Skin flora: implications for nursing


Abstract

Many patients receiving inpatient care or admitted as day cases undergo invasive procedures that place them at potential risk of healthcare-associated infection. Human skin is populated with microorganisms most of which are harmless, however some have pathogenic potential. This article outlines the protective function of intact skin and describes its resident and transient microbial flora. The role and limitations of antiseptics in reducing the risk of infection are discussed.

Aims and intended learning outcomes

The aim of this article is to describe the structure and function of the skin, including its microbial flora, and the use of skin antiseptics to reduce the risk of healthcare-associated infection (HCAI). After reading this article and completing the time out activities you should be able to:

- Describe the structure and function of human skin.
- Distinguish between resident and transient microbial flora on the skin.
- List skin antiseptics available and the advantages and limitations associated with each.
- Discuss the evidence base underpinning skin disinfection.

Introduction

Normal flora is comprised of microorganisms that usually colonise the human body (Gould and Brooker 2008). Most are described as commensals – microorganisms that derive shelter and nourishment from their host without causing harm. The skin can also become colonised with microorganisms that have pathogenic potential (Gould 1991) and heavy colonisation increases the risk of infection (Coia et al 2006). Intact skin is the body’s best defence against invading pathogens, but when the skin is broken underlying tissues are exposed and there is an increased risk of infection (Hinchliff et al 1996). Antiseptic agents are frequently applied to the skin to remove microorganisms before surgery (Webster and Osborne 2007) and other invasive procedures, for example insertion of a vascular access device (Scales 2009).

Complete time out activity
Structure and function of the skin

The condition of the skin and its appearance provide important indicators of the individual’s general health. The skin has a major protective function. It reduces risks of mechanical, physical, chemical and microbiological damage to underlying tissues. Intact skin is impermeable to microorganisms (Hinchliff et al 1996). The skin is the body’s largest organ, consisting of two layers: the epidermis and the underlying dermis (Hinchliff et al 1996). Thickness, pigmentation and hairiness vary over the skin surface, but functions of the skin are the same regardless of location (Box 1).

Epidermis

The epidermis functions as a barrier between the body’s external and internal environment. It lacks blood vessels, nerve endings and lymphatics. Nutrients and oxygen are derived from the underlying dermis (Hinchliff et al 1996). The epidermis consists of stratified squamous epithelium made up of five different layers of cells. Cells in the basal layer continually divide. New cells move towards the surface of the skin and more cells are generated below. During their passage cells become flattened and impregnated with a waterproof protein called keratin. By the time they reach the surface of the skin they are dead. Keratinised cells are continually shed (desquamated) from the stratum corneum (uppermost layer of the skin) with bodily movements. The process of desquamation takes place within about 35 days.

Dermis

The dermis functions as an elastic bed to provide support and nourishment to the overlying epidermis and its appendages (hair and nails). It consists of loose areolar connective tissue strengthened by collagen and elastin fibers, and contains blood vessels, lymphatic vessels and nerve endings. Hair follicles, sweat glands and sebaceous glands are also present in the dermis (Figure 1). Complete time out activity 2

Skin bacteria

There are two types of skin flora, resident and transient, as distinguished by Price (1938) who conducted laboratory experiments in which the hands were repeatedly scrubbed or immersed in alcohol. Even after prolonged disinfection, it was still possible to isolate some bacteria from the deeper layers of the stratum corneum, ducts of the hair follicles and beneath the nails (subungual spaces). These bacteria have traditionally been regarded as resident or ‘true’ skin flora. They are difficult to dislodge and therefore are not thought to contribute significantly to exogenous (cross) infection under normal circumstances. In addition, they are not thought to be pathogenic or weakly pathogenic.

Transient flora is carried superficially on the surface of the skin. These bacteria are acquired readily during contact with the environment, including touching other people, and are easily transferred during subsequent contacts. In environments where health care is delivered, transient skin flora is likely to include potential pathogens and antibiotic-resistant strains (Noble and Somerville 1974). Gram-negative bacteria and

BOX 1

Functions of the skin

- Protection.
- Absorption.
- Cutaneous sensation.
- Temperature regulation.
- Excretion.
- Synthesis of vitamin D.
- Storage of energy and water.

FIGURE 1

Structure of the skin
Learning zone infection control

Staphylococcus aureus are potentially pathogenic and are frequently found on the skin (Gould 1991). Healthy skin is heavily populated with microorganisms (Fredricks 2001). Examples of Gram-positive and Gram-negative bacteria are listed in Box 2.

Gram-negative bacteria
The skin of people who are chronically ill or have been in long-term care often becomes heavily contaminated with Gram-negative bacilli that have pathogenic potential (Sanderson and Weissler 1990). Gram-negative bacilli were once thought to be carried on the skin for only a few hours or days, but it is now known that they can be carried for much longer, sometimes for weeks or months (Gould 1991). Strains that are able to resist drying tend to survive longer and are more likely to be responsible for HCAI (Filho et al 1985). Skin that has become moist or excoriated is particularly likely to become heavily colonised. Skin can act as a reservoir of Gram-negative bacteria and patients affected are a risk to others (Curie et al 1978). The hands of healthcare workers can also become heavily colonised with Gram-negative bacteria, particularly if the skin is damaged, and also beneath rings (Ojäjarvi et al 1977). Healthcare workers’ hands have been responsible for outbreaks of Gram-negative infection, thus emphasising the importance of good hand hygiene and care (Box 3).

S. aureus
S. aureus is carried in the nose, throat, axillae, toe webs and perineum of 30-50% of healthy people (Coia et al 2006). Staphylococci are well adapted to survive on the dry surface of the skin because they are resistant to desiccation and are able to tolerate the acidic environment of the stratum corneum (Coia et al 2006). Transient carriage has been reported on the skin of 30-70% of the healthy population (Williams 1963). Up to one million squames (dead epithelial cells) are shed every 40 minutes, carrying microorganisms present on the outer surface of the skin with them. The rate of desquamation is higher if the person has a skin condition such as eczema, explaining why people with such conditions are particularly likely to disseminate microorganisms (Hinchliff et al 1996).

Meticillin-resistant Staphylococcus aureus
Some strains of S. aureus have developed resistance to antibiotics as an adaptive response that enables them to survive and multiply at the expense of antibiotic-sensitive strains (selective pressure), giving them selective advantage (Duckworth et al 1998). Meticillin-resistant S. aureus (MRSA) causes the same range of infections as meticillin-sensitive S. aureus (MSSA) and is carried on the skin and spread in the same way. Infections caused by MRSA are more difficult to treat than those caused by MSSA because they are resistant to a much wider range of antibiotics. If MRSA replaces MSSA at sites where the skin is damaged, eradication is particularly difficult. The anterior nares are most often colonised by MRSA.
Much of the research undertaken to establish the density of bacterial populations on the skin and the different groups of bacteria present was carried out many years ago. However, it has since become clear that bacteria carried on the skin are more likely to be resistant to antibiotics than they used to be, especially for some high-risk groups. For example, 10-20% of nursing home residents carry MRSA (Barr et al 2007).

Sources of infection

There are two possible sources of infection-causing microorganisms, including:

- **Endogenous (self) infection** – occurs when microorganisms are transferred from their original location to a vulnerable site on the same patient such as a wound, or the insertion point of an intravenous catheter. Transfer from the skin into the bladder is possible, especially via an indwelling urinary catheter.
- **Exogenous infection** – occurs when pathogenic microorganisms are spread from one person to another.

The risks of endogenous infection are reduced by applying antiseptics to patients’ skin. The risk of exogenous or cross-infection is reduced by cleansing the hands of healthcare workers – surgical hand antisepsis performed by surgical teams and hand hygiene in other situations where health care is delivered.

**Complete time out activity**

Evidence base for skin disinfection

Evidence for the effectiveness of skin preparation with antiseptics to prevent infection is mixed, although a large number of trials have been conducted (Tanner and Khan 2008). The findings of a Cochrane review failed to identify any evidence that pre-operative skin preparation reduced the risk of post-operative wound infection (Edwards et al 2004). However, a well-controlled trial has since demonstrated a reduction in surgical site infection when the skin is cleaned pre-operatively with 2% chlorhexidine in 70% isopropyl alcohol compared to povidone-iodine (Darouiche et al 2010). This finding has resulted in changes to recommendations for pre-operative skin preparation issued by the Department of Health (DH) (2011) and has promoted the use of chlorhexidine-alcohol preparations before other invasive procedures such as the insertion of a vascular access device.

Patients screening positive for MRSA should undergo decolonisation, but regimens are only effective in 50-60% of cases and at present there is no consensus that any single regimen is better than another (Coia et al 2006).

**Skin antiseptics**

A range of skin antiseptics is available, including:

- Iodine and iodophors (preparations containing iodine).
- Chlorhexidine.
- Alcohol-based preparations.
- Hexachlorophene.
- Triclosan.
- Octenidine dihydrochloride.

**Iodine and iodophors**

These agents are still sometimes used although the disadvantage of iodine is that it stains the skin and causes allergies in some people (Hoffman et al 2004). A 1% solution of iodine in alcohol is considered to be effective. Iodophors are chemical complexes of iodine to which stabilising substances have been added. They have the same level of activity as iodine, but do not stain the skin. Betadine and povidone-iodine are frequently used for pre-surgical hand antisepsis. Iodophors are available in 10% alcohol solutions for pre-surgical skin preparation. Iodine is the only skin antiseptic that destroys spores. It is sometimes used for patients undergoing surgery where infection with Clostridium perfringens might be a risk.

**Chlorhexidine gluconate**

Chlorhexidine gluconate is highly active against vegetative Gram-positive organisms, but slightly less effective against Gram-negative bacilli (Hoffman et al 2004). It is an effective fungicide, but has minimal effect on Mycobacterium tuberculosis and some viruses or spores (Ehrenkranz 1992). Chlorhexidine destroys bacteria for up to six hours after it has been applied to the skin, a property described as residual effectiveness. It remains active even in the presence of body fluids that deactivate other antiseptics (Hoffman et al 2004). However, it is deactivated by soap. Chlorhexidine is non-toxic and widely used as a skin antiseptic in 0.5% or 2% solution. Detergent solutions containing 4% chlorhexidine, for example Hibiscrub, are used for hand hygiene.

**What skin antiseptics are used in the clinical area in which you work? Write concise notes about the effectiveness and limitations of each.**
Alcohol-based preparations
Seventy per cent ethanol and 60% isopropyl alcohol are highly effective, rapidly acting skin antiseptics (Hoffman et al 2004). In contrast to chlorhexidine, alcohol-based products are effective against mycobacteria, but have no residual effectiveness. However, like chlorhexidine, they are unable to destroy spores. Activity against viruses is variable and enveloped viruses, such as norovirus, tend to be resistant to their effects. Alcohol hand rubs have been widely promoted for routine hand hygiene (Gould and Drey 2008).

Hexachlorophene
Hexachlorophene, used as a skin antiseptic, is particularly active against Gram-positive organisms, but less active against Gram-negative organisms (Hoffman et al 2004). It does not dissolve well in aqueous solution, but can be incorporated into detergent solutions without becoming inactive. A major disadvantage is that such products can become contaminated by Gram-negative bacteria, creating reservoirs of infection (Ehrenkranz 1992). Hexachlorophene is still sometimes used as a pre-surgical hand preparation and in pre-operative skin antisepsis, but is seldom used for other purposes as it is neurotoxic, especially to neonates (Hoffman et al 2004).

Triclosan
Products that contain triclosan are generally less effective than those that contain chlorhexidine. However, they may be used to decolonise MRSA carriers as they tend to be better tolerated by patients (Hoffman et al 2004). They are also useful for healthcare workers who have skin reactions to other commonly-used hand hygiene products. Triclosan has a similar range of action to hexachlorophene, but is not toxic to neonates.

Octenidine dihydrochloride
Octenidine dihydrochloride is a new antiseptic that has been used for MRSA decolonisation in some countries (Krishna and Gibb 2010). However, clinical trials are needed to provide further information about its usefulness in the clinical setting.

Each antiseptic has strengths and limitations and no single antiseptic has a complete spectrum of activity. Some commercially marketed preparations combine two different antiseptics to overcome their individual limitations. Preparations combining 10% povidone-iodine with alcohol are often used pre-operatively on the skin, but at present the most popular combination is chlorhexidine with alcohol.

Until recently there was no clear evidence that any particular antiseptic might be more effective than another (Edwards et al 2004). A trial reported by Darouiche et al (2010) has provided important definitive evidence. It established that 2% chlorhexidine and 70% isopropyl alcohol in the same preparation combine the properties and antimicrobial activity of both substances to optimal effect: residual activity with rapid action. Two per cent chlorhexidine in 70% isopropyl alcohol has been recommended as a skin antiseptic in the epic 2 guidance, which also advises use of applicators designed for single use to reduce risks of contamination associated with large, multiple-use containers (Pratt et al 2007).

Pre-operative skin preparation
Seminal research has demonstrated that surgical site infection is one of the most common types of HCAI (Plowman et al 2001). Surgical site infection is a leading cause of morbidity and mortality, has major implications for quality of life, delays return to work, domestic and social activities, and has a significant effect on NHS resources (Plowman et al 2001). Traditionally, antiseptics have been applied to the skin in the operating theatre immediately before the surgical incision is made to help reduce the risk of surgical site infection (Tanner and Khan 2008). Guidelines on how antiseptics should be applied differ slightly.

The Association for Perioperative Practice (APP) (2008) has issued standards recommending cleansing with an antiseptic immediately before the operation, using a sponge or swabs, moving outwards from the planned site of the incision in a circular motion. Sponges and swabs should be used once and discarded. Swabbing ‘dirty’ areas such as the umbilicus with a separate swab at the beginning or end of the procedure is recommended (APP 2008). The Centers for Disease Control and Prevention (CDC) in the United States recommend pre-operative preparation of the skin with an antiseptic applied in concentric circles, moving outwards from the site where the incision will be made (Mangram et al 1999). In the UK, the most recent guidelines from the National Institute for Health and Clinical Excellence (NICE) (2008) recommend cleansing the skin immediately before the incision is made.
Identifying the most effective skin antiseptic has recently been the focus of attention. The DH (2011) recommends the use of 2% chlorhexidine in 70% isopropyl alcohol based on the evidence of a trial reported by Darouiche et al (2010), which demonstrated a 41% lower infection rate among patients whose skin had been disinfected with this combination of agents compared to patients whose skin had been disinfected with povidone-iodine. If the patient is sensitive to these agents, povidone-iodine can be used (Darouiche et al 2010).

**Skin preparation before insertion of intravenous devices**

In the UK, 6,000 patients develop a catheter-related infection every year (Hart 2007). Catheter-related infections account for 80% of all bloodstream infections (Eggimann et al 2004). Risks are greater for central venous catheters than peripheral catheters (Scales 2009). The intravenous route is a major risk for HCAI because it provides microorganisms with direct access from the external environment into the bloodstream (Ingram and Murdoch 2009). The mechanisms by which vascular access devices can become infected are shown in Box 4. The patient’s skin is usually the source of infection (Hart 2007). Therefore, thorough disinfection of the skin is necessary before a vascular access device is inserted. The device should be disinfected before and after administration of drugs and fluids. Two per cent chlorhexidine in 70% isopropyl alcohol is the recommended disinfecting agent (Scales 2009).

**MRSA decolonisation**

Many countries have moved towards universal MRSA screening for all new hospital admissions (Gilligan et al 2010). In England, screening was introduced for elective surgical patients in 2009 and became mandatory for all patients in 2010 (DH 2006). Patients who screen positive for MRSA must undergo decolonisation. For those admitted electively, decolonisation should take place before admission. In the case of an emergency admission, decolonisation should begin as soon as possible (Coia et al 2006). The purpose of decolonisation is to:

- Protect patients from endogenous infection.
- Prevent transmission to other patients by eradicating potential reservoirs of infection.

Decolonisation, however, is only partially effective: long-term clearance is achieved in only 50-60% of cases (Coia et al 2006). Nevertheless, it is recommended because the presence and shedding of MRSA and associated risk of transmission decline as soon as the regimen is implemented (Coia et al 2006). The areas that need to be treated are skin, hair, nose, throat and wounds or cannula insertion sites. Complete time out activity

**Complete time out activity**

Recommended body-washing products for skin decolonisation include 4% chlorhexidine gluconate, 7.5% povidone-iodine or 2% triclosan for five days (Coia et al 2006). Hair should be washed daily for five days using an antiseptic shampoo. Nasal carriage is usually treated by applying an antiseptic agent such as mupirocin for five days. Some strains of MRSA have developed resistance to mupirocin. If treatment does not appear to be effective after two courses of application it should be stopped to reduce the risk of bacterial resistance. The patient can be treated with topical creams containing chlorhexidine or neomycin instead. Carriage of MRSA in the nasopharynx is treated with an antibacterial mouthwash such as 0.2% chlorhexidine gluconate used twice daily (Coia et al 2006). Repeat swabs are taken at the end of the regimen to determine whether decolonisation has been effective.

None of the existing decolonisation regimens are completely effective and at present there is lack of consensus regarding which is most effective, especially with regard to eradication of long-term MRSA colonisation (Gilpin et al 2010). Decolonisation may not be successful for a variety of reasons, including:

- Non-adherence or poor adherence to decolonisation regimens. This is a particular risk if patients undertake decolonisation at home without nursing support.

**Box 4**

Mechanisms of vascular access device-related infection

- Intraluminal migration via catheter hubs.
- Extraluminal migration via catheter insertion sites.
- Contaminated infusates.
- Contamination of the catheter tip during insertion.
- Migration of microorganisms from another site in the body to the vascular access device (haematogenous seeding).

(Scales 2009)
Learning zone infection control

or medical supervision, while awaiting elective admission. Older people, those with disabilities and individuals who cannot read because of visual impairment or because English is not their first language may find decolonisation regimens difficult.

Failure of the products to eradicate MRSA. Strains sensitive to mupirocin may still be ineffective if the bacteria are in deep tissue, for example in the sweat glands (Gilpin et al 2010). Eradication of MRSA from the throat and skin lesions is especially problematic.

**Total body washing**

Awareness of the limitations of MRSA decolonisation and the propensity of the skin to become colonised with other potential pathogens in addition to S. aureus, has led some authorities to suggest routine showering or bathing with an antiseptic before hospital admission (Tanner and Khan 2008) or during hospital stay (Borer et al 2007). Chlorhexidine is the antiseptic most often recommended. Total body washing is already undertaken routinely before elective admission in a number of countries, but its use is controversial in the UK. When used before admission its effectiveness depends on patients’ ability and willingness to follow instructions and it also increases the costs of health care. At present, guidelines produced by NICE (2008) recommend that patients wash or shower the evening before surgery using soap and water.

**Surgical hand antisepsis**

Surgical teams have disinfected their hands immediately before performing operations for 150 years (Tanner et al 2008). The aim is to remove transient and resident flora from the hands, in contrast to hand hygiene in wards, where the aim is to remove transient organisms to prevent cross-infection (Ayliffe et al 1978). The effects of surgical hand antisepsis may have to last for hours if the operation is lengthy (O’Farrell et al 1994). Moreover, the number of organisms able to contribute to infection increases as they are leached out of the deeper layers of the stratum corneum and subungual spaces when hands sweat beneath surgical gloves. Gloves may also become perforated, allowing microorganisms to escape into the open tissues (Reichman and Greenberg 2009).

The CDC suggests that hands and forearms are washed before the first case on the operating list and then scrubbed for two to five minutes with aqueous antiseptic solution (Mangram et al 1999). Since the publication of the CDC guidelines on the prevention of surgical site sepsis, alcohol has been introduced for pre-operative hand antisepsis (Tanner et al 2007). In the UK, 20% of practitioners report using alcohol hand rubs for repeated cases, but chlorhexidine remains the most popular method of pre-operative hand antisepsis overall (Tanner et al 2007). A Cochrane review has established that pre-operative hand antisepsis with alcohol is as effective as scrubbing with traditional aqueous antiseptics to prevent surgical site infection, but there is no evidence that any alcohol product is more effective than another (Tanner et al 2008).

**Hand hygiene**

The aim of hand hygiene in wards and other clinical areas is to remove transiently carried bacteria from the hands to prevent and control cross-infection (Ayliffe et al 1978). When hands are washed with soap and water microorganisms are removed by mechanical action as they are rubbed together and by friction created during drying. Hands that have become physically soiled must be washed with soap and water because alcohol has no detergent activity (Gould and Drey 2008). Repeated washing damages the skin, and the number of microorganisms present increases as does the risk of cross-infection (Ojajärvi et al 1977). The use of hand rubs and gels containing 70% isopropyl alcohol or another alcohol is widely recommended because they are convenient and less damaging to the skin. A disadvantage is that rapid, tokenistic use can result in areas of the hand surface failing to have contact with the antiseptic (Gould and Drey 2008). When there is a high risk of infection caused by Clostridium difficile hands must be washed with soap and water to remove spores mechanically (Health Protection Agency 2008). The extent to which good hand hygiene contributes to the prevention of HCAI is difficult to establish. Many authors have made encouraging claims for the success of campaigns intended to boost hand hygiene (Harbarth et al 2002, Lam et al 2004),
but equally there have been several initiatives in which attempts to increase hand hygiene compliance have not been successful (Gould and Chamberlain 1997, Marra et al 2007, Rupp et al 2008). A Cochrane review established only scant evidence that hand hygiene is effective (Gould et al 2010). Many factors contribute to the transmission of infection and the susceptibility of the individual patient. Some pathogens responsible for HCAI are transmitted more readily than others, for example because they resist drying and survive for relatively long periods on the skin (Filho et al 1985).

The severity of the patient’s underlying illness and the number of invasive procedures they have undergone, such as surgical operations, mechanical ventilation and urinary catheterisation, are also important factors contributing to susceptibility to infection. The cleanliness of the clinical environment is also important in determining rates of HCAI. Although there is a lack of evidence to demonstrate the effect of environmental cleanliness on rates of HCAI (Rampling et al 2001), it is logical to suppose that hands are likely to become re-contaminated easily after cleansing and that pathogens are transferred more readily in a heavily contaminated environment then in one that is clean. In addition, it is worth considering what comprises good hand hygiene. Most research studies and audits measuring hand hygiene compliance address the frequency with which hands are cleansed and whether cleansing occurs before and after patient contacts, and other clean and dirty activities, but few studies have assessed technique (Gould and Drey 2008).

Despite these criticisms, it is logical to suppose that hand hygiene should have an important role in the prevention and control of methicillin-resistant Staphylococcus aureus on length of stay in an emergency department. Journal of Hospital Infection. 75, 2, 99-102.


References


of HCAI because if performed correctly, it should interrupt the chain of infection (Beggs et al 2009). Moreover, a recent trial has indicated that ensuring that hands receive contact with adequate amounts of antiseptic for long enough for the product to exert its antimicrobial effects is central to reducing the numbers of bacteria present, in turn reducing the risk of cross-infection (Widmer et al 2007).

Hand hygiene is relatively inexpensive and straightforward compared to many other infection prevention and control interventions and it is within the power of individual practitioners to strive to improve their practice. Policy makers, healthcare providers and managers are acting in the patient’s best interest when they emphasise the importance of hand hygiene compliance as part of an overall strategy to prevent and control infection.

Conclusion

Intact skin is the body’s first line of defence against invading microorganisms. The skin is populated with resident and transient bacteria that act as a source of infection if they gain access to the underlying tissues, for example when a surgical incision is made or an invasive device is inserted. Antiseptics are important in reducing the risk of infection. Nurses employed in a range of clinical settings need to know how antiseptics are used as part of infection prevention and control precautions.

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