.282	0.307	0.63 to 1.94	15	−1.486	0.330	−2.19 to −0.78
Commode seat	16	1.123	0.248	0.59 to 1.65	16	−1.521	0.404	−2.38 to −0.66
Overall	79	1.042	0.127	0.79 to 1.30	79	−1.499	0.188	−1.87 to −1.12
Hypothesis test results – main effects								
Product								$P < 0.0001$
Week								$P = 0.1633$ (NS)
Day of week								$P = 0.0006$
House								$P = 0.1340$ (NS)
Area								$P = 0.7675$ (NS)

SEM, standard error of the mean; CI, confidence interval; NS, not significant.

et al. have proposed levels of <5 and <2.5 cfu/cm^2, respectively.[4,5] Table III indicates the postcleaning pass rates for each product against these two proposed benchmarks. Using the <2.5 cfu/cm^2 criterion, the overall postcleaning pass rate with electrolysed water was 63/79 (80%), whereas the overall pass rate for the in-use quaternary ammonium disinfectant was 12/80 (15%). Using the <5 cfu/cm^2 criterion, the overall postcleaning pass rates for electrolysed water and the in-use quaternary ammonium disinfectant were 68/79 (86%) and 17/80 (21%), respectively. The difference between the two disinfectants was highly significant ($P < 0.0001$) for both criteria.

Discussion

This study investigated the effectiveness of two disinfectants against microbial counts on a range of hand-touch surfaces in a care home using actual cleaning regimens rather than laboratory-controlled processes. The study design was as rigorous as possible within the limitations of the practical situation under investigation. Although the individual performing the cleaning and screening operations was not blinded to the product being used, there was no evidence of bias in the study results.

The results were consistent across all test surfaces used in the study, and demonstrate that electrolysed water was much more effective than the in-use quaternary ammonium disinfectant. On average, electrolysed water resulted in a significant reduction in surface microbial load, whereas the in-use quaternary ammonium disinfectant increased the bacterial load. One possible explanation is contamination of the cleaning cloth, as described by Dharan *et al.* who suggested that cloths themselves contribute to the mechanical spread of bacteria from contaminated sites over entire surfaces.[16] A laboratory-based study by Moore and Griffith specifically examined different types of microfibre cloths, and found potential for microbial contamination.[17] This study used microfibre cloths that were initially used on 'clean' (just sanitized) surfaces and then on progressively more contaminated surfaces within a room, with a fresh cloth only provided for a different room. Due to time constraints, staff have to spray and wipe down an area without necessarily waiting for the disinfectant to have sufficient contact time to be effective. Used cloths are kept segregated after use and are subjected to a sterilizing wash before re-use, so the increase in contamination was not attributable to initially contaminated cloths. Since electrolysed water gave consistently acceptable cleaning results, the product facilitated the killing of organisms transferred to a surface by the cloth, as well as killing those organisms already present on the surfaces studied. This suggests that the time required for inactivating micro-organisms is crucial when using disinfectants for cleaning healthcare environments.[9]

Although no official standards are available for acceptable microbial levels on surfaces in healthcare environments, levels of <5 and <2.5 cfu/cm^2 have been proposed.[4,5] In terms of both of these proposed benchmarks, electrolysed water resulted in much higher postcleaning pass rates than the in-use

Table III
Summary and analysis of postcleaning pass rates for the two cleaning products according to two proposed criteria

	Proportions (%) achieving specified 'pass' criteria				Significance of difference between products*	
	Electrolysed water		In-use quaternary ammonium disinfectant			
	<2.5 cfu/cm² criterion[a]	<5 cfu/cm² criterion[b]	<2.5 cfu/cm² criterion[a]	<5 cfu/cm² criterion[b]	<2.5 cfu/cm² criterion[a]	<5 cfu/cm² criterion[b]
Week 1	31/39 (79%)	33/39 (85%)	9/40 (23%)	10/40 (25%)	$P < 0.0001$	$P < 0.0001$
Week 2	32/40 (80%)	35/40 (88%)	3/40 (8%)	7/40 (18%)	$P < 0.0001$	$P < 0.0001$
House 1	16/19 (84%)	17/19 (89%)	1/20 (5%)	4/20 (20%)	$P < 0.0001$	$P < 0.0001$
House 2	15/20 (75%)	16/20 (80%)	2/20 (10%)	3/20 (15%)	$P < 0.0001$	$P < 0.0001$
House 3	17/20 (85%)	17/20 (85%)	7/20 (35%)	8/20 (40%)	$P = 0.0031$	$P = 0.0079$
House 4	15/20 (75%)	18/20 (90%)	2/20 (10%)	2/20 (10%)	$P < 0.0001$	$P < 0.0001$
Monday	12/20 (60%)	15/20 (75%)	5/20 (25%)	6/20 (30%)	$P = 0.0536$ (NS)	$P = 0.0104$
Tuesday	18/20 (90%)	18/20 (90%)	0/20 (0%)	1/20 (5%)	$P < 0.0001$	$P < 0.0001$
Wednesday	17/20 (85%)	19/20 (95%)	2/20 (10%)	3/20 (15%)	$P < 0.0001$	$P < 0.0001$
Thursday	16/19 (84%)	16/19 (84%)	5/20 (25%)	7/20 (35%)	$P = 0.0003$	$P = 0.0031$
Sluice door handle	14/15 (93%)	14/15 (93%)	4/16 (25%)	6/16 (38%)	$P < 0.0001$	$P = 0.0021$
Sink in lavatory	13/16 (81%)	13/16 (81%)	2/16 (13%)	2/16 (13%)	$P < 0.0001$	$P < 0.0001$
Patient hoist	8/16 (50%)	11/16 (69%)	2/16 (13%)	3/16 (19%)	$P = 0.0538$ (NS)	$P = 0.0113$
Room vanity top	15/16 (94%)	16/16 (100%)	3/16 (19%)	3/16 (19%)	$P < 0.0001$	$P < 0.0001$
Commode seat	13/16 (81%)	14/16 (88%)	1/16 (6%)	3/16 (19%)	$P < 0.0001$	$P < 0.0001$
Overall	63/79 (80%)	68/79 (86%)	12/80 (15%)	17/80 (21%)	$P < 0.0001$	$P < 0.0001$

cfu, colony-forming unit; NS, not significant.
*Fisher's exact test (two-sided); all tests other than overall test should be considered exploratory in nature.
[a] Criterion proposed by Griffith CJ *et al*. *J Hosp Infect* 2000;**45**:19–28.
[b] Criterion proposed by Dancer SJ. *J Hosp Infect* 2004:**56**:10–15.

quaternary ammonium disinfectant. Given the significant effect between the two disinfectants, the difference between the two proposed standards was arbitrary.

This was a small-scale study in four houses belonging to a single care home; it would be appropriate to repeat the study on a much larger scale in a number of different community care homes managed by a range of different providers. In addition, these houses received a high standard of disinfectant-based cleaning in general; this is reflected in the relatively low microbial counts retrieved from sampling overall. For full assessment of the potential impact of electrolysed water, it would be helpful to investigate its environmental impact in a busy hospital.

In conclusion, electrolysed water offers significant benefits in cleaning efficacy compared with the in-use quaternary ammonium disinfectant, probably due to the rapid speed of action of electrolysed water.[18] An additional benefit is that electrolysed water does not have the toxicity and consequent health and safety issues of established chemical agents. Standardized benchmarking measures for evaluating and comparing surface disinfectants are helpful when assessing different agents, and should be established as part of the continuing public health action on infection control.

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Conflict of interest statement
The authors report no conflicts of interest at the time of the study. N.S. Meakin has since become a shareholder in Aqualution Systems Ltd. S.J. Dancer has received support for studies on hospital cleaning from UNISON, the healthcare workers union.

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