Early Detection of Stage I Pressure Ulcers by Identification of Non-Blanchable Erythema Using Electric Impedance

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BACKGROUND and AIMS
Early detection and identification of pressure ulcers is very important to ensure the well-being of patients and control medical expenses. In Japan, the average estimated occurrence rate of pressure ulcers in 2013 was 1.66% in general hospitals and 6.72% in homes. Early detection of pressure ulcers continues to be important and requires further investigation. The Japanese Society of Pressure Ulcers guidelines state that either the finger method or disk method is considered appropriate to identify erythema or pressure ulcers because non-blanchable erythema (NBE) is not always clearly visible. Because electric impedance typically reduces resistance in interstitial fluids, measuring the impedance of skin tissue under erythematous conditions can help to determine whether a stage I pressure ulcer exists. The purpose of this study was to examine the relevance of impedance measurement for classifying complete NBE or blanchable erythema (BE) to establish an objective tool using impedance.

Visible Change in Color of Erythema by Disk Method

Press slightly on erythematous region for 3 seconds using a transparent disk
Judgement of color changes during application of pressure

NBE: pressure ulcer
Erythema color: Not changeable
BE: no pressure ulcer
Erythema color: Changeable, fades to white
Partial NBE: obscure
Erythema color: Mixed color change

METHODS
The study included in-hospital patients who were judged to have complete NBE, partial NBE, or BE by the disk method. Impedance data were collected by the two-electrode method using an LCR meter (NF Corp.). The two-terminal method was used to connect the electrodes to the peri-erythematous skin. One electrode gel sensor (Φ 2 mm) was placed on the edge of the erythematous region, and another electrode gel sensor (Φ 2 mm) was placed on the opposite edge of the erythematous region. The following settings were used: frequency range 1 mHz to 100 kHz, AC power, 1 V, and 1 mA (Fig. 1). Sweep measurements were performed with output of 2 (impedance), 0 (phase in complex number), X (reactance), and Y (admittance). Sum of deviation values were based on the difference between erythema and healthy control impedance.

Ethical Considerations
Ethical approval was obtained from the Research Ethics Committee of Wanyakama Medical University (2012/2013). Permission for data collection was obtained from the 4 hospitals.

RESULTS
- Participants: 23 bedbound patients (15 women and 8 men)
- Average age: 72.3 years (BE group), 82.8 years (partial NBE group), 83.0 years (NBE group)
- Color classification by disk method or finger method: NBE (BE group), 11 (partial NBE group), 8 (NBE group)
- Erythema location and number: heel, 4; toe, 5; hip, 2; knee, 3; sacrum, 1; coccyx, 1; spine, 1; tibia, 3; fibula, 1; ankle, 2
- Erythema size: 11.9 ± 6.1 mm (BE group), 10.5 ± 12.8 mm (partial NBE group), 18.6 ± 12.6 mm (NBE group)
- ANOVA among sum of deviation values of impedance and frequency series: significant difference (p = 0.000)

Sum of deviation was used after eliminating dependence on erythema size (Fig. 2).
- Electric impedance values could be devided into 3 groups based on the sum of deviation after eliminating dependence on erythema size (Fig. 3).
- Multiple comparison test (Bonferroni): NBE vs. BE (p = 0.000), NBE vs. partial NBE (p = 0.000), BE vs. partial NBE (p = 0.000)

Discussion
- Classification by the color change response was coincident with the grouping (NBE, partial NBE, BE) based on the sum of deviation of impedance values after eliminating dependence on erythema size.
- Partial NBE was identified in 11 patients (47.8% of all participants).
- Clinically, a color change response in an erythematous area often indicates obscure or partial NBE.
- Nurses often cannot determine whether a detected area of erythema is a pressure ulcer or not.
- Impedance is correlated with the color change response; that is, early detection of a pressure ulcer may be possible by measuring impedance.

CONCLUSIONS
Our results demonstrate the possibility of early detection of stage I pressure ulcers. Impedance of partial NBE was highest; therefore, some sort of resistive properties in the skin tissue might exist. In the case of partial NBE, impedance at high frequencies must be utilized to identify deep tissue resistive conditions. The highest impedance values of partial NBE may not support the first theory that resistance decreases through interstitial fluids. Therefore, erythema judged as partial NBE by the disk method might indicate deep skin tissue deformation or injury.

Figure 1: Impedance measurement by LCR meter ZM2371

Figure 2: Impedance of independence on erythema size

Figure 3: Frequency Series of Total Deviation of Impedance

Figure 4: Classification of partial NBE and BE