# Pressure Injuries

Subjects: Dermatology

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Pressure injuries have been identified as one of the main health hazards among bedridden elderly people. Bedridden elderly people often stay in the same position for a long time, because they cannot switch positions; thus, the blood flow in the part of the body that is being compressed between the bed and their own weight is continuously blocked. As a result, redness and ulcers occur due to lacking oxygen and nutrients in the skin tissues, and these sites are often infected with microorganisms and, thus, become suppurative wounds, a condition commonly determined as pressure injuries. If left untreated, the pressure injury will recur with microbial infections, often resulting in cellulitis, osteomyelitis, and sepsis. The skin microbiome, in which many types of bacteria coexist, is formed on the skin surface. However, it remains unclear what characteristic of the skin microbiome among the bedridden elderly constitutes the development and severity of pressure injuries and the development of post-pressure injury infections.

Keywords: pressure injury ; bedridden elderly ; skin microbiome ; infection

## 1. Introduction

People who are in a bedridden state often have many health problems. A typical example is pressure injuries. Bedridden elderly people during their sleep often cannot change their positions [1][2][3][4][5][6][7][8]. Therefore, bedridden elderly people often stay in the same position for a long time during their sleep, thus making the blood flow in the part of their body that is compressed by their own weight from the bed continuously blocked [8][9]. Then, oxygen and nutrients in the continuously compressed skin tissue become low, resulting in redness, ulcerations, and suppurative wounds by pathogenic microorganism infections in the skin fragile site [1][2][3][4][5][6][7][8][9][10], a skin condition referred to as pressure injuries.

The most common site of a pressure injury is the area that is in direct contact with the bed and is continuously compressed, i.e., back of head, ear, shoulder, elbow, hip area, sacrum, heel, and ankle [11][12]. External factors (pressure acting perpendicular to the tissue and stress against tension and shear caused by friction between the tissue and the supporting surface) and internal factors (aging, undernutrition, paralysis, various skin abnormalities, etc.) have been determined to be the causative factors of pressure ulcers [11][12]. Especially in the case of undernutrition, the risk of developing a pressure injury remains high [11][12]. In addition, the symptoms of pressure injuries only become severe if left untreated.

One indicator of pressure injury progression is the National Pressure Ulcer Advisory Panel (NPUAP) classification [13], which categorizes pressure injuries into the following: suspected Stage 1 pressure injury, Stage 2 pressure injury, Stage 3 pressure injury, Stage 4 pressure injury, Unstageable pressure injury, and Deep tissue pressure injury. Stage 1 pressure injury indicates intact skin with a localized area of non-blanchable erythema, which may appear differently in darkly pigmented skin. The presence of blanchable erythema or changes in sensation, temperature, or firmness may precede visual changes. Color changes do not include purple or maroon discoloration. Stage 2 pressure injury indicates a partial-thickness loss of skin with exposed dermis. The wound bed is viable, pink or red, moist, and may also present as an intact or ruptured serum-filled blister. Adipose is not visible, and deeper tissue is not visible. Granulation tissue, slough and eschar, are not present. These injuries commonly result from adverse microclimates and shear in the skin over the pelvis and shear in the heel. Stage 3 pressure injuries indicate full-thickness skin losses, in which adipose is visible in the ulcer and granulation tissue, and epibole (rolled wound edges) is often present. Slough and/or eschar may be visible. The depth of the tissue damage varies by anatomical location; areas of significant adiposity can develop deep wounds. Undermining and tunneling may occur. Fascia, muscle, tendon, ligament, cartilage, or bone is not exposed. If slough or eschar obscures the extent of tissue loss, this is an unstageable pressure injury. Stage 4 pressure injuries indicate that full-thickness skin and tissue loss with exposed or directly palpable fascia, muscle, tendon, ligament, cartilage, or bone in the ulcer. Slough and/or eschar may be visible. Epibole (rolled edges), undermining, and/or tunneling often occur. The depths vary by anatomical location. If slough or eschar obscures the extent of the tissue loss, this is an unstageable pressure injury. Unstageable pressure injuries indicate full-thickness skin and tissue loss, in which the extent of tissue damage within the ulcer cannot be confirmed, because it is obscured by slough or eschar. If slough or eschar is removed, a Stage

3 or Stage 4 pressure injury will be revealed. Stable eschar (dry, adherent, and intact, without erythema or fluctuance) on an ischemic limb or heels should not be softened or removed. Deep tissue pressure injuries indicate intact or nonintact skin with localized areas of persistent non-blanchable deep red, maroon, purple discoloration, or epidermal separation revealing a dark wound bed or blood-filled blister. Pain and temperature changes often precede skin color changes. Discoloration may appear differently in darkly pigmented skin. This injury results from intense and/or prolonged pressure and shear forces at the bone–muscle interface. The wound may evolve rapidly to reveal the actual extent of the tissue injury or may resolve without tissue loss. If necrotic tissue, subcutaneous tissue, granulation tissue, fascia, muscles, or other underlying structures are visible, this indicates a full-thickness pressure injury [13].

Basically, as the pressure injury progresses, the category in the NPUAP classification shifts from a Stage 1 pressure injury to a Stage 4 pressure injury, and the range of the injury progresses from the epidermis to the dermis and further to the subcutaneous tissue and bone. It should be noted that the lesions are usually infected with pathogenic microorganisms, which are mainly bacteria, and the infection often contributes to the onset, progression, and recurrence of the pressure injury. Further, the infection on the pressure injury lesions often results in cellulitis, osteomyelitis, and sepsis, which, in turn, can lead to death [14][15][16][17][18][19][20][21][22]. It is thought that the majority of pressure injury infections are caused by the dermis getting exposed due to damage to the epidermis and with the exposed area getting infected with pathogenic microorganisms [14][15][16][17][18][19][20][21][22].

What kind of bacteria exist in the prelesion of a pressure injury, and which bacteria contribute to the onset, progression, and recurrence of pressure injuries? Although various investigators have examined and reported on the above questions, there remains no clear answer.

## 2. The Skin and the Skin Residential Microbiome among Bedridden Elderly and Their Association with the Risk of Pressure Injury

### 2.1. Skin Structure, Skin Physiology, and Skin Residential Microbiome in Elderly People

It has been reported that the physiological condition of the skin in elderly people living in nursing homes is considerably different from that of healthy people [23][24]. It was also reported that the proportion of the *Cutibacterium* spp. in the composition of the skin microbiome has been decreased in the elderly [23][25]. More interestingly, one study showed that the skin microbiome of the elderly with care support in nursing homes is very different from that of age-matched community participants [26]. The results suggest that the skin microbiome in elderly and elderly with care support can change as the physiological function of the skin also changes.

The following reports support this possibility. Some symbiotic bacteria on the skin can maintain a slightly acidic pH, and such acidic conditions can promote the growth of these symbiotic bacteria [27]. Paradoxically, pathogens can multiply when the pH of the skin is high [28]. Elderly people usually use diapers, and their skin is often in contact with urine and/or stool for a long time. Sleeping with elevated skin pH and incontinence-related skin deterioration such as dysbiosis is also a problem [29][30].

Moreover, the situation of bedridden elderly patients can be more serious than the situation of elderly patients that can support themselves. Bedridden elderly people are more prone to inconvenience in terms of performing their daily hygiene activities compared to self-supporting elderly people, with their living space and personal hygiene environment more likely to be in poor condition. In addition, they often suffer from poor nutritional status, and it is highly possible that their immunity has also weakened. Due to various factors different from those of the elderly who can support themselves, the skin microbiome composition in bedridden elderly people may be different from that of the self-supporting elderly people.

### 2.2. Characteristics of Residential Microbiome of the Dorsal Sacral Skin in Bedridden Elderly People Compared with Ambulatory Elderly People and Healthy Young People

We determined the characteristics of the skin microbiome composition in bedridden elderly people by comparing them with ambulatory elderly people and healthy young ones [23]. The measurement site was the skin of the dorsal sacral region, which is a frequent site for pressure injury. The number of bacterial genera that constitute the skin microbiome was compared via the α-diversity analysis method, wherein we found that the number of bacterial genera in the bedridden elderly group was larger than that in the other two groups [23]. The composition of the skin microbiome was almost the same between the healthy young people and ambulatory elderly people, whereas, in bedridden elderly people, *Cutibacterium* spp. (which was abundant in the two healthy groups), *Enhydrobacter* spp., *Methylobacterium* spp., and other constituent bacteria of various skin microbiomes in healthy people were noted to decrease. Instead, in bedridden elderly people, the *Corynebacterium* spp. and *Staphylococcus* spp. were found to increase, and *Enterobacteriaceae* such

as *Escherichia* spp., *Shigella* spp., *Bacteroides* spp., and *Klebsiella* spp. and anaerobic bacteria that live in the intestinal tract like *Bifidobacterium* spp. were also increased [23].

Furthermore, we examined the differences of skin microbiome composition between the three groups via the heat map method. As per the results, it was determined that there was no significant difference between ambulatory elderly people and healthy young ones. Meanwhile, the skin microbiome composition in bedridden elderly was completely different from that in ambulatory elderly people and healthy young ones. The β-diversity analysis supported the data in the heat map method. Further, the β-diversity analysis suggested that this difference was influenced by the decrease in *Cutibacterium* spp. and *Enhydrobacter* spp. and the increase in *Escherichia* spp., *Shigella* spp., *Corynebacterium* spp., and *Staphylococcus* spp. in bedridden elderly people [23].

### 2.3. Association of Skin Microbiome with the Onset of Pressure Injury and Post-Pressure Injury Infections in Bedridden Elderly

It has been determined that the composition of the skin residential microbiome in bedridden elderly people is significantly different from that in ambulatory elderly people and healthy young ones. Thus, in this study, we aimed to determine whether such differences in the skin microbiome in bedridden elderly people is associated with the onset risk of a pressure injury. During the assessment of the skin residential microbiome composition in the sacral skin of bedridden elderly people, we found that three bedridden elderly people had pressure injuries in the sacral skin. Therefore, we additionally examined the skin microbiome composition at the lesions of the pressure injuries and found that the compositions of the lesions of the pressure injuries were like the compositions of the same lesions before the onset of the pressure injuries [23].

These results raised a new question: which bacteria are mostly often detected in the primary lesion during pressure injury development. Thus, it is necessary to clarify what bacteria are frequently detected before and after the onset of a pressure injury. It is well-known that pressure injuries in bedridden elderly people often recur [31]. Therefore, we investigated the frequency of the onset of recurrent pressure injuries, the physiological condition of the skin at the recurrent pressure injury lesion sites, and the bacteria that are frequently present in bedridden elderly people who have once suffered from the same condition before [31]. In total, 30 bedridden elderly who were admitted to a medical facility and who had completely recovered from a pressure injury within 1 month as regards skin physiology, composition of the skin residential microbiome, and the presence or absence of a recurrent pressure injury for 6 weeks were assessed. In this study, eight patients developed a recurrent pressure injury. The affected individuals had lower water contents in the stratum corneum than the nonaffected individuals, while the abundance ratio of *Staphylococcus* spp. was found to be significantly higher in the composition of the skin microbiome [31].

*Staphylococcus* spp. include coagulase-positive *S. aureus*, which is highly pathogenic and has a harmful effect on the skin, and coagulase-negative *S. epidermidis*, which is relatively low pathogenic and is thought to contribute to the barrier function of skin infections; in other words, *Staphylococcus* spp. include a variety of bacterial species. Therefore, it is necessary to determine which *Staphylococcus* spp. is associated with the development of recurrent pressure injuries, which we are currently investigating.

## 3. Conclusions

Bedridden elderly people were identified to be at higher risk of developing pressure injuries due to weakened immunities and skin functions caused by poor nutrition and decreased physiological functions. However, as per the results of our study, it is possible that the composition of the skin microbiome in bedridden elderly people, which is different from that in ambulatory elderly people and healthy young ones, and the increase in the abundance ratio of pathogenic bacteria such as *Staphylococcus* spp. may be considered the main factors contributing to a pressure injury and post-pressure injury infections. To determine the mechanisms of pressure injuries among bedridden elderly people, it is necessary to identify the characteristics of the changes in the composition of the skin microbiome in addition to the skin physiology and immunity, as well as to determine the interrelationship of these three factors in the onset of a pressure injury and post-pressure injury infections.

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