Saturation of Percutaneous Oxygen Decreases with Meal Consumption in Patients with Acute Pneumonia

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Objective: This study aimed to investigate how respiratory status may be affected during meal consumption in patients with acute pneumonia, mainly aspiration pneumonia, using percutaneous oxygen saturation (SpO_2) and pulse rate (PR) measurements.
Methods: We recruited 44 inpatients at the Towada City Hospital and divided them into 'pneumonia' and 'control' groups. Generalized linear mixed effects model was used for analysis. The pneumonia group comprised 22 patients (mean age 81.2 ± 7.0 years, body mass index [BMI] 21.1 ± 4.0 kg/m^2) with 1–3 points A-DROP scores. The control group comprised 22 patients (mean age 80.5 ± 4.9 years, BMI 20.9 ± 2.9 kg/m^2) with no obvious respiratory diseases. SpO_2 and PR were measured 30 min before, during, and 30 min after meals.
Results: SpO_2 was significantly lower during meals in the pneumonia group (−1.60%; 95% confidence interval = −2.76 to −0.44). There were no significant changes in PR during or after meals in the pneumonia group.
Conclusions: This study suggests pneumonia may worsen respiratory status during meal intake. Patients with pneumonia may be unable to eat adequately due to worsened oxygenation during meals, even in the absence of aspiration. Therefore, it is important to observe whether there is a decrease in respiratory status during meals.

Key words: dysphagia, oxygen saturation, pneumonia, pulse rate, respiratory status

INTRODUCTION

Swallowing function declines with age; thus, it is becoming increasingly important to devise ways to maintain oral intake, especially in Japan's aging society [1]. Moreover, the prevalence of dysphagia is higher in the elderly population, causing aspiration pneumonia [2]. Early initiation of oral intake is a favorable prognostic factor in patients with aspiration pneumonia [3, 4]. However, in some cases, patients with aspiration pneumonia have poor respiratory status and are unable to consume food orally. In a previous study, we compared the presence or absence of laryngeal penetration using videoendoscopic examination of swallowing function and the 13 items on the Kuchikara Taberu Balance Chart and found that respiratory status, posture, and chewing were the three most important factors for eating [5]. Of the three factors, the effect of respiratory diseases, such as pneumonia, on breathing during meals has not been reported. Chapma *et al.* reported that percutaneous oxygen saturation (SpO_2) decreased to 85% during meals in a 25-year-old woman with spinal kyphosis; however, oxygen therapy improved SpO_2 and dysphagia, suggesting that dysphagia may be a sign of hypoxemia [6]. Therefore, we hypothesized that the condition of patients with respiratory disorders is further aggravated while eating, which may be one of the factors that prevent them from eating.

Factors used to assess respiratory status at the bedside are SpO_2 and pulse rate (PR). Many reports have shown the relationship between SpO_2 and aspiration during meals in patients with chronic obstructive pulmonary disease (COPD), acute stroke, neurogenic dysphagia, and cerebral palsy [7–17]. Ramsey *et al.* reported that a decrease in SpO_2 of 2% or more while swallowing may be predictive of aspiration in patients with acute stroke [14]. In contrast, Leder reported that aspiration status during swallowing examination did not result in an obvious decrease in SpO_2 [18]. Regardless, the issue of whether the decrease in SpO_2 is due to aspiration or not remains controversial. Colodny *et al.* also reported an increase in PR during meals and a decrease after meals in elderly patients in a nursing home [19] Similar results were reported by Leder *et al.* in hospitalized patients [18]. However, no follow-up studies on respiratory status during meals in patients with acute pneumonia have been reported to date.

In this study, we aimed to investigate how the respiratory status of patients with acute pneumonia, mainly

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Table 1 Clinical Characteristics: Pneumonia and Control groups

	Pneumonia group	Control group	p value
n (Male/Female)	22 (17/5)	22 (10/12)	0.06
Mean age (years)	81.2 ± 7.0	80.5 ± 4.9	0.67
Mean BMI (kg/m^2)	21.1 ± 4.0	20.9 ± 2.9	0.88
Mean mealtime (min)	23.1 ± 5.0	21.1 ± 11.1	0.45
Received feeding assistance(%)	6 (27.2)	1 (4.5)	

aspiration pneumonia, is affected during meals, using SpO_2 and PR measurements.

MATERIALS AND METHODS

Patients

Patients with acute pneumonia, mainly aspiration pneumonia, admitted to our hospital between July 2020 and September 2021 were included in the study. Pneumonia was diagnosed by a general physician based on the results of blood sampling, chest radiography, chest computed tomography, and sputum culture. According to the A-DROP scoring system, patients were scored (1–3 points) on admission. The control group consisted of patients who were admitted to the hospital for reasons other than acute pneumonia during the same period and who wore a SpO_2 monitor. The patients included in the control group had no obvious respiratory or cardiac diseases and did not have dysphagia. Therapeutic intervention was provided to patients in the pneumonia group, and their respiratory status was stabilized. Thereafter, swallowing endoscopy was performed to determine whether patients could swallow, and feeding was initiated based on each patient's swallowing ability by adjusting the meal forms. There were no obvious laryngeal inflow or aspiration findings. Videoendoscopic evaluation of swallowing was performed according to the procedures outlined by the Japanese Society for Rehabilitation of Dysphagia [20]. The examiner was a physician who participated in a workshop on the evaluation of swallowing function.

Patients were excluded from the study if they were unable to swallow (judged by swallowing endoscopy) and unable to wear SpO_2 monitor, including those with obvious respiratory diseases other than pneumonia, and had stage C or higher heart failure, according to the American College of Cardiology Foundation/American Heart Association heart failure stage classification [21].

Informed consent was obtained from all patients included in the study. This study followed the principles of the Declaration of Helsinki and was approved by the Ethics Committee of the Towada City Hospital (ethics permission number 1–8) and the University of Tokyo Hospital (ethics permission number 2020068NI).

Assessment of respiratory status while eating

Data were collected 30 min before, during, and 30 min after breakfast, lunch, or dinner. SpO_2 and PR were measured noninvasively every minute by pulse oximetry, using a WEP-5258 Telemetry System (NIHON KODEN CORPORATION, Tokyo, Japan). SpO_2 monitors were attached to the non-dominant hand or foot so as not to interfere with feeding. Calories and meal forms were not standardized in this study.

Statistical analysis

The clinically meaningful outcome difference was set as a 2% decrease in SpO_2 [14], and the sample size was calculated to be 44 patients (22 in each group). Student's t-test was used for continuous variables to compare the SpO_2 and PR between patients with aspiration pneumonia and patients in the control group at 30 min before, during, and 30 min after meals. We examined whether having pneumonia affected changes in SpO_2 and PR during and after meals using a generalized linear mixed effects model with random intercept. In this model, we examined the significance of an interaction term for pneumonia and meal category to quantify the effect of pneumonia on respiratory status. $P < 0.05$ indicates a significant difference. The other independent variables included in the model were age, sex, BMI, A-DROP score, mean mealtime, and meal dependence. In the case of missing values, retesting was performed, and if values remained missing after three measurements, the data with the fewest missing values were used for that patient. All statistical analyses were performed using JMP® Pro 15 (SAS Institute Inc., Cary, NC, USA) and R version 4.0.3.

RESULTS

Characteristics

As shown in Table 1, 22 patients (mean age 81.2 ± 7.0 years, body mass index [BMI] 21.1 ± 4.0 kg/m^2) in the pneumonia group (5, 11, and 6 patients with an A-DROP score of 1, 2, and 3, respectively) and 22 patients in the control group (mean age 80.5 ± 4.9 years, BMI 20.9 ± 2.9 kg/m^2) were included in our study. There were no significant differences in age and BMI between the two groups. Six out of 22 patients in the pneumonia group received feeding assistance, compared to one in the control group. Underlying diseases in the control group were urinary tract infection, lumbar compression fracture, and others. The patients in the control group could eat in a sitting position with no problems. The mean mealtime was 23.1 ± 5.0 min for the pneumonia group and 21.1 ± 11.1 min for the control group, with no apparent significant difference between the two groups. No obvious adverse events, such as choking, were observed during the study.

SpO_2 and PR in the pneumonia group vs. control group (univariate analysis)

The results of the comparison between the pneumonia and control groups are shown in Fig. 1. There were significant differences in SpO_2 and PR between the pneumonia group and the control group 30 min before meal consumption (SpO_2: 95.0 ± 3.0% vs. 96.5 ± 2.2%; $p < 0.0001$, PR: 71.8 ± 14.6 vs. 69.3 ± 12.4%; $p < 0.01$). During meals, SpO_2 was significantly lower in the pneumonia group than in the

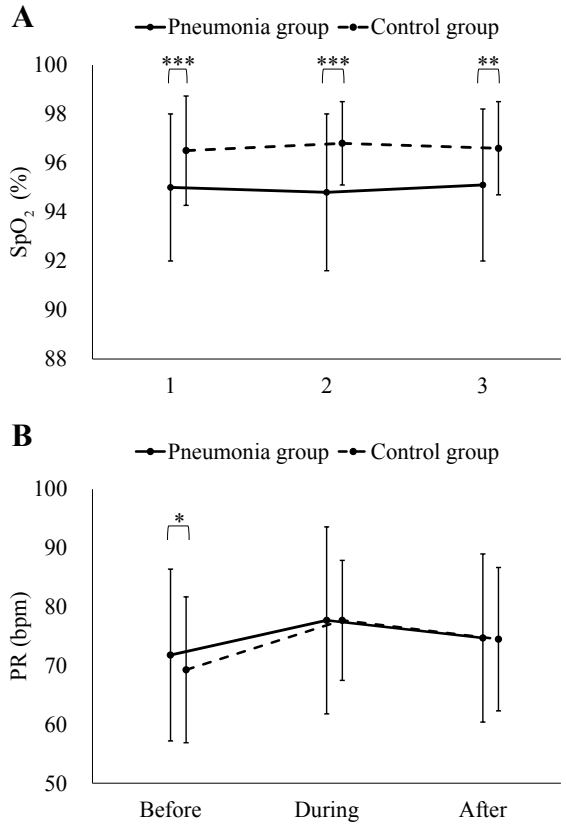

Fig. 1 Comparison of SpO_2 and PR in the pneumonia and control group: an univariate analysis
A Comparison of SpO_2 before, during, and after meal consumption between the pneumonia and control groups
Student's t-test was used for statistical analysis. The dashed line represents the control group, and the solid line represents the pneumonia group. SpO_2 during each period was significantly lower in the pneumonia group than in the control group (***$p < 0.0001$, **$p < 0.001$). SpO_2: Oxygen saturation
B Comparison of PR before, during, and after meal consumption between the pneumonia and control groups
Student's t-test was used for statistical analysis. The dashed line represents the control group, and the solid line represents the pneumonia group. PR before meal consumption was significantly lower in the pneumonia group than in the control group (*$p < 0.01$). PR during and after meal consumption was not significantly different between the pneumonia and control groups ($p = 0.95$, 0.88). PR: Pulse rate

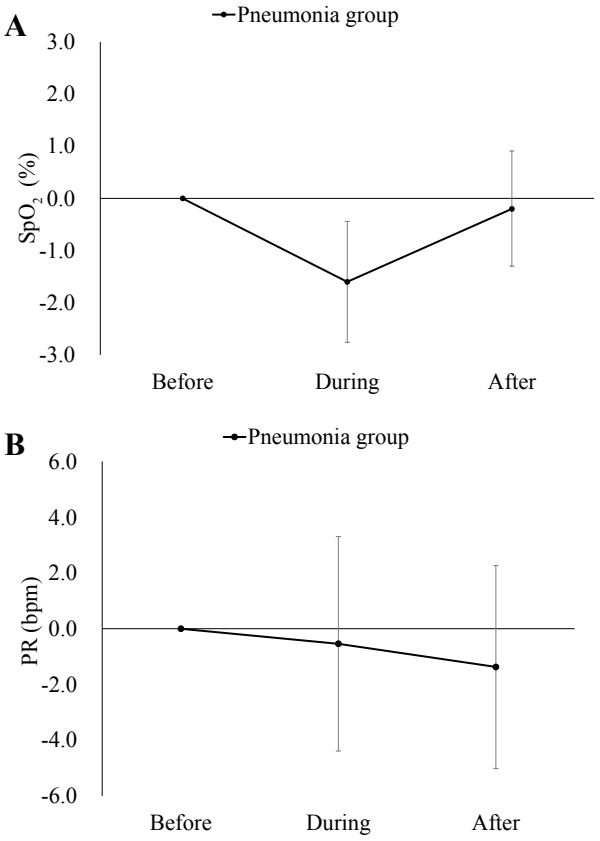

Fig. 2 Comparison of SpO_2 and PR between the pneumonia and control groups: A multivariate analysis
A Comparison of SpO_2 between the pneumonia and control groups
SpO_2 significantly decreased during meal consumption in the pneumonia group (−1.60%; 95% confidence interval [CI] = −2.76 to −0.44) but did not change significantly after the meal (−0.20%; 95% CI = −1.30 to 0.91) using a generalized linear mixed effects model with random intercept. The dashed line represents the control group, and the solid line represents the pneumonia group. SpO_2: Oxygen saturation
B Comparison of PR between the pneumonia and control groups
PR did not change significantly during and after meals in the pneumonia group (−0.54; 95% CI = −4.39 to 3.31, −1.37; 95% CI = −5.01 to 2.27) using a generalized linear mixed effects model with random intercept. The dashed line represents the control group, and the solid line represents the pneumonia group. PR: Pulse rate

control group (94.8 ± 3.2% vs. 96.8 ± 1.7%; $p < 0.0001$), but there was no significant difference in PR between the groups (77.7 ± 15.9 vs. 77.7 ± 10.2%; $p = 0.95$). Furthermore, 30 min after meal consumption, SpO_2 was significantly lower in the pneumonia group than in the control group (95.1 ± 3.1% vs. 96.6 ± 1.9%; $p < 0.001$), but there was no significant difference in PR between the groups (74.7 ± 14.3 vs. 74.5 ± 12.2%; $p = 0.88$).

SpO_2 and PR in the pneumonia group vs. control group (multivariate analysis)

The results showed that SpO_2 significantly decreased during meal consumption in the pneumonia group (−1.60%; 95% confidence interval [CI] = −2.76 to −0.44) but did not change significantly after the meal (−0.20%; 95% CI = −1.30 to 0.91) (Fig. 2A). PR did not change significantly during and after meals in the pneumonia group (−0.54; 95% CI = −4.39 to 3.31, −1.37; 95% CI = −5.01 to 2.27) (Fig. 2B).

DISCUSSION

In this study, we investigated the relationship between pneumonia and respiratory status during meal consumption in elderly patients with and without acute pneumonia by comparing changes in SpO_2 and PR 30 min before, during, and 30 min after meal consumption. SpO_2 decreased significantly during meal consumption in the pneumonia group but did not change significantly after the meal. Swallowing endoscopy showed no obvious findings of aspiration in any of the patients, and all patients were able to swallow. Although a decrease in SpO_2 was observed during meal consumption in the pneumonia group, it did not reach the 2% or greater decrease proposed by Ramsey *et al.* and Higo *et al.* [12, 22]. The change in SpO_2 during meals did not exceed 2%, which may be related to the absence of aspiration on swallowing endoscopy, suggesting that aspiration was unlikely to be the cause of the decrease in SpO_2. An important indicator of the coordination of breathing and swallowing is the pattern of respiratory phases and swallow apnea time [23]. Swallow apnea duration is the centrally controlled respiratory arrest duration that occurs during each swallow. Longer swallow apnea duration has been observed in older adults [23] and in patients with neurological diseases [24]. The possibility that apnea duration during swallowing may compete with ventilation depending on the presence or absence of respiratory disease has been discussed [25]. Since the present patient had no obvious aspiration on swallowing endoscopy, it is possible that the imbalance with this arousal was not due to an obvious aspiration during the meal and that this imbalance with arousal caused the decrease in SpO_2. In other diseases, Tamura *et al.* reported that oral intake placed a greater burden on the cardiopulmonary function in people with severe disabilities, which may help to estimate the prevalence of eating disorders [17]. It has been reported that in patients with COPD, a decrease in SpO_2 during meal consumption occurred due to aspiration and decreased alveolar arousal [10]. Teramoto *et al.* also considered that a decrease in SpO_2 may have occurred in patients with acute stroke due to dysphagia and abnormal gas exchange related to dysphagia and circulatory abnormalities in the monitored area [7].

In our study, PR increased during meal consumption and decreased after the meal in both groups, and there were no significant differences in the degrees of elevation between both groups. The increase in PR during meals in both groups may be due to a compensatory response to the exertion of hand movement, chewing, and swallowing that accompany eating. Another factor may be the physiological mechanism by which blood pressure is not well controlled in older adults, and postprandial hypotension causes blood to accumulate in the gastrointestinal tract, resulting in an increase in heart rate. The observation of no significant difference between the two groups suggests that eating and PR variability are unlikely to be related to respiratory status.

A previous study has reported an association between the presence of laryngeal influx by swallowing videoendoscopy and a higher risk of aspiration [26]. Our study suggests that, in patients with poor respiratory status, eating may further exacerbate respiratory status, even in the absence of obvious aspiration. There was no significant difference in BMI between patients in both groups. However, more patients in the pneumonia group received feeding assistance than in the control group. Kuroda *et al.* found that swallowing function may possibly decline in older adults due to a decrease in muscle strength required for swallowing [27]. The patients in our study may also suffer from frailty and sarcopenia as their activities of daily living decline, thus leading to a decline in swallowing function. If the problem is not only a decline in swallowing function but also a worsening respiratory status that causes a patient to be unable to eat, then oxygen should be administered in the short term. Diseases that cause respiratory disorders, such as pneumonia and COPD, should be identified and treated in the medium to long term. Rehabilitation intervention for declining respiratory status and oral function is also important to prevent frailty and sarcopenia.

We believe that it is highly important to carefully monitor the respiratory status of patients during meal consumption; it should be noted that there can be about a 2% measurement error in the SpO_2 monitoring results [28] and a time lag in the results of SpO_2 monitoring depending on the measurement location. The same monitors were used and measurements were taken every minute, which reduced errors in the measurement analysis results. It has been reported that it takes 77 s in fingertip measurements to reflect SpO_2 when the fraction of inspired oxygen changes and approximately 10 s in anterior forehead measurements [29]. More real-time assessments are required to evaluate changes in SpO_2 due to aspiration; SpO_2 monitoring at the site of the anterior forehead may be more appropriate and should be considered in the future.

This study had some limitations. Swallowing was not assessed in the control group, so potential dysphagia cannot be ruled out, and factors that affect pulse rate, such as atrial fibrillation, were not adjusted for. The participants were elderly patients with an average age of ≥ 80 years, and additional studies are needed to determine whether eating worsens respiratory status in relatively younger patients with pneumonia as well.

This is the first report showing an association between food intake and respiratory status in patients with pneumonia. It also supports our previous report showing an association between dysphagia and respiratory status [5]. This study suggests that the presence of pneumonia may worsen respiratory status during meal intake. Patients with pneumonia may be unable to eat adequately due to decreased SpO_2 during meals, even when aspiration is absent. Therefore, it is more important to monitor respiratory status during meals, and appropriate respiratory management may be necessary if a decline is observed.

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REFERENCES

1) Iida T, Tohara H, Wada S, Nakane A, Sanpei R, Ueda K. Aging decreases the strength of suprahyoid muscles involved in swallowing movements. Tohoku J Exp Med 2013; 231: 223–8.

2) Cabré M, Serra-Prat M, Force L, Almirall J, Palomera E, Clavé P. Oropharyngeal dysphagia is a risk factor for readmission for pneumonia in the very elderly persons: observational prospective study. J Gerontol A Biol Sci Med Sci 2014; 69: 330–7.
3) Koyama T, Maeda K, Anzai H, Koganei Y, Shamoto H, Wakabayashi H. Early commencement of oral intake and physical function are associated with early hospital discharge with oral intake in hospitalized elderly individuals with pneumonia. J Am Geriatr Soc 2015; 63: 2183–5.
4) Momosaki R, Yasunaga H, Matsui H, Horiguchi H, Fushimi K, Abo M. Predictive factors for oral intake after aspiration pneumonia in older adults. Geriatr Gerontol Int 2016; 16: 556–60.
5) Tonosaki K, Yonenaga K, Ono S, Itai S, Oyamma S, Mizuno T, *et al*. Swallowing evaluation by the Kuchikara Taberu Balance Chart and videoendscopic examination reveals that respiratory conditions, chewing, and position are strongly related to dysphagia. Odontology 2021; 109: 448–52.
6) Chapman KR, Rebuck AS. Dysphasia as a manifestation of occult hypoxemia. The role of oximetry during meal times. Chest 1991; 99: 1030–2.
7) Teramoto S, Fukuchi Y, Ouchi Y. Oxygen desaturation on swallowing in patients with stroke: what it mean? Age Ageing 1996; 25: 333–4.
8) Zaidi NH, Smith HA, King SC, Park C, O'Neill PA, Connolly MJ. Oxygen desaturation on swallowing as a potential marker of aspiration in acute stroke. Age Ageing 1995; 24: 267–70.
9) Smith HA, Lee SH, O'Neill PA, Connolly MJ. The combination of bedside swallowing assessment and oxygen saturation monitoring of swallowing in acute stroke: a safe and humane screening tool. Age Ageing 2000; 29: 495–9.
10) Wolkove N, Fu LY, Purohit A, Colacone A, Kreisman H. Meal-induced oxygen desaturation and dyspnea in chronic obstructive pulmonary disease. Can Respir J 1998; 5: 361–5.
11) Rowat AM, Wardlaw JM, Dennis MS, Warlow CP. Does feeding alter arterial oxygen saturation in patients with acute stroke? Stroke 2000; 31: 2134–40.
12) Ramsey DJ, Smithard DG, Kalra L. Early assessments of dysphagia and aspiration risk in acute stroke patients. Stroke 2003; 34: 1252–7.
13) Sellars C, Dunnet C, Carter R. A preliminary comparison of videofluoroscopy of swallow and pulse oximetry in the identification of aspiration in dysphagic patients. Dysphagia 1998; 13: 82–6.
14) Ramsey DJC, Smithard DG, Kalra L. Can pulse oximetry or a bedside swallowing assessment be used to detect aspiration after stroke? Stroke 2006; 37: 2984–8.
15) Rogers BT, Arvedson J, Msall M, Demerath RR. Hypoxemia during oral feeding of children with severe cerebral palsy. Dev Med Child Neurol 1993; 35: 3–10.
16) Morgan AT, Omahoney R, Francis H. The use of pulse oximetry as a screening assessment for paediatric neurogenic dysphagia. Dev Neurorehabil 2008; 11: 25–38.
17) Tamura F, Shishikura J, Mukai Y, Kaneko Y. Arterial oxygen saturation in severely disabled people: effect of oral feeding in the sitting position. Dysphagia 1994; 14: 204–11.
18) Leder SB. Use of arterial oxygen saturation, heart rate, and blood pressure as indirect objective physiologic markers to predict aspiration. Dysphagia 2000; 15: 201–5.
19) Colodny N. Comparison of dysphagics and nondysphagics on pulse oximetry during oral feeding. Dysphagia. 2000; 15: 68–73.
20) Swallowing Endoscopy Procedure 2021 Revised. Japanese Society of Dysphagia Rehabilitation. 201; 25: 268–280. in Japanese.
21) WRITING COMMITTEE MEMBERS, Yancy CW, Jessup M, Bozkurt B, Casey DE Jr, Drazner MH, *et al*. 2013 ACCF/AHA guideline for the management of heart failure: a report of the American College of Cardiology Foundation/American Heart Association Task Force on practice guidelines. Circulation 2013; 128: e240–327.
22) Higo R, Tayama N, Watanabe T, Nito T. Pulse oximetry monitoring for the evaluation of swallowing function. Eur Arch Otorhinolaryngol 2003; 260: 124–7.
23) Martin-Harris B, Brodsky MB, Michel Y, Ford CL, Walters B, Heffner J. Breathing and swallowing dynamics across the adult lifespan. Arch Otolaryngol 2005; 131: 762–70.
24) Hadjikoutis S, Pickersgill TP, Dawson K, Wiles CM. Abnormal patterns of breathing during swallowing in neurological disorders. Brain 2000; 123: 1863–73.
25) Britton D, Roeske A, Ennis SK, Benditt JO, Quinn C, Graville D. Utility of Pulse Oximetry to Detect Aspiration: An Evidence-Based Systematic Review. Dysphagia 2018; 33: 282–92.
26) Yonenaga K, Majima HJ, Oyama S, Ishibashi K, Tanno H. Diagnosis and evaluation of 100 dysphagia patients using videoendoscopy at a core hospital of a local city in Japan. Odontology 2017; 105: 222–8.
27) Kuroda Y, Kuroda R. Relationship between thinness and swallowing function in Japanese older adults: implications for sarcopenic dysphagia. J Am Geriatr Soc 2012; 60: 1785–6.
28) Fukushima H. Pulse oximetry — Pitfalls and solution — . Jpn. Respir. Care Rehabil. J. 2007; 17(3): 219–24.
29) Bebout DE, Asbagh NA. Detection of hypoxemia during peripheral vasoconstriction at the radial artery and various pulse oximeter sensor sites. Crit Care Med 2002; 30: A72.