CLINICAL MANAGEMENT

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Skin Bacteria: Implications for Wound Care

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This continuing educational activity will expire for physicians on May 31, 2014.

PURPOSE:

To enhance the learner's competence with knowledge of the implications of skin bacteria for wound care.

TARGET AUDIENCE:

This continuing education activity is intended for physicians and nurses with an interest in skin and wound care.

OBJECTIVES:

After participating in this educational activity, the participant should be better able to:

1. Demonstrate knowledge of the implications of skin bacteria for wound care.

2. Apply knowledge of skin bacteria regarding wound care to patient care scenarios.

ABSTRACT

Skin is the body's physical barrier to the outside world. Its primary role is to protect the body from organisms or toxic substances, while maintaining fluid and electrolyte balance. Because skin interfaces with the outside world, it develops an ecosystem that may be colonized with bacteria, viruses, fungi, and mites.

KEYWORDS: skin bacteria, bacteria, and wounds microbiome

ADV SKIN WOUND CARE 2013;26:231-6, quiz 237-8.

INTRODUCTION

Skin is the largest organ of the body and is the body's physical barrier to the outside world. Skin's primary role is to protect the body from organisms or toxic substances, and to maintain fluid and electrolyte balance. However, because skin does interface with the outside world, it develops an ecosystem that may be colonized with bacteria, viruses, fungi, and mites. This flora is also referred to as the skin microbiome or skin microbiota. Some of these microorganisms are mutualistic (offer a benefit to the host) and may actually have a role in the skin's T cells developing immunity so it can react against more virulent strains of the colonizing organism.[1] Most other organisms on the skin are commensals (not harmful to the host).[1]

Different areas of the body that are moist (axilla, perineal area, and between toes), dry (legs), or oily (nose and face) have varied amounts and types of microorganisms present.[2,3] Despite the fact that organisms are present, people do not develop an infected wound every time they have a break in their skin. Healthy persons have immunity against their own bacteria, but if someone becomes immunocompromised, or if there are large amounts of bacteria or virulent bacteria present, infection can occur.

Reading this article will help clinicians to better assess the implications of bacteria in wound care, the importance of hand hygiene, and the risks for infection.

SKIN BACTERIA

Fetal skin is sterile in utero, but colonization begins immediately after birth. This happens regardless of vaginal or cesarean delivery.[3,4] How the microbial colonization is established during the first years of life is not known. In adults, bacteria colonization is present on normal intact skin, with the estimated amounts to total 10^{12} and represent about 1000 species.[4] Such bacteria rarely result in the person developing an infection, and the types and amounts of bacteria remain relatively constant over time. One reason bacteria numbers and types change little is that skin has an acid (pH <5) mantle. An acid skin pH (4–4.5) keeps the resident bacterial flora attached to the skin, whereas an alkaline pH (8–9) promotes the dispersal from the skin.[2] A small study with healthy volunteers showed that women (pH 5.54) had a significantly more acidic pH than men (pH 5.8).[5] This may be explained because of physiologic differences, such as hormones, sweat, and sebum production; however, the significance of this is not known.[5] The second reason bacterial numbers rarely change is because the outer layer of skin is constantly being shed. In fact, the outer layer of skin is renewed about every 4 weeks, with 30,000 to 40,000 skin cells shed each hour.[4]

Much of the early information on skin bacteria comes from handwashing literature.[6–8] Bacteria on the skin and the importance of hand hygiene have been studied for more than 70 years.[9,10] Table 1 illustrates the hand hygiene research agenda from the Centers for Disease Control and Prevention.[9] Currently, new laboratory testing using molecular methods (sequence analysis of rRNA genes) is better able to accurately quantify and identify skin and wound organisms. In 2008, the National Institutes of Health started the Human Microbiome Project.[11] One of the goals of this project is to sequence the organisms present on the skin of healthy persons. This has led to a more precise understanding of the skin's ecosystem. Prior to using a molecular method of analysis, *Staphylococcus epidermidis* and *Staphylococcus aureus* were thought to be the most common bacteria on the skin. However, it is now known that these make up only 5% of the skin's bacteria. The total number of bacteria on the skin is estimated to be more than 1 trillion.[11]

Bacteria varies by site because skin varies in thickness and has areas with folds and sebaceous and sweat glands (apocrine and eccrine), as well as hair follicles. Each area develops its own microsystem. Consequently, different types and numbers of bacteria and other organisms are found in dry (β-proteobacteria and flavobacterials), moist (corynebacteria and staphlyococcci), and oily (propionibacteria and staphylococci) areas of the body.[2,3] Skin and its outer colonies of bacteria have a normally symbiotic relationship, but anything, externally or internally, can disrupt the delicate relationship. Even resident microbes can cause skin disease or enter the bloodstream, creating life-threatening illness, with a poorly functioning immune system. Therefore, good hand hygiene is critical, especially to stop transmission of hospital-acquired infection.[9,10] Figure 1 illustrates the process for the transmission of bacteria.

Figure 1.
TRANSMISSION OF BACTERIA DURING CARE[9,10]

$$\text{Infection} = \frac{\text{No. of organisms} \times \text{organisms' virulence}}{\text{Host immune functioning}}$$

Table 1.
HAND-HYGIENE RESEARCH AGENDA

Education and promotion

- Provide healthcare workers (HCWs) with better education regarding the types of patient-care activities that can result in hand contamination and cross-transmission of microorganisms.
- Develop and implement hand-hygiene programs in pregraduate courses.
- Study the impact of population-based education on hand-hygiene behavior.
- Design and conduct studies to determine if frequent glove use should be encouraged or discouraged.
- Determine evidence-based indications for hand cleansing (considering that it might be unrealistic to expect HCWs to clean their hands after every contact with the patient).
- Assess the key determinants of hand-hygiene behavior and promotion among the different populations of HCWs.
- Develop methods to obtain management support.
- Implement and evaluate the impact of the different components of multimodal programs to promote hand hygiene.

Hand-hygiene agents and hand care

- Determine the most suitable formulations for hand-hygiene products.
- Determine if preparations with persistent antimicrobial activity reduce infection rates more effectively than do preparations whose activity is limited to an immediate effect.
- Study the systematic replacement of conventional hand washing by the use of hand disinfection.
- Develop devices to facilitate the use and optimal application of hand-hygiene agents.
- Develop hand-hygiene agents with low irritancy potential.
- Study the possible advantages and eventual interaction of hand-care lotions, creams, and other barriers to help minimize the potential irritation associated with hand-hygiene agents.

Laboratory-based and epidemiologic research and development

- Develop experimental models for the study of cross-contamination from patient to patient and from environment to patient.
- Develop new protocols for evaluating the in vivo efficacy of agents, considering in particular short application times and volumes that reflect actual use in healthcare facilities.
- Monitor hand-hygiene adherence by using new devices or adequate surrogate markers, allowing frequent individual feedback on performance.
- Determine the percentage increase in hand-hygiene adherence required to achieve a predictable risk reduction in infection rates.
- Generate more definitive evidence for the impact on infection rates of improved adherence to recommended hand hygiene practices.
- Provide a cost-effectiveness evaluation of successful and unsuccessful promotion campaigns.

Source: Centers for Disease Control & Prevention. Morbidity and Mortality Weekly Report, October 25, 2002. http://www.cdc.gov/mmwr/PDF/rr/rr5116.pdf. Last accessed February 19, 2013.

Bacteria on skin has been categorized as transient or residual in nature since 1938.[12] Transient bacteria are most often associated with healthcare transmission from healthcare worker to patient, or patient to patient. Residual bacteria are attached to deeper tissues of the skin and are difficult to remove even with proper hand-washing techniques. In addition, residual skin bacteria prevent transient pathogens by secreting chemicals against them and stimulating the body's immune system, thus maintaining the delicate balance between host and bacteria.[10]

Bacteria have also been found in higher concentrations under rings, especially gram-negative bacteria and Enterobacteriaceae. However, there was no significant difference in rates of transfer between persons wearing a ring and those who did not.[13,14] There are about 150 different types of residual bacteria on hands. And, both increased amounts and different species of residual bacteria are found on the dominate versus nondominate hand, and only about 17% of the species are common to both hands.[13,14] Quantities of bacteria experience a temporary decrease after hand washing, but are back to their "usual" amount within 2 to 4 hours.[15,16]

Some medical conditions affect the types and amount of bacteria present. Persons with diabetes, chronic renal failure, or

dermatitis are more likely to have intact skin colonized with *S aureus*.[16] Age, tissue oxygenation, and the immune system also influence quantity and type of bacteria present.[16] Older adults have been found to have higher amounts of yeast, and hospitalized persons have gram-negative bacteria.[10] Other factors that affect types and amounts of microorganisms are geographic residence (hot or cold/moist vs dry), moisture, and products used on the skin, such as cosmetics and soaps.[2] In the hospital setting, bath wipes have been found to maintain the skin's acidity and have less drying effects than soap. In older adults, soap is especially drying, but may alter the skin's ecosystem in any individual.[17] Although bars of soap have been found to be colonized with bacteria, there is no research showing this is transmitted to hands during washing. Methods of drying hands may also change bacterial counts on hands. For example, paper towels have been found to decrease the total number of bacteria, whereas warm air dryers significantly increased the bacteria amounts and dispersed the bacteria up to 3 to 6 feet, even onto clothing.[18]

WOUND BACTERIA AND INFECTION

When a wound occurs in the skin, a potential for infection exists. All wounds become contaminated by bacteria from the surrounding skin, the local environment, and patient sources. The potential for infection increases for persons on anti-inflammatories or prednisone, chemotherapy, or anyone at high risk for immunosuppression. Classic signs of infection include erythema of surrounding tissue that either increases or does not resolve, increased pain, friable tissue, no response to therapy, or probes to the bone.

Table 2 shows the importance of the immune system in mediating the introduction of bacteria into the open area.[19] Even intact immune systems can be overwhelmed if there are large amounts or very virulent bacteria introduced. Wounds are considered to range on a continuum from colonized to critically colonized to infected. However, this continuum does not definitively answer how quantities of bacteria affect wound healing. The typical threshold of bacterial amounts exceeding 105 organisms/g of tissue of impeding wound healing does not take into account the status of the individual's immune system and virulence and types of bacterial species present.[3]

The identification of biofilms in wounds has complicated the diagnosis and treatment of wound infection. A biofilm is a population or community of bacteria living in organized structures at a liquid interface. Bacteria within a biofilm live in microcolonies that are encapsulated in a matrix composed of an extracellular polymeric substance separated by open water channels.[20] The biofilm environment provides physical protection to bacteria. The biofilm bacteria actually communicate with each other (quorum sensing), which may lead to an increase in virulence.[20] Chronic wounds offer ideal conditions for biofilm production because proteins (collagen, fibronectin) and damaged tissues are present, which can allow biofilm attachment. Biofilms have been found to be present in 70% to 80% of chronic wounds.[21]

CHRONIC WOUNDS

In the United States, approximately 6.5 million persons develop chronic wounds annually,[22] with an estimated 1% to 2% of people in developing countries experiencing a chronic wound in their lifetime. In 2009, $25 billion was spent on wound care in the United States. Globally, this is $13 to $15 billion annually.[23] The majority of persons with wounds that fail to heal have multiple comorbidities, especially diabetes and peripheral vascular issues. In acute care, 72% of patients with pressure ulcers were older than 65 years.[22] Chronic wounds are associated with diabetes, congestive heart failure and other vascular diseases, and immobility resulting from strokes and traumatic paralysis. The wound care product market is expected to rise from $16.8 billion this year to $21 billion in 2015.[24,25]

The longer an ulcer remains unhealed, the more likely it will acquire multiple aerobic organisms (mean, 4.3 species) and a significant anaerobic population (mean, 2.0 species).[26] Chronic wounds tend to have a low tissue oxygen level that facilitates the growth of anaerobes. In fact, chronic wounds have a statistically higher proportion of anaerobes than acute wounds (2.0 vs 1.1 species, respectively).[26]

BACTERIA IMPLICATIONS FOR WOUND CARE

Many of the skin cells that are shed daily contain bacteria. These skin cells/bacteria may shed onto patient linen, gowns, and other

Table 2.
INFECTION POTENTIAL[10]

Your Hands
Transmission of healthcare-associated pathogens from one patient to another via the hands of healthcare workers requires the following sequence of events:
1. Organisms present on the patient's skin, or those that have been shed onto inanimate objects (in close proximity to the patient), must be transferred to the hands of healthcare workers.
2. These organisms must then be capable of surviving for at least several minutes on the hands of personnel.
3. Next, hand washing or hand antisepsis by the worker must be inadequate or omitted.
4. Finally, the contaminated hands of the caregiver must come in direct contact with another patient, or with an inanimate object, that will come into direct contact with the patient.

PRACTICE PEARLS

- Skin develops an ecosystem colonized with bacteria, viruses, fungi, and mites referred to the skin microbiome.
- The acidic nature of the skin keeps the resident bacteria attached to the skin and the consistent turnover or shedding of the outer layer keeps the bacterial numbers fairly constant.
- Medical conditions, age, geographic location of residence (hot/cold, wet/dry), and products used on skin and moisture affect the type and amount of bacteria present on skin.
- The longer a wound remains unhealed the more aerobic and anaerobic organisms it will acquire.
- When a dressing is changed on a colonized wound, the surrounding hospital area may be contaminated with the same bacteria.

objects in close patient proximity.[27] Consequently, even clean activities, such as straightening the bed linen or patient gown, taking a pulse, or touching items that have been in contact with a patient, can transfer patient bacteria to the healthcare workers' hands, including methicillin-resistant *S aureus* (MRSA) and vancomycin-resistant enterococcus.[27] Bacteria have also been found on sink faucets and wall soap dispensers.[10] Yet, use of tap water versus sterile saline has not been found to increase infection rate.[30]

When a dressing is changed on a colonized wound, the surrounding hospital areas may be contaminated with bacteria.[10]

Figure 2.
ABSCESS CAUSED BY MRSA

Pictured is a cutaneous abscess on the knee of a prison inmate, which had been caused by methicillin-resistant *Staphylococcus aureus* (MRSA) bacteria. *S aureus* bacteria are among the populations of bacteria normally found existing on one's skin surface. However, over time, various populations of these bacteria have become resistant to a number of antibiotics, which makes them very difficult to fight when attempting to treat infections where MRSA bacteria are the responsible pathogens. These antibiotics include methicillin and other more common antibiotics, such as oxacillin, penicillin, and amoxicillin.
Source: Centers for Disease Control and Prevention. http://www.cdc.gov/mrsa/mrsa_initiative/skin_infection/mrsa_photo_7824.html. Last accessed March 15, 2013.

Figure 2 shows a patient with a MRSA wound. More than 40% of air samples collected and 50% of surface areas sampled were positive for bacteria.[27] For MRSA carriers, 12% to 44% of the patient's room was found to be contaminated.[27] This has led some researchers to recommend that rooms be cleaned after dressing changes and that gowns and masks should also be used for patient care. Building on this room contamination concept are also controversies on best practices of care.

Clean versus sterile technique has long been discussed for wound care both for dressings and cleansing solutions.[28–30] Yet, there are no definitive answers for best practice.[28] New understanding of residual bacteria types of location may facilitate future research. Normal skin bacteria have been found to populate the wound immediately after dressing change. This is one reason culture swabbing may be measuring only residual bacteria if it is taken around the wound edges or before the wound is cleaned.

Results from the Human Microbiome Project showed different types and amounts of bacteria by body location. This has practice implications. For example, if dressing A is changed on the sacrum and then dressing B on the foot, it stands to reason that different bacteria may be transmitted between wounds. Whether this would cause harm or increase the risk of infection is not known. Some long-term-care facilities have been cited by state surveyors for not changing gloves after removing the old wound dressing. Certainly, if gloves are heavily soiled, common sense dictates they should be changed, but there is no evidence that not changing gloves will impact the rate of infection or that anything other than "normal" residual bacteria already present will be introduced into the wound. Both bacteria present in multiple wounds on the same person and the need to change gloves during dressing changes are areas in need of further research for evidence-based practice.

SUMMARY

Numerous bacteria are found all over the skin, and these microorganisms are shed onto the bed and surrounding objects in a patient's room. Appropriate hand washing, disinfecting, and hand drying with paper towels are the most effective ways of removing the transient bacteria picked up during care. Most of the bacteria on the skin never causes an infection, but the potential exists, especially if immunosuppression is present.

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