REMOTE MONITORING

RESEARCH ARTICLE

A Patient-centered Educational Approach to Intrathoracic Impedance Remote Monitoring Can Reduce Hospitalizations

JONATHAN ROSMAN, MD, FACC, FHRS1,2, MURRAY ROSENBAUM, MD, FACC, FHRS1,2 and E. MARTIN KLOOSTERMAN, MD, FACC, FHRS1,2

1Cardiac Arrhythmia Service, Boca Raton Regional Hospital, Delray Medical Center, Boca Raton, FL
2Affiliate Assistant Professor of Clinical Biomedical Science, FAU Medical School, Boca Raton, FL

ABSTRACT. Congestive heart failure (CHF) hospitalizations are a major economic burden. Elevated intrathoracic fluid levels on implantable defibrillators are associated with a higher risk of CHF hospitalization. We present a method of scheduled screening and a patient-centered educational approach to elevated intrathoracic fluid levels that can reduce CHF hospitalizations. Patients with Medtronic, Inc. or St. Jude Medical defibrillators were included. Remote monitoring was performed every 31 days for 12 consecutive months. Patients with elevated intrathoracic fluid levels were managed as follows: 1) patients were called by a physician or a nurse trained in CHF management. They were educated on diet, weight monitoring, and recognizing signs and symptoms of CHF; 2) patients with no CHF symptoms were instructed to watch for signs and symptoms of CHF; 3) patients with stable CHF symptoms were instructed to see their cardiologist if symptoms worsened; 4) patients with significant CHF symptoms were referred to their cardiologist who was also contacted by the monitoring physician. A total of 1,772 remote checks were performed in 158 patients over the 12-month period. One hundred and sixteen (6.5%) remote measurements had an elevated fluid level. Nine hospitalizations occurred in six patients (4%) over the 12-month period. Only one of 116 (<1%) elevated fluid measurements resulted in a CHF hospitalization. Scheduled screening of intrathoracic fluid measurements with a patient-centered educational approach to elevated fluid levels may reduce CHF hospitalizations. Prospective randomized controlled studies utilizing this system are warranted.

KEYWORDS. Congestive heart failure, defibrillator, intrathoracic impedance, remote monitoring.

Introduction

Remote monitoring of cardiac implantable electronic devices (CIEDs) improves patient outcomes.1,2 Implantable defibrillators have the capability of measuring intrathoracic impedance values that correlate with pulmonary fluid status. Low intrathoracic impedance values precede clinical signs and symptoms of congestive heart failure (CHF).3–5 Patients with low intrathoracic impedance measurements are at increased near-term risk of CHF hospitalization.6,7 However, to date studies have not successfully utilized intrathoracic impedance to reduce CHF hospitalizations.8,9 We present a method of scheduled remote screening and a patient-centered educational approach to low intrathoracic impedance measurements that can reduce CHF hospitalizations.

Methods

Patients with systolic heart failure, ejection fraction ≤40%, and Medtronic Inc. or St. Jude Medical defibrillators were
included. Remote monitoring was performed every 31 days from December 2013 to November 2014. Patients with at least 11 of 12 monthly remote interrogations were included for analysis. Every remote interrogation was reviewed by a cardiac electrophysiologist. For Medtronic implantable cardioverter-defibrillators (ICDs), low intrathoracic impedance measurements were determined by an OptiVol (Medtronic Inc., Minneapolis, MN) fluid index level of >80 Ω·days at the time of monthly measurement. The OptiVol fluid index level is the difference between the baseline and daily measured intrathoracic impedance. As fluid accumulates in the lungs, intrathoracic impedance decreases and the OptiVol fluid index level increases. For St. Jude Medical ICDs, low intrathoracic impedance measurements were determined by a CorVue™ (St. Jude Medical, St. Paul, MN) thoracic impedance measurement below baseline for >7 days at the time of monthly measurement.

Patients with abnormal intrathoracic impedance values were managed as follows:

1. Patients were called by a nurse trained in CHF management who evaluated patients for signs and symptoms of CHF. Patients were educated on diet, weight monitoring, and recognizing signs and symptoms of CHF.
2. Patients with no CHF symptoms were instructed to watch for future signs and symptoms of CHF.
3. Patients with stable CHF symptoms were instructed to see their cardiologist if symptoms worsened.
4. Patients with significant or worsening CHF symptoms were referred to their cardiologist who was also contacted by a cardiac electrophysiologist.
5. If atrial fibrillation was thought to be the etiology of abnormal intrathoracic impedance measurements the patient was further evaluated by a cardiac electrophysiologist.
6. Patients were called a month later to follow up their symptoms and see if they had seen their cardiologist and/or had a change in medication regimen.

Patient data was de-identified for analysis.

Results

A total of 158 patients met criteria for analysis. One hundred and eighteen patients (75%) had a Medtronic, Inc. ICD and 40 patients (25%) had a St. Jude Medical ICD. Seven patients died and five patients entered hospice and were removed from remote monitoring during the study period. Baseline characteristics are listed in Table 1. Most patients were men and had ischemic cardiomyopathy. Most patients had New York Heart Association (NYHA) class II or III heart failure and 56% of patients had biventricular defibrillators.

A total of 1,772 remote checks were performed over the 12-month period. One hundred and sixteen (6.5%) remote measurements had abnormal intrathoracic impedance values. Of those, 27% were associated with clinical signs or symptoms of CHF. Monthly patient follow-up was available for 101 out of 116 (87%) abnormal intrathoracic impedance values. Sixty-six of 101 (66%) abnormal intrathoracic impedance value patients saw their cardiologist and 13 out of 101 (13%) had a change in their heart failure medical regimen in the month following the abnormal measurement. Nine CHF hospitalizations occurred in six out of 158 (4%) patients over the 12-month study period. Only one out of 116 (<1%) abnormal intrathoracic impedance values resulted in a CHF hospitalization.

Discussion

CHF treatment is a major economic burden, and hospitalizations from acute CHF exacerbation account for the majority of healthcare spending in these patients. Signs and symptoms of CHF, including weight gain and shortness of breath, present too late to prevent hospital admission. Remote monitoring for CIEDs has dramatically improved patient care. The ability to wirelessly monitor patients’ ICDs has allowed for early detection and treatment of arrhythmias and lead and device malfunctions. ICDs can now provide physiologic data that can also be remotely monitored.

Medtronic, Inc. and St. Jude Medical ICDs measure intrathoracic impedance from the right ventricular coil to the ICD can. Electricity travels faster in fluid than air and therefore increased fluid in the lungs results in a decrease in intrathoracic impedance. Intrathoracic impedance therefore correlates with pulmonary vasculature congestion. Changes in intrathoracic impedance values precede clinical signs and symptoms of CHF. Patients with decreased intrathoracic impedance measurements are at higher risk of CHF hospitalization in the ensuing weeks. Utilizing intrathoracic impedance values may help identify patients at risk of CHF exacerbation and hospitalization. Appropriate intervention and early treatment when necessary can prevent CHF exacerbation and hospitalizations (Figure 1).

The DOT-HF study evaluated whether intrathoracic impedance values could be utilized to decrease hospitalizations. Patients received an audible alert to a decrease in intrathoracic impedance as measured by an OptiVol fluid index level >60 Ω·days. Every alert required a patient–physician encounter either by phone or in person. Forty-six percent of office visits during the study period were managed as follows:

1. Patients were called by a nurse trained in CHF management who evaluated patients for signs and symptoms of CHF. Patients were educated on diet, weight monitoring, and recognizing signs and symptoms of CHF.
2. Patients with no CHF symptoms were instructed to watch for future signs and symptoms of CHF.
3. Patients with stable CHF symptoms were instructed to see their cardiologist if symptoms worsened.
4. Patients with significant or worsening CHF symptoms were referred to their cardiologist who was also contacted by a cardiac electrophysiologist.
5. If atrial fibrillation was thought to be the etiology of abnormal intrathoracic impedance measurements the patient was further evaluated by a cardiac electrophysiologist.
6. Patients were called a month later to follow up their symptoms and see if they had seen their cardiologist and/or had a change in medication regimen.

Patient data was de-identified for analysis.

Table 1: Baseline characteristics

<table>
<thead>
<tr>
<th>Patient characteristic</th>
<th>Total number patients (n = 158)</th>
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</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>78.5 ± 9.9</td>
</tr>
<tr>
<td>Female</td>
<td>29 (18.4)</td>
</tr>
<tr>
<td>Heart failure etiology</td>
<td></td>
</tr>
<tr>
<td>Ischemic</td>
<td>124 (78.5)</td>
</tr>
<tr>
<td>Non-ischemic</td>
<td>34 (21.5)</td>
</tr>
<tr>
<td>Left ventricular ejection fraction (%)</td>
<td>29.1 ± 6.3</td>
</tr>
<tr>
<td>Biventricular ICD</td>
<td>89 (56.3)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>53 (33.5)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>86 (54.4)</td>
</tr>
<tr>
<td>NYHA functional class</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>8 (5.1)</td>
</tr>
<tr>
<td>II</td>
<td>52 (32.9)</td>
</tr>
<tr>
<td>III</td>
<td>98 (62)</td>
</tr>
</tbody>
</table>

ICD: implantable cardioverter-defibrillator; NYHA: New York Heart Association.
were solely a result of an audible alert for an abnormal OptiVol fluid index level. Fifty percent of patients who had an in-office review of cardiac compass trends had a change in heart failure medication. There was an increase in hospitalizations in the treatment group compared with the control group. The authors concluded that an audible alert for decreased intrathoracic impedance did not reduce CHF hospitalizations. However, the presence of an audible alert and the lack of remote monitoring may have impacted these results since CHF treatment and hospitalizations were often driven by the audible alert even in the absence of clinical symptoms.\textsuperscript{9,12} The LIMIT-CHF similarly evaluated the efficacy of an audible alert.\textsuperscript{8} Patients in the audible alert group were instructed to increase their diuretic dose for a week following an intrathoracic impedance alert. This was done even in the absence of clinical signs or symptoms of heart failure. There was no significant difference between the group with an active audible alert and the control group. However, similar to the DOT-HF study, it is possible that treating all patients irrespective of clinical symptoms may have led to overtreatment and increased hospitalizations in some patients.

Improved algorithms to measure intrathoracic impedance values attempt to identify patients at highest risk of CHF exacerbation.\textsuperscript{13–15} However, because intrathoracic impedance is an early measurement of pulmonary fluid accumulation it often normalizes without any intervention. It is therefore difficult to predict which patient with a decreased intrathoracic impedance measurement will progress to clinical CHF symptoms and hospitalization. We therefore sought to use intrathoracic impedance values as a screening method rather than an indicator for patient treatment.

We present a patient-centered educational approach that sought to minimize overtreatment and intervene only in patients at highest risk of CHF exacerbation and hospitalization. The heart failure nurse educated all patients with abnormal intrathoracic impedance values to enable them to recognize their own CHF signs and symptoms. The CHF nurse was able to identify patients with signs and symptoms of CHF and refer them to their cardiologist for further management. We explained to patients that intrathoracic impedance value is an early marker for CHF and abnormal levels do not necessarily result in CHF exacerbation. We instructed cardiologists to treat for clinical findings of CHF and not solely based on abnormal intrathoracic impedance levels. By remotely screening patients we were able to refer those with symptomatic CHF for immediate evaluation by their cardiologist. By educating those without symptomatic CHF, we were able to help patients recognize their own CHF symptoms so they could seek attention if they were to develop CHF symptoms.

Sixty-six percent of our patients with decreased intrathoracic impedance measurements saw their cardiologist over the following month. However, only 13% of low intrathoracic impedance values resulted in CHF medication change. That is compared with a medication change of 50% in the DOT-HF trial\textsuperscript{9} and 100% medication change in the LIMIT-CHF trial.\textsuperscript{8} In our study, medication change was a result of signs, symptoms or a physical examination consistent with CHF, but not solely based on an abnormal intrathoracic impedance measurement.

Our algorithm yielded a very low incidence of CHF hospitalization. Over the 12-month period, six patients (4%) had a total of nine hospitalizations and only one of 116 (0.8%) abnormal intrathoracic impedance values resulted in a CHF hospitalization. PARTNERS HF Study evaluated predictors of CHF exacerbation and hospitalization.\textsuperscript{7} A total of 694 cardiac resynchronization therapy ICD patients were followed for 12 months. Ninety (13%) patients had 141 CHF hospitalizations over the study period. In the DOT-HF trial control group, 24 patients (14%) accounted for 36 hospitalizations over the 15-month follow-up period.\textsuperscript{9} In the LIMIT-CHF control group five patients (13%) accounted for six CHF hospitalizations over the 12 month study period. By utilizing the decreased intrathoracic impedance values as a screening tool rather than an indication of treatment, we were able to minimize CHF hospitalizations in our cohort.

**Study limitations**

This was a retrospective assessment of a single group’s current clinical practice. This is a relatively small sample...
size with 158 patients included in analysis. We have a relatively elderly population compared with other trials with an average age of 79 years. Results may differ with a larger cohort and a younger population. We used an 80 Ω day OptiVol fluid index level cutoff to reduce overtreatment. A 60 Ω cutoff may have identified more patients at risk for CHF hospitalization but may also have resulted in overtreatment and increased hospitalizations. We included patients who transmitted at least 11 out of 12 monthly remote interrogations. These patients may therefore be more compliant patients who are more likely to follow their medical regimen resulting in fewer CHF hospitalizations.

Conclusion
We present monthly remote screening combined with a patient-centered educational approach to abnormal intrathoracic impedance values. We had a low incidence of CHF hospitalizations, especially in patients with decreased intrathoracic impedance. Based on these results, our patient centered screening method may help reduce CHF hospitalizations. Randomized controlled prospective studies evaluating similar algorithms are warranted.

References