

PROPOSAL OF ELECTRICAL CONTROL-TYPE SPEAKING VALVE SYSTEM CONTROLLED BY NECK MYOELECTRIC

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ABSTRACT

We aimed to develop some welfare devices for patients with phonation disorder. These devices include the artificial larynx, the compact pump unit for speech assist and the electric control type speaking valve, all of these are controlled by our control unit using neck myoelectric signal. The conventional speaking valves have one-way valve architecture, they open when the patient breathes in, and they close when patient breathes out or produces a sound. Therefore, the patients feel closeness in case of exhalation without phonation. In this report, we described about the proposal of myoelectric control-type speaking valve, and evaluated the performance. From the result, it was clarified that this valve system was better than conventional valves.

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 artificial larynx (Ooe & Kishimoto, 2013). In this step, we aimed to develop other welfare devices controlled by this unit, proposed two devices. One of them was a speech assist compact pump (Ooe, 2013) and the other was an electric control type speaking valve. In this report, we described about the speaking valve.

The speech cannula and tracheal opening retainer (TOR) were used as spacers to prevent tracheostoma closure. Patients who use these devices can not vocalize because exhalation can not vibrate the vocal cords. This valve is a one-way valve that is connected to a commercial speech cannula or a TOR. The valve closes during expiration; as a result, the air passes through the glottis, vibrates the vocal cords, and produces a laryngeal tone. However, This valve closes during the non-vocalization phase, causes resistance during inspiration, and can make the user feel uncomfortable. Therefore, the new type speaking valve was desired by the patients.

PURPOSE

Characteristics of the ideal speech valve include

- 1) Low resistance to airflow in the opening.

- 2) Noninvasion of parts in the case of device breakage.

- 3) High-speed operation (reaction time of 300msec)

Accordingly, we designed and prepared the prototype speaking valve shown in Figure 1. This valve has an electromagnetic slider and an elastic tube for its open/close mechanism, and the elastic tube is clamped by the electromagnetic slider when the valve is closed. The elastic tube is made of silicone rubber. Its inner diameter is 12 mm and its outer diameter is 13 mm.

This elastic tube is connected to the speech cannula that is attached to the tracheostoma. This mechanism does not have any structures inside the tube; thus, there is no danger of part invasion into the trachea upon device breakage, and resistance within the tube is low. The size of this valve system is $65 \times 65 \times 160$ mm, making it easy to use at the bedside, but it is not suitable for wearing.

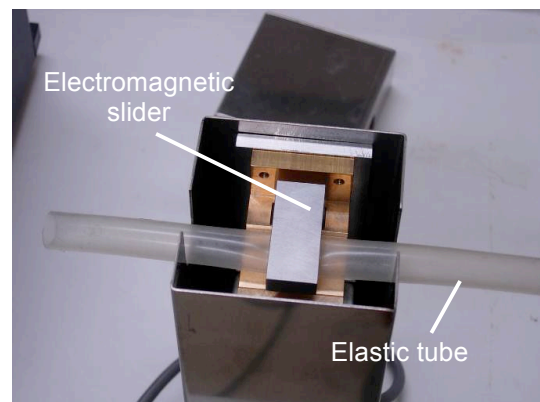


Figure 1: The electrical control-type speaking valve

METHOD

We evaluated this speech valve prototype by assessing patients for smothering feelings during use. The evaluation test was carried out using the following workflow with continuous SpO₂ and EtCO₂ monitoring:

- 1) To place the burden on the cardiopulmonary function, the test subject stepped up and down an 18-step staircase 5 times.
- 2) To monitor the stability of breathing during phonation, after stepping the stairs, the subject sat

down and read a 219-word English short story aloud.

- 3) After that, the recovery time of EtCO₂ to 40 mgHg was measured.

We chose the oxygen saturation of arterial blood (SpO₂) and the end-tidal carbon dioxide concentration (EtCO₂) as assessment criteria. These values are used as clinical markers of the smothering feeling and are suitable assessment criteria.

The measurement conditions of the control-type speech valve prototype are shown in Figure 2. The subject of this experiment was a 40-year-old man who had a closable tracheostoma by his mind. He had stenosis of the glottis and felt that breath constrictions would cause tracheostoma closure.

RESULTS & DISCUSSION

Results of evaluation of the speech valve system prototype are shown in Table 1. Compared with condition 1 (the least resistant condition), the minimum SpO₂ values were lower in other conditions and the maximum EtCO₂ values were higher in conditions 2, 4, and 5. These findings confirmed the degradation of ventilation efficiency.

This comparison revealed that the maximum EtCO₂ was lower, the minimum SpO₂ was higher, and the recovery time was shorter with the prototype valve than with the existing valve.

The prototype speech valve had the same maximum EtCO₂ value as that of condition 6. The recovery time of the prototype valve was shorter than those of conditions 2, 4, and 5. The prototype valve had low flow resistance. Additionally, since the user can control the opening and closing of this valve, misvocalization by closure insufficiency was not a problem.

From the aforementioned results, it was confirmed that this prototype speech valve system with compact control unit had a better performance than the existing speaking valve.

CONCLUSION

The prototype electrical control-type speaking valve was prepared as a new piece of equipment that operates at the time of vocalization. This speaking valve used a compact control unit, and it was confirmed that its performance was better than that of the existing speech valve. This prototype speech valve was too big for portable use but was suitable for bedside use. Upon miniaturization, the dream of a wearable high-performance speech valve system will be realized.

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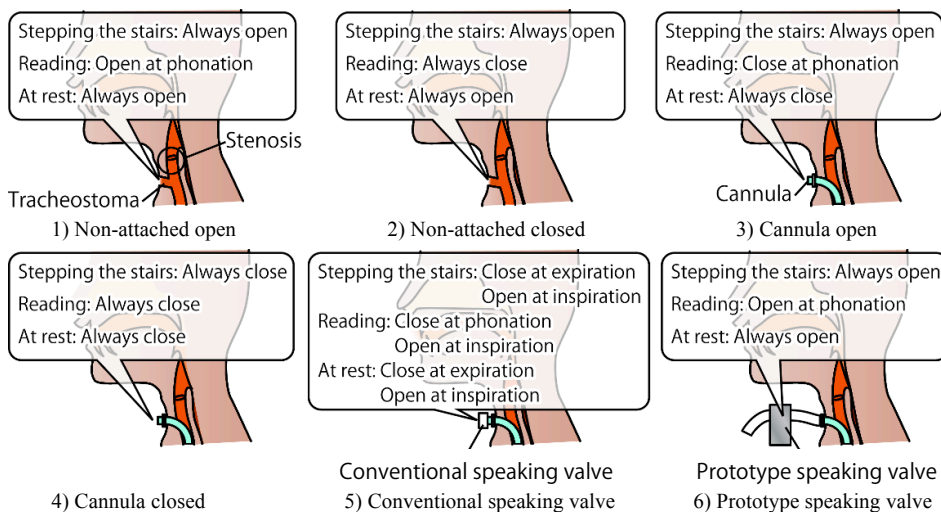


Figure 3: Measurement conditions of prototype speaking valve

Table 1: Results of evaluation for prototype speaking valve.

	Min SpO ₂ (%)	Max EtCO ₂ (mmHg)	Recovery time (sec)
1)	96	53	92
2)	86	60	168
3)	94	53	118
4)	86	58	172
5)	89	58	162
6)	94	53	128