Case report

An application of pacemaker respiratory monitoring system for the prediction of heart failure

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ABSTRACT

Sleep-disordered breathing (SDB) is one of the most common complications among heart failure (HF) patients. Changes of respiratory patterns during the various stages in patients with HF have not been fully investigated. In this case, the algorism using thoracic impedance sensor and minute ventilation (sleep apnea monitoring [SAM] algorithm) with implanted pacemaker (REPLY 200 SR or DR, Sorin CRM SAS, Clamart, France) was used to monitor respiration. Impedance data from the implanted pacemaker can be converted into respiratory data, which can be used to calculate the respiratory disturbance index (RDI) per unit of time. Using this algorithm, we observed a sudden appearance of abnormal breathing at the onset of HF, followed by gradual improvement of respiratory patterns during the recovery stage. The results from respiratory monitoring using the SAM algorithm were strongly correlated with those from the positive airway pressure device. This case report could imply that proper utilization of this sensor could facilitate the early detection and therapeutic control of HF.

1. Introduction

Sleep-disordered breathing (SDB) is a frequent complication in patients with cardiovascular disease and is an important therapeutic target [1]. Obstructive SDB is an independent risk factor for cardiovascular diseases such as coronary artery disease, fatal arrhythmia, and heart failure (HF). The upper airway edema caused by the fluid shift in HF patients can lead to obstructive apnea. This vicious cycle can worsen the prognosis of heart failure. Central SDB has been studied with interest as a factor that could be used to predict the severity and prognosis of HF [2]. Thus, the respiratory monitoring is an effective and important diagnostic approach to manage the heart failure.

Because HF patients exhibit a functional decline of the conduction system due to the impairment of cardiac muscles and the use of HF medications, they often need pacemaker implantations to control bradyarrhythmias. Recently, HF monitoring systems that can detect thoracic impedance may provide useful data for managing HF. Impedance data from the implanted single- and dual-chamber pacemakers (REPLY 200 SR or DR, Sorin CRM SAS, Clamart, France) can be converted into respiratory data, which can be used to calculate the respiratory disturbance index (RDI) per unit of time [3]. HF patients can experience

various types of abnormal breathing, such as rapid and shallow breathing or irregular respiration other than SDB [4]. Although the SAM algorithm originally has been used as a method of screening for SDB, the algorithm can identify various temporal and spatial respiratory disturbance. According to this hypothesis, respiratory monitoring using the SAM algorithm in HF patients could be an important diagnostic tool for predicting the onset of disease and evaluating the recovery process in HF. In this unique case, we show that RDI data from the SAM algorithm of implanted pacemaker can be effective to monitor the onset and to evaluate the recovery process of HF.

2. Case report

The patient was a 78-year-old woman hospitalized for HF complicated by bradycardic atrial fibrillation. A pacemaker has already been implanted to manage the bradycardic atrial fibrillation. Fig. 1 shows the clinical course of this patient after hospital admission. The patient exhibited shortness of breath on exertion and exhibited slight congestion on chest radiography. Echocardiography showed a left ventricular ejection fraction of 70% and a left atrial diameter of 60 mm. Her circulating brain natriuretic peptide (BNP) levels, measured by blood

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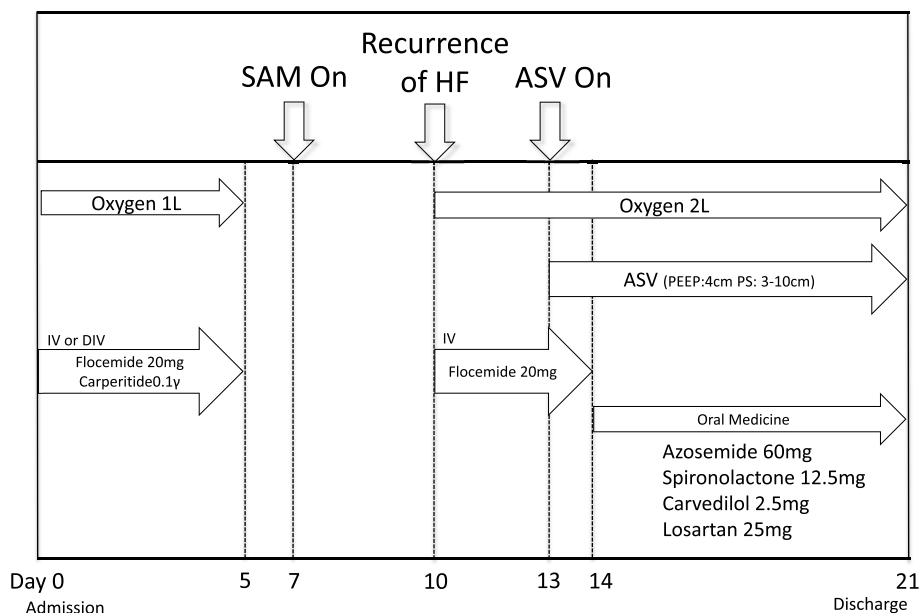E-mail address: koyamat@chushin-miniren.gr.jp (T. Koyama).

Fig. 1. The clinical course of this patient's case. SAM = sleep apnea monitoring, HF = heart failure, ASV = adaptive servo ventilation, IV = intravenous injection, DIV = drip infusion into vein, PEEP = positive end-expiratory pressure, PS = pressure support.
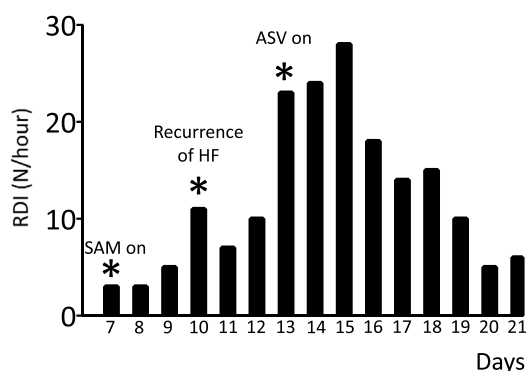

Fig. 2. RDI values obtained from the pacemaker over time. SAM = sleep apnea monitoring, RDI = respiratory disturbance index, HF = heart failure ASV = adaptive servo ventilation.
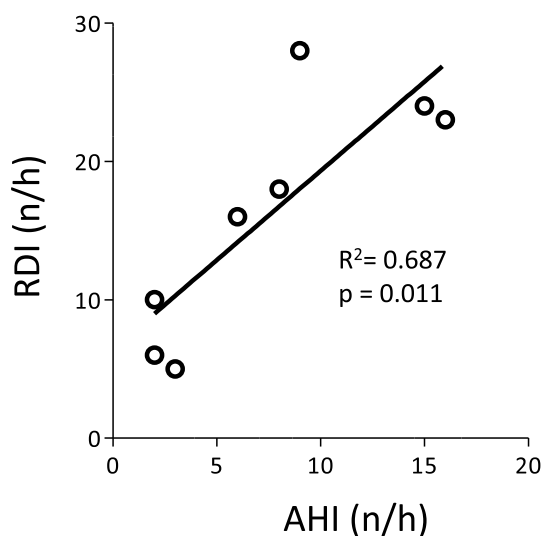

Fig. 3. Correlations between RDI and AHI values. RDI = respiratory disturbance index, AHI = apnea hypopnea index.

sampling, were 230pg/ml. On the basis of these findings, she was diagnosed with HF with preserved ejection fraction. After the admission, transnasal oxygen at 1L/min, a continuous infusion of carperitide 0.1 γ, and intravenous injections of 20 mg furosemide for 5 days were administered to her. Her HF symptoms improved temporarily after the initial treatment, however, she experienced a recurrence of HF on disease day 10, suggesting that this initial treatment regime was insufficient. The transnasal oxygen along with 20 mg of intravenous furosemide was administered and adaptive servo ventilation (ASV, AutoSV; PHILIPS Respironics, Murrysville, PA, USA) was initiated. ASV therapy began at a low pressure of PEEP (5 cmH$_2$O) and pressure support (3–10cmH$_2$O). Several oral diuretic and HF drug were also administered. These interventions successfully controlled her HF and she was discharged on disease day 21. Fig. 2 shows the RDI records from the SAM algorithm of this patient. The SAM functions in the implanted pacemaker were initiated on disease day 7. On disease day 10, which was the day of HF recurrence, RDI suddenly increased and gradually decreased after the peak on disease day 15. ASV therapy was initiated on disease day 13 (Fig. 2 asterisk). In addition to these therapies, the use of an oral HF drug helped improving her HF condition. By monitoring respiratory flow with ASV device, we were able to calculate ventilation rate/minute and the apnea-hypopnea index (AHI). Fig. 3 shows the correlations between the RDI data from implanted

pacemaker and AHI data acquired from ASV devise. The relatively high correlations were found between the two parameters. Fig. 4 shows the respiratory waveforms on disease day 13 when ASV was introduced and on day 21 when the patient was discharged from the hospital. On disease day 13, there were major changes in the amplitude of the respiratory waveform and the respiration intervals were disordered. These respiratory patterns indicate abnormal breathing which are different from SDB. On disease day 21, both the amplitude and intervals were stabilized.

3. Discussion

This case demonstrates that the SAM algorithm could be an effective diagnostic tool to detect abnormal breathing which are associated with the prediction of the onset of HF and the evaluation of the recovery process of HF. Abnormal breathing, such as rapid and shallow breathing or irregular breathing, is frequently observed in HF patients. SDB, which is one of the abnormal breathing, could improve after the

A: Disease Day 13
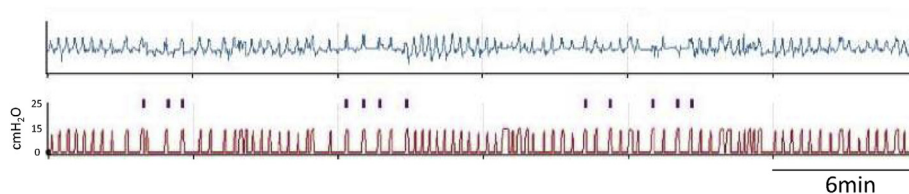
Upper panel : Respiratory waveform from ASV devise
Lower panel : Pressure waveform from ASV devise

B: Disease Day 21
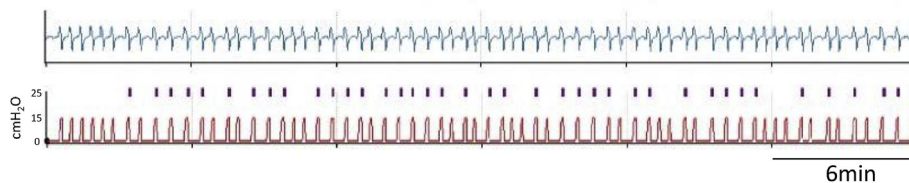
Upper panel : Respiratory waveform from ASV devise
Lower panel : Pressure waveform from ASV devise

Fig. 4. Examples of respiratory waveforms obtained from adaptive servo ventilation (ASV) on disease day 13 and 21.

recovery of HF. According to the respiratory response in HF patients, the analysis of respiratory pattern in HF patients is an effective diagnostic approach to manage HF patients.

Recent study has shown that the thoracic impedance system from implanted pacemakers could be an effective approach to monitor the worsening HF in a clinical setting [5]. The SAM algorithm, which is installed in the pacemaker of this case, could derive respiratory cycles and minute ventilation through the thoracic impedance measurement. The algorithm applies the mechanism that the thoracic impedance varies with respiratory movements, body posture, and cardiac contractions. Although the SAM algorithm was originally designed to screen for SDB, this function could accurately derive abnormal respiratory pattern other than SDB in HF patients. Because the SAM algorithm could provide the information regarding the deterioration of HF, resulting in the improvement of the quality of life for HF patients and reduction of the re-hospitalization associated with HF. As shown in Fig. 2, there was a sudden increase of RDI that corresponded to the day of HF onset; RDI subsequently decreased during the recovery process. These results suggest that the respiratory monitoring of this device could be an extremely important factor in understanding the status of HF patients.

ASV was another piece of equipment used to treat HF in this case. ASV is reported to improve HF by removing congestions of the lung and reducing the preload with relatively low PEEP, and by assisting a patient's spontaneous respiration and relieving respiratory muscle fatigue with pressure support [6]. Data downloaded from an ASV unit can be used to obtain the AHI and specific respiratory waveforms from HF patients. AHI was high when ASV was introduced, but it had improved by the day of hospital discharge. These responses of AHI data from ASV device match the responses of RDI data calculated from pacemaker data. As shown in Fig. 3, a correlation was observed between the data obtained from these 2 devices, which indicates that RDI accurately reflects the respiratory status of patients.

Observations of specific waveforms showed that immediately after the onset of HF, the respiratory waveforms obtained from ASV exhibited disordered amplitude and intervals, although these had stabilized by hospital discharge (Fig. 4). These data provide further evidence that RDI is a relatively accurate method of respiratory monitoring. According to these results, respiratory monitoring using the thoracic

impedance system could be an effective diagnostic approach to clarify the onset of HF. The establishment of remote notification system using this device could develop the early diagnosis of worsening HF.

Conflicts of interest

All authors declare no conflict of interest. Appropriate written informed consent was obtained for publication of this case report and accompanying images.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rmcr.2019.02.008.

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