

## The utility of thoracic impedance monitoring in a patient with biventricular defibrillator

Biventriküler defibrilatörlü bir hastada torasik impedans ile takibin yararı

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The severity of pulmonary congestion can be assessed by monitoring thoracic impedance (TI). In patients with congestive heart failure (CHF), TI monitoring provides a unique opportunity to foresee decompensation before clinical signs and symptoms ensue. Some biventricular defibrillators (BiV-ICD) have TI monitoring capability, providing hemodynamic data as well as treatment of CHF and arrhythmias. We present an 80-year-old male patient in whom TI monitoring by BiV-ICD was utilized for clinical decision making. He had undergone coronary artery bypass graft surgery and BiV-ICD implantation, and had decompensated CHF on admission. Interrogation of BiV-ICD revealed a substantial decrease in TI compatible with volume overload. Shortly after treatment for CHF, a steady increase was noted in TI parallel to effective diuresis. However, after discharge, a decrease in TI was again noted without any signs and symptoms of decompensation. Treatment was tailored and TI values became normal. No need for hospitalization occurred and he showed a steady decrease in the ventricular rate in parallel to increases in TI and heart rate variability.

**Key words:** Cardiography, impedance; defibrillators; heart failure, congestive; hemodynamic processes; pacemaker, artificial.

Thoracic impedance (TI) provides quick and noninvasive assessment of cardiac output and gives useful information about the severity of pulmonary congestion.<sup>[1-4]</sup> There is an inverse relationship between TI and pulmonary congestion.<sup>[4,5]</sup> Thoracic impedance monitoring can be used to determine the severity of pulmonary congestion and volume status in patients with congestive heart failure (CHF).<sup>[4-6]</sup> It may also be helpful in decreasing the frequency of hospitalization and cost of patient care in the management of CHF.<sup>[4-7]</sup>

Torasik impedans (Tİ) takibiyle pulmoner konjestiyonun ciddiyetini belirlemek mümkündür. Konjestif kalp yetersizliği olan hastalarda Tİ takibi, klinik bulgu ve belirtiler ortaya çıkmadan önce dekompanseasyonun tahmin edilmesi için eşsiz bir fırsat sağlar. Bazı biventriküler defibrilatörlerin Tİ ölçme ve takip etme özelliği de vardır; bunlar konjestif kalp yetersizliği ve aritmilerin tedavisi yanı sıra hemodinamik veri de sağlarlar. Bu yazıda, biventriküler defibrilatör aracılığıyla Tİ takibi yapılan 80 yaşında bir erkek hasta sunuldu. Koroner baypas ameliyatı geçiren ve biventriküler defibrilatör takılan hasta dekompanse kalp yetersizliği nedeniyle yatırıldı. Biventriküler defibrilatör cihazından sağlanan veriler hacim yüklenmesiyle uyumlu olarak Tİ'de belirgin bir azalma gösterdi. Konjestif kalp yetersizliğine yönelik etkili tedavi sonucunda hastanın Tİ değerleri de yükseldi. Ancak, taburcu edildikten sonra Tİ değerlerinde yeniden düşme görüldü; dekompanseasyonu gösterir herhangi bir belirti veya bulgu yoktu. Diüretik dozu artırıldıktan sonra Tİ değerleri normale döndü. Hastaneye yatırılmasına gerek kalmaksızın, hastadaki Tİ değerlerindeki ve kalp hızı değişkenliğindeki artışa paralel olarak ventriküler hız da giderek azaldı.

**Anahtar sözcükler:** Kardiyografi, impedans; defibrilatör; kalp yetersizliği, konjestif; hemodinamik proses; yapay pacemaker.

Biventricular defibrillators (BiV-ICD) combine biventricular pacing (BiV) and implantable cardioverter defibrillator (ICD) in the same device.<sup>[8]</sup> They are designed to target the two most common causes of death in patients with CHF, namely ventricular arrhythmias and end-stage pump failure.<sup>[8,9]</sup> One of the ultimate features of these high-technology devices is TI monitoring capability. This paper presents a patient in whom TI monitoring by BiV-ICD was clinically utilized for the follow-up.

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## CASE REPORT

An 80-year-old male was admitted to our department with progressive dyspnea. He underwent coronary artery bypass graft surgery and BiV-ICD implantation (InSync Sentry, Medtronic Inc., Minnesota, USA) two weeks before admission. He had dilated cardiomyopathy. The indications for biventricular pacing and defibrillator were decompensated congestive heart failure and documented ventricular tachycardia, respectively. On physical examination, he was in severe respiratory distress. His blood pressure, pulse, axillary temperature and respiratory rate were 90/50 mmHg, 110 bpm, 37 °C, and 35 bpm, respectively. Pulmonary auscultation revealed inspiratory rales at the base of the lungs. A moderate holosystolic murmur and an S3 gallop were detected at the apex. Hepatomegaly and pretibial (++) edema were also noted. An electrocardiogram showed pacemaker rhythm with ventricular capture (rate 110/minute). The chest X-ray was consistent with bilateral pulmonary edema and apparent cardiomegaly. Transthoracic echocardiography revealed moderate mitral regurgitation, left atrial enlargement (44 mm), left ventricular dilatation, and reduced ejection fraction (20%). Interrogation of the device revealed normal pacing and sensing thresholds, and impedances at atrial, right ventricular, and left ventricular leads. A substantial decrease in TI (45 Ohm) was also depicted as a graphical output (Fig. 1a). The patient was hospitalized with the diagnosis of decompensated heart failure and treatment was instituted with intravenous diuretics, morphine, digitalis, an ACE inhibitor, and nitrate. On the following days, a steady increase in TI (18 Ohm in 3 days) was observed parallel to clinical stabilization (Fig. 1a). He was discharged on the tenth day on treatment with the ACE inhibitor, digitalis, nitrate, and a low-dose diuretic.

On the follow-up examination 20 days later, he was asymptomatic with no signs of decompensation, but a decrease in TI (from 63 Ohm to 57 Ohm) was noted (Fig. 1a). The diuretic dose was increased and a low sodium diet (<3 gr/day) was advised. Clinical follow-ups continued on an outpatient basis without any decompensation and with normal TI values (around 60 Ohm). No need for hospitalization occurred. Carvedilol was also started and the dosage was increased to 50 mg/day. Subsequent interrogations showed a steady decrease in the ventricular rate in parallel to increases in TI and heart rate variability (Fig. 1b).

## DISCUSSION

Impedance cardiography enables noninvasive assessment of cardiac output by measuring TI.<sup>[1-3]</sup> In this method, changes in electrical resistance are measured by the external electrodes over the thorax. Cardiac output and ejection fraction estimated with the use of TI correlate well with those of standard methods of cardiac output assessment.<sup>[10]</sup> Thoracic impedance reflects the changes in intrathoracic fluid and pulmonary congestion. It may be used to monitor the hemodynamic status of the patients. This feature makes TI a valuable tool for follow-up.

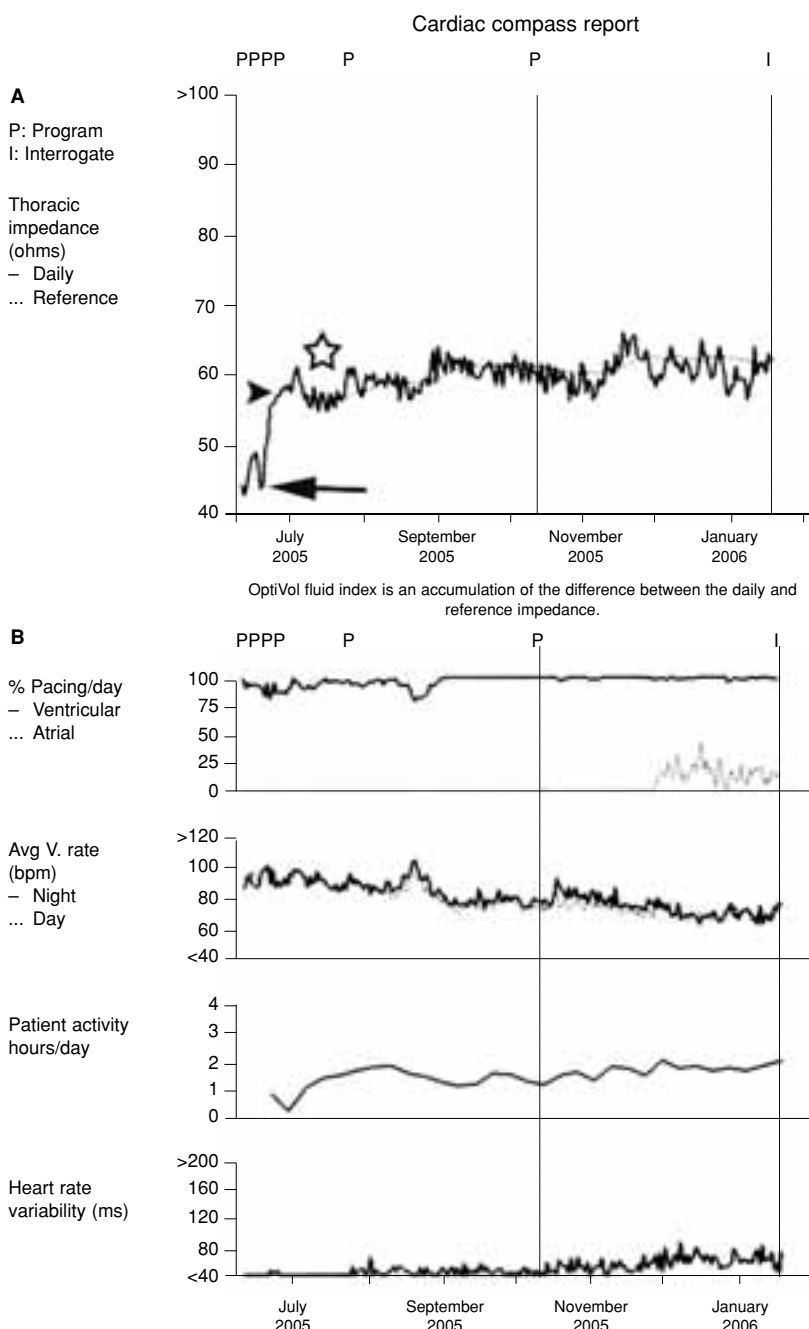
The indications for implantation of ICD and BiV pacemaker often coexist. The incidence of heart failure is very high in patients with the indication for ICD. Similarly, the incidence of ventricular arrhythmia is high in cases where BiV is indicated.<sup>[8,9]</sup> Instead of implanting only BiV or ICD, implantation of BiV-ICD has been advocated. With technological improvements, measurement of TI is now incorporated in BiV-ICDs.<sup>[2,4,5,7]</sup> Unlike impedance cardiography which measures TI externally, these devices measure impedance internally, determining the changes in the impedance of the lung tissue between the generator can and the tip of the lead. Devices with TI measuring capability provide clinically useful hemodynamic data and guide for the treatment of CHF.

The correlation of TI values with volume status data was derived from clinical studies.<sup>[4]</sup> The InSync Sentry BiV ICD has TI monitoring capability. The presence of TI monitoring software increases the cost of the device (approximately \$2,500 per device) in some countries. However, in our country, there is no additional cost for this feature (personal communication). The device uses an algorithm that has been developed to track fluid build-up using TI. Multiple TI measurements are made each day between noon and 5:00 PM, which are averaged to provide a single measurement for the day. This daily value is depicted on a graph (Fig. 1a). The reference TI value is derived from multi-day averages and reflects expected changes over time, from which daily TI changes can be compared. Thus, each patient serves as his/her own control. The patient's current TI is always compared to an average of previous days' values rather than targeting a particularly desired impedance value.

Traditionally, clinical follow-up of patients with CHF is conducted on the basis of symptoms, phys-

ical examination, and laboratory findings. However, the absence of specific signs and symptoms and X-ray findings of heart failure does not exclude the possibility of worsening heart failure.<sup>[11,12]</sup> Daily weight monitoring is an easy and helpful method for assessing heart failure status, but it is not a reliable predictor for decompensation. In patients with heart failure, lung congestion precedes clinical worsening and hospitalization.<sup>[13]</sup> As lung congestion increases, a parallel decrease in TI is detected well before clinical decompensation

(i.e. before the symptoms and signs of CHF become overt).<sup>[2,4,5,7]</sup> Wang et al.<sup>[7]</sup> studied 22 hospital admissions in nine patients with heart failure and found reduced TI about two weeks before hospitalization. Yu et al.<sup>[4]</sup> reported that decrease in TI began about two weeks before clinical worsening. Both studies also reported an inverse correlation between pulmonary capillary wedge pressure and TI. It was concluded that the need for hospitalization could be determined earlier than clinical decompensation.



**Fig. 1. (A)** Interrogation report showing changes in thoracic impedance (TI) over time. A decrease in TI was seen at the beginning of the graph (arrow). TI increased as the patient was treated effectively with diuretics (arrowhead). Although the patient was asymptomatic, a minimal decrease in TI was detected at the follow-up (star), indicating volume overload before the development of clinical deterioration. At this point, outpatient optimization of the diuretic dose improved the TI values. **(B)** Interrogation report showing changes in the percent of atrial and ventricular pacing, average ventricular rate, patient activity, and heart rate variability over time. Decrease in the heart rate was mostly secondary to improved heart failure status and increased beta-blocker administration.

Congestive heart failure is one of the leading causes of hospitalization worldwide. Any parameter like TI indicating decompensation, especially before the development of clinical symptoms, would be very helpful in designing a more tailored treatment. With this strategy, the need for frequent hospitalization may be decreased, together with the cost of patient care and the quality of life may be increased. In addition, as a noninvasive method, TI may be used to guide diuretic treatment during the acute phase of decompensation in patients with CHF. Monitoring pulmonary congestion by daily TI measurements may be useful in adjusting diuretic dose and deciding the length of stay in intensive care unit. However, controlled clinical studies are needed to validate the benefit of such an approach. In our patient, on detecting the decrease in TI at a time he was asymptomatic with no signs of decompensation, we increased the diuretic dose, after which he enjoyed normal TI values without any decompensation. Early detection and treatment of pulmonary congestion guided us to appropriate treatment and decreased the need for possible hospitalization.

In conclusion, our case is a good example of how TI can be used for clinical decision making in a patient with BiV-ICD. Pacemakers and other implantable devices may include valuable features for assessment of clinical status of patients. It is recommended that physicians be more familiar with these features and incorporate them into their treatment and follow-up endeavors.

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