Preoperative skin preparation: a historical perspective

The incidence of health-care-associated infections has reduced since skin antisepsis was introduced in the 19th century. Despite this, health-care-associated infections, including post-surgical sepsis, continue to cause significant morbidity and mortality. This article reviews the evidence for the use of preoperative skin preparations.

Before the mid-19th century, surgical sites commonly developed postoperative wound complications that included local wound infection, generalized sepsis and often death (Mangram et al, 1999). In 1847, Semmelweis was the first to identify the relationship between microorganisms and the transmission of infection and introduced chlorinated lime for hand dipping (Gaw, 1999). A few years later, Lister designed and introduced the steam-generated carbolic acid spray for surgical patients in a further attempt to keep the operative wound clean (Gaw, 1999). Indeed, when the principle of antisepsis was implemented the prevalence of postoperative wound infections decreased. However, even in the early 20th century, the prevalence of postoperative wound infection was still high and this prompted the British surgeon Sir Berkeley Moynihan to comment that 'every operation in surgery is an experiment in bacteriology and the success of the experiment, in respect of the patient, depended not only on the skill, but also on the care exercised by the surgeon in the ritual of the operation' (Klenerman, 2002).

What have we learned from these early experiences? The Health Protection Agency's *Surveillance of Surgical Site Infection in England* described the incidence of surgical site infection as ranging from 1% in knee prostheses to 13.1% in limb amputation (Health Protection Agency, 2006). Surgical site infection therefore remains, albeit reduced, a significant cause of morbidity and mortality despite the endeavours of the early workers. How can we now improve this situation?

Surgical site infection

To address prevention of surgical site infection effectively, health-care practitioners must first understand the contributors to infection. The majority of surgical wounds are contaminated by microorganisms, but the risk for development into infection depends on various factors, including the size of the inoculum, the virulence of the microbial contaminant, the microenvironment of the wound and the integrity of host defenses (Fry, 2006). Microorganisms may enter the wound endogenously from the patient's skin or by an exogenous route, including the health-care worker, the operating room environment or from surgical instruments.

Mangram and colleagues (1999) concluded that most surgical site infections develop from microorganisms already present in the skin, mucous membranes or hollow viscera. They further commented that the surgical incision of the skin or mucous membrane results in contamination of associated tissue with this endogenous flora. The risk of developing a surgical site infection varies depending on the type of surgical wound and other factors, such as the health status of the patient and the duration of the operation (Fry, 2006).

Effective risk management to reduce surgical site infection involves a multifaceted approach that includes understanding the pathogenesis of surgical site infection, assessing individual patient risk, and being conversant with evidence-based recommendations and current initiatives to reduce the incidence of surgical site infection. This article reviews the role of skin antiseptics, which are a vital component of the prevention of postoperative sepsis.

Patient preoperative skin preparation

Sub-optimal skin antisepsis is considered one of the primary causes of health-care-associated infections. Adequate skin cleansing and protection is essential to pre- and post-care of patients undergoing invasive medical procedures. The skin, which consists of the epidermis, dermis, and subcutaneous tissue, is crucial for human survival. A mature and intact epidermis is an effective barrier in preventing infection. Numerous invasive procedures, such as vascular access, haemodynamic monitoring, drainage tubes and surgical intervention, break the skin's barrier allowing the ingress of microorganisms into the deeper layers.

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Evidence demonstrates that the most likely source of device-related infection and clean surgical site procedures is the microorganisms on the patient's skin (Maki, 1994; Elliott et al, 1997; Livesley et al, 1998; Jeske et al, 2003). More recently, the Health Protection Agency suggested that 50% of surgical site infection is caused by the endogenous skin bacterium *Staphylococcus aureus* (64% of which was meticillin-resistant *S. aureus*) (Health Protection Agency, 2006). Cutaneous antisepsis is therefore critical in infection prevention and control.

Cutaneous or topical antiseptics are antimicrobial agents that kill or inhibit the microorganisms on the skin. They must be active against both resident and transient microorganisms. Health-care antiseptic formulations have a variety of mechanisms, rapidity of antimicrobial activity, persistent or residual properties, and demonstrate varying levels of toxicity.

Various antiseptics are used throughout health-care facilities including iodophors, such as povidone-iodine, chlorhexidine gluconate and isopropyl alcohol. There are specific characteristics to consider when selecting antiseptics for health-care hand washing, surgical scrub for surgeons and operating room personnel, and patients' preoperative skin preparation. The selection of an antiseptic should consider the safety and efficacy, quality of the evidence, ease of implementation, availability of product and health economic value. Ideal properties for an antiseptic agent include:

- Broad spectrum
- Rapid bactericidal (killing) activity
- Residual antimicrobial activity
- Active in the presence of organic matter, such as blood
- Non-allergic or non-toxic responses
- No systemic absorption.

Some of the important characteristics of cutaneous antiseptic solutions are outlined in *Table 1*.

Mode of action and concentration of agent

The activity of a cutaneous antiseptic solution can be affected by a number of factors, including the type of microbial species and the nature and concentration of the antiseptic solution. The higher the number of the microorganisms, referred to as the bioburden, the longer it takes to inhibit or kill the individual microorganisms. The exponential decrease in the number of pathogens will require longer exposure to the antiseptic solution.

The concentration of a cutaneous antiseptic agent can influence its efficacy in reducing skin-colonizing pathogens. For example, Adams and colleagues (2005) studied the efficacy of 2% chlorhexidine gluconate/70% isopropyl alcohol. They reported an improved antimicrobial effect compared with the other three standard preparations of chlorhexidine gluconate available in the UK, namely 0.5% aqueous chlorhexidine gluconate, 2% aqueous chlorhexidine gluconate, and 0.5% chlorhexidine gluconate/70% isopropyl alcohol when tested against *Staphylococcus epidermidis* RP62A.

Another important factor which can influence antiseptic efficacy is the time that the microorganisms are exposed to the agent – the antiseptic needs time to act. This concept is probably one of the most poorly understood and applied aspects of skin antisepsis, particularly among clinicians.

Efficacy

Many studies have evaluated the difference in efficacy of the various cutaneous antiseptic solutions. Chlorhexidine gluconate has repeatedly been shown to be more effective than povidone-iodine or alcohol in the prevention of intravascular bloodstream infections. In an evaluation of antiseptic agents using three major criteria – immediacy, persistence and cumulative action – chlorhexidine gluconate was more effective than alcohol or povidone-iodine as a preoperative skin preparation for patients (Hibbard, 2005). In a clinical trial comparing the efficacy of 2% chlorhexidine gluconate/70% isopropyl alcohol with that of 70% isopropyl alcohol for skin disinfection to prevent peripheral venous catheter colonization and contamination, the addition of 2% chlorhexidine gluconate significantly reduced (P=0.001) the number of peripheral venous catheters that were colonized or contaminated (Small et al, 2008). Similarly, a meta-analysis of the prevention of central venous catheter-related bloodstream infection demonstrated a 49% reduction in risk

Table 1. Characteristics of skin antiseptic agents

	Spectrum of activity					
Antiseptic	Gram positive	Fungi	Gram negative	Speed of action	Residual activity	Affected by organic matter
Isopropyl alcohol	+++	+++	++	Rapid	Minimal	Yes
Aqueous chlorhexidine	+++	++	++	Intermediate	Excellent	Minimal
Chlorhexidine in isopropyl alcohol	+++	+++	++	Rapid	Excellent	Minimal
Aqueous povidone-iodine	+++	+	++	Intermediate	Minimal	Yes
Povidone-iodine in isopropyl alcohol	+++	+++	++	Rapid	Minimal	Yes

Modified from Larson (1988)

of bloodstream infections when chlorhexidine gluconate was the primary active agent for skin antisepsis (Chaiyakunapruk et al, 2002).

There are, however, few studies focusing specifically on preoperative antisepsis of patients before surgery. In foot and ankle surgery, patients' skin that was prepared with 2% chlorhexidine gluconate/70% isopropyl alcohol demonstrated a significant reduction in microorganisms compared with that prepared with 0.7% iodine/74% isopropyl alcohol or 3.0% chloroxylenol (Ostrander et al, 2005). In a similar study for elective foot and ankle surgery, chlorhexidine gluconate and alcohol paint preparations were found to be better than povidone-iodine (Bibbo et al, 2005).

In a coronary artery bypass graft surgery study, the skin for the harvest of the saphenous vein was prepared with either 2% chlorhexidine gluconate/70% isopropyl alcohol or 0.5% chlorhexidine gluconate/70% isopropyl alcohol. There was a trend for a greater reduction in the total number of microorganisms with 2% chlorhexidine gluconate/70% isopropyl alcohol compared with 0.5% chlorhexidine gluconate/70% isopropyl alcohol (P=0.07). In addition, in the 2% chlorhexidine gluconate/70% isopropyl alcohol group both the absorbent and the adhesive components of the dressings removed 24 hours post-surgery contained a significantly lower number of microorganisms than those of the 0.5% chlorhexidine gluconate/70% isopropyl alcohol group (P=0.02 and P=0.007 respectively) (Casey et al, 2008).

Guidelines

There are now a number of studies on the efficacy of antiseptic skin preparation before intravascular catheter insertion. Guidelines based on the data from these studies have subsequently been produced. For example, the epic2 guidelines clearly recommend 2% chlorhexidine gluconate/70% isopropyl alcohol solution for use before intravascular catheter insertion (Pratt et al, 2007). In comparison the American Centers for Disease Control produced guidelines for the prevention of intravascular catheter-related infection (O'Grady et al, 2002). O'Grady and colleagues recommended the use of 2% chlorhexidine gluconate but did not specify whether it should be aqueous or with alcohol. The Society of Cardiovascular Angiography and Interventions (Chambers et al, 2006) guidelines, in contrast, specify that 2% chlorhexidine gluconate/70% isopropyl alcohol is preferred for use in venous and arterial catheterization.

Despite apparent differences in the efficacy of antiseptic solutions in preoperative studies as discussed above, sub-optimal preoperative skin preparations are still commonly used in the operating theatre today.

There has generally been a lack of recommendations or preference for specific antiseptic agents in current guidelines for surgical skin preparations both nationally and internationally. However, the National Institute for Health and Clinical Excellence (NICE) issued guidelines on surgical site infection in October 2008 (National Collaborating Centre for Women's and Children's Health, 2008). These guidelines recommend either povidone-iodine or chlorhexidine but do not stipulate the concentration of the antiseptic to be used. The guidelines review a range of studies but consider many to be underpowered. Indeed, some show no statistically significant difference between the two compounds.

The Health Protection Agency Rapid Review Panel, which assesses new and novel products that add value to the NHS in reducing health-care-associated infections, issued a Recommendation 1 on 15 July 2005 for ChloraPrep (Enturia Ltd, Reigate, UK), a 2% chlorhexidine gluconate/70% isopropyl alcohol preoperative skin preparation, indicating that the product should be available to NHS bodies to include in their cleaning, hygiene or infection control protocols (Health Protection Agency, 2005). This recommendation took into account increasing evidence, some reviewed above, that suggests chlorhexidine gluconate has greater activity than iodine-based preparations and that a concentration of 2% chlorhexidine gluconate is more effective than 0.5% chlorhexidine gluconate.

Conclusions

Since the 19th century, considerable progress has been made in understanding the mechanisms of the antibacterial action of antiseptics. However, there is still an inadequate amount of data in areas such as preoperative skin care.

The formulation of specific preoperative skin preparation protocols is a key part of a wider ongoing range of measures which should be taken in response to the Department of Health (2007) *Clean, Safe Care* Saving Lives initiative. It is a simple yet important way of improving procedures and reducing rates of postoperative infection. Based on the evidence related to skin antisepsis for intravascular device insertion as recommended by the epic 2 guidelines and the Health Protection Agency of using 2% chlorhexidine gluconate in 70% isopropyl alcohol formulation, the authors would suggest this approach should be taken for all preoperative skin preparations unless there is a contraindication such as allergy to chlorhexidine gluconate. In addition, care must be taken to avoid the use of excess alcohol when diathermies are used. **BJHM**

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KEY POINTS

- Postoperative infection remains a preventable cause of morbidity and even mortality in the UK.
- Half of all surgical site infections are caused by the endogenous skin bacteria Staphylococcus aureus.
- Studies have shown that 2% chlorhexidine in 70% isopropyl alcohol is the most effective skin preparation agent.
- UK surgical skin preparation guidelines have been issued by the National Institute for Health and Clinical Excellence which recommend either povidone-iodine or chlorhexidine.
- UK and US guidelines recommend 2% chlorhexidine/70% isopropyl alcohol for catheter insertion and site maintenance and for prevention of intravascular catheter-related infection respectively. The Health Protection Agency also issued a Recommendation 1 for a 2% chlorhexidine/70% isopropyl alcohol preparation in reducing health-care-associated infection.
- Using 2% chlorhexidine/70% isopropyl alcohol may be an effective way of reducing rates of surgical site infection.