

Antistatic nurses' aprons may contribute to a reduction of hospital infection in isolation wards

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Summary In the past, nurses' cotton uniforms have been implicated in the spread of micro-organisms and this led to the widespread use of disposable plastic aprons. However, plastic is notorious in acquiring static electric charge which is able to attract airborne micro-organisms. In this study, five different types of ordinary and antistatic nurses' plastic aprons were tested both electrostatically and bacteriologically. The purpose was to investigate whether antistatic aprons may constitute an improved barrier to the spread of micro-organisms, particularly in isolation wards where immuno-compromised patients are more susceptible to infecting organisms. Results showed that one antistatic apron from five types tested exhibited a 38% reduction in bacteria attracted onto its surface compared with the white plastic aprons currently in use. We suggest that antistatic aprons may contribute to a reduction in hospital infections, particularly in isolation wards such as those in bone marrow transplant units.

KEYWORDS

Hospital infections; Antistatic aprons; Nurses' plastic aprons; Disposable plastic aprons; Airborne bacteria; Isolation wards

Introduction

Historically, the use of nurses' plastic aprons was adopted in favour of cloth aprons because of the risk of contamination from the nurses' uniforms. Some years ago, bacteriological studies on bedmaking showed that strains of *Staphylococcus aureus* carried on nurses' external clothing were often transferred to the patient's bedclothes.^{1, 2, 3} The bedclothes were shown to be the mediators of the dispersal of bacteria about the ward,¹ with tests showing that more than 50 000 particles were liberated during the process of bedmaking. These particles originate from the shed skin squamae of hospital staff or visitors: the average person liberating approximately three hundred million squamae per day.⁴ The total output of particles actually carrying bacteria was found to be around one thousand per minute⁵ with each one supporting an average of four viable bacteria.⁶ The use of plastic aprons that can be decontaminated, or a disposable covering for the front of the uniform was suggested.² The efficacy of disposable plastic aprons has long since been demonstrated^{3, 7, 8, 9} and disposable plastic aprons were recommended for use in intensive care environments to prevent dissemination of infection from heavily contaminated gowns.⁹

However, plastic is well known to easily acquire static electric charge which can attract airborne bacteria. Several workers have highlighted the role played by static charge in the occurrence of hospital infections: the inadvertent intravenous infusion of *Mucor* during parenteral feeding of a neonate;¹⁰ increased deposition of bacteria on surgeon's gloves during endoscopic surgery;¹¹ and treatment of plastic items in a hospital ward with antistatic solution decreased the deposition of airborne bacteria onto them, compared with items untreated.¹² In addition, a dose-response effect has been demonstrated¹³ in which the deposition of airborne bacteria onto a surface increases with increased static charge for either negative or positive polarity.

Bacteria themselves can carry thousands of elementary electric charges on their surfaces, both airborne bacteria¹⁴ and waterborne species.¹⁵ The bacterial surface acts as a highly reactive interface due to an abundance of reactive constituents, such as carboxyl, hydroxyl, phosphoryl and amine groups.¹⁶ They may carry up to 13 000 positive or negative charges¹⁷ and in this high charge state, they can move swiftly within an electric field.¹⁸

We have previously carried out a pilot study¹⁸ electrostatically and bacteriologically comparing nurses' white disposable plastic aprons with conducting plastic aprons made with aluminized plastic film. Figure 1 is a schematic diagram to show the effects of static charge build-up on highly insulated plastic aprons. A nurse wearing a plastic apron with static charge will set up an electric field between nurse and patient where an equal and opposite charge will be induced on the patient. Two methods of transfer of micro-organisms to the patient are envisaged: (i) positively charged bacteria are attracted to the apron and may be subsequently transferred to the patient either by direct contact or by contact with bedclothes, and (ii) negatively charged bacteria are attracted directly to the patient. This will equally apply where the polarities are reversed. Pilot study

measurements showed that the mean electric potential induced on the plastic apron during pull-off from the dispenser was -5.33 kV (range -9.90 to -2.87 kV) compared with a mean electric potential of 0.00 kV (range -0.09 to +0.06 kV) for the conducting apron. In addition, after pull-off and 10 minutes wear, the bacteria deposited on the plastic apron surface increased by 83%, compared with an increase of only 17% on the conducting apron.

Although the use of disposable plastic aprons provided a marked improvement on cloth aprons in the past, we are interested in further improvements in the incidence of hospital infections, particularly in isolation wards where the patient's immune system is compromised.

As a result of our pilot study, the apron manufacturers (**bpi** British Polythene Industries PLC) made for us several different types of aprons with different levels and combinations of antistatic additives in the polythene mixture. The plastic recipe remained unknown to us to avoid experimental bias. The five different types of aprons were tested both electrostatically and bacteriologically to examine whether any of them may be suitable for introduction into isolation wards. This paper describes the methods employed and the results obtained.

Methods

Electrical charge decay times

A meter was used (Static Monitor JCI 140C, John Chubb Instrumentation, Cheltenham), to make measurements of electrical potential due to static charge at the apron surface. The JCI 140C is a compact instrument which measures the electrical potential on surfaces, having a 2 kV and a 20 kV range with 1 V and 10 V resolution respectively. The instrument was calibrated by the manufacturers and the zero reading was checked and adjusted regularly.

An apron from each of the 5 types supplied was set up inside a Faraday cage so that it was 10 cms from the meter, according to manufacturer's instructions. The use of a Faraday cage ensured that no stray electric fields would interfere with the measurements of electrical potential. Each apron was clamped in position so that a large surface area was presented before the meter. The holding clamps were covered in conducting plastic such as aluminised mylar. The meter was connected to a laptop computer to monitor readings every second over several hours. Each apron surface was stroked 5 times in same direction with a paper hand-towel to obtain initial charge on the apron. The whole setup was left to run until the level of charge on the apron surface had decreased to $1/e$ ($= 0.369$ or 37%) of the initial electrical potential. In some cases the setup was left overnight to obtain a value for $1/10$ of initial potential. Results for initial potential, time to $1/e$ and time to $1/10$ for the different types of aprons were compared. The temperature and relative humidity were recorded.

Electrical charge at pull-off and wearing of aprons

Nurses' plastic aprons come in a large roll which is then placed in a plastic wall dispenser. For everyday use in the ward, aprons are pulled out of the dispenser and torn off at the perforation. In order to measure the static electric potential generated on the apron during pull-off and during wearing of the apron, two field mill meters were set up in the following ways:

The first was clamped in a position next to the wall dispenser in such a way that it was 10 cms from the apron surface when aprons were pulled out of the dispenser. The electric potential generated during pull-off was read from the meter's digital display. The second was clamped in position on top of a desk in the same room, but about 3 metres away. It was set at just below waist height, so that a volunteer wearing the apron approached the meter to 10 cms to take an immediate reading.

The electric potential acquired by the apron during pull-off and wear was measured for forty aprons of each type supplied, i.e. Sample 1, Sample 2, Sample 3, Pink and White: two hundred aprons altogether. The mean electric potential for pull-off and for wear was calculated. The temperature and relative humidity of the room during testing was noted.

Colony counts on aprons

Commercially pre-prepared tryptone soya agar 55 mm diameter contact plates (Oxoid Ltd, Basingstoke, UK) were used in the bacteriological testing of the aprons. Five volunteers were enlisted to wear the aprons for the test procedures and one organiser to take the contact plate impressions on the aprons. The same room was used each time during the tests. Altogether seventy one sets of aprons were tested, each of five different apron types, three hundred and fifty five aprons altogether.

To begin testing, volunteer 1 held the roll of aprons by its ends (without touching the surfaces of the aprons) in front of the organiser. The organiser took three contact plate impressions from the apron surface, constituting the 'before' reading. The organiser then wiped an area of the apron on the roll, corresponding to the area just below the waist, with a paper cloth soaked in alcohol in order to kill any bacteria on the surface of the apron. The wiped area was identified by drawing around it on the apron with a felt marker pen. Three contact plate impressions were taken inside the marked area, constituting the 'after alcohol wipe' reading. Volunteer 1 then placed the apron roll carefully into the wall dispenser, so that none of the apron surface was touched by hand. The apron was then pulled out of the dispenser, and the volunteer wore the apron for 10 minutes (timed by clockwork timer), and acted as if attending to a patient. After 10 minutes wear, the organiser took three more impressions by contact plate within the marked area on the apron, but in a different spot to the 'after alcohol wipe' plates. These constituted the 'after wear' readings.

This procedure was repeated concurrently by volunteers 2 to 5 for the other four apron samples. Altogether, two hundred and eleven blanks were included to check the integrity of the pre-prepared plates. The agar plates were incubated at 37°C for 36 hours and the colonies counted.

Results

Electrical charge decay times

A series of charge decay time measurements are given in Table I which shows the initial potential induced on the surface, the time to decay to 1/e and to 1/10. Sample 2 and 3 acquired no static charge, while Sample 1, Pink and White acquired charge with a potential of over 4 kV. Samples 2 and 3, with no static, gave no measurable time to decay to 1/e, while White needed more than four hours, with Pink more than six hours and Sample 1 more than seven hours.

Electrical charge at pull-off and wearing of aprons

Electrical potential acquired by aprons at pull-off from the dispenser and during wear are shown in Table II. Samples 1, Pink and White acquired mean negative charge potentials of over 3.5 kV with ranges from around 1.5 kV to over 9 kV. The mean potential acquired during pull-off of Sample 2 and 3 was around 1 kV, but during wear averaged around 0 kV.

Colony counts on aprons

Colony count distributions for the five different apron types showed that Samples 2 and 3 had the highest percentage of agar plates with zero colony counts: 30.0% and 33.5% respectively, compared with Samples 1, Pink and White with 22.1%, 19.5% and 20.2% respectively. Table III lists the number of bacterial colonies found on the apron surfaces after pull-off and 10 minutes wear. A total of two hundred and eleven blank agar plates gave only two colonies, demonstrating the integrity of the commercially made pre-poured agar plates. The results given in Table III were used to compare Samples 2 and 3 with Samples 1, Pink and White shown in Table IV. Samples 2 and 3 both have lower colony counts than Samples 1, Pink and White. However, Sample 2 demonstrates the least attraction of bacteria onto its surface with 24% less than Sample 1, 39% less than Pink and 38% less than White.

The average concentration of bacteria in the air overall for the 10 weeks of apron testing was 645 cfu m⁻³, with a range of 190 to 1429 cfu m⁻³. The temperature remained fairly steady at an average of 23.4°C. The percentage relative humidity also remained fairly steady at an average of 57% RH except for the last day when it increased to 72% RH due to heavy rain that day.

Discussion

In the normal course of events, bacteria will deposit onto surfaces by gravity or by adhesion due to air currents. After ten minutes wear of Samples 2 and 3, the level of bacteria which they acquired (Table III) must be due to other means besides static charge, such as gravity, air movements or direct contact. This is evident because they have no static (Table I) and it is essentially impossible to induce a static charge potential on these surfaces (only 8 volts instead of 8 kilovolts).

On the other hand, Sample 1, Pink and White do have static because high static electric potential (~5 kV) can be readily induced on their surfaces (Table I) and they have long decay times (several hours) in relation to the time they will be worn.

For the colony count distributions, we cannot easily quantify the difference that the antistatic makes, but the reduction in bacteria count in Table IV probably represents the minimum reduction.

For example, if there were no bacteria present in the air, there would be no advantage in the use of antistatic aprons and no reduction in deposited bacteria will be detected. If there was a high concentration of bacteria in the air, the advantage of antistatic aprons would be clearly seen. In this study we have used an ordinary room and because there are low levels of airborne bacteria, there will be a high incidence of agar plates with zero bacteria.

In contrast to no static potential on Samples 2 and 3 shown in Table I, the comparatively low level of static acquired by these samples shown in Table II was most likely due to the static induced on the plastic dispenser itself as the aprons were pulled out and off the roll, especially since the static during wear was around 0 kV. For Samples 1, Pink and White, there is likely to also be a contribution from the plastic dispenser during pull-off.

Table IV shows that after pull-off and 10 minutes wear, Sample 2 acquired less bacteria compared to Sample 1 (24% less), Pink (39% less) or White (38% less). Similarly, Sample 3 acquired less bacteria after pull-off and 10 minutes wear when compared to Sample 1 (3% less), or Pink (23% less) or White (21%) less.

Conclusion

These results show that at the very least, antistatic plastic aprons reduce the build-up of micro-organisms on their surfaces. We suggest that the use of such aprons may be effective in reducing patient contact with micro-organisms and induced direct deposition on the patient.

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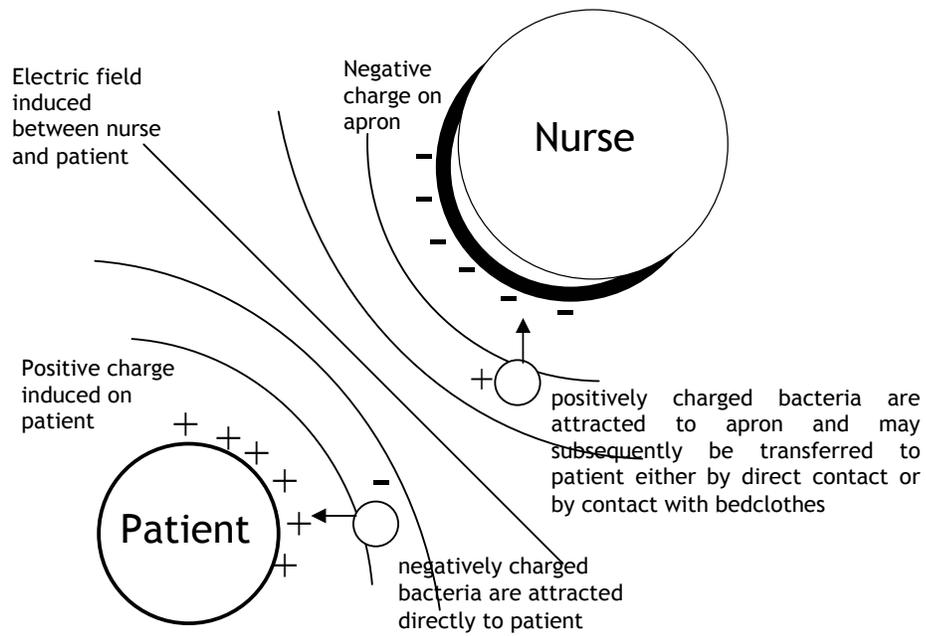


Figure 1 Schematic diagram of the effects of static charge build-up on highly insulated plastic aprons

Table I Initial electrical potential and charge decay times for different apron types

Sample	Initial potential, kV	Time to decay to 1/e of initial potential, min	Time to decay to 1/10 of initial potential, min
Sample 1	-5.493	425	588
Sample 2*	-0.009	-	-
Sample 3*	+0.008	-	-
Pink apron	-8.106	368	692
White apron	-4.335	282	484

Apron stroked 5 times in same direction to obtain initial voltage

*Not possible to induce static charge
39-48 %RH Temp 22.0-24.7°C

Table II Electrical potential due to static charge acquired by aprons at pull-off from the dispenser and during wearing of the apron

Sample	At apron pull-off, Mean (Range) kV	During wearing of apron, Mean (Range) kV
Sample 1	-5.05 (-2.01 to -9.37)	-0.148 (-0.069 to -0.247)
Sample 2 (antistatic)	-1.16 (-0.38 to -2.92)	+0.036 (-0.175 to +0.205)
Sample 3 (antistatic)	-1.21 (-0.45 to -1.78)	+0.089 (+0.037 to +0.270)
Pink apron	-3.61 (-1.59 to -8.01)	-0.127 (0.649 to +0.158)
White apron	-4.49 (-1.43 to -9.62)	-0.278 (-0.107 to -0.565)

Table III Number of bacterial colonies incubated from apron surfaces after pull-off and 10 minutes wear. Results for 71 sets, each of 5 different aprons

	Total number from 71 sets	Mean per apron ± SE
Sample 1		
After alcohol wipe	136	0.64 ± 0.15
After pull-off and 10 mins wear	574	2.76 ± 0.40
Sample 2 (antistatic)		
After alcohol wipe	59	0.28 ± 0.08
After pull-off and 10 mins wear	446	2.10 ± 0.32
Sample 3 (antistatic)		
After alcohol wipe	74	0.35 ± 0.11
After pull-off and 10 mins wear	560	2.67 ± 0.52
Pink		
After alcohol wipe	108	0.51 ± 0.14
After pull-off and 10 mins wear	730	3.46 ± 0.44
White		
After alcohol wipe	93	0.44 ± 0.10
After pull-off and 10 mins wear	665	3.36 ± 0.60

Colony counts for a total of 211 blank tests gave only 2 colonies
 SE = Standard Error on the mean = SD / \sqrt{n}

Table IV Comparison of numbers of colony counts from non-static Samples 2 and 3 with Samples 1, Pink and White

	Ratio with Sample 1		Ratio with Pink		Ratio with White	
	mean per apron	% less	mean per apron	% less	mean per apron	% less
Sample 2	0.8*	24	0.6	39	0.6	38
Sample 3	1.0	3	0.8	23	0.8	21

* Defined such that this entry is given by: $\text{mean count on sample 1} / \text{mean count on sample 2} = 0.8$