Blowing time ratio and high-resolution manometry to evaluate swallowing function of patients with oral and oropharyngeal cancer

Komatsu, Hirokazu ; Furukawa, Tatsuya ; Iritani, Keisuke ; Tatehara, Shun ; Takahashi, Miki ; Iwaki, Shinobu ; Kakei, Yasumasa ; Hasegawa,…

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Authors: Hirokazu Komatsu MD[1], Tatsuya Furukawa MD[1], Keisuke Iritani MD[1], Shun Tatehara MD[1], Miki Takahashi PhD[2], Shinobu Iwaki PhD[2], Yasumasa Kakei MD[3], Takumi Hasegawa DDS MD[3], Masanori Teshima MD PhD[1], Hirotaka Shinomiya MD PhD[1], Naoki Otsuki MD PhD[1], Kazunobu Hashikawa MD PhD [4], Naomi Kiyota MD PhD [5], Ryohei Sasaki MD PhD [6], Masaya Akashi DDS MD [3], Ken-ichi Nibu MD PhD[1].

Affiliations:

1. Department of Otolaryngology-Head and Neck Surgery, Kobe University Graduate School of Medicine, Kobe, Japan
2. Department of Rehabilitation, Kobe University Hospital
3. Department of Oral and Maxillofacial Surgery, Kobe University Graduate School of Medicine, Kobe, Japan
4. Department of Plastic Surgery, Kobe University Graduate School of Medicine, Kobe, Japan
5. Department of Medical Oncology/Hematology, Kobe University Graduate School of Medicine, Kobe, Japan
6. Division of Radiation Oncology, Kobe University Graduate School of Medicine, Kobe, Japan

Corresponding Author: Tatsuya Furukawa, MD

7-5-1, Kusunoki-Cho, Chuo-Ku, Kobe 650-0017, Japan

Department of Otolaryngology-Head and Neck Surgery

Kobe University Graduate School of Medicine

Email: ftatsuya@med.kobe-u.ac.jp; TEL: 81+78-382-6024

Title: Blowing Time Ratio and High-Resolution Manometry to Evaluate Swallowing Function of Patients with Oral and Oropharyngeal Cancer

Abstract

Objective: The blowing time ratio, which is the ratio of the blowing time when the nostrils are open and closed, is significantly correlated with velopharyngeal pressure, not only during speech but also during swallowing. This study aimed to further evaluate the usefulness of the blowing time ratio as a screening tool to evaluate the swallowing pressure of patients treated for oral and oropharyngeal cancers using high-resolution manometery (HRM).

Methods: Ten patients treated for oral or oropharyngeal cancer were recruited for this study. Swallowing pressures at the velopharynx, oropharynx, and upper esophageal sphincter (UES) were measured using HRM. Their correlations with the blowing time ratio were analyzed.

Results: The blowing time ratio was significantly correlated with the swallowing pressures of the oropharynx (CC = 0.815, p = 0.004) and the velopharynx (CC = 0.657, p = 0.039), but not of the UES.

Conclusions: The present results further support our previous finding that the blowing time ratio is a useful screening tool

to evaluate velopharyngeal and oropharyngeal swallowing pressures in patients treated for oral and oropharyngeal cancer.

Key Words: velopharyngeal insufficiency; swallowing pressure; chemoradiotherapy; reconstruction; head and neck cancer

Introduction

In the past three decades, remarkable developments, including free flap reconstruction, induction chemotherapy, chemoradiotherapy (CRT), and intensity-modulated radiotherapy (IMRT), have provided favorable oncological outcomes in the treatment of oral and oropharyngeal cancers (1-5). While IMRT has been reported to decrease long-term dysphagia in several studies (6), swallowing difficulties have been relatively frequent in patients with advanced oral or oropharyngeal cancer treated with chemoradiotherapy as well as radical resection (7, 8). Although oncological outcomes are clearly the major goal of treatment, functional outcomes are equally important. Dysphagia leads to malnutrition, reduced quality of life (QOL), and depression. Thus, the impact of swallowing rehabilitation has been emphasized (9-11).

Currently, swallowing function is commonly evaluated by video-endoscopic examination (VE) and/or video-fluoroscopic examination (VF) (12-14). While these examinations are excellent at observing the swallowing movement as well as passing of contrast medium and foods, including aspiration, penetration, or residue, they have drawbacks such as being subjective (not objective), qualitative (not quantitative), time-consuming, radiation exposure, and require special equipment and are difficult to perform at the bedside.

Blowing time was originally developed to evaluate respiratory pressure using an around-the-house device (15). However, the blowing time differs greatly among individuals. To overcome this drawback, in 1978, Ainoda et al. proposed the idea of the "blowing time ratio," the ratio of blowing time when the nostrils are open to that when they are closed, as a simple clinical measure of velopharyngeal function in the cleft palate (16). In our previous study, we applied the blowing time ratio to evaluate postoperative speech and swallowing functions in patients with oral and oropharyngeal cancer (17). We showed that blowing time ratio significantly reflected the velopharyngeal pressure of the patients with oral or oropharyngeal cancer, not only during speech but also during swallowing, using 4-channel manometry (POLYFGRAF ID. Medtronic, Minneapolis, MN, USA).

Because of the small number of sensors in Conventional manometry, the station pull-through method is mainly used (18), in which the sensor is inserted into the cervical esophagus, pulled out 1 cm at a time, and swallowing movements are performed each time until the sensor reaches the soft palate. The results are interpreted by combining the measurements from multiple swallowing movements, and it is necessary to constantly check the direction of the pressure receptor by indirect laryngoscopy or X-ray fluoroscopy to prevent changes in the direction of the pressure receptor during withdrawal. Fox MR et al. reviewed the evolution of manometry, noting that overall diagnostic agreement between HRM and conventional manometry is high but HRM increases diagnostic yield especially in cases of functional dysphagia and pointed out that HRM should be widely used in clinical practice (19).

Recently, several studies on the correlation between high-resolution manometry (HRM) and established examinations such as video fluoroscopy in physiological and pathological swallowing functions have been reported (20-28). Encouraged by these studies, we conducted a pilot study to further investigate the usefulness of blowing time ratio as a screening tool to evaluate swallowing pressures in patients with oral and oropharyngeal cancer using HRM.

Material and Methods

Patients:

Patients who were treated for oral or oropharyngeal cancer at the Department of Otolaryngology-Head and Neck Surgery or Department of Oral and Maxillofacial Surgery, Kobe University Hospital, were recruited for this study. Patients who met the following criteria were excluded: 1) patients who were younger than 20 years old; 2) patients who could not recognize foods due to cognitive impairment; 3) patients who had neurovascular and/or neuromuscular diseases; 4) patients who had allergy to xylocaine; 5) patients who were pregnant or breastfeeding; 6) patients who had obvious swallowing dysfunction before the treatment of oral or oropharyngeal cancer; and 7) patients who had recurrent and/or metastatic disease.

Blowing Time Ratio:

Plastic bottles (500 mL) and straws (4 mm in diameter) were used for the blowing test. The distal end of the straw was placed 5 cm below the surface of the water. After several episodes of deep breathing, patients were asked to softly blow air through a drinking straw placed in bottled water with and without pinching their nostrils (Fig. 1). The duration of blowing at each session (blowing time) was recorded, and the blowing time ratio was obtained by dividing the blowing time during an open nose by the blowing time during a closed nose (17).

Swallowing Pressure:

Starlet Stealth (ST4000/20K12, Starmedical, Inc. Tokyo, Japan) was used for HRM. The diameter of the catheter was 5 mm. Twenty sensors were placed in the catheter at 1-cm intervals to simultaneously measure the circumferential pressures from -50 to

700 mmHg. The measured pressures were shown as topography imaging in real time. Prior to the manometric studies, all patients were examined using a flexible laryngoscope to confirm the absence of pharyngo-laryngeal lesions or aspiration with 3 mL of water.

Swallowing pressure was measured in the sitting position. Bilateral nasal cavities were anesthetized with 4% xylocaine using a cotton swab. The catheter was inserted through the nostril, and a flexible laryngoscope was simultaneously inserted through the contralateral nostril. The laryngoscope was removed as soon as we confirmed that the tip of the catheter was correctly inserted into the inlet of the cervical esophagus. The position of the catheter was determined by checking the waveform of topography imaging during dry swallowing and pronouncing /pa/, /pa/, and /pa/. Swallowing pressures were measured when patients were asked to swallow 3 mL of water (or thick water) (17, 20). Examinations were aborted when patients had a coughing spell due to aspiration. Patients in whom swallowing pressures were recorded five times or more were included in the statistical analysis. Levels of the velopharynx, oropharynx, and upper esophageal sphincter (UES) were determined using the waveform (Fig. 2) (29-31). The maximum swallowing pressure (MSP) and contractile integral (CI) at the velopharynx and oropharynx as well as MSP before and after swallowing and opening duration of UES were recorded at every swallowing (Fig. 3).

Statistical Analysis and Informed Consent

The Spearman's rank-order correlation coefficient test was used for statistical analysis of the correlation between the blowing time ratio, MSP, and CI. A coefficient of correlation (CC) of more than 0.6, and a p-value less than 0.05 were considered significant. This study was approved by the Institutional Review Board of Kobe University Hospital(#290091). All procedures were performed after obtaining written informed consent from the participants.

Results

Ten patients were enrolled in this study. Nine patients were male, and one was female. Their ages ranged from 35 to 78 years, with an average age of 63 years. The primary sites were the oropharynx in four patients and the oral cavity in six patients (tongue, two; buccal mucosa, three; lower gingiva, one). All patients with oropharyngeal cancer were treated with cisplatin-based concomitant chemoradiotherapy (CRT), and all patients with oral cancer were treated with radical resection followed by reconstruction using a vascularized free flap (Table 1). Healthy volunteers participated in this study as a normal control.

The average MSP and CI at the velopharynx and oropharynx and MSP before and after swallowing and opening duration of UES of the respective patients are summarized in Table 1. Scatter diagrams of the Spearman's rank-order correlation coefficient test between blowing time ratio and MSP/CI of the velopharynx and oropharynx are shown in Figure 4A-D. Strong correlations were observed between the blowing time ratio and MSP (CC = 0.815, p = 0.004) as well as CI (CC = 0.772, p = 0.009) of the oropharynx. Significant correlations were also observed between the blowing time ratio and the MSP of the velopharynx (CC = 0.657, p = 0.039). The blowing time ratio also tended to correlate with the CI of the velopharynx (CC = 0.608, p = 0.062). In contrast, no significant correlations were observed between the blowing time ratio and pre- (CC = 0.535, p = 0.111) and post-MSP (CC = 0.091, p = 0.802), or opening duration of UES (CC = -0.049, p = 0.894) (Table 2).

Discussion

In our previous study, we reported the usefulness of the blowing time ratio for the quantitative evaluation of postoperative velopharyngeal function in patients with oral and oropharyngeal cancer palates (17). Patients were asked to softly blow air through a drinking straw placed in bottled water with and without pinching their nostrils. The duration of blowing at each session (blowing time) was recorded, and the blowing time ratio was obtained by dividing the blowing time during an open nose by the blowing time during a closed nose. We showed that the blowing time ratio was significantly correlated with the score of speech intelligibility test, questionnaire for aspiration, velopharyngeal backflow, amount of food to swallow, and oropharyngeal pressure during swallowing.

Here, we conducted a pilot study to further investigate the usefulness of blowing time ratio as a screening tool to evaluate swallowing pressures in patients with oral and oropharyngeal cancer using HRM. As shown above, HRM clearly demonstrated the detailed swallowing pressures of not only the velopharynx but also the oropharynx and UES of patients treated with CRT or radical surgery followed by free flap reconstruction. In addition, as expected, significant correlations between the blowing time ratio and velopharyngeal and oropharynx swallowing pressures were observed. On the other hand, in the present study, there was no correlation with BTR for pre- and post- MSP and UES duration time. This may be because the BTR itself is mainly defined by the movement of the soft palate, which reflects the function of the velopharynx and oropharynx. Since patients with hypopharyngeal cancer or cervical esophageal cancer were not included in this study, it is assumed that the UES function of patients is close to normal since the UES is not strongly affected by the treatment.

Although HRM is less invasive than video fluoroscopy in terms of exposure to radiation, HRM requires dedicated equipment that does not prevail today. However, the blowing time ratio can be performed with daily commodities and is easy to perform at the bedside or outpatient clinic.

In the previous study, there was a significant correlation between blowing time ratio and oropharyngeal pressure during swallowing (correlation coefficient 0.506; p = .024) (17).These results further support our previous study reporting the usefulness of the blowing time ratio to evaluate the insufficiency of velopharyngeal closure in patients with oral or oropharyngeal cancer , as a similar correlation was found in a smaller number of patients in the present study.

Based on the results, we may consider that patients with low BTR have decreased function of the velopharynx and oropharynx and should consider swallowing rehabilitation and surgical treatment to strengthen these areas.

This study has several limitations. First, the number of normal volunteers and patients with oral and oropharyngeal cancers was quite small. In addition, the treatments for these patients were heterogeneous, and the types of surgery were different. Thus, we could not draw definitive conclusions from the present study. Currently, we are conducting a multi-institutional longitudinal prospective study on the swallowing function of patients with oral and pharyngeal cancer using HRM and blowing time ratio. This study will further demonstrate the roles of HRM and blowing time ratio in evaluating swallowing function, planning a rehabilitation program, considering surgical procedures such as laryngeal suspension, cricopharyngeal myotomy, and pharyngeal flap, and evaluating the effects of rehabilitation and/or these surgical procedures on the treatment of swallowing difficulties in patients treated for oral and oropharyngeal cancer.

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Disclosure Statement

The authors have no conflict of interest related to this article to be disclosed.

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Legends of Figures and Tables

Figure 1. Blowing time ratio.

Patients were asked to softly blow air through a drinking straw placed in bottled water with and without pinching their nostrils. A: blow without pinching nostrils; B: blow with pinching nostrils; C: plastic bottles of 500 mL and straws of 4 mm in diameter used for the blowing test. The distal end of the straw was placed 5 cm below the surface of the water.

Figure 2. Levels measured by high-resolution Manometry

Levels of the velopharynx, oropharynx, and upper esophageal sphincter (UES) were determined using the waveform.

Figure 3. Sites and timing measured by high-resolution manometry

A: velopharynx; B: oropharynx; C: pre-swallowing upper esophageal sphincter (UES); D: post-swallowing UES; and E: opening duration of UES.

Figure 4. Scatter diagrams of Spearman's rank-order correlation coefficient test between blowing time ratio and maximum swallowing pressure (MSP)/ contractile integral (CI) of velopharynx and oropharynx

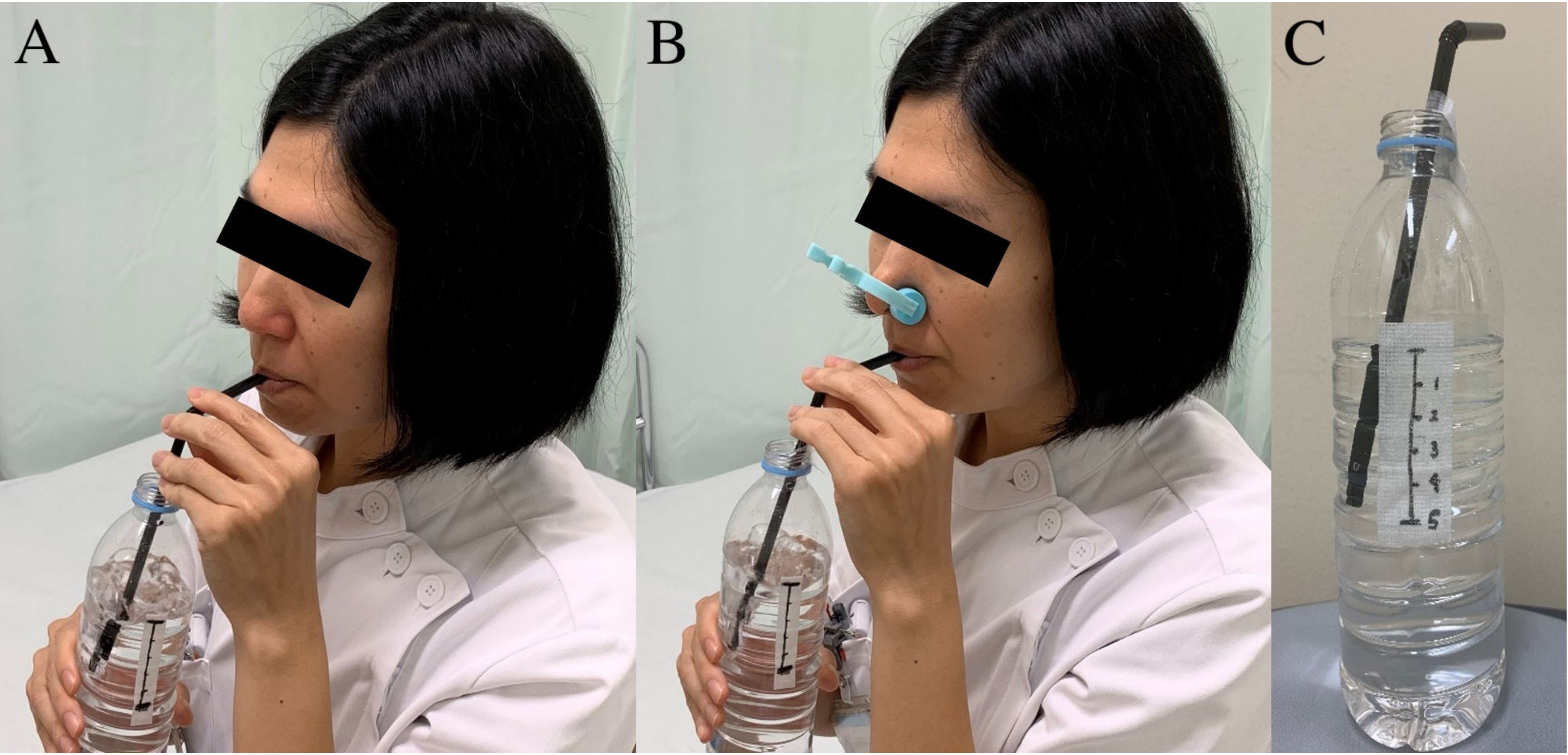
CC, correlation coefficient; P, P-value

Table 1. Swallowing pressures at the velopharynx, oropharynx, and upper esophageal sphincter.

MSP, maximum swallowing pressure; **CI**, contractile integral; **UES**, upper esophageal sphincter

Table 2. Correlations between the blowing time ratio and swallowing Pressures.

MSP, maximum swallowing pressure; **CI**, contractile integral; **UES**, upper esophageal sphincter.


A
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1
2
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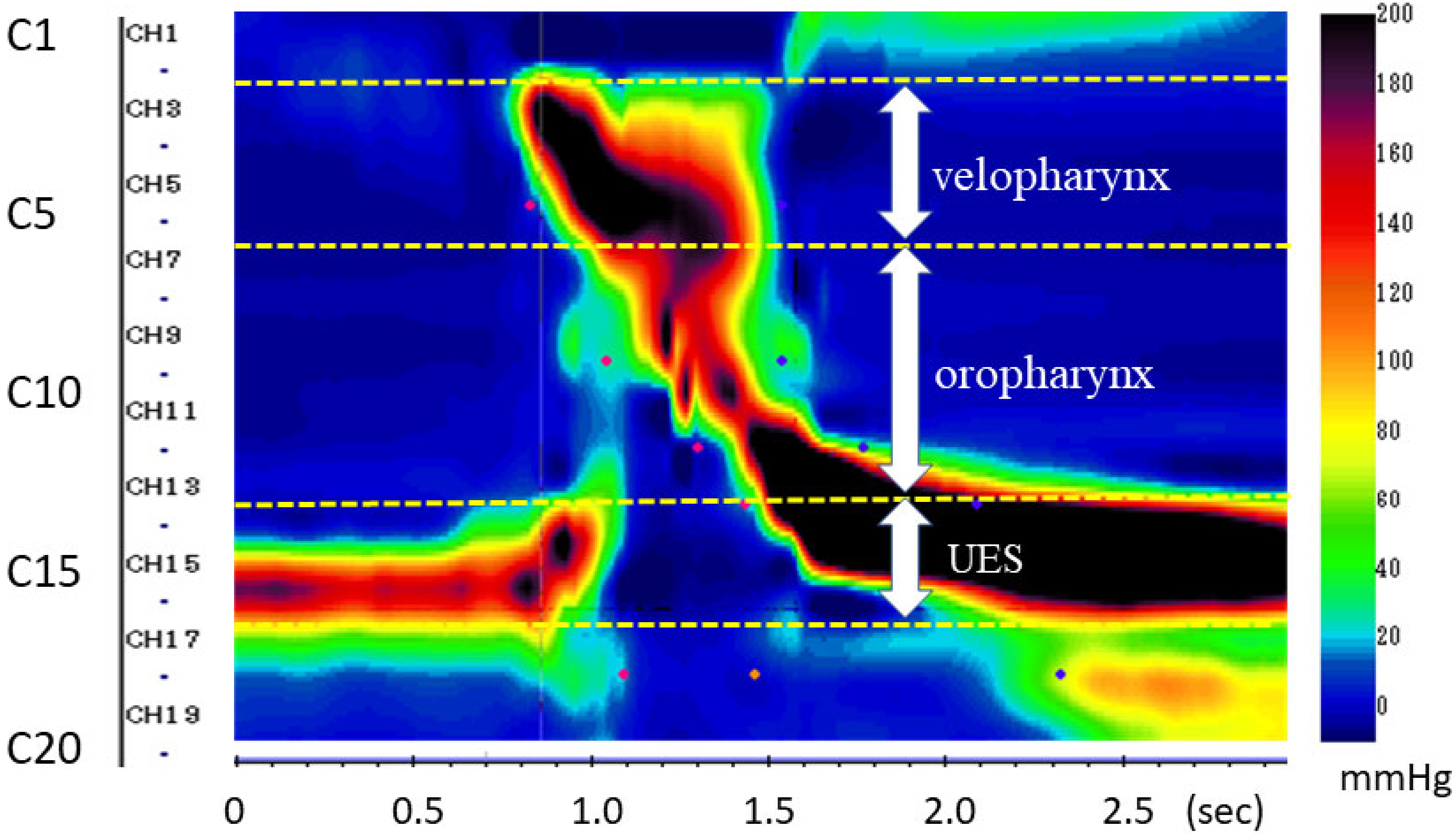
5



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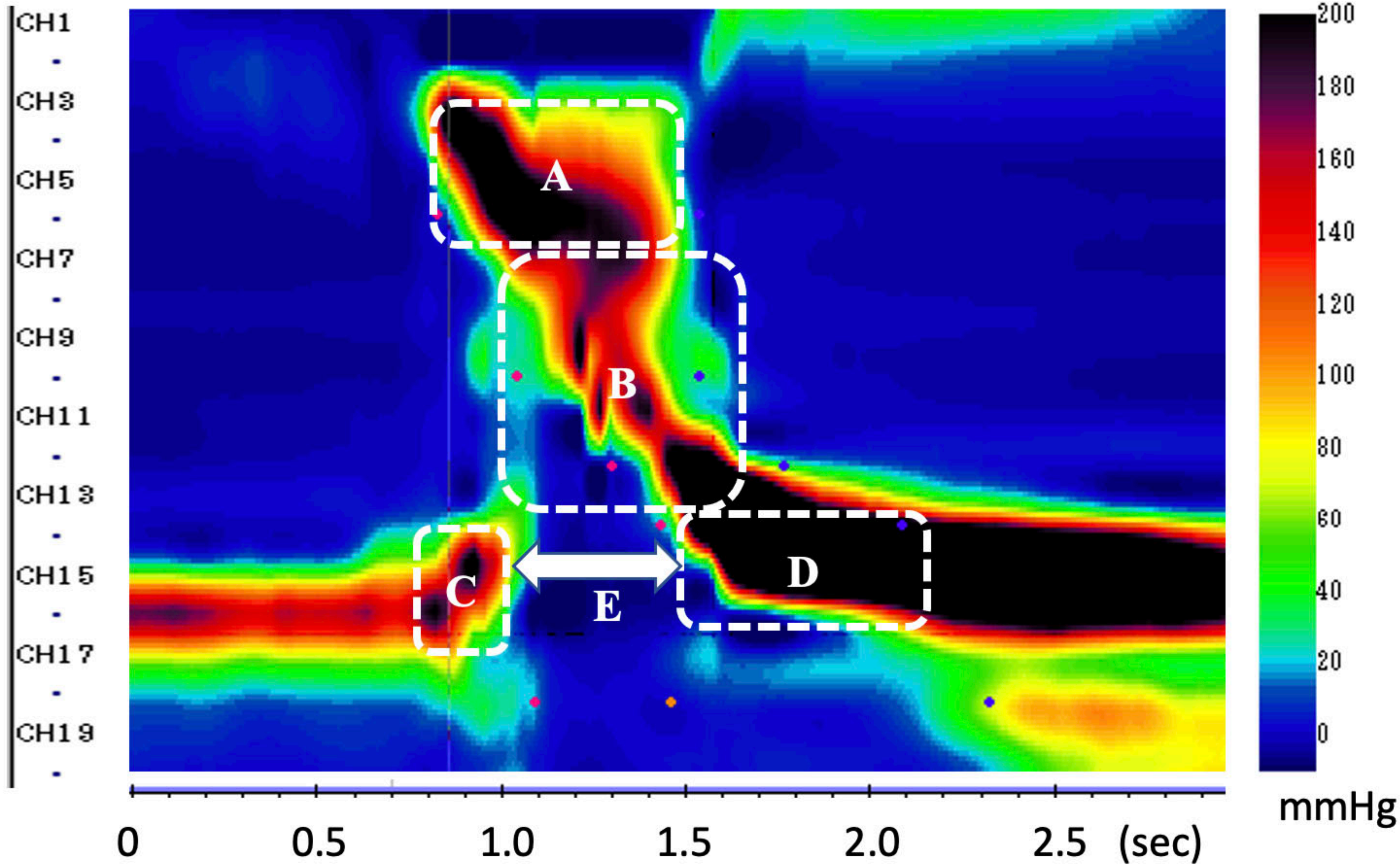
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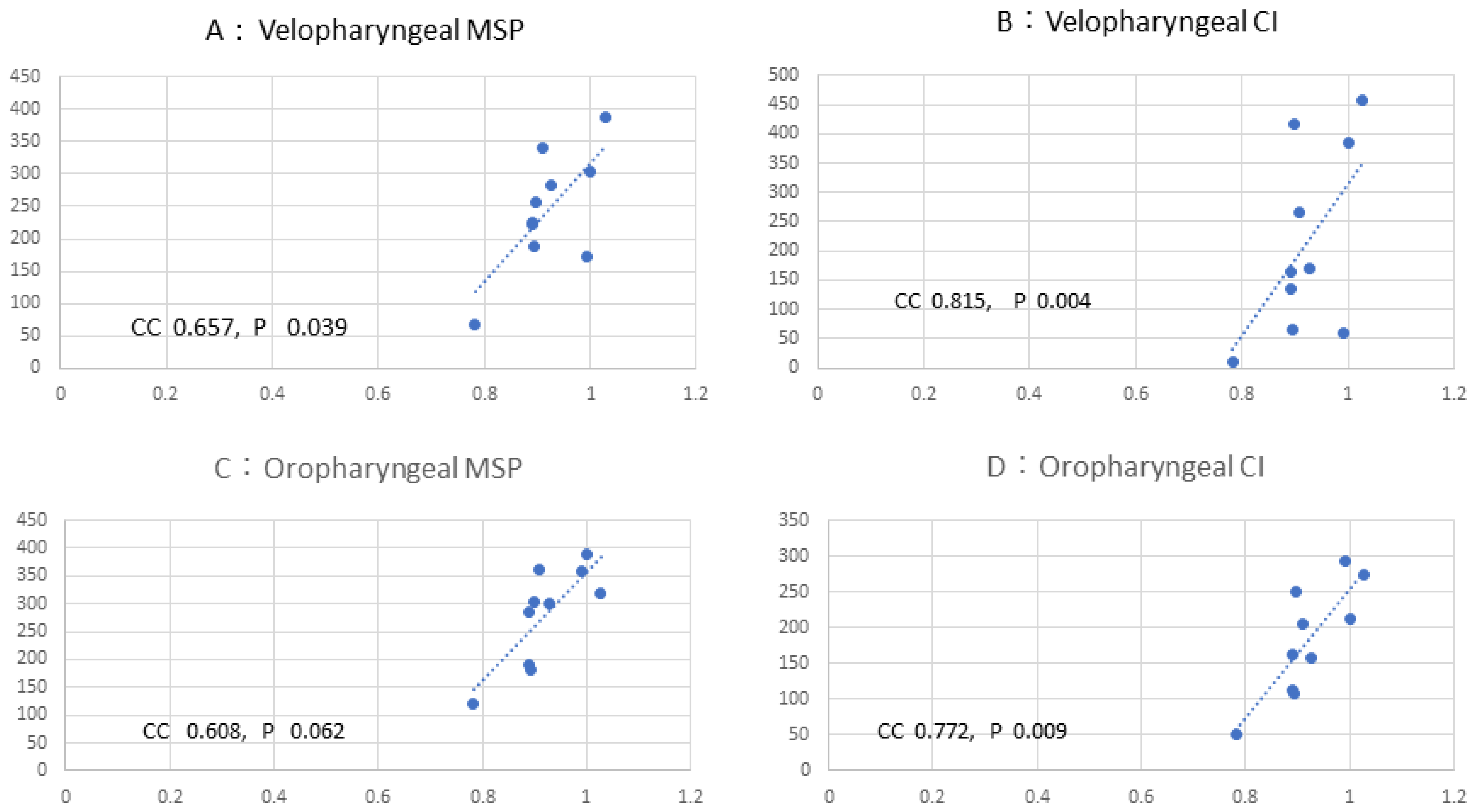
A： Velopharyngeal MSP
450
400
350
300
250
200
150
100
50
0
CC 0.657, P 0.039
0
0.2
0.4
0.6
0.8
1
1.2
B：Velopharyngeal CI
500
450
400
350
300
250
200
150
100
50
0
CC 0.815, P 0.004
0
0.2
0.4
0.6
0.8
1
1.2
C：Oropharyngeal MSP
450
400
350
300
250
200
150
100
50
0
CC 0.608, P 0.062
0
0.2
0.4
0.6
0.8
1
1.2
D：Oropharyngeal CI
350
300
250
200
150
100
50
0
CC 0.772, P 0.009
0
0.2
0.4
0.6
0.8
1
1.2

				Blowing Time			Velopharynx		Oropharynx		Upper Esophageal Sphincter		
	Age	Sex	Primary	open (sec) (SD)	closed (sec) (SD)	Ratio (Open/Closed) (SD)	MSP (mmHg) (SD)	CI (mmHg/s/cm) (SD)	MSP (mmHg) (SD)	CI (mmHg/s/cm) (SD)	Pre Peak Pressure (mmHg) (SD)	Post Peak Pressure (mmHg) (SD)	Opening Duration (msec) (SD)
1	27	M	volunteer	33.89 (2.73)	30.27 (0.16)	1.12	299.73 (25.30)	229.66 (24.18)	230.75 (19.15)	163.07 (40.58)	219.76 (66.73)	649.85 (51.66)	46.7 (4.20)
2	37	M	volunteer	30.39 (3.34)	32.62 (1.84)	0.932	332.35 (42.90)	226.85 (49.64)	479.15 (59.57)	215.11 (45.21)	276.76 (89.42)	687.01 (31.54)	23.13 (4.51)
3	26	M	volunteer	41.00 (2.00)	45.00 (1.00)	0.911	284.2 (17.55)	235.95 (52.54)	291.68 (58.21)	146.35 (29.82)	182.3 (22.29)	586.85 (68.93)	46.33 (6.13)
4	69	M	buccal mucosa	64.37 (9.81)	62.63 (12.82)	1.028	389.25 (22.17)	456.79 (47.81)	318.85 (48.80)	273.54 (56.58)	298.79 (21.94)	577.71 (38.88)	65.6 (2.76)
5	78	M	lower gingiva	19.37 (1.33)	21.57 (1.97)	0.898	256.36 (23.73)	416.29 (50.70)	304.79 (127.83)	250.33 (68.04)	89.06 (24.19)	120.25 (22.99)	46.5 (7.39)
6	76	M	buccal mucosa	29.67 (0.94)	32.00 (2.45)	0.927	283.34 (28.52)	169.86 (17.44)	301.93 (9.36)	158.51 (13.44)	353.19 (27.34)	703.67 (60.34)	36.4 (1.80)
7	62	M	tongue	20.33 (3.09)	26.00 (2.94)	0.782	66.57 (28.28)	9.69 (9.75)	121.29 (14.26)	50.87 (21.44)	129.36 (53.96)	518.97 (135.81)	60.7 (12.25)
8	77	M	buccal mucosa	5.63 (0.58)	6.30 (0.94)	0.894	187.44 (44.47)	64.60 (33.13)	181.11 (20.96)	109.02 (28.45)	468.44 (65.71)	581.97 (187.02)	56.75 (6.50)
9	35	F	tongue	132.97 (26.59)	134.07 (8.46)	0.992	171.3 (39.59)	59.06 (27.25)	358.82 (72.02)	292.7 (41.88)	369.3 (73.18)	487.97 (20.21)	51.6 (7.90)
10	55	M	oropharynx	49 (0.00)	55 (0.00)	0.891	225.08 (30.52)	136.44 (20.72)	283.99 (127.27)	162.03 (19.69)	248.84 (74.15)	571.79 (95.29)	41.5 (7.79)
11	52	M	oropharynx	56 (0.00)	56 (0.00)	1.00	304.32 (5.33)	384.44 (11.63)	388.72 (38.42)	212.84 (19.54)	477.4 (39.72)	592.86 (23.32)	34 (2.28)
12	55	M	oropharynx	49 (0.00)	55 (0.00)	0.891	222.48 (24.44)	164.95 (8.60)	191.92 (37.03)	111.75 (15.15)	205.4 (36.41)	593.02 (100.72)	38.67 (5.76)
13	67	M	oropharynx	30 (0.00)	33 (0.00)	0.909	339.55 (11.54)	266.17 (52.98)	362.67 (34.31)	206.2 (33.01)	130.45 (26.02)	295.02 (69.76)	50 (6.27)

Site	Parameter	Correlation Coefficient	*P*-value
Velopharynx	MSP	0.657	0.039
	CI	0.608	0.062
Oropharynx	MSP	0.815	0.004
	CI	0.772	0.009
UES	pre-MSP	0.535	0.111
	post-MSP	0.091	0.802
	Opening Duration	-0.049	0.894