Daily Shock Impedance Measured by Implantable Cardioverter Defibrillator is Useful in the Management of Congestive Heart Failure

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Background Clinical data suggest that changes in intrathoracic impedance and fluid accumulation in the lung are inversely related.

Methods and Results Daily shock impedance (S-IMP) was evaluated in 29 patients in whom a Ventak Prizm 2 was implanted (61±14 years old). The mean follow-up period was 45±18 weeks, during which 6 patients had episodes of decompensated heart failure (DHF group) and the others did not (NHF group). There was no significant difference between the DHF group and NHF group in the mean value of the S-IMP (46.4±3.3 vs 45.4±5.4 Ω). The range of S-IMP in individual patients in the DHF group was significantly greater than that in the NHF group (13.8±0.38 vs 7.0±3.1 Ω, p<0.0001). Mean weekly change of S-IMP in individual patients in the DHF group was significantly greater than that in the NHF group (1.583±0.630 vs 1.092±0.361 Ω, p<0.0176). When the cut-off value was set at >1.242 Ω, sensitivity was 100% and specificity was 69.6% for a diagnosis of DHF. There was a significant negative correlation between the percent increases in brain natriuretic peptide (BNP) and S-IMP (correlation coefficient: –0.775 p<0.0001) in the DHF group. There was an inverse relation between BNP and S-IMP.

Conclusions Measurement of shock impedance may be useful in the management of congestive heart failure.

Key Words: Electric countershock; Heart failure; Implantable defibrillator; Monitoring; Pulmonary edema; Thoracic impedance

The implantable cardioverter-defibrillator (ICD) is used worldwide for the treatment of fatal arrhythmia, but patients with ICD often have heart failure, which must be managed. Clinical data suggest that changes in intrathoracic impedance and fluid accumulation in the lung are inversely related, so to evaluate whether or not measurement of shock impedance would be useful in the management of congestive heart failure (CHF), we examined the time course of changes in shock impedance in patients with or without decompensated heart failure (DHF), and the relationship between shock impedance and brain natriuretic peptide (BNP) levels in patients with DHF.

Methods

We retrospectively evaluated daily shock impedance (S-IMP) in 29 consecutive patients in whom a Ventak Prizm 2 was implanted; 10 patients were excluded because of lung disease or hemodialysis. Mean follow-up was 45±18 weeks in these 29 patients (61±14 years old). DHF developed during the follow-up in 6 patients (DHF group) and the remaining 23 patients comprised the non-decompensated heart failure (NHF) group, which included patients with a low left ventricular ejection fraction (LVEF <40%; n=6) or history of CHF (n=5).

The Ventak Prizm 2 automatically performs a painless impedance check daily. The impedance test uses a biphasic pulse of 15 mA/60 μs, 0.4 J. A shock is delivered on the R wave every 24 h. Daily data are stored in the memory for 1 week, and every week for 1 year. We evaluated the changes in S-IMP in both groups of patients during the follow-up period.

Comparison of DHF and NHF Groups

To evaluate the importance of changes in shock impedance to predict DHF, we compared the range (highest value minus lowest value) of S-IMP values in individual patient in the 2 groups, as well as the mean change (absolute number) in the weekly S-IMP.

Relationship of BNP and S-IMP

We compared the BNP and S-IMP values for the DHF group, as well as the BNP and weekly shock impedance data. When the day of obtaining BNP data and shock impedance data differed, the mean value of shock impedance before and after the day of obtaining BNP data was used. To
compare the values of BNP and S-IMP in the DHF group, percent increases of BNP and S-IMP were calculated.

**Statistical Analysis**

Measured variables are expressed as mean ± SD. Statistical analysis was performed by Student’s t-test to compare the NHF group and DHF group, and simple linear regression analysis was performed to evaluate the relationship between percent increases of BNP and S-IMP in the DHF group. Statistical significance was set at p<0.05.

**Results**

Patient’s baseline characteristics and shock impedance data are shown in Table 1. There was no significant difference between the DHF group and NHF group in the mean value of S-IMP (46.4±3.3 vs 45.4±5.4 Ω). The range of the S-IMP value in individual patients of the DHF group was significantly greater than that of the NHF group (13.8±0.38 vs 7.0±3.1 Ω, p<0.0001). The mean change in the weekly S-IMP in individual patients in the DHF group was significantly greater than that in the NHF group (1.583±0.630 vs 1.092±0.361 Ω, p<0.0176). S-IMP was stable in the NHF group. When the cut-off value was set at >1.242 Ω, sensitivity was 100% and specificity was 69.6% for diagnosis of DHF. The area under the receiver-operating characteristic curve was 0.812 (Fig 1).

In the NHF group, S-IMP was stable. Representative cases from the NHF group are shown in Fig 2a. A 55-year-old woman with sustained ventricular tachycardia and cardiac sarcoidosis had a LVEF of 28.8% and BNP level of 49.9 pg/ml. She had history of CHF, but had no episodes of DHF during follow-up. Her S-IMP did not show significant changes during follow-up. A 67-year-old man with ventricular fibrillation and ischemic heart disease had a LVEF of 59.9% and BNP level of 31.6 pg/ml. He did not have a history of CHF and his S-IMP did not show significant changes during follow-up.

In the DHF group, BNP values were available for 3 patients. A representative case is shown in Fig 2b. The 78-year-old man with sustained ventricular tachycardia and ventricular fibrillation had BNP and impedance values of 407.7±177.3 pg/ml and 45.4±5.4 Ω, respectively. The correlation coefficient between BNP and shock impedance was −0.700 (p<0.0005), −0.778 (p<0.0001) between the increase in BNP and shock impedance, and −0.767 (p<0.0005) between the percent increase of BNP and shock impedance (Fig 3).

Simple linear regression analysis is shown in Fig 4. There were strong negative correlations between BNP and shock impedance, the increase in BNP and shock impedance, and between percent increase of BNP and shock impedance. There was a significant negative correlation between percent increases of BNP and S-IMP (correlation coefficient: −0.775, p<0.0001) in the DHF group.

**Discussion**

Volume overload is a major problem for patients with moderate to severe heart failure, and is a frequent cause of repeated hospital admissions. Clinical data suggest that changes in intrathoracic impedance and fluid accumulation in the lung are inversely related: as fluid accumulates in the lungs, intrathoracic impedance decreases. An increase in intrathoracic impedance may also indicate a reduction in pulmonary capillary wedge pressure.

In the present study, both the range of S-IMP values in individual patients and the mean change in the weekly S-IMP in individual patients of the DHF group were significantly greater than those in the NHF group. The NHF group included patients with a history of CHF or with a low

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**Table 1 Patients’ Baseline Characteristics and Shock Impedance Data**

<table>
<thead>
<tr>
<th></th>
<th>All patients (n=29)</th>
<th>NHF group (n=23)</th>
<th>DHF group (n=6)</th>
<th>NHF vs DHF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>61±14</td>
<td>60±3</td>
<td>62±5</td>
<td>NS</td>
</tr>
<tr>
<td>Follow-up period (weeks)</td>
<td>45±18</td>
<td>41±6</td>
<td>58±7</td>
<td>NS</td>
</tr>
<tr>
<td>History of CHF (n)</td>
<td>9</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>LVEF (%)</td>
<td>51±19</td>
<td>54±4</td>
<td>40±6</td>
<td>NS</td>
</tr>
<tr>
<td>LV end-diastolic dimension (mm)</td>
<td>57±10</td>
<td>56±10</td>
<td>64±9</td>
<td>NS</td>
</tr>
<tr>
<td>Cardiothoracic ratio (%)</td>
<td>56±6</td>
<td>55±2</td>
<td>59±1</td>
<td>NS</td>
</tr>
<tr>
<td>Mean value of S-IMP (Ω)</td>
<td>45±6±5.0</td>
<td>45.4±5.4</td>
<td>46.4±3.3</td>
<td>NS</td>
</tr>
<tr>
<td>Mean range of S-IMP in individual patients (Ω)</td>
<td>8.4±4.2</td>
<td>7.0±3.1</td>
<td>13.8±3.8</td>
<td>p&lt;0.0001</td>
</tr>
<tr>
<td>Mean change of S-IMP (Ω)</td>
<td>1.19±0.46</td>
<td>1.09±0.36</td>
<td>1.58±0.63</td>
<td>p&lt;0.05</td>
</tr>
</tbody>
</table>

NHF, non-decompensated heart failure; DHF, decompensated heart failure; CHF, congestive heart failure; LVEF, left ventricular (LV) ejection fraction; S-IMP, value of daily shock impedance.

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Fig 1. Receiver operating characteristic (ROC) curve. Area under the ROC curve was 0.812. When the cut-off value was set at >1.242 Ω, sensitivity was 100% and specificity was 69.6% for diagnosis of decompensated heart failure. CI, confidence interval.
Fig 2. Time course of changes in daily shock impedance after implantable cardioverter-defibrillator. (a) Representative cases (Patient A, B) from the non-decompensated heart failure group. (b) Representative case from the decompensated heart failure group. LVEF, left ventricular ejection fraction; BNP, brain natriuretic peptide.

Fig 3. Relationship between brain natriuretic peptide (BNP) level and shock impedance (a), increase in BNP level and shock impedance (b), and percent increase in BNP level and shock impedance (c) in a representative case. There was a significant negative correlation between BNP and shock impedance ($r^2=0.517$, $p<0.0005$), between an increase in the BNP level and shock impedance ($r^2=0.605$, $p<0.0001$), and between a percent increase in BNP and shock impedance ($r^2=0.463$, $p<0.001$).
LVEF. The intrathoracic impedance was stable if the patient did not develop DHF. Our data suggest that a patient in whom the mean change in the S-IMP values is >1.242 Ω might have DHF.

In the DHF group, there was a sudden decrease in the S-IMP before the development of heart failure, and there was a strong negative correlation between BNP and the shock impedance data stored automatically in the Ventak Prizm 2. This finding is compatible with previous reports. In the follow-up of heart failure patients, a sudden decrease of the S-IMP may be a warning of impending heart failure, so measurement of shock impedance may be useful in the management of CHF. These results may be applied to the patient alert system or to the home monitoring system of the ICD.

The measurement of intrathoracic impedance by an ICD may be affected by some factors. Factors that may contribute to a decrease in impedance include lung resistance, heart and lung tissue mass, skeletal tissue and ICD pocket fluid build-up. Factors that may contribute to an increase in impedance include lung resistance, lymphatic drainage, fluid redistribution because of biventricular failure and muscle resistance. However, a sudden decrease in shock impedance may occur after pulmonary edema.

In our study, BNP data were not obtained on the same day as the stored impedance data, so the negative correlation was not very strong. In addition this report was a retrospective study and further investigations are needed.

**Conclusion**

Shock impedance is stable in patients without DHF. A sudden decrease in the shock impedance occurs before the development of heart failure and so measurement of shock impedance may be useful in the management of CHF.

**References**