Assessing Impedance in Heart Failure
From Device Diagnostics to Population Health Opportunities?

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Heart failure care is expensive and resource intensive. In the era of population medicine, accountable care organizations, and bundled care, an inexpensive noninvasive technique to facilitate the management of this population would be a valuable asset. Although continuous remote monitoring of pulmonary artery pressure (PAP) is available and proven to improve outcomes in the clinical trial setting, it is invasive and expensive to implant and requires dedicated personnel to routinely monitor the patient, interpret the data, and consistently use the information. Indeed, few practices are prepared for the type of infrastructure investment required to effectively monitor PAP at the present time under the current payment model. Hence, the adoption of PAP monitoring has been slow and likely limited to patients with advanced heart failure within health systems with sophisticated heart failure programs. Unlike cardiac implantable electronic devices, current trends indicate that PAP monitoring will be used more commonly in patients with heart failure and a preserved ejection fraction because this is a group that is most difficult to manage and accounts for the majority of readmissions.

Impedance measurements from cardiac implantable electronic devices have been clinically available for over a decade. The scientific principle underlying the measurement of impedance, which is the biological equivalent of resistance, is Ohm’s law: $R = \frac{V}{I}$. Resistance ($R$) is a function of the relationship between the applied voltage ($V$) and the current ($I$) measured across an electric field. In patients with cardiac implantable electronic devices that can measure impedance, the electric field includes the lung and thoracic tissue that lie between the device and the tip of the pacing electrode. Presumably, a congested chest has higher fluid content and thus a lower resistance (or impedance), as water is a better electric conductor than air. Indeed, impedance signals have been demonstrated to track with physiological alterations in heart failure. Hence, recognizing alterations in impedance trends may uncover vulnerabilities that can be associated with adverse clinical events.

Meanwhile, accessing the information requires no special equipment or complex logistics, and there is no additional cost. In fact, the data are already incorporated into routine remote and in-person cardiac implantable electronic device checks. Nonetheless, the majority of patients in whom these devices are currently implanted do not have the information reviewed as a part of their routine follow-up. In part, the resistance to using these data has been a reflection of the healthy skepticism of practicing physicians. The concept of impedance is not intuitive. Initial attempts to measure thoracic impedance using surface electrodes (BioZ) proved unreliable because of the low signal:noise ratio such that changes in the impedance signal were obscured by small variances in lead position or skin preparation. Physiological changes other than congestion will affect impedance, and there is a low frequency of false-positive findings (low impedance without clinical congestion) that has been difficult to explain. Furthermore, the literature has not supported the routine monitoring of thoracic impedance using implanted devices. Enabling an automatic alert to notify providers of device-detected fluid-related changes may paradoxically increase costs without providing substantial clinical benefit.

In addition, billing guidelines require coordination between the electrophysiology service and heart failure programs to avoid inappropriate charges and can be intimidating. Specifically, the electrophysiology-related and heart failure–monitored physiological parameters (including impedance) have distinct billing codes and are reimbursed separately. There are also time parameters, which limit the frequency of payment when monitoring is performed remotely. Furthermore, clinical logistics may need to be adjusted so that device interrogations do not interfere with established workflows. Patients with impedance measuring devices should be identified before seeing the provider. Technicians can independently interrogate the device (or download data from a website), which generates the report so that disruptions of patient flow are avoided. Taken together, the practical result of these concerns and challenges has been that physiological parameters generated by implanted devices have been underused and thoracic impedance oftentimes ignored.

Some of the confusion on impedance data from implanted devices is related to a misunderstanding of its utility. Unlike PAP, impedance is not necessarily actionable. PAP is the potassium of congestion. It is an absolute measurement, which can be treated directly. Impedance is more analogous to creatinine. Is creatinine important? Definitely. However, it is a prognostic marker and an indirect signal, which may or may not warrant changes in therapy or alter the natural history despite its prognostic value. What we have learned is that impedance is probabilistically predictive, but not necessarily prescriptive. Although there are certainly instances when abnormally low impedance will help in the detection of subtle congestion,
there are also false-positives, which can be misleading. Ideally, impedance measurements should be interpreted along with clinical data and other measures of device and cardiac function.

In this issue of *Circulation: Heart Failure*, Zile et al. report a retrospective analysis of a large data bank correlating device-derived absolute impedance measurements and subsequent Medicare-reported outcomes. Patients were empirically divided into 3 groups (low, medium, and high impedance) after a 6-month censored period to allow for signal stabilization. Those with the lowest averaged impedance measurements 6 to 9 months post implant had the highest mortality. Patients with the highest impedance had the lowest mortality, and those with an intermediate range measurement had a corresponding midrange mortality risk. Changes between the baseline and the subsequent measurements at 9 to 12 months post implant added predictive value. In contrast to previous study, which have examined the calculated impedance trends and mortality relationship, impedance measurements from the first 6 months after implant were censored in this study to allow time for the signal to stabilize and no algorithmic manipulation of the data was performed. Various measurement intervals were examined. Averaged impedance measurements over periods as brief as 1 day provided important prognostic information. These results add support to the concept that changes in device-monitored physiological parameters (specifically impedance) can track with patient outcomes on rehospitalization, decompensation, and mortality. It offers a simplified and more usable context in that impedance alone has prognostic value whether measured on a single day or serially over several months.

So, how do we interpret the findings in the context of previous neutral (if not negative) trial data, and how can we begin to incorporate this information into clinical practice? And can we use these data to actually affect outcomes or simplify practice? It is important to emphasize that routine monitoring of impedance from implanted devices has not been proven to improve individual clinical outcomes. However, this does not mean that such information cannot be used for population health management. Unlike a drug or the device itself, a diagnostic tool will not change outcome, but relies on interpretation, communication, and patient compliance to effect change. Thus, it has been much harder to demonstrate that proactive monitoring of impedance can change individual outcomes than it has been to demonstrate that impedance predicts population outcomes. As Zile et al. demonstrate, stable or increasing impedance indicates a better prognosis and thus less intense follow-up might be appropriate. Limiting routine monitoring to high-risk patients (recent hospitalization, chronic noncompliance, or those requiring frequent diuretic adjustments) might be a cost-effective intervention. If we accept that impedance can identify high-risk profiles, then there are ways to use the information to simplify practice in population health perspectives. Changes in impedance might influence the frequency of clinic appointments either remotely or in person. Falling impedance might prompt case review with the potential for recommending more frequent follow-up to uncover early decompensation or poor compliance. What has not been traditionally tested in clinical studies but is highly relevant to appropriate allocations of scarce resources is the ability to proactively provide palliative care options as a care management strategy. Specifically, patients with progressively declining or persistently low impedance despite all attempts to optimize medications and ancillary therapies might identify a subgroup in which end-of-life discussions should be considered. Although economically and logistically challenging, future studies should examine the opportunity on whether these data can be used to improve outcomes and deliver more cost effective care delivery on a population basis in addition to that offered by individual clinicians.

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**Disclosures**

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**References**


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