REVIEW ARTICLE

Accuracy of Impedance Cardiography in Acute Myocardial Infarction: A Literature Review

Lucelia dos Santos Silva, Fernanda Faria Reis, Monyque Evelyn Santos Silva, Dalmo Valerio Machado de Lima

Programa de Pós-graduação em Ciências Cardiovasculares da Universidade Federal Fluminense (UFF), Niterói, RJ - Brazil

Introduction

Hemodynamic monitoring of individuals with acute myocardial infarction, for evaluation of progression and prognosis of the patient's clinical picture, has been studied for years.

The Swan-Ganz catheter is an invasive hemodynamic monitoring measurement, indicated for clinical situations, such as acute heart failure (e.g. acute myocardial infarction, complicated by progressive hypotension or cardiogenic shock); mechanical complications of acute myocardial infarction; right ventricular infarction; refractory congestive heart failure; pulmonary hypertension.[1]

Although there are indications, there is no consensus among them, since there is an enormous amount of work published on the clinical use of the Swan-Ganz catheter, but with doubtful methodology, allowing controversies regarding its true indications. Moreover, some authors have even published test results correlating the use of the Swan-Ganz catheter with increased mortality.[1,2]

Electrical impedance cardiography (ICG) or thoracic bioimpedance, among other forms of monitoring, is a noninvasive method for the estimation of hemodynamic variables. The method assumes that the thorax is a homogeneous fluid cylinder, composed of blood tissue, air and organs, with a specific resistance, and thus measures the electrical resistance at high frequencies with low steady current amplitude (1.5 mA, 86 KHZ) generated by external sensors and electrodes (in the thoracic and cervical regions) that capture instantaneous voltage changes.[3]

The device behaves according to Ohm's law: when a steady current is applied to the thorax, the voltage changes are directly proportional to the impedance changes. The total thoracic impedance, named baseline impedance (Z), is the sum of the impedance of all thoracic components (adipose tissue, heart, lung, skeletal muscle, vascular tissue, bones and air).[4]

The electrodes sense the Z change resulting from the pulsatile blood flow through the descending aorta during systole and diastole. Over time, this alteration has a direct impact on the left ventricular contractility. The alteration of Z is converted to stroke volume and cardiac output values using mathematical algorithms. The other hemodynamic variables are measured or calculated from the ICG data and provided on a continuous and real-time basis.[3,4]

Major studies demonstrate the efficacy of this method, making possible an early evaluation of heart failure, treatment guidelines in hypertension and monitoring of hemodynamic performance in acute myocardial infarction and in the postoperative of cardiac surgery. Normally, these hemodynamic measurements would be obtained for only the most critically-ill patients, such as Swan-Ganz catheter monitoring. However, due to the risk, discomfort, and cost of invasive procedures, bioimpedance is considered safer and more economical.[4]

Impedance cardiography has been an attractive alternative for determining body composition, since

Keywords

Myocardial Infarction / physiopathology; Data Accuracy; Hemodynamics; Cardiography, Impedance; Electric Impedance.

Mailing Address: Lucelia dos Santos Silva
Rua Otavio Mangabeira, 2031. Postal Code: 25555-120, Jardim Meriti, São João de Meriti, Rio de Janeiro, RJ - Brazil.
E-mail: luceliasantos.ufrj@gmail.com, luceliasantos.cap31@gmail.com

it is a noninvasive, portable, easy to handle and has good reproducibility and, therefore, is viable for clinical practice and epidemiological studies. Impedance cardiography has been increasingly used as a prognostic indicator in acute myocardial infarction.[3]

Objectives

- To verify the accuracy of the use of impedance cardiography in patients with acute myocardial infarction.

- To compare the indications of the impedance cardiography with the Swan-ganz catheter in patients with acute myocardial infarction.

Method

It was a descriptive, retrospective research, based on a quantitative approach, conducted by means of literature review. For the survey of articles in the literature, a search was conducted in the following databases: Latin American and Caribbean Literature in Heath Sciences (LILACS), Medical Literature Analysis and Retrieval Sistem on-line (Medline), Cumulative Index to Nursing & Allied Health Literature (CINAHL) and COCHRANE LIBRARY.

The electronic search was guided by the PICO strategy. The PICO acronym stands for: Patient, Intervention, Comparison and Outcomes.[5] Table 1 presents the components of the PICO strategy.

The collection of data occurred in the period from January to August 2015. The following controlled descriptors were used to find the articles in databases: myocardial infarction, cardiography impedance, catheterization, Swan Ganz, invasive hemodynamic monitoring and hemodynamics. The composition of the sample met the inclusion criteria: Articles in Portuguese, English and Spanish; Articles that compared bioimpedance cardiography and invasive hemodynamic

monitoring; Population: adult patients (aged older than 18 years) in critical condition; Articles published between 2005 and 2015. And as exclusion criteria: Articles not available in full-text; Studies conducted with animals; Articles that compared bioimpedance cardiography with other methods; Revision articles. For data collection, an instrument was developed composed of data related to the journal (title, area, database, country, language, year of publication), the authorship (number of authors, profession of the authors) and to the study (place of research, sample identification, design, type of participants, type of publication, results and conclusions).

In the search, 108 articles were found in MEDLINE (02 articles were added due to similarity), 126 in CINAHL, 11 in LILACS, and 62 in COCHRANE, totaling 307 articles in an initial sample.

Following the eligibility criteria, 259 (84.36%) articles were excluded. A dynamic reading of the 48 (15.63%) remaining articles was taken, and 38 (12.37%) articles were excluded since they were related to heart failure or compared bioimpedance cardiography with other methods. 10 articles were absorbed from the initial sample in order to develop this study.

Results

Ten articles were selected for review, among which eight (80%) were found in the Medline database and two (20%) in Cochrane. The USA and Lithuania were the countries that most published on the proposed outcome, totaling 60% of the results. It was found no indexed publication in Brazilian journals (Chart 1).

It was shown that 80% of the articles were developed by doctors, 10% by nurses and 10% by professionals of both categories (Chart 2).
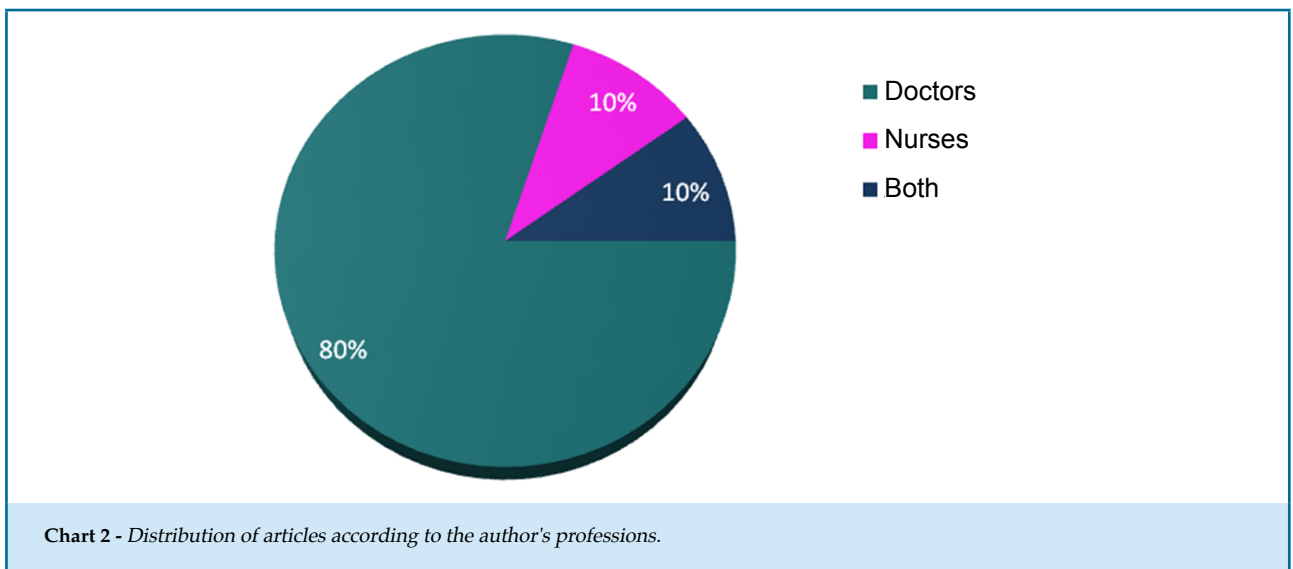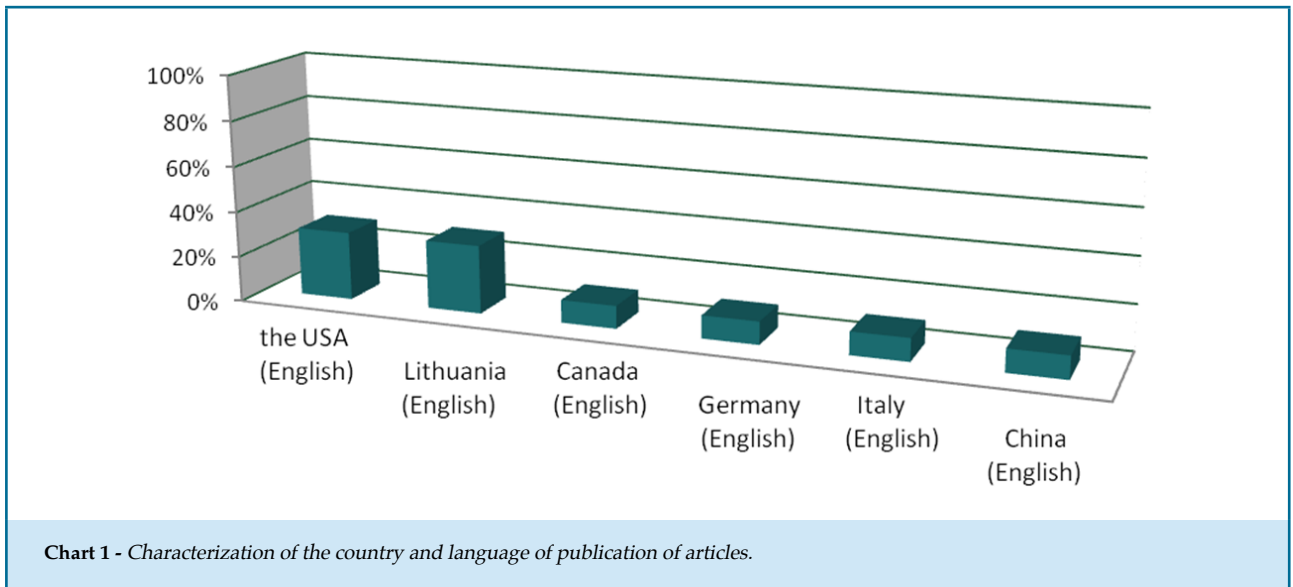
Discussion

In accordance with this study's objective, which refers to the identification of the accuracy of impedance cardiography compared to the Swan-Ganz catheter, this revision was concerned to elect clinical trial articles, considering their scientific magnitude to the scientific society, in addition to checking the journal's origin and its scientific relevance.

Impedance cardiography (ICG) is a reliable method for hemodynamic monitoring in cases of acute myocadial infarction without complications.[7]

Table 1 - Components of the PICO* strategy	
P	Patient with acute myocardial infarction
I	Impedance Cardiography
C	Swan-Ganz catheter
O	Hemodynamic variables

*Adapted from Lima, 2009.[6]

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Chart 1 - *Characterization of the country and language of publication of articles.*

Chart 2 - *Distribution of articles according to the author's professions.*

The comparison of cardiac output (CO) accuracy determined by bioimpedance, thermodilution, and the Fick method led to the conclusion that the three techniques are not interchangeable in a heterogeneous population of critically ill patients. Measurements of CO by thermodilution were more significant than by bioimpedance. However, for each subject, the bioimpedance method varies less than the thermodilution method varies.[8]

ICG could decrease the need for placement of a pulmonary artery catheter in critically ill patients in coronary care units (CCU). The benefits of pulmonary artery catheter (PAC) may not justify the risks associated

with invasive hemodynamic monitoring, such as the potential for infection and other complications associated with a catheter. Although ICG does not provide pulmonary artery pressure, it does provide reliable and reproducible measures of cardiac index, stroke volume, systemic vascular resistance, and other hemodynamic parameters. Clinicians utilizing ICG believe it aids medical decision-making and improves patient outcomes in coronary care units, and in the comparison of average hospital cost, it was found PAC 2165$ / ICG 34$ per procedure.[9]

ICG data could reflect the early cardiac functions of AMI patients, but the accuracy of ICG in evaluating cardiac

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Chart 3 - Description of Results

Author	Year	Results	Conclusions
Braždžionytė and Macas[7]	2007	Compared statistically, in 34 patients, based on graphical techniques and simple calculations, two methods: the Swan-Ganz (recognized and accepted as a "Gold standard" for hemodynamic monitoring) and impedance cardiography (newly introduced method). It was presented an alternative approach, suggested by DG Altman and JM Bland, for cardiac output measurement simultaneously in patients with acute myocardial infarction.	Bland-Altman analysis is an alternative approach for evaluation of agreement between two methods for clinical measurement. According to data, it is a noninvasive technique. Impedance cardiography is a reliable method for hemodynamic monitoring in cases of acute myocardial infarction without complications.
Engoren and Barbee.[8]	2005	Determined the accuracy of cardiac output (CO) assessment through bioimpedance, thermodilution and Fick methods. In a sample of 46 patients, 15 used the Flick method. Mean (SD) cardiac output in all patients was 6.3 (2.2) L/min by thermodilution and 5.6 (2.0) L/min by bioimpedance. In the 15 patients in whom all 3 methods were used, mean cardiac output was 6.0 (1.7) L/min by thermodilution, 5.3 (1.7) L/min by bioimpedance, and 8.6 (4.5) L/min by the Fick method.	The determinations of CO using the three techniques are not interchangeable in a heterogenous population of critically ill patients. Measurements of cardiac output by thermodilution were significantly greater than by bioimpedance. But for each subject, the bioimpedance method varied less than the thermodilution method varied.
Silver et al.[9]	2005	The hypothesis was that ICG could decrease the need for placement of a pulmonary artery catheter in critically ill patients in coronary care units (CCU). After evaluating the need for hemodynamic monitoring of 107 patients admitted to the CCU, 14 were judged to have indications, and all patients were monitored by ICG. ICG parameters were provided to the attending physician who then decided whether pulmonary artery catheter insertion was still necessary. 10/14 patients (71%) were monitored only by bioimpedance and clinicians reported that the information was helpful in 10/10 patients (100%; 95% confidence interval, 74.1%–100.0%). ICG can replace the pulmonary artery catheter in coronary care unit and clinicians utilizing ICG believe it aids medical decision-making and improves patient outcomes.	The benefits of pulmonary artery catheter (PAC) may not justify the risks associated with invasive hemodynamic monitoring, such as the potential for infection and other complications associated with a catheter. Although ICG does not provide pulmonary artery pressure, it does provide reliable and reproducible measures of cardiac index, stroke volume, systemic vascular resistance, and other hemodynamic parameters. Total Procedure Cost – PAC 2165$ / ICG – 34$
Chen et al.[10]	2014	Evaluated with impedance (ICG) the cardiac function of 99 acute myocardial infarction patients. Blood was obtained for the detection of BNP, NT-proBNP and troponin, followed by ICG, which measured: Thorax fluid capacity (TFC); pre-ejection period (PEP); left ventricular ejection fraction (LVEF); cardiac output (CO); stroke index (SI); stroke volume (SV); systemic vascular resistance (SVR); systemic vascular resistance index (SVRI); cardiac index (CI); end-diastolic volume (EDV); systolic time ratio (STR). All these patients underwent ICG and echocardiography 2 days after surgery. The results indicate that NT-proBNP and BNP are associated with SVR, SVRI, PEP and STR, independently (P < 0.05). Troponin was associated with SVR and SVRI (p < 0.05).	ICG data could reflect the early cardiac functions of AMI patients, but the accuracy of ICG in evaluating cardiac functions should be combined with detection of blood NT-proBNP, BNP and cTnT and echocardiography.

Cont. Chart 3 - Description of Results

Author	Year	Results	Conclusions
Ablonskytė-Dūdonienė et al.[5]	2012	Due to ICG, it was possible to offer an integrated analysis with electrocardiogram to help identify the patients at risk of serious adverse events after ST-segment. All-cause or cardiac mortality and in-hospital recurrent ischemia, recurrent nonfatal MI, and need for revascularization were considered as serious adverse events. A greater risk of cardiac death was observed within a 5-year period after STEMI.	A greater risk of cardiac death was observed within a 5-year period after STEMI. An integrated analysis of electrocardiogram and impedance cardiogram helps estimate patient's risk of adverse outcomes after STEMI.
Braždžionytė and Macas[11]	2006	Hemodynamic evaluation in patients with acute myocardial infarction (AMI) is crucial. The management of the intra-aortic balloon (IAB) in patients with cardiogenic shock can be made by the invasive Swan-Ganz method. However, noninvasive methods, such as impedance cardiography (ICG), can also have a place in monitoring these patients. The study aimed to evaluate the possibility of applying a noninvasive method in the hemodynamic monitoring during AMI complicated by cardiogenic shock, managed by an intra-aortic balloon. A total of 16 patients were selected; anterior AMI was diagnosed in 68.75% of them, inferior in 25% and circular in 6.25%. Primary angioplasty was successfully performed in 43.75% of the patients; unsuccessfully, in 1 patient, who died within the first 18 hours. Half of patients underwent cardiac surgery within the first two weeks. Mortality rate was 68%. A total of 109 paired measurements were carried out in 16 patients in accordance with different IABP stages. Monitoring of cardiac output, cardiac index, systemic vascular resistance and systolic volume were compared by the two methods, every 12 hours.	Significant correlation of cardiac output values was observed between the impedance cardiography and the Swan-Ganz technique during intra-aortic balloon use. Noninvasive evaluation of hemodynamic indices by continuous monitoring of impedance cardiography during acute myocardial infarction complicated by cardiogenic shock and managed by an intra-aortic balloon is a reliable method for further application.
Fuller[12]	2006	The study examined the use of impedance cardiography to stimulate cardiac output in critically ill patients in the intensive care unit. Cardiac output was measured, concurrently, in 61 patients with a pulmonary artery catheter (PAC) and impedance cardiography (ICG).	The study has found a low correlation between PAC and ICG in critically ill patients, with 95% confidence interval, but the exclusion of patients with valve regurgitation and adjustment for hematocrit and skinfold thickness improved agreement. The support of clinicians for the introduction of any new technology is as important as the accuracy and reliability of that technology. Only with such support can impedance cardiography be accepted. The use of bioimpedance led to a 71% reduction in PAC usage in critically ill patients.
Keuhne et al.[13]	2013	Fifteen postinfarction patients, with symptomatic heart failure and akinetic or dyskinetic segment were included in the study. During the implantation of a cardiac resynchronization therapy (CRT) device, stroke volume was measured via impedance cardiography. It has shown an advantage over the pulmonary artery catheter because it is a simple method for measuring daily hemodynamic data of patients.	Impedance cardiography is a valid parameter to estimate stroke volume and to guide optimization of CRT timing in postinfarction patients.

Piepoli et al.[14]	2010	It used impedance cardiography, and not the pulmonary artery catheter, to assess stroke volume, in post-MI patients, and the use of bone marrow stem cells to improve cardiac function.	The study showed the beneficial effect of stem cells usage in post-MI patients with depressed LV function.
Albert[15]	2006	Comparison between hemodynamic variables: **Cardiography impedance** Stroke volume / stroke index; cardiac output / cardiac index; systemic vascular resistance; left cardiac work / left cardiac work index. Other contractility parameters: - Systolic time ratio; Pre-ejection period; Left ventricular ejection time; Velocity index; Thoracic fluid content. **Pulmonary Artery Catheter** - Stroke volume / stroke index; cardiac output / cardiac index; left cardiac work / left cardiac work index; systemic vascular resistance and peripheral vascular resistance index; pulmonary vascular resistance and pulmonary vascular resistance index; pulmonary artery pressure; right atrial pressure..	Impedance cardiography provides contractility data that can increase traditional hemodynamic information. Current measure systems that measure thoracic impedance to electrical current are user friendly, easy to apply and safe. The use of impedance cardiography may enlarge the relationships between hemodynamic and cardiovascular parameters and circulation disorders that may subsidize patient care.

functions should be combined with detection of blood NT-proBNP, BNP and cTnT and echocardiography.[10]

The use of ICG made it possible to offer an integrated analysis with electrocardiogram to help identify the patients at risk of serious adverse events after ST-segment. All-cause or cardiac mortality and in-hospital recurrent ischemia, recurrent nonfatal MI, and need for revascularization were considered as serious adverse events. A greater risk of cardiac death was observed within a 5-year period after STEMI.[5]

Significant correlation of cardiac output values was observed between the impedance cardiography and the Swan-Ganz technique during intra-aortic balloon (IAB) usage. Noninvasive evaluation of hemodynamic indices by continuous monitoring of impedance cardiography during acute myocardial infarction complicated by cardiogenic shock and managed by an intra-aortic balloon is a reliable method for further application.[11]

There is a low correlation between PAC and ICG in critically ill patients, but the exclusion of patients with valve regurgitation improves the results. The use of ICG led to a 71% reduction in PAC usage in critically ill patients. The support of clinicians for the introduction of any new technology is as important as the accuracy and reliability of that technology. Only with such support can impedance cardiography be accepted.[12]

Impedance cardiography is a valid parameter to estimate stroke volume and to guide optimization of CRT timing in postinfarction patients. It has shown an advantage over the pulmonary artery catheter because it is a simple method of measuring daily hemodynamic data of patients.[13]

Impedance cardiography, similarly to the pulmonary artery catheter, measures stroke volume, and in post-MI patients, it was possible to show the beneficial effect of stem cells usage in patients with depressed LV function using ICG, without the need for an invasive method.[14]

Impedance cardiography provides contractility data that can increase traditional hemodynamic information. Current measure systems that measure thoracic impedance to electrical current are user friendly, easy to apply and safe. The use of impedance cardiography may enlarge the relationships between hemodynamic parameters and cardiovascular and circulation disorders that may subsidize patient care. Comparison between hemodynamic variables:

Cardiography impedance - Stroke volume / stroke index; cardiac output / cardiac index; systemic vascular resistance; left cardiac work / left cardiac work index. Other contractility parameters: - Systolic time ratio; Pre-ejection period; Left ventricular ejection time; Velocity index; Thoracic fluid content.

Pulmonary Artery Catheter - stroke volume; stroke index; cardiac output; cardiac index, left cardiac work; left cardiac index; systemic vascular resistance and peripheral vascular resistance index; pulmonary vascular resistance and pulmonary vascular resistance index; pulmonary artery pressure; right atrial pressure.[15]

Conclusion

ICG has shown to be a reliable method for hemodynamic monitoring in cases of acute myocardial infarction without complications. This method enlarges the relationships between hemodynamic/cardiovascular parameters and circulation disorders that may subsidize patient care.

It is emergent that we understand the importance of assisting the client based on clinical evidence. Our knowledge about the pathology and its hemodynamic repercussions assures the appropriate diagnosis identification, allowing the implementation of client care with quality and safety.

Author contributions

Conception and design of the research: Silva LS, Lima DVM. Acquisition of data: Silva LS. Analysis and interpretation of the data: Silva LS, Reis FF, Silva MES. Writing of the manuscript: Silva LS, Reis FF, Silva MES.

Critical revision of the manuscript for intellectual content: Silva LS, Lima DVM.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

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