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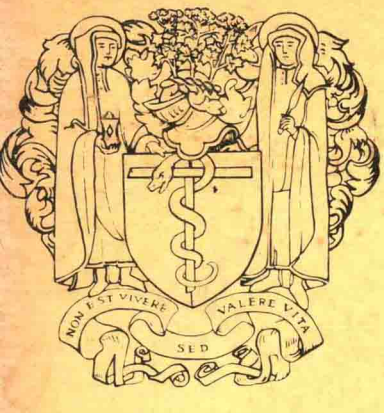

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Problems in the Control of Hospital Infection

Edited by

S. W. B. NEWSOM and A. D. S. CALDWELL

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Problems in the Control of Hospital Infection

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Review of the Problems of Cross-infection Control

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Introduction

Hospital-acquired infection, while mainly concerned with people, is, to a lesser extent, also concerned with their environment, where many of the hazards should be understood and, hopefully, be controllable. The classical infecting organisms *Pseudomonas aeruginosa* and *Staphylococcus aureus* are still present, but do not pose an increasing problem in the UK. Indeed, Ayliffe *et al.* (1979) recently reported the "decline of the hospital *Staphylococcus*", and today more concern is expressed about multiply antibiotic resistant *Klebsiella* (Casewell and Phillips, 1977).

The patients most at risk are usually those in a passive state and the germs involved are thus either carried to them, usually on a staff member's hands, or are autogenous. Complex treatment can create special problems: for example, in Addenbrooke's Hospital in 1978, a quarter of all the positive blood cultures originated in the leukaemia and transplant units where immunosuppressive therapy was being used. Intensive care ward patients have many tubes attached to them and this gives cause for more worry. Patients with surgical implants are also at risk; 20% of the initial recipients of artificial heart valves developed *Staph. aureus* endocarditis, and ever after, perhaps in a defeatist way, antibiotics have been used to cover open-heart surgery.

Some infections are caused by the normal skin flora of patients at risk, and others by germs harmless to healthy subjects. Some years ago five patients died after post-operative chest infections. All were being artificially ventilated and, as tracheostomy tubes were used, they had ice to suck to keep their mouths clean. Unfortunately the ice came from a contaminated machine, but although it harmed the patients, the surgeons used the same ice for lunchtime drinks without any ill effects (Newsom, 1968).

Hand Care

Hand care remains central to infection control and much has been written about it. Three personal anecdotes illustrate the major role hands play in spreading infection.

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Firstly, when we were short of nurses in the cardiac surgery wards, two post-operative patients on ventilators were nursed in one room, despite the fact that one had a chest infection with *Pseudomonas*, which was in his bronchial aspirate. Quite separate equipment was used, but both patients had to be nursed by the same nurses, who were given strict instructions on hand care for tracheal toilet. Daily throat swabs from the uninfected patient revealed *Pseudomonas* after three days. It was discovered that a sudden emergency had occurred when this patient disconnected himself from the ventilator, the nurse realizing the patient had only two minutes to live had no time for hand care and the patient was subsequently infected. The nurse's hands were certainly the route of infection.

Secondly, some years ago Dr Casewell gave me some *Staph. aureus* strains from Addenbrooke's Hospital for bacteriophage typing. Three were from blood cultures taken from patients thought to have septicaemia, in whom the diagnosis had been "confirmed" by the culture. However, two identical strains came from the nose and fingers of the doctor who venepunctured all three patients. If she could insert her staphylococci into blood culture bottles, she was also presenting a threat to the hospital environment.

Thirdly, an infection control team recently investigated several bacteriophage type 80/81 staphylococcal deep wound infections following laminectomy (A. Spark and R. E. Warren, unpublished). The only staff member to carry the same strain was an operating theatre nurse. Her job was to stand behind the surgeon and spray antiseptic (with ungloved hands) deep into the wound, just before it was sewn up. We assume that she put her thumb over the end of the aerosol spray and blew her bacteria into the wound. The makers (ICI) have redesigned the nozzle to prevent such contamination.

These three points illustrate a need for hand care, but how can this be achieved? On arrival at Papworth, I found that liquid hexachlorophane* soap was totally ignored because of the effect it had on staff hands. Eventually chlorhexidine† scrub was introduced, and it is well tolerated. Currently, we are evaluating the alcoholic chlorhexidine rub,‡ rather reluctantly, because of general satisfaction with the scrub. Presentation of soaps to the user may create problems. I dislike permanent wall-mounted dispensers for every hospital washbasin, because of the potential hazard—for example, those in a nearby hospital had to be removed and returned to the makers for sterilization following use of a batch of contaminated soap. A single-use disposable container is preferable, and should be used in high-risk areas such as operating theatre, intensive care wards, transplant and leukaemia units, etc. Elsewhere, bar soap should be used as it is quite adequate for removing transient as opposed to resident bacteria, and is naturally disposed of by use.

Even when the need for hand care is understood problems still arise. Twenty years ago I investigated three post-operative intraocular *Pseudomonas* infections. The source was a virtually uncleanable wood and bristle scrubbing brush, kept in a bowl of a quaternary ammonium disinfectant which was totally neutralized by a thick layer of soap at the base of the bristles. Use of the ward scrubbing brush resulted in the fingers of the eye ward sister being covered with *Pseudomonas* before she changed dressings on the three patients. Figure 1 shows the effect of drawing the fingers across a blood agar plate before and after scrubbing. Spirit is quite effective, just a quick wash with it removed most bacteria. Half the brushes in the hospital were laden with *Pseudomonas*, but only ocular infection occurred, the eyes being a defenceless area of the body. Today, nail brushes are less frequently needed, and those that are used are made of autoclavable nylon.

* 3% hexachlorophane in a detergent base.
† 4% chlorhexidine gluconate in a detergent base.
‡ 0·5% chlorhexidine gluconate in an alcoholic solution.

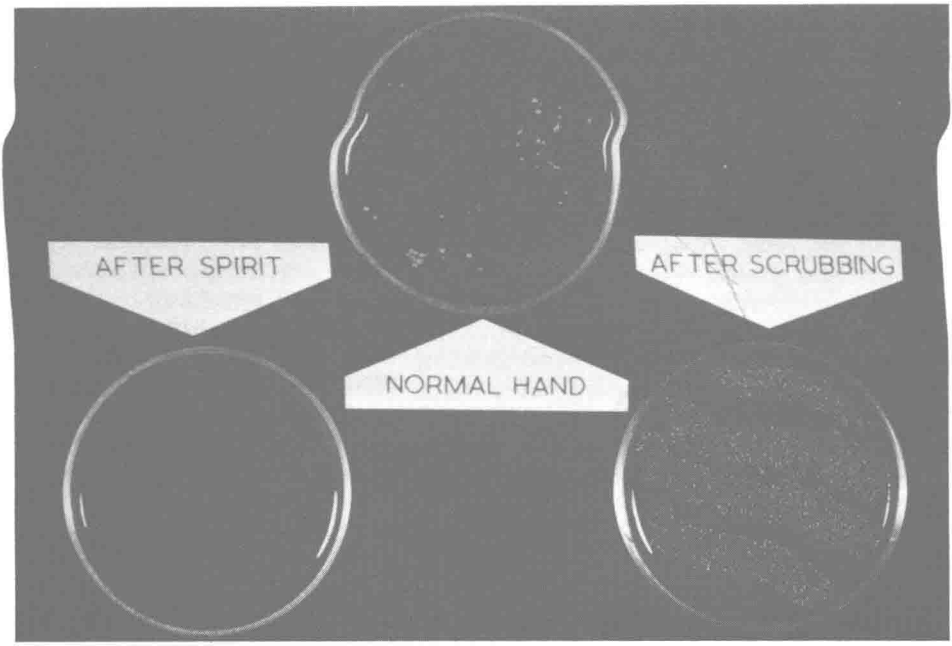

Figure 1. Effect of scrubbing and spirit on Pseudomonas *colonies.*

At Papworth recently, a need for intensive nursing was generated by a heart transplant. The patient's room was well provided with chlorhexidine scrub and the nurses were asked to use it frequently. Blood agar plates were provided for random fingerprints throughout the day. Two points emerged. Firstly, occasional plates revealed sterile fingers but a contaminated thumb, suggesting that the nurse had rubbed her fingers together and forgotten her thumbs. Secondly, showing the nurses the culture results soon improved their hand washing techniques.

Problems in Infection Control

The insertion or implantation of foreign materials such as heart valves, hip joints, pacemakers and electrodes, tubes, shunts and catheters, creates special problems. Implants are often infected by skin microbes, for example prosthetic valve endocarditis occurring within 60 days of operation is commonly caused by *Staph. aureus*, *Staph. epidermidis* or diphtheroids. Whether the patient or the surgeon is the source remains uncertain. Although prophylactic antibiotics are used, problems with resistance occur. Three cases of cephalothin-resistant *Staph. epidermidis* prosthetic valve endocarditis have been reported from a unit in Minnesota that used routine cephalothin prophylaxis (Lavadiere *et al.*, 1978) and the only infection in more than 1,000 recent open-heart operations at Papworth was with a gentamicin-resistant strain. Skin staphylococci have been found in various operating theatre sites (Kluge *et al.*, 1974) and recently we recovered several strains from saline used by the surgeon to rinse glutaraldehyde from Hancock pig prosthetic valves. The valves were immersed in a bowl of saline beside the surgeon. Every now and then he turned and stirred them with his fingers, and the saline was changed two or three times. All the first six valve rinses to be tested were contaminated. Thereafter valves were rinsed in a bowl with a lid on, and no more positive cultures were obtained.

The insertion of cannulae or pacemaker wires into the body, that are left *in situ* for long periods, also creates infection hazards. I think no tube should remain in place longer than a week unless great care is taken. Some centres carry out satisfactory long-term infusions, but usually such a place contains a proper team dedicated to setting up, inspection and maintenance of drips; under such circumstances infection can be avoided (Tuck *et al.*, 1979). However, an example of the possible failure in such a situation was provided by two of our patients who had temporary external pacemakers fitted in the same week; both developed septicaemia with benzylpenicillin sensitive *Staph. aureus* strains, presumably from their own flora. Previously, such patients had flucloxacillin cover. Investigations revealed that this had been abandoned on the advice of a visiting expert. One patient died. Thus, when one stops a technique it is vital to introduce safeguards, in this case proper skin care.

Dermatology wards also present an infection control problem with cross-infection due to multiply-resistant staphylococci. This area remains confused as some dermatologists appear to treat skin infections if staphylococci and streptococci are present, but ignore Gram-negative rods, while others do the reverse.

Conclusion

This short introduction, based on personal experience in infection control, has centred on skin and skin bacteria. Antibiotic resistant Gram-negative bacilli remain a worry in the intensive care ward, although to date there have been no major epidemics in Cambridge. Nonetheless, a recent liver transplant patient illustrates the potential of such microbes; his strain of *Klebsiella* became sequentially resistant to all the amino-glycosides and cephalosporins used in treatment. Later antibiotics were stopped and the strain reverted to sensitive.

The knowledge and the materials to prevent many of the previously described problems exist, the following papers will demonstrate this. However, a difficulty lies in the education of staff to make use of such knowledge.

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Summary

Antibiotic resistant Gram-negative bacilli pose very real problems in the hospital environment, especially in units such as intensive care, premature baby, leukaemia wards and transplantation units where immunosuppressive therapy may be used. Additional hazards are the long-term use of in-dwelling cannulae and catheters.

Effective control of hand washing techniques is essential in preventing the dissemination of the opportunist organisms responsible for hospital outbreaks. Some of the measures currently being used in the Cambridge group of hospitals are described and it is concluded that the central factor is still the maintenance of control procedures by all personnel involved in the care of patients at risk.

Zusammenfassung

Gram-negative Bazillen, die resistent gegen Antibiotika sind, verursachen sehr große Probleme im Krankenhaus—insbesondere auf Stationen für Insentivpflege , Frühgeburtenpflege, Pflege von Leukämiepatienten oder Transplantationsabteilungen, wo immunosuppressive Therapie angewandt wird. Weitere Gefahren entstehen bei Verwendung von Dauerkathetern und Dauerkanülen. Wirksame Kontrolle der Technik des Händewaschens ist absolut notwendig, um die Verbreitung der Erreger zu verhüten, die eine Krankenhausverseuchung verursachen können. Einige Maßnahmen, die zur Zeit in den Krankenhäusern der Cambridge Gruppe angetroffen werden, sind beschrieben, und man ist der Ansicht, daß der wesentliche Faktor die Aufrechterhaltung der Kontrolle durch alles Personal ist, das mit der Pflege gefährdeter Patienten zu tun hat.

Résumé

Les bacilles Gram négatifs résistants aux antibiotiques posent de réels problèmes dans l'environnement hospitalier, en particulier dans les services de réanimation, de prématurés, de leucémies et de transplantation, où des traitements immunosuppresseurs sont utilisés. L'emploi de canules ou de catheters à demeure crée des risques supplémentaires. Un contrôle efficace des techniques de lavage des mains est essentiel dans la prévention de la dissémination des organismes opportunistes responsables des épisodes infectieux dans les hôpitaux. Certaines des méthodes couramment utilisées dans le groupe des hôpitaux de Cambridge sont décrites et il est conclu que le maintien des mesures de contrôle chez tout le personnel qui s'occupe des patients à haut risque continue à être l'élément central d'une telle prévention.

Resumen

Los bacilos gramnegativos resistentes a los antibióticos plantean verdaderos problemas en el medio hospitalario, especialmente en las unidades de cuidados intensivos, de neonatos prematuros, salas de leucemia y unidades de transplantación, en que se pudiera emplear la terapéutica immunosupresora. Otros peligros consisten en el empleo a largo plazo de cánulas y catéteres a permanencia. El control eficaz de las técnicas de lavado de manos es esencial para prevenir la diseminación de los microorganismos oportunistas responsables de las epidemias nosocomiales. Se describen algunas de las medidas recientemente adoptadas por el grupo de hospitales de Cambridge, y se concluye que el factor central continúa siendo el mantenimiento de los procedimientos de control por parte del personal que cuida de los pacientes en peligro.

Carriage of Micro-organisms on Skin

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Our knowledge of the skin as a microbial habitat has been summarized by Noble and Somerville (1974) who report on the skin pH, temperature, chemical composition and give details of the microbial flora. The average human has a skin area of about 1·75 m^2 composed of a mosaic of about 10^9 flat pavement-like cells known as skin scales or squames; these are about 25 μm square and 3–5 μm thick. It is these cells which are lost in the process of desquamation, a complete layer being lost every 1–4 days. With the exception of the nail plate, no area of the body is free of resident micro-organisms, though the density varies from site to site and between individuals (Noble and Somerville, 1974; Evans, 1975). The arms and legs, which comprise about half the skin area, have a low density of micro-organisms (between 10^2 and $10^3/cm^2$) but the forehead may have populations in excess of $10^6/cm^2$ or the diseased toewebs support population densities of $10^9/cm^2$. Table 1 shows the mean density of organisms at various sites in normal individuals. At a microscopic level the flora is not disposed evenly over the surface of the skin but in the form of microcolonies. Determining the number of cells in a microcolony is not easy; most attempts have been made by comparing an estimate of the total bacterial cells present with the number of aggregates; the first measured by a scrub technique and the last by a contact count. Colony sizes are diverse (Table 2) and estimates from the same individual on different occasions differ considerably. Males are more heavily colonized than females (Table 3). The concept of microcolonies is, however, important in any consideration of skin degerming, for even moderately large colonies cannot be eliminated by an agent that kills only 99% of organisms. In Table 2 it can be seen that 15% of mean microcolonies were greater than 1,000 cells. Since the mean was over an area of 4 cm^2 individual colonies must greatly exceed this value.

The species of organism carried on normal human skin are varied. The predominant floras are of cocci—*Staphylococcus*, *Micrococcus* and the anaerobic *Peptococcus* species—and of the coryneforms (diphtheroids)—*Corynebacteria*, *Brevibacterium* and the anaerobic *Propionibacterium*. Minority floras include *Streptococcus*, *Neisseria* and *Bacillus*, with *Acinetobacter* (*Mima/Herellea*) as the only Gram-negative rod resident

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Table 1

Geometric mean count/cm² of skin surface in 11 normal healthy males and 11 normal healthy females

Site	Aerobic flora		Anaerobic flora	
	Males	Females	Males	Females
Forehead	2075	1225	8000	13500
Sternum	2125	165	50000	3500
Subclavicular area	350	130	18500	2275
Centre back	450	155	67500	7500
Shoulder	128	48	1025	1075
Deltoid area	118	65	57	127
Forearm	250	35	9	13
Palm	98	155	33	85
Lower axilla	500	92	14	12
Lumbar area	300	33	178	142
Periumbilical area	850	175	55	80
Thigh—upper front	325	140	9	35
Thigh—lower front	350	67	14	16
Thigh—back	325	82	4	5
Shin	190	77	7	8
Calf	173	20	2	5
Dorsum of foot	80	122	3	10
Sole	22750	675	10	4

Taken from Noble, (1975).

Table 2

Mean microcolony size on chest and abdomen of 38 male surgical staff

Microcolony size	1–10	11–100	101–1000	1001–10000	>10000
Distribution (%)	14	35	35	12	3

The figures record the per cent distribution of colony size in 38 males; the mean colony size for the chest and abdomen was very similar (Table 3). Data drawn from a study of surgical personnel summarized by Noble *et al.* (1976).

on normal skin. Carriage of potentially pathogenic organisms such as *Staphylococcus aureus* is confined to specialized areas, such as the anterior nares and perineum and, much less often, the axillae and toewebs may carry *Staph. aureus*. Gram-negative bacilli are most common on the perineum (of faecal origin) and in the toewebs.

We should consider here the concept of "resident" and "transient" organisms that was developed by Price (1938), a concept that is simple to understand yet difficult to apply. Resident organisms are those that are multiplying at a site and maintain themselves on the skin for a period despite the normal onslaught of desquamation and hygiene. Transients are contaminants, organisms that multiply elsewhere but are found at the skin surface, thus many nasal carriers of *Staph. aureus* have some contamination of the face with this organism, which is then a "transient" on the cheeks. In the past, few workers have attempted to separate residents from transients.

Table 3

Mean microcolony size of aerobic flora in 38 males and 34 females

Site	Chest	Abdomen	Thigh	Back	Shin	Arm
Males	98	93	74	60	28	21
Females	38	36	37	40	20	19

The figures record the mean number of cells per viable unit over an area of 4 cm^2 and are obtained by comparison of scrub and contact plate counts. Data drawn from a study of surgical personnel summarized in Noble *et al.* (1976).

Table 4

Comparison of the carriage of Staph. aureus *in those with normal skin and those with various forms of eczema*

	Carriage of *Staph. aureus* (%)	
Site	Normals	Eczema patients
Nose	33	59
Chest	4	48
Periumbilicus	3	52
Groin	3	41
Thigh	4	43
Shin	2	46
Scapular area	2	46
Lumbar back	1	46
Forearm	2	63
Toewebs	1	48
Axilla	1	28
Forehead	6	48
Cheek	8	63

Drawn from Noble *et al.* (1969).

In disease, however, the picture may become very different. Especially in skin disease such as atopic eczema (atopic dermatitis), even the unaffected skin surface may become heavily colonized with resident *Staph. aureus*, this is clearly a response to the host condition (Table 4). However, other diseases may also result in changes in the skin flora and a particular example is that of the heavy colonization of the hemiplegic hand with *Clostridium welchii*, perhaps in response to excess sweating (Chin and Davies, 1976). It is the availability of water which largely governs the degree of colonization of human skin, e.g. males sweat more than females and have a correspondingly more plentiful skin flora. Sweating under occlusion, e.g. in a surgical glove, encourages the rapid growth of skin bacteria. Gram-negative bacilli are kept in check by desiccation.

Skin is a complex microbial habitat. In the past it has been studied largely to discover how it might be degermed, only in recent times have we begun to appreciate the intrinsic interest of skin as a home for microbes. Some members of the skin's normal (or