SHAPE OPTIMIZATION OF ELECTRICAL CONTROL-TYPE SPEAKING VALVE CONTROLLED BY NECK MYOELECTRIC SIGNAL

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ABSTRACT

We aimed to develop welfare devices for patients with phonation disorder. One of these devices is the electrical control-type speaking valve system. The conventional speaking valves have one-way valve architecture, they open when the user breathes in, and they close when user breathes out and produce voices. This type is very simple and tough, but some users feel closeness in case of exhalation without phonation. This problem is caused by its mechanism what can not be controlled by user's will. Therefore, we proposed an electrical control-type speaking valve system to resolve this problem. This valve is controlled by neck myoelectric signal of sternohyoid muscle. From our previous report, it was clarified that this valve had better performance about easy-to-breath. Furthermore, we proposed the compact myoelectric control-type speaking valve system. The new-type speaking valve was enough small to attach the human body, and its opening area is larger than that of conventional one. In this report, we described the improvement of flow channel shape by using of FEM analysis. According to the result of the analysis, it was clarified that the shape-improved speaking valve gets the low flow resistance channel.

BACKGROUND

We developed the compact control unit using of neck myoelectric signal for controllable artificial larynx (Ooe & Tercero, 2010). In our previous research, it was clarified that this unit could control on/off and pitch frequency of the electrolarynx (Ooe & Kishimoto, 2013). Especially, the on/off control had near the 100% accuracy, therefore, we conceived that this control unit can be used as another welfare devices.

The speech cannula and tracheal opening retainer (TOR) were used as spacers to prevent tracheostoma closure. Patients who use these devices are not able to vocalize because their exhalation can't vibrate the vocal cords. For these patients, the speaking valve was developed. This valve is a one-way valve that is connected to a commercial speech cannula and TOR. The valve closes during expiration; as a result, the air passes through the glottis, and vibrates the vocal cords. However, the users feel closeness in case of exhalation without phonation. This problem is caused by its mechanism that can't be controlled by their will. One of the answers for solving this problem is "an electrical control-type" speaking valve.

We choose the controllable speaking valve as one of the above-mentioned welfare devices. In our previous research, it was clarified that this valve led the easy breathing (Oe, 2014). However, this valve had disadvantages about its size and weight.

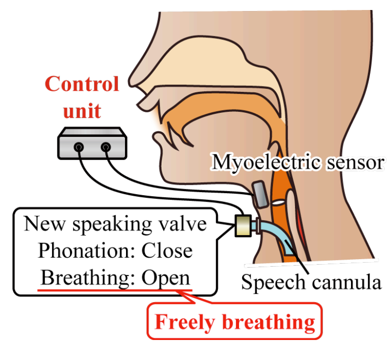

Figure 1: Schematic diagram of the compact neck myoelectrical control-type speaking valve system.

Therefore, we aimed to develop the compact speaking valve system. Figure 1 shows the schematic diagram of proposed speaking valve. In this report, the development of the new speaking valve is described. In addition, the optimization of flow channel shape by FEM analysis for reduction of the flow resistance inside the valve is reported.

CONVENTIONAL SPEAKING VALVE

The mechanism of conventional speaking valve is one-way valve with a thin plastic plate. When the valve is closed, the exhalation loses its outlet port at tracheostoma and it must pass through the narrowed trachea by cannula. Additionally, the airway of open phase, during inspiration, is very narrow and complicated shape. Therefore, its flow resistance is high. As the result, the user becomes feel choking.

Figure 2 shows the cut model of conventional speaking valve. The airflow of inspiration is drawn in figure 2 a). The measured opening area of this valve is 56mm^2. To confirm the performance of it, we used a FEM analysis. From the result of the analysis, the calculated pressure loss between inlet and outlet was 83.7Pa.

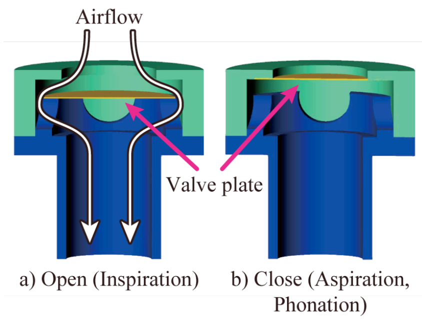

Figure 2: Cut model of conventional speaking valve and airflow of inspiration.

NEW TYPE SPEAKING VALVE SYSTEM

Concept of new type speaking valve

The first reason of these problems is that user can't control open/close of the valve by user's will. However, this was cleared by using of our myoelectrical control unit (Oe, 2014), but the prototype valve was too big and heavy to carry on. We decided the compact speaking valve shown in figure 3. The dimension of this valve is as follows: diameter: 27mm, height without actuator: 11mm.

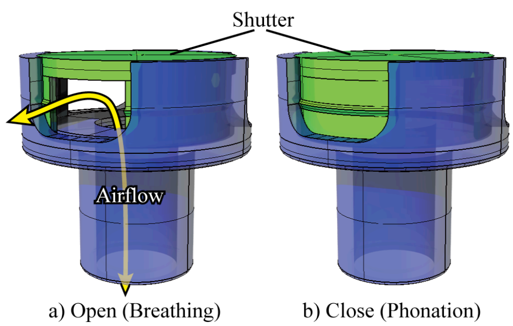

Figure 3: Concept design of new type speaking valve

Optimization of flow channel

The second reason is its flow resistance. From the result of FEM analysis of above-mentioned valve, some vortex flows were found inside the flow channel. The vortex flow is a frequent cause of bad effect for flow resistance, to delete the vortex flow, the components with function of current plate were put into the valve. These components are shown in figure 4, one of them was named "cone" and the other was named "current plate".

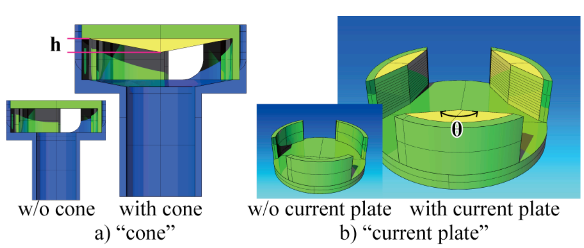

Figure 4: Schematic diagram of "cone" and "current plate".

To estimate the effectiveness of these components, the pressure loss between inlet and outlet were calculated from the results of FEM analysis.

RESULTS

The effect of "cone" and "current plate" is shown in figure 5. It was clarified that these parts could reduce the flow resistance of airway. The pressure loss of optimized valve was 71.1kPa, this was smaller than conventional one.

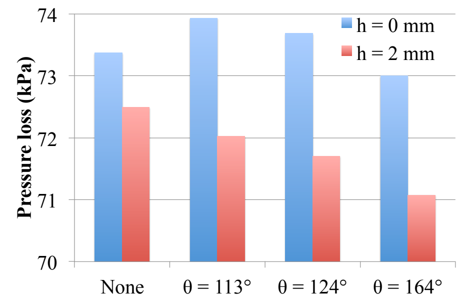

Figure 5: Pressure loss between inlet and outlet, when the height of "cone" and angle of "current plate" were changed.

CONCLUSION

The prototype neck myoelectrical control-type speaking valve was proposed. In this report, the downsized and shape optimized valve were described. This speaking valve has larger opening area than that of the conventional one, and it has simple shape flow channel. In addition, the applicable current plates made the reduction of pressure loss between inlet and outlet, their effectiveness were verified.

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