Should Noninvasive Impedance Cardiography

Be a Standard of Care in the Management of Systolic Heart Failure?

By

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The members of the Committee appointed to examine the clinical project of CAROL JEAN WILLIAMS find it satisfactory and recommend that it is accepted.

Chair

[Signatures]
Should Noninvasive Impedance Cardiography Be a Standard of Care in the Management of Systolic Heart Failure?

Abstract

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December 2005

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PURPOSE: To provide an overview of impedance cardiography and to address the controversial question of whether impedance cardiography should be used as a standard of care in the management of systolic heart failure.

DATA SOURCES: Selected research-based articles from PubMed and ProQuest on bioimpedance cardiography and Cox’s Interaction Model of Client Health Behavior.

CONCLUSION: Noninvasive impedance cardiography provides a means of obtaining hemodynamic measurements which can assist healthcare providers to more effectively manage patients with systolic heart failure.

IMPLICATIONS FOR PRACTICE: Incorporating the Interaction Model of Client Health Behavior with the use of impedance cardiography may assist the client to actively engage in the management of their disease and improve the client-practitioner interaction; provides objective evidence of systolic heart failure status on which to base clinical decisions; and may ultimately lead to improved patient outcomes.

KEY WORDS: impedance cardiography, noninvasive impedance cardiography, Interaction Model of Client Health Behavior, systolic heart failure

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Noninvasive Impedance Cardiography
In the Management of Systolic heart failure

Introduction

Heart Failure (HF) is a complex clinical syndrome where the ventricle has impaired ability to fill or eject blood. HF can be caused by structural or functional disorders of the pericardium, myocardium, endocardium, or great vessels with a greater incidence of left ventricular dysfunction (Jessup & Brozena, 2003). HF has an incidence of almost 10 per 1000 population in people older than 65 years; approximately, 5 million (Hunt et al., 2005).

The typical work-up for systolic heart failure patients in the primary care setting includes a cardiac and pulmonary assessment, electrocardiogram, monitoring vital signs, and weight. The goal of impedance cardiography (ICG) is to prevent or slow the development of systolic heart failure. This goal can best be achieved by using ICG to provide baseline, serial, or continuous hemodynamic monitoring and assist in the development of treatment plans, medication titration, and trending of improvement. The use of noninvasive impedance cardiography would provide objective hemodynamic measurements in which the nurse practitioner bases treatment decisions to optimize medications to prevent disease progression and improve heart function.

The following manuscript will discuss the pathophysiology and classification of systolic heart failure, impedance cardiography (ICG), and the Interaction Model of Client Health Behavior (IMCHB). The literature review of ICG will be applied to the IMCHB in order to demonstrate how the model can be used in clinical practice to improve patient outcomes and guide the nurse practitioner’s use of noninvasive impedance cardiography.
The review of literature will be used to answer the question, should noninvasive impedance cardiography be used as a standard of care in the management of patients with systolic heart failure?

Pathophysiology of Heart Failure

Left ventricular heart failure can be categorized into diastolic and systolic, or both. The differences in diastolic and systolic heart failure are presented in Table 1, with the biochemical theories of the development of systolic heart failure presented in Table 2. The goal of care for patients with heart failure is to decrease the workload of the heart and stop or reverse the remodeling of the heart (Copstead & Banasik, 2000).

Purpose

Heart failure symptoms are very subjective. The purpose of this manuscript is to determine if noninvasive impedance cardiography can be utilized as a clinical tool to optimize treatment regimens in the prevention and management of systolic heart failure and should be used as a standard of care in the treatment of systolic heart failure.

Framework

The Interaction Model of Client Health Behavior (IMCHB), developed by Cox (Figure 1), consists of three elements: client singularity, client-professional interaction, and client health outcomes. “The potential for positive patient health outcomes increases as the provider’s intervention or interaction is tailored to the uniqueness of each patient,” is the hypothesis of the IMCHB model (Cox, 1993, p. 4).

Client singularity is comprised of two different sets of factors (Table 3): background variables and dynamic variables. Background variables explain health behavior by describing the client. The dynamic variables are affected by interventions...
more readily, than the background variables that change more subtly over time (Cox, 2003).

The ICG can provide objective health to help individualize patient’s treatment for systolic heart failure. It can be used as a tool to expand patient understanding of systolic heart failure by showing how lifestyle modifications and medications affect their health. ICG data has the potential to modify patients’ knowledge, attitudes, and beliefs about systolic heart failure. The data can also improve treatment and motivate individuals’ health behaviors.

The client-professional interaction element is defined by affective support (bonding), provision of health information, decisional control and professional competencies. Provision of health information can be examined from different directions: the nature and content of information provided, in what medium the information is conveyed such as written, audio, video, one-on-one interaction, the patient’s affective state on delivery of information, and the amount of information given. Decisional control is the providers’ recognition of the patients’ ability to participate in health care decision making. Finally, the professional competencies factor refers to the provider’s ability to interact with the client respecting their singularity and understanding the technical versus interpersonal needs in light of their healthcare problems (Cox, 2003).

Objective information obtained through ICG can help patients understand their disease and treatment regimens. The ICG data, examined through classification systems (New York Association & American College of Cardiology/ American Heart Association), gives a context in which the patient can see the evolution and progression of their disease process and the degree of function they experience. The provision of
health information, in the IMCHB framework, helps patients participate in making health
decision about interventions and helps providers recognize the patient’s ability to
participate in health care decision making.

The health outcomes element consists of healthcare utilization, health status
indicators, problem-severity indicators, adherence to recommended care regimens, and
care satisfaction. Healthcare utilization refers to the use of health care resources as a
health-promoting behavior. Health status indicators refer to all types of clinical health
outcomes, such as weight or objective and subjective health status. Problem severity
indicators can be used to measure progression of disease, stabilization, return of function
and other endpoints. Adherence to the recommended care regimen is how much the
client actual engages in the behaviors or treatments to optimize health. Finally,
satisfaction with care reflects how sensitive the provider was with the clients’ singularity
and the content of the intervention, (Cox, 2003).

**Impedance Cardiography**

Impedance cardiography is a form of plethysmography that is a noninvasive
method providing hemodynamic measurements of flow, resistance, pressure and indices
of ventricular performance. These measurements include cardiac output (CO), stroke
volume (SV), systemic vascular resistance (SVR), and indices of contractility and
thoracic fluid content. The physical theory of impedance cardiography is derived from
Ohms Law, which is a basic law of electrical currents. The current in amperes (I) in a
circuit equals to the voltage (E) in volts divided by the resistance (R) in ohms, \( I = \frac{E}{R} \).

The hemodynamic measurements from ICG can be used as a health status
indicator, through the serial collection of objective data, to measure clinical outcome of
life style modifications and the titration of medications. ICG can also provide information such as cardiac output and systemic vascular resistance to measure progression and severity of patients with systolic heart failure. The advantage to using this Interaction Model of Client Health Behavior in clinical practice is it helps to organize all the different aspects of the health care for the patient while involving the patient in the process.

As suggested by Ohm’s Law, changes in voltage are directly proportional to changes in measured impedance, when a direct current is applied to the thorax. The base impedance is the overall impedance of the thorax, the sum of impedance of components of the thorax including fat skeletal and cardiac muscle, and lung and vascular tissue, air, and bone. Lung volumes with respiration and changes in volume and velocity of blood in the great vessels during diastole and systole cause changes in the base impedance. The respiratory variance is filtered out, leaving the impedance due to the ventricular ejection, which is then applied to algorithms in order to obtain the hemodynamic measurements. Thoracic fluid volume is also obtained and can only be measure through impedance cardiography. The total fluid content of the thorax is composed of the intravascular, intra-alveolar and interstitial volume. The thoracic fluid content measurement can be use to intensify diuretic therapy (Stobeck & Silver, 2004).

Impedance cardiography is done using a small portable machine, which can easily be used in all departments of the hospital and also in outpatient settings, such as in provider offices. The procedure can be done by providers, nurses, or technicians after minimal training. Four dual sensors (Figure 2) are placed on the client’s neck and chest. The outer sensors transmit an alternating electrical low-amplitude, high-frequency current
which is not felt by the patient, the inner sensors measure the changes in electrical impedance, as it passes through the thorax. The current seeks the path of least resistance which is the blood filled aorta. The ICG measures the baseline impedance to the current and also the change in impedance that occurs during the change in blood volume and velocity in the aorta with each heart beat. The changes are applied to algorithms to provide the hemodynamic parameters of cardiac output, stroke volume, systemic vascular resistance, indices of contractility and fluid status (Albert, 2004).

*Classification of Systolic Heart Failure*

The American College of Cardiology and the American Heart Association (ACC/AHA, 2005) recognize that there are established risk factors for the development of HF. The ACC/AHA writing committee took a new approach to the classification of HF emphasizing evolution and progression of the disease. Four stages were identified (see Table 4). Hypertension increases the risk for heart failure by two-to-threefold and precedes the development of heart failure in 90% of patients (Joint National Committee, 2003).

The control of blood pressure and other vascular risks can help slow the progression of systolic heart failure. The blood pressure goals suggested by the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC VII) are listed in Table 5.

The ACC/AHA classification system is not intended to replace the New York Heart Association (NYHA) (Table 4) functional classification system, but to compliment it by attempting to introduce therapeutic interventions, prior to the development of left ventricular (LV) dysfunction or symptoms occur, thus reducing the morbidity and
mortality of HF. The NYHA system gauges the degree of effort needed to elicit symptoms and assigns patients to functional classes from 1 through 4; a level of exertion which would limit a normal individual through symptoms of HF at rest. The NYHA system primarily focuses on patients in ACC/AHA’s Stage C or D (Hunt et al., 2005).

Review of the Literature

Using PubMed and ProQuest, the key terms impedance cardiography, noninvasive impedance, noninvasive impedance cardiography, and impedance were used for the literature search. The literature review was limited to studies which used impedance cardiography in patients with hypertension or systolic heart failure, were written in English, and that were accessible by electronic retrieval. The literature review included studies comparing ICG to pulmonary artery catheterization, which has been the gold standard in hemodynamic monitoring. Articles about the use of impedance in respiratory, sepsis, or dietary evaluations were not included. Of the 126 articles produced by the data base search, only five research articles contained studies about noninvasive impedance cardiography in patients with hypertension or systolic heart failure. Articles about systolic heart failure were also obtained as references for supportive literature.

Impedance cardiography (ICG) can be utilized by providers to obtain objective data reflecting changes in disease status and treatment effectiveness. In a study of 33 patients with acutely decompensating complex heart failure, cardiac output (CO) and cardiac index (CI) were measured using thermodilution and impedance. Researchers found that the CO and CI measurements from the thermodilution and impedance were significantly correlated. The concordance correlation coefficient of all 29 paired measurements was 0.89 (p<.001) for cardiac output and 0.82 (p<.001) for cardiac index.
Mean bias between the two methods was small, suggesting clinical utility for impedance in patients with complex decompensated heart failure (Albert, Hail, Li, & Young, 2004). Limitations of this study included the use of a convenience sample and the researchers were not blinded to results of the other method when collecting data, which could create the potential for a measurement bias. The measurements from thermodilution and impedance cardiography correlate and each individual patient should be evaluated (professional competencies factor) for their particular need for one study or the other keeping in mind medical need, convenience, cost, and risk to the patient.

The Evaluation Study of Congestive Heart Failure and Pulmonary Artery Catherization Effectiveness (ESCAPE) trial studied 433 patients at 26 sites. Two hundred and fifteen randomized patients were assigned to receive therapy guided by clinical assessment and pulmonary artery catheterization or to clinical assessment alone (n=218). Seventeen of the patients randomized to the pulmonary artery catheterization group did not receive pulmonary artery catheterization and 21 of the patients assigned for clinical assessment only received pulmonary artery catheterization later. Resolution of clinical congestion was the target for both groups. The primary endpoint for the study was the number of days “alive” out of the hospital for 6 months. The patients in the pulmonary artery catheterization group, lived an average of 133 days out of the hospital versus 135 days in the clinical assessment group (P=0.99). In the pulmonary artery catheterization group 43 patients died, versus 38 deaths is the control arm (P=0.35). Based on the ESCAPE trial there is no indication for routine use of PA catheterization to adjust therapy during hospitalization for decompensation of chronic heart failure.

Limitations of the ESCAPE trial include lack of a standardized plan in response to the
hemodynamic information and the considerable variation between sites in use of medications (Binanay et al., 2005).

The ESCAPE trial suggested that the use of pulmonary artery (PAC) catheters is not a health promoting action. The data obtained by the PAC (cardiac output, cardiac index, etc.), did not significantly improve survival rates. The results are confounded by not having an universal treatment algorithm based on health status indicators (cardiac output, cardiac index, etc.). The IMCHB (information portion) would suggest discussing these results with the patient as they are confronting how to choose the best management tools available for heart failure.

The validity of impedance cardiography was demonstrated in a retrospective study of 64 heart failure patients with paired impedance cardiography (ICG) measurements. The study was conducted to determine whether ICG parameters were associated with changes found in functional status and quality-of-life measures. Significant correlation was between multivariate ICG changes and the outcome measures of New York Heart Association Class (R, 0.80), 6-minute walk distance (R, 0.94), patient visual analog scale score (R, 0.69), and Minnesota Living with Heart Failure Questionnaire score (R, 0.67). R is a multiple correlation coefficient which varies between .00-1.00, showing the strength but not direction of the relationship between several independent variables and a dependent variable. The study was limited by its retrospective design and small number of subjects (Vijayaraghavan, Crum, Cherukui, & Barnett-Avery, 2004).

Based on client singularity and the information provided during client/professional interaction, treatment should be individualized to the patient’s
symptoms and desired outcome. Impedance cardiography has been shown to provide objective data that can be used to tailor treatments for patients with systolic heart failure. This information could be used to assist the provider/client in making consensual decision about what type of management to use. Thus ICG data based on objective hemodynamic results, can then be used to guide the client-practitioner interaction to create consensual goal-setting and treatment decisions. This process can ultimately lead to improved patient outcomes, through increased feeling of control by the patient and thus intrinsic motivation to continue compliance with therapy; a major barrier to successful treatment.

Taler, Textor, Augustine (2002) studied the utility of serial hemodynamic parameters in the selection and titration of medication in resistant hypertensive patients using noninvasive thoracic impedance cardiography. In this randomized, prospective study of 117 subjects with refractory hypertension, medication was given per a drug protocol established by either a hypertension specialist or an algorithm based on measurements from impedance monitoring. After three months of therapy, blood pressure was lower in both groups, but more significantly in the impedance group than the specialist group alone (139±2/72±1 versus 147±2/79±1 mm Hg, p<0.01) for systolic and diastolic pressures. Superior blood pressure control was obtained using a treatment algorithm and serial hemodynamic measurements from impedance monitoring compared with clinical judgment alone when medicating patients resistant to empiric therapy. The measurement of thoracic fluid volume, through impedance measurements, supported occult volume expansion, as a mediator of antihypertensive drug resistance. In addition, thoracic fluid volume measurement guided the use of advanced diuretic doses and the
adjustment of multidrug antihypertensive treatment. The study is limited by convenience sampling and small number of patients selected, and the short, three-month length of time of the study.

The Efficacy of Noninvasive Hemodynamic Monitoring to Target Reduction of Blood Pressure Level (CONTROL Trial) studied hypertension therapy guided by the use of hemodynamic monitoring with impedance cardiography. Eleven primary care centers participated in the study. One hundred and sixty-four patients with essential hypertension, currently on one, but not more than four antihypertensive medications with ranges of systolic BP of 140 to 179 mm Hg and/or diastolic BP of 90 to 109 mm Hg were studied. The patients underwent a two-week period in which all hypertensive medications were stopped. After this two-week wash-out period, patients were randomized in a 3:2 ratio to standard antihypertensive therapy per the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC-VI) guidelines (Standard Care Arm) or antihypertensive therapy aided by impedance cardiography (ICG) hemodynamic information (Hemodynamic Care Arm). During the trial, medications choices were made either by published guideline, usual practice pattern or patient clinical characteristics by the Standard Care Arm and in the Hemodynamic Care Arm. The physician was encouraged to use the hemodynamic data to guide therapeutic decisions about medications, dosing, and patient education (Smith, Levy, Ferrario, 2005).

Systolic blood pressure in the Hemodynamic Care Arm was greater from baseline visit ($19 \pm 17$ vs. $11 \pm 18$ mm Hg, $p<0.01$) and post-washout visit ($25 \pm vs. 19 \pm 17$ mm Hg, $p<0.05$) than in the Standard Care Arm. Diastolic blood pressure reductions were
also greater in the Hemodynamic Care Arm from baseline visit (12 ± 11 vs. 5 ± 12 mm Hg, p< 0.001) and in the post-washout visit (17 ± 12 vs. 10 ± 11 mm Hg, p<0.001), than
in the Standard Care Arm. The blood pressure goal (<140/90 mm Hg) was achieved
more frequently by the Hemodynamic Care Arm, than in the Standard Care Arm (77 vs.
57 %, p< 0.01) (Smith, Levy, & Ferrario, 2005). Results indicate that antihypertensive
therapy guided by ICG hemodynamic measurements in uncontrolled hypertension is
more effective, than standard care in uncontrolled hypertension. The CONTROL trial
was limited by the small number of patients in the trial and being spread out in eleven
different facilities, making it difficult to ensure the physicians in the Standard Care Arm
gave comparable care. The research trial was done before the updated JNC-VII
guidelines were published.

Healthcare utilization refers to the use of health care resources as a health-
promoting behavior. The above studies show how utilization of impedance cardiography
helps promote better blood pressure outcomes in patients that previously had either
essential or resistant hypertension. The measurement of thoracic fluid, as a health
indicator, can only be done through impedance. The titration of diuretics improved
outcomes in the hemodynamic groups. The competencies of the provider, an integral part
of the IMCHB model, would also apply to this study. If the provider is well acquainted
with and follows the treatment algorithms, then improved outcomes can be attained.

The objective of the Prospective Evaluation of Cardiac Decompensation in
Patients with Heart Failure by Impedance Cardiography Test (PREDICT) Multicenter
Trial was to predict the short-term risk of patients for a heart failure event. The
researchers evaluated 212 patients who had a prior episode of heart failure
decompensation within the last 3 months. A multivariate regression analysis was performed and resulted in six independently associated variables to a heart failure event \( \leq 14 \) days, patient self-assessment of quality of life with visual analog score (VAS), systolic blood pressure (SBP), New York Heart Association class (NYHA) and three noninvasive impedance cardiography (ICG) parameters (velocity index, thoracic fluid content index, left ventricular ejection time). When ICG variables were combined to form a composite ICG score, the ICG score had the strongest association (chi square 13.83, \( p<0.0002 \)) with the subsequent heart failure occurrence, followed by visual analog score, NYHA class, and systolic blood pressure occurrence.

The PREDICT study indicated that ICG can identify patients at highest and lowest short-term risk for heart failure. It was concluded that ICG along with other clinical variables could improve the short-term predictive power of the clinical assessments currently in use (Abraham, Trupp, Mehra, Lawless, Mitchell, Le, et al., 2004). This study suggests that impedance cardiography could be used in the follow-up treatment in outpatients to prevent, improve, and control systolic heart failure.

The PREDICT trial found that the ICG score had a strong association with subsequent heart failure and that it could be used along with other clinical variables to predict heart failure. Impedance cardiography measurements could be used in follow-up treatments in the prevention of further occurrences of systolic heart failure. ICG could be used to monitor health outcomes by providing objective data to base ongoing treatment and as a problem severity indicator to follow the progression of disease and stabilization of the disease. The objective data provided by impedance cardiography could help as a
tracking mechanism for motivating the patient towards healthy behavioral goals (Cox, 2003).

A prospective study with a convenience sample of 101 patients was done at the University of California, San Diego Medical Center to assess the utility of impedance cardiography in the emergency department. The researchers were looking at the physicians’ abilities to assess stroke volume (SV), cardiac output (CO), and systemic vascular resistance (SVR) by comparing the clinicians’ estimates of the values to impedance cardiography. Patients had a chief complaint of chest pain, abdominal pain, or shortness of breath. The patient’s SV, CO, and SVR were obtained by a technician and the numeric values were rated as high, normal or low (Neath, Lazio, Guss, 2005).

The physicians were blinded to the ICG measurements. The only data available to the treating physician was vital signs of heart rate, blood pressure, temperature, and pulse oximetry. After performing a history and physical, the physicians were asked to estimate SV, CO, and SVR as low, normal or high. Then the physicians were asked to report on their preliminary diagnosis and therapeutic plan. Physicians’ estimates of hemodynamic parameters were compared with ICG measure for concordance. The treating physicians assessments and ICG hemodynamic measurements were concordant in 62 of 101 (62%) cases for stroke volume (kappa=0.068), in 53 of 101 (53%) cases for cardiac output (p=0.125) and 50 of 101(50%) measurements for systemic vascular resistance (p =0.148). The low concordance suggests that the treating physicians do not consistently estimate SV, CO or SVR correctly and impedance cardiography offers clinical utility and potential value in emergency rooms (Neath, Lazio, Guss, 2005).
Limitations included a convenience sample with a small number of patients and the varying skill levels of the different physicians.

Impedance cardiography had clinical utility in the emergency room when compared to physicians’ assessment skills. Health status indicators of this study, using the IMCHB, constitute the cardiac output, stroke volume and systemic vascular resistance. When compared, impedance cardiography (ICG) has been shown to be more consistent with the patient health status than the physician’s assessment. Although ICG measurements were only used at admission, they could be used as a problem severity indicator for use throughout the patients hospital stay to measure progression of disease, stabilization, return of function and other endpoints. Later as an outpatient using impedance cardiography, the health indicators above could demonstrate adherence to the recommended care regimen and assist in optimizing medications and care.

Cost Comparisons

Therapeutic interventions can reduce morbidity and mortality even before symptoms of left ventricular dysfunction. Pulmonary artery catheters have been traditionally used for hemodynamic monitoring and medication adjustments in advanced complex systolic heart failure patients, but there have been studies showing an association with increased morbidity and mortality with their use. Impedance cardiography can provide the same data used for HF management in a noninvasive, safe, convenient and affordable way (Binanay et al., 2005).

Silver et al, (2004) compared the cost between pulmonary artery catheterization (PAC) and using impedance cardiography (ICG). The cost of placing and maintaining a PAC line including equipment, additional intensive care days, nursing care, physician
charges for insertion, medication for procedural sedation was $1,280-$3,495, with the
typical cost being estimated at $2,165. The cost for the ICG which included physician
professional interpretation, ICG disposable, procedural cost, and ICG technician time was
$34.00 and took 5-10 minutes to perform. The patient does not need hospitalization,
because the procedure can be done in the office. This cost analysis does not include the
cost to the patient in time, comfort, or possible complications that can happen when using
an invasive line, such as infection, pulmonary infarction, or pneumothorax.

Therapeutic Interventions

Medication recommendations for systolic heart failure include thiazides, beta-
blockers (BB), angiotensin-converting-enzyme inhibitors (ACE), angiotensin-receptor
blockers (ARBs), and aldosterone antagonists (Joint National Committee, 2003) Table 6
provides an overview of these treatments.

Significance for Clinical Practice and the Role of the Nurse Practitioner

Noninvasive impedance cardiography can be used to more effectively titrate
medication treatment used with systolic heart failure, rather than relying upon self-
reported levels of dyspnea, fatigue and weight gain alone. Impedance cardiography
provides objective measures and is a convenient way for nurse practitioners to
individualize the treatment decisions for systolic heart failure patients. Impedance
cardiography can be utilized in different departments within in the hospital, office or
clinic. The use of impedance cardiography can lead to more timely interventions,
resulting in clinical improvement, and decreased morbidity and mortality. Management
of systolic heart failure could be improved, if nurse practitioners had a safer and more
attainable way to monitor disease progression, efficacy of treatment, and had treatment algorithms based on ICG measurements.

Conclusion

The goal in treating systolic heart failure is to prevent progression through stages A-D, thus preventing or slowing the development of systolic heart failure. Albert, Hail, Li, & Young, found that the CO and CI measurements from the thermodilution and impedance were significantly correlated, so noninvasive hemodynamic information is now more assessable to providers. Hemodynamic information, cardiac output, stroke volume, systemic vascular resistance, indices of contractility and fluid status obtained through impedance cardiography, can assist the provider to adjust medication more aggressively and achieve better outcomes in the control of hypertension as seen in the CONTROL Trial. Taler, Textor, Augustine (2002) found superior blood pressure control was obtained using a treatment algorithm and serial hemodynamic measurement, compared with clinical judgment alone for patients resistant to empiric therapy.

The University of California, San Diego Medical Center study showed a low concordance between the physicians’ abilities to assess stroke volume, cardiac output, and systemic vascular compared to impedance cardiography. The low concordance suggests that cardiac impedance offers clinical utility and potential value in emergency rooms (Neath, Lazio, Guss, 2005).

Impedance cardiography should be a standard of care to assist providers in the treatment of patients with systolic heart failure. The studies reviewed demonstrate that invasive monitoring with pulmonary artery catheters should not be routinely used in patients with chronic decompensated heart failure. The studies confirmed that using
impedance cardiography (ICG) to guide treatment is comparable to invasive monitoring and demonstrate that ICG can improve outcomes in the treatment of hypertension. Impedance cardiography has utility as an assessment tool to assist providers in assessing, treating and maintaining health in patients. ICG can assist in the control of hypertension, which is an important key to the treatment of systolic heart failure.

The application of the IMCHB model, when using ICG can assist nurse practitioners in improving the health of clients by being used as a guide to direct the plan of care that is individualized to the client. This can be achieved by using the objective data obtained such as CO, SV, and SVR to identify targets for interventions. Possible interventions using data from ICG could include health promotion, risk reduction, and medication management. Utilizing the IMCHB model when doing ICG can also measure health outcomes, such as health status indicators, problem severity, and adherence to care regimen of the interventions problem.

Research is needed to examine how IMCHB can be used to offer a conceptual structure that can support exploratory studies and intervention trials in the use of noninvasive impedance cardiography in systolic heart failure. The IMCHB would be of use by being a guide in designing studies using different elements (client singularity, client/professional interaction, and health outcomes) of the theory, thus separating and defining concepts to enable more focused interventions. Research using the IMCHB is also be needed to determine if information gained through the ICG can assist providers and patients in making management decisions, increases compliance of treatment regimens and help to achieve optimization of therapy in patients with systolic heart failure.
References


Table 1. Left Ventricular Heart Failure

<table>
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<th>Diastolic Heart Failure</th>
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<tr>
<td>Lost ability to relax normally and stiffness hampers filling, this is due to ischemia and to collagen deposition which results in left ventricular remodeling with hypertrophic thickening of left ventricular wall</td>
<td>Lost ability to contract, although able to fill, emptying is impaired due to left ventricular remodeling, a process in which the left ventricle chamber dilates and the left ventricular wall thins</td>
</tr>
<tr>
<td>Ejection fraction above 40%</td>
<td>Decreased cardiac output and ejection fraction below 35-40%.</td>
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<td>Patients are: Elderly, frequently female who have HTN, CAD with comorbidities including renal dysfunction, diabetes, aortic stenosis, or atrial fibrillation</td>
<td>Patients are: All ages, typically 50-70 years, more often male who have HTN, CAD with comorbidities including renal dysfunction, diabetes</td>
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<td>Common causes include: MI, occasional left ventricular hypertrophy, chronic lung disease, sleep apnea, left atrial enlargement, hyperplasia, and fibrosis</td>
<td>Common causes include: HTN, CAD, MI, dilated cardiomyopathies, viral cardiomyopathies, sleep apnea, cor pulmonale, severe anemia, hyperthyroidism, and kidney failure</td>
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(Dipiro et al., 2002).
Table 2. Biochemical Theories of the Development of Systolic Heart Failure.

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<td>Down regulation of cardiac beta-adrenergic receptors, due to overexcitation of beta-adrenergic receptors by high levels of norepinephrine, as the body attempts to compensate and restore cardiac output.</td>
</tr>
<tr>
<td>Abnormal form of myosin that has reduced ability to use adenosine triphosphate.</td>
</tr>
<tr>
<td>The altered metabolism of myocardial calcium. Diminished contractility can also be the result of significant loss of myocardial muscle due to infarction.</td>
</tr>
</tbody>
</table>

(Dipiro et al., 2002).
Table 3. Client Singularity Factors in the Interaction Model of Client Health Behavior.

<table>
<thead>
<tr>
<th>Background Variables</th>
<th>Dynamic Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sociodemographic Characteristics</td>
<td>Cognitive Appraisal</td>
</tr>
<tr>
<td>age</td>
<td>Patient’s knowledge, attitudes,</td>
</tr>
<tr>
<td></td>
<td>and beliefs toward illness and</td>
</tr>
<tr>
<td></td>
<td>treatment.</td>
</tr>
<tr>
<td>gender</td>
<td></td>
</tr>
<tr>
<td>ethnicity</td>
<td></td>
</tr>
<tr>
<td>Social Influences</td>
<td>Affective Response</td>
</tr>
<tr>
<td>culture</td>
<td>Based on emotions such as fear,</td>
</tr>
<tr>
<td></td>
<td>anxiety, sadness or joy and</td>
</tr>
<tr>
<td>religion</td>
<td>contribute to decision making.</td>
</tr>
<tr>
<td>family</td>
<td></td>
</tr>
<tr>
<td>peers</td>
<td></td>
</tr>
<tr>
<td>community</td>
<td></td>
</tr>
<tr>
<td>Previous Health Experience</td>
<td>Motivation</td>
</tr>
<tr>
<td>health history</td>
<td>Based on the content of a patient’s</td>
</tr>
<tr>
<td>objective health data</td>
<td>behavior goals and the regulatory</td>
</tr>
<tr>
<td>developmental Status</td>
<td>processes through which the goals</td>
</tr>
<tr>
<td></td>
<td>are pursued.</td>
</tr>
<tr>
<td>Environmental resources</td>
<td></td>
</tr>
<tr>
<td>income</td>
<td></td>
</tr>
<tr>
<td>access to health care</td>
<td></td>
</tr>
<tr>
<td>residential stability</td>
<td></td>
</tr>
</tbody>
</table>

(Cox, 2003).
Table 4. New York Heart Association Functional Classification System (NYHA) and The American College of Cardiology and the American Heart Association (ACC/AHA, 2005) Classification Systems of Systolic Heart Failure.

<table>
<thead>
<tr>
<th>NYHA Classification System</th>
<th>ACC/AHA Classification System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I (Mild)</td>
<td>Stage A - Identifies the patient who is high risk for developing HF, but has no structural disorder of the heart</td>
</tr>
<tr>
<td>No physical limitations of activity</td>
<td>Stage B - Refers to a patient with a structural disorder of the heart, but who has never developed symptoms of HF</td>
</tr>
<tr>
<td>Class II (Mild)</td>
<td>Stage C - Denotes the patient with past or current symptoms of HF associated with underlying structural heart disease</td>
</tr>
<tr>
<td>Slight limitations in ordinary physical activity, resulting in fatigue, palpitation, dyspnea, or angina</td>
<td>Stage D - Designates the patient with end-stage disease who requires specialized treatment strategies such as mechanical circulatory support, continuous inotropic infusions, cardiac transplantation, or hospice care (Hunt et al., 2005).</td>
</tr>
<tr>
<td>Class III (Moderate)</td>
<td></td>
</tr>
<tr>
<td>Marked limitations in activity; patients are comfortable at rest, but ordinary activity leads to symptoms</td>
<td></td>
</tr>
<tr>
<td>Class IV (Severe)</td>
<td></td>
</tr>
<tr>
<td>Symptoms are present at rest; any activity leads to increased discomfort</td>
<td></td>
</tr>
</tbody>
</table>

(Hunt, et al., 2005.)
Table 5. Blood Pressure (mm Hg.)

<table>
<thead>
<tr>
<th>Category</th>
<th>SBP</th>
<th>DBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&lt;120 &amp;</td>
<td>&lt;80</td>
</tr>
<tr>
<td>Pre-HTN</td>
<td>120-139 or</td>
<td>80-89</td>
</tr>
<tr>
<td>HTN, Stage 1</td>
<td>140-159 or</td>
<td>90-99</td>
</tr>
<tr>
<td>HTN, Stage 2</td>
<td>≥160 or</td>
<td>≥100</td>
</tr>
</tbody>
</table>

(Joint National Committee, 2003).
### Table 6. Drugs Used in the Treatment of Systolic Heart Failure

<table>
<thead>
<tr>
<th>Drugs</th>
<th>Action</th>
<th>Stage A NYHA Class I</th>
<th>Stage B NYHA Class I</th>
<th>Stage C NYHA Class II-III</th>
<th>Stage D NYHA Class IV</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angiotensin Converting Enzyme Inhibitors (ACE inhibitor)</td>
<td>Decreases afterload by interfering with the renin-angiotensin-aldosterone system.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Improve survival, hospitalization rates, symptoms, neurohormonal levels, cardiac performance, and reverse remodeling.</td>
</tr>
<tr>
<td>Angiotensin Receptor Blockers (ARBs),</td>
<td>Same as above.</td>
<td>Yes, if not tolerating Ace Inhibitor</td>
<td>Yes, if not tolerating Ace Inhibitor</td>
<td>Yes, if not tolerating Ace Inhibitor</td>
<td>Yes, if not tolerating Ace Inhibitor</td>
<td></td>
</tr>
<tr>
<td>Beta Blockers (BB)</td>
<td>Decreases heart rate and blood pressure. Improves ejection fraction.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Improves survival. Decreases remodeling and incidences of sudden death.</td>
</tr>
<tr>
<td>Diuretics</td>
<td>Loop diuretics used for control of fluid retention.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Diuretics decrease preload through diuresis and vasodilation</td>
</tr>
<tr>
<td>Aldosterone Antagonists</td>
<td>Reduces preload and afterload</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Medications and Therapies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Inotropic drugs, implantable defibrillators, biventricular pacemakers, mechanical-assist devices, or heart transplantation</td>
</tr>
</tbody>
</table>

( Hunt et al., 2005).
Figure 1. Interaction Model of Client Health Behavior.

(Cox, C. L. 2003).
Figure 2. Placement of Leads on Neck and Thorax for Impedance Cardiography.

(CardioDynamics, 1998).
Definitions

**Cardiac index:** The volume of blood pumped by the heart in a unit of time divided by body surface area. It is usually expressed in liter per minute per square meter.

**Cardiac output:** Heart Rate time stroke volume of heart.

**Decompensation:** Failure of the heart to maintain adequate blood circulation, marked by labored breathing, engorged blood vessels, and edema.

**Electrical current:** The flow of electrical charge (Q) through a cross-section in a second. Measured in amperes (A).

**Heart failure:** It is a complex clinical syndrome where the ventricle has impaired ability to fill with or eject blood. A condition marked by weakness, edema, and shortness of breath.

**Hypertrophy:** A nontumerous enlargement of an organ as a result of increase in the size rather than the number of constituent cells.

**Olm:** A unit of electrical resistance or impedance.

**Remodeling:** Left ventricular remodeling is the process by which the ventricular size, shape, and function is alter by mechanical, neurohormonal, or possible genetic factors.

**Systemic vascular resistance:** An index of arteriolar constriction throughout the body.

**Thoracic fluid content:** The total fluid content of the thorax (intravascular, intra-alveolar and interstitial).

**Voltage:** The electrical force that causes current to in a circuit.