

Behaviours and Rituals in the Operating Theatre

A report from the Hospital Infection Society Working Group on
Infection Control in the Operating Theatres

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Preface

In order to provide clear and practical guidelines for infection control practitioners and others working in the operating theatres, the Hospital Infection Society (HIS) established a Working Party (WP) on Infection Control in the Operating Theatres in 1999 to examine many of these issues. Three subgroups were established with the following remits,

- 1 to review the scientific and other evidence for current infection control practices in theatre and following this, to make recommendations on which practices are essential, which are preferred and which are optional or are of little perceived benefit.
- 2 to produce rational, feasible and applicable guidelines for the environmental monitoring (including bacteriological air sampling) of operating theatre facilities, and specifically to address when monitoring is indicated, how it should be carried out and what action should follow if abnormal.
- 3 to consider optimal theatre facilities including when ultraclean or plenum theatre ventilation is required in the light of recent changes in surgical practice such as the increasing use of minimally invasive surgery.

The following document is the report from Group 1. The report from Group 2 can also be viewed on the HIS Website. Work in Group 3 is on going and the conclusions reached will be available on the HIS Website in the next 12 months or so.

The Working Party included microbiologists/infection control doctors, an infection control nurse, an operating theatre nurse, general surgeon, orthopaedic surgeon, aerobiologist, engineer and a representative of NHS Estates. The members of the Working Party were: Gordon Bannister, Alan Bennett, Terie Chesworth, Marjory Greig, Peter Hoffman, Liz Jones, Geoff Ridgway, Hilary Humphreys (Chair), Edward Smyth, Andrew Stacey (Honorary Secretary), Eric Taylor, Kate Woodhead, Chris Dobson and John Williams. The WP reviewed the literature in the relevant areas so that as far as possible the guidelines would be evidence based. Members of the WP also consulted with other health care professionals as appropriate and achieved consensus following discussion amongst the members on areas where scientific evidence was not available.

Draft documents were widely circulated to professional groups and organisations seeking comment and suggestions, and posted on the HIS Website in early 2001. During the second half of 2001, the documents were revised in the light of this feedback, circulated to WP members and what follows is the result of this wide consultation exercise.

1. Introduction

Myths and rituals abound in operating department practice, as demonstrated by anecdotal evidence and current literature. Redfern¹ describes a study in which only 12% of practitioners based infection control (IC) practice in the Operating Theatre on evidence. Wicker² describes ‘sacred cows’ of IC behaviour in perioperative practice, and Parker talks of ‘ritualistic practice.’³

Myths have developed as historical narratives or true stories which gradually become part of a culture or institution⁴. Rituals are described as any action performed according to custom, without understanding the reasons why it is being practised. Words which may be associated with ritualistic behaviour are: protocol, routine, tradition and habit. There are however references to the comfort and familiarity of ritualistic behaviour, enabling staff to standardise processes and systems of care. Wicker² describes situations which may be more efficiently handled, particularly if they are unpleasant, by standardised behaviour. He also mentions that ‘sacred cows’ are not confined to nurses alone and that medical staff like them as well. Holland⁵ concludes that some elements of ritualistic practice can be harmless, perhaps even beneficial.

The Working Part has attempted to review the scientific evidence for many of the rituals we practise in our operating theatres and to indicate the strength of that evidence. The recommendations were categorized according to those used by epic-Developing National Evidence-Based Guidelines for Preventing Health Care associated Infections⁶. These are:

- Category 1: generally consistent findings in a range of evidence derived from a majority of acceptable studies.
- Category 2: evidence based on a single acceptable study, or a weak or inconsistent finding in multiple acceptable studies.
- Category 3: limited scientific evidence that does not meet all the criteria of 'acceptable studies,' or an absence of directly applicable studies of good quality. This includes expert opinion derived from systematically retrieved and appraised professional, national and international publications.

To ‘debunk’ some of the myths and rituals of our daily practice for which there is no evidence or scientific basis may seem sensible but it must be done against a basis of sound infection control and maintain the safety of both patient and healthcare professional. It should also be against a background that recognises the importance of care, concern and discipline in the operating theatre department. The working party recognises that the benefits of good infection control practice are team based, and rely on all team members having similar standards of understanding and knowledge. Whilst individual aspects of practice may be subject to recommendations within this document, patient outcome is affected by the good practice by all members of the team. Practice principles should

therefore be set and mutually agreed by the team, with advice and guidance from the local Infection Control Team.

2. Infection Control Policy

Sound infection control practice should be based on available evidence and consistent policy implementation by all healthcare professionals. Recent reports⁷ have re-iterated the significant costs to patients if best practice standards are not followed. The report suggested that every infection acquired by a patient should be considered a potentially fatal, life long or life threatening complication of hospitalisation or surgery.

Every Operating Department should develop its own IC policy manual. The National Audit Office report⁷ suggests that 95% of NHS Trusts in England have Manuals for Infection Control but that 8% of these had not been updated during the last four years and are seriously out of date. The report suggests that time could be saved and consistency achieved if an Infection Control Manual were developed by the Department of Health, to save 're-invention of the wheel'. They commend the Scottish Office *Scottish Infection Manual*⁸ which was published to "provide guidance on core standards for the control of infection in hospital, health care premises and the community interface". It was issued and will be amended centrally, all Health Boards and hospitals in Scotland are expected to conform to it.

The Report states that in recent visits to NHS Trusts it found IC manuals were not easily accessible. Reasons for the reduced use of manuals are:

- there were insufficient number of copies,
- staff did not know where copies are kept
- staff were discouraged by the sheer bulk of some volumes

The use of hospital intranets to disseminate information and to maintain up to date policies is cited as a way of gaining acceptance and increasing the use of IC policies within Trusts.

2.1 Precautions – Universal or Standard

The risk of infection is included in the UK Health and Safety legislation, in particular the 1999 COSHH Biological Agents Approved Code of Practice.⁹ The legislation states that "*a suitable and sufficient assessment should always be made, though the scope for risk reduction and the range of applicable control measures, and therefore the level of detail required in the assessment, may be less for an activity in category ii than for one in category iii.*" (Category ii is where exposure does not arise out of the work itself but is incidental to it, an example of which is given as health care. Category iii is where there is a deliberate intention to work with a biological agent, as in a microbiology laboratory)

The concept of “Universal Precautions” (UP), which suggests that all patients be treated with “full” infection control precautions, is not in accord with UK legal Health and Safety philosophy. Indeed UP have been replaced in the Centers for Disease Control recommendations for Isolation Precautions by “Standard Precautions”, with additional precautions as and when judged appropriate.¹⁰

It seems appropriate, after “suitable and sufficient” risk assessment, to adopt precautions for specific procedures in individual patients. Within any one category of operation there is a standard set of generic precautions deemed appropriate for that procedure, with additional, specific precautions for different patients or variations in procedure. Precautions could be based on the likelihood of the presence of an infectious agent, the nature of the infectious agent (i.e. how infectious it is) and the likelihood of dispersion (splashing, dispersal by power tools).

Precautions that prevent liberation of an infectious agent should take precedence over control of that agent once liberated which, in turn, take precedence over individual protection using personal protective equipment.

Recommendation: Category 3

That a standard set of precautions be established for every invasive procedure, with additional risk assessment of each patient to determine extra and specific precautions that may be appropriate.

3. Theatre Rituals

There are many rituals in the operating theatre that have evolved under the pretext of preventing post-operative wound infection. Whilst there is little doubt that the degree of bacterial contamination of the operative wound is the major determinant of the incidence of post-operative infection, the virulence of the organisms contaminating the wound, the amount of tissue trauma, and the body’s ability to resist that contamination are all important factors. The skill of the surgeon undertaking the operation is reflected not only in the degree of trauma that he/she causes but also in his/her general conduct of the operation and awareness of what is, and what is not, important in reducing bacterial contamination of the wound. Maintenance of infection control discipline by all members of the team is important to the patient outcome.

3.1 Rituals in Patient Preparation

3.1.1 Patient personal clothing

A recent editorial from Canada¹¹ noted no increase in infection rates in patients undergoing day-case cataract removal when the patients remained fully dressed to enter the theatre, including their ordinary shoes.

Brown¹² describes the ritual of making patients coming to the operating theatre remove their underwear as the “most illogical of rituals”. It is still practised in many surgical units and should be stopped for the good reason that it causes embarrassment to the patient and serves no useful purpose. Patients are also often required by hospital policy to wear a hat to cover their hair, during surgery. There is no evidence to suggest that the patients’ hair is the cause of an increase in infection in the Operating Theatre, and it would seem sensible therefore to cease this unnecessary practice.

Recommendation: Category 3

The current practice of divesting patients of all their clothes may be unnecessary. Further work is required to confirm this.

3.1.2 Patients Jewellery

The literature suggests that jewellery should be removed where possible^{13,14}, but plain wedding rings could be taped to the patients’ finger if necessary. Ring taping is not for infection control purposes but to stop the rings being lost in the drapes.¹⁵ Ring removal can be very traumatic for patients, and Redfern¹ suggests that rather than putting the patient through this distressful process, a thorough handwash prior to surgery would be an effective alternative. There is no evidence in the literature to guide advice on the management of rings or jewellery at other sites – nasal studs, navel rings, nipple rings etc., but there would seem to be no reason to remove these unless they are directly in the field of operation. In the absence of specific infection evidence, a consistent management policy should be developed related to preoperative preparation of the patient.

Recommendation: Category 3

There is no reason to continue the practice of removing the patients rings or other jewellery unless they are in the operative or anaesthetic field.

3.1.3 Shaving

It has long been tradition that the patient should be shaved pre-operatively in the belief that removal of the hair reduces the incidence of wound infection. Shaving was traditionally done on the night prior to operation. This method of hair removal can injure the skin, however, and such injury may cause increased risk of infection by producing microscopic infected lacerations by the time of operation. The benefit of the use of depilatory creams was demonstrated in 1973 by Cruise and Foord.¹⁶ They found an infection rate of 2.3% in patients who were shaved but only 1.7% in patients who were not shaved but had their hair clipped, whilst in those patients who were neither shaved nor clipped the infection rate was 0.9%.

A number of other studies have been undertaken: de Koos and McComas¹⁷ and found no difference in the incidence of postoperative infection between shaving and chemical depilation in 253 patients but

they noted that the depilatory cream saved time by allowing the hair to be removed the day before operation and was advantageous in areas that were difficult to shave. Zentner et al¹⁸ showed a lower incidence of infection in patients who were wet shaved over those dry shaved but this difference did not reach statistical significance. Seropian and Reynolds,¹⁹ in a study of 406 clean wound operations, reported patients shaved had a 5.6% incidence of infection whereas those not shaved or where a depilatory cream was used the incidence of infection was 0.6%. The hard, chitinous surface of a hair is easier to clean with the skin preparation solution than the skin on which it grows.

Oie and Kamiya have investigated the bacterial contamination of brushes used for shaving and found heavy contamination.²⁰ They recommend shaving foam be used.

A study by Alexander et al²¹ examined infection rates in 1013 patients undergoing elective surgery who had their hair removed by either clipping or shaving the night before or the morning of operation. Fewer infections were found both at discharge and 30 days after surgery in the group that had hair removal by clipping on the morning of surgery.

Recommendation: Category 1

Only the area to be incised needs to be shaved and, if this cannot be done by depilatory cream the day before operation, it should be done in the anaesthetic room immediately pre-operatively, using clippers rather than a razor. Shaving brushes should not be used.

1. Avoid shaving if at all possible
2. Use depilatory cream, if this is not possible, use clippers
3. Only shave if other options are not possible

3.1.4 Pre-operative Showering

The patients' skin is a major source of bacterial contamination in clean wound operations. It was traditional to ask the patient to bathe or shower before elective surgical procedures but there is no evidence to suggest this influences infection rates. Cruise and Foord¹⁶ showed that the use of hexachlorophene soap had a small effect in reducing infection rates and chlorhexidine showers became an important part of the pre-operative preparation of the patient.

Ayliffe²² found that pre-operative washing with an antiseptic did not reduce the infection rate but Hayek²³ showed a reduction in infection when chlorhexidine was used – 9% compared with 12.8% using normal bath soap, and 11.7% in placebo groups. In Hayek's clean wound group the infections were 7.2%, 10.2% and 10% respectively. Byrne et al²⁴ showed in a study of ten healthy volunteers that the greatest fall in bacterial skin flora was achieved by the first and second showers and that there was no further significant fall with subsequent showers. From this study they recommended that each patient undergo three pre-operative showers with 4% chlorhexidine detergent. However, when this same group studied the effect of chlorhexidine showers on 3482 general surgical patients in the clean

or clean-contaminated categories they found no significant difference in the incidence of wound infection and concluded that pre-operative whole body disinfection with chlorhexidine detergent was not a cost effective treatment for reducing wound infection.²⁵

Garibaldi *et al.*,²⁶ however, showed that 4% chlorhexidine showers reduced both pre-operative and intra-operative skin contamination. The incidence of a positive intra-operative wound culture was 4% with chlorhexidine and 9% with povidone-iodine and 15% with medicated soap and water. However, these authors do not report the incidence of post-operative wound infection and whether this was related to this contamination.

In a study of 64 patients undergoing vascular surgery reported by Earnshaw *et al.*,²⁷ the wound infection rate was higher after chlorhexidine baths (26%) than after baths with non-medicated soap (11%). However, this difference did not reach statistical significance in such a small study. Kaisar *et al.*²⁸ found chlorhexidine more effective than povidone-iodine in reducing the skin count of staphylococcus and also found that repeated applications of chlorhexidine were more effective than a single shower.

Repeated chlorhexidine showers appear to reduce the bacterial count from the skin particularly of staphylococcus, but there is little evidence that this makes significant reduction to the incidence of postoperative infection and has not been found to be cost effective in the UK. In one study of vascular surgical patients²⁷ there was a higher incidence of postoperative wound infection in the group that used chlorhexidine than those who used soap but this may be related to the distal infection in the leg and contamination of the wound via lymphatics.

Recommendation: Category 1

There is no evidence that chlorhexidine showers reduce the incidence of postoperative infection.

3.2 Rituals at the operating table

3.2.1 Preoperative hand hygiene

It is important for the surgeon to wash his/her hands prior to operating. How long the preoperative wash or 'surgical scrub' should be and what type of antiseptic should be used is not so universally agreed. Any agent or method of skin decontamination which causes skin abrasions should not be used and using a scrubbing brush on the skin is not recommended. Dineen²⁹ found no significant difference between a 5 and a 10 minute handwash. Rehorik and Ruden³⁰ using a 5 minute initial wash found that if the operation was of less than an hour duration the wash prior to the next operation need only be for 1 minute but for operations of more than one hour the results were inconclusive and a longer wash may be required. Pereira, Lee and Wade³¹ compared a 3 minute wash and a 30 second subsequent wash, with a 5 minute initial and a 3 minute subsequent wash. They also compared 4%

chlorhexidine gluconate with 7.5% povidine-iodine. Their optimal regimen was 5 minutes initially followed by the 3 minute wash using chlorhexidine gluconate. Washing for 2 minutes is at least as effective as the 10 minute wash in reducing hand bacterial colony counts but the optimal duration of washing is not known.³² The first wash of the day should include a thorough clean under the fingernails. A brush or orange stick can be used.

Alcoholic hand rubs are increasingly available as alternative products for hand hygiene for ward use³². The application of alcohol as a gel, foam, or as a liquid to clean hands is highly effective at destroying micro-organisms on skin surfaces. Ethanol or isopropanol, 60-80%, are even more effective than detergents or antiseptic soaps, if applied to clean hands. These products may be considered by Infection Control Teams for specific situations within Operating Theatre Practice.^{33, 34} The recent British Medical Journal editorial recommended that alcohol hand rubs should replace washing as the recommended method of hand hygiene on the wards³⁵, and their use is considered adequate in the operating theatre between cases where the surgeons hands are clean and have already been decontaminated by conventional methods³⁶

Recommendation : Category 3

Hand decontamination is an important contributor to reducing infections. There is no evidence that more than a two minute wash (decontamination) using aqueous disinfectants is required, before any procedure regarded as 'sterile'. Alcoholic hand rubs are an acceptable alternative to repeated washing.

3.2.2 Skin Preparation at Operation

In 1960 Lilly and Lowbury³⁶ showed that 1% iodine in 70% alcohol and 0.5% chlorhexidine in 70% alcohol were the two most effective skin antiseptics for preoperative hand decontamination by the surgeon and 'scrub' nurse. These two antiseptics have become popular for use for skin preparation of the patient in the operating theatre but a number of accidents have been reported in which diathermy sparks have caused the alcoholic vapour to explode. Gilliam and Nelson³⁷ have shown that a two stage skin preparation with aqueous iodophor scrub and iodophor solution to be as effective as a one step application of iodophor in alcohol solution. However, they recommend the alcohol solution has been more convenient, easier to apply, less time consuming and potentially less expensive.

Ritter et al³⁸ assessed the bacteriological effect of eight different skin preparation agents – one triclosan compound, one hexachlorophene compound and six iodophors. They found that two of the iodophors, when applied as sprays, demonstrated excellent bactericidal activity, were less time consuming and were easier to use than compounds which were traditionally applied. There was no significant difference in the infection rate with any of the agents.

The ideal antiseptic should possess the following properties:

- The spectrum of activity should be broad, with rapid and persistent effects against Gram negative and Gram positive bacteria (and against fungi and viruses which are resistant to some antiseptics).
- It should be resistant to inactivation by organic materials, such as blood and faeces
- There should be no toxicity or allergic reaction
- Cosmetically acceptable

Ideally antiseptics should be supplied at ready-for-use dilution in small, single-use containers with dispensers attached where necessary. Multiple-use containers are liable to contamination each time they are opened and the re-use of hand pumps and topping up of half-used containers has been implicated in outbreaks of infection by resistant organisms that can multiply in antiseptic solutions.³⁹ Antiseptic ‘cocktails’ should not be used because many antiseptics are mutually inactivating. For this reason if several consecutive applications are made to the same body site, the same agent should be used.

Gross contamination at the site of incision should be removed before the antiseptic skin preparation.⁴⁰ The antiseptic skin preparation should be performed in concentric circles moving away from the proposed incision site to the periphery allowing sufficient prepared area to accommodate an extension to the incision or new incisions or drain sites to be made.⁴¹ The application of the skin preparation may need to be modified according to the condition of the skin (eg burns) and the location of the incision site (eg face). Sufficient time must be allowed for alcohol based skin preparation to dry thoroughly before commencing the procedure to ensure that all combustible ingredients have evaporated.

Recommendation : Category 2

Alcohol solutions are preferred to aqueous solutions for skin preparation but it is important to allow the alcohol to dry after application and before the use of electrocautery. Solutions should be available in single-use sachets and not multi-use bottles as these may become contaminated on repeated opening. Where multi-use bottles have to be used they should be used within the ‘Use by Date’ and should not be refilled.

3.2.3 Protecting the wound

The bacteria that cause post-operative surgical wound infection can arise from a number of sources, generally classified into *endogenous* or *exogenous*. *Endogenous* contamination arises from the patient’s own bacterial flora. Sites from which contamination arises include the skin, nares and the

bacterially colonised tracts of the body – gastrointestinal tract, the genito-urinary tract, the bronchial tract, the sinuses and antra of the skull and the diseased biliary tract.

Alternative sources are *exogenous*, that is from the environment in which the operation is conducted. Sources here include the instruments used to perform the operation or from the hands of the surgeon and other healthcare workers involved in the procedure. However, the major exogenous source is transmission by air. The air introduced by the ventilation system in the operating theatre should be passed through bacterial filters and this is dealt with elsewhere in this report. Other sources of airborne bacteria are the skin and hair of the healthcare workers present in the operating theatre being shed into the atmosphere and circulated into the wound. Caps, gowns, masks are designed to prevent such shedding. Caps and gowns are dealt with elsewhere, as is the use of surgical gloves.

It is traditional that sterile linen is used to drape the patient around the operating area and the surgeon, scrub nurse and scrubbed assistants all wear sterile gowns. However perhaps 95% of post-operative wound infections are caused by endogenous bacterial contamination of the wound. It is therefore reasonable to expect that any assessment of the efficacy of different types of linen, surgical gowns, etc., should be undertaken purely on those patients having “clean” wound operations where endogenous contamination is minimal and there should be no contamination other than from the patient’s skin.

3.2.3.1 Surgical drapes

The traditional use of a waterproof sheet over the caudal end of the wound – where instruments are frequently laid, is based on the philosophy that this area gets moist and the instruments can be contaminated by bacterial strike-through. If this is valid for the caudal end of the wound it is probably valid for all sides and ends of the wound. See section 3.2.7 on surgical linen.

3.2.3.2 Adhesive Sheets

Thin transparent plastic adhesive incise drapes were introduced in the 1960s. They adhere to the whole operative field and to the surrounding disposable or reusable linen drapes avoiding the need for towel clips. However, there was no evidence that they reduce the incidence of post-operative wound infection. Antiseptic impregnation of these drapes with povidone iodine has been tried but again, although reducing a skin bacterial count, they do not appear to reduce the incidence of infection.²⁴

Johnston et al⁴² examined the rate of recolonisation of the skin surface after different skin preparations. Recolonisation of the skin surface was reduced by the application of an iodophor impregnated incise drape compared with other skin preparation methods. The results showed a significantly reduced rate of recolonisation of organisms on the skin surface that could be mechanically transferred to the wound edge but these authors did not investigate changes in the incidence of subsequent wound infection

3.2.3.3 Wound Guards

Polymeric sheet placed over the wound edge with an attached ring within the peritoneal cavity to hold these in place appear to reduce bacterial contamination of the wound during open bowel surgery but, again, no reduction in the incidence of wound infection has been demonstrated. In a randomised controlled study Psaila *et al*⁴³ showed no difference between adhesive plastic drapes with or without an internal plastic ring protector and patients having standard cloth towels. Nystrom *et al*⁴⁴ in a study of 140 patients showed that the wound ring drape prevented neither contamination nor infection of the wound in colorectal surgery. In contrast, Sookhai *et al*⁴⁵ have shown in a recent paper that an impervious wound edge protector reduced the incidence of infection after trans-abdominal surgery in 352 patients with gastro-intestinal disease. The use of the wound edge protector in this study produced an 84% reduction in post-operative wound infection rate in the contaminated group when compared with those in which a wound protector was not used. This has clear financial implications but in view of the extensive literature with conflicting results further work would seem necessary.

Recommendation Category 1

There is no clear benefit from the use of adhesive or other wound edge guards.

3.2.4 Gloves

Gloves play a dual role:

- as a barrier for personal protection from patients' blood and exudates
- to prevent bacteria from the surgeon's hands from entering the surgical site.

Randomised studies within various surgical specialities have shown that wearing two pairs of gloves decreases leaks by 3-9 fold in water permeability tests, when compared with wearing one pair of gloves⁴⁶. Double gloving may be uncomfortable, reduce manual dexterity and tactile sensitivity but it provides increased protection from penetration of needlestick injuries.⁴⁷ The use of double gloves also reduced the percentage of hand contamination.⁴⁸ All examination and surgical gloves must conform to BS EN 455-2. 'Scrub' team members should wear sterile gloves donned after the sterile gown. A fresh pair of sterile gloves should be worn for each procedure. It has been traditional teaching that gloves should be changed promptly if punctured.⁴⁹ However Dodds *et al* demonstrated no increase in bacterial contamination of the surgeons hands or the outside of the surgical gloves in operations where gloves were shown to be punctured, and could find no association between glove perforation and postoperative wound infection.⁵⁰

Recommendation: Category 1

Wearing double gloves at surgical procedures helps to protect the wearer from viral transmission. There is no evidence that perforated gloves increase the incidence of infection and needle puncture of a glove is not an indication to change gloves. If any action is taken it is preferable to don a second pair of gloves to protect the operating surgeon or individual undertaking the procedure.

3.2.5 Face Masks

The use of masks to reduce post-operative wound infections is questionable. Orr⁵¹ reported that there was no increase in infection rate when masks were not worn for general surgery. Bacterial shedding onto the operative field was found by Berger et al⁵² to be significantly higher when no mask (as compared to a full mask) was worn. However, a relationship between contaminant density and wound infection rate could not be established. Oral microbial flora dispersal by unmasked male and female volunteers, standing one metre from the table, failed to contaminate exposed settle plates placed on the operating table. Mitchell and Hunt⁵³ suggested, therefore, that the wearing of face masks by non-scrubbed staff working in an operating room with plenum ventilation appears to be unnecessary.

A controlled, prospective study by Tunevall⁵⁴ recorded incidence of wound infection in 3,088 patients over a 2 year period in acute and general surgery. The study design randomised patients into weeks during which staff were 'masked' or 'unmasked'. Results were statistically insignificant. The 1,537 'masked' operations having an infection rate of 4.7% compared with 1,551 'unmasked' operations with an infection rate of 3.5%. However, McLure *et al*⁵⁵ demonstrated that facemasks significantly reduced the number of bacterial colonies on the operating field.

Masks not only provide a barrier for airborne organisms but also protection for the wearer against blood and body fluid splashes. Risk assessment of such invasive procedures indicates the need for personal protective equipment to be worn by any member of the team undertaking a sterile procedure.⁵⁶ There is a need for staff to be protected from inhalation of surgical smoke and laser plumes.⁵⁷

A mask (with a filter size <1.1 microns) may be worn over the mouth and nose by all members of the 'scrub' team, with a visor or goggles as desired, for protection. A fresh mask should be worn for each operation and masks that become damp should be replaced. Whilst there is no evidence to prove the point either way it seems reasonable for the scrub team to continue to wear a mask when performing prosthetic implant operations. In vertical laminar flow theatres a mask should be worn during prosthetic implant surgery. Although there is no evidence on which to base the recommendation it would seem reasonable that surgeons with beards should wear a facemask.

Recommendation: Category 2

Risk assessment should be undertaken and if necessary masks should be worn for the protection of the wearer, however there is insignificant evidence to support the continued wearing of masks to prevent wound infection. The Working Party accept that it would be prudent for the 'scrub' team to wear a face mask for prosthetic implant operations. If worn, the mask should be changed after each operation or if deemed to have become contaminated or saturated.

3.2.6 Theatre caps

Humphreys *et al.*⁵⁸ suggest that non-‘scrubbed’ staff do not need to wear headgear since effective theatre ventilation probably counteracts any possible increase in bacterial shedding. However, ‘scrubbed’ staff should continue to wear disposable headgear because of their proximity to the operating field, particularly in a laminar flow field. Despite the evidence, headgear is worn by all theatre staff in most UK operating departments, different colours are frequently used to indicate seniority.

Recommendation: Category 3

There is no need for non-scrubbed staff members of the operating team to wear disposable headgear, however common sense dictates that hair should be kept clean and out of the way. Hats must be worn in laminar flow theatre during prosthetic implant operations.

3.2.7 Theatre Linen

There are a number of areas where linen or other fabrics are used in the operating theatre, ostensibly to prevent infection:

- the clean linen into which staff change on entering the department (surgical suits),
- the linen worn by the patient,
- the overgowns worn by staff on leaving the department for short periods,
- the sterile gowns worn by the ‘scrub’ team,
- the sterile drapes used around the operation incision.

3.2.7.1 Surgical linen

There is no evidence, and no reason to believe, that the linen used for surgical suits, overgowns or for patients to wear needs to be anything but socially clean. For the appropriate use of this apparel see the relevant section below.

3.2.7.2 Sterile theatre gowns and surgical drapes

The purpose of the theatre gown and theatre drapes is to prevent bacteria from the healthcare worker, or the non-sterile area of the patient, passing through the material directly into the wound or into the air or, when the clothing is wet, to prevent bacteria being drawn through the garment by capillary action called wicking or bacterial strike-through. See also 3.2.3 above.

The clothing also has a protective action as far as the surgical team is concerned preventing them being contaminated by blood from the patient. In assessing the qualities of material for surgical clothing and surgical drapes both the airborne bacterial dispersion and strike-through need to be considered.

3.2.7.3 Airborne dispersion

The skin of staff working in the operating theatre is the major source of bacteria dispersed into the air.⁵⁹ Bacteria are dispersed on the epithelial cells that break into smaller fragments of approximately 20µm. These are quite small enough to pass through the interstices of the usual cotton fabric which have a pore size of 80-100µm.

People disperse bacteria at a different rate and most skin cells carrying bacteria pass from the bottom of the gown to mix with the air circulating in the operating theatre. Trousers would appear to be preferable to skirts although women disperse less bacteria, particularly less *Staph aureus*, than men.

Total body exhaust suits have been utilised particularly for orthopaedic surgery but for most situations the choice is between disposable non-woven fabrics and close woven polyester or polycotton fabrics.⁶⁰

In 1986 Garibaldi *et al*⁶¹ reported a study to compare non-woven and woven gown and drape fabric and its effect on intra-operative wound contamination and post-operative infection. They found no significant difference between the two in either the degree of wound contamination or the incidence of post-operative infection.

Lippert and Gutschik⁶² showed there was a significant difference in the sedimentation and estimated airborne concentration of bacteria depending on whether staff were wearing open woven clothing, open style non-woven and closed style non-woven material during cardiac surgery. However, their study does not report the influence these differences had on post-operative wound infection. Verkkala *et al*⁶³ have also demonstrated that in cardiac surgery contamination of the external wound and leg wounds can be reduced depending upon the type of garment that the operating staff wear.

Moylan *et al*⁶⁴, in a study of 2181 clean and clean-contaminated general surgical operations, showed that there was a significant reduction in the postoperative infection rate in both categories of operation when a disposable gown and drape system was used compared with a cotton system. The risk of developing a wound infection was 2½ times greater with the cotton system than with the disposable system. They also demonstrated that this had a cost benefit effect and that the use of disposable gown and drape systems could be less expensive.

Linen has a limited life and, if used, it is essential to adhere to the manufacturers recommendations on the number of wash cycles for which the material is used before it is replaced.

3.2.7.4 Bacterial strike-through

The ability of the material used for gown and drape construction to prevent fluid penetration and with it wicking or bacterial strikethrough by capillary action may be important. The benefit of such

material is not only to the patient in terms of reducing bacterial contamination of the wound but may be important in preventing the transmission of viral infection from the patient to the surgeon or assistant should they have an open wound exposed to blood or body fluids via the gown.

Hubble *et al*⁶⁵ showed that settle plates may be unreliable as a method of assessing the purity of theatre air systems because of the shedding of bacteria by the surgeon or assistant standing directly over the wound in laminar flow ventilation can distort the counts. These authors showed that the type of gown was important as was wearing a hat and face mask, and that each of these had their own contribution to the bacterial contamination of the wound. Muller *et al*⁶⁶ showed that the use of disposable drapes and gowns made a significant difference, particularly in clean wound operations in a study of 1,033 operations. A much smaller difference was seen in clean-contaminated and contaminated wounds and there was no difference in dirty wounds. These findings are much as one might expect. These authors also demonstrated a 7.5% reduction in cost over a 12 month period, and claim that both doctors and nurses preferred the use of the disposable material.

3.2.7.5 European Standard for Theatre Gowns and Drapes

The Working Party understand that the CEN (Committee Europeane de Normalisation)⁶⁷ has contracted with the European Commission to establish a mandatory European Standard of basic requirements for disposable and re-usable materials to protect the patient and surgical team. The new draft standard recommends gowns and drapes to be resistant to liquid penetration, resistant to microbial penetration with a minimal release of particles (i.e. lint). Further use of cotton and polyester-cotton-blended drapes and surgical gowns is not recommended. Comparison of fabrics indicate that disposable, polypropylene, spunbond laminate materials offer best protection.⁶⁸

In 1983 Whyte *et al*⁶⁹ concluded that, in a laminar flow enclosure, clothing made from hydrophobic, spun laced 70g/m² polyester-pulp, non-woven material is as effective as a total body exhaust gown and was more comfortable and convenient to wear.

Recommendation: Category 2

Theatre gowns and drapes should be made of waterproof, disposable material. It is understood that more specific recommendations will be made by CEN in the near future.

3.3 Rituals perpetuated by theatre staff

3.3.1 Jewellery for staff

The National Association of Theatre Nurses (NATN)⁷⁰ recommend that jewellery is removed before changing into theatre suits. No evidence base could be found to justify this, but this is also recommended by the Association of Operating Room Nurses (AORN) in their document *Surgical*

*Attire. Standards, Recommended Practices and Guidelines*⁷¹. As a corollary to this, it is recommended that this includes necklaces and rings with stones.

In an assessment of glove perforations Nicolai *et al*⁷² found multiple perforations at the base of the ring finger in surgeons who wore a wedding ring during major joint replacement operations and recommend that these be removed.

Recommendation : Category 3

It is recommended that necklaces, ear-rings and rings with stones be removed but wedding rings may continue to be worn by 'scrub' and 'non-scrub' staff although surgeons may be advised to remove these, particularly if working with metal prostheses.

3.3.1.1 False finger nails

Hedderwick *et al*⁷³ have shown that false finger nails harbour pathogens, the longer they are worn the more likely it was that a pathogen would be isolated. They confirm the recommendation that false nails should not be worn in the operating theatre.

Recommendation: Category 2

False finger nails should not be worn by 'scrub' staff in the operating theatre

3.3.2 Dress when leaving theatre - Cover Gowns/Coats

There is little or no research based evidence to show that wearing surgical attire outside the theatre and returning to the theatre without changing into clean theatre suits increases surgical wound infection rates. However, in a small study Copp *et al*⁷⁴ reported that reduced levels of contamination were found on theatre suits when cover gowns were worn outside the operating room. Practise varies: in the USA there is no recommendation restricting the use of scrub suits to the operating suite or for covering the suit when out of the operating suite whilst in the UK, NATN recommend that '*all personnel should change into outer clothes when leaving the perioperative environment and don a new set of theatre attire upon their return*'.

Perceptions from staff, visitors and the public concerning 'theatre discipline' suggest that, although there is insufficient evidence, theatre personnel should wear a fastened, cover gown/coat over theatre suits before leaving the department.

Recommendation : Category 3

There is insufficient evidence to support the wearing of cover gowns over surgical attire to prevent infection when theatre staff leave the theatre area temporarily. However, it is recommended that local policy reflects aesthetic and discipline requirements.

3.3.3 Theatre footwear

The floor surface of the operating theatre should be kept clean but the affect this has on infection rates remains uncertain. Studies of bacterial contamination of the operating theatre corridor floors indicate that a change of footwear should occur as far from the operating theatre as possible.⁷⁵ Well fitting footwear with impervious soles should be worn and regularly cleaned to remove splashes of blood and body fluid. All footwear should be cleaned after every use, and procedures should be in place to ensure that this is undertaken at the end of every session.

Humphreys *et al*⁷⁶ illustrated that the use of plastic overshoes led to a significant increase in floor colony counts rather than a decrease. Carter⁷⁷ also showed that hands became contaminated when overshoes were put on or removed.

Recommendation: Category 3

Special footwear should be worn in the operating department and regularly cleaned. The practice of wearing plastic overshoes should cease.

3.4 Departmental Rituals

3.4.1 Visitors to the Operating Department

Visitors who enter the theatre complex need not change whilst those entering the Operating Theatre itself, should be properly attired. Parents and other carers are often invited to undergo the ritual of dressing with over-gown and overshoes to accompany the patient to the anaesthetic room. There is no evidence to support this practice, and overshoes have been shown to positively increase contamination risks to the wearer (see section on overshoes).

Recommendation : Category 3

There is no evidence to support the practice of visitors wearing over-gowns and overshoes in the anaesthetic room. If the visitor is to enter the operating theatre itself then they should change into theatre suits.

3.4.2 Order of patients on the operating list: dirty/clean cases

The two most probable routes of infection transmission between successive/sequential surgical patients are via the air, from instruments, or from environmental surfaces.

3.4.2.1 Airborne Contamination

Microbial dispersion increases with movement. Most microbes in theatre air are from staff and few from the patient. Each air change will, assuming perfect mixing, reduce airborne contamination to 37% of its former level. A theatre should have an air change rate of around 20 air changes per hour

(one air change every three minutes) and the effect of this rate of change on air dilution is discussed in the section of this Working Party report entitled *Microbiological Commissioning and Monitoring of Operating Theatres*.

Assuming 12 minutes between the “dirty” patient leaving theatre and the “clean” patient’s wound being exposed to the theatre air, there should be under 2% of the former airborne contaminants which will then rapidly decrease further. If theatre ventilation is effective, air should not be a source of infection transmission between sequential patients.

3.4.2.2 Surface contamination

Surfaces that do not have direct patient contact (e.g. floor, wall and light) do not become more contaminated after dirty than after clean operations.⁷⁸ Surfaces such as operating tables and other furniture, and instruments that make contact with more than one patient have a greater potential for transmission of infection between “dirty” and subsequent cases than does air. In the absence of sterilisation (autoclaving), the only practical reduction of viable microbes will be by cleaning and disinfection. These decontamination processes are greatly affected by the diligence with which they are done. It seems inevitable that, when there is knowledge of an “infectious” patient, diligence will be increased. The tradition of placing dirty cases at the end of a list facilitates this diligence.

If “dirty” cases (that is, patients likely to disperse microbes of particular risk to other patients) are placed last on a list, this will facilitate the process of adequate decontamination. However, if it is judged locally that these processes can be carried out adequately during a list, there should be no extra hazard. Possible (and rare) exceptions to this may be where there is profuse dispersion, for example eczema colonised with MRSA or where aerosol-dispersing powertools are used on infected tissue. It is recognised that in hospitals where universal precautions are practised, it is unlikely that operating department staff will always be aware of whether a patient is likely to be ‘dirty’, and therefore it is recommended that diligence should be applied to cleaning the operating theatre furniture and visibly contaminated surfaces between every patient.

Recommendation: Category 2

There is no reason to require a conventionally ventilated operating theatre to lie fallow for more than 15 minutes before a clean procedure is performed following a dirty operation. Vertical laminar flow theatres need only five minutes to replace the full volume of air in the theatre.

3.4.3 Movement in the theatre complex

The main routes of microbial entry into an open clean surgical wound are from the patient’s skin, from the surgeon’s hands or by airborne microbes settling into the wound or onto instruments that will be used in the wound. Control of movement in, and entry into, the theatre environment is aimed at reducing the airborne contamination routes. General traffic in and out of the operating theatre itself

should be reduced as far as possible. Doors should be closed in order to optimise the efficiency of the ventilation system.

3.4.3.1 Red lines

Theatre suites are designed to have gradients of cleanliness from general areas at the periphery of the suite (changing rooms, rest/refreshment rooms, corridors and disposal rooms), through intermediate areas (scrub, anaesthetic) to the cleanest areas (theatre and lay-up). Even within these cleanest areas, there are gradients: the periphery of the theatre versus the “scrub-team” area around the patient. Given this concept of gradients, measures such as red lines (over which non-theatre feet must not tread) are arbitrary. Whilst they may enforce discipline, they are unlikely in themselves to have any effect on patient infection.

If this is the case, the equivalent must be true of theatre footwear crossing the line to outside and then back in. It would be more meaningful if movement into and out of theatres could reflect these gradients with the various staff understanding how far they can venture into, and out of, the theatre suite. Whilst theatre discipline should be applied in this area, control of staff movement should not be elevated to a major contribution to infection control.

3.4.3.2 Adhesive mats

Adhesive, “~~Tae~~ mats” used to be commonplace at the entrance to the Operating Department, and at that time were believed to reduce bacteriological contamination of the environment by removing contaminants from bed and trolley wheels. There is no published evidence to support their continued use. Hingst⁷⁹ found that the mats could become a reservoir and source of contamination

3.4.3.3 Transfer zones

Similar logic applies to these situations as it does to the red line. Use of either one or two transfer trolleys (i.e. one trolley from ward to operating table or one trolley from ward to transfer zone in theatre and another from transfer zone to table) does not seem to affect number of airborne bacteria in theatre⁸⁰. It did have an association with bacterial numbers on floors (with two trolleys resulting in lower counts), but the significance of bacteria on floors is doubtful.⁸¹

Bringing beds from ward into the theatre could transfer contamination onto surfaces, particularly floors, or disperse contamination into the air. It is thought that micro-organisms on the operating theatre floor are not readily re-suspended and have a negligible contribution to airborne infection.^{82,83} Loosely-adherent, ward-acquired contamination on bed wheels will rapidly be lost as the bed is moved away from the ward with little that is not firmly embedded remaining when it arrives in theatre. Bedding will have skin fragments shed by the occupant trapped within it. A proportion of these particles will carry microbial contamination reflecting that of the person it was derived from as well as the ward environment.⁸³ These particles are readily shed into the air when the bedding is

disturbed.⁸⁴ If beds are to be used to transport patients from wards into theatre, the bedding that is to be disturbed (i.e. the upper layers rather than under sheet) should be removed and can be replaced with freshly laundered linen.

Recommendation: Category 2

Red lines may assist with discipline but have no effect in preventing infection and are therefore irrelevant in modern operating departments.

Moving a patient on their bed to the Operating Theatre may increase the bacterial floor count but this is of little significance in increasing wound infection rates.

Clean bed linen prior to the patient being transferred to the theatre is of significant benefit.

3.4.4 Environmental cleaning in the theatre suite

The inanimate theatre environment should, under normal circumstances, have a negligible contribution to the incidence of postoperative infection. Floors and walls will not be sterile nor is there any point in trying to achieve that state. Floors are rapidly re-contaminated after cleaning and disinfection⁷¹. Floors of operating theatres should be cleaned at the end of each session. Disinfectants are not required, apart from their use in the removal of body fluid spillage. Spillage on floors should be removed as soon as possible and the area washed with detergent and dried. Walls and ceilings are rarely heavily contaminated; for general housekeeping purposes, cleaning them twice a year is reasonable.

Cleaning should remove rather than redistribute contamination. Floor-scrubbing machines should have detergent reservoirs that can be cleaned; mops should be hot-washed and thoroughly dried daily; horizontal surfaces should be damp-dusted with single-use fabric or paper cloths.

Recommendation: Category 3

Floors of the operating room should be disinfected at the end of each session and be scrubbed daily. Wall washing is recommended twice per year. Specific spillages of blood or body fluids should be dealt with immediately. Mop buckets for spillage should be emptied after each use and kept dry until the next occasion when they are required. Lint free cloth is recommended for all operating theatre cleaning.

4. References

- 1 Redfern S. Myths and Rituals in the Operating Suite. 1998. MSc Dissertation, Monash University, Australia)
- 2 Wicker P. Sacred Cows and Sound Practice. *Br J Theatre Nurs* 1997; 7: 31-4
- 3 Parker L. Rituals versus risks in the contemporary Operating Theatre environment. *Br J Theatre Nurs* 1999; 9: 341-5
- 4 Eliade M in: *Myth and Reality*. Harper and Row, New York. 1968
- 5 Holland CK. An ethnographic study of nursing culture as an exploration for determining the existence of a system of ritual. *J Advanced Nursing* 1993; 18: 1461-70
- 6 Pratt RJ, Pellowe C, Loveday HP, Robinson N. Epic phase 1: The development of National Evidence-based Guidelines for Preventing Hospital-acquired infections in England associated with the use of short-term indwelling urethral catheters in acute care: Technical Report. London: Thames Valley University; 2000.
- 7 National Audit Office. *Acute Infection Control in Acute Hospitals in England*. Audit Commission , London 2000
- 8 *Scottish Infection Manual*, Scottish Office 1998
- 9 Statutory Instrument No 3246. *The Control of Substances Hazardous to Health Regulations*. London, HMSO, 1994.
- 10 The Hospital Infection Control practices Advisory Committee. Guidelines for isolation procedures in hospitals, Part II. Recommendations for isolation precautions in hospitals *Am J Infect Control* 1996; 124 : 32-45.
- 11 Editorial *OR Manager* 1997; 13: ()8
- 12 Brown G H . The Sacred Cow Contest: *The Canadian Nurse* 1993; 89: 31-33.
- 13 O'Hara L. The Operating Theatre as a degradation Ritual: A Student Nurse's View, *Science as Culture* 1989; 6 : 20-8
- 14 Jordan D.M. – There is a reason for dress codes. *Imprint* 1991; 38 : 46-8
- 15 Fogg D. Clinical issues *AORN Journal* 1995 ; 62 : 102-4
- 16 Cruse PJ, Foord R . A five-year prospective study of 23,649 surgical wounds. *Arch Surg* 1973 ; 107: 206-10.
- 17 Thur de Koos P, McComas B. Shaving versus skin depilatory cream for preoperative skin preparation. A prospective study of wound infection rates. *Am J Surg* 1983 ; 145: 377-8.
- 18 Zentner J, Gilsbach J, Daschner F Incidence of wound infection in patients undergoing craniotomy: influence of type of shaving. *Acta Neurochir Wien* 1987; 86 : 79-82

- 19 Seropian R, Reynolds BM. Wound infections after preoperative depilatory versus razor preparation. *Am J Surg* 1971; 121: 251-4.
- 20 Oie S, Kamiya A. Microbial contamination of brushes used for preoperative shaving *J Hosp Infect* 1992; 21: 103-10.
- 21 Alexander JW, Fischer JE, Boyajian M, Palmquist J, Morris MJ. The influence of hair removal methods on wound infections. *Arch Surg* 1983; 118: 347-52
- 22 Ayliffe GA. Surgical scrub and skin disinfection. *Infect Control* 1984 ; 5: 23-7.
- 23 Hayek LJ, Emerson JM, Gardner AM. A placebo-controlled trial of the effect of two preoperative baths or showers with chlorhexidine detergent on postoperative wound infection rates. *J Hosp Infect* 1987; 10: 165-72
- 24 Byrne DJ, Napier A, Cuschieri A. Rationalizing whole body disinfection. *J Hosp Infect* 1990; 15: 183-7.
- 25 Lynch W, Davey PG, Malek M, Byrne DJ, Napier A. Cost-effectiveness analysis of the use of chlorhexidine detergent in preoperative whole-body disinfection in wound infection prophylaxis. *J Hosp Infect* 1992; 21: 179-91.
- 26 Garibaldi RA, Skolnick D, Lerer T, Poirot A, Graham J, Krisuinan E, Lyons R. The impact of preoperative skin disinfection on preventing intraoperative wound contamination. *Infect Control Hosp Epidemiol* 1988; 9: 109-13.
- 27 Earnshaw JJ, Berridge DC, Slack RC, Makin GS, Hopkinson BR. Do preoperative chlorhexidine baths reduce the risk of infection after vascular reconstruction. *Eur J Vasc Surg* 1989; 3: 323-6.
- 28 Kaiser AB, Kernodle DS, Barg NL, Petracek MR. Influence of preoperative showers on staphylococcal skin colonization: a comparative trial of antiseptic skin cleansers. *Ann Thorac Surg* 1988; 45: 35-8.
- 29 Dineen P. An evaluation of the duration of the surgical scrub. *Surg Obstet* 1969; 129: 1181-4.
- 30 Rehork B, Ruden H. Investigations into the efficacy of different procedures for surgical hand disinfection between consecutive operations. *J Hosp Infect* 1991; 19 : 115-27
- 31 Pereira LJ, Lee GM, Wade KJ. The effect of surgical handwashing routines on the microbial counts of operating room nurses. *Am J Infect Control* 1990;18 : 354-64
- 32 O'Shaughnessy M, O'Malley VP, Corbett G, Given HF. Optimum duration of surgical scrub time. *Br J Surg* 1991; 78: 685-6
- 33 Larson EL. APIC guideline for handwashing and hand antisepsis in healthcare settings. *Am J Infect Control* 1995; 23: 251-69
- 34 Babb RJ. The action of disinfectants and antiseptics and their role in surgical practice. In: *Infection in Surgical Practice*. Ed EW Taylor. Oxford Medical Publications 1992 pp56-67.
- 35 L Teare, B Cookson, S Stone. Hand hygiene. *BMJ* 2001; 323: 411-2

- 36 Lilly HA, Lowbury EJ. Disinfection of the skin: an assessment of some new preparations. *B M J* 1971; 3: 674-6.
- 37 Gilliam DL, Nelson CL. Comparison of a one-step iodophor skin preparation versus traditional preparation in total joint surgery. *Clin Orthop* 1990; 250: 258-60.
- 38 Ritter MA, French ML, Eitzen HE, Gioe TJ. The antimicrobial effectiveness of operative-site preparative agents: a microbiological and clinical study *J Bone Joint Surg Am* 1980; 62: 826-8.
- 39 Ayliffe GAJ, Fraise AP, Geddes AM, Mitchell. *Control of Hospital Infection*, 4th Edition, p.101. London, Arnold
- 40 Recommended practices subcommittee AORN Proposed recommended practices for preoperative skin preparation of patients. *AORN J* 1982; 35: 918-23.
- 41 Hardin WD, Nichols RL. Handwashing and patient preoperative skin preparation. In: Malangoni MA ed. *Critical issues in Operating room Management*. Philadelphia: Lippincott-Raven 1997, pp 133-49
- 42 Johnston DH, Fairclough JA, Brown EM, Morris R. Rate of bacterial recolonization of the skin after preparation: four methods compared. *Br J Surg*, 1987; :74 : 64
- 43 Psaila JV, Wheeler MH, Crosby DL. The role of plastic wound drapes in the prevention of wound infection following abdominal surgery. *Br J Surg* 1977; 64: 729-32.
- 44 Nystrom PO, Broome A, Hojer H, Ling L. A controlled trial of a plastic wound ring drape to prevent contamination and infection in colorectal surgery. *Dis Colon Rectum* 1984; 27: 451-3.
- 45 Sookhai S, Redmond HP, Deasy JM. Impervious wound-edge protector to reduce postoperative wound infection: a randomised, controlled trial. *Lancet* 1999 8; 353: 1585.
- 46 Doyle PM, Alvi S, Johanson R. The effectiveness of double gloving in obstetrics and gynaecology. *Br J Obstet Gynaecol* 1992; 99: 83-4
- 47 Patterson JM, Novak CB, Mackinnon SE, Patterson CA. Surgeons concern and practices of protection against blood-borne pathogens *American Surgery* 1998; 228: 266-72
- 48 Fisher MD, Reddy VR, Williams FM, Link Y, Thacker JG, Edlich RF. Biochemical performance of latex and non-latex double glove systems, *J Biomed Mater Research* 1999; 48: 797-806
- 49 Eckesley JRT, Williamson DM. Glove punctures in an orthopaedic trauma unit. *Br J Accident Surg* 1990; 21: 177-8
- 50 Dodds RD, Guy, PJ, Peacock AM, Duffy SR, Barker SG, Thomas MH. Surgical glove perforation. *Br J Surg* 1988; 75: 966-8.
- 51 Orr NW. Is a mask necessary in the operating theatre? *Ann R Coll Surg Eng* 1981; 63: 390-2
- 52 Berger SA, Kramer M, Nagar H, Finklestein A, Frimmerman A, Miller HI. Effect of surgical mask position on bacterial contamination of the operative field. *J Hosp Infect* 1993; 23: 51-4

- 53 Mitchell NJ, Hunt S. Surgical face masks in modern operating rooms - a costly and unnecessary ritual? *J Hosp Infect* 1991; 18: 239-42
- 54 Tunevall TG. Postoperative wound infections and surgical face masks in a controlled study. *World J Surg* 1991; 15: 383-8
- 55 McLure HA, Tallboys CA, Yentis SM, Azadian BS. Surgical face masks and downward disposal of bacteria, *Anaesthesia* 1998; 53: 624-6
- 56 Health and Safety Commission. Control of Substances Hazardous to Health Regulations Biological Agents Approved Code of Practice. HSE Books, Sudbury, UK.1999
- 57 Taravella MJ, Weinberg A, May M, Stepp P. Live virus survives excimer laser ablation. *Ophthalmology* 1999; 106: 1498-9.
- 58 Humphreys H, Russell AJ, Marshall RJ, Ricketts VE, Reeves DS. The effect of surgical theatre headgear on bacterial counts. *J Hosp Infect* 1991; 19: 175-80
- 59 Mitchell NJ, Evans DS, Kerr A. Reduction of skin bacteria in theatre air with comfortable, non-woven disposable clothing for operating-theatre staff. *Br Med J* 1978; 1: 696-8.
- 60 54 Garibaldi RA, Maglio S, Lerer T, Becker D, Lyons R. Comparison of nonwoven and woven gown and drape fabric to prevent intraoperative wound contamination and postoperative infection. *Am J Surg* 1986; 152: 505-9.
- 61 Lippert S, Gutschik E. Bacterial sedimentation during cardiac surgery reduced by disposable clothing. *Scand J Thorac Cardiovasc Surg* 1992; 26: 79-82.
- 63 Verkkala K, Eklund A, Ojajarvi J, Tiittanen L, Hoborn J, Makela P. The conventionally ventilated operating theatre and air contamination control during cardiac surgery - bacteriological and particulate matter control garment options for low level contamination.. *Eur J Cardiothorac Surg* 1998; 14: 206-10.
- 64 Moylan JA, Fitzpatrick KT, Davenport KE. Reducing wound infections. Improved gown and drape barrier performance. *Arch Surg* 1987; 122: 152-7.
- 65 Hubble MJ, Weale AE, Perez JV, Bowker KE, MacGowan AP, Bannister GC. Clothing in laminar-flow operating theatres. *J Hosp Infect* 1996; 32: 1-7.
- 66 Muller W, Jiru P, Mach R, Polaschek F, Fasching W. The use of disposable draping materials in the operating room and its effect on the postoperative wound infection rate *Wien Klin Wochenschr* 1989; 101: 837-42.
- 67 CEN : Surgical clothing and drapes used as medical devices in healthcare facilities. Second Draft. CEN/TC 205/WG 14 N 61
- 68 Granzow JW, Smith JW, Nicholls RL, Waterman R, Muzik AC. Evaluation of the protective value of hospital gowns against blood strike-through and MRSA penetration. *Am J Infect Control* 1998; 26: 85-93

- 69 Whyte W, Bailey PV, Hamblen DL, Fisher WD, Kelly IG. A bacteriologically occlusive clothing system for use in the operating room. *J Bone Joint Surg (Br)* 1983; 65-B: 502-6
- 70 National Association of Theatre Nurses. Principles of safe practice in the perioperative environment. NATN, 1998, Harrogate
- 71 Association of Operating Room Nurses. Recommended practices for surgical attire. *AORN J* 1998; 68: 1048-52.
- 72 Nicolai P, Aldam CH, Allen PW. Increased awareness of glove perforation in major joint replacement. A prospective, randomised study of Regent Biogel Reveal gloves. *J Bone Joint Surg (Br)* 1997; 79: 371-3.
- 73 Hedderwick SA, McNeill SA, Lyons MJ, Kauffman CA. Pathogenic organisms associated with artificial fingernails worn by healthcare workers. *Infect Control Hosp Epidemiol* 2000; 21: 505-9
- 74 Copp G, Mailho CB, Zaler M, Slezak L, Copp AJ. Cover gowns and the control of operating room contamination, *Nursing Research* 1986; 35: 263-8
- 75 Nagai I, Kadata M, Takechi M, Kumamoto R, Ucoka M, Matsuoka K, Jitsukawa S. Studies on the mode of bacterial contamination of the operating theatre corridor floor. *J Hosp Infect* 1984; 15: 50-5
- 76 Humphreys H, Marshall RJ, Ricketts UE, Russell AJ, Reeves DG. Theatre overshoes do not reduce operating theatre floor bacterial counts, *J Hosp Infect* 1991; 17: 117-23
- 77 Carter R. Ritual and risk, *Nursing Times* 1990; 86: 63-4
- 78 Hambraeus A, Bengtsson S, Laurell G. Bacterial contamination in a modern operating theatre. 3. Importance of floor contamination as a source of airborne bacteria. *J Hygiene* 1978; 80: 57-67
- 79 Hingst V The importance of adhesive dry mats for the reduction of germ spreading in hospitals *Zentralbl Bakteriol* 1978; 167: 83-6.
- 80 Lewis DA, Weymont G, Nokes CM, Cribb J, Prothero DL, Marshall DW, James PA. A bacteriological study of the effect on the environment of using a one- or two-trolley system in theatre. *J Hosp Infect* 1990; 15:35-53.
- 81 Ayliffe GAJ, Collins BJ, Lowbury EJJ, Babb JR, Lilley HA. Ward floors and other surfaces as reservoirs of hospital infection. *J Hygiene* 1967; 65: 515-36.
- 82 Ayliffe GA. Role of the environment of the operating suite in surgical wound infection. *Rev Infect Dis* 1991; 13 Suppl A ,10 : S800-4
- 83 Maki DG, Alvarado CJ, Hassemer CA, Zilz MA. Relation of the inanimate hospital environment to endemic nosocomial infection. *N Engl J Med* 1982; 307: 1562-6.
- 84 Litsky BY, Litsky W. Bacterial shedding during bed-stripping of reusable and disposable linens as detected by the high volume air sampler. *Health Lab Sci* 1971; 8: 29-34.