Location of Patient Laid Down on Gatch Bed in order to Decrease Pressures around Abdominal Regions While Backrest Lifting - Experiment Using a Developed Patient Dummy -*

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Abstract

The purpose of this study is to propose a lying location on a gatch bed for bedridden elderly people or patients, in order to decrease pressures around the abdominal region during backrest lifting. A proposed lying location is defined as the location where an ischial tuberosity of the patient is positioned right above the rotational axis of the backrest. A patient dummy has been developed to directly measure the abdominal pressures. Experiments were carried out to verify the effects of the proposed lying location during the backrest lifting and lowering. The pressures and slipping displacements were measured using the developed patient dummy in the conventional and proposed lying location. As a result the pressures and slipping displacements were decreased in the proposed lying location.

Key words: Lying Location, Gatch Bed, Backrest Lifting, Abdominal Pressure, Patient Dummy

1. Introduction

The average percentage of the population over age 65 in seven developed countries (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States) is expected to grow from 15% to 27% in the next 50 years (1). As physical and mental health tends to deteriorate with age, the elderly need much more health care, including nursing care and other social services. In 1997 Japanese average life expectancy reached 77.19 years for men and 83.82 years for women, and Japan became a longest-lived society in the world (2). Along with the progress of aging society, the number of elderly people who required long-term care for bedridden condition, dementia, or physically weak was rapidly increased. The projected total number of the elderly needing care grew from 3.922 million in 2005 to 7.020 million in 2025 in Japan (3).

Care for those deteriorated considerably is usually implemented on the bed. In hospital beds the back-support portion (backrest) is allowed to rise for the comfort and well-being of the patient and for the convenience of health care workers. The hospital bed, which elevates a patient's head or feet by way of a crank, has been invented by Willis D. Gatch and then is called as Gatch bed (4). Fowler's position to relax and to increase comfort during eating and
other activities on the hospital bed is also realized with the Gatch bed (5).

However, when the backrest is elevated, the patient tends to slide down and flex the neck and back on the Gatch bed. Such poor body alignment and the pressures or sharing forces occurring during the backrest lifting can cause a lot of disorders, such as pressure ulcers and contractures, respiratory infections, pneumonia, and ischemia (6). Furthermore, in the poor body alignment on the bed there is no support in the lower back and that leads the back to the hyperextension. This hyperextension can cause strain on the abdominal and back muscles (6). Mimura et al. have studied the pressure ulcers due to the shear force and pressures during a bed operation (7). Tanimoto et al. have measured buttock pressures related to the Gatch bed angle (8). Grap et al. have investigated the relationship between the backrest lifting and development of ventilator-associated pneumonia (9). Patel et al. have compared hospital mattress and patient support surfaces with regard to interface pressures during the backrest lifting (10).

Some gatch mechanisms have been proposed in order to decrease the pressures and prevent development of those disorders. Mori et al. developed a backrest lifting system in which the backrest was extended upward with lifting (11). They reported that the surface pressure and the slipping displacement were smaller than those of a commercially hospital bed. Jae et al. designed a five-degree of freedom bed mechanism in order to change the posture of pressure ulcer patients and reduce sliding between the bed and the patient (12). However these mechanisms are considerably complex. They may be inappropriate for home care use.

The purpose of this study is to propose a good lying location of the patient on the conventional Gatch bed, in order to decrease pressures around an abdominal region of the patient during the backrest lifting. A patient dummy substituted for bedridden elderly person is developed to directly measure the pressures around the abdominal region, and experiments are carried out to verify the effects of the proposed lying location using the developed patient dummy.

2. Development of a patient dummy

In this study, a patient dummy has been developed in order to directly measure the pressures around abdominal region during using the Gatch bed. Figure 1 shows an appearance of the patient dummy developed in this study. The patient dummy consists of twelve segments, such as a head, chest, abdomen, hip, upper limbs, and lower limbs. The patient dummy without any drive system can be substituted for bedridden elderly people or patients who cannot move their body for themselves.

Wooden boards are used as the bases of each segment of the patient dummy. Some steel blocks are attached to the wooden boards to simulate the weight of every body part and

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Fig. 1 Developed patient dummy to measure the pressures around abdominal regions
wrapped with vinyl chloride sheets whose coefficient of friction nearly equals to that of a human skin. The back of the patient dummy is also covered with the vinyl chloride sheet. The head is made of expanded polystyrene (EPS) with steels at the core. The patient dummy has 156 cm height and 50 kg weight of Japanese average elderly woman (13). Table 1 summarizes the weights of each segment. All joints between every two segments are constructed to allow flexion and extension by hinges with little friction.

In order to evaluate the pressures around the abdominal region, a model of the abdominal cavities and vertebrae has been constructed in this study. The model is shown in Fig.2. Figure 2(a) shows the ventral cavities and vertebrae of the human body. The ventral cavities are divided into three parts, namely, thoracic cavity (TC), abdominal cavity (AC), and pelvic cavity (PC). Each internal pressure acts to each other. Their volume changes owing to the breathing or posture. Figure 2(b) shows a model of the cavities and vertebrae proposed in this study. Three cavities are supposed to be separated at the positions corresponding to the T12/L1 and L4/L5 joint of the vertebrae. In this study the forces $F_T$ and $F_A$ are measured to evaluate the internal pressures, where $F_T$ is the force acting from the cavity TC to AC, and $F_A$ is the force acting from the cavity PC to AC.

Figure 3 shows the mechanism in the patient dummy to measure the forces $F_T$ and $F_A$ around the abdominal region. The model as shown in Fig.2(b) is embodied in the mechanism. Namely, the trunk of the patient dummy is divided into three segments at the positions corresponding to the T12/L1 and L4/L5 joint. These segments are connected with two hinges in order to represent the fundamental human spine curve. L-shaped brackets are mounted on the boards substituted for vertebrae over each hinge joint. The forces $F_T$ and $F_A$ as shown in Fig.2(b) are defined as the forces acting upon the L-shaped brackets by way of the springs when the vertebrae are bent. The forces are measured using strain gauges.
(KFG-3-120-C1-11-L2M2R, KYOWA, Japan) attached on the L-shaped brackets.

3. Experiments of backrest lifting and lowering

Experiments were carried out to measure the forces acting around abdominal region and slipping displacements during the backrest lifting and lowering using the developed patient dummy. The patient dummy was laid down on a conventional Gatch bed providing for the elevation of the trunk or knees with two motors. The total length of the bed and the backrest length were 2,000 and 780 mm, respectively. The backrest and knees section could rise together up to 70 and 6 degrees, respectively. A slightly firm mattress covered with a toweling sheet was laid on the bed in the experiments. The thickness of mattress was 60 mm. The patient dummy without pajamas and a pillow was laid down on the mattress.

The experiments of backrest lifting and lowering were carried out with regard to two types of patient lying location as shown in Fig.4. Figure 4(a) shows the lying location where the position of iliac crest of the patient exists right above the position of rotational axis of the backrest. Because the backrest length in the commercial bed is relatively short, the patient tends to lie down shifting toward the feet. Therefore Figure 4(a) shows a
conventional lying location. Figure 4(b) shows the lying location where the position of ischial tuberosity of the patient exists right above the position of rotational axis of the backrest \(^{(14)}\). This lying location is proposed in this study. The backrest length has to be extended by about 300 mm so that the patient can be moved to the upper side of the backrest.

The comparative experiments were conducted between the both lying locations in order to verify an effect of the proposed lying location. Firstly, the backrest was continuously elevated from 0 to 50 degrees at a uniform speed. The forces around abdominal regions of the patient dummy were continuously measured and captured to a PC during the backrest lifting. Secondly, after the backrest stopped, the slipping displacements of the patient dummy and the mattress were measured at 50 degrees of backrest angle. Thirdly, the backrest was continuously lowered from 50 to 0 degrees at a uniform speed. Similarly, the forces were measured and captured to the PC during the backrest lowering. Finally, after the backrest stopped, the slipping displacements of the patient dummy and the mattress were measured at 0 degrees of backrest angle. These procedures were repeated three times each lying location. The slipping displacement of the patient dummy was measured by the difference of the position of ischial tuberosity before and after lifting. The displacement of the mattress was measured by the difference of the cranial bed edge.

To verify the slipping displacements of the patient dummy, they were measured for the real and healthy female elderly aged 65. Her weight and height were 55kg and 154cm close to the patient dummy. The measurements were repeated three times of the backrest lifting and lowering in each lying location. Written informed consent was obtained from her, and these measurements were conducted in accordance with the Helsinki Declaration.

4. Result

Figure 5 shows the postures of the patient dummy when the backrest stopped at the Gatch up angle 50°. Figure 5(a),(b) show the cases of the conventional lying location and

\[ \text{(a) Conventional lying location} \]

\[ \text{(b) Proposed lying location} \]

Fig. 5 Postures of the patient dummy during backrest lifting (Gatch up angle 50°)
the proposed lying location, respectively. It is recognized that the curvatures of neck and abdomen in the conventional lying location become large compared with those in the proposed lying location. It is suggested that the curvatures become a cause of increasing the abdominal pressure.

Figure 6 shows the comparisons of the slipping displacements in the conventional and proposed lying location after the backrest lifting and lowering. The vertical axis indicates the average of the slipping displacements. Figure 6(a) illustrates the slipping displacements of the patient dummy. A couple of bars in the left and right side in this figure indicate the slipping displacements after the backrest lifting and lowering, respectively. The white and gray bars correspond to the case of the conventional and proposed lying location, respectively. As shown in this figure, the slipping displacements in the conventional lying location become 46.3 and 36.7 mm, after the backrest lifting and lowering, respectively. On the other hand, in the proposed lying location they become 7.5 and 10.0 mm. It is found that the slipping displacements of the patient dummy are much improved in the proposed lying location. Figure 6(b) similarly illustrates the slipping displacements of the mattress. Also in the case of the mattress it is shown that the slipping displacements are much improved from 18.7 to 0 mm and from 33.3 to 5 mm after the backrest lifting and lowering, respectively.

In the case of the real female elderly, her average slipping displacements in the conventional lying location became 56.5 and 30.0 mm, after the backrest lifting and lowering, respectively. Their values in the proposed lying location became 10.0 and 7.5 mm. The slipping displacements of the mattress in the conventional location became 12.4 mm, 30.0 mm, and in the proposed location became 2.5 mm, 7.5 mm. Their values were rather near to those of the patient dummy. In one of the other studies (15), the slipping displacements of the head were 49 mm or 46 mm at 75° backrest lifting in the conventional lying location. Their values were of the same order of length as those of the patient dummy although the measuring methods or conditions were not same as those in this study. It is concluded that the patient dummy in this study can substitute for an elderly person.
Figure 7 shows the relationship between the backrest angle and the forces measured by the patient dummy. The forces are the average of data obtained from three repetitions. The horizontal axis indicates the backrest angle during the backrest lifting or lowering vs. the vertical axis the forces acting around the abdominal region. Figure 7(a) indicates the result in the case of the conventional lying location. The forces are increased and decreased with the backrest angle. The forces of the abdominal region are increased rapidly after the backrest angle becomes about 30 degrees during the backrest lifting. The force of abdominal region exceeds 90 N after reaching 50 degrees of the backrest angle. Based on the average abdominal circumference 85cm of Japanese elderly woman\(^{13}\), the abdominal cross section area can be estimated at approximately 570cm\(^2\). Supposing the internal section area of abdomen is 500cm\(^2\), the force 90N could be converted into the pressure 13.5mmHg. The normal intra-abdominal pressure (IAP) is defined as the range from 5 to 7mmHg\(^{16}\). The IAP above 12mmHg is regarded as abdominal hypertension (IAH) which becomes a cause of organ dysfunction. Consequently, it is concluded that the force 90N is rather large for human abdomen.

In contrast, the forces around abdominal region in the proposed lying location are almost not applied as shown in Fig. 7(b). It is obvious that the pressures around the abdominal region are decreased due to the proposed lying location.

5. Conclusion

In this study, the lying location on the Gatch bed is proposed to decrease the pressures around abdominal region during backrest lifting and lowering. In order to verify the effect of the proposed lying location, the patient dummy has been developed to directly measure the pressures around abdominal region. The pressures around the abdominal region and the slipping displacements of the patient dummy and mattress are measured during backrest lifting and lowering. The results are summarized as follows;

(1) The patient dummy developed in this study is substituted for bedridden elderly person and can be used to investigate the mechanics of the patient on the Gatch bed.
(2) The patient lying location has been proposed where the position of ischial tuberosity of the patient exists right above the position of rotational axis of the backrest. The backrest length has to be extended by about 300 mm so that the patient can be laid down on the proposed lying location.

(3) The slipping displacements of the patient dummy and mattress are decreased by laying the patient on the proposed lying location.

(4) The pressures around abdominal region of the patient are increased during backrest lifting in the conventional lying location, while they are almost not applied in the proposed lying location.

References


