

A novel optimized adaptive servo-ventilation setting for a patient with severe heart failure based on the echocardiogram: a case report

Haruki Sekiguchi ^{1,2,3,4,5*}, Sae Tanino¹, Naoki Serizawa¹, and Nobuhisa Hagiwara¹

¹Department of Cardiology, The Heart Institute of Japan, Tokyo Women's Medical University, 8-1, Kawada-cho, Shinjyuku, Tokyo 162-8666, Japan; ²Division of Comprehensive Sleep Medicine, Tokyo Women's Medical University, Tokyo 162-8666, Japan; ³Institute of General Medicine, Tokyo Women's Medical University, Tokyo 162-8666, Japan; ⁴National Hospital Organization Yokohama Medical Center, Kanagawa 245-8575, Japan; and ⁵National Hospital Organization Kyoto Medical Center, Kyoto 612-8555, Japan

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Background

Adaptive servo-ventilation (ASV) is a non-invasive positive-pressure ventilation therapy considered beneficial for treating heart failure (HF) in patients with central sleep apnoea. However, to the best of our knowledge, there is no evidence indicating that this therapy increases the mortality in HF patients. We hypothesized that ASV settings are important for HF patients with reduced ejection fraction. Therefore, to determine the suitable ASV setting for such patients, we optimized these settings to improve the left ventricular (LV) output during the therapy.

Case summary

We present a case of HF caused by dilated cardiomyopathy in a 45-year-old man. He was hospitalized due to HF; his LV ejection fraction was ~20%, and haemodynamics analysis revealed his HF grade was Forrester subset IV. During hospitalization, he was diagnosed with sleep apnoea; therefore, we induced ASV with our optimized setting using an echocardiogram evaluating stroke volume (SV). Using this method, we could determine the appropriate setting that increased his SV and improved his apnoea–hypopnoea index. At the 5th-year follow-up, he had no dyspnoea on effort (New York Heart Association Functional Classification I). He continued using the ASV with good adherence, and no hospitalization for ventricular arrhythmia and HF was reported.

Discussion

Our ASV optimized setting showed beneficial effects in an HF patient with reduced ejection fraction. This method improved the patient's SV and apnoea–hypopnoea index, indicating that this novel method should be considered for HF patients with reduced ejection fraction.

Keywords

Heart failure • Adaptive servo-ventilation therapy • Apnoea–hypopnoea index • Case report

ESC Curriculum

6.1 Symptoms and signs of heart failure • 2.2 Echocardiography

Learning points

- Adaptive servo-ventilation (ASV) affects the left ventricular stroke volume (SV) of patients with severe heart failure with reduced ejection fraction (HFrEF).
- Exceeding the expiratory positive airway pressure reduced the SV in a patient with HFrEF.
- Our optimized ASV setting focused on the SV and may optionally benefit patients with HFrEF and prevent heart failure exacerbation.

* Corresponding author. Tel: +81 3 3353 8111, Fax: +81 3 3356 0441, Email: gucci_0418@yahoo.co.jp

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Introduction

Adaptive servo-ventilation (ASV) is a non-invasive ventilator therapy that effectively alleviates central sleep apnoea (CSA), including Cheyne–Stokes respiration, in patients with heart failure (HF) by delivering servo-controlled inspiratory pressure support in addition to expiratory positive airway pressure (EPAP).¹ The results of the Treatment of Sleep-Disordered Breathing with Predominant Central Sleep Apnoea by Adaptive Servo Ventilation in Patients with Heart Failure (SERVE-HF) trial, which assessed the effects of ASV on the cardiovascular outcomes of patients who had HF with reduced ejection fraction (HFrEF),² suggested that ASV increases the long-term mortality rate. In contrast, beneficial effects, such as improved cardiac function and prognosis, were reported when ASV was used clinically in the acute phase of HF.³ In the recent Treatment of Sleep Apnoea Early After Myocardial infarction with Adaptive Servo-Ventilation trial (TEAM-ASV I) trial, ASV promoted myocardial salvage and healing in the acute phase after myocardial infarction.⁴ Furthermore, some studies have reported novel applications of ASV for patients with HF and have reported an increased cardiac output (CO) during ASV titration.^{5,6} One possible cause of the previously reported increased mortality rates following ASV was the low CO induced by a high EPAP for improving the apnoea–hypoxia index (AHI) against the background of a low left ventricular ejection fraction (LVEF). However, ASV-mediated changes in CO in patients with severe HFrEF have not been investigated.

This study presents a case of HF caused by dilated cardiomyopathy (DCM) in a 45-year-old man.

Timeline

Date	Event
11 years earlier	Indications of heart failure with reduced ejection fraction and treatment initiation for heart failure
3 years earlier	Diagnosis of dilated cardiomyopathy
Day 0	Urgent hospitalization for heart failure
Day 15	First optimal adaptive servo-ventilation (ASV) titration
Day 30	Second optimal ASV titration
Day 50	Discharge with wearable cardioverter-defibrillator (WCD)
Day 65	Third optimal ASV titration and discontinuation of WCD use

Case presentation

In our study, the patient had no abnormalities during the annual health check. At 36 years, when he was hospitalized for treatment of Type 2 diabetes mellitus (T2DM), his LVEF had reduced to 37%, and

he was diagnosed with idiopathic cardiomyopathy. Medications for HF, including beta-blockers and angiotensin-converting enzyme inhibitors, were administered. At 44 years, coronary angiography was performed, and no significant stenosis was noted. The patient was diagnosed with DCM.

At 45 years, he was emergently hospitalized for HF [New York Heart Association (NYHA) Class III] caused by infection-induced appendicitis. On admission, he had T2DM but no recent history of syncope. He had a medium height and build (height, 173 cm; weight, 87 kg), and clinical examination revealed a normal blood pressure of 102/72 mmHg and oxygen saturation of 98%; his brain natriuretic peptide (BNP) level was 1260 pg/dL (≤ 20 pg/dL), and the LVEF was 25% on echocardiography. He was treated with carvedilol (5 mg) and furosemide (20 mg). Coronary angiography and biopsy were performed, no significant stenosis was noted in his coronary artery, and his LVEF was 18%. Right heart catheterization (RHC) revealed that his HF was Forrester subset IV haemodynamics (CO, 1.5 L/min; mean pulmonary capillary wedge pressure, 37 mmHg). The biopsy confirmed the diagnosis of idiopathic DCM.

Polysomnography was performed to determine the presence of sleep apnoea syndrome, which revealed an AHI of 43.1; obstructive sleep apnoea manifested more than central apnoea. Thus, severe obstructive sleep apnoea syndrome was diagnosed. Thereafter, we attempted ASV (AutoSet S-A Type TJ, ResMed, San Diego, CA, USA) for his HF. We introduced ASV 2 weeks after hospitalization (BNP, 879 pg/dL). The ASV optimal titration protocol was modified from that used in a previous study⁶ (Supplementary material online, Figure S1), and the patient's stroke volume (SV) [calculated as left ventricular (LV) outflow tract area \times velocity-time integral of the LV outflow velocity and averaged over three cardiac cycles] increased from 31.1 to 34.4 mL when the EPAP was 2 cmH₂O (Table 1, first titration); however, it decreased to 33.2, 31.9, and 29.9 mL when the EPAP was 4, 6, and 8 cmH₂O, respectively (Figure 1A). We determined that the suitable EPAP setting was 2 cmH₂O. At this ASV setting, the AHI was 13.6.

Ten days later, we re-evaluated his EPAP setting under catecholamine (dobutamine 3 μ g/kg/min) use (BNP, 227 pg/dL). Stroke volume peaked at 54.8 mL when the EPAP was 2 cmH₂O and decreased proportionately with EPAP (Table 1, second titration). When the EPAP was >6 cmH₂O, the SV was worse than that when ASV was not used (Figure 1B). We determined that the optimal EPAP was 2 cmH₂O. Two weeks later, the patient's HF resolved (LVEF, 27%; NYHA, Class II; 6-min walk distance, 400 m), and he was discharged with a prescription for carvedilol (12.5 mg), perindopril erbumine (8 mg), spironolactone (50 mg), and azosemide (60 mg) (BNP, 183 pg/dL).

Two months after discharge, we tested the optimal ASV setting (BNP, 103 pg/dL). Stroke volume peaked at 44.8 mL and decreased proportionately with EPAP (Table 1, third titration) (Figure 1C). We determined that the suitable EPAP setting was 2 cmH₂O. During these 2 months, the patient's adherence to ASV was $>90\%$ (average usage time, 7 h per night; AHI, <0.5). At the 5th-year follow-up, he had never been re-hospitalized, and there was no increase in the BNP level (<50 pg/dL). Treatment with carvedilol (12.5 mg), perindopril erbumine (5 mg), spironolactone (25 mg), and azosemide (60 mg) was continued. Therefore, ASV was the likely factor that ameliorated the symptoms of the patient in this case.

Table 1 Echocardiogram data during the optimal adaptive servo-ventilation setting

	Parameter	Pre	EPAP 2 cmH ₂ O	EPAP 4 cmH ₂ O	EPAP 6 cmH ₂ O	EPAP 8 cmH ₂ O
First titration	<i>E/A</i>	2.7	4.2	3.7	4.2	5.1
	Dct (ms)	102	94	94	73	94
	<i>E/e'</i>	9	10.4	11.8	12.8	14
	VTI at LVOT (cm)	7.5	8.3	8	7.7	7.2
	SV (mL)	31.1	34.4	33.2	31.9	29.9
Second titration	<i>E/A</i>	1.4	1.3	1.2	0.8	1.1
	Dct (ms)	124	129	154	118	133
	<i>E/e'</i>	6.9	8.9	8.3	5.6	9.2
	VTI at LVOT (cm)	10.5	13.2	10.8	9.3	9.1
	SV (mL)	43.6	54.8	44.8	38.6	37.8
Third titration	<i>E/A</i>	0.7	0.6	0.5	0.8	0.9
	Dct (ms)	186	189	204	145	155
	<i>E/e'</i>	7	6.3	4.8	8	10
	VTI at LVOT (cm)	9.5	10.8	10.3	9.6	8.6
	SV (mL)	39.4	44.8	42.7	39.8	35.7

Dct, deceleration time; *E/A*, the ratio between early and late diastolic transmitral flow velocities; *E/e'*, the ratio of the maximal early diastolic filling wave velocity to the maximal early diastolic myocardial velocity; EPAP, expiratory positive airway pressure; LVOT, left ventricular outflow tract; SV, stroke volume (SV was calculated as LV outflow tract area × VTI at the LVOT); VTI, velocity-time integral.

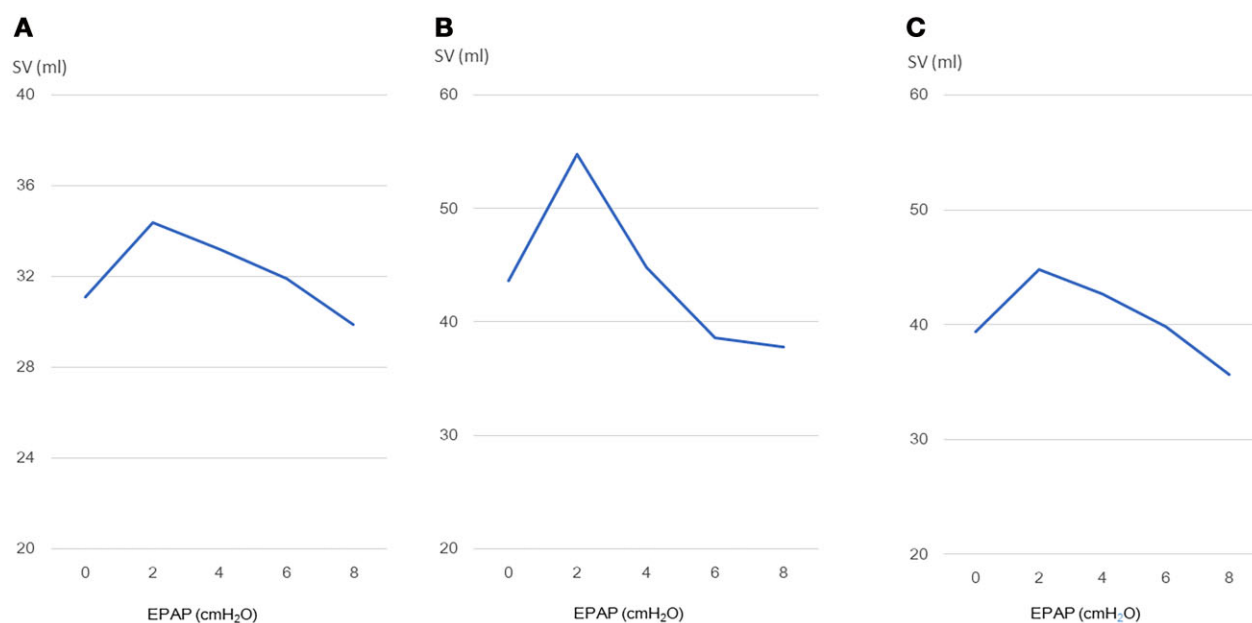


Figure 1 Stroke volume change by adaptive servo-ventilation. (A) First titration: the x-axis is the expiratory positive airway pressure, and the y-axis is the stroke volume. (B) Second titration: the x-axis is the expiratory positive airway pressure, and the y-axis is the stroke volume. (C) Third titration: the x-axis is the expiratory positive airway pressure, and the y-axis is the stroke volume.

Discussion

We present a case of HF caused by DCM in a 45-year-old man who greatly benefitted from our novel optimized ASV setting. We hypothesized that an optimized ASV setting is determined by evaluating the CO based on echocardiography findings, thereby ensuring

benefits for patients with severe HFrEF and aiming to determine the optimal ASV setting for this patient by focusing on the CO rather than the AHI.

Our case study revealed that ASV increased the SV in the short term, whereas an increased EPAP decreased the SV. The target of our optimal ASV setting was not AHI but was SV; however, we

observed that a low EPAP improved the AHI. The SERVE-HF trial aimed to reduce the CSA, with a target AHI of <10 events/h within 14 days after starting ASV. In fact, the ASV device used in that trial had relatively high default pressures as part of its ventilation algorithm (minimum EPAP, 5 cmH₂O; minimum inspiratory pressure support, 3 cmH₂O), which is likely to lower the CO in patients with normal or low LV filling pressures when compared with a device with a lower default pressure.⁷ Moreover, a high positive end-expiratory pressure setting may stimulate sympathetic nerve activity accompanied by a decreased CO.⁶

Our data also confirmed that SV decreased when the EPAP was higher than the optimal setting. We focused on the SV instead of AHI, including CSA, for patients with severe HF. Despite the AHI not being a target of our optimal ASV setting, it improved to <5 events/h. A previous study reported that patients with AHI >20 had higher mortality rates than those with AHI <20.⁸ However, to the best of our knowledge, there is no evidence indicating that patients with low AHI (<20) have lower mortality rates if their AHI is improved. Thus, achieving a lower AHI may not be necessary in severe HF.

Our patient's AHI also improved from 43.1 to 13.6, the duration of saturation of percutaneous oxygen (SpO₂) under 90% improved from 77 to 2 min per night, and the median heart rate (HR) decreased from 84 to 70 beats/min. Thus, maintenance of SpO₂ and HR may be important for HFrEF treatment.

High inspiratory pressure support could lead to hyperventilation, alkalosis, and accompanying hypokalaemia, which may increase the propensity for cardiac arrhythmias.⁹ In patients with chronic HFrEF, sudden cardiac death due to ventricular arrhythmia is one of the most important causes of death.¹⁰ Thus, patients with a high risk of sudden cardiac death, such as those with HFrEF and LVEF <35%, are advised to use an implantable cardioverter-defibrillator.¹¹ However, in our patient, no shock had to be applied by his wearable cardioverter-defibrillator 3 months after discharge, and his HF symptoms had improved to NYHA Class I.

Patients with HF show an increased right ventricular (RV) volume owing to fluid retention, and this increased volume exerts pressure on the left ventricle via the ventricular septum. The volume loss from the left ventricle and pressure from the right ventricle cause LV diastolic dysfunction. As ASV decreases the venous return, the dilatation of the RV volume ceases; the left ventricle can then dilate sufficiently to increase the SV. Stroke volume is largely dependent on the preload, and ASV causes an SV reduction by the Frank–Starling mechanism because of a decrease in venous return¹² and LV filling.^{13,14}

Our optimal ASV setting, as determined by echocardiography findings, revealed changes in SV with each EPAP setting in a patient with severe HFrEF. As the patient's characteristics were not the same as those in the SERVE-HF study, the suitable EPAP setting is likely to differ for each patient according to their specific characteristics and conditions. In addition, long-term mortality rates should be evaluated in patients with HFrEF using our optimized ASV setting. We plan to conduct an observational cohort study for such an investigation, comparing the clinical effects between our optimized setting and the standard ASV settings. A limitation of our report is that we did not perform repeated RHC to evaluate the haemodynamic effect of different ASV regimens. Therefore, repeated RHC should be

performed for standardization to achieve comparable results in the clinical arena.

In conclusion, our optimized ASV setting demonstrated a beneficial effect in a patient with HFrEF by improving the SV and AHI. This is a novel ASV setting that should be considered for other patients with HFrEF.

Lead author biography



Haruki Sekiguchi graduated from Tokyo Jikei Medical University. I started my residency in department cardiology Tokyo Women's medical University (TWMU). After residency, I entered graduate school in TWMU and studied abroad in USA. I worked for Caritas St. Elizabeth's Medical Center and Northwestern University Feinberg Cardiovascular Research Institute as a cardiovascular fellow. After that, I worked for

Vascular Regeneration Research Group, Institute of Biomedical Research and Innovation as a visiting research fellow. After getting the PhD, I worked for the National Hospital Organization, Yokohama Medical Center. I'm working for Department of Cardiology in TWMU as an assistant professor.

Supplementary material

[Supplementary material](#) is available at *European Heart Journal - Case Reports* online.

Slide sets: A fully edited slide set detailing this case and suitable for local presentation is available online as [Supplementary data](#).

Consent: The authors confirm that written consent for submission and publication of this case report including images and associated text has been obtained from the patient in line with COPE guidance.

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