The accuracy of two algorithms of artificial intelligence based on neural networks and the CaRDIA-X algorithm in the identification of electronic implantable cardiac devices by chest x-rays.

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Abstract

Objectives: In this study, we aim to describe the diagnostic accuracy of two applications neural networks-based system and a visual algorithm performed by different evaluators to identify the manufacturer of electronic implantable cardiac devices by chest x-rays. **Background**: cardiac rhythm devices frequently require interrogation, and they have different software depending on the manufacturer. Currently, there are a visual algorithm and two applications based on artificial intelligence for the identification of the manufacturer from chest radiographs. **Methods**: Retrospective trial between January 2010 and December 2021 at a single institution. Chest radiographs were obtained from patients with cardiac devices; they were cropped and resized to 224 by 224 pixels. Then, they were analyzed using the applications Pacemaker ID ® with a cell phone, Pacemaker ID ® web and PPMnn ® web, and the visual algorithm CaRDIA-X ® performed by evaluators at different levels of training. **Results**: 400 radiographic images with cardiac devices were collected comprising 4 manufacturers and 40 different models. The agreement for Pacemaker ID ® with a cell phone was 90.6% (p <0.001), for Pacemaker ID ® web was 81.2% ($p < 0.001$); and for PPMnn ® web was 82% ($p < 0.001$). The agreement from the CaRDIA-X ® algorithm performed by 4 evaluators ranged from 73.8% to 97.7% ($p < 0.001$). **Conclusions**: The use of applications based on neural networks offers a good agreement in the identification of the manufacturer and is a tool for clinical use. In our paper, the visual algorithm has a better agreement in identifying the manufacturer and it doesn't require much training.

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Abstract

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Background : cardiac rhythm devices frequently require interrogation, and they have different software depending on the manufacturer. Currently, there are a visual algorithm and two applications based on artificial intelligence for the identification of the manufacturer from chest radiographs.

Methods : Retrospective trial between January 2010 and December 2021 at a single institution. Chest radiographs were obtained from patients with cardiac devices; they were cropped and resized to 224 by 224 pixels. Then, they were analyzed using the applications Pacemaker ID® with a cell phone, Pacemaker ID®web and PPMnn® web, and the visual algorithm CaRDIA-X® performed by evaluators at different levels of training.

Results : 400 radiographic images with cardiac devices were collected comprising 4 manufacturers and 40 different models. The agreement for Pacemaker ID® with a cell phone was 90.6% (p <0.001), for Pacemaker ID®web was 81.2% ($p < 0.001$); and for PPMnn® web was 82% ($p < 0.001$). The agreement from the CaRDIA-X® algorithm performed by 4 evaluators ranged from 73.8% to 97.7% ($p < 0.001$).

Conclusions : The use of applications based on neural networks offers a good agreement in the identification of the manufacturer and is a tool for clinical use. In our paper, the visual algorithm has a better agreement in identifying the manufacturer and it doesn't require much training.

Key Word: Pacemakers; implantable cardioverter-defibrillators; cardiac resynchronization therapy; artificial intelligence, machine learning.

Condensed abstract

This is the first study in Latin America that evaluates the agreement of two applications based on artificial intelligence and the CaRDIA-X® manual algorithm that allows rapid identification of the manufacturer of the cardiac device in a free and easily accessible way. For the first time, an agreement greater than 90% was obtained with the CaRDIA-X® algorithm with a short training period and rapid interpretation.

Abbreviations

ICD = Implantable cardioverter-defibrillator

PA = Posterioanterior

AP = Anteroposterior

Introduction

More than 3 million people in the world use some type of cardiac electronic device (1,2). These usually require interrogation; however, there is a different programmer and software for each manufacturer, and many times patients do not remember or don't know the manufacturer of their device, which leads to a delay in medical care (2).

As a solution, a visual algorithm called CaRDIA-X® was created in 2011, which uses chest X-rays to identify the type of device and the manufacturer (3), but requires a training period. To facilitate identification, two applications based on artificial intelligence and machine learning were created, particularly deep neural networks (4,5). Pacemaker ID® is available on a mobile app (PIDa®) and a web page (PIDw®), and Pacemaker Identification with Neural Networks® (PMMnn®) is available on the web page, both free.

The use of applications is becoming more widespread; they generally do not require training and can be used easily; however, in artificial learning models, the risk of "overfitting" has been evidenced, which consists in the fact that the neural network is excellent at recognizing frequently seen images but is less accurate with real-world examples (6,7). In Colombia and Latin America, to this date, there are no data on the accuracy of this type of artificial intelligence algorithm or the CaRDIA-X® visual algorithm. This study aims to describe the diagnostic agreement in the manufacturer's discrimination of two applications in web and mobile versions (PIDa®, PIDw® and PMMnn®) (4,5) and the CaRDIA-X® visual algorithm performed by evaluators with different levels of medical training.

Methods

Data extraction

Chest X-ray images with adult implanted cardiac devices (pacemakers, ICD cardioresynchronizers, and event monitors) were collected between January 2010 and December 2021 at a single institution. Radiographs with AP and PA projection were included; those with lateral projection (except in the presence of a subcutaneous ICD) or those with suboptimal quality were excluded. Complementary data (age, sex, manufacturer, model, and indication for device implantation) were obtained by reviewing electronic medical records.

The images were downloaded from the Kanteron Viewer® system in JPG format (Joint Photographic Experts Group); each image was cropped at the region of interest and resized to 224 by 224 pixels. The REDCap® data collection tool was used (8). This study was approved by the research and ethics committee of the institute (FM-CIE-0243-21).

For the PIDa® application, an iPhone with a 12-megapixel camera was used. For CaRDIA-X ® visual algorithm, the images were reviewed by 4 independent evaluators with different levels of medical training blinded to the manufacturer (medical student, internal medicine resident, cardiology resident, and electrophysiology resident) using the CaRDIA-X® (3). They had to identify the type of device and the manufacturer.

Manufacturer options were: Biotronik® (Oregon), Boston Scientific® (including Guidant® and Cameron Health®, Massachusetts), Medtronic®, Sorin® (including Liva Nova®, Colorado), or St. Jude Medical® (owned by Abbott Medical®)

Statistical Analysis

The comparison measure used was statistical agreement, defined as the number of correctly classified images divided by the total number of images submitted to the test. Cohen's Kappa coefficient was used to compare artificial intelligence algorithms, and Fleiss' Kappa coefficient was used to compare different evaluators with the CaRDIA-X algorithm (9).

The sample size was calculated based on the results of Jay Chudow (10), using the formula proposed by Lachenbruch in 1992 (11), implemented in the biostatUZH R package by the sampleSizeMcNemar function. For an estimated overall accuracy of 80%, an alpha of 0.05, the minimum number of images was 395.

The pre-specified primary outcome was an analysis of the agreement in the identification of the cardiac device manufacturer of the PIDa®, PIDw® and PMMnn® applications and the CaRDIA-X® algorithm

performed by 4 evaluators with different levels of medical training (operator 1: medical student, operator 2: internal medicine resident, operator 3: cardiology resident, operator 4: electrophysiology resident). The standard of comparison was the interrogation of the device and recorded in the clinical history. A p -value calculation was performed to adjust for the effect of chance on the observed proportion of agreement. For all calculations, R Core Team (2020) was used (12).

Results

400 images were obtained from 399 patients (one individual had more than one device during the study period). 221 (55.2%) images were in PA projection, most devices were pacemakers (58.5%), followed by implantable cardioverter-defibrillators (30.2%) and resynchronizers (10.5%) (Table 1). St. Jude Medical® was the most common manufacturer (64.2%) followed by Medtronic (27.8%), Boston Scientific (7%), and Biotronik (1%). There were no devices manufactured by Sorin® (Table 2). Clinical indications are summarized in the supplementary material (Supplemental table 1).

Global performance of applications based on artificial intelligence

The concordance of the PIDa® application was 90.6% ($p< 0.001$) and for the PIDw® was 81.2% ($p < 0.001$). Concordance for PPMnn® web was 82% ($p < 0.001$) as shown in the Central Illustration (left panel). The agreement of the PIDa® application for manufacturer identification was greater than 80% for the manufacturers St. Jude Medical, Medtronic, and Boston Scientific (Table 3). However, the PIDw® and PMMnn® applications had less agreement for the manufacturer St. Jude Medical.

Global performance of different evaluators using the CaRDIA-X® algorithm

Agreement was in a range of 73.8% to 97.7% among the 4 operators. The three evaluators with the highest performance were operators 2 (internal medicine resident), 3 (cardiology resident), and 4 (electrophysiology resident). Operator 1 (medical student) with the lowest level of training had less agreement on the correct classification of the device. This is shown in the Central Illustration (right panel).

Agreement for operators 2, 3, and 4 was greater than 90% for manufacturers St. Jude Medical, Medtronic, and Boston Scientific. The agreement to identify the manufacturer for operator 1 was lower for St. Jude Medical devices. The agreement for all operators was lower in the identification of the Biotronik manufacturer (Supplemental table 2).

Discussion

Our study presents a description of the diagnostic concordance of two applications based on artificial intelligence and a visual discrimination algorithm for the identification of manufacturers of implantable cardiac devices, conducted out differentially at 4 levels of medical training.

An increase in the use of rhythm control devices is evident; however, usually the manufacturer is not known. In 2011, the CaRDIA-X® algorithm manual was created, this seeks to identify 5 manufacturers (Medtronic, St. Jude Medical, Boston Scientific, Biotronik, and Sorin) based on the unique morphological characteristics of each manufacturer observed on chest radiographs. However, it requires difficult training, and up to 80% of doctors report difficulties in applying it (3).

To do this, two applications based on artificial intelligence were created, achieving a faster, simpler, and more accurate identification. Howard et. of 72% (62.2% - 88.9%) to identify the manufacturer, the best agreement was between two electrophysiologists, but neither could identify the model. Subsequently, Weinreich et al. (4) developed PID® (available on the web and cell phones) that identifies 4 manufacturers by chest X-ray and correctly classifies 95% of the devices. The application returns the probability percentage of each manufacturer's option.

In 2020, these apps and the CaRDIA-X® algorithm were compared with 93% and 86% agreement, respectively (13). This information was obtained from a poster publication at the American Congress of Cardiology

2020 (ACC 2020), does not have a sample size calculation, and was performed by the app developers at a single institution.

Regarding our results, the three applications based on artificial intelligence behaved well, with percentages of agreement higher than 80%. The highest concordance was achieved with the use of PIDa® (Percentage of concordance 90.69%, kappa 0.63). The PPMnn® and PIDw® applications had the lowest concordance with 82% and 81.2%, respectively. These results are similar to those found in recent studies such as those one by Chudow (PIDa® 89%, PIDw® 73%, and PPMnn® 71%) (13), and Sabbotke (PIDa® 87.5%) (14). This finding has been explained because web page applications are the ones that most depend on the quality of the photograph, and it has been shown that changes in the angle of capture, as well as electromagnetic interference from the screen, can substantially affect image interpretation (12).

The mean agreement of the CaRDIA-X® algorithm in our study (91%) is higher than that reported in the literature. Chudow et al. describe an 85% agreement (13) and Shams et al. reported a 61% concordance using the mobile version of the algorithm (7). The lowest concordance was found in the medical student (73.8%), which is explained by their lesser experience with patients with implantable cardiac devices. The three levels of medical specialization show a concordance of over 95%, requiring a short training period.

This is the first study to report a higher concordance of the visual algorithm in applications based on artificial intelligence. This may be because the most common St Jude Medical® models have the "St Jude dot" that facilitates identification using the visual algorithm. Artificial intelligence-based applications are fast; however, those available for the web page may be less accurate. In our study, the mean time to perform the CaRDIA-X ® algorithm was approximately 1 min per radiograph at the end of training with a concordance greater than 90%, which makes these reading strategies complementary and not exclusive. Combined analysis studies are required to determine whether the use of two or more strategies in the same patient can improve diagnostic discrimination.

Contributions

This is the first study in Latin America that evaluates the concordance of applications based on artificial intelligence and the CaRDIA-X® manual algorithm that allows rapid identification of the manufacturer of the heart device at no cost and with easy access. For the first time, greater than 90% agreement was obtained with the CaRDIA-X® algorithm with a short training period and rapid interpretation.

Study limitations

The different orientations, projections, and directions of the devices can modify the interpretation of applications based on artificial intelligence; they also require cell phones with a high-resolution camera to obtain good-quality images. However, this study resembles the reality doctors face when interpreting images and applying algorithms. The need for image editing (cutting, resizing and standardization) makes it difficult to use applications with a web platform.

The CaRDIA-X® algorithm requires a certain degree of training and is not designed to identify more recent models. Despite these considerations, a high discrimination capacity was obtained.

Conclusions

The use of applications based on artificial intelligence has a good agreement for the identification of the manufacturer of implantable cardiac devices through chest radiography. In our study, the CaRDIA-X® algorithm also has a good agreement with a short training period.

Clinical competencies

Artificial intelligence is a new field in medicine and cardiology. The use of free applications available for mobile phones and the website allows rapid identification of the manufacturer of cardiac devices, which leads to better medical care. This study provides information from the "real world" so that in the future it can be applied in Latin America and the world.

Translational outlook

This study allows to understand the operation in the "real world" of tools that help to identify in an objective, easy and free way the manufacturer of the device when such information is not available. More studies are needed for widespread use

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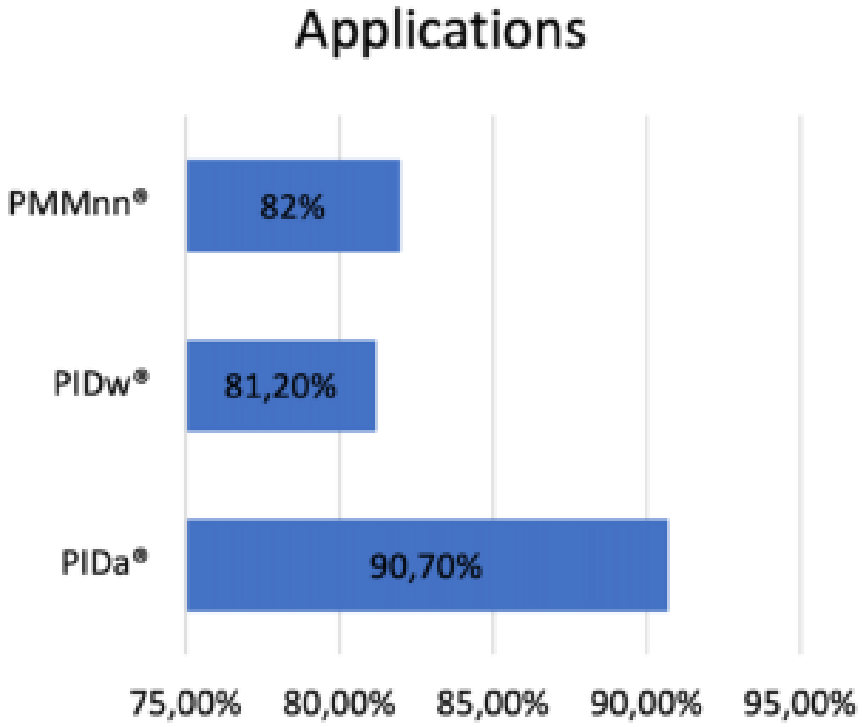
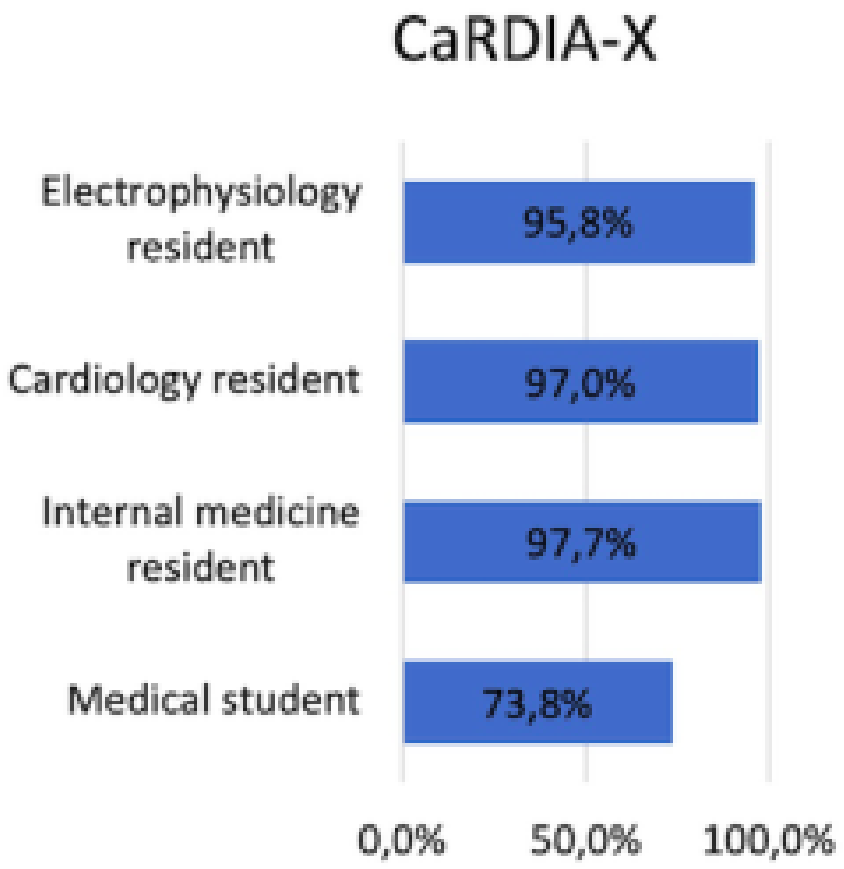
Central ilustration. Agreement of applications based on artificial intelligence and the CaRDIA-X algorithm





(Left) The bar chart shows the agreement to identify the manufacturer using the applications based on artificial intelligence. (Right) The bar chart shows the agreement to identify the manufacturer of 4 evaluators with different levels of medical training using the visual algorithm CaRDIA-X®. PIDa®= Pacemaker ID mobile, PIDw®= Pacemaker ID web, PMMnn®= Pacemaker Identification with Neural Networks®

Table 1. Clinical characteristics of the patients

Variable	Variable	Number/percentage (%)
Age (average)	70.4 years	
Sex	Male Female	249 (62.25%) 151 (37.75%)
Type of device	Pacemaker Implantable cardioverter-defibrillator Cardioresynchronizer Event monitors	234 (58.5%) 121 (30.25%) 42 (10.5%) 3 (0.75%)

Table 2. Device characteristics

Characteristics	Characteristics	Number/percentage (%)
Manufacturer	St Jude Medical Medtronic Boston Scientific Biotronik	257 (64.25%) 111 (27.75%) 28 (7%) 4 (1%)

Characteristics	Characteristics	Number/percentage (%)
Model	Assurity Advisa Elipse Accent Evera Quadra Fortify Otros	115 (28.75%) 52 (13%) 49 (12.25%) 29 (7.25%) 22 (5.5%) 20 (5%) 15 (3.75%) 69 (17.25%)

Table 3. Diagnostic agreement using the applications according to manufacturer.

Variable	**Variable**	**Agreement (%)**
PIDa®	St. Jude Medical®	89.1%
	Medtronic®	85.3%
	Boston Scientific®	95.2%
	Biotronik®	50%
PIDw®	St. Jude Medical®	74.1%
	Medtronic®	87.1%
	Boston Scientific®	90.2%
	Biotronik®	50%
PMMnn®	St. Jude Medical®	42.6%
	Medtronic®	92.3%
	Boston Scientific®	91.1%
	Biotronik®	0%