



Visualization of the Load on the Human Body and Mechanical Analysis of Injury Mechanism Caused by the Posture during da Vinci Surgery

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introduction

- In da Vinci surgery using a surgical support robot, which is a minimally invasive surgical procedure, it is required to maintain a special posture (Trendelenburg position).
- Surgical patients are forced to stay in the same body posture for a long time. There is a risk of developing local pressure ulcer and peripheral neuropathy^{1,2)}.



Trendelenburg position

Countermeasures against injury risk during surgery

- The choice of the posture fixation method is judged at each clinical site, and the load on the human body is not quantified at present.
- Previous studies have compared postural fixation methods based on the amount of movement measured before and after surgery³⁾. However, this method does not fully elucidate the burden on the human body in Trendelenburg position is sufficiently clarified.

The purpose of this study

We aim to mechanical analysis of injury mechanism caused by the posture during da Vinci Surgery. We measure body pressure distribution, skin strain and motion analysis, and investigate the load on the human body in Trendelenburg position.

Materials & Methods

Subject

The experiment was conducted with eight healthy men in their 20s and 30s as subjects.

Detail of subject

Subject	Age	Height [m]	Weight [kg]
1	24	1.67	65
2	23	1.73	62
3	22	1.70	70
4	23	1.75	70
5	24	1.80	59
6	34	1.67	65
7	27	1.68	61
8	25	1.60	65

Experimental conditions

- Experiments were performed to simulate the surgical environment
- Subjects placed in trendelenburg position on the operating table
- At this time, we measure the back skin strain and perform motion analysis

<Simulating the surgical environment>

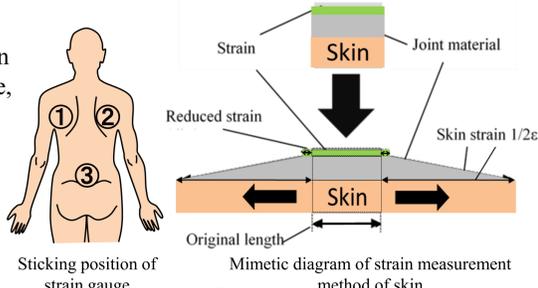
We placed the subjects in the 30° trendelenburg position for 2 minutes. Also, the experiment simulated the actual prostate surgery used da Vinci in the operating room of this university hospital. Furthermore, we measured each with and without the head and neck protection device used by this Yamanashi University Hospital.

<Trendelenburg position>

Subjects placed in lithotomy position (the position involves the positioning of an individual's feet above or at the same level as the hips) on the operating table. After that, we tilted the operating table at a constant speed and placed the subjects in the trendelenburg position. The subjects was kept in trendelenburg position for a certain period of time and then placed in lithotomy position again.

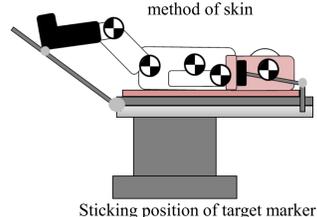
<Skin strain measurement>

The skin strain was measured using a strain gauge at three points: ①left shoulder blade, ②right shoulder blade, and ③sacrum, where body pressure is likely to be concentrated when the bone is in a supine position.



<Motion analysis>

The target markers, which are the tracking points in motion analysis, were stuck to a total of five points: head, shoulders, fifth rib, waist, knees.

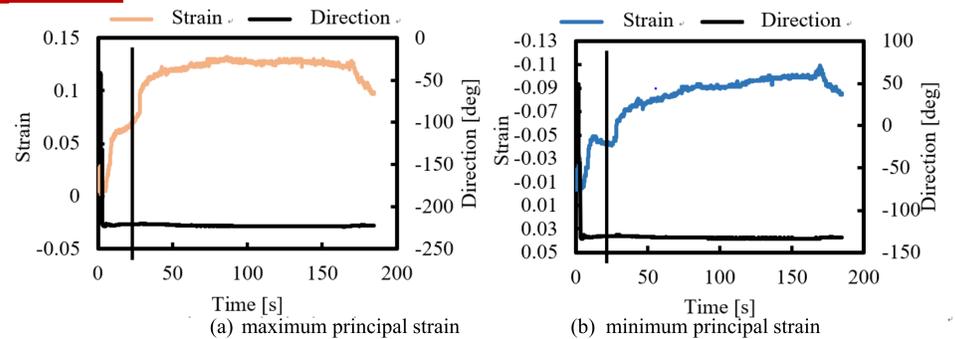


Sticking position of target marker

Results & Discussion

The result of the subject 4 is shown as a representative example. The line in the figure shows the time when the angle of the operating table reaches 30°.

Skin strain

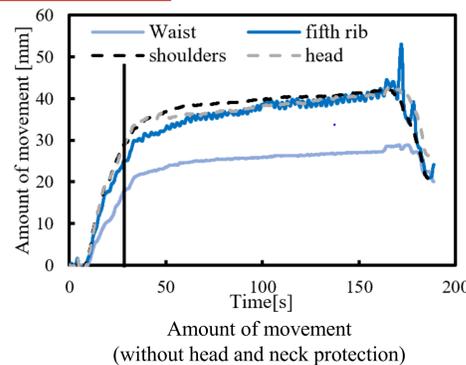


Principal strain amount and direction (position ①, subject 4, no protector)

- It became clear that the maximum principal strain and the minimum principal strain tended to increase in proportion to the angle until the angle of the operating table reaches 30°.
- The maximum principal strain and the minimum principal strain are orthogonal with opposite signs.

Since shear strain is a cause of skin damage, we quantitatively show the load on the skin due to the posture during surgery.

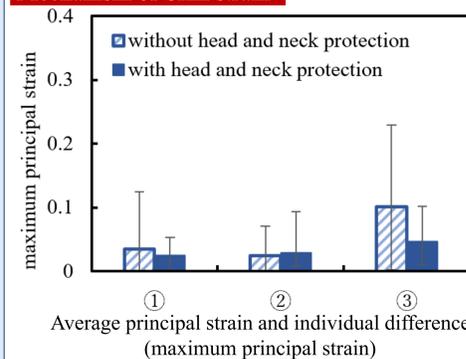
Motion analysis



- It became clear that the amount of movement tended to increase in proportion to the angle until the angle of the operating table reaches 30°.
- It is understood that there is a difference in movement amount at each measurement point.

Tensile strain occurs due to the difference in amount of movement. This indicates that the nerve and joint hyperextension that can cause peripheral neuropathy can occur.

Mechanism of Skin strain



- It is understood that the skin strain of the sacral region is reduced by using the head and neck protector.
- Using head and neck protection device reduces the amount of shoulder movement and reduces sacral skin strain.

the human body slips down when the operating table is tilted. At this time, since the body pressure is concentrated on the buttocks and scapula, it is considered that the skin of the sacrum and scapula is pulled. When the shoulder is supported, the difference in the amount of movement between the waist and shoulder is reduced. As a result, the sacral skin strain is thought to have decreased.

Conclusions

- It became clear that skin strain and amount of movement tended to increase in proportion to the angle until the angle of the operating table reaches 30°.
- It is inferred that shear strain occurs because the maximum principal strain and the minimum principal strain are orthogonal with the opposite sign. This shear strain is considered to be a cause of skin damage.
- The amount of movement of the human body is different for each parts, which causes tensile strain. As a result, there is a possibility that nerve extension and joint hyperextension may occur which are causes of peripheral neuropathy.

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