



## Original Research

# The Value of the Tei Index in Predicting Implantable Cardioverter Defibrillator Shocks

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### Abstract

**Objectives:** An implantable cardioverter defibrillator (ICD) decreases the risk of sudden death in the appropriate patients. However, a relationship between ICD shocks and increased mortality and morbidity has been suspected. This report is an investigation of an association between ICD shocks and the Tei index, an echocardiographic parameter now commonly used to predict cardiovascular events.

**Methods:** The basic characteristics of 250 patients with chronic heart failure who had an ICD implanted and 2 years of follow-up device recordings were retrospectively analyzed. Patients who received shock therapy during follow-up were compared with those who did not, based on demographic and other characteristics and the Tei index.

**Results:** The mean Tei index value of ICD shock recipients was significantly higher than the score of non-recipients of ICD shock ( $0.70 \pm 0.10$  vs  $0.56 \pm 0.10$ ;  $p < 0.001$ ). The percentage of patients for whom it was primary prevention who received either appropriate or inappropriate ICD shocks was 28.9%, whereas in those who received an ICD for secondary prevention, the percentage was 71.1% ( $p < 0.001$ ). ICD shock recipient patients were older, and had a greater rate of hypertension and smoking pack-years compared with those to whom an ICD shock was not delivered ( $p < 0.001$ ).

**Conclusion:** The results of this study demonstrated a relationship between the Tei index and ICD shocks, either appropriate or inappropriate. The Tei index is a simple method to predict ICD shocks.

**Keywords:** Inappropriate shock, implantable cardioverter defibrillator, Tei index.

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Implantable cardioverter defibrillators (ICDs) are widely used and known to decrease mortality in patients at risk for sudden cardiac arrest and high-risk cardiac disease.<sup>[1-3]</sup>

However, at the same time, ICD shocks can have adverse effects on quality of life and the psychological state of patients. Studies have detected that the physical and mental health state of patients deteriorates with the delivery of ICD shocks.<sup>[4-9]</sup> As the number of shocks increases, patients are hospitalized for longer periods, which also adversely affects healthcare expenses. In addition, frequent shocks

may shorten the battery life of the device.

It has been reported that in 2 years post implantation, appropriate ICD shocks were delivered to only 50% to 70% of patients with an ICD implanted to manage ventricular tachycardia /fibrillation (VT/VF).<sup>[10]</sup> Inappropriate shocks have been seen in 15% to 25% of patients.<sup>[11, 12]</sup>

Predictors of ICD shock have been thoroughly investigated. The potential usefulness of parameters such as ejection fraction (EF), renal dysfunction, age, and atrial fibrillation (AF) has been demonstrated.<sup>[13]</sup> If we can identify the pa-

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tients at risk for inappropriate shock after ICD implantation, then the ability to prevent these shocks may increase.

The Tei index is not affected by the geometric configuration of ventricle as delineated by Doppler echocardiography, and it is used in the assessment of both systolic and diastolic functions of the ventricle.<sup>[14]</sup> The simplicity and reproducibility of this technique offer an advantage to the physician. It has a prognostic value in a wide spectrum of cardiac diseases, from myocardial infarction to heart failure. This study was an investigation of the use of the Tei index in patients who received ICD shocks.

## Methods

### Patient Population

A retrospective analysis was conducted of the baseline characteristics of patients who received an ICD between 2013 and 2015 and 2 years of follow-up data. ICD devices were implanted in a total of 250 patients with the diagnosis chronic heart failure (CHF), with or without a documented heart attack, in compliance with the current guidelines. Baseline physical electrocardiographic and echocardiographic examination details, laboratory results, and risk factors were retrieved from patient files and recorded. Patients who did not complete 2 years of follow-up for any reason (excluding those who died after receiving ICD shock therapy with the indication of arrhythmia) were not included in the study. Furthermore, patients were excluded from the study if the estimated Tei indices were not reliable; if AF, aortic stenosis, or atrioventricular block was present; or if they had a pacemaker with a basal battery rhythm. The patients were grouped according to those who had and had not received shock therapy, and intergroup characteristics were analyzed. The study protocol was approved by the Ethics Committee of Mersin University.

### The Devices and Programs Used

The ICD was implanted from the left pectoral region in all cases. During and after the procedure, device threshold and sensing measurements were made. The devices used were all manufactured by Biotronik SE & Co. KG (Berlin, Germany) and standard defibrillator programs were used. If the heart rate is between 130 and 161 bpm, then the device records the cardiac event without delivering any treatment. In Zone 2, a ventricular arrhythmia greater than 162 bpm is perceived as VT and antitachycardic pacing of 2 bursts and 2 ramps is delivered. In the event of persistent arrhythmia, the device delivers defibrillator shocks. However in Zone 3, if a ventricular arrhythmia is greater than 210 bpm, the device delivers a shock as the initial treatment. Algorithms to distinguish between supraventricular tachycardia and VT

are activated to prevent delivery of inappropriate shocks.

### Calculation of the Tei Index

The Tei index is measured using ejection time, and the isovolumetric contraction and relaxation times, determined based on Doppler echocardiographic values (Fig. 1). These time periods may be calculated from recordings obtained from apical 5-chamber echocardiographic views with the sample volume placed just behind the aortic valve, that is, over the left ventricular outflow tract.

### Follow-up

All of the devices were checked at an average interval of 3 months and the data obtained were recorded. Appropriate and inappropriate ICD shocks were determined and recorded. ICD shocks not delivered for VT or VF were interpreted as inappropriate shocks. Patients who had missing data for a period of more than 6 months were considered lost to follow-up.

### Statistical Analysis

The Shapiro-Wilks test was used when the normality test of the numerical variables was  $n < 50$ , and the Kolmogorov-Smirnov test was used when the  $n > 50$ . In comparisons of 2 independent groups, when the data were normally distributed, a parametric independent samples t-test was used. In comparisons of categorical variables, which were tabulated in 2x2 tables, Pearson's chi-square test was used. The statistical analyses were performed using the R 3.3.2v program (The

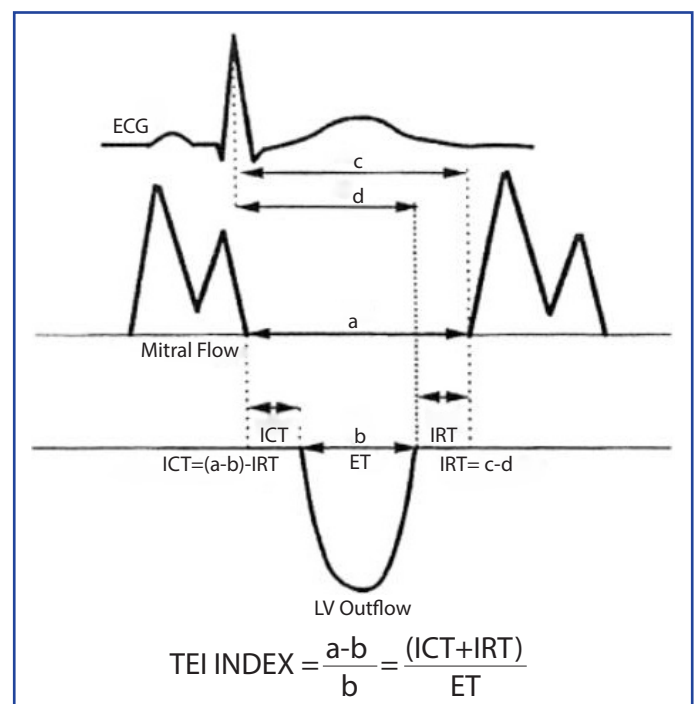


Figure 1. Calculation of Tei index.

R Foundation for Statistical Computing, Vienna, Austria), and the level of significance was a p value of 0.05.

## Results

The comparison of the baseline demographic and clinical characteristics of patients who did and did not receive ICD shocks in the 2-year period after ICD implantation is provided in Table 1. In this study population with heart failure, among the patients who did receive shock therapy (appropriate or inappropriate), the mean age of the patients was

older ( $p < 0.001$ ), and the incidence of hypertension was greater ( $p = 0.002$ ), as well as the number of smoking pack-years ( $p < 0.001$ ) compared with the patients who did not receive a shock.

In all, 28.9% of the CHF patients who underwent ICD implantation for primary prophylaxis received shock therapy, while 71.1% of the patients for whom ICD implantation was for secondary prophylaxis received appropriate or inappropriate shocks ( $p < 0.001$ ).

The EF index was lower and the Tei index was higher in the

**Table 1.** Comparison of basic demographic and clinical characteristics of patients who did and did not receive an ICD shock within 2 years after ICD implantation

	No ICD shock (n=205)	ICD shock delivered (n=45)	p
Age (years)	58.44±9.1	67.11±9.75	<0.001
Sex, n (%)			
Female	68 (33.2)	13 (28.9)	0.578
Male	137 (66.8)	32 (71.1)	
Hypertension, n (%)			
Yes	120 (58.5)	15 (33.3)	0.002
No	85 (41.5)	30 (66.7)	
Diabetes mellitus, n (%)			
No	154 (75.1)	37 (82.2)	0.310
Yes	51 (24.9)	8 (17.8)	
Smoking, n (%)			
No	96 (46.8)	6 (13.3)	<0.001
Yes	109 (53.2)	39 (86.7)	
Ischemic etiology, n (%)			
No	51 (24.9)	8 (17.8)	0.310
Yes	154 (75.1)	37 (82.2)	
Primary prophylaxis, n (%)			
No	59 (28.8)	32 (71.1)	<0.001
Yes	146 (71.2)	13 (28.9)	
Secondary prophylaxis, n (%)			
No	146 (71.2)	13 (28.9)	<0.001
Yes	59 (28.8)	32 (71.1)	
Hyperlipidemia, n (%)			
No	75 (36.6)	16 (35.6)	0.897
Yes	130 (63.4)	29 (64.4)	
Stroke, n (%)			
No	124 (60.5)	23 (51.1)	0.247
Yes	81 (39.5)	22 (48.9)	
Body mass index*	27.05±2.43	26.5±2.7	0.190
Systolic blood pressure*, mmHg	125.37±7.22	127.33±7.80	0.104
Diastolic blood pressure*, mmHg	74.05±6.24	75.44±5.92	0.172
Pulse rate*, bpm	68.15±6.04	67.31±7.17	0.416
Ejection fraction*, %	32.32±4.68	27.09±4.82	<0.001
Glomerular filtration rate*, mL/min/1.73m <sup>2</sup>	76.75±13.98	54.87±11.80	<0.001
Tei index*	0.56±0.10	0.70±0.10	<0.001

Chi-square test was used to compare categorical variables; Student's t-test was used for the comparison of numerical variables; \*Numerical data are reported as mean±SD; ICD: Implantable cardioverter defibrillator.

**Table 2.** Correlation table

Age & ejection fraction	250	-0.314	<0.001
Age & eGFR	250	-0.375	<0.001
Age & Tei index	250	0.417	<0.001
eGFR & Tei index	250	-0.757	<0.001

Pearson's correlation coefficient was used; eGFR: Estimated glomerular filtration rate.

group who received shock therapy within 2 years following ICD implantation relative to those who didn't receive shock therapy ( $p < 0.001$ ). The mean estimated glomerular filtration rate (eGFR) was also higher in the group that received shock therapy ( $p < 0.001$ ).

Among the entire study population ( $n = 250$ ), a weak but significant negative correlation was observed between the Tei index value and age of the patients ( $p < 0.001$ ) (Table 2). The Tei index value increased in parallel with the age of the patients, while the EF and eGFR scores decreased as age increased ( $p < 0.001$  for both).

A strong negative correlation was found between eGFR value and the Tei index: the Tei index value increased as the eGFR value decreased ( $p < 0.001$ ).

## Discussion

This study was an investigation of echocardiographic findings, which may predict ICD shocks in patients with implanted ICD devices. In our study population, a significantly higher Tei index value was detected in CHF patients who received either appropriate or inappropriate ICD shocks within 2 years after ICD implantation compared with those who did not.

A correlation between ICD shocks and mortality has been reported, regardless of whether the ICD shocks are appropriate or inappropriate. The risk increases slightly in patients receiving appropriate ICD shocks.<sup>[15]</sup> In addition, after 5 inappropriate shocks, each ICD shock has been associated with a 3.7 times increase in mortality.<sup>[13]</sup> Myocardial damage has been demonstrated in patients who received ICD shocks.<sup>[16]</sup>

However it is still controversial whether or not ICD shocks are a cause or an outcome of increased risk of mortality. According to some opinions, deterioration of left ventricular function during the natural course of heart failure increases the frequency of arrhythmic episodes and thus, ICD shocks. AF, which is the most commonly seen arrhythmia in heart failure, is the most frequent cause of inappropriate ICD shocks.<sup>[17]</sup> The occurrence of AF is an independent marker of mortality in heart failure and a greater number of shocks increases mortality.

While an ICD can provide benefits, ICD shocks can also adversely affect the physical and mental health of recipients. Multiple ICD shocks often seriously frighten patients and some even have concerns that the device may kill them.<sup>[18]</sup> Fear sometimes leads some of these patients to refrain from performing daily activities.<sup>[19]</sup>

The Tei index is the sum of both isovolumetric times divided by the ejection time. In patients with impaired cardiac function, the isovolumetric contraction time and the isovolumetric relaxation time are prolonged, while the ejection time is shortened. Therefore, the Tei index value of cardiac patients is greater than that of healthy individuals. The prognostic value of the Tei index has been demonstrated in patients who experienced myocardial infarction, dilated cardiomyopathy, and the general population.<sup>[20-22]</sup>

One study has reported a cardiovascular mortality rate nearly 13 times higher in cardiac failure patients with a Tei value greater than 0.67.<sup>[23]</sup>

It is reasonable to assume that the decline of cardiac sufficiency increases the frequency of arrhythmia and increases mortality in patients who receive appropriate shock therapy. Our results indicate that a greater Tei index value, which may be a criterion of a clinically poor prognosis, is also associated with increased frequency of ICD shocks.

In our study, ICD shocks were more frequently observed in patients who had an ICD implanted as secondary prophylaxis. This finding has been reported in various studies.<sup>[24]</sup>

We also detected a correlation between smoking and ICD shocks. Sanchez et al.<sup>[25]</sup> also observed a significant correlation between smoking and ICD shocks.

In conclusion, this research revealed a correlation between the Tei index and ICD shocks. The ability to predict ICD shocks may allow for preventive measures to be taken. The Tei index is easily standardized and measurable echocardiographic parameter that may be a useful tool. Prospective, randomized studies could provide additional, valuable results.

## Disclosures

**Ethics Committee Approval:** The study was approved by the Local Ethics Committee.

**Peer-review:** Externally peer-reviewed.

**Conflict of Interest:** None declared.

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