CLINICAL STUDY

Visceral Fat Area by Abdominal Bioelectrical Impedance Analysis as a Risk of Obstructive Sleep Apnea
A Single-Clinic Retrospective Case Study

Hiromitsu Sekizuka,1,2 MD, Yoshiaki Ono,1 MD, Tsuyoshi Saitoh,1 and Yoshitaka Ono,1,3 MD

Summary
This is the first study to evaluate directly visceral fat area (VFA) using a visceral fat (VF) meter by the abdominal bioelectrical impedance analysis (A-BIA) method in obstructive sleep apnea (OSA) patients diagnosed with polysomnography (PSG). The purpose of this study is to clarify (1) whether VFA measurement using a VF meter by the A-BIA method is possible even in a private clinic without burdening patients and staff and (2) how much VFA affects OSA compared to body mass index (BMI). Even without a computed tomography scan, which is the gold standard for VFA measurement, a VF meter could analyze patients by the A-BIA method and easily measure VFA. Therefore, it could be used safely even in a private sleep clinic, with very little burden on the patients and the medical staff. We investigated the association between OSA and VFA in 133 OSA patients. Multiple regression analysis revealed that VFA (β = 0.28; P = 0.020) was a stronger coexisting factor for OSA than age, male gender, or BMI (β = 0.26; P = 0.032) in all OSA patients. In the OSA patients with VF accumulation, only VFA was a significant component of OSA severity (β = 0.36; P = 0.006). The A-BIA method instrument could become a useful device for the evaluation of VF accumulation in OSA patients in private sleep clinics. VFA accumulation should be recognized as an important risk factor as well as a known risk factor for OSA.

Key words: Sleep-related breathing disorder, Visceral fat accumulation, Polysomnography, Abdominal bioelectrical impedance analysis, Obesity

Obesity is the greatest risk factor for obstructive sleep apnea (OSA).1) Among patients with obesity, those with visceral fat obesity (VFO) have a particularly high risk of developing OSA. 1) However, the majority of Far-East Asian people are found to be nonobese but have severe OSA.2) Even in Japan, there are many nonobese OSA patients.

It is also known that patients with visceral fat (VF) accumulation have a high risk of cardiovascular disease (CVD) onset.4,5) VF accumulation has been reported to correlate with arteriosclerosis risk accumulation even in nonobese individuals.6,7) Therefore, more attention should be paid not only to body mass index (BMI) but also VF accumulation in sleep medical care.

VF volume is highly correlated with visceral fat area (VFA) at the umbilical level.7) A computed tomography (CT) scan is generally used to measure VFA, but we made it possible to measure VFA easily with a VF scale using the abdominal bioelectrical impedance analysis (A-BIA) method at our private sleep clinic in this study.8) The purpose of this study is to clarify (1) whether VFA measurement using a VF meter by the A-BIA method even without a CT scan is possible and safe even in a private clinic without burdening patients and staff and (2) how much VFA affects OSA compared to BMI.

Methods

Subjects: This study used a retrospective, single-center, observational design. A total of 140 patients who visited the Sleep Apnea Syndrome Outpatient Department at Yokohama Respiratory Clinic between January 2019 and October 2019 and underwent polysomnography (PSG) for sleep-related breathing disorders (SRBDs) were selected for this study. Of the 135 patients without pacemakers who consented to participate, 133 patients diagnosed with SRBDs with an apnea hypopnea index (AHI) ≥ 5/hour were included in the final analysis. All 133 patients with SRBDs were Japanese and had obstructive sleep apnea (OSA). The VFA value corresponding to the average number of complications of the three risk factors of obesity-related health disorders, namely, hypertension, dyslipidemia, and hyperglycemia, is ≥ 100 cm².4,9) According to the Japan Society for the Study of Obesity, VFA accumulation...
is defined as VFA ≥ 100 cm² for both men and women. Therefore, we defined the 133 patients as the all patients group, those with VFA < 100 cm² as the VF accumulation (-) group (n = 35), and those with VFA ≥ 100 cm² as the VF accumulation (+) group (n = 98).9) We investigated the association of AHI with age,10) male sex,1,10) and obesity (BMI)1) as risk factors for OSA and with VFA among the three groups.

Measurement of visceral fat area: Patients with an implanted medical device, such as a pacemaker, or implanted metal medical device were excluded from the study. VFA was measured in the included patients on the day of PSG after fasting for 3 hours before measurement. A VF scale was used to investigate the relationship between OSA and VF accumulation. We used a VF meter (EW-FA90, Panasonic, Osaka, Japan) by the A-BIA method to measure VFA in the patients in an outpatient laboratory. The BIA method is based on the electric resistance difference between the fat and components of other organs.8) The conventional BIA approach estimates the total fat content of the subject’s whole body, not the local distribution of fat.11) Therefore, an attempt to evaluate the amount of fat in the abdomen by the A-BIA method was reported.12) This measuring instrument by the A-BIA method is specialized for measuring abdominal fat mass. VFA was measured horizontally and directly on the skin at the umbilical level during the spontaneous exhalation phase while the patients were standing and holding their breath.

Polysomnography: PSG (PSG-1100, Nihon Kohden, Tokyo, Japan) was employed to evaluate SRBDs. A nasal cannula was placed at the nares to measure the respiratory airflow using a disposable airflow sensor, and a strain gauge sensor was used to monitor respiratory movements of the chest and abdominal walls. Arterial oxygen saturation (SpO₂) was measured with a pulse oximeter by detecting the percentage of oxygenated hemoglobin in arterial blood with two wavelengths of light transmitted to the finger and extracting the pulse wave components according to the heartbeat.13,14) The results obtained during sleep were manually analyzed by specialist laboratory technicians using the Rechtschaffen and Kales criteria.15) Apnea was defined as abnormal breathing events with cessation of airflow for 10 seconds or longer. Hypopnea was defined as an obvious reduction in airflow (less than 50%) for 10 seconds or longer compared with stable breathing before and after the event and a decrease in oxygen saturation of 3% from baseline or a decrease in oxygen saturation of 3% that was associated with arousal.16) AHI was defined as the frequency of apnea/hypopnea per hour. Low-oxygen exposure was defined as SpO₂ < 90% and a rate of SpO₂ < 90% (cumulative percentage of time at saturation below 90%, CT90%). Patients with an AHI ≥ 5 were defined as having OSA. The SRBD experienced by all patients in this study was OSA.

Statistical analyses: All measurements are indicated as mean ± standard deviation values. Differences between the VF accumulation (-) and VF accumulation (+) groups were determined by analysis of variance. The Mann-Whitney U-test, Student’s t-test, and Pearson’s χ² test were used for multigroup comparisons. Before multivariate analysis was performed, correlation coefficients were calculated for the relationships of AHI with age, BMI, and VFA. In addition, we performed a multiple regression analysis for all the patients to evaluate the association of AHI with VFA and each risk factor recognized as having
a strong association with the development of OSA, BMI, gender, and age. Statistical analyses were conducted using the JMP software for Windows (version 10.0; SAS Institute, Cary, NC, USA). Significant differences were defined at a $P$-value for the hazard ratio of $< 0.05$.

**Ethics:** This study was conducted in accordance with the Helsinki Declaration. In conducting the study, we anonymized all information that could identify individuals and conducted the study under strict controls with reference to the “Guidelines for Proper Handling of Personal Information by Medical Care/Nursing Care Service Providers” of the Ministry of Health, Labour and Welfare of Japan. Written informed consent was obtained from all subjects enrolled for this study. This study was reviewed and approved by the Yokohama Respiratory Clinic Ethics Committee.

**Results**

**Background characteristics of the patients:** Table I summarizes the patients’ background characteristics. The average age and BMI for the patients ($n = 133$) were $56.0 \pm 11.7$ years and $25.7 \pm 4.2$ kg/m$^2$. Men accounted for 80% of the patients. Significant differences in age ($P = 0.003$), rate of male gender ($P = 0.017$), BMI ($P < 0.001$), VFA ($P < 0.001$), AHI ($P = 0.014$), and CT90% ($P = 0.036$) were found between the VF accumulation (+) and VF accumulation (-) and VF accumulation (+) groups.

**Associations of AHI with age, gender, BMI, and VFA in OSA patients:** We also analyzed the correlation of AHI with age, BMI, and VFA individually, because these variables are considered to increase OSA severity (Table II). This analysis was performed in the all patients, VF accumulation (-), and VF accumulation (+) groups, respectively. The results of the analysis revealed the correlation of AHI with age, BMI, and VFA in all three groups. In the all patients group, significant correlation was found between AHI and two risk factors: BMI ($r = 0.45; P < 0.001$) and VFA ($r = 0.48; P < 0.001$). In the VF accumulation (+) group, significant correlation was also found between AHI and two risk factors: BMI ($r = 0.42; P < 0.001$) and VFA ($r = 0.50; P < 0.001$).

The results of multiple regression analysis showed that age, male gender, BMI, and VFA were associated with AHI in the three groups (Table III). In the multiple regression analysis, BMI ($\beta = 0.26; P = 0.032$) and VFA ($\beta = 0.28; P = 0.020$) were independently associated with AHI. In the patients with VFA, only VFA ($\beta = 0.36; P = 0.006$) was associated with AHI.

| Table I. Patient Backgrounds |
|-----------------------------|
| Number of patients | All patients | VF accumulation (-) | VF accumulation (+) | $P$-value |
|-------------------|-------------|---------------------|---------------------|--------|
| Age, years        |            |                     |                     |        |
| Male no., %       |            |                     |                     |        |
| BMI, kg/m$^2$     |            |                     |                     |        |
| AHI, events/hour  |            |                     |                     |        |
| Lowest oxygen saturation, % | |                     |                     |        |
| CT90%, %          |            |                     |                     |        |

Values are mean $\pm$ SD values or percentages. *Mann–Whitney $U$-test. $^1$Pearson’s $r^2$. $^1$Student’s $t$-test. VF indicates visceral fat; BMI, body mass index; VFA, visceral fat area; AHI, apnea hypopnea index; and CT90%, cumulative percentage of time at saturation below 90%.

| Table II. Correlation of Apnea Hypopnea Index with Age, Body Mass Index, and Visceral Fat Area in the Patients with or Without Visceral Fat Accumulation |
|-----------------------------|
| AHI (events/hour) | All patients $r$ | VF accumulation (-) $r$ | VF accumulation (+) $r$ |
|-------------------|-------------|---------------------|---------------------|
| Age               | -0.13       | -1.00               | -0.08               | 0.456   |
| BMI               | 0.45        | 0.23                | 0.42                | < 0.001 |
| VFA               | 0.48        | 0.27                | 0.50                | < 0.001 |

AHI indicates apnea hypopnea index; VF, visceral fat; BMI, body mass index; and VFA, visceral fat area.

| Table III. Multivariate Regression Analyses to Determine Factors Associated with Apnea Hypopnea Index |
|-----------------------------|
| Variables | All patients $\beta$ | VF accumulation (-) $\beta$ | VF accumulation (+) $\beta$ |
| Age (1 year) | 0.02        | -0.06               | 0.02                | 0.826   |
| Male gender ($0 = \text{no;} 1 = \text{yes}$) | 0.07        | 0.15                | 0.08                | 0.449   |
| BMI (kg/m$^2$) | 0.26        | 0.13                | 0.22                | 0.113   |
| VFA (cm$^2$)   | 0.28        | 0.17                | 0.36                | 0.006   |

VF indicates visceral fat; BMI, body mass index; and VFA, visceral fat accumulation.
Discussion

To the best of our knowledge, this is the first report of the direct measurement of VFA using a VF meter by the A-BIA method in OSA patients diagnosed by PSG (Figure). The findings of this study can be summarized as follows: (1) We were able to measure VFA safely in a private sleep clinic using an EW-FA90 VF meter by the A-BIA method. (2) In patients with OSA, VF accumulation was a significant coexisting factor for OSA and was no less so than age, gender, or obesity. (3) In the OSA patients with VF accumulation, VFA was a more significant component of OSA severity than BMI.

Visceral fat area measured by abdominal bioelectrical impedance analysis method: VF accumulation is associated with health problems.7-9 Furthermore, in patients with lifestyle-related diseases, the VF volume reflects the risk of CVD. Evaluation of VF accumulation is generally performed by measuring VFA at the umbilical level, which is highly correlated with the VF volume.10 A CT scan is commonly used to measure VFA.11 However, there are some issues with respect to the performance of CT examinations, including the cost, time, facilities required for installation of a CT scanner, and radiation exposure. Therefore, a VF meter was used in this study to measure VFA by the A-BIA method.12 VFA measurements obtained with this device show a strong correlation with VFA measurements obtained by CT scan (r = 0.88, P < 0.0001).13 The VFA presumed by the conventional measurement method estimated from body composition using the BIA method correlates to some extent with VFA determined by CT scan (r = 0.65-0.78).17,18 The A-BIA method has higher measurement accuracy in VFA measurement than the conventional BIA method. In addition, this device is smaller than a measuring instrument using the dual BIA method and can be used anywhere.19 By using a measuring instrument with the A-BIA method, the subjects can be measured in a standing position by attaching only the pad for the abdomen without undressing (Figure). The device is portable, and taking measurements only for a few minutes with this device is very easy and noninvasive. There are some reports on this device in medical facilities for patients with metabolic syndrome and diabetes, medical examinations, and health guidance after medical examinations.20-22 In sleep medical facilities, which see many obese OSA patients with VF accumulation, there have not been any reports about the use of this device for direct measurement of VFA by the A-BIA method. We were able to use it in our private sleep clinic without undue burden on patients and staff. This device has also been shown to be useful in patient education for improving lifestyle.23 In fact, in our private sleep clinic, it conveyed a concrete image of the VF accumulation to patients, and the device was very useful in lifestyle guidance for patients.

Visceral fat accumulation and obstructive sleep apnea: VFO is considered an OSA risk.24 It is considered a risk factor for OSA because, in addition to other reasons, VFO patients have fat accumulation around the upper airway that results in upper airway narrowing25 and because VF accumulation causes a decrease in lung volume that results in upper airway collapse.26 Our findings showed that VFA was significantly associated with OSA severity in OSA patients and was no less so than BMI. VFA, not BMI, was significantly positively associated with OSA severity, especially in OSA patients with VF accumulation. In this study, there were 36 OSA patients with a BMI < 25 kg/m² and VFA ≥ 100 cm², representing 27% of the all patients group and 36% of the VF accumulation (+) group. There are some reports indicating that VF accumulation, rather than BMI, leads to a risk of CVD.6,27 In other words, the results of this study suggest that it is necessary to pay attention not only to BMI but also to VF in OSA patients from the viewpoint of CVD risk assessment.

Clinical implications of the results of this study: An EW-FA90 by A-BIA method could become a useful instrument for evaluating VF accumulation in OSA patients in private sleep clinics. VF accumulation should be recognized as an important risk factor as well as a known risk factor for OSA.

Study limitations: Some limitations of this study must be noted. Firstly, it focused on AHI, as there is some debate about whether AHI represents OSA severity.28,29 Secondly, abnormalities in craniofacial morphology and upper airway soft tissue are thought to have a significant effect on the development of OSA,10 but these risks were not considered in this study. Finally, the number of cases was small, so the results of this study cannot be generalized.

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Disclosure

Conflicts of interest: The authors declare no conflicts of interest.

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