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成果報告書

以脈衝式血氧定量儀偵測吞嚥障礙患者之吸入現象

Pulse Oximetry does not Reliably Detect Aspiration in Dysphagia Patients

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一、Abstract

Objective: Pulse oximetry has recently attended in dysphagia literature because of its potential in detecting aspiration in dysphagia patients. This study aimed to examine the reliability of pulse oximetry in identifying of aspiration by comparing it with videofluoroscopic swallowing study (VFSS), a gold standard of swallowing evaluation.

Design: Non-randomized prospective double blind study

Setting: Videofluoroscopic swallowing study laboratory in a teaching hospital

Participants: A total of 60 of 130 patients with dysphagia diagnosed by clinical evaluation between September and December 2002.

Intervention: Not applicable

Main Outcome Measurement: Simultaneously monitoring the arterial oxygen saturation (SpO2) when patients performing VFSS. SpO2 fall greater than 3% was defined as significant desaturation. A bolus or portion of bolus passing through the vocal cords and entering the subglottic space was defined as aspiration on VFSS. The results of pulse oximetry and VFSS were compared.

Results: There was no significant correlation between desaturation of SpO2 and aspiration on VFSS by chi-square test ($p=0.87$). The positive predictive rate of pulse oximetry in detecting aspiration on VFSS was 33.3% and the negative predictive rate was 61.1%

Conclusions: The aspiration occurred on VFSS cannot be predicted by fall of SpO2 in pulse oximetry. The application of pulse oximetry in detecting aspiration on meal needed further study

二、Introduction

Videofluoroscopic examination of swallow (VFSS) is generally regarded as the " gold standard" in the assessment of oropharyngeal dysphagia, especially in the detection of laryngeal penetration or subglottic aspiration (1-3). However, It has several unavoidable limitations. VFSS can only be performed on cooperative patients, has radiological exposure, and is a single time measurement whereas aspiration may be a variable phenomenon on feeding (4). Moreover, VFSS may over-diagnose the disorder of swallowing function since the unflavored barium could disturb deglutition ability of the patients, particularly in those who having impaired cognitive function. Various bedside clinical evaluations such as neurological examination (5-6), water swallow test (7-8), swallowing provocation test (9), and cough reflex (10) have been used in identifying or predicting aspiration. When comparing the VFSS, their prediction rate of aspiration varied from 35% to 100%. As a result, the researchers to a saturation of 50% although some errors such as motion artifact, insufficient hemoglobin, and comprised peripheral perfusion may limit its accuracy (14-15). The use of pulse oximetry to detect aspiration is based on the hypothesis that aspiration of food into the airways causes reflex bronchospasm that leads to ventilation-perfusion mismatch and oxygen desaturation (16-17). Pulse oximetry has many attractions in assessment of swallowing function if its accuracy of detecting aspiration is proved. It is noninvasive without exposure to radiation, readily portable and widely available, requires minimal patients cooperation, and provides objective quantitative measures. Moreover, it gives continue monitoring of the swallowing condition of the patients during the meal, which can be further stored and downloaded to computer for detailed analysis.

However, the reports regarding the accuracy of pulse oximetry to detect aspiration were debated. Some researchers reported there is as high as 81.5% predictive rate of pulse oximetry in defining the aspiration (18-19), but others questioned the correlation between the desaturation measured by oximetry and episode of aspiration on VFSS (20-21). The aim of the study was to characterize the relationship between oxygen desaturation and radiographically detected aspiration in an attempt to broadly define the role of pulse oximetry in the evaluation of swallowing dysfunction

三、Materials and Methods

Subjects

The study was conducted in a prospective, double blind design. Between September and December of 2002, approximately 130 adult patients from an inpatient and outpatient population were referred for VFSS examination due to clinical suspecting swallowing disorder. Of these, sixty of

prior to initiation of VFSS. Recording of SpO2 were continuously taken throughout the VFSS examination and for 5 or more minutes thereafter.

A research assistant who had no any information of the result of VFSS read the episodes of desaturation of SpO2 including its occurring time and duration. Previous experience and manufacturer's literature suggests that the error of pulse oximetry is $\leq$2%. Moreover, the result of pretest showed that the fluctuation of SpO2 in normal subjects were between 1 to 3 %. Therefore, a drop of > 3% of SpO2 between baseline and the lowest was considered significant and recorded as one episode of desaturation.

A radiologist used of a fluoroscope to perform standardized VFSS with remote control (KOX-850, Toshiba Corp., Tokyo, Japan; RSZ-2000, Shimadzu Corp., Kyoto, Japan) equipped with a high-resolution Super-VHS recorder (BR 1200, JVC, Japan). The videotape recorder offered a frame rate of 33 frames per second and could display real-time dynamic images and frame-by-frame static images. Patients were instructed to sit on a specially designed chair (VESS chair, Vess Chairs Inc., Milwaukee, WI, USA) for both lateral and frontal anterior-posterior views. Each patient swallowed the three standardized formula (5 ml each of thin, thick and paste) of barium sulfate (E-Z-HD, E-Z-EM, Inc., Westbury, NY, USA) two times. The thin barium sulfate (suspension of 340 gram E-Z-HD and 65 ml of water) is standard in performing routine gastrointestinal examination. Thick barium was prepared with adding extra 7.5 ml E-Z HD powder in 15 ml standard thin barium preparation while paste barium was prepared with adding extra 12 ml E-Z-HD powder in 15 ml standard thin barium preparation. An experienced radiologist who had no information about the result of pulse oximetry interpreted the result of VFSS.The special interest was focused on the existence of penetration (a bolus or portion of bolus entering the laryngeal vestibule but not passing through the vocal cords) or aspiration (a bolus or portion of bolus passing through the vocal cords and entering the subglottic space). The exact time of test barium swallowing and occurrence of penetration or aspiration was read and recorded for comparing them with the episodes of desaturation recorded by pulse oximetry. A third researcher compared the result of pulse oximetry and VFSS.

Statistical analysis

Relationship between the events of desaturation and aspiration were examined by the chi-square test.

四、Result

There was no obvious fluctuation of SpO2, less than 3 %, in resting normal subjects. During ten minutes' rest stage, four of the 40 normal individuals had no change of SpO2, 10 reduced 1% of SpO2, 18 reduced 2% of SpO2, and 8

them were included in the present study. Exclusion criteria included presence of peripheral vascular disease, chronic lung disease, smoking history, and incomplete study of VFSS. There were 43 men and 17 women, with a mean age of 61 years (ranged 19 to 89 years). The causes of dysphagia were mainly from cerebrovascular accident and nasopharyngeal cancer post-radiation (table1). The procedures of study were well explained to the patients and informed consent was obtained from each patient.

Table 1: The etiology of swallowing disorders

Etiology	Number (60)
Cerebrovascular accident	27
Nasopharyngeal cancer post-radiotherapy	10
Motor neuron disease	4
Parkinsonism	4
Brain tumor	2
Multiple sclerosis	2
Traumatic brain injury	2
Esophagneal cancer	2
Vocal cord palsy	2
Scleroderma	1
No definite diagnosis	4

Pre-test

For understanding the change of SpO2 on normal swallowing, 40 healthy individuals (14 male and 23 female with the mean age of 40.8± 11.7 years old) received monitor of pulse oximetry during water drinking. All of them had no history of smoking, lung disease, peripheral vascular disease, or dysphagia. The subjects had probes fitted to finger sites, which were clean and warm. Continuing SpO2 reading with a 12-second sampling interval were obtained by using a pulse oximetry (Novametrix, Medical System Inc, USA). The data was recorded and stored by a compact flash memory card and allowed the off-line analysis in personal computer. Baseline SpO2 were recorded for 10 minutes with the subjects sitting comfortably. Then, the subjects were asked to drink 20 mL water twice in the comfortable speed and the SpO2 was continuously recorded for 5 minutes thereafter.

Instrumentation and method

Prior to performance of VFSS, all patients had received pulse oximetry monitoring (Novametrix, Medical System Inc, USA) as described in previous paragraph. In addition, the patients were instructed to keep the arm with probe still during the study to prevent movement artifacts. Prior to monitoring SpO2 and VFSS examination, the timer of pulse oximetry and recorder of VFSS were synchronized. Baseline SpO2 was determined for a minimum of 5 minutes

reduced 3% of SpO2. While drinking 20 mL water, none of the normal subjects had fall of SpO2 greater than 2%. 15 of them had no change of SpO2, 24 reduced 1 % of SpO2, and one reduced 2 % of SpO2.

23 of the 60 patients were defined as aspirator on VFSS examination with at least one episode of aspiration on VFSS examination. 14 of the 23 aspirator belonged to silent aspiration (aspiration without cough response). There was no significant difference on the terms of age and basic SpO2 between aspirator and non-aspirator. The mean age of aspirator was 62.4±14.9 years old while that of non-aspirator was 59.8± 18.4 years old (P=0.54). The basic mean SpO2 in aspirator was 96.8±1.0 % and that of non-aspirator was 96.7+1.0 % (p=0.77). The fluctuation of SpO2 in the patients before VFSS was less than 2%. Before VFSS, SpO2 of most of the patients was above 95%, and only two patients had transient desaturation with SpO2 below 95%.

When comparing the result of pulse oximetry with VSFF findings, eight patients (39.1%) of 23 aspirators had significant oxygen desaturation (SpO2 decline greater than 3%) at the point of swallow/aspiration. While of the 37 patients without aspiration on VFSS examination, 15 of them (40.5%) had SpO2 fall greater than 3%. In other word, the sensitivity of pulse oximetry to detect aspiration was 39.1% and the specificity was 59.9%. In the study sample as a whole, 31 patients (51.7%) were accurately predicted as aspirators or non-aspirators. The positive predictor rate of pulse oximetry in detecting aspiration was 37.5%, and the negative predictive rate was 61.1%. There was no significant relationship between SpO2 decrement and aspiration by chi-square test (p=0.87; Table 2).

Of the 60 patients, 27 were stroke patients. 12 of them were rated as aspirator, and only seven had significant SpO2 fall at the point of aspiration on VFSS (Table 3). So, the sensitivity of pulse oximetry in detecting aspiration in stroke patients was 58.3% and the specificity was 66.7%. The fall of SpO2 was not correlated with aspiration on VFSS in stroke patients by chi-square test (P=0.36).

When compared each event of aspiration with every episodes of aspiration. There were 39 events of desaturation defined by pulse oximetry and 37 events of aspiration occurred in the 23 aspirators on VFSS examination. Of the 37 events of aspiration, only 11 (29.7%) were found to combine with simultaneous desaturation of SpO2 (the desaturation occurred followed by aspiration within 2 minutes), and 12 (30.8%) of the 39 events of desaturation combined with aspiration on VFSS examination.

Table 2. The relationship between the SpO2 desaturation and aspiration

	Aspirator*	Non-aspirator
SpO2 desaturator#	9	15
SpO2 non-desaturator	14	22

P= 0.87 by Chi-square test

*: The subjects who had at least one episode of aspiration on VFSS examination

#: The subjects who had SpO2 decrement greater than 2 % by pulse oximetry on VFSS examination

Table 3. The relationship between SpO2 desaturation and aspiration VFSS in stroke patients

	Aspirator*	Non-aspirator
SpO2 desaturator#	7	5
SpO2 non-desaturator	5	10

P = 0.36
Sensitivity = 7/12 = 58.3%
Specificity = 10/15 = 66.7%
Accurary = 17/27 = 62.9%

五、Discussion

The present study objectively evaluated the correlation between SpO2 decline on pulse oximetry and aspiration on VFSS using a prospective double blind design. The authors found that there was no significant correlation between them on the present setting. The reduced SpO2 greater than 3% cannot predict the occurrence of aspiration on VFSS with the accuracy only 51.7%. This result seems against most of the previous reports (13,18-19,24).

Roger et al (13) reported two adult cerebral palsy and one multiple sclerosis patients who had obvious hypoxemia on meal, and it only occurred in taking specific food. Based on this observation, Roger proposed that the hypoxemia occurred on feeding maybe result from mis-swallow of food into airway. However, this report only presented three cases and no direct evidence or observation to prove the cause-result relationship between aspiration and hypoxemia. There was one patient even had no aspiration on regular VFSS. Moreover, either multiple sclerosis or cerebral palsy may have weakness of respiratory muscle or in-coordination of respiration, which all probably caused hypoxemia without aspiration. Although this report strongly implicate that pulse oximetry might be a good monitor method of detecting aspiration, Roger et al confess that direct association between aspiration and hypoxemia cannot be made from that their study.

Zaidi et al (18) analyzed the degree of SpO2 decrement among three different risky aspiration groups of stroke patients. They are classified as definite aspirator, possibly aspirator, and non-aspirator based on the evaluation of speech pathologist. They demonstrated that the mean fall of SpO2 (1.4%) in non-aspirator group was significant less than that of aspirator group (4.6%) when the patients drinking 10 mL water. However, the accuracy of defining aspiration by clinical evaluation was questioned by the presence of silent aspiration, which occurred in about 40% of dysphagic stroke individuals (23). Some researches (2,5) that the combination of multiple clinical evaluation tools can increased the accuracy of clinical evaluation in detecting the aspiration, nevertheless, clinical evaluation is still not accepted as standard method of defining aspiration. Moreover, from Zaidi's study, we can only concluded that the aspirator had the trend to have SpO2 fall and do not know the correlation between each episode of desaturation and aspiration because the study only compared the mean SpO2 in different groups and lack of individual comparison. Whether the time of desaturation indicated occurrence of aspiration needed further study.

Sherman et al (24) further classified 46 patients with dysphagia into four groups; those are aspirated, penetrated and not cleared, penetrated and cleared, and no penetration by VFSS. They demonstrated that patients exhibiting aspiration or penetration without clearing had a significant decline in SpO2 when compared with those patients who without aspiration or having penetration but clearing out it. The result implied that SpO2 fall is associated with aspiration and suggested that a direct relationship between the degree of SpO2 decline and the severity of aspiration. However, this study was still not demonstrated the relationship between each episode of desaturation and aspiration.

Collins et al (19) simultaneously monitored the SpO2 of 54 dysphagic stroke patients when they underwent VFSS. They compare the level of SpO2 with swallowing condition of the subjects. The result depicted that 73% of aspirator in VFSS was defined by pulse oximetry. The pulse oximetry correctly detect 81.5 % of stroke patients with dysphagia whether they had aspiration or not in VFSS. Collins, then, concluded that pulse oximetry is a reliable method in diagnosis of aspiration in most dysphagic patients. The result of Collins' study was different from the present one, although both studies had almost the same design. The only different procedure between Collins' study and the present study was the amount of test meal on VFSS. Collins used 150 mL liquid, 3oz mouse, and one half of a 2-inche barium impregnated shortbread biscuit as the barium meal. The amount of test meal

used by Collins was not regular in modified barium swallowing examination (3). Regularly, only 10 to 15 mL of barium was recommend to used in VFSS to avoid aspiration pneumonia caused by aspiration of test meal. So, the present study used 5 mL thin, thick, and paste barium twice and will stop the examination if profound aspiration was observed. Probably, the amount of aspiration in the present study was not adequate enough to cause the SpO2 fall, and it might explain the different result of present study to Collins' partially. However, to our experience, most of our patients referred for VFSS were incapable of swallowing so large amount of test barium meal in Collins' study. Although Collins did not mention the severity of dysphagia of the patients in their study, we provided that the patients in Collins' study were relatively mild dysphagic patients because they were capable of eating large amount of test meal. The conclusion of the result was only suitable for mild deglutition disorder patients with still actively oral feeding. Sellars et al (21) performed standard VFSS and pulse oximetry simultaneously in six dysphagia patients and had the similar result as the present study, no correlation between SpO2 decline and aspiration detected by VFSS.

The cause of SpO2 falls in dysphagia patients on meal is still wondering. The researches that believed aspiration cause falls of SpO2 of the patients assumed that the ingested material when aspirate into airway would occlude the airway, reduce airflow of lung tissue. In addition, the ingested material would stimulate laryngeal chemoreceptor, causing bronchospasm (16). Either reaction would cause ventilation-perfusion impairment, and then declination of SpO2. Furthermore, the ingested material would stimulate center chemoreceptor, induce respiratory depression, and more falls in SpO2 resulted (27). The question is how much amount of ingested material will cause the above reaction and cause significant fall of SpO2. Some reports used 10 to 15 mL of barium as test meal, and the amount of aspiration may be as little as 1 to 2 mL, the desaturation was still observed. Whether this amount of aspiration will cause desaturation is questioned. Teramoto et al (20) believed that even greater than 50 mL of water into one lobe of lung for bronchoalveolar lavage does not always cause significant desaturation(20) ◦ And they believed that the occurrence of hypoexemic in dysphagic patients on meal might result from in-coordination between swallowing and breathing rather than aspiration. According to Teramoto's report, the amount of aspiration in routine VFSS, like Sellars' (21) and the present studies, should not cause significant fall in SpO2. This might explain why there was no

correlation between declination of SpO2 on pulse oximetry and aspiration on VFSS in the above studies. The test meal that Collins used was as great as 150 mL, and if aspiration occurred the amount of aspiration might be much greater than the previous reports. This might explained why there was a high correlation between aspiration and decline of SpO2 in Collin's study (19). Rogers observe the change of SpO2 in dysphagia patients on regular meal (13). The amount of meal was much greater than the test meal on VFSS, and why cause significant SpO2 fall if occurring aspiration. So, the amount of aspiration may be one of the determinant factors in causing fall of SpO2 in dysphagia patients.

The other factor to cause fall of SpO2 on meal in dysphagia patients was probable the in-coordination of breathing when swallowing (20). Clark et al found that normal subjects will hold their breathing for 0.5 to 0.25 seconds at swallowing when larynx elevated, and called it deglutition apnea (28). Selley et al (25) further described the breathing pattern in normal swallowing. She depicted that the normal subjects inhaled first, a small expiration occurred before swallow, swallowing occurred during deglutition apnea, and then exhaled. And the deglutition apnea may delay as long as 1.0 seconds in the aged (26). It may further prolonged to 3.4 seconds in the dysphagia stroke patients (26). The as long as 3.5 seconds apnea on swallow probably cause fall of SpO2 even without aspiration. Therefore, the fall of SpO2 was not necessary well correlated with aspiration on VFSS.

Generally, pulse oximetry was a reliable method to measure arterial oxygen saturation; however, arterial oxygen saturation is not as reliable as blood gas in detecting arterial oxygen tension because of its sigmoid shape of oxygen dissociation curve. Pulse oximetry was chosen in this study because it is non-invasive, widely available, and then more practical in clinical application. Patients with respiratory problem may have a low SpO2, such as in low 90. In this situation, when aspiration occurred and arterial oxygen tension was reduced, SpO2 will fall more obvious than those patients in high 90. The error may happen. In the present studies, we excluded the patients with respiratory disease or having smoking history. The patients in this study had their basic SpO2 above 95% and reduced this type error to the least.

In the present study, we found that the regular amount of test barium meal on VFSS seemed not to cause desaturation even aspiration occurred. Fall of SpO2 greater than 3% do not indicate an aspiration on VFSS. To clear out the relationship of aspiration and the change of SpO2, we may need simultaneously monitor patients with pulse oximeter, VFSS with different amount of test barium meal, and respiratory inductively plethymography.

Then, we may more understand the cause of SpO2 fall in swallow, from aspiration or breathing hold. With this information, we might more comfortably to use pulse oximetry in monitoring the dysphagia patients and help in managing deglutition disorder.

六、Acknowledge

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