Body Pressure Sensing Mattress for Bedsore Prevention

Akitsugu MISAKI*, Kyoko IMANISHI, Shin-ichiro TAKASUGI, Mika WADA, Shuji FUKAGAWA and Masutaka FURUE

We have developed an air mattress that prevents patients from developing pressure ulcers (bedsores), thereby improving their quality of life (QOL), promoting their rehabilitation, and reducing the burden of caregivers when changing a patient's body position. Based on suggestions from medical professionals, our mattress is equipped with "Smart Rubber" (SR) sensors and two-balloon air cells. The sensors measure body pressure and the tension of the air cells is accordingly adjusted in order to fit to the patient's body shape. This mattress disperses body pressure smoothly, provides comfortable bed rest and helps patients' early ambulation.

Keywords: mattress, bedsore, sensor, air cell

1. Introduction

Along with population ageing, issues concerning elderly care are being paid serious attention. We have been working on the project to lower the incidence of pressure ulcers (bed sores) in bedridden patients. The pressure ulcer is a condition caused by pressure or sheer stress applied to the body surface for a certain period of time, resulting in cutaneous necrosis due to blood flow insufficiency. In order to prevent pressure ulcers, caregivers are recommended to change the patient body positioning periodically, for example once every 2 hours, to prevent continuous pressure from the bed to the body surface. However, the physical burden of the caregivers is increasing in order to fully implement this patient-repositioning due to caregivers' aging.

Body pressure dispersion mattresses are useful tools for preventing pressure ulcers. There are currently two types of body pressure dispersion mattress: reactive support surface mattresses, which are composed of materials such as urethane foam and active support surface mattresses, which use a combination of various air cells. In particular, the active support surface mattresses are often used for patients with a high risk of developing pressure ulcers. In order to constantly relieve the body pressure, these conventional active support surface mattresses use a system with air cells which split into several sets, thus continuously move in a wave-like motion, giving various discomfort like a seasick-feeling. Other downsides are that these mattresses make it difficult to perform rehabilitation practice on the mattress due to their softness. Delayed mobilization and rehabilitation may increase a risk of further developing disuse syndrome or new pressure ulcers.

The basic function of a mattress is to keep comfortable condition for the patient in the bed, as well as to provide an adequate environment in performing appropriate rehabilitation and nursing. This not only prevents pressure ulcers, but also helps the physical and mental stability of the patient, leading to an early rehabilitation and improvement in their QOL. In addition, we have to give a sense of relief to caregivers by reducing their physical and mental burden.

In order to achieve such a nursing care environment, the authors have been working on the technological development of a new kind of mattress which has built-in pressure sensors with a constant feedback system by automatically adjusting the mattress tension to fit to the body shape and posture of a patient.

2. System Summary

The current active support surface mattresses on the market do not have the capability of self-detecting the body pressure and reducing the pressure by lowering the single air cell tension in an automatically-regulated fashion. We assume this operation system does not induce a wave-like motion which causes discomfort in patients.

The authors have designed a mattress which is able to disperse body pressure with minimal movement by installing "Smart Rubber" (SR) sensors capable of measuring body pressure directly at a whole-body basis in order to identify high pressure regions[1]. In addition, two-balloon air cells are arranged in a 6 x 10 matrix on the bottom of an SR sensor and individually change their tension according to the respective body pressure information. Therefore, our mattress automatically changes its surface conformation to fit to the shape of the patient lying on the bed and disperses body pressure (**Fig. 1, Fig. 2**).

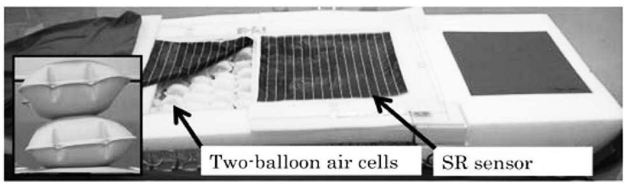

Fig. 1. Internal mattress structure

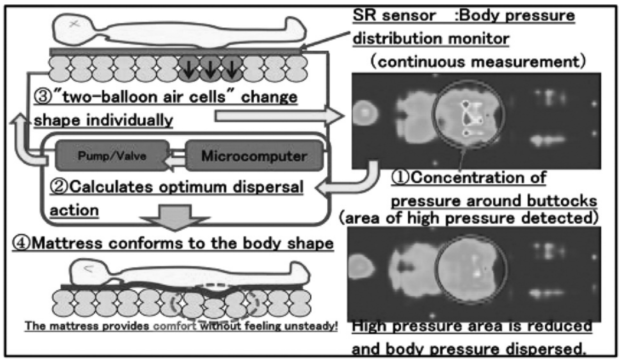

Fig. 2. System of operation

2-1 SR sensors

The SR sensor is a flexible capacitive pressure sensor composed of flexible substrates and electrodes[(2)] (**Fig. 3**). The mattress in development is equipped with two sets of sensor sheets with 16 x 16 = 256ch. pressure sensing points.

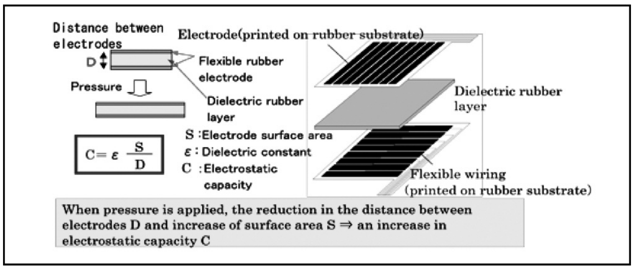

Fig. 3. SR sensor measurement principles

2-2 Two-balloon air cells

The two-balloon air cells are 80 x 80mm and have a vertical stroke of around 100mm. The structure is designed to release transverse (shearing) forces via a narrow section in the middle. As shown in **Fig. 4**, each air cell oscillates towards the center of the load, enabling the body to be immersed in the mattress. As conventional mattresses employ relatively large air cells, shearing strain or stress tends to be directly transmitted to the skin of the patient, and this could increase the risk of developing pressure ulcers. Our two-balloon air cell system effectively reduces the shearing stress.

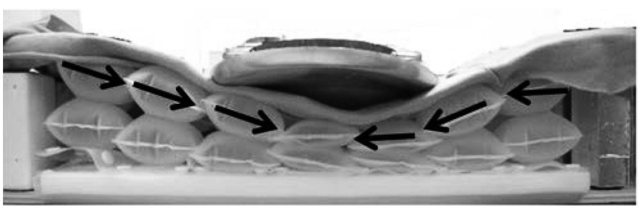

Fig. 4. Two-balloon air cells

2-3 Operation algorithms

Below is a summary of how the mattress operates. Body pressure distribution is constantly measured by the SR sensors. Upon detection of a change in patient movement, the entire surface of the mattress is initially flattened. The inner pressure of each air cell is adjusted according to the site-specific body pressure data, which makes the bed surface to fit the lying shape of the patient. Patient movement is constantly monitored by the SR sensors, and its information is continuously feed-backed to air cell tension. If, for example, a patient turns over in their sleep during the night, the sensor will detect the change in the pressure distribution data and determine that the patient has moved. The mattress will initially return to a flat state and then begin the operation again. By doing this, our mattress can automatically track the posture change of a patient. Moreover, if no movement is detected, the mattress will remain stationary and will not disturb the patient's sleep.

3. Evaluation of Body Pressure Dispersion

In order to evaluate the performance of body pressure dispersion of our mattress, trials were carried out using 14 in-patients with C1 and C2 levels of ADL[*1]. The performance of the mattress was evaluated by comparing pressure dispersion performance with that of three different types of conventional active support surface mattresses. Comparisons were conducted under a similar condition of positioning and physical status of the patients.

These clinical trials were conducted with the prior approval of the hospital's ethics committee and with the consent of the subjects or their relatives. Each subject took part in the trial for around one day and there were no incidences of new pressure ulcers.

The comparative data of pressure distribution are depicted in **Figs. 5-7** (left panel; conventional mattress, right panel; our mattress in development). **Figure 5** shows rep-

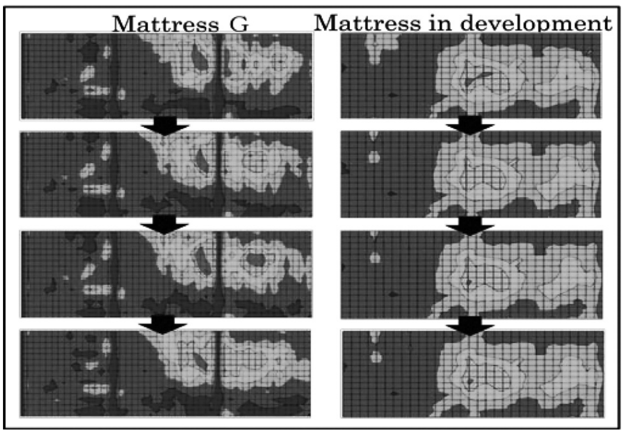

Fig. 5. Body pressure dispersal comparison ①

resentative data of body pressure distribution in 20min lying-down examination comparing conventional mattress G and our mattress. The difference is obvious. In the conventional mattress G (left panel), high pressure area (red zone) is widely distributed. According to the change of the subject's lying position, the red zone moves but a new high pressure area appears in the vicinity of previous red zone. We assume the shearing force may be intense between the red zone and the neighbouring low pressure green zone. On the other hand, our mattress shows very stable results. The high pressure red zone is distributed in only a small area, and the low pressure, green or pink, region is widely distributed. The low pressure data remains even when the patient changed the lying position. The most important fact is that the pressure zone distribution is stably maintained in low in every minute, mostly under a pressure of 35mmHg or less.

Figure 6 is a comparison between conventional mattress A and our mattress in the development. The high pressure red zone distribution is much larger than that of our mattress. Our mattress again keeps a stable low pressure pressure-dispersing pattern. **Figure 7** is a comparison between conventional mattress B and our mattress in the development. Similar results are obtained like **Fig. 5** and **Fig. 6**.

Although it is difficult to state superiority from the results of this trial, we could say that our mattress is feasible to maintain low pressure condition regardless of the patient's lying position. We assume that we are successful, at least, in smoothly reducing the body pressure by adjusting the air cell tension according to the patient's movement. In addition, our mattress system could reduce the sea-sickness like feeling induced by other conventional mattresses, providing a comfortable sleep.

In addition to hospitals, we also conducted long term monitoring at care facilities and homes (over 30 cases). Beneficial results were obtained, such as the disappearance of redness (an early symptom of pressure ulcer) and the absence of any pressure ulcer occurrence even without any repositioning of the patient for three months.

Since the development objective of the authors was to bring about positive changes in the field of nursing care through the introduction of a new type of mattress, we would like to continue the monitored tests with the cooperation of those working in the field in order to further assess the effectiveness of the mattress.

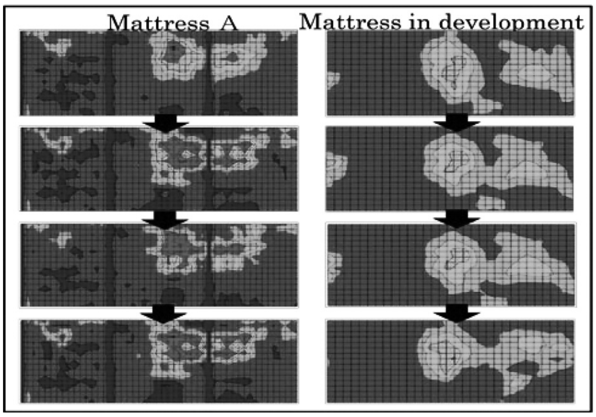

Fig. 6. Body pressure dispersal comparison ②

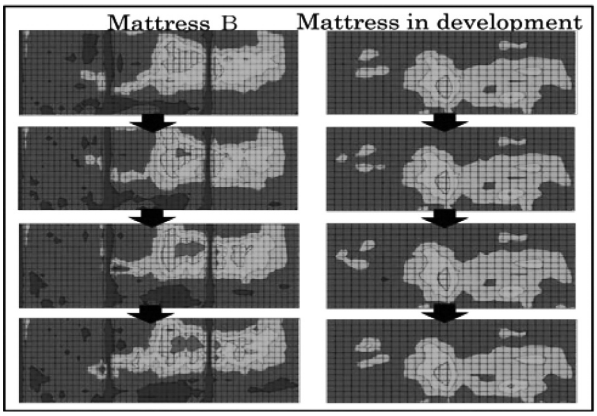

Fig. 7. Body pressure dispersal comparison ③

4. Evaluation of Bed-to-Ambulation Activity

It is important that a patient is able to easily move or be moved on the mattress when getting out of bed, or when a care giver is moving them to a wheelchair. Stability, safety and easy mobilization are important issues for patients and caregivers. Functionality of mattress edges is also a pivotal point, where patients sit upright while getting out of bed. Easy mobilization around the bed edge can encourage patients to actively leave the bed and to prevent disuse syndromes that are caused by being bedridden. Improvement of self-support was another aim of this mattress development.

In order to achieve body pressure dispersion with maintaining easy mobilization, it is necessary to adjust the firmness of the mattress rapidly in a self-feedback fashion in conditions of lying and getting up to ambulation. **Figure 8**

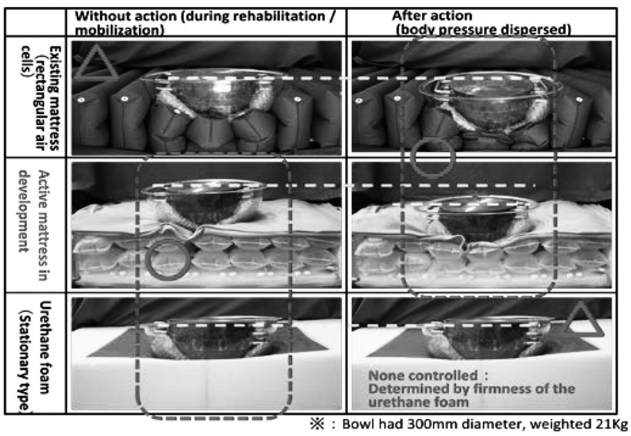

Fig. 8. State of mattress sinking

shows differences of sinking depth among the conventional mattress (upper panel), our mattress in development (middle panel) and urethane mattress (lower panel). Urethane mattress is unable to restore its sinking shape because it does not have a self-feedback control function. Although conventional air mattress has the self-feedback control function to make the mattress surface firm in times of mobilization and rehabilitation, the air cells are depressed deeply maybe because the air cell size is too large to tolerate against pin-point pressure stress. In contrast, our mattress sinks only in a minimal extent keeping the firmness of each air cell by supplying extra air via the self-feedback adjustment system. Our air cell can manage to disperse the body pressure while keeping the body lift function.

Figure 9 and **Fig. 10** show the actual comparative data of sinking depth between our mattress and the conventional mattress when loaded with graded weights (semi-spherical shape; 300mm in diameter) which resembles buttocks. The sinking depth becomes deep in a weight-dependent fashion (**Fig. 10**). The sinking depth in our mattress is significantly less than that in the conventional mattress. The sinking depth is almost twice deeper in the conventional mattress compared to our mattress[3]. In future, we would like to expand our observation by checking the smoothness of movement in bed-to-ambulation and by measuring the more precise body pressure distribution and myoelectricity in the clinical situation.

We think that our compact double-layered air cell is very useful in supporting both the patient's body pressure relief and smooth movement.

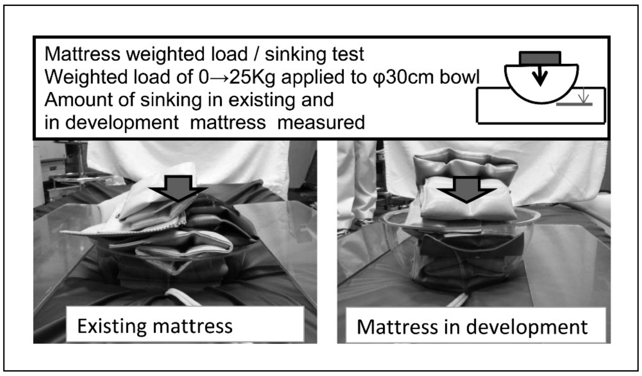

Fig. 9. Mattress sinking test

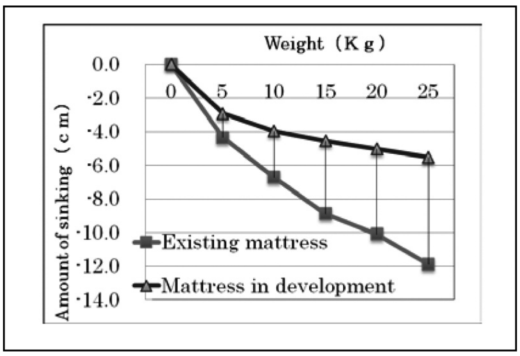

Fig. 10. Mattress sinking test measurement results

5. Conclusion

The authors have been working on the development of a new mattress which fulfils diverse aspects of clinical and patient's demands; e.g. 1) equipped with an automatically-regulated body pressure relief function, 2) supporting a comfortable sleep, 3) providing a good-practice on-bed condition for rehabilitation, and 4) accelerating safe and smooth support in bed-to-ambulation movement. The goal is still far, but the present mattress equipped with a self-feedback pressure dispersion system and specially developed double-layered compact air cells meets with the above demands, at least, in an acceptable level. The developed mattress will relieve the physical and psychological burden of caregivers. We also have to think about the economic benefits and cost performance of the present mattress. In order to encourage the widespread use of our mattress, we would like to welcome criticism and evaluation from patients, physicians, nurses, caregivers and other staffs.

Finally, we would like to express our deep gratitude to Kiyoe Harada (WOC nurse*2), Keiko Miyazaki (WOC nurse), Yukiko Tachibana (WOC nurse), Takahide Kamishima (Physiotherapist), Mitsue Uryu, (Occupational therapist) and Yuki Tajiri (Occupational therapist) of the Kyushu University Hospital for their kind cooperation in the development of the mattress.

Technical Terms

*1 Activities of Daily Living (ADL) levels C1 and C2: ADL is an index for evaluating the degree of self-reliance in a patient's daily activities.
Levels C1 and C2 are defined as follows:
C1: The patient is able to turn over unaided
C2: The patient is unable to turn over unaided

*2 WOC nurse: A nurse certified in wound, ostomy and continence care

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