Heart failure is characterized by frequent hospitalization and doctor visits. Despite a great progress in medical and device therapy for chronic heart failure (CHF) over the past decades, annual mortality rates remain high in this lethal disorder. Therefore, much effort has been expanded to the evaluation of a new and more sensitive predictor of worsening heart failure. Augmented sympathetic discharge known to be a prognosticator of early mortality causes chronic perturbation of the cardio-respiratory system in CHF that leads to a progressive respiratory control instability in the form of periodic breathing. Despite of the importance of Cheyne-Stokes respiration or central sleep apnea, respiratory instability in patients with CHF is characterized more frequently by rapid and shallow respiration, irregular nonperiodic respiration with transient sigh or apnea, or nonapneic periodic breathing. Recently, we have developed a new indicator, Respiratory Stability Index (RSI), to quantify atypical periodic breathing or unstable respiration other than central sleep apnea or Cheyne-Stokes respiration.

Respiratory Stability Index (RSI)

In the present study, we revealed clinical significance of RSI in evaluating the severity of heart failure and applied RSI to the telemedical management of CHF using fully automated and real-time biosignal processing system and high-quality internet television. The maximum entropy method was applied to measuring spectral components of respiratory flow. RSI was obtained from the reciprocal of the standard deviation of respiratory spectral ranges. The lower RSI indicates more broad spectral components and unstable respiration.

Assessment of Severity of Heart Failure with RSI

In 80 patients with CHF without Cheyne-Stokes respiration during daytime, RSI was 43 in New York Heart Association Class I (n=40), 35 in Class II (n=19), and 21 in Class III-IV (n=21, p<0.05 Class I vs. Class III-IV). In 10 Class I patients with normal RSI, adaptive servo-ventilation (ASV) did not change the respiratory pattern (35 to 31). However, ASV tended to augment RSI toward the normal (25 to 41, P=0.07) in 8 Class II patients, and significantly increased RSI (14 to 27, p<0.05) in 7 Class III-IV patients. The significant negative correlation (r= -0.59) between the baseline RSI and the magnitude of the improvement with ASV suggests that ASV could be effective in patients with a low RSI, even if they did not have Cheyne-Stokes respiration.

Telemedical Management of Heart Failure with RSI

Telemedicine offers a modern and emerging concept to manage patients with CHF optimally at home. We have recently developed a brand-new telemonitoring and telecommunication system using non-attached sensor technologies for heart failure patients at home. While the patient was lying in bed, an under-pillow sensor continuously recorded respiratory signals (100 Hz sampling) and cardiac pulse, and a sheet-sensor measured body temperature, and lying position and periods everyday. The obtained information was full-automatically processed in real time and transferred to the server placed in our hospital via virtual private network. Face-to-face communication between the patient and hospital staffs was constructed with high-resolution internet television, which could provide not only information on patients’ symptoms and physical signs but also remote multidisciplinary approach to self-care behaviour. The multidisciplinary intervention was aimed to reinforce patient’s education, ensure compliance with medications and diet, and identify recurrent heart failure symptoms. These systems were installed in the home of eight patients with moderately severe and severe heart failure. In all patients, five-minute data of nocturnal respiratory signals (0 to 6 AM) were serially obtained by shifting the data range every 50 sec and served to calculate RSI in each segment. The average of these RSIs was used for continuous telemonitoring of worsening heart failure. All patients felt safe and satisfied with this telemedical management. Remote multidisciplinary intervention significantly improved the patient’s self-care behaviour. During monitoring periods more than 5 months, 4 patients showed heart failure deterioration, and two of them were admitted to the hospital. As the heart failed, sustained reduction in RSI reflecting unstable respiration preceded any symptom and sign of worsening heart failure. With early intensive treatment, RSI recovered and remained unchanged above 20, while the patient was stable. Thus, respiratory instability quantified by RSI could faithfully identify severity and worsening of heart failure. Our fully-automated network system equipped with RSI monitoring technologies has the potential to improve telemedical management of CHF by facilitating the patient’s self-care behaviour, the earlier detection of worsening heart failure, and timely intervention.