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Static Electric Fields as a Mediator of Hospital Infection

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Key Words

Static charge · Charge decay times · Static electric fields · Electrical potential · Hospital infection · Plastic aprons

Abstract

Static electric charge at the surface of nurses' plastic aprons was examined as a possible contributor to hospital infections in a bone marrow transplant ward. Transplant patients undergo high-dose chemotherapy and radiotherapy which compromises the immune system, rendering these patients highly susceptible to infecting organisms. Results of this pilot study showed that the velocity of a bacterium in air close to the apron surface was sufficient for swift attraction onto the surface. In addition, an electric field may be induced around the patient by the presence of the plastic apron, attracting airborne bacteria directly onto the patient. Tests showed that the polyethylene plastic aprons attracted about 83% more bacteria onto their surfaces during wear, compared with only 17% more acquired by aluminium foil aprons. We suggest that these results implicate static charge on aprons as a mediator of hospital infection.

Introduction

Over one hundred thousand hospital-acquired infections are estimated to occur each year, costing the NHS in England alone approximately £1 billion per annum [1]. In patients undergoing bone marrow transplantation, for example, high dose chemotherapy and radiotherapy used in preparing the recipient lead to compromise of the immune system and to breaches in the gastro-intestinal tract mucosa. The skin is also broached by the insertion of venous catheters through the chest wall. Both sites provide a way for bacteria and fungi to enter the circulation. Although nursed in a protected environment, 95% of transplant patients develop potentially life-threatening infections and hospital infection is the eventual cause of death in 10–15% of these patients. The majority succumb to catheter infections which necessitate the removal and replacement of the plastic lines. The micro-organisms involved are of low pathogenicity in people with a normal immune system, but pose a serious threat to transplant patients.

Plastic materials are in widespread use in hospitals and are prone to the collection of static electric charge with the result that they can be very efficient at collecting airborne micro-organisms. Micro-organisms, whether

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aerosolised or resident on airborne skin squamae, when in the vicinity of charged surfaces are strongly influenced by the associated electric fields (E-fields). Such E-fields can cause otherwise clean surfaces to become contaminated with pathogenic micro-organisms. A dose-response relationship has been demonstrated where excess deposition of airborne bacteria onto surfaces was greater with greater electrical potential on that surface [2]. Infections acquired in bone marrow transplant units (BMTU) may be mediated by static electric charge on disposable aprons and other plastic items**.**

Several authors have pointed to a possible role of electrostatic charge in mediating hospital infections. Todd [3] measured the electrostatic charge on six "giving set" needles and found values corresponding to 1–5 kV for an object of typical dimensions around 5 cm. Becker [4] found that during endoscopic surgery, the act of pointing to a VDU screen for teaching purposes significantly increased the deposition of bacteria onto surgeons' gloves. Cozanitis [5] demonstrated that plastic items in a hospital ward which were treated with antistatic solution attracted less airborne bacteria when compared to similar plastic items left untreated.

Indoors, bacteria usually become airborne as a result of frictional processes (e.g. by sneezing, coughing or the shedding of skin squamae). A major source of bioaerosols results from the skin squamae shed from the body of hospital staff or visitors. The average person liberates approximately 3×10^8 squamae per day [6]. Staphylococci are found on skin rafts of 13 mm equivalent particle diameter [7] and those found in hospital wards supported an average of 4 viable bacteria per scale [8]. Particles this size were estimated to remain airborne for an average of 17 min [9].

In air, the electric charge carried by a bacterium consists of two components: its own natural charge, which can be high and the charge imposed on it by the dispersion process [10]. Mainelis [11] demonstrated that airborne bacteria can carry up to 10,000 electric charges. Their results showed that there is close symmetry between negatively and positively charged bacteria. In an electrostatic field, such bacteria will be subject to a drift velocity according to their electrical mobility and in their high charge state, could move quickly to deposit onto surfaces, including directly onto patients.

This study sought to determine whether or not aprons made of conducting aluminium foil would attract fewer airborne bacteria onto their surfaces than white plastic aprons currently in use. This was achieved by measuring the electrical potential of both plastic and conducting aprons during use and by measuring the deposition of airborne bacteria onto their surfaces during use. The object of this work was to establish whether or not conducting aprons might be a preferable option for use in bone marrow transplant wards.

Materials and Methods

Measurements were made of the static charge decay time for various plastic medical items in a bone marrow transplant unit and in an ordinary children's ward using a JCI 140C field mill meter (John Chubb Instrumentation, Cheltenham). Initial potentials were artificially induced by gentle rubbing on several plastic medical items such as plastic tubing, examination gloves, etc. In order to compare results directly, the decay time to 1/e of the initial potential was measured.

To quantify the transport of bacteria in air due to static charge on a surface, we needed to know:

(1) the electrical mobility of bioaerosols,
(2) their charge state, and
(3) the electric field in air generated by the static charge environment.

Values for mobility were obtained with permission from the work of Dr A. Peter Fews (unpublished data).

The electric field in air was calculated using the relationship:

$$\text{E-field at surface} = P/R(\text{kV}\cdot\text{m}^{-1}) \qquad (1)$$

Where P = the electrical potential measured at the surface of the apron in kV and R = the radius calculated from the circumference of a nurse just below waist height,

The velocity of a bacterium in air close to a surface with static charge is calculated as follows:

$$\text{Velocity} = \text{Electrical mobility} \times \text{Number of charges} \times \text{E-field} \qquad (2)$$

White disposable plastic aprons come in a roll and are placed in a plastic wall dispenser. They are pulled out and torn off at the perforation. The aprons are worn when attending a patient in a transplant isolation ward. In addition, alternative aprons were made in the laboratory using conducting plastic, i.e. aluminium-coated plastic film. The electrical potential acquired by both types of apron was measured as the apron was pulled off the roll and then during the wearing of the apron. The results were related to the bacterial deposition on the aprons during wear. Contact agar plates were used to determine the viable bacterial count on both the plastic and the conducting aprons before and after use. The agar plates were incubated for 48 h at 37°C and colonies were counted.

Results

Charge decay times are given in Table 1. They were a few minutes for items such as sterile examination gloves, syringes and oxygen tubing, but several hours for plastic disposable aprons. The highest initial electrical potential was measured for a plastic mattress cover, but the decay time was short.

Table 1. Charge decay times for plastic items in the bone marrow transplant unit

Item	Initial electrical potential (kV)	Time to decay to 1/e of initial potential (min)
Examination glove	+0.270	0.1
Sterile examination glove	−0.155	9.4
20 ml syringe, outer wrapper	−0.238	6.5
20 ml syringe	−0.289	6.1
Oxygen tubing	−3.043	3.5
Plastic mattress cover	−16.187	0.2
White plastic apron	−2.517	205.0
Green plastic apron*	+1.459	156.5
Plastic cupboard*	−0.549	1.5

*Children's Hospital Ward.
Temperature = 19.5°C; RH = 44%.

The velocity of a particle in air such as a skin squama carrying bacteria close to a plastic apron worn by a nurse was calculated and is shown in Table 2.

Comparison of the electrical potential induced during pull-off and during wear are shown in Table 3. Mean electrical potential for plastic aprons was −5.33 kV compared to 0.00 kV for conducting aprons. Electrical potentials as high as −9.90 kV were measured while pulling a plastic apron off the roll. The mean electrical potential during wear was much lower at −0.32 kV for plastic and 0.02 kV for conducting aprons.

Results for the bacterial viable counts are shown in Table 4. For the white disposable plastic aprons there was an 82.6% increase in viable bacteria attracted onto the apron's surface during wear, compared with an increase of only 16.7% for the conducting aluminium foil aprons.

Table 3. Comparison of electrical potential on aprons. Results from forty tests

Apron type	Pull-off apron Mean, (range) (kV)	Wearing apron Mean, (range) (kV)
Plastic	−5.33 (−9.90 to −2.87)	−0.32 (−0.76 to −0.09)
Conducting	0.00 (−0.09 to 0.06)	0.02 (0.01 to 0.03)
Cotton	0.16 (0.00 to 0.56)	0.08 (0.04 to 0.20)

Table 4. Comparison of viable bacteria counts from plastic and conducting aprons. Number of apron sets = 90. Number of tests per apron type = 270.

	Plastic apron		Conducting apron	
	Before	After	Before	After
Total viable count	258 ± 2.2	445 ± 2.9	186 ± 1.2	238 ± 1.5
Mean per apron	0.69 ± 0.13	1.26 ± 0.17	0.42 ± 0.08	0.49 ± 0.09
% Increase		82.6 ± 0.3		16.7 ± 0.1

Table 2. The velocity of a particle of 10 μm diameter with 10 or 10,000 charges in E-fields of different strengths

Potential at surface (kV)	E-field at surface ($kV{\cdot}m^{-1}$)	Number of charges	Velocity ($cm{\cdot}min^{-1}$)
1	7.0	10	0.04
		10,000	42.00
3	21.0	10	0.13
		10,000	130.00
6	42.0	10	2.52
		10,000	2518.00
9	63.0	10	3.78
		10,000	3776.00

Discussion and Conclusion

The natural charge on a bacterium is provided by the ionic structure of the bacterial cell wall: the lipopolysaccharide outer membrane of the Gram negative bacteria, or the teichoic acid structures in the peptidoglycan layer of the Gram positive bacteria. In addition, bacteria can carry up to around 10,000 electric charges imposed by the dispersion process [10,11].

Our calculations show that a bacterium carrying 10,000 charges near to a surface with an electrical potential of 6 kV, and a drift velocity of $2518\,cm \cdot min^{-1}$ ($42\,cm \cdot sec^{-1}$), would certainly have sufficient velocity for capture of the bacterium onto the plastic apron surface.

A nurse wearing a plastic apron with a static charge will set up an electric field between nurse and patient and may facilitate the transfer of micro-organisms in air either directly onto the patient or indirectly by transfer of airborne bacteria onto the apron and then by contact after the nurse has touched the apron. The highest electric potential was induced during pull-off of the plastic aprons and therefore constitutes the most crucial time for airborne deposition onto the apron. The mean electrical potential maintained during wear was much lower than that at pull-off, but was also highest on the plastic aprons.

In contrast, conducting aprons carried almost zero electrical potential, even during pull-off of the apron. Consequently, aprons made of conducting material may be a novel solution to the static electric fields acquired by plastic aprons as they are less likely to attract airborne bacteria onto their surfaces compared to plastic aprons.

Our results using home-made conducting aprons in the laboratory suggest that a static charge on plastic aprons may mediate hospital-acquired infections and that conducting or antistatic aprons may help to lessen this effect. To examine this further we approached the manufacturers of the white plastic aprons and in response to the results of this pilot study, they have specially manufactured for us various types of conducting and antistatic aprons. A full study is now underway.

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