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Case Report

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Utilization of Bio Impedance Spectroscopy in lieu of Invasive Monitoring for Monitoring Fluid Overload

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Abstract

Congestive heart failure (CHF) has become one of the most common diagnoses and a leading cost concern for Medicare and insurance companies. The majority of costs associated with CHF surround hospitalization and re-admissions. As a result of these rising costs, there has been a push to identify early markers of impending congestion as a surveillance tool and possible measure of effectiveness of treatment. The measurement of diastolic pulmonary artery (PA) pressure from invasive devices has been shown to be useful in the management of New York Heart Association (NYHA) class III heart failure (HF) patients. It has been suggested that bio impedance spectroscopy (BIS) could be used as a surrogate for volume overload, offering a non-invasive option for patients. We present a case of a NYHA class III HF patient with end stage liver disease. The patient had previously been implanted with a Cardio MEMS device. Over several weeks, diastolic PA pressures and weight were compared to BIS measures from a SOZO, (noninvasive fluid monitoring system). The use of BIS to estimate extracellular fluid accumulation shows excellent correlation to both diastolic PA pressure and weight, suggesting a use for non-invasive monitoring.

Introduction

The American Heart Association characterizes the costs of heart failure (HF) in the United States [1]. Estimates suggest a rise from 30 billion dollars a year currently to 70 billion by 2030. HF is one of the highest costs for private insurers with the majority of the expenses surrounding hospitalization and re-admissions and represents an ongoing challenge for Medicare regarding resource utilization

The Cardio MEMS device is an implantable pulmonary artery (PA) pressure sensor, which is inserted during a cardiac catheterization procedure. The invention has been shown to reduce HF admissions and improve quality of life in NYHA class III patients [2,3]. As with other invasive technologies, this may be associated with increased costs, and may not be available for all HF patients. Therefore, surrogates for congestion that are non-invasive, accurate, and inexpensive are needed to better manage this population. Bioimpedance, both single and multi-frequency, has been investigated as a means to detect early congestion but has not consistently been shown to be a reliable indicator [4-6]. Single-frequency bio impedance analysis (SF-BIA) relies on the information from a single frequency reading, typically 50 kHz with population-specific algorithms (based on gender, ethnicity, height, weight, and age) used to estimate the composition of body compartments. Multi-frequency bio impedance (MF-BIA) uses 2 or more frequencies but is still limited in its ability to detect total body fluid, particularly in patients with fluid imbalances due to the use of calculations based on normalized fluid distributions. Bioimpedance spectroscopy (BIS) uses a broad spectrum of frequencies. It has been shown that by using a range of frequencies, a graph can be constructed to estimate the impedance of values at zero and infinity (Cole analysis) [7]. These end-spectrum frequencies allow for individualized information specific to the extracellular and total-body fluid with increased accuracy and without the need for normalized population-specific algorithms [8,9]. Bioimpedance spectroscopy (BIS) technology has several advantages over SF-BIA and MF-BIA. Most importantly, because BIS measures impedance over an entire range of frequencies, it does not depend upon population-specific prediction equations to generate tissue masses or fluid volumes. Additionally, BIS measurements do not assume that extracellular fluid and intracellular fluid are uniformly distributed. Therefore, this technique provides a more direct and individualized measure of fluid compartments of the body as compared with SF-BIA and MF-BIA approach. Thus, BIS has a significant advantage, particularly in patient populations with altered fluid homeostasis.

Several studies have been conducted using BIS technology that demonstrates its utility in tracking changes in fluid levels associated with decompensating HF and other associated conditions [4]. The SOZO unit (ImpediMed, Qld, Australia) utilizes BIS to generate a spectrum of frequencies to provide impedance measures at both zero (extracellular fluid) and infinite (total body water) frequencies. It has the added advantage of being easy to use, facilitating the ability to obtain repeated measures for monitoring chronic illness such as HF. With improved performance and individualized results, BIS allows the extracellular and total body fluid volume to be tracked accurately and noninvasively.

Case Presentation

A 77 year old patient with HF, who due to his multiple admissions and numerous comorbidities had been previously, implanted with a Cardio MEMS device, From Aug 7th through September 20th, 2017, the patient's diastolic PA pressure, weight, blood pressure and bio impedance measures were monitored. The patient's advanced HF required changes in his diuretic regimen to maintain euvolemia. Because of his history of cirrhosis, his fluid status was difficult to estimate by weight alone. His weight, mental acuity, as well as PA pressures were utilized to guide therapy.

On August 18th, the patient's diastolic PA pressure decreased to 11 mmHg from a previous measure of 13 mmHg (August 16th). Because of his fatigue coupled with objective data, it was decided he was dehydrated. His dose of diuretic was decreased to enhance hydration. In response to a decreased diuretic dose, his weight increased, diastolic PA pressure rose and his impedance level dropped. On August 23rd, his diastolic PA pressure dropped again and his diuretic (Lasix) was discontinued. As a result of this medicine change, his diastolic PA pressure rose, and his impedance dropped (Table 1). As the patient also had cirrhosis and was predisposed to hepatic encephalopathy, he was on bowel therapy including lactulose but remained prone to uremia and altered mental status. While attempts were made to prevent trips to the ER, he ultimately deteriorated and presented to the ER on August 26th with confusion and dry mucous membranes. The recent changes in his diuretic dosing, coupled with uremia on labs, led the clinician to believe the patient was dehydrated. However, review of the patient's labs showed they were virtually unchanged from one month earlier and his delirium with tachypnea may have dried his mucosa mimicking a dehydrated state. Upon review of the record, we noted his stable weight and rising diastolic PA pressures the day prior to admission. These data points argued against dehydration as a cause of encephalopathy.

Table 1: Monitoring Results

Date	Weight (kg)	Diastolic Pulmonary Artery Pressure (PAD) (mmHg)	Impedance at frequency zero (R0) (Ohms)	Extracellular Fluid (ECF) (liters)	Systolic Blood Pressure (mmHg)
7-Aug-2017	95.3	12	545	25.1	122
9-Aug-2017	96.6	17	563	24.7	110
11-Aug-2017	97.8	14	552	25.1	130
14-Aug-2017	96.3	10	556	24.8	126
16-Aug-2017	95.7	13	583	24.0	120
18-Aug-2017	94.8	11	591	23.7	142
21-Aug-2017	95.7	12	585	24.0	124
23-Aug-2017	94.0	11	617	23.0	122
25-Aug-2017	94.5	14	588	23.8	114
18-Sep-2017	102.5	22	451	29.2	122
20-Sep-2017	101.6	26	458	28.8	130
CORRELATIONS	Weight(kg) to PAD (mmHg)	Weight (kg) to Impedance (Ohms)	Impedance (Ohms) to PAD (mmHg)	ECF (liters) to PAD (mmHg)	
	0.898	**-0.962**	**-0.868**	**0.888**	

A hospitalist service managed the patient for hepatic encephalopathy and administered fluids as well as bowel care. Upon discharge from the hospital, the patient was considerably overhydrated based on weight, diastolic pulmonary pressures, and systolic blood pressure and required diuresis. His hydration status throughout the continuum was monitored by the diastolic pulmonary pressure of the Cardio MEMS unit and correlated well with the BIS measurements (Figure 1, 2).

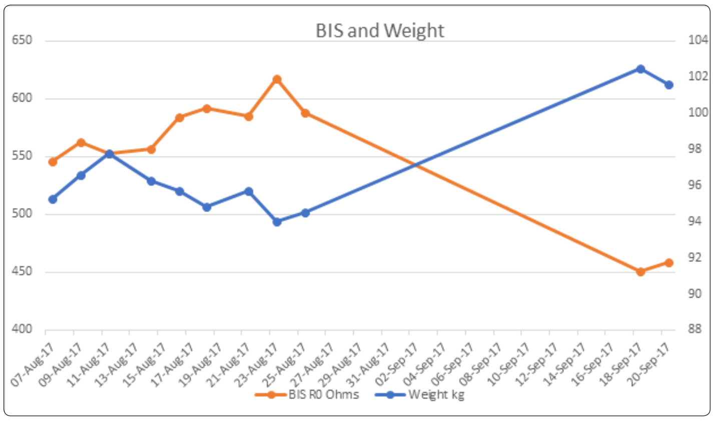

Figure 1: Comparison of BIS (R0) and weight (kg)

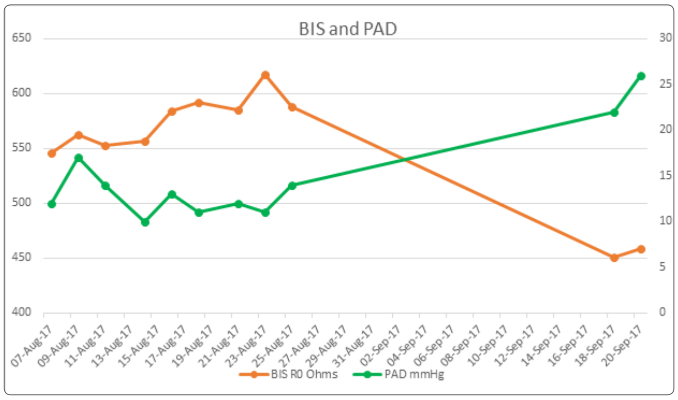

Figure 2: Comparison of - BIS (R0) and PA diastolic (mmHg)

Discussion

This case presented allows for demonstrates a correlation of the diastolic PA pressure to BIS estimates of extracellular fluid. Because of the patient's wide range of pulmonary pressures, the data presents the rare opportunity to follow these readings in various patient states including stable volume status, during volume overload, and post-treatment. The data showed highlights the possibility of using BIS as a non-invasive measure of extracellular fluid for HF management.

There is a suggested role for BIS to better manage fluid for patients in the ER, home, and office setting. For chronic illness, a baseline impedance can be established which would be superior to weight alone. In our case, the BIS measures coupled with weight seem to enhance the assessment of volume status whether that be volume overload or dehydration. As most patients will not have an implantable Cardio MEMS unit to guide therapy, an alternative measure of fluid state coupled with a robust heart failure management plan is needed.

Limitations: This single reported case is by no means definitive, and further research is necessary to define the role that BIS may play in the assessment and treatment of the HF patient. The current SOZO design is unique in that it does not require leads like traditional impedance devices. While the hand and footplates limit movement artifacts from electrode placement, further studies are needed to prove their superiority.

Conclusions

Most HF patients have multiple comorbidities and are managed by weight, physical exam, and standard diagnostics. This traditional management has been shown to be ineffective for early detection of congestion. Due to the high cost of invasive devices, they have a limited application for the millions of patients suffering from HF. The case presented suggests that BIS may provide an additional tool for the clinician to allow for early detection of congestion, edema, or dehydration. Data from this case demonstrates the BIS correlates well with diastolic PA pressure. Because diastolic PA pressures from invasive devices are recognized as a way to prevent CHF hospitalizations, we postulate that BIS may potentially provide a surrogate, noninvasive method and therefore, may prove a useful adjunct in the management of HF. There may also be a role for BIS in the emergency setting when fluid management has been tracked and a patient's baseline is known. Further research is needed to identify what amount of change from baseline in the BIS measurement is clinically significant, if BIS can be used to better optimize fluid balance before discharge, and if a normalized curve for patients can be developed. Clearly, additional studies and data are needed to help define the potential role of BIS in the adjuvant management of patients with HF but the data presented are promising.

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