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Cardiovascular and Metabolic Science

Continuation of the Revista Mexicana de Cardiología

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Editorial statement

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In search of an operational and science-based definition of obesity, a multifaceted and complex global health threat

En busca de una definición operativa y científica de la obesidad, una amenaza multifacética y compleja para la salud mundial

Yara Irene López-Dionicio,*,‡ Eleazar Lara-Padilla,*,§ Gustavo Guevara,*,¶ Daniela Ivonne Amador-Jara,*,‖ Jaime García-Rodríguez,*,‖ Fanny Martínez-Quintero,*,‖ Nayelli Nájera,*,‡ Guillermo Ceballos,*,‡ Eduardo Meaney*,‡

Abbreviations:
AC = Alternating Current
ADP = Air Displacement Plethysmography
ASCVD = Atherosclerotic Cardiovascular Diseases
BFM = Body Fat Percentage
BIA = Bioelectrical Impedance Analysis
BMI = Body Mass Index
DM2 = type 2 Diabetes Mellitus
DXA = Dual-Energy X-ray Absorptiometry
HBP = High Blood Pressure

Obesity, one of the leading health problems worldwide, is not only a severe and disabling systemic disease itself, but also a significant risk factor for other threatening conditions, such as type 2 diabetes mellitus (DM2), high blood pressure (HBP), atherosclerotic cardiovascular diseases (ASCVD), and a cluster of many other health problems, including diverse mental and behavioral disorders. Due to its inherent complexity, multiple interconnections with various physiological and structural abnormalities, intertwining with psychological, socioeconomic, and environmental factors, and intricate origin, obesity is a poorly understood entity from genetic, social, nutritional, pathophysiological, anthropometric, psychological, and clinical perspectives. Science and scientific medicine require absolute precision and clarity in their terminology. Through its language, medical science unambiguously marks the nature and limits of the phenomena it scrutinizes, standardizes applicable terminology, and ensures the replicability of data obtained in research. This research, validating or rejecting conclusions drawn in independent studies. Obesity is apparently easily diagnosed to the point that a layperson can, in most cases, simply by looking at people, perceive whether they are obese. However, the matter is somewhat more complicated. Attempts to define and categorize obesity date back a long time. For example, Galen (129-216),[1] categorized corpulence into εὐσαρκία (*eusarkia*, literally «good fleshiness»), *παχύς* (*pachýs*, fat), εφσαρκος (*efsarko*, fleshy), and πολυσαρκο (*polisarko*, very fleshy),[2,3] simply by observation, without any objective measure of body mass. Together with him, several Greek and Roman physicians considered obesity an unhealthy condition and recommended a balanced diet and regular exercise to combat it,[1] as we still do today.

The Belgian scholar and statistician Lambert Adolphe Jacques Quetelet was not interested in medicine or physiology, but rather in social and demographic studies. In the distant year of

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1835, he introduced the ratio of weight divided by height squared as part of his impossible search for the physical characteristics of the «average man». Following this erroneous search for average anthropometric measurements (in contradiction with natural diversity and ethnic differences), when body weight balances became available, weight was the only parameter used to define obesity, comparing an individual's body weight against the average value for their age and gender in the population. It must be said that in the last decades of the 19th century and in the first half of the previous century, life insurance companies had been interested in identifying health factors associated with premature death, such as blood pressure and body weight. Before physiologists and physicians, it was life insurance merchants and statistical actuaries who first identified the death risk associated with hypertension and obesity. The so-called «reference values» for weight and height in both genders and several age groups were derived from data collected during medical examinations as part of the life insurance acquisition process. In this way, the now-discredited concept of «ideal weight» was employed, with longevity as the primary definition trait. These tables of reference values, which were carried out in the United States population, were used worldwide, regardless of nutritional, anthropometric, ethnic, and national differences.[4]

Ancel Keys, the giant of physiology and epidemiology, analyzing the data from his seminal Seven Countries Study,[5] discredited the use of the ratio of weight to height to diagnose obesity and proposed Quetelet's relationship between weight/height squared (renaming it as the body mass index, BMI) to define obesity. Based on these observations, the World Health Organization (WHO) defined obesity as «a chronic, complex disease characterized *by excessive fat deposits that can impair health*».[6] Additionally, the diagnosis of overweight and obesity is determined by measuring a person's weight and height and calculating the BMI: weight (kg) ÷ height^2 (m^2). *Table 1*[6,7] shows the WHO classification of underweight, «normal» or desirable corpulence, overweight and obesity.

These cutoff points were established in populations of European origin. However, some studies have shown that the cutoff thresholds for the onset of type 2 diabetes mellitus (DM2) differ across distinct ethnicities.[9] This fact is often overlooked when applying the method to other ethnic groups, such as Asians, Blacks, and Latin Americans, among others.

Table 1: Body mass index categories (World Health Organization).

Category	Value of BMI (kg/m^2)
Underweight	< 18.5
Desirable	18.5-24.9
Overweight	25.0-29.9
Obesity (grade)	
I	30.0-34.9
II	35.0-39.9
III (morbid or extreme obesity)	≥ 40

Adapted from: Purnell JQ.[8]

The BMI was rapidly accepted as a credible and affordable diagnostic tool for assessing obesity or underweight in clinical settings, but not without criticisms. For obscure reasons, Ancel Keys (1904-2004) has been and continues to be the target of scientific and vicious personal attacks.[10] His comprehensive Seven Countries Study and the BMI he introduced to medical research have been criticized, sometimes legitimately, but sometimes driven by personal aversion.[10]

To begin with, BMI is a marker of corpulence, and not of the fat mass, as admitted by Keys himself (that is, it does not differentiate fat from muscle or water compartments). Additionally, it does not distinguish between fat distribution around the waist or in the femoral and gluteal regions (the so-called android and gynecoid types of obesity; the former is more associated with abnormal lipid and carbohydrate metabolism). Furthermore, the BMI does not provide insight into body composition, particularly fat percentage, which is expected to become the gold standard for diagnosing obesity in the near future.[11] Clearly, in addition to estimating BMI, clinical anthropometry routines should incorporate

abdominal circumference measurements,[12] which, in general (excluding cases of pregnancy, ascites, large abdominal hernias, and tumors from within and outside the abdominal cavity), reflects well the amount of subcutaneous and intrabdominal fat. BMI has many virtues and advantages, despite its limitations, making it suitable for epidemiological, anthropometric, and population research, as well as for individual clinical nutrition guidance and follow-up. It can be quickly and easily calculated using weight and height, which are part of a standard clinical assessment routine. It is also deeply ingrained in the minds of physicians, nutritionists, dietitians, and physical trainers, as well as the public. Furthermore, despite its shortcomings, it has been extensively tested in numerous research studies where its close relationship with all-cause death rates, the risk of DM2, and the incidence of ASCVD outcomes (mainly, myocardial infarction, stroke, heart failure, and cardiovascular mortality) has been found.[13-20] Furthermore, it has high correlation coefficients when compared with measurements of fat mass and Body Fat Percentage (BFM) estimated by electrical bioimpedance.[21] Furthermore, BMI has a moderate correlation with Air Displacement Plethysmography (ADP), a sophisticated and reliable technique for measuring body fat.[22]

Over the past few years, our group has developed a definition of obesity that meets clinical criteria and it is based on proven scientific facts. *Obesity is a chronic, heterogeneous, relapsing, and progressing structural disease characterized by an excessive accumulation and abnormal distribution of body fat due to the loss of balance between caloric intake and energy expenditure. Its basic anatomical and structural alterations include hypertrophy, hyperplasia (or both) of adipocytes, frequently associated with other functional and anatomical alterations, such as ischemia, macrophage invasion and activation, and necrosis, apoptosis, and autophagy of the fat tissue. At the same time, it is often accompanied by resistance to insulin and secondary hyperinsulinism, inflammation, oxidative stress, and endothelial dysfunction. The last tetrad leads to the development of morbid conditions that affect the arteries and the parenchyma of multiple organs and systems, causing various complications and comorbidities, shortening life span, and seriously affecting its quality*.[23] An important subclass of this condition is abdominal obesity (characterized by an abdominal circumference of ≥ 80 cm in women and ≥ 90 cm in men[24]), which is well-known to be related to insulin resistance, and the so-called «metabolic syndrome», more appropriately named, dysmetabolic obesity. Other names for this condition include «central obesity», «android obesity», and «visceral obesity», among others.

According to the above, obesity is, essentially, an excess of fat mass. The challenges lie in defining «excess» and measuring it correctly, primarily in the daily clinical setting. It is known that body composition analysis, i.e., the percentage of corporeal mass of fat, is, so far, the better tool for that purpose.[25] An economical method for estimating body fat percentage was introduced in the 1970's and is based on measuring skinfold thickness at the chest, axilla, triceps, subscapular, and thigh sites with calipers.[26,27] Nevertheless, the procedure requires accredited training, is time-consuming, operator-dependent, and relies on comparing skinfold thickness results with body density and fat proportion obtained through the hydrostatic method of underwater weighing, which is based on Archimedes' principle.[28] The method has certain limitations, since the regression equations are specific to the population in which they were tested. In addition, while the slopes of the regression curves for different age and gender groups are similar, the intercepts differ.[28] For all the aforementioned reasons, this method is hardly suitable for use in an ordinary clinical setting. The other well-established method is Air Displacement Plethysmography. Unfortunately, although it is non-invasive and relatively easy to perform, it requires costly equipment that encloses the subject being studied immobile in an airtight chamber, which not everyone can tolerate or perform. Additionally, the results can be affected by the isothermal air close to or trapped in skin, hair, and loose clothing.[29]

Dual-Energy X-ray Absorptiometry (DXA) scan reveals well the fat content, its distribution, and bone density (in fact, it is the method used to analyze osteopenia or osteoporosis),

based on the different tissue absorption of two low-power X-ray beams.[30] The results are obtained by measuring the attenuation of the energy beam by the thickness and density of the body's various structures. This attenuation can differentiate between bone, fat, and lean (free-lipid soft tissue) masses. However, DXA does not directly measure body water. Another source of inaccuracy is the indirect analysis of soft tissue in pixels containing bone.[31] The exposure to ionizing radiation is not a problem because it is very low. However, the DXA machine's high price and bulky size make the method unusable in daily practice.

Bioelectrical Impedance Analysis (BIA) technology is another tool used in body composition analysis. The technique has gained popularity due to the portability and safety of BIA instruments. Unlike conventional scales that only measure weight, BIA scales utilize a low-intensity electric current to analyze the impedance of different body tissues, enabling the calculation of body composition. In basic physics, impedance is the combination of two phenomena: reactance and resistance.[32] The former is defined as the opposition of a capacitor to an alternating current (AC). A capacitor is a device that temporarily stores energy in an electric field by accumulating charges of opposite polarity on two conductors separated by an insulating material. The capacitor opposes a variable obstacle to the current flowing through it, especially at specific frequencies. Reactance increases when the frequency across the capacitor diminishes, and vice versa. In bioimpedance, the cell membrane, with a polar disposition of charges on either side, behaves as a capacitor. On the other hand, resistance is defined in physics as the opposition a material offers to the flow of electrons, according to its properties for electrical conduction (a conductor is a material that facilitates the transit of electrons, like copper or gold, while a resistor is a poor conductor, like glass or wood). Contrary to reactance, resistance remains constant despite the variations in the frequency of the AC signal. In bioimpedance, resistance is measured against the body's water and electrolytes, i.e., their capacity to conduct electricity,[33] while reactance refers to the opposition of the cell membranes to the flow of AC.

In conclusion, from a biophysical perspective, the term bioelectrical impedance refers to the behavior of tissues in response to an electric AC passing through them, encompassing the combined opposition to alternating electron flow across cell membranes and the intra- and extracellular fluid.

A low-voltage electric current through the trunk and the four extremities allows for analyzing the body compartments, including fat and free-fat masses, as well as bone, intracellular, and extracellular body water.[34] Although one of its first indications was measuring body water,[33] it subsequently extended its applications to analyze the composition of all the body compartments. Several BIA techniques are available, including those that utilize a single frequency and others that use multiple frequencies or an entire range of them (spectroscopy). Utilizing a broad-spectrum, multiple-frequency analysis differentiates the diverse body compartments more effectively.[35] In this way, BIA can discriminate between fat and free-fat masses based on the body compartments' different impedances.[36]

However, some shortcomings limit the certainty or applicability of this technique, starting with the considerable price of the most sophisticated BIA machines. Additionally, the equations used are based on assumptions derived from populations that differ in age, gender, clinical status, and ethnicity. Furthermore, hydration status can affect the accuracy of the assessment. Several studies comparing BIA and BMI for assessing obesity have found some differences between the two methods, but none are significant.[37] On the contrary, the correlation between BMI and fat content is around 0.8 or higher in both genders.[38] Also, BIA also has a good correlation with DXA (0.88 for both genders [0.78 in men, and 0.85 in women]).

In conclusion, there is no perfect or universally applicable technique for assessing obesity in the clinical setting. Nevertheless, these methods can be used in daily caregiving with an acceptable degree of certainty. However, due to their ease and economy, clinicians would often choose BMI calculations,

waist perimeter assessments, and body composition calculations obtained from relatively inexpensive impedance devices, despite evidence that these estimations are only approximations. A similar phenomenon occurs with blood pressure measurement. There are relatively significant differences between the actual blood pressure measured through a catheter or needle placed into a systemic artery and the indirectly estimated blood pressure with a mercury sphygmomanometer. Also, the blood pressure values measured by mercury and digital manometers differ.[39] And yet, these latest devices have simplified measurement and «democratized» their use to the point that these electronic manometers are now part of domestic technology. Serious therapeutic decisions are made daily, some of which have vital relevance, based on these measurements that only approximately reflect reality.

To further obscure an already confusing situation, recently, the Lancet Diabetes & Endocrinology,[40] a renowned medical journal, gathered an international, multidisciplinary group of 58 experts on obesity and formed one of its self-appointed commissions whose aims were: «*to establish objective criteria for disease diagnosis, aiding clinical decision making and prioritization of therapeutic interventions and public health strategies*».[40] The Commission was established with the assistance of the Institute of Diabetes, Endocrinology, and Obesity at King's Health Partners, a group dedicated to education and research, comprising King's College London and three trusts of the National Health Service in the United Kingdom. No other governmental or international health agency has endorsed the conclusions of this group to date. Notwithstanding, one acceptable recommendation (that most obesity study groups worldwide have been following for some time now) is that although BMI is not a perfect instrument, it remains a useful diagnostic tool, especially when it is complemented with the measure of the abdominal perimeter, waist-to-hip ratio, waist-height ratio, or direct body fat measure.[40] However, although the first three anthropometric measures have a close relationship with the presence of visceral fat and the abnormal distribution of fat mass, they do not reflect the total amount of adipose tissue, which is the key anatomical abnormality of obesity. In this context, the Commission recommends DXA fat measurement,[40] despite its cost and impracticality for daily clinical use. Surprisingly, BIA scales are not mentioned among the Commission's recommendations, even though they are currently increasingly accessible and are becoming standard devices in clinical practice.

Nevertheless, the confusing problem arises when the Lancet Commission categorizes obesity into two categories: «preclinical» and «clinical obesity», based on the presence or absence of clinical manifestations of organ compromise or disability.[41] What is «preclinical» obesity in the Commission proposal? The excess of adiposity, but without organ dysfunction.[41] As it is known, clinical diagnosis involves identifying a health condition (disease, syndrome, toxicity, or trauma/injury) using the clinical history and physical examination, maybe with the help of simple instruments like stethoscopes, diagnosis lamps, magnifying lens, wires for assessing sensitivity, weight balances, metric tapes, and the like, that do not substitute our sense organs but only amplify their capacity and certainty. A preclinical condition refers to a stage of health that precedes the onset of clinical symptoms and signs. To reveal these structural or functional anomalies, the use of devices that go beyond the reach of our senses is necessary: radiological or magnetic resonance imaging, electrocardiogram, ultrasound registers, functional tests, etc. So, if a frankly obese person feels well and does not have any objective or subjective manifestation of cardiovascular, metabolic, liver, or bone-arthro-muscular dysfunction, is not clinically obese despite weighing 100 kg, and having a BMI of 35 kg/m^2. In other words, from the medical point of view, obesity is always a clinical entity, because with ordinary, basic anthropometry (the simple inspection, a weight scale, a stadiometer, and a measuring tape), it is possible to establish the excess of adiposity with a high degree of certainty, even in borderline cases.

The presence of symptoms or signs is not necessarily related to the amount of adiposity because there are numerous phenotypic variants and chance associations with several

risk factors. Whether it is a special phenotype or simply an early, transitory state of the disease, there are cases of «healthy or metabolically healthy obesity» without any evidence of cardiometabolic dysfunction.[42] On the other hand, biological tolerance to adiposity is modified phenotypically, or if obesity is associated, for example, with diabetes, genetically determined lipid abnormalities, high blood pressure, or behavioral factors such as binge eating, emotional hunger, smoking, excess alcohol consumption, or sedentary behavior. To this basic term, obesity, several distinctive features can be added, such as «central, android or abdominal», «femoro-gluteal or gynecoid», «normometabolic or dysmetabolic», «complicated or non-complicated», and if obesity is associated with diabetes («diabesity»), among others.

Fortunately, entities that can only superficially cast doubt on the aforementioned concepts are rare. One such entity is lipodystrophy syndrome,[43] a heterogeneous set of congenital or acquired conditions characterized by partial or complete loss of fat tissue. This condition is accompanied by ectopic fat deposits in the liver, heart, pancreas, skeletal muscle, and other areas. In general, lipodystrophy is associated with severe insulin resistance and significant metabolic and cardiovascular complications. Paradoxically, in some varieties of partial lipodystrophy, the lack of fatty tissue in most body regions is associated with an abnormal accumulation of abdominal visceral fat. In those cases, the anthropometric diagnostic clue is the discrepancy between a low BMI and an expanded waist circumference. In any case, since lipodystrophy is a disorder of fat tissue, it is not a state of obesity, but rather the opposite.[44]

This definition of «entanglement» stems from the fact that the commissioners become embroiled in the outdated and, in our opinion, irrelevant debate about whether obesity is or is not a disease.[45,46] The classical definition of disease is any structural or functional alteration of an organ or part of a body system, resulting from genetic or developmental errors, metabolic disorders, infectious, parasitic, or toxic/poisonous factors, nutritional deficiencies or excesses, and traumatic or environmental causes.[45] A structural disease has specific macro- or microanatomic hallmark lesions, contrasting with a functional disease, which has only an abnormal function without specific anatomic alterations. Liver cirrhosis, myocardial infarction, and hypertrophic myocardial disease are examples of structural diseases, while fibromyalgia and anxiety are functional conditions. Symptoms and signs frequently accompany structural abnormalities, but sometimes, even during a considerable lapse, do not cause clinical manifestations. The increase in the size (thickness, length, or both) of left ventricular cardiac myocytes (hypertrophy), frequently accompanied by an increase in dense collagen in the extracellular matrix (dystrophy), defines myocardial hypertrophy. The disease is known as hypertrophic cardiomyopathy, leading to functional disorders like systolic or diastolic left ventricular dysfunction, which can remain asymptomatic for an extended period. To reveal its existence and assess its severity, paraclinical studies are required, including electrocardiograms, chest X-ray films, transthoracic echocardiograms, computed tomography scans, magnetic resonance images, and other diagnostic tests. Once the carrier of this condition experiences dyspnea or other clinical manifestations of cardiac dysfunction, they are in the clinical phase of the disease, suffering overt heart failure. Similarly, obesity is characterized by an expansion of fatty tissue, resulting from the hyperplasia or hypertrophy (or both) of adipocytes, a structural phenomenon. While the nutrient vessels of the fatty tissue (an angiogenesis phenomenon) increase proportionally to the fat expansion, there is no adipocyte dysfunction. Genetic and epigenetic influences partly determine the extension of the angiogenic phenomenon.[47] But, when growth exceeds the angiogenic capacity, ischemia of the fatty tissue develops, which in turn triggers the series of events that characterize anatomically and functionally the dysmetabolic obesity: local inflammation, recruitment and activation of macrophages, necrosis, apoptosis, autophagy of the fatty tissue, and a fibrous scar reaction. All these structural alterations are accompanied by systemic low-grade inflammation, insulin resistance/hyperinsulinemia, nitroxidative stress, and endothelial dysfunction, among

other functional disorders. Other structural abnormalities that occur when the balance between fatty tissue expansion and angiogenesis is disrupted include the deposition of fat in non-adipose tissues, such as striated muscle, heart, kidney, pancreas, brain, and others. Our group has coined the term extra-adipocyte lipothesaurosis (literally, fat storage), which is part of the physiologic and anatomical pathology of obesity. This abnormal structural fact is responsible for the production of toxic lipid metabolic byproducts, which damage the cell and lead to apoptosis (lipotoxicity).[48] All these abnormalities can be expressed in an abundant conjunction of symptoms and clinical signs, which are added to those that are due to the effect of obesity on the osteo-arthro-muscular complex, the nervous system and behavior, the skin, and the rest of the organs and systems of the body.

The Lancet Commission proposal offers no benefits in clarifying the basic conceptualization of this complex disease. Not only does it not help in the management of the entity, but it can also contribute to the obese patient not becoming aware of his illness and not actively collaborating with the interdisciplinary team (physicians, nutritionists, physical trainers, and psychologists) to control it. Telling obese persons that they are not obese (only «preclinical obese») and that they do not suffer from a disease, but only a risk factor, because there are no symptoms or disability, can lead to abandonment of diet, psychotherapy, or drug therapy.

To avoid blindly and uncritically following what is said or dictated in other latitudes, all those interested in obesity in our country should convene a meeting where we develop our concept of this disease and formulate clinical, preventive, and therapeutic recommendations for our community and health authorities.

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Letter to the Editor

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Cardio-protected areas are a paradox of teaching in medical schools

Los espacios cardioprotegidos son una paradoja de la enseñanza en las escuelas de medicina

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Keywords:
cardio-protected area, teaching, medical school.

Palabras clave:
espacio cardioprotegido, enseñanza, escuela de medicina.

Abbreviations:
AED = Automatic external defibrillator
CPA = Cardio-protected areas
CPR = Cardiopulmonary resuscitation
OHCA = Out-of-hospital cardiac arrest
SCD = Sudden cardiac death

The highest kind of man is he who acts before he speaks and professes what he practices.
Confucius

The primary purpose of medical schools is to train health professionals with the skills, knowledge, and attitudes necessary to prevent, preserve, restore, and promote health in individuals, families, and communities through prevention, diagnosis, treatment, and rehabilitation of health disorders. In addition, it also seeks to train university students with solid scientific, ethical, and humanistic foundations. Those foundations will enable students to adapt to all the changes that occur and will occur in the field of health. They will also encourage students to contribute to advancing medical knowledge in their field and the community. The social responsibility of medical schools is a growing philosophical concept that is beginning to permeate the field and requires rethinking their mission in society and how they can contribute to its development.[1]

On the other hand, sudden cardiac death (SCD) is a world health problem that represents around 30% of the total cardiovascular mortality, and nearly 20% of all deaths in adults. The one-year survival rate for an out-of-hospital cardiac arrest (OHCA) is around 8 to 10%. Interventions such as early initiation of cardiopulmonary resuscitation (CPR) by laypersons and use of an automatic external defibrillator (AED) may increase the survival rate.[2] Based on this, the concept of cardio-protected areas (CPA) should be considered in public and private places with high traffic, as well as specific establishments where a rapid response is required for cardiac emergencies. This includes airports, shopping centers, stadiums, schools, universities, and public buildings, among others.

SCD is a global health problem, and Mexico is not an exception. Several challenges persist in improving survival rates, including the implementation of public policies, the provision of generalized CPR training across all educational levels, from elementary to professional, and the enactment of laws that foster the establishment of CPAs.[3] All medical schools, when teaching the concept of CPR and SCD, have the social, scientific, ethical, and human obligation to be CPA, as well as to promote the free teaching of CPR to the general population. From a university's social responsibility standpoint, cardiopulmonary resuscitation teaching should be regarded with the same relevance as support of vaccination campaigns, promotion of timely cervical and breast cancer detection and prevention, and other public health issues that are addressed in academic institutions.

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There are approximately 105 medical schools in Mexico. However, only a few have managed to be CPA, for example: UNAM, the University of Colima, the University Center for Health Sciences of the University of Guadalajara, the University of Guanajuato, the Autonomous University of Morelos, and the Autonomous University of Nuevo León.

The inevitable question arises: why aren't they all? Quoting Dr. Albert Einstein: *«Teaching by example is not a way of educating; it is the only way!»*

It is also important to showcase that universities are a representation of society. It might be thought that their main population is young, healthy people. However, there are many other actors from different social strata with different risk factors that might be the subject of an OHCA or other cardiac emergencies, or any other emergency, for instance. Although a medical school campus is not a hospital, it should be prepared to diagnose an emergency, administer first aid, and activate the emergency medical system.

It's worth clarifying that the mere presence of an AED does not make a CPA. What does a CPA entail? In summary:[4,5]

1. Easy and fast access to AEDs: placed at strategic, easily accessible, and marked locations.
2 Staff training: staff and students are provided with CPR and AED training.
3. Maintenance: a plan is established for the maintenance and monitoring of equipment, ensuring its proper functioning.
4. Action plan: developed to respond to a cardiac emergency, including the activation of emergency services, start CPR, and use of an AED, and ensure prehospital and hospital emergency cardiac care.

Returning to our initial thoughts: if we consider that promoting community health and adapting to the changes that the community itself requires are some of the main opportunity areas for medical schools, are not these principles perfectly applicable to the creation of CPA and the teaching of CPR in our country? We call on Mexican universities, and especially medical schools and faculties, to transform their campuses into CPA, thereby promoting and disseminating their social commitment to help reduce the scourge of SCD that affects us so much.

Those who have the mission to teach great things are equally obligated to practice them. (Saint Gregory the Great).

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ORIGINAL RESEARCH

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Acute pressor response after isometric training session in adults with controlled hypertension

Respuesta presora aguda tras una sesión de entrenamiento isométrico en adultos con hipertensión controlada

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Keywords:
handgrip strength, high blood pressure, isometric resistance training, exercise, blood pressure.

Palabras clave:
fuerza de prensión manual, hipertensión arterial, entrenamiento de resistencia isométrica, ejercicio, presión arterial.

ABSTRACT

Introduction: hypertension is the main risk factor for cardiovascular diseases and has a high global prevalence. Its treatment includes physical activity, exercise, and lifestyle changes. Isometric handgrip strength training has shown significant long-term reductions in blood pressure. However, knowing its acute effect is key to understanding the immediate effects and efficacy, although it has been little studied. **Objective:** to assess the blood pressure response after a single session of isometric resistance training in adults with hypertension and hypertension combined with insulin resistance. **Material and methods:** thirty older adults from the More Self-Sufficient Older Adults program (MSROA) participated in Paine, Chile. They were divided into two groups: twenty with pure hypertension (G-HTN) and ten with hypertension and insulin resistance (G-HTN/IR). Both groups performed one session of four isometric contractions, each lasting two minutes at 30% of their maximum strength, with two-minute rest intervals between each contraction. Blood pressure was measured post-intervention for one hour and again after 24 hours. **Results:** significant differences were found in systolic arterial pressure (SAP) between groups at minutes one and twenty, while diastolic arterial pressure (DAP) and mean arterial pressure (MAP) showed no significant differences. Both groups showed reductions in SAP and MAP, with decreases of −8.21 mmHg (SAP) and −4.49 mmHg (MAP) in G-HTN, and −11.3 mmHg (SAP) and −1.43 mmHg (MAP) in G-HTN/IR. **Conclusion:** isometric training reduces SAP and MAP. Although a transient increase in SAP is observed immediately after the intervention, this effect is followed by a significant reduction at 24 hours.

RESUMEN

Introducción: *la hipertensión es el principal factor de riesgo de las enfermedades cardiovasculares y tiene una elevada prevalencia mundial. Su tratamiento incluye actividad física, ejercicio y cambios en el estilo de vida. El entrenamiento de fuerza isométrica de prensión manual ha demostrado reducciones significativas de la presión arterial a largo plazo. Sin embargo, conocer su efecto agudo resulta clave para comprender los efectos y eficacia inmediata, aunque ha sido escasamente estudiado.* ***Objetivo:*** *evaluar la respuesta de la presión arterial tras una única sesión de entrenamiento de resistencia isométrica en adultos con hipertensión e hipertensión combinada con resistencia a la insulina.* ***Material y métodos:*** *participaron treinta adultos mayores del programa Más Adultos Mayores Autosuficientes (AMA) en Paine, Chile. Se dividieron en dos grupos: 20 con hipertensión pura (G-HTN) y 10 con hipertensión y resistencia a la insulina (G-HTN/IR). Ambos grupos realizaron una sesión de cuatro contracciones isométricas de dos minutos de duración cada una al 30% de su fuerza máxima, con intervalos de descanso de dos minutos entre cada contracción. Se midió la presión arterial después de la intervención durante una hora y de nuevo al cabo de 24 horas.* ***Resultados:*** *se encontraron diferencias significativas en la presión arterial sistólica (PAS) entre los grupos en los minutos uno y veinte, mientras que la presión arterial diastólica (PAD) y la presión arterial media (PAM) no mostraron diferencias significativas. Ambos grupos mostraron reducciones de la PAS y la PAM, con descensos de −8.21 mmHg (PAS) y −4.49 mmHg (PAM) en G-HTN, y de −11.3 mmHg (PAS) y −1.43 mmHg (PAM) en G-HTN/IR.* ***Conclusión:*** *el entrenamiento isométrico reduce la PAS y PAM. Si bien se observa un aumento transitorio de la PAS inmediatamente posterior a la intervención, este efecto es seguido por una reducción significativa a las 24 horas.*

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Abbreviations:
BP = Blood Pressure
CO = Cardiac Output
DAP = Diastolic Arterial Pressure
G-HTN = Group with Isolated Diagnosis of HTN
G-HTN/IR = Group with both HTN and Insulin Resistance
HTN = Hypertension
IR = Insulin Resistance
MAP = Mean Arterial Pressure
MIGS = Maximal Isometric Grip Strength
MSROA = More Self-Sufficient Older Adults program
SAP = Systolic Arterial Pressure
TPR = Total Peripheral Resistance

INTRODUCTION

Arterial hypertension (HTN) is the leading risk factor for cardiovascular diseases, affecting 30% of the global population (1.4 billion adults), with a projected increase to 1.6 billion by 2025, according to the World Health Organization (WHO).[1] It is closely associated with overweight and obesity, increasing the risk of complications such as heart failure, ventricular hypertrophy, cerebrovascular accidents, and chronic kidney disease. Cardiovascular events are linked to the deterioration of vascular function and endothelial tissue, impairing the regulation of vascular tone and peripheral vascular resistance.[2]

The treatment of HTN includes both pharmacological and non-pharmacological therapy.[3] Within the latter, in addition to lifestyle and dietary modifications, regular physical activity stands out,[4] with recommendations of 150-300 minutes per week of moderate-intensity exercise, 75-150 minutes of vigorous-intensity exercise, or an equivalent combination of both.[5,6]

Aerobic exercise and resistance training contribute to blood pressure (BP) regulation[7] and may reduce the reliance on antihypertensive medications.[8] However, many individuals do not engage in these activities due to barriers such as a lack of time or motivation.[9] In this context, isometric resistance training has emerged as a more effective strategy for BP control.[10,11] This modality involves muscle contractions against a fixed load, such as handgrip exercises, with the most common protocol consisting of unilateral upper limb training, performing four sustained contractions of two minutes each at 30% of maximal voluntary contraction, three times per week.[11,12] This therapeutic approach has demonstrated clinically significant BP reductions in both hypertensive and normotensive individuals over short- and long-term periods, with greater efficacy than antihypertensive medications,[13] However, the immediate effects following a single session remain insufficiently explored. Therefore, knowing the effects of isometric training would be of great relevance since it is of low volume and intensity can generate cardiovascular changes in the short-term whit at low cost and high applicability, it could be an effective strategy with good adherence. Thus, the objective of this study is to evaluate the pressor response following a single session of isometric resistance training in adults with hypertension and hypertension combined with insulin resistance.

MATERIAL AND METHODS

This quasi-experimental, analytical, cross-sectional, and prospective study was approved by the Scientific Ethics Committee of the Metropolitan South Health Service in Santiago, Chile (MEMO 155/2024, PROTOCOL 75-23072024), adhering to the seven ethical principles for human research outlined by Ezekiel Emanuel.[14,15]

Participants were selected through convenience sampling and comprised 100% of the population enrolled in the national More Self-Sufficient Older Adults program (MSROA) at CESFAM Dr. Raúl Moya Muñoz in the municipality of Paine. The study included 30 older adults (≥ 65 years) diagnosed with HTN *(Table 1)*. Participants with an isolated diagnosis of HTN were assigned to the G-HTN group (n = 20), while those with both HTN and insulin resistance (IR) were assigned to the G-HTN/IR group (n = 10).

The inclusion criteria required active participation in the MSROA program, up-to-date medical check-ups, and the absence of musculoskeletal injuries, uncontrolled chronic diseases, or neurological conditions that could affect participation.

Procedure

Day 1. Prior to the training session, blood pressure (BP) was recorded while the participant

was seated in a chair with back support and no armrests. Measurements were taken on the dominant upper limb using a digital blood pressure monitor (Omron HEM 7130),[16] after five minutes of rest. Following BP measurement, maximal isometric grip strength (MIGS) was directly assessed using a Jamar hydraulic hand dynamometer,[17] *(Table 2)* on the dominant upper limb. The test was conducted in a seated position without armrests, with feet flat on the floor, the upper limb adducted, the elbow flexed at 90º, the wrist in a neutral position, and the back upright while looking straight ahead,[18] The highest value from three maximal grip strength attempts, with one-minute rest intervals between trials, was recorded.

Table 1: Antihypertensive pharmacological treatment categorization in both groups.

Drug	G-HTN (n = 20)	G-HTN/IR (n = 10)
Losartan	6	3
Enalapril	5	0
Losartan-Amlodipine	6	6
Losartan-Carvedilol	1	0
Atenolol-Hydrochlorothiazide	1	0
Losartan-Amlodipine-Hydrochlorothiazide	1	1

G-HTN = Group with Isolated Diagnosis of HTN. G-HTN/IR = Group with both HTN and Insulin Resistance. HTN = Hypertension.

Day 2. After baseline BP and MIGS measurements, each participant performed the isometric training protocol, consisting of four isometric muscle contractions sustained for two minutes at 30% of their MIGS, with two-minute rest intervals between repetitions, maintaining the same position used for the MIGS assessment. BP was measured on the dominant arm immediately after the final repetition, every 10 minutes for one hour, and again at 24 hours *(Figure 1)*.

Throughout days one and two, participants were advised to abstain from consuming cardiovascular system stimulants (such as caffeine, alcohol, tobacco, and yerba mate) and to avoid strenuous exercise while maintaining their regular antihypertensive medication regimen without interruption.

Statistical analysis

A statistical analysis was conducted, including both descriptive and inferential approaches, to evaluate differences between the G-HTN and G-HTN/IR groups.

Table 2: Mean baseline characteristics of each intervention group, including age, sex, systolic arterial pressure (SAP), diastolic arterial pressure (DAP), one-repetition maximum (1RM), and mean arterial pressure (MAP).

	All (n = 30)			G-HTN (n = 20)			G-HTN/IR (n = 10)		
	Mean ± SD	LL	UL	Mean ± SD	LL	UL	Mean ± SD	LL	UL
Age (years)	72.07 ± 6.43	65	86	70.11 ± 5.37	65	83	76.5 ± 6.1	65	86
SAP (mmHg)	140.27 ± 18.72	103	198	136.63 ± 16.79	103	168	148.90 ± 19.64	130	198
DAP (mmHg)	75.10 ± 8.19	59	93	75.32 ± 8.87	63	93	74.10 ± 6.85	59	86
MAP (mmHg)	96.82 ± 10.27	78.33	120	95.75 ± 10.31	78.33	116.33	99.03 ± 10.36	82.67	120
1RM (kg)	25.10 ± 9.15	10.8	46.8	24.85 ± 8.03	11.10	45.80	25.90 ± 11.25	10.80	46.80
Sex									
Male	8			6			1		
Female	22			14			9		

G-HTN = Group with Isolated Diagnosis of HTN. G-HTN/IR = Group with both HTN and Insulin Resistance. HTN = Hypertension. LL = Lower Limit. SD = Standard Deviation. UL = Upper Limit.

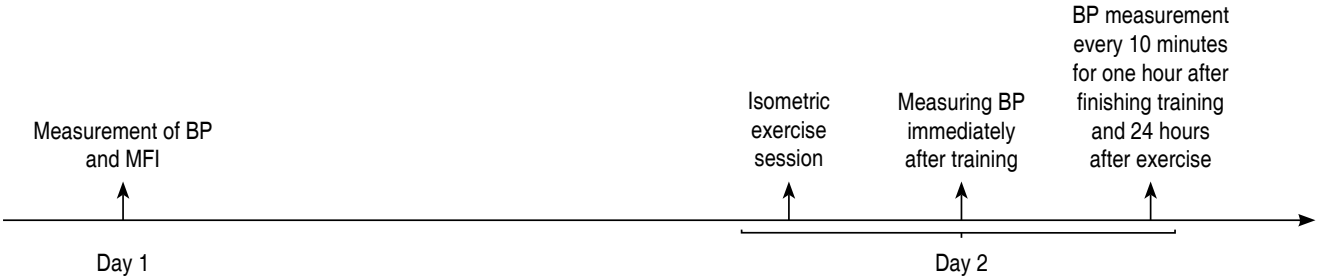

Figure 1: Summary of the intervention process.
Note: Isometric exercise session: four sustained contractions for two minutes at 30% of MFI, with two minutes of rest between contractions. The two intervention days are consecutive.
BP = Blood Pressure. MFI = Maximum Isometric Force.

RESULTS

The isometric handgrip intervention elicited distinct hemodynamic responses between the study groups. Participants with G-HTN/IR consistently exhibited higher systolic arterial pressure (SAP) and mean arterial pressure (MAP) values compared to those with G-HTN, from the first minute of the intervention through the 24-hour follow-up *(Figure 2)*. The peak SAP in the G-HTN/IR group was observed at minute 10 (148.5 ± 16.42 mmHg), whereas the corresponding value in the G-HTN group was 135.95 ± 15.31 mmHg. At 24 hours, both SAP and MAP remained elevated in the G-HTN/IR group (137.6 ± 10.13 mmHg and 97.6 ± 7.58 mmHg, respectively), relative to the G-HTN group (128.42 ± 14.28 mmHg and 91.26 ± 10.61 mmHg). All values are reported with a 95% confidence interval, supporting the reliability of the findings and indicating a more sustained hemodynamic burden in individuals with concomitant insulin resistance in response to isometric loading.

Low-intensity isometric resistance training was well tolerated by both groups, with no adverse effects or significant discomfort reported during or after the intervention, thereby confirming its safety as a training modality in this population. The majority of participants in both groups were women: the G-HTN group comprised 14 women and six men, whereas the G-HTN/IR group included nine women and one man. Mean maximal handgrip strength was comparable between groups, recorded at 24.85 ± 8.03 kg in the G-HTN group and 25.9 ± 11.25 kg in the G-HTN/IR group. Notably, the G-HTN group exhibited lower mean blood pressure values across all time points compared to the G-HTN/IR group, which also presented with a higher mean age, potentially contributing to the augmented cardiovascular response observed.

Prior to analysis, normality tests were conducted using the Kolmogorov-Smirnov test to ensure that the data met the necessary assumptions. The statistical significance level was set at $p < 0.05$, indicating that observed differences were statistically significant. All statistical analyses were performed using IBM SPSS 19.[19]

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The majority of participants in both groups were women: the G-HTN group included fourteen women and six men, while the G-HTN/IR group consisted of nine women and one man. Mean maximal handgrip strength values were similar between groups: 24.85 ± 8.03 kg in the G-HTN group and 25.9 ± 11.25 kg in the G-HTN/IR group. Additionally, the G-HTN group exhibited lower mean blood pressure values compared to the G-HTN/IR group, with the latter also having an older average age.

DISCUSSION

Our results indicate that a single session of isometric handgrip strength exercise initially increases systolic arterial pressure (SAP), diastolic arterial pressure (DAP), and mean arterial pressure (MAP) post-exercise, followed

by a gradual decrease in these pressures for at least 24 hours after the intervention *(Table 3)*. This finding aligns with Wiles (2018), who assessed heart rate (HR) and blood pressure (BP) during isometric lower limb training and aerobic exercise. Wiles demonstrated that BP and HR initially increased in response to exercise, attributed to vascular compression or, in some cases, occlusion of blood vessels in active muscles. This phenomenon leads to increased cardiac output (CO) due to enhanced chronotropic activity, without significant changes in total peripheral resistance (TPR).[20,21] These alterations in the components of the blood pressure (GC × TPR These alterations in BP components (CO × TPR) result in a pronounced rise in BP, particularly in hypertensive individuals, explaining the acute BP elevation during exercise and within the first minute post-intervention.

Additionally, we observed a notable post-training reduction in SAP and MAP *(Figures 3A, 3B and 3C)*, but not in DAP. In fact, SAP significantly decreased at minutes 1 and 20 when comparing the G-HTN and G-HTN/IR groups. This finding is consistent with the review by Almeida (2021), who analyzed the effects of isometric handgrip exercise on BP and heart rate variability. Almeida concluded that isometric handgrip training positively impacts SAP but does not significantly affect DAP or heart rate variability. The reduction in SAP was attributed to a decrease in peripheral vascular resistance, triggered by endothelium-dependent vasodilation in response to reactive hyperemia caused by

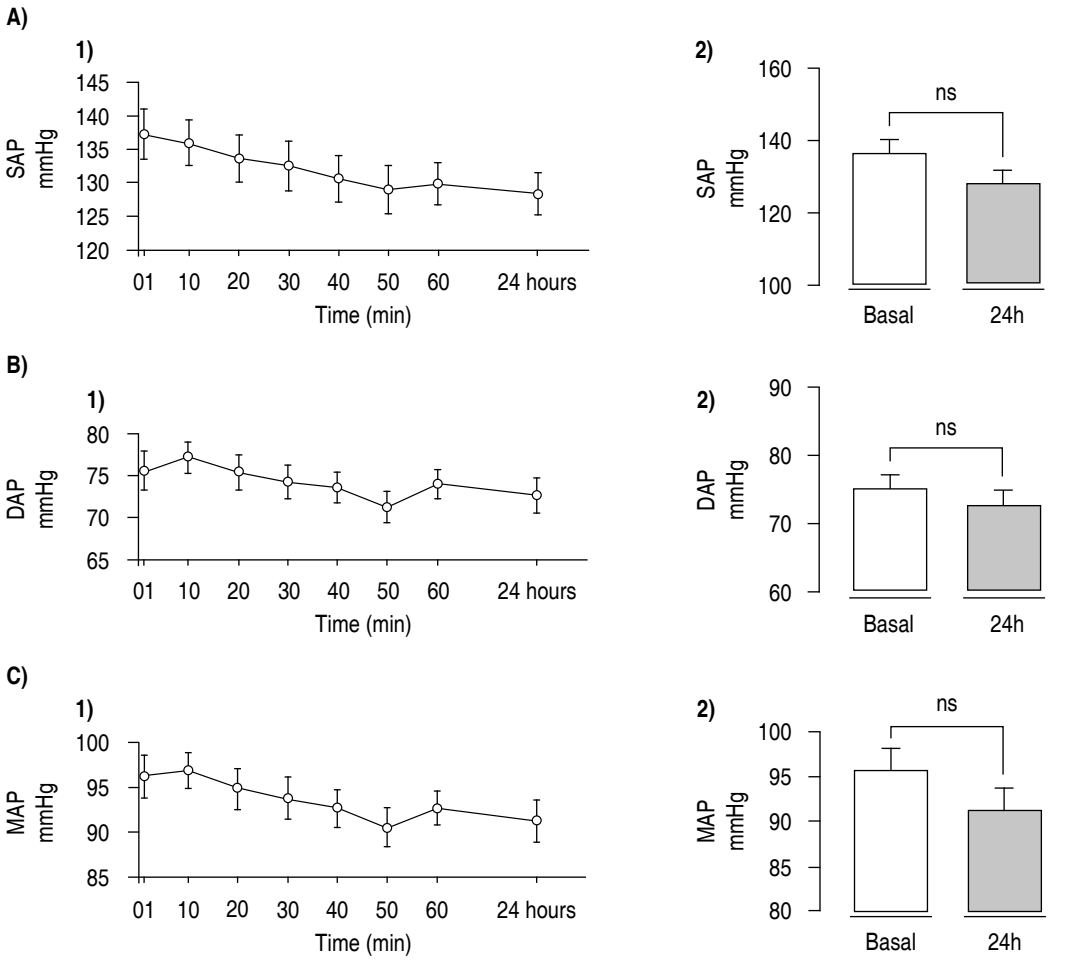

Figure 2: Blood Pressure of the G-HTN group during intervention.

Table 3: Average systolic arterial pressure (SAP), diastolic arterial pressure (DAP), and mean arterial pressure (MAP) values following isometric training.

Blood pressure (mmHg)	G-HTN (n =20)			G-HTN/IR (n =10)		
	Mean ± SD	LL	UL	Mean ± SD	LL	UL
	Minute 1					
SAP	137.37 ± 16.47	110	172	152.00 ± 11.58	140	178
DAP	75.63 ± 10.62	58	101	78.30 ± 4.45	73	87
MAP	96.21 ± 10.78	79	124.7	102.87 ± 5.98	96	117.3
	Minute 10					
SAP	135.95 ± 15.31	111	161	148.50 ± 16.42	119	179
DAP	77.26 ± 8.81	61	95	75.50 ± 7.90	57	87
MAP	96.82 ± 9.06	79	116.7	99.83 ± 9.86	77.7	117.7
	Minute 20					
SAP	133.63 ± 15.65	111	163	147.20 ± 14.21	127	175
DAP	75.42 ± 9.85	56	96	77.50 ± 7.53	58	86
MAP	94.82 ± 10.31	78	115	100.73 ± 9.08	81	113.7
	Minute 30					
SAP	132.58 ± 16.33	103	159	144.10 ± 14.52	118	176
DAP	74.32 ± 9.49	58	95	76.70 ± 6.28	63	84
MAP	93.74 ± 10.51	73	116.3	99.17 ± 8.67	81.3	114.7
	Minute 40					
SAP	130.68 ± 15.29	103	159	143.90 ± 17.06	110	171
DAP	73.68 ± 8.60	55	90	78.12 ± 7.29	58	86
MAP	92.68 ± 9.61	71	110	100.03 ± 9.76	75.3	11.7
	Minute 50					
SAP	129 ± 15.96	99	158	141.70 ± 17.74	109	171
DAP	71.37 ± 8.42	56	87	76.20 ± 7.45	58	86
MAP	90.58 ± 9.83	71	104	98.03 ± 10.46	75	111
	Minute 60					
SAP	129.95 ± 13.93	103	155	140.80 ± 16.20	112	168
DAP	74.11 ± 7.98	63	89	76.60 ± 7.62	62	88
MAP	92.72 ± 8.49	78.7	107.7	98 ± 9.93	81	111.3
	24 hours					
SAP	128.42 ± 14.28	103	156	137.60 ± 10.13	120	153
DAP	72.68 ± 9.51	54	90	77.60 ± 7.95	58	92
MAP	91.26 ± 10.61	70.3	110	97.60 ± 7.58	80.7	111

G-HTN = Group with Isolated Diagnosis of HTN. G-HTN/IR = Group with both HTN and Insulin Resistance. HTN = Hypertension. LL = Lower Limit. SD = Standard Deviation. UL = Upper Limit.

isometric training, along with shear stress that enhances nitric oxide bioavailability.[22] Furthermore, Almeida suggested that the lack of significant DAP response to exercise could be explained by the normal baseline DAP values before the intervention and the use of antihypertensive medications with peripheral actions (e.g., angiotensin-converting enzyme

inhibitors, aldosterone antagonists, and diuretics). This finding is particularly relevant to our study, as both intervention groups had controlled hypertension managed with these medications, which may have attenuated the effects of exercise on DAP and contributed to the observed post-intervention fluctuations.[11,23]

Similarly, in 2013, Halliwill and colleagues explained that following an aerobic training session, a rapid reactivation of blood flow occurs in previously compressed vessels, similar to the response observed in isometric exercise. This process induces a phase of reactive hyperemia, which increases endothelial shear stress and promotes the release of vasoactive substances such as nitric oxide, prostaglandins, potassium, adenosine triphosphate, and, importantly, the activation of histamine H1 and H2 receptors. The release of nitric oxide contributes to sustained post-exercise vasodilation by reducing α-adrenergic receptor sensitivity, which is associated with enhanced baroreflex reestablishment and increased sympathetic inhibition. This mechanism explains why, in our study, blood pressure (BP) continued to decrease up to 24 hours post-intervention *(Figure 4)*. Additionally, the activation of histamine receptors acts as a potent immediate vasodilator following exercise, accounting for the BP reduction observed during the first hour post-intervention in our investigation.[24-27]

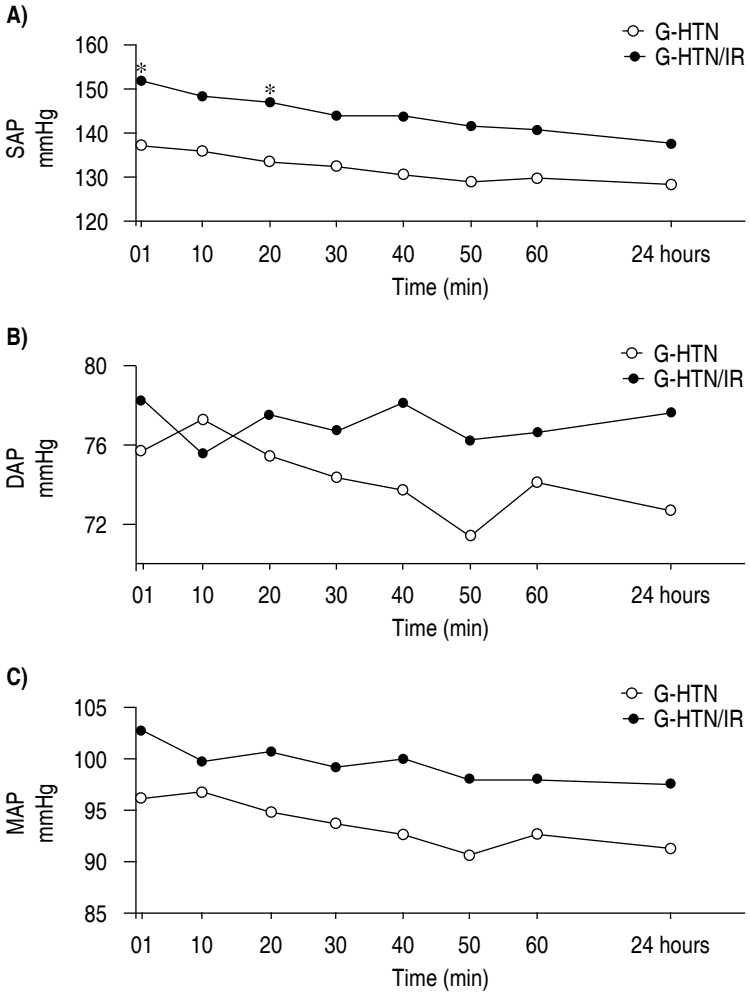

Figure 3: Blood pressure of G-HTN group versus G-HTN/IR group.

Another important point is that, similar to antihypertensive pharmacological treatment, a higher baseline resting BP is generally associated with more significant BP reductions following physical training. In normotensive individuals, these reductions are limited by counter-regulatory mechanisms that prevent BP from dropping below clinically homeostatic levels.[28] This observation aligns with our results, which suggest that the G-HTN/IR group experienced a more pronounced BP reduction post-training, likely due to their higher baseline BP values.

For optimal benefits, isometric handgrip training should be performed at 30% of one repetition maximum when targeting upper limb muscles. Lower or higher intensities have not been shown to yield distinct or enhanced benefits. A study by Espinoza et al. (2019) compared the hypotensive response induced by one week of isometric handgrip training at different intensities in small versus large muscle groups in young obese adults. Their findings suggested that the most potent hypotensive effect occurred in individuals training small muscle groups at low intensity (30% of maximal isometric force).[29] Future research should explore these effects in larger muscle groups to identify the exercise modality that provides the most beneficial BP response, as evidence suggests that interventions targeting larger muscle groups may yield superior outcomes.

Additionally, our study population is affected by physiological aging-related changes, including hemodynamic alterations, arterial stiffness, reduced baroreflex sensitivity,

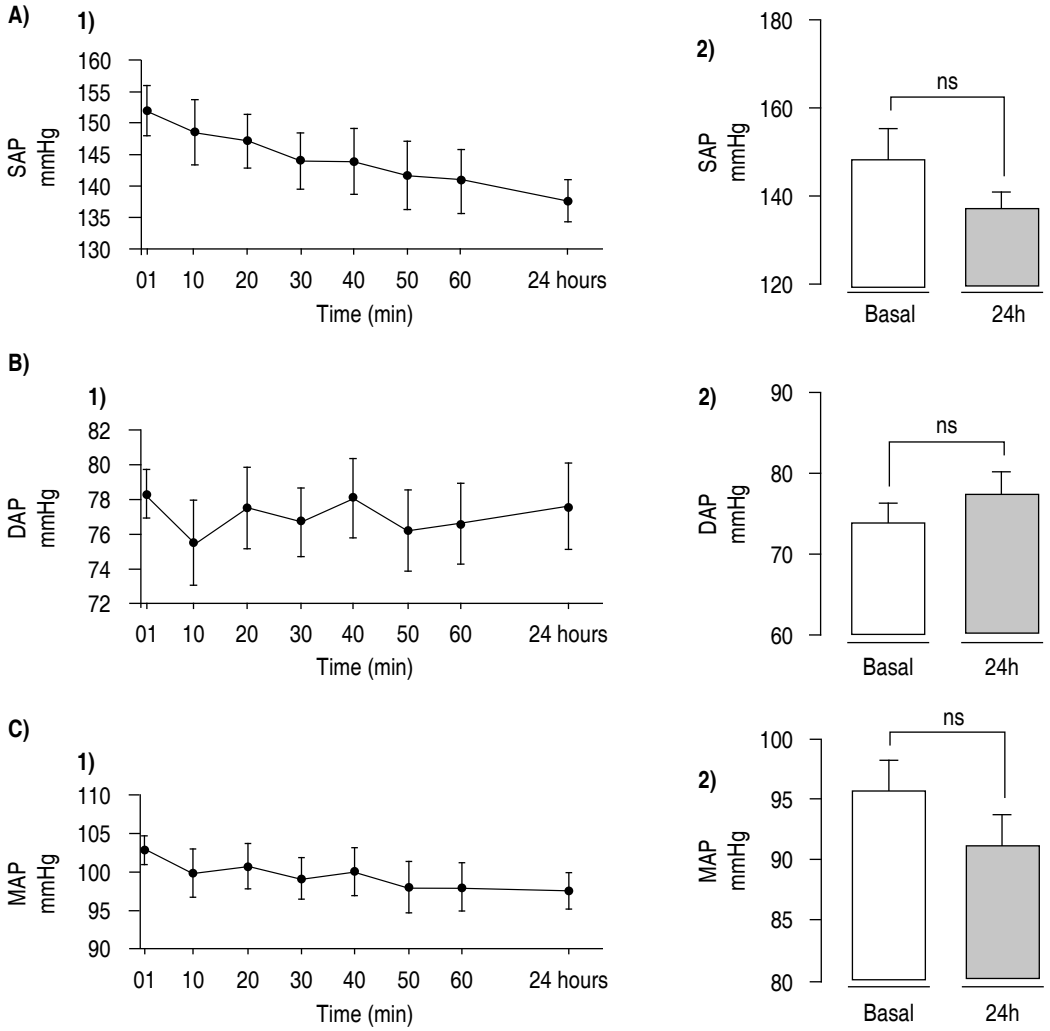

Figure 4: Blood Pressure of the G-HTN/IR group during intervention.

and neurohormonal, autonomic, and renal modifications, all of which contribute to hypertension and may explain the diminished BP response observed in some cases.

From a clinical perspective, the reductions in SAP and MAP observed in the G-HTN and G-HTN/IR groups after a single session of isometric exercise could lower the risk of cardiovascular disease, stroke, and chronic kidney disease, highlighting the importance of this intervention in the ambulatory management of hypertension. Therefore, the inclusion of an isometric training protocol at 30% of maximal manual grip strength during cardiovascular rehabilitation could constitute an effective strategy to induce a hypotensive response. Moreover, this type of intervention presents additional advantages such as high patient adherence and low implementation cost.

Finally, it is important to acknowledge that the studies by Espinoza, Wiles, Almeida, and Halliwill utilized larger population samples than our study. Future research should consider this factor to enhance the generalizability of findings.

CONCLUSION

In conclusion, a single session of isometric handgrip exercise at 30% of maximal isometric

force significantly reduces SAP and MAP values in individuals with hypertension and those with hypertension and insulin resistance. This intervention is safe, well-tolerated, and presents a promising non-pharmacological approach for the outpatient management of hypertension.

The evaluation of the effects within the first 24 hours is relevant, as it allows us to understand the magnitude and temporality of the acute hemodynamic response. This projects the efficacy of isometric training in contexts of continuous exercise prescription.

Future studies should consider a larger sample size, reduced heterogeneity in pharmacological treatment, and greater control over nutritional factors to clarify further the acute effects of an isometric training session in the studied population.

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Declaration of confidentiality and patients consent: the authors confirm that they have complied with the relevant workplace protocols for the use of patient data. Furthermore, the authors confirm that the patient has been duly informed and has provided written informed consent for the publication of their images and other clinical information in the journal without any identifying details in order to safeguard their right to privacy. Additionally, the authors attest that no form of generative artificial intelligence was employed in the preparation of this manuscript or the creation of figures, graphs, tables, or their corresponding captions or legends.

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Early changes in global longitudinal strain after transcatheter aortic valve replacement

Cambios tempranos del strain global longitudinal posterior a sustitución valvular aórtica percutánea

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Keywords: aortic stenosis, transcatheter aortic valve replacement, global longitudinal strain, echocardiography, Généreux classification.

Palabras clave: *estenosis aórtica, sustitución valvular aórtica percutánea, strain global longitudinal, ecocardiograma, clasificación Généreux.*

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ABSTRACT

Introduction: aortic stenosis is a prevalent and progressively worsening valvular heart condition associated with elevated rates of morbidity and mortality. While the left ventricular ejection fraction has traditionally served as the standard parameter for assessing systolic function, global longitudinal strain has gained recognition as a more sensitive marker capable of detecting subclinical myocardial impairment, even in individuals with preserved LVEF. Transcatheter aortic valve replacement offers a minimally invasive alternative to surgical valve replacement, particularly in high-risk patients. The Généreux classification stratifies patients with severe AS into stages based on extra-valvular cardiac involvement to better characterize the extent of myocardial damage. While long-term structural improvements after TAVR have been reported, early functional recovery remains underexplored. **Objective:** in this context, we aimed to evaluate early changes in GLS and the E/e' ratio three months after TAVR in patients stratified by the Généreux classification. **Material and methods:** a descriptive, observational, and cross-sectional study was conducted at the *Centro Médico Nacional 20 de Noviembre*. Demographic, echocardiographic, and hemodynamic variables were obtained from institutional electronic medical records. For statistical analysis, the χ^2 test or Student's t-test was used, and Spearman's correlation test was applied to evaluate associations between quantitative variables. **Results:** our study demonstrated a significant improvement in GLS across all stages, including patients with advanced myocardial involvement. In contrast, no significant changes were observed in the E/e' ratio, suggesting that early GLS improvement may not be directly associated with changes in diastolic filling pressures. **Conclusion:** these findings highlight the potential of GLS as an early marker of myocardial recovery following TAVR and support the prognostic value of the Généreux classification in this population.

RESUMEN

Introducción: *la Estenosis Aórtica (EAo) es una valvulopatía prevalente y progresiva, asociada con un aumento en la morbilidad y la mortalidad. Si bien la Fracción de Eyección del Ventrículo Izquierdo (FEVI) ha sido utilizada tradicionalmente para evaluar la función sistólica, el Strain Longitudinal Global (SLG) ha surgido como un marcador más sensible para detectar disfunción miocárdica temprana, incluso en pacientes con FEVI preservada. La Sustitución Valvular Aórtica Percutánea (TAVR, por sus siglas en inglés) ha demostrado ser una alternativa eficaz y menos invasiva que el reemplazo quirúrgico, particularmente en pacientes con alto riesgo. La clasificación de Généreux estratifica a los pacientes con EAo severa en estadios basados en el compromiso cardiaco extravalvular, con el objetivo de caracterizar mejor el grado de daño miocárdico. Aunque se han descrito mejoras estructurales a largo plazo posteriores al TAVR, la recuperación funcional temprana sigue siendo poco estudiada.* ***Objetivo:*** *en este contexto, el objetivo fue evaluar los cambios tempranos en el SLG y el índice E/e' a los tres meses posteriores al TAVR en pacientes estratificados según la clasificación de Généreux.* ***Material y métodos:*** *se realizó un estudio observacional, descriptivo y transversal en el Centro Médico Nacional 20 de Noviembre. Se obtuvieron variables demográficas, ecocardiográficas y hemodinámicas a partir de los expedientes electrónicos institucionales. Para el análisis estadístico, se utilizó la prueba de χ^2 o la prueba t de Student y se empleó la prueba de correlación de Spearman para evaluar asociaciones entre variables cuantitativas.* ***Resultados:*** *nuestro estudio demostró una mejoría significativa en el SLG en todos los estadios, incluyendo pacientes con daño miocárdico avanzado. En contraste, no se observaron cambios significativos en el índice E/e', lo que sugiere que la mejoría temprana del SLG podría no estar directamente relacionada con*

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modificaciones en las presiones de llenado diastólico. ***Conclusión:*** *estos hallazgos resaltan el potencial del SLG como un marcador temprano de recuperación miocárdica posterior al TAVR y respaldan el valor pronóstico de la clasificación de Généreux en esta población.*

Abbreviations
AS = Aortic Stenosis
GLS = Global Longitudinal Strain
GLS-LV = Global Longitudinal Strain of the Left Ventricle
LV = Left Ventricle
LVEF = Left Ventricular Ejection Fraction
LVH = Left Ventricular Hypertrophy
SAVR = Surgical Aortic Valve Replacement
TAVR = Transcatheter Aortic Valve Replacement

INTRODUCTION

Aortic Stenosis (AS) is one of the most widespread valvular heart disorders globally. It is defined by the gradual narrowing of the outflow tract from the Left Ventricle (LV) to the aorta. This hemodynamic obstruction induces pressure overload within the LV, subsequently triggering Left Ventricular Hypertrophy (LVH) as an adaptive response. In the absence of timely intervention, AS can progress to impair both systolic and diastolic function, ultimately leading to heart failure and elevated mortality rates.[1,2]

Contemporary clinical guidelines establish two principal criteria for indicating valve replacement: (i) the echocardiographic confirmation of severe aortic stenosis based on parameters such as Maximum Aortic Velocity (Vmax), mean transvalvular pressure gradient, and Aortic Valve Area or its Index (AVAi); and (ii) the presence or absence of symptoms attributable to the valvular pathology, including dyspnea, heart failure, angina, or syncope. Furthermore, preoperative risk assessment primarily considers comorbid conditions while excluding other structural or functional cardiac characteristics from the decision-making framework.[2,3]

To provide a more comprehensive assessment of the hemodynamic impact of severe aortic stenosis, Généreux and colleagues proposed a classification system based on the extent of extra-valvular cardiac damage, using easily obtainable and broadly applicable echocardiographic parameters. This stratification includes five progressive stages: Stage 0 refers to patients with severe AS and no evidence of extra-valvular cardiac involvement; stage 1 includes LV dysfunction (LVEF < 50%, E/e' ratio > 14, or LVH); stage 2 includes left atrial enlargement, atrial fibrillation, or at least moderate mitral regurgitation; stage 3 includes moderate or more significant tricuspid regurgitation or pulmonary hypertension (sPAP > 60 mmHg); and stage 4 includes right ventricular dysfunction, defined by parameters such as TAPSE < 17 mm or S wave < 9.5 cm/s. When criteria from multiple stages are met, the highest stage is assigned.[3,4]

The underlying hypothesis was that the progression of extra-valvular cardiac damage could have significant prognostic implications. To validate this, data from the PARTNER 2 trial were used, which included 1,661 patients with severe AS who underwent valve replacement (TAVR or surgical). Most patients were in advanced stages (50.8% in stage 2, 24.9% in stage 3, and 8.7% in stage 4), while only 2.8% were classified as stage 0. One-year survival analysis showed a statistically significant and progressive increase in both all-cause and cardiovascular mortality as stages advanced. Multivariate analysis confirmed that the cardiac damage stage was one of the strongest predictors of one-year mortality, with an estimated 40-45% increased risk of death per stage, surpassing other comorbidities such as chronic kidney disease or coronary artery disease. These findings position the Généreux classification as a valuable prognostic tool that could complement current decision-making criteria for AS management.[4]

Surgical Aortic Valve Replacement (SAVR) has traditionally represented the cornerstone treatment for patients with symptomatic severe aortic stenosis. However, in recent decades,

Transcatheter Aortic Valve Replacement (TAVR) has gained prominence as a less invasive option, especially advantageous for patients at high surgical risk. Clinical evidence supports the non-inferiority of TAVR relative to SAVR with respect to symptom alleviation and hemodynamic performance while also highlighting its association with expedited recovery and lower perioperative mortality.[5]

LV systolic function has conventionally been evaluated using Left Ventricular Ejection Fraction (LVEF). However, LVEF may remain preserved despite the presence of early myocardial dysfunction. In this regard, a Global Longitudinal Strain of the Left Ventricle (GLS-LV), derived from two-dimensional speckle-tracking echocardiography, has proven to be a more sensitive technique for detecting early impairments in LV systolic mechanics. GLS-LV facilitates the identification of subtle myocardial alterations prior to any measurable reduction in LVEF, thus providing important prognostic insights in patients with aortic stenosis.[6,7]

Myocardial strain analysis is beneficial for assessing ventricular function and as a complementary tool for risk stratification. Even with preserved ejection fraction, these patients may exhibit reduced GLS due to chronic pressure overload impairing longitudinal contractility. This impairment is more pronounced in recently symptomatic patients or those with low-flow, low-gradient variants, where myocardial damage tends to be more severe and sometimes irreversible.[4,6,7]

Several studies have demonstrated improvement in LV longitudinal strain following intervention, especially in patients with concentric hypertrophy. Cimino and colleagues evaluated GLS in 68 patients with concentric and eccentric hypertrophy, showing significant improvement in both groups, with the greatest benefit in patients with eccentric hypertrophy.[8] Significant recovery has also been reported in different AS subtypes, particularly in those with greater postoperative valve area and less prosthesis–patient mismatch.[9] However, in low-flow forms, improvement was only partial, suggesting persistent myopathic involvement.[9,10] Winker and colleagues identified an inverse relationship between GLS recovery and survival.[5,11]

Other echocardiographic parameters, such as the E/e ratio, are used to estimate LV filling pressure and evaluate diastolic function.[6] This ratio is derived from the early diastolic mitral inflow velocity (E wave) and early myocardial displacement velocity at the mitral annulus (e' wave), measured by tissue Doppler imaging.[6,7] Elevated E/e' values are associated with diastolic dysfunction and increased left atrial pressure.[6]

In the context of aortic stenosis, E/e' becomes relevant as a marker of diastolic overload. Disease progression induces LVH, reduced myocardial compliance, and impaired relaxation, all of which lead to increased filling pressures reflected by elevated E/e' values. This underscores the importance of the E/e' ratio in AS management, highlighting its clinical relevance.[6,7,10]

After aortic valve replacement, whether surgical or transcatheter, diastolic function has been shown to improve, with progressive reductions in E/e' ratios. E/e' has not only prognostic value in AS, but its post-procedural changes also allow assessment of ventricular response and prediction of persistent heart failure risk.[7,8,10]

The safety and efficacy of aortic valve replacement for treating AS are well established. However, premature valve replacement may expose patients to unnecessary periprocedural risks by exchanging native valve disease for prosthetic valve degeneration and thrombosis.[6,7,11]

Recent research has examined changes in GLS following TAVR. One study reported early and significant improvement in GLS, from –8.18 ± 1.81 to –14.52 ± 2.52 one month after TAVR, reaching –16.12 ± 2.69 at one year. This early improvement was not observed in SAVR patients, suggesting that TAVR may facilitate more favorable and rapid LV remodeling.[11,12]

Multiple studies have documented structural changes following TAVR. Liedman et al. demonstrated LVH regression one year after valve implantation, quantified by LV mass index.[7,10] Kempny et al. showed improvement in right ventricular function after one year of TAVR. However, there is a lack of studies evaluating early functional and structural changes following valve replacement. For instance, Kashish et al. reported functional

class improvement six months after TAVR.[13,14] Therefore, this study aims to describe early GLS changes after valve replacement according to Généreux classification.

Objective: to assess changes in global longitudinal strain and E/e' ratio before and three months after TAVR in patients with severe aortic stenosis, stratified by the Généreux classification.

MATERIAL AND METHODS

This was a descriptive, observational, retrospective, and cross-sectional study conducted at the *Centro Médico Nacional 20 de Noviembre*. We reviewed institutional electronic medical records of patients who underwent Transcatheter Aortic Valve Replacement (TAVR) between 2015 and 2021. To preserve clinical heterogeneity, patients were not excluded based on clinical conditions or comorbidities. Demographic, echocardiographic, and hemodynamic variables were obtained from the institutional records. The variables analyzed included weight, height, age, sex, and echocardiographic parameters such as Left Ventricular Ejection Fraction (LVEF), Global Longitudinal Strain (GLS), and mean transvalvular gradient. Echocardiographic data were collected before the procedure and six months after valve implantation. All echocardiographic measurements were performed in the institution's echocardiography laboratory using a PHILIPS EPIQ 7 system.

Descriptive statistics were used to summarize the study population, including measures of central tendency and variability for continuous variables, as well as proportions for categorical variables. Continuous variables are presented as mean ± standard deviation. For statistical analysis, the χ^2 test or Student's t-test was applied as appropriate for the type of variable. Correlation analyses were performed using Pearson or Spearman tests, depending on the distribution of the data. Statistical significance was defined as a p-value < 0.05. All analyses were performed using GraphPad Prism, version 9.

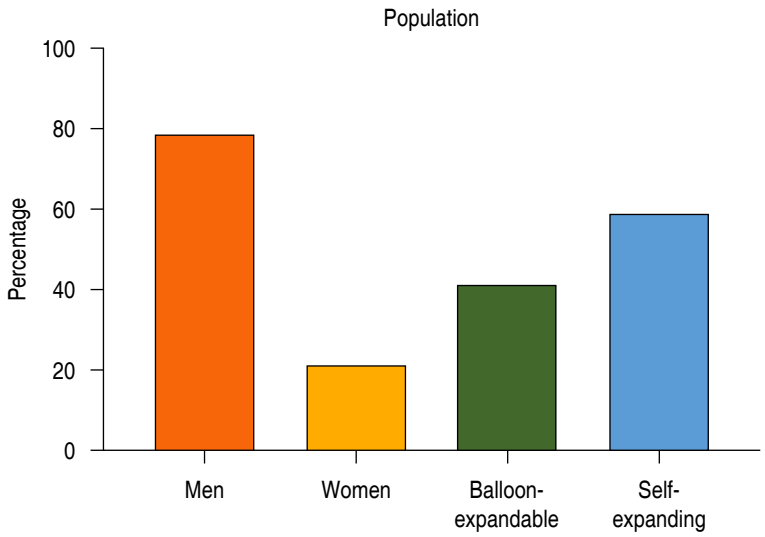

Figure 1: Bar chart showing population distribution by sex and type of transcatheter aortic valve (self-expanding vs balloon-expandable).

RESULTS

A total of 304 patients were analyzed, with a mean age of 75.29 ± 8.19 years; 78.6% (239) were male, and 21.4% (65) were female, with a mean body weight of 69.39 ± 13.88 kg and mean height of 160 ± 9.58 cm. Among the patients, 58.8% (179) received a self-expanding valve, and 41.2% (125) received a balloon-expandable valve. The mean implantation depth was 4.54 ± 0.18 mm *(Figure 1)*.

The pre-TAVR mean transvalvular gradient was 48.32 ± 1.01 mmHg. Three months after valve implantation, the mean transvalvular gradient was 9.93 ± 0.40 mmHg. A correlation analysis was performed between the changes in mean transvalvular gradient (Δ) and GLS (Δ), showing a strong correlation ($r = 0.81$, $p < 0.01$).

Patients were stratified into two groups based on the Généreux classification: those in stages 0, 1, and 2 (mild or minimal cardiac involvement, 36%) and those in stages 3 and 4 (advanced cardiac damage, 64%). GLS was compared before and after TAVR in the group classified as stages 0-2, showing a statistically significant improvement ($p < 0.012$). Similarly, a significant improvement was observed in the group classified as stages 3-4 ($p < 0.002$) *(Figure 2)*.

The E/e ratio was also compared before and after TAVR in both Généreux subgroups. No statistically significant difference was observed

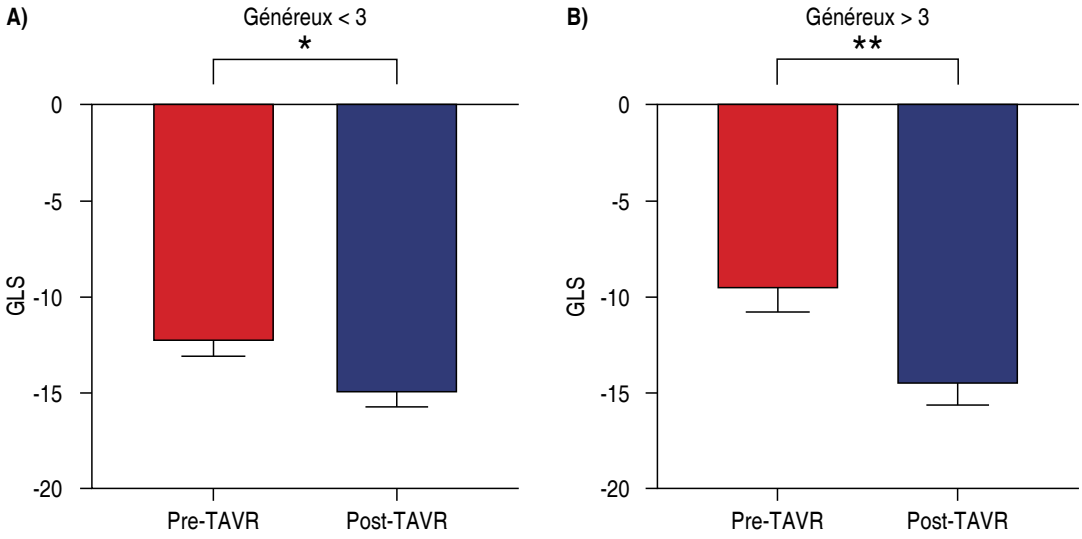

Figure 2: Bar chart of GLS. **A)** Compares GLS before and three months after valve implantation in patients with Généreux classification < 3. **B)** Shows the same comparison in patients classified as Généreux ≥ 3.
GLS = Global Longitudinal Strain. TAVR = Transcatheter Aortic Valve Replacement.
* p< 0.05. ** p < 0.01.

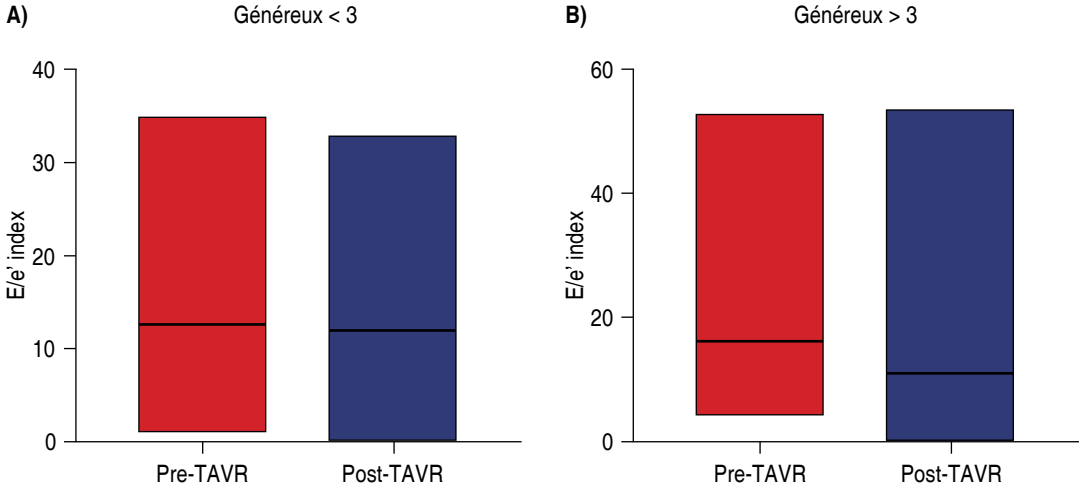

Figure 3: Bar chart of E/e' index. **A)** Shows E/e' before and three months after valve placement in patients with Généreux classification < 3. **B)** Shows the same comparison in patients with Généreux classification ≥ 3.
TAVR = Transcatheter Aortic Valve Replacement.

in patients classified as stage 0-2 (p = 0.19) or stage 3-4 (p = 0.26) *(Figure 3)*.

DISCUSSION

This study analyzed a cohort of 304 patients who underwent TAVR, with a mean age of 75.29 ± 8.19 years, predominantly male (78.6%). The distribution of implanted valve types showed a slight predominance of self-expanding valves (58.8%) over balloon-expandable valves (41.2%). The mean implantation depth was 4.54 ± 0.18 mm, with no reported differences between groups.

To evaluate the presence and progression of myocardial structural damage, patients were

stratified using the Généreux classification into groups: those with mild or minimal changes (stages 0-2) and those with advanced changes (stages 3-4). A significant improvement in Global Longitudinal Strain (GLS) was observed after TAVR in both groups, with statistically significant differences in both the less affected myocardial group ($p < 0.012$) and the more structurally compromised group ($p < 0.002$). These findings suggest that TAVR has a positive effect on overall myocardial function, regardless of the degree of pre-existing damage.[4,6,10]

However, analysis of left ventricular filling pressure through the E/e' index showed no significant differences in either subgroup ($p = 0.19$ for stages 0-2; $p = 0.26$ for stages 3-4). These results indicate that LV filling pressure does not significantly change within three months after TAVR despite improvements in myocardial strain. Furthermore, the lack of statistically significant changes in E/e' suggests that the observed GLS improvements are unlikely to be directly related to hemodynamic alterations from the valve replacement itself.[6,8]

The findings of this study reinforce the utility of TAVR in improving myocardial function in patients with severe AS, including those with advanced myocardial disease. However, the absence of improvement in diastolic filling parameters highlights the need for additional studies to evaluate the long-term impact of TAVR on diastolic dysfunction and post-procedural ventricular remodeling.[4,6] Future research should also explore the influence of valve type on postoperative hemodynamic changes.

This study is among the first to investigate early changes in ventricular function following valve replacement. Including a large group of patients allows for a comprehensive evaluation of the impact of transcatheter aortic valve replacement on myocardial function. However, additional long-term research is needed to examine the effects of factors such as comorbidities, the initial health of patients, and post-procedural monitoring. Future investigations will be fundamental in establishing the long-term sustainability of the observed myocardial function improvements and delineating the relationship between systolic function recovery and diastolic functional changes.

CONCLUSION

TAVR significantly improves GLS at three months after valve implantation. Our findings confirm the favorable hemodynamic impact of the procedure and demonstrate an early recovery in myocardial contractility, as reflected by improved GLS independent of EF. Notably, when stratifying patients according to the Généreux classification, those in stage 3 or higher (indicating more advanced extra-valvular cardiac damage) showed more significant improvement in GLS than those in earlier stages. This finding highlights the utility of the Généreux classification not only as a prognostic tool but also as a potential indicator of myocardial recovery following TAVR. Unlike prior studies by Généreux, Kempny, and Liedman, which focused on longer-term structural regression, our results provide evidence of early left ventricular contractility response, suggesting that TAVR may trigger functional remodeling processes from early stages — even in patients with advanced extra-valvular involvement.

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Multimodal approach to assess a circumflex artery extrinsic stenosis after five years of mitral plasty

Evaluación multimodal de la compresión extrínseca de la arteria circunfleja cinco años post-valvuloplastia mitral

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Keywords: chronic extrinsic compression, circumflex artery stenosis, mitral valve plasty, annuloplasty ring, intravascular ultrasound.

Palabras clave: *compresión extrínseca crónica, estenosis de la arteria circunfleja, valvuloplastia mitral, anillo de anuloplastia, ecografía intravascular.*

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ABSTRACT

Introduction: acute complications are common after a Mitral Valve (MV) replacement or annuloplasty. Ischemia induced by stenosis of the Circumflex Artery (CxA) caused by sutures of the MV annuloplasty is the most frequent acute complication. **Presentation of case:** a 69-year-old woman with a successful MV annuloplasty performed five years previously presented with a four-month history of chest tightness on exertion. An exercise stress echocardiogram displayed ischemia and inferolateral wall hypokinesia. A coronary computed tomography angiography revealed extrinsic stenosis at the middle third of the CxA, close to the annuloplasty ring, consistent with coronary angiography findings. The cardiac magnetic resonance demonstrated inferolateral wall hypokinesia and basal inferolateral wall transmural necrosis. We performed a percutaneous coronary intervention with Intravascular Ultrasound (IVUS), showing the stenosis. We performed an angioplasty and stent placement with post-stent IVUS, which showed adequate angiographic apposition. The patient was discharged home two days later with optimal medical therapy. **Conclusion:** chronic stenosis of the CxA after MV annuloplasty is extremely rare, with only four cases reported in the literature. A multimodal approach, including IVUS, can help identify the ischemia mechanism of a CxA chronic occlusion, supporting clinical decision-making to manage this complication.

RESUMEN

Introducción: *las complicaciones agudas son frecuentes tras una sustitución o anuloplastia de la Válvula Mitral (VM). La isquemia inducida por la estenosis de la Arteria Circunfleja (ACx) causada por las suturas de la anuloplastia de la VM es la complicación aguda más frecuente.* ***Presentación del caso:*** *una mujer de 69 años con anuloplastia de la VM realizada con éxito cinco años previos se presentó con una historia de cuatro meses de dolor precordial opresivo al esfuerzo. Un ecocardiograma de esfuerzo mostró isquemia e hipocinesia de la pared inferolateral. La angiografía coronaria por tomografía computarizada reveló estenosis extrínseca en el tercio medio de la ACx, cerca del anillo de anuloplastia, en consonancia con los hallazgos de la angiografía coronaria. La resonancia magnética cardiaca demostró hipocinesia de la pared inferolateral y necrosis transmural de la pared inferolateral basal. Se realizó intervención coronaria percutánea con Ultrasonido Intravascular (IVUS) que mostró la estenosis. Realizamos angioplastia y colocación de stent con IVUS post-stent que mostró una adecuada aposición. El paciente fue dado de alta dos días después con tratamiento médico óptimo. La estenosis crónica de la ACx tras anuloplastia de la VM es extremadamente rara, con sólo cuatro casos descritos en la literatura.* ***Conclusión:*** *un enfoque multimodal, que incluye el uso de IVUS, puede ayudar a identificar el mecanismo de isquemia de una oclusión crónica de la ACx y en la toma de decisiones clínicas para un abordaje apropiado.*

Abbreviations:
MV = Mitral Valve
CxA = Circumflex Artery
CARE = Case Reports
CMR = Cardiac Magnetic Resonance
IVUS = Intravascular Ultrasound

INTRODUCTION

The prevalence of mitral regurgitation is continuously increasing, becoming the most common valvular disease in patients over 75 years in the United States. Worldwide,

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Mitral Valve (MV) annuloplasty is used to repair mitral regurgitation. Valvular heart disease guidelines recommend annuloplasty with prosthetic rings as the preferable management.[1] Acute complications are a common occurrence after an MV replacement or annuloplasty. Most complications associated with annuloplasty occur during the surgery or 30 days after.[2] Ischemia induced by stenosis of the Circumflex Artery (CxA) caused by sutures of the MV annuloplasty is the most frequent acute complication. Following the Case Reports (CARE) guidelines,[3] we report a case with myocardial ischemia secondary to a coronary CxA extrinsic stenosis five years after mitral annuloplasty.

We systematically reviewed studies, including at least one case report of chronic CxA extrinsic compression after any MV interventional procedure. The assessment was made through Google Scholar, PubMed, Scopus, Embase, and Medline. We analyzed studies published between 1980 and March 2023, finding few cases of chronic complication after mitral annuloplasty.[4-6]

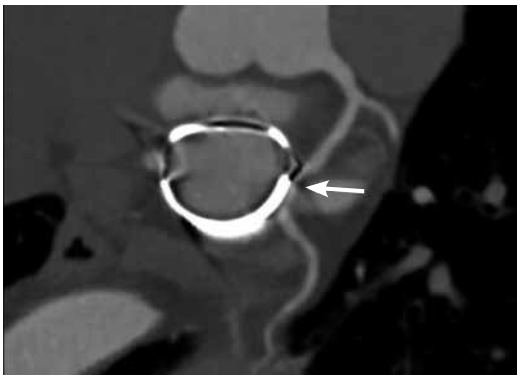

Figure 1: Coronary computed tomography angiography of the Circumflex Artery (CxA). Extrinsic stenosis of 90% at the middle third of the CxA, close to the annuloplasty ring (white arrow).

CASE PRESENTATION

We evaluated a 69-year-old woman with a four-month history of chest tightness with exertion. The past medical history included hypertension, hypothyroidism, and paroxysmal atrial fibrillation. She also had a successful MV annuloplasty with a 30 mm ring secondary to severe mitral regurgitation five years prior to the current evaluation. The medications included rosuvastatin, losartan, and levothyroxine. Before admission, a 24-hour Holter electrocardiogram showed single monomorphic ventricular extrasystoles, and an exercise stress echocardiogram displayed ischemia and inferolateral wall hypokinesia with normal left ventricular function. The physical examination and laboratory tests were normal.

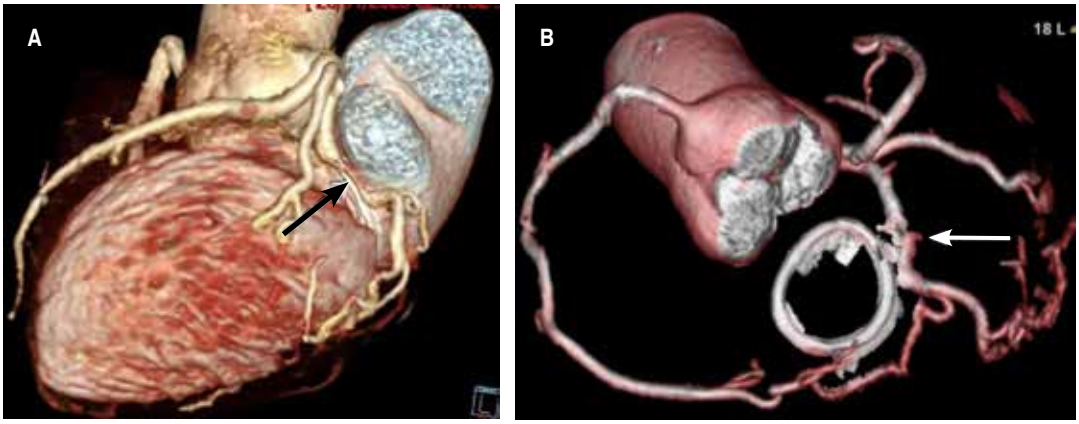

Figure 2: Coronary computed tomography angiography three-dimensional reconstruction. **A)** Stenosis at the middle third of the Circumflex Artery (CxA) with close relation to the annuloplasty ring (white arrow shows the annuloplasty ring). **B)** Three-dimensional reconstruction of the CxA and the annuloplasty ring that shows how the annuloplasty ring compresses the CxA with a significant stenosis (white arrow).

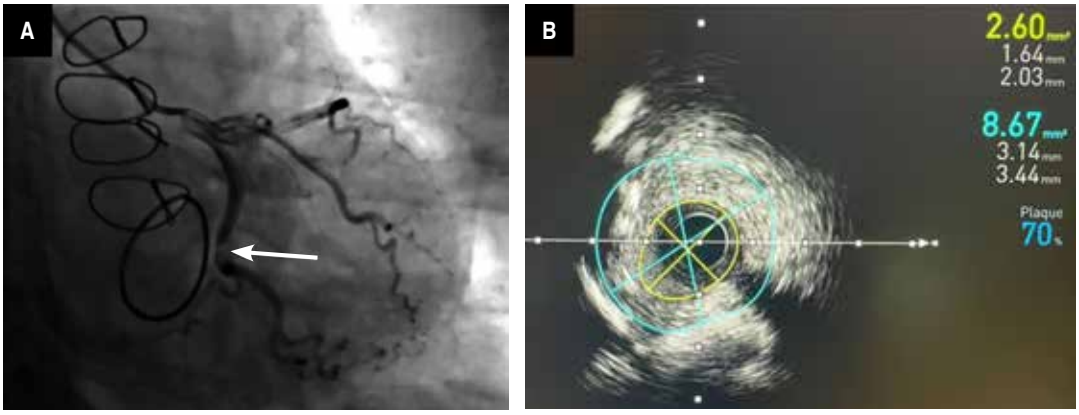

Figure 3: Coronary angiography and intravascular ultrasound. **A)** Coronary angiography with 90% stenosis of the circumflex artery related to the annuloplasty ring (white arrow). **B)** Intravascular ultrasound with a luminal area of the stenosis of 2.6 mm^2 without plaques.

The electrocardiogram showed a previous left bundle branch block.

Given the results, we performed a coronary computed tomography angiography, revealing a 90% extrinsic stenosis at the middle third of the CxA, close to the annuloplasty ring without coronary atherosclerosis *(Figures 1 and 2)*. Coronary angiography revealed a 90% stenosis of the middle third of the CxA related to the mitral annuloplasty ring *(Figure 3)* without coronary artery disease. Therefore, we performed an adenosine stress Cardiac Magnetic Resonance (CMR) with late gadolinium enhancement for ischemia and necrosis/fibrosis evaluation to establish revascularization *(Figure 4)*. The CMR demonstrated inferolateral wall hypokinesia and basal inferolateral wall transmural necrosis with reversible ischemia and without fibrosis. Additionally, there was no mitral regurgitation. Consequently, we performed a percutaneous coronary intervention with Intravascular Ultrasound (IVUS) that showed a luminal area at the site of the stenosis of 2.6 mm^2 without calcified or fibrous plaques *(Figure 3 and Video 1 https://www.medigraphic.com/videos/cms/cms253v_1)*; we decided to use a drug-eluting stent of 3.5 × 16 mm and post-stent IVUS showed adequate apposition and expansion of the stent, with a luminal area of 6.45 mm^2 *(Figure 5 and Video 2 https://www.medigraphic.com/videos/cms/cms253v_2*. We performed a complication-free procedure, and the patient was discharged home two days later with optimal medical therapy based on a statin, aspirin, and P2Y2 inhibitor. In addition, we observed normal left ventricular function and no motion abnormalities in a follow-up transthoracic echocardiogram.

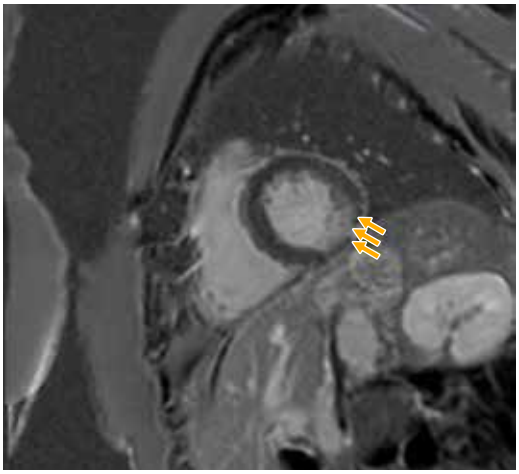

Figure 4: Cardiac magnetic resonance imaging with late gadolinium enhancement. Basal inferior and inferolateral subendocardial late gadolinium enhancement (yellow arrows).

DISCUSSION

Chronic stenosis of the CxA after MV annuloplasty is exceptionally uncommon, with only four cases reported in the literature, and according to our understanding, our case

represents the longest-time complication after the initial procedure. Based on the literature review, there is just one case with a greater temporality that differs to our patient because it had an anomalous origin of CxA;[5] the rest of the cases occurred within the first two years.[2,4,6]

In this case, the key findings are as follows: first, the case highlights an extrinsic CxA stenosis as an exceptional long-term complication after an MV procedure; CxA occlusion with a suture surrounding or partially occluding the artery remains the primary mechanism in acute cases; several mechanisms, such as retraction of the CxA, distortion of the vasculature in proximity to the suture, compression of the tissue near the mitral annulus in a CxA with anomalous origin, and CxA retraction has been described in chronic cases. Non-invasive imaging technologies, most notably computed tomography angiography, are of critical importance in the diagnosis of external compression, given their ability to reveal the extent of compression and assist in differentiating it from other etiologies of chest pain, such as atherosclerosis or acute coronary syndrome.[7] Secondly, contrasting with the rest of the literature, where the evaluation before catheterization was limited to an echocardiogram, to establish the decision for revascularization, we performed an ischemia and fibrosis evaluation with a CMR using adenosine and late gadolinium enhancement. Additionally, we performed a contractile functional assessment with a stress echocardiogram. This case demonstrates the multimodal approach's usefulness in demonstrating ischemia and establishing the diagnosis and clinical decision-making.

All reported cases in the literature were evaluated at the catheterization laboratory, and percutaneous coronary intervention resolved (angioplasty and stent) the chronic extrinsic CxA occlusion.[2,4,6] Intravascular imaging has proven to be a tool for guiding procedures in complicated and unconventional scenarios, providing information on coronary anatomy and its structural integrity in real-time.[8,9] In three reported cases, intravascular imaging guided the procedure,[4-6] with optical coherence tomography used in only one case.[4] Intravascular imaging offers significant advantages in the assessment of extrinsic coronary artery compression by providing visualization of the relationship between the coronary artery and adjacent structures. This capability is essential for assessing the severity and extent of the compression, which may otherwise be difficult to identify using traditional angiography alone. It facilitates the selection of the appropriate stent size and optimizes its placement. Furthermore, intravascular imaging is invaluable in the post-intervention assessment phase, as it allows clinicians to evaluate the stent expansion and detect potential complications, such as restenosis or malposition.[10] In our case, the

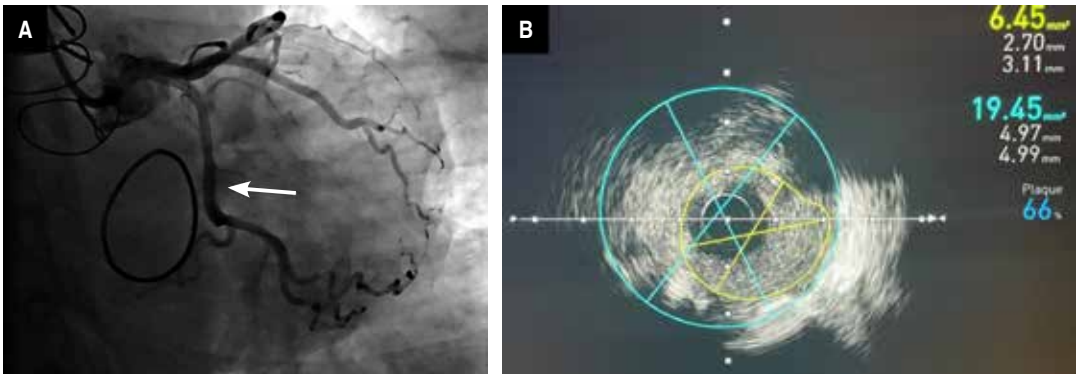

Figure 5: Post-stent implantation imaging. **A)** Coronary angiography showing correct angiographic stent placement with adequate antegrade flow of the circumflex artery (white arrow). **B)** Post-stent intravascular ultrasound with good apposition with a luminal area of 6.45 mm^2.

IVUS identified an extrinsic vessel compression excluding coronary artery disease and proved effective for endovascular treatment, making it an unusual case among the previous evidence. In our case, we ruled out atherosclerotic disease through IVUS; therefore, distortion and fibrosis near the vasculature secondary to the suture of the mitral annuloplasty was the most probable occlusion mechanism and likely the explanation of why the symptoms and ischemia occurred after five years rather than immediately after surgery.

There is a lack of international valvular disease[1] and myocardial revascularization[11] recommendations for interventional decision-making in extrinsic coronary occlusions. Our case highlights an unusual chronic CxA occlusion in which the multimodal imaging approach identified the ischemia mechanism excluding coronary disease and demonstrated a practical endovascular approach. As a take-home message, chronic CxA stenosis after MV replacement or annuloplasty is an entity that needs to be more frequently addressed, and early identification through a multimodal approach is possible through close follow-up after an MV procedure with ischemia detection tests.

CONCLUSIONS

Chronic stenosis of the CxA after MV annuloplasty is extremely rare, and the most common acute complication that induces ischemia is usually secondary to surgical sutures. However, chronic CxA stenosis after MV annuloplasty may be caused by distortion of the vasculature in proximity to the suture, compression of the tissue near the mitral annulus, and CxA retraction due to fibrosis near the coronary artery. A multimodal approach, including intravascular imaging, could identify the ischemia mechanism of a chronic occlusion and help in the clinical decision-making to manage this complication.

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Right coronary sinus fistula for ruptured aneurysm to the right atrium in a patient with Noonan syndrome

Fístula del seno coronario derecho por aneurisma roto hacia aurícula derecha en una paciente con síndrome de Noonan

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Keywords:
vascular fistula, Noonan syndrome, ruptured aneurysm, mutation.

Palabras clave:
fístula vascular, síndrome de Noonan, aneurisma roto, mutación.

ABSTRACT

Introduction: an aneurysm at the level of the sinuses of Valsalva is a pathology of congenital or acquired origin. The presence of a fistula can also be asymptomatic or express itself at any age with different manifestations. **Case presentation:** 34-year-old female patient carrier of Noonan syndrome (NS); surgical history of ventricular septal defect closure. Since the patient was 27 years old, she presented episodes of dyspnea. Cardiopulmonary auscultation revealed the presence of a continuous murmur in the second right parasternal intercostal space. A transthoracic echocardiogram was performed with findings of a fistulized right coronary aneurysm. Surgery was performed where a fistula from the right coronary sinus to the right atrium was observed, proceeding to closure. **Conclusions:** a fistula from a coronary sinus to a cardiac cavity is a rare presentation of a ruptured aneurysm, so it highlights the presentation of this pathology in a patient with a RASopathy related to cardiac defects. Diagnosis requires an adequate approach. However, in some cases, the exact location of the defect can be determined during surgery. Early diagnosis and treatment are crucial.

RESUMEN

Introducción: *un aneurisma a nivel de los senos de Valsalva es una patología de origen congénito o adquirido. La presencia de fístulas, pueden así mismo, ser asintomáticas o expresarse a cualquier edad con distintas manifestaciones.* ***Presentación del caso:*** *paciente mujer de 34 años, portadora de síndrome de Noonan (SN); antecedente quirúrgico de cierre de comunicación interventricular. Desde los 27 años presenta episodios de disnea. La auscultación cardiopulmonar destaca la presencia de soplo continuo en segundo espacio intercostal paraesternal derecho. Se realiza ecocardiograma transtorácico con hallazgos de un aneurisma coronario derecho fistulizado. Se llevó a cabo cirugía donde se observa fístula de seno coronario derecho a aurícula derecha, procediendo a cierre.* ***Conclusiones:*** *una fístula de un seno coronario hacia una cavidad cardíaca es una presentación poco frecuente de un aneurisma roto, por lo que destaca la presentación de esta patología en una paciente con una RASopatia relacionada con defectos cardíacos. El diagnóstico requiere un adecuado abordaje. Sin embargo, en algunos casos, la localización exacta del defecto se consigue en la cirugía. Su diagnóstico y tratamiento temprano es crucial.*

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Abbreviation:
MAPK = Mitogen-Activated Protein Kinase.
NS = Noonan syndrome.

INTRODUCTION

An aneurysm at the level of the sinuses of Valsalva is a pathology of either congenital or acquired origin, with an incidence from 0.14 to 3.5% of patients undergoing cardiac surgery. Regarding its congenital origin, it seems to be related to defects during the formation of the cardiac loop in the embryonic period, during the fusion of the arterial cones to form both infundibula. An inadequate fusion in this area would result in an area of weakness that would

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undergo progressive dilation. The same origin would have the interventricular communication that sometimes accompanies it. Associated cases of aortic coarctation and bileaflet aorta have been reported.[1] The clinical presentation is variable, presenting even in acute heart failure, when they are ruptured, and according to the site where the fistula develops, and may cause sudden death, secondary to open rupture of the pericardium, myocardial infarction, or atrioventricular block. The presence of a fistula can also be asymptomatic or express itself at any age with different manifestations.[2]

The case of a young patient with Noonan syndrome (NS) with a history of surgical closure of a ventricular septum defect in childhood, with a right coronary sinus aneurysm, probably congenital, which was ruptured, with a fistula to the right atrium, causing precapillary pulmonary hypertension.

CASE PRESENTATION

34-year-old female patient with the following important antecedents: smoking and ethylism denied; carrier of Noonan syndrome; surgical history of ventricular septal defect closure at 4 years of age.

Since the patient was 27 years old, presented episodes of dyspnea on small efforts and palpitations, and was kept under expectant management until the patient was 34 years old, reinitiating the approach due to further deterioration of her functional class. Physical examination revealed hypertelorism and eyelid ptosis, short stature, and mild neurocognitive deficit; cardiopulmonary auscultation revealed the presence of a continuous grade IV/VI murmur in the second right parasternal intercostal space.

A transthoracic echocardiogram was performed with findings suggestive of fistulized right coronary aneurysm, a high velocity flow was found in the subaortic region (at 10-11 hour clockwise in short axis projection) which is directed towards the right cavities *(Figure 1)*, with a coronary flow pattern on continuous Doppler interrogation, with a maximum velocity recorded of 6. 2 m/s, maximum gradient of 154 mmHg, dilated right ventricle (basal diameter 39 mm, medium 30 mm, longitudinal 90 mm). Angiotomography was performed with the presence of a right coronary aneurysm type defect communicating to the right cavities *(Figure 2)*.

With these findings, an invasive approach by hemodynamics was performed, where the aortogram showed evidence of a fistula at the level of the right coronary sinus draining into the right cavities, resulting in a QP:QS of 1.66, in addition to precapillary pulmonary hypertension (> 51 mmHg mean pulmonary pressure and 3.8 Wood units of PVR) *(Figure 3)*.

Surgery was performed where a fistula from the right coronary sinus to the right atrium above the septal valve of the tricuspid was observed, proceeding to closure in two planes and placement of a pericardial patch in the right atrium *(Figure 4)*. There were no postoperative complications, and the clinical course was uneventful.

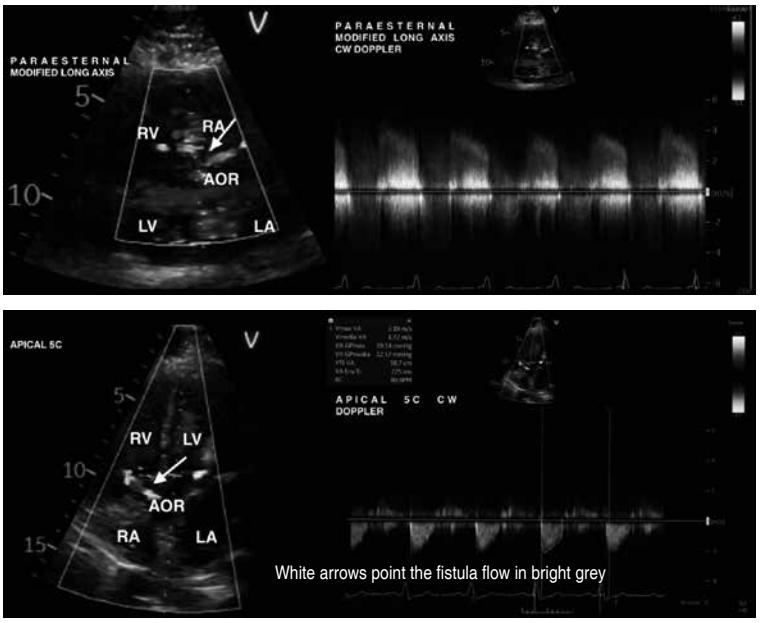

Figure 1: Transthoracic echocardiogram. Upper images in the parasternal long axis, lower images in the four-chamber apical axis showing a fistulized right coronary aneurysm (white arrows), with high-speed flow in the subaortic region, which is directed towards the right cavities.
AOR = aortic root. LA = left atrium. LV = left ventricle. RA = right atrium. RV = right ventricle.

DISCUSSION

The RASopathies are a group of disorders caused by a germline mutation in one of the

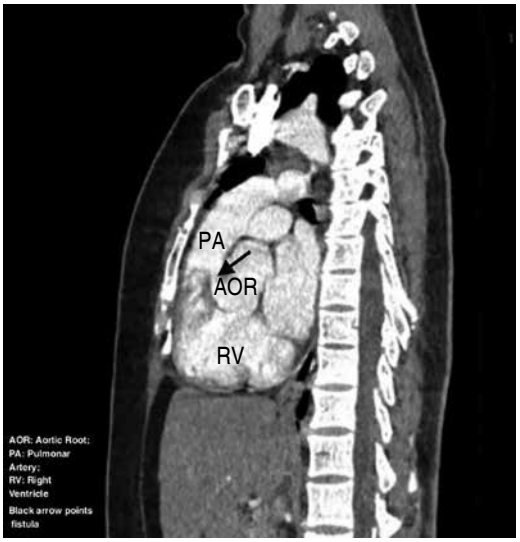

Figure 2: Angiotomography showing a right coronary aneurysm type defect that communicates to the right cavities.
AOR = aortic root. PA = pulmonar artery. RV = right ventricle.

genes encoding a component of the RAS/MAPK (Mitogen-Activated Protein Kinase) pathway, a signal transduction system that regulates cell growth, division, and differentiation. These disorders, including neurofibromatosis type 1, Noonan syndrome, cardiofaciocutaneous syndrome, Costello syndrome, and Legius syndrome, among others, have overlapping clinical features due to RAS/MAPK dysfunction. Although several of the RASopathies are very rare, collectively, these disorders are relatively common.[3] No generally accepted definition and definitive delineation of RASopathies exist, so far.[4]

Noonan syndrome is characterized by a high clinical and genetic heterogeneity, with variable and age-varying involvement of multiple organs and systems. Because of this variability, it is essential that physicians involved in its care are familiar with its manifestations and aware of follow-up recommendations, including monitoring of growth and development.[5]

Essential phenotypic features of NS include facial anomalies, short stature, congenital cardiac anomalies, coagulation disorders, and a variable degree of cognitive delay. In the face, one can observe a broad forehead, hypertelorism, ptosis, epicanthal fold, high labial philtrum, and labial ridges with accentuated upward angulation, low-set and posteriorly rotated ears, arched eyebrows or with a superior vertex angle, light blue iris, wide neck, and low posterior hairline. In the thorax, pectus excavatum inferior/carinatum superior and separated areolas are common; in 50-80% of cases there are congenital cardiac anomalies, mainly pulmonary stenosis (20-50%) and hypertrophic cardiomyopathy (20-30%), but also atrial and ventricular septal defects and tetralogy of Fallot. There is considerable clinical and genetic heterogeneity in NS, and a much larger series of patients needs to be studied.[6]

Sinus of Valsalva aneurysm, a congenital or acquired cardiac defect present in approximately 0.09% of the general population, often presents as an incidental finding during cardiac imaging. However, an echocardiogram is the standard imaging technique for such findings; cardiac computed tomography angiography has been increasingly utilized.[7]

Aneurysms of the sinus of Valsalva usually develop due to weakness of the aortic wall that is part of the coronary sinus; the right one is most frequently affected, through which a saccular aneurysm gradually and progressively protrudes into a cardiac cavity, usually the right ventricle. The acquired ones are secondary to trauma, endocarditis, or syphilis, or to aging itself. Congenital are the most frequent, secondary to failure in the fusion of the middle layer of the aorta with the fibrous skeleton of the heart, which is the basis for its development.[8]

The right coronary sinus is most frequently affected, followed by the non-coronary sinus and rarely the left coronary sinus, which are associated with other defects, including ventricular septal defect in 30 to 60% and aortic valve anomalies, such as aortic insufficiency (20 to 30%), bicuspid valve (10%), aortic stenosis (6.5%), as well as such as pulmonary stenosis (9.7%), coarctation (6.5%), patent ductus arteriosus (3.2%), tricuspid regurgitation (3.2%) and interatrial defect.[9] It is a rare pathology. It has been reported in 0.09% in a series of autopsies, in 0.14 to 0.23% in Western surgical studies, and in 0.46 to 3.5% in Eastern studies.[10]

From an embryological point of view, aneurysmal dilation of one of the sinuses of Valsalva results from an incomplete fusion of

the valvular part of the septum in its distal part. It is, therefore, related to defects of the membranous septum of the ventricular septum, as occurs more frequently with the type of interventricular communications that are of this type, a membranous defect.[11]

Our patient has a history of a congenital ventricular septal defect. As mentioned, this defect is the most common associated lesion, followed by aortic insufficiency, which is often associated with a ventricular septal defect or a bicuspid aortic valve. The patient's sinus of Valsalva aneurysm was detected in adulthood, presenting with a rupture with a fistula towards the right atrium.

According to the study group of De Bakey et al., anomalies of the sinus of Valsalva can be classified into three groups:[12]

1. Sinus aneurysm.
2. Aneurysm with fistula.
3. Fistula.

The patient belongs to group 2, draining into the right atrium, which is the second common site (60%). Other sites where fistulization can

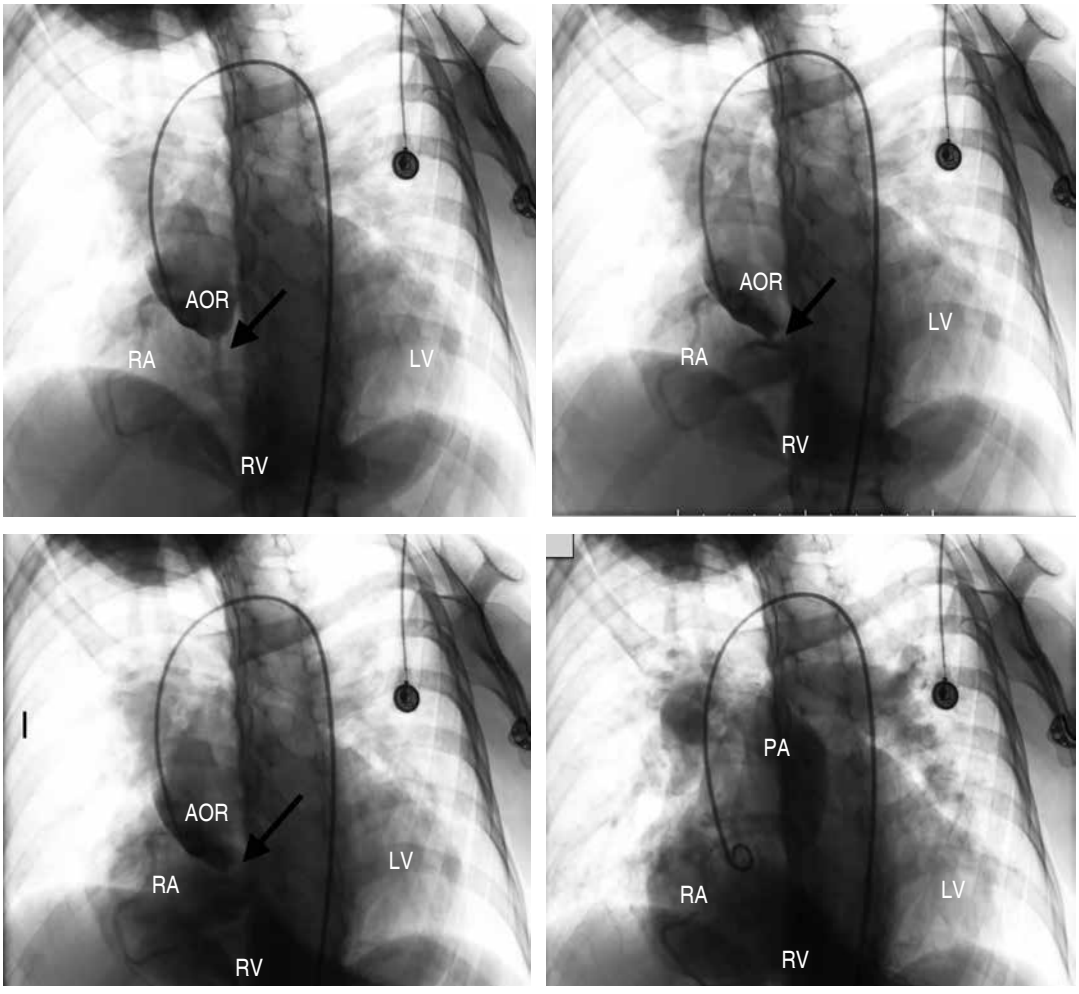

Figure 3: Aortogram in different phases of the cardiac cycle that shows a fistula at the level of the right coronary sinus that drains into the right cavities (black arrows). In the lower right box, the passage of contrast medium into the pulmonary circulation is observed.
AOR = aortic root. LV = left ventricle. PA = pulmonar artery. RA = right atrium. RV = right ventricle black arrow points fistula.

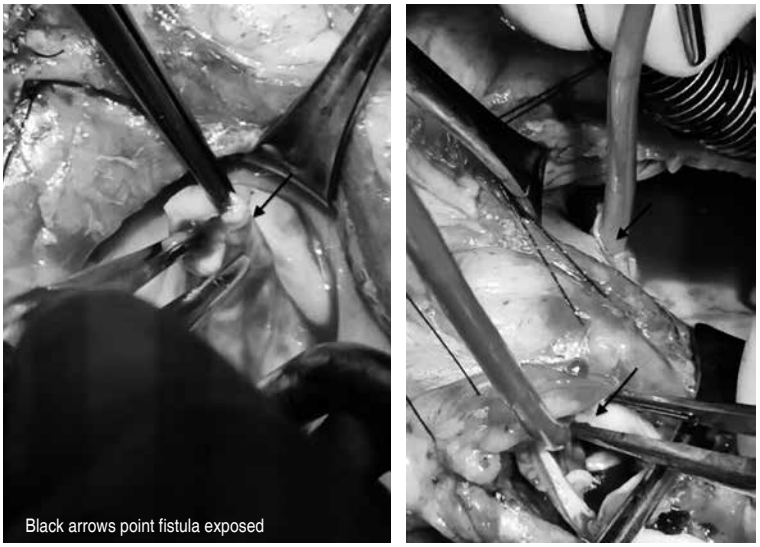

Figure 4: Images obtained during surgery. In the left image, adequate exposure of the fistula is achieved, observed from the right atrium. In the right image, a crossed fistula is observed, extending the from the right atrium (above) to the aorta (below).

occur are the right ventricle (60%), left atrium (6%), left ventricle (4%), or pericardium (1%). It is relevant to mention that the rupture of acquired aneurysms is usually towards the pericardium or the pleural space and is generally fatal.[9] A fistula of the sinus of Valsalva was reported after a Ross procedure.[13]

Usually, the aneurysm is asymptomatic until it ruptures, usually between the second and third decades of life. The clinical picture may be acute chest pain or heart failure. The physical examination of patients with a ruptured aneurysm typically presents a continuous murmur in the mesocardium; however, only an expulsive murmur or an expulsive murmur combined with a diastolic murmur may be heard.[14]

Cardiovascular imaging plays a crucial role in the assessment and management of aortic root and thoracic aorta ectasia and aneurysms. Sinus of Valsalva aneurysms are rare entities. Unique complications associated with sinus of Valsalva aneurysms make them different from traditional aortic root aneurysms. Established guidelines on the diagnosis and management of sinus of Valsalva aneurysms are lacking.[15]

Regarding diagnosis, angiography was considered the gold standard for diagnosis, however, less invasive techniques such as transthoracic and transesophageal echocardiography are the most used currently with a diagnostic certainty of 75 and 90% respectively for ruptured and unruptured aneurysms, allowing a more precise localization of the affected sinus, of the fistula to the cavities, in the identification of other cardiac alterations, in the delimitation of the size and morphology of congenital aneurysms as well as in the identification of aneurysm prolapse through a ventricular septal defect.[16]

In transthoracic echocardiography, the demonstrated diastolic flow reversal in the descending thoracic aorta occurs due to a significant left-to-right shunt from the aortic root to the right-sided cardiac chamber, creating similar hemodynamic physiology as severe aortic regurgitation.[17]

This condition, left to its evolution, can lead to symptoms of pulmonary hypertension, heart failure, and myocardial ischemia. The patient had already presented in a symptomatic context, corroborating precapillary pulmonary hypertension through hemodynamics.[18] This is due to excessive blood flow to the right cavities, which overloads them. The increase in pulmonary arterial pressure and blood flow causes pulmonary edema and right heart failure, which can lead to a fulminant course and premature death.[19]

Timely surgical intervention is imperative to address these complications once the diagnosis is confirmed. The prognosis following surgical repair of SoVA is generally favorable. Early diagnosis and prompt surgical intervention are essential for enhancing survival rates. The reported preoperative mortality rate stands at 7%, with a long-term survival rate of approximately 63% in extensive case series.[20]

The repair reduces the risk of the aforementioned complications, improving life expectancy. Successful repair has been achieved via transcatheter methods, using septal occlusion devices, ductal occluders, Amplatzer vascular occluders, and even Rashkind umbrellas. Due to the rarity of this pathology, no clinical trials have been carried out that compare the superiority of different surgical techniques. The most commonly used is the «double exposure technique», in which both the aorta and the fistula end chamber are

explored. The aneurysmal sac is removed, and the resulting defect is repaired by direct suture or patch closure. Currently, the 10-year survival rate after surgical repair is 90%.[18]

CONCLUSIONS

A fistula from a coronary sinus to a cardiac cavity is a rare presentation of a ruptured aneurysm, so it highlights the presentation of this pathology in a patient with a rasopathy related to cardiac defects. Diagnosis requires an adequate approach, ranging from experience in physical examination to studies such as echocardiography and cardiac catheterization. However, in some cases, the exact location of the defect can be determined during surgery. Early diagnosis and treatment are crucial, since free evolution can lead to various complications, including pulmonary hypertension, as in the case of the patient. If complications occur, they can significantly impact the quality of life and life expectancy. For this reason, its diagnostic and therapeutic approach requires specialized centers with experience in congenital heart disease.

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REVIEW

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Protocol of the National Association of Cardiologists of Mexico (ANCAM) for the creation of cardioprotected areas in sports races and Marathons in Mexico

Protocolo de la Asociación Nacional de Cardiólogos de México (ANCAM) para la creación de espacios cardioprotegidos en carreras deportivas y maratones en México

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Keywords:
marathon sports races, sudden cardiac arrest, cardiopulmonary resuscitation, cardioprotection, automated external defibrillator.

Palabras clave:
carreras deportivas de maratón, paro cardiaco súbito, reanimación cardiopulmonar, cardioprotección, desfibrilador automático externo.

ABSTRACT

Large-scale sporting events, such as races and marathons in particular, present a unique cardioprotection challenge due to the geographical extent of the route and the large number of participants. This protocol proposes a comprehensive approach to minimize the risk of sudden cardiac death and optimize the response to cardiovascular emergencies during these events held in Mexico.

RESUMEN

Los eventos deportivos de gran escala, como lo son las carreras deportivas y más aún los maratones, presentan un desafío único en términos de cardioprotección debido a la extensión geográfica del recorrido y el gran número de participantes. Este protocolo propone un enfoque integral para minimizar el riesgo de muerte súbita cardiaca y optimizar la respuesta ante emergencias cardiovasculares durante estos eventos realizados en México.

Abbreviations:
AED = Automated External Defibrillator
CPR = Cardiopulmonary Resuscitation
EMS = Emergency Medical Services
SCA = Sudden Cardiac Arrest
SCD = Sudden Cardiac Death

INTRODUCTION

Exercise has several cardiovascular and general health benefits. However, Sudden Cardiac Death (SCD) can occur in seemingly healthy athletes who perform high-performance exercise, such as marathon running. Cardioprotection at sporting events, such as 5 K, 10 K, and marathon races, is vital to guarantee the safety and well-being of participants. The intense and prolonged nature of these races may increase the risk of SCD events.[1] Many diseases can cause Sudden Cardiac Arrest (SCA) and SCD. Like the general population, athletes may suffer from heart disease and be unaware of its existence. The most common causes of SCD in people under 35 years of age are primary cardiomyopathies, such as hypertrophic, dilated, non-compacted, and arrhythmogenic cardiomyopathies. Less common causes include ischemic heart disease and channelopathies such as long QT or Brugada syndrome.[2] In people over 35 years of age, the leading cause of SCD is ischemic heart disease, followed by the cardiomyopathies reported in those under 35 years of age.[3] Drug use or medication has been reported in up to 12% of athletes with SCD. Furthermore, acute physiological changes related to high-

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performance exercise (dehydration, electrolyte, and acid-base imbalance) and increased sympathetic tone may also play a key role.[4]

In the United States, the incidence of SCD among marathon runners ranged from 0.6 to 1.9 per 100,000, where males (from 37 to 48 years old) are from 57.1% to 100%.[5] The available data indicate a concentration of cases of sudden death at the stage finishes of marathon races. An investigation revealed that approximately 50% of sudden deaths during these athletic events occur within the final two kilometers of the race route.[6] The distance at which the marathon SCD takes place throughout the route is shown in *Figure 1*.

Most episodes of SCD in athletes occur during intense exercise, and only a third of these events may occur during sleep.[7] The rhythms reported in athletes who present SCA are in a high percentage (up to 78%) of ventricular tachycardia and ventricular fibrillation that are reversed with electrical defibrillation.[8] Immediate treatment with cardiopulmonary resuscitation (CPR) and early defibrillation has achieved survival rates of up to 70% of SCA victims, significantly reducing the incidence of SCD during athletic competitions. To prevent SCD, each athlete must undergo a pre-participation evaluation, which is recommended for children and adolescents to include at least a physical examination and a review of their medical history.[9] For adults over 35 years of age, in addition to the clinical history and physical examination, an electrocardiogram should be included. In abnormal cases, a physical stress test should be performed to rule out the presence of ischemic heart disease.[3]

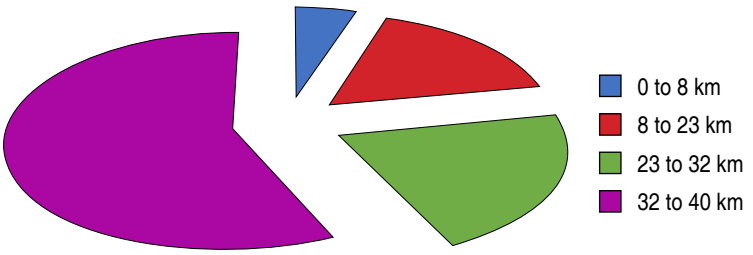

Figure 1: Distance at which marathon SCD occurred throughout the marathon course. Modified from.[16]

These measures can reduce the incidence and prevalence of SCA and SCD during athletic competitions, especially in marathons, half marathons, and long-distance races.

JUSTIFICATION

The recent increase in SCD cases, as well as their dissemination through the mass media and social networks has raised awareness of the need for established protocols for the development of cardioprotective sporting events. While the presence of an Automated External Defibrillator (AED) is essential for cardioprotection at sporting events, it does not make the space cardioprotective. Therefore, implementing an adequate cardioprotection protocol is essential to ensure a rapid and effective response in a cardiovascular emergency. In Mexico, there are no protocols for dealing with the presence of an SCA in athletic races. This proposal offers athletic leagues and organizations a protocol to help reduce the risk of SCA events during their competitions. At the same time, it provides the logistics and organization necessary for victims to receive adequate treatment, thereby reducing the possibility of an SCD.

OBJECTIVES

Ensure a rapid and effective response to SCA events during the marathon, ensure the availability and accessibility of AEDs throughout the marathon route, form and maintain teams trained in CPR and AED use, establish a coordinated action plan with Emergency Medical Services (EMS) and reference hospitals, promote awareness and continuous training in cardioprotection among event organizers, volunteers, and participants and create a protocol to follow that serves to carry out cardioprotection races.

IMPLEMENTATION STRATEGY

A. Arrangement of Automatic External Defibrillators (AED)

1. **Quantity and Location:** strategically plan the placement of AEDs so that they cover a radius of 2.5 minutes between potential victims and AEDs. Place AEDs at key points

along the route, especially in high-traffic areas and medical assistance stations. Ensure the visibility and accessibility of AEDs, using appropriate signage and approved display cases. Use technologies to deliver and deploy AEDs at the site where the potential victim is located, such as drones, remote-controlled cars, motorcycles, and bicycles, depending on the distance.

2. Characteristics of the AEDs: use AED equipment authorized by the Federal Commission for the Protection against Sanitary Risks (COFEPRIS for its Spanish abbreviation) with biphasic waves and adult and pediatric patches. Ensure that batteries and pads are in good condition and within their dates 24 hours before use.
3. **If possible, facilitate the initiation of CPR by a witness:** as indicated later, establish a dissemination protocol before the event that includes the competitors. The protocol must specify that, in the event of any collapse of a competitor, it is a priority for the event witnesses to activate the EMS and, if possible, initiate CPR. Only with the hands until the arrival of EMS. The Basic actions to help those witnessing sudden cardiac death during a race are shown in *Table 1*.

B. Training

1. **Trained Personnel:** ensure that sufficient volunteers and medical assistance personnel are trained in basic CPR and using AEDs. Ideally, the number of rescuers per AED is between three and five to cover the requirements requested in the CPR triangle and the team dynamics. Organize training and refresher courses in CPR and the use of AEDs (ideally at no cost) endorsed by officially established training centers, such as the National Association of Cardiologists of Mexico (ANCAM).
2. **Timed Drills:** carry out a drill prior to the event, with the personnel involved, in the coverage area to evaluate the protocol's effectiveness and the personnel's response capacity. Ensure that the drills include the activation of EMS, initiation of CPR, and use of the AED at appropriate times, as well as ambulance and transfer access routes (including alternate routes) in case of any contingency.
3. **Access maps:** the security and civil protection personnel covering the event must have maps that ensure at least two ambulance accesses (in case one has access problems for any reason) to each of the sites where the race will take place, as well as real-time maps through mobile applications, for example, on the routes to take to the access hospital. It will facilitate the response time to access the victim and reduce their travel time. Thus, optimizing the results. An example of the map with the location of the AEDs is shown in *Figure 2*. It is an example of the route and map created for the 2024 Mexico City Marathon.

Table 1: Basic actions to help those witnessing sudden cardiac death during a race.

Basic actions	Response
1. Recognize the emergency	Identify if the person is unconscious and not breathing normally
2. Activate emergency services	Immediately call the local emergency number (e.g. 911)
3. Start CPR	Begin high-quality chest compressions
4. Chest compressions	Press hard and fast on the center of the chest, at least 100-120 compressions per minute
5. Allow chest expansion	Allow the chest to expand fully between compressions
6. Minimize interruptions	Keep pauses between compressions to a minimum
7. Rotate rescuers	If possible, change the person giving compressions every two minutes
8. Use Automated External Defibrillator	If an automated external defibrillator is available, use it according to its instructions
9. Continue until help arrives	Maintain CPR until the emergency services arrive

Figure 2: Route of the Mexico City Marathon 2024, with the proposed sites for cardioprotection based on a temporal radius of less than five minutes in case of sudden death, and with emphasis on the last km of the route where there may be a greater probability of sudden cardiac death.

C. Coordination with Emergency Medical Services (EMS)

1. **Rapid Activation:** establish an agreement with EMS to ensure a rapid response to SCD events. Define a clear protocol for EMS activation, with a target response time of less than two minutes from the start of the SCA event to the arrival of the AED.
2. **Transfer and Specialized Care:** ensure the availability of high-tech ambulances and specialized medical personnel trained in advanced cardiopulmonary resuscitation to transfer victims to nearby reference hospitals *(Table 2)*. Establish agreements with hospitals with a Cardiovascular Intensive Care Unit and hemodynamics room available, both with certified personnel, during the event (from one hour before and up to two hours after the event).
3. **Functionality of AEDs AED inspection:** ensure that the equipment and its accessories are in optimal condition and have their maintenance logs or the guarantee of new equipment within 24 hours before use *(Table 3 and 4)*.
4. **Diffusion and Awareness:** diffuse the SCA response protocol to all participants, organizers, and volunteers of the event at least 24 hours before so that they are familiar with the response protocol for the event. Use digital and physical tools, such as mobile applications, to activate the protocol during the event.
5. **Emergency Number:** provide clear and accessible information on the emergency number and the steps to follow in the event of SCD. Ensure that everyone involved in the event is aware of this number and the action protocol, including the chain of survival and possible hands-only CPR by the witness.[10]

DISCUSSION

Implementing this cardioprotection protocol in sports races, regardless of the distance, not

only increases the chances of survival in SCD events but also promotes a culture of safety and prevention. Through the strategic deployment of AEDs, continuous training, and coordination with EMS and reference hospitals, a rapid and effective response can be ensured, saving lives.[11] By implementing these measures, marathon organisers can ensure the safety and protection of their events, providing reassurance to all participants and attendees that they are well-prepared to handle any potential cardiovascular emergencies. The survival obtained by using an AED during an SCD event in marathons can be 5 times greater, and death events can be reduced by more than half, as seen in *Figure 3*.

Moreover, if athletes and organizers of this type of event have adequate foresight and implement Mexican positioning for cardiovascular screening and evaluation prior to sports participation,[12] an almost absolute reduction in the risk of cardiovascular mortality during an event, such as a marathon, will be achieved. It should be an event of celebration and passion for the sport, and not become something regrettable due to the death of a participant during the event. It is the obligation of doctors, medical organizations, authorities at the three levels of government, and non-governmental organizations to promote the development

Table 2: Ambulance crash cart supply and equipment checklist.

Recommended equipment	Recommended medication (units)
Airway (oral and nasal) all sizes	Aspirin 81 mg tablets (4)
Three laryngoscope and endotracheal tubes	Morphine Hydrochloride 10 mg/mL-20 mg/mL
Bag valve mask (adult and pediatric)	Injectable ampoule (2)
Nasal cannula (adult and pediatric)	Nitroglycerin spray or 0.4 mg sublingual tablets (3)
Non rebreather oxygen face masks (three sizes)	Dextrose 50% (dextrose 25% if treating pediatrics)
IV start packs	0.9 NaCl normal saline solution 1,000 mL (5)
Normal saline solution (1,000 mL bags)	Dextrose 5% in water 1,000 mL (3)
IV tubing	Lactated Ringer´s solution 5% dextrosa 1,000 mL (3)
Angiocaths (various sizes)	Lactated Ringer´s solution 1,000 mL (3)
10 mL normal saline flush syringes (3 pieces)	Narcan (Naloxona) 1 mg/mL (6)
5 mL normal syringe (10 pieces)	Flumazenile 1 mg/10 mL amplue (2)
Gauze	Epinephrine 1:10,000 auto injector (10)
Alcohol preps	Atropine sulfate 1 mg (3)
Monitor with defibrillator (preferred) or AED	Amiodarone 150 mg Vial (3)
Syringe nasal adaptor (nasal narcan atomizer)	EpiPen® or epinephrine 1:1,000 (2)
A checklist confirming everything that should be on the cart	EpiPen Jr® or epinephrine 1:1,000 (2)
	Solumedrol 125 mg (1)
	Benadryl 50 mg vial (2)
	Adenosine 6 mg (3)
	Lopressor 10 mg (2)
	Cardizem 20 mg vial (2)
	Pronestyl (procainamide) 1 g (1)
	Lidocaine 100 mg (3) Midazolam
	Dopamine ampule 200 mg (2)
	Dobutamine ampule 250 mg (2)
	Adenosine 6 mg ampule (5)
	Water
	Midazolam ampule 5 mg

Table 3: Automated External Defibrillator maintenance checklist.

Troubleshooting		
Item	Problem	Solution
Automated External Defibrillator	Signs of foreign substances	Clean according to manual
	Signs of damage	Contact manufacturer
	Chirping noise	Follow troubleshooting guidelines; check battery and pads
Status ready indicator	Status ready indicator is showing unit is not ready	Follow troubleshooting guidelines; contact manufacturer if no resolved
Automated External Defibrillator battery	Date expired	Replace item
Automated External Defibrillator pads	Date expired	Replace item

Table 4: Automated External Defibrillator maintenance checklist.

Date of inspection	✓	x
Status ready indicator shows the unit is ready		
Battery is working and not expired		
Unit is free of cracks, foreign substances, or other signs of damage		
Pads are sealed, unused and not expired		
Supporting materials are sealed and unused before expiration – face shield, scissors, gloves, razor, alcohol wipes		

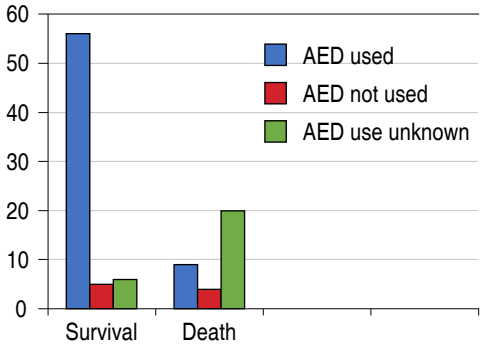

Figure 3: Outcome of SCD in marathons with respect to AED use in resuscitation.
Modified form.[16]

of cardioprotective spaces in Mexico and to educate the general population on hands-only CPR and the use of CPR, provided free of charge by AED.[13] Although some protocols for the creation of cardioprotective spaces have been published in Mexico.[14] Much more needs to be done to improve survival rates for out-of-hospital cardiac arrest in order to achieve the triple survival rates reported in other countries.[10,15] This will help address a public health problem that, unfortunately, tends to affect productive individuals, altering the personal, economic, and family expectations of everyone involved.

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Hypertension: the role of scientific dissemination in its prevention and control

Hipertensión: el papel de la divulgación científica en su prevención y control

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Keywords:
hypertension, outreach, age, education, blood pressure, communication.

Palabras clave:
hipertensión, divulgación, edad, educación, presión arterial, comunicación.

ABSTRACT

This article explores the repercussions of science communication concerning hypertension on individuals afflicted with the condition, emphasizing the necessity of ascertaining the target demographic. In this regard, the analysis focuses on the primary factors influencing the dissemination of health information to the Mexican population with hypertension, including their age range, educational level, and perception of science. Conversely, the article puts forward a series of resolution strategies, encompassing a review of educational and informative programs that have been implemented in various countries to reduce blood pressure and whose implementation could be considered for application in the local population. In conclusion, to have better control of hypertension, it is important to know the specific needs of patients to determine the appropriate methods to communicate information about disease, prevention, and treatment.

RESUMEN

Este artículo habla sobre el impacto que tiene la divulgación científica sobre la hipertensión en personas que viven con esta enfermedad y la importancia de identificar al público objetivo. En este sentido, se analizan los principales factores que impactan en la divulgación de la salud hacia la población mexicana con hipertensión como; su rango de edad, nivel educativo y percepción sobre la ciencia. Por otro lado, se proponen estrategias resolutivas, donde se hace una revisión de programas educativos e informativos que han promovido la disminución de la presión arterial en otros países y que podrían aplicarse en nuestra población. En conclusión, para tener un mejor control de la hipertensión, es importante conocer las necesidades específicas de los pacientes para determinar los métodos apropiados con los que se comunicará la información sobre la enfermedad, prevención y tratamiento.

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INTRODUCTION

Arterial hypertension is defined as a sustained increase in blood pressure, which affects one in three people in Mexico and the world, making it one of the most important cardiovascular diseases. Despite its chronic nature, hypertension is a modifiable risk factor for cardiovascular accidents,[1] underscoring the necessity for effective management to avert potential future complications in patients. However, if society does not reverse the high prevalence rates of hypertension, the average annual expenditure for this disease, which currently exceeds 17 billion pesos, will continue to increase, and there will not be enough budget to meet the health needs in the near future, in addition to the imminent reversal of the population age pyramid in Mexico.[2,3]

In this context, it's important to note that the population is largely unaware of health-related issues. This lack of awareness contributes to a deficiency in healthcare, which in turn fosters the development of diseases, including those affecting the cardiovascular system.

In this regard, the objective of disseminating information on hypertension and related subjects is to furnish the general public with pertinent knowledge that may exert a beneficial influence on the population afflicted by this malady.

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To effectively disseminate information regarding hypertension, it is imperative to comprehend the social problem underlying this condition. This understanding is crucial for ensuring the dissemination of information that truly reaches all socioeconomic strata of the population. It is imperative to formulate strategies that are tailored to the needs of the hypertensive population in Mexico.

1. THE TARGET AUDIENCE FOR HYPERTENSION INFORMATION DISSEMINATION

Information on hypertension should be accessible to patients with hypertension and their caregivers. Therefore, it should be emphasized that in the process of writing and disseminating health texts, it is essential to understand the type of audience to which this information is addressed and the way in which it is communicated. Consequently, health texts addressing hypertension should prioritize clarity, practicality, and brevity, as these qualities are instrumental in ensuring the long-term positive impact of the information on the health of the population.

It is imperative to acknowledge that education about hypertension is chiefly directed towards individuals living with this condition. In this regard, the National Institute of Public Health (2018) observes that more than half of hypertensive individuals are over 60 years old, and 54.4% of those who have already been diagnosed do not manage their blood pressure adequately *(Figure 1)*.[1] It is noteworthy that up to 47.3% of hypertensive individuals are unaware of their condition, due to the lack of regular medical checkups and limited or inadequate information about the disease.[4]

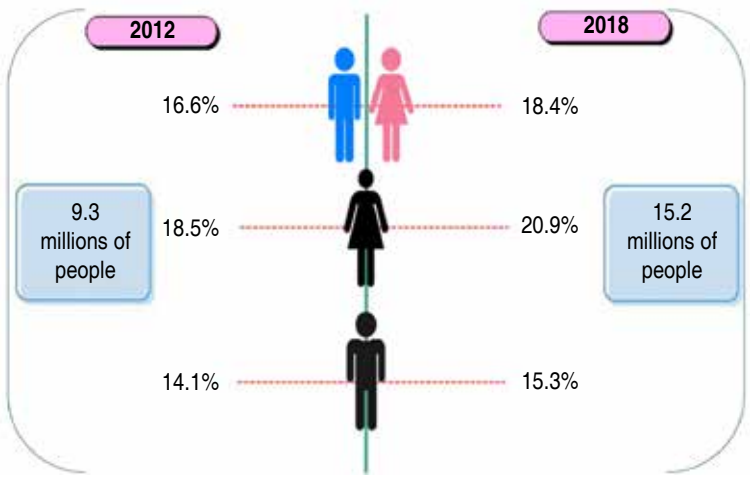

Figure 1: Population over 60 years of age with hypertension.
Source: This text has been modified from INSP, 2018.[1]

2. FACTORS THAT INFLUENCE HEALTH COMMUNICATION IN MEXICO

2.1. Educational level

It is imperative to acknowledge the significant efforts made to disseminate knowledge regarding hypertension to all interested parties. In this regard, it is imperative to consider the educational level of hypertensive patients, who constitute the target demographic for this initiative. This demographic is crucial in determining their ability to understand the information imparted.

In this regard, Ramos Serpa and López Falcón (2015) elucidate that the formation, assimilation, and development of concepts is facilitated by educators in an educational context that becomes increasingly intricate as the educational level advances.[5]

In this sense, approximately 50% of individuals living with hypertension are often deprived of the opportunity to access higher education *(Figure 2)*, and consequently, they are the most susceptible to poor diet, and it is prevalent that they also suffer from diabetes and obesity.[4]

The data presented indicates that individuals afflicted with hypertension are predominantly older adults who have received a basic education. This observation prompts the recommendation that scientific researchers, healthcare professionals, and students pursuing higher education should prioritize the development of educational materials that are comprehensible and accessible to individuals across all socioeconomic strata.

2.2. Limitations on basic education

It is imperative to acknowledge that basic education addresses health knowledge in a cursory manner, which engenders the prevalence of chronic degenerative diseases in the population due to the dearth of knowledge

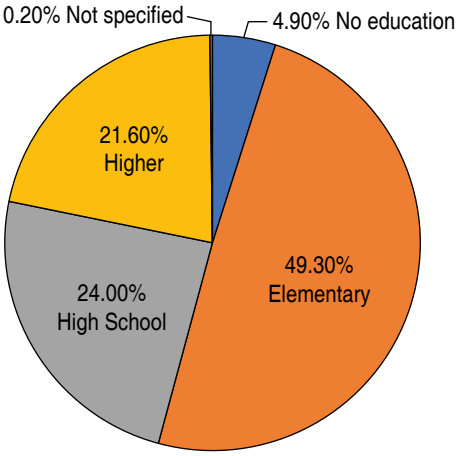

Figure 2: Percentage of population aged 15 and over by level of education. Source: This text has been modified from INEGI. Censos y Conteos de Población y Vivienda 2020.[6]

concerning risk factors, genetic predisposition, diagnosis, and treatment. According to the curriculum map of the Public Education Secretary (SEP), health education commences in the third grade of primary school and persists until the final year of secondary school. However, of health education at the basic level focuses mainly on sexuality, overlooking national health issues such as hypertension, diabetes, and obesity.[7]

Concurrently, numerous authors have examined primary and secondary school health education curricula and determined that there is a paucity of instruction on chronic diseases such as hypertension and diabetes. Even in the elective curricula of institutions that offer health-related programs, the instruction of these chronic diseases is deficient and does not enable students to comprehend their implications.[8]

The dearth of health education is not the sole factor influencing the comprehension of popular texts; the reading and scientific performance of the Mexican population is also impacted. According to data from the Organisation for Economic Cooperation and Development (OECD),[9] Mexico ranks among the five countries with the lowest scores on the PISA test. The PISA test assesses reading performance by evaluating the ability to understand and use written texts, as well as the application of scientific knowledge to explain phenomena and draw conclusions based on evidence.

Despite the above, the 2013 and 2017 survey on public perceptions of science and technology indicates that approximately 75% of Mexicans aged 17 and over *(Figure 3)* express interest in advances in the field of medicine and health science.[10] This represents a significant opportunity to explore innovative strategies for fostering public engagement with health-related issues.

However, despite the apparent interest in science, National Institute of Statistics and Geography (INEGI) reports that from 2013 to 2017 there was a decrease in the consultation of newspapers and magazines, the means by which the population is informed about science and technology. Therefore, it is essential to undertake efforts to regain the population's interest in reading.

3. PROPOSALS FOR DISSEMINATING INFORMATION TO THE PUBLIC

3.1. Language

It is important to highlight the positive elements that should be maintained in hypertension-related texts. Firstly, it is imperative to ensure that the development of these texts adheres to the principle of continuity, which stipulates that the depth of explanation should increase in accordance with the reader's progression in acquiring knowledge.[11] However, it is crucial to avoid the use of terminology from specialized domains such as physiology or pharmacology,

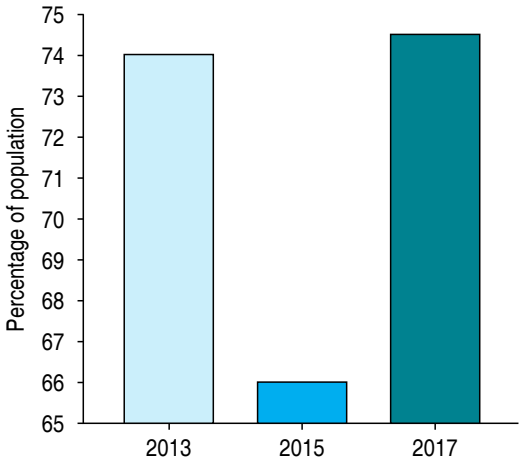

Figure 3: Mexican population interested in scientific developments in medicine or health sciences, 2013-2017. Source: This text has been modified from INEGI. Banco de Indicadores 2017.[10]

which may impede comprehension for individuals lacking expertise in these areas. Furthermore, didactic illustrations for patients and family members should be incorporated into triptychs or digital materials.

3.2. Ongoing conversations and workshops

One proposal to promote health outreach to people with hypertension would be to conduct a hands-on educational intervention, as this method has been shown to be effective in increasing the level of knowledge about hypertension in older adults, which could be very beneficial to patients with hypertension and their families.[12] Furthermore, an educational intervention has been demonstrated to modify inadequate knowledge about hypertension and reduce the number of patients with elevated blood pressure.[13]

Additionally, the implementation of a health education program in patients with hypertension has been shown to have a positive effect on blood pressure control and reduce mortality.[14]

3.3. Community Health Programs

To achieve the objective described above, and as previously mentioned, a prior diagnosis of the target population's knowledge and an assessment of their needs must be made in order to provide them with the information they truly require.

For instance, in 1990, a fundamental community education program was implemented for a period of six months with the objective of achieving blood pressure control. At the conclusion of the project, a reduction in systolic blood pressure was observed during the subsequent 18 months.[15] This finding underscores the efficacy of educational programs in fostering individual and familial self-care, thereby enhancing population health outcomes, including life expectancy.[16]

The dissemination of hypertension can be enhanced by patient-to-patient recommendations, as evidenced by Rosado et al., (2005). Their observations revealed that individuals with hypertension are willing to share their experiences, thereby supporting the care of others and fostering the dissemination of information within their social networks.[17]

In this regard, some authors have demonstrated that public understanding of science is developed collectively and that the dissemination of information within a community can generate interest and higher levels of knowledge.[18]

As Sanchez (2008) has explained, an understanding of how perceptions of scientific projects have benefited communities can facilitate the identification of scenarios where scientific dissemination in health is required. Furthermore, by comprehending the nature of the information disseminated and the public's interpretation of it, we are able to ascertain the most effective means of communication.[19]

It is imperative that outreach initiatives targeting individuals with hypertension exhibit a genuine interest in their well-being, respect their values and self-esteem, and foster an environment of trust and autonomy.

The existence of educational programs that address the needs of this population is of paramount importance, as they can lead to a change in their lifestyle, resulting in the control of the disease.[20]

3.4. Sensitization of scientists to the need for dissemination

Ungar (2000) observed that any topic facilitating social interaction is well received; however, if a topic becomes a language barrier, most individuals withdraw from the conversation, causing scientists to become entrenched in their niches, avoiding the simplification of their knowledge, resulting in the termination of the conversation and mutual ignorance.[21] Consequently, the employment of sophisticated language replete with technical jargon, as evidenced in certain literature concerning hypertension, has the potential to dissuade individuals lacking specialized knowledge from engaging with the material.

Furthermore, it is important to acknowledge that scientists are not systematically trained to communicate their findings beyond academic circles,[22] and they often recognize their deficiencies in communication skills.[23] This creates an opportunity for communication professionals, who can serve as guides, advisors, and promoters of these training programs. Their

role would be to facilitate the dissemination of health information to the target population, ensuring its comprehension.

It is imperative to acknowledge that the creation and restructuring of popular science books should be directed towards rendering complex and often inaccessible subjects comprehensible to students and readers lacking scientific training, as science is intrinsically linked to society and its primary objective is human benefit. A proposal that could facilitate the dissemination of knowledge related to hypertension is the involvement of a pedagogue and a communicologist, who would enhance and support the transmission of information to the population.

The role of health education in modifying habits and behaviors, thereby promoting the preservation of health and the enhancement of living conditions, is indisputable. Consequently, the dissemination of straightforward materials on hypertension can contribute to the prevention and management of blood pressure, a matter of paramount importance to health institutions in our nation.[13]

Additionally, this dissemination strategy aims to promote equitable access to information and culture by making pertinent issues more accessible to the Mexican population, facilitating their comprehension of the significance and rationale behind these issues.[24]

At present, a number of promotional programs have been implemented in Mexico. Among these are initiatives by the National Institute of Public Health, which have given rise to platforms such as EDUCAD. EDUCAD offers a variety of interactive materials designed for different audiences, with the aim of providing guidance on the management of chronic diseases.[25] In the private sector, the Carlos Slim Foundation promotes the ClikiSalud.net platform, which provides access to visual and multimedia educational resources on hypertension, contributing to a better understanding of health.[26] Conversely, the PrevenIMSS program of the Mexican Social Security Institute (IMSS) encompasses detection measures, guidance, and nutritional monitoring, leveraging digital and printed tools.[27] These initiatives exemplify a patient-centered health communication perspective, wherein science functions as a medium for social empowerment. The sustained implementation of these measures is imperative to alleviate the burden of hypertension-related diseases within the nation. However, its dissemination is limited, as it is currently restricted to the health sector, i.e., patients. This information is not disseminated to the public, where its impact could be generated to prevent the disease rather than cure it.

4. SOCIAL NETWORKS AND SCIENTIFIC DISSEMINATION

Consequently, in the contemporary digital era, social networks have emerged as indispensable instruments that exert a profound influence on diverse sectors, notably healthcare. These networks have enabled healthcare professionals to disseminate information and enhance health education, a subject that will be examined in this report. Furthermore, social networks empower patients by furnishing them with greater access to medical information. However, the complexity of this information, often characterized by technical jargon, poses a significant challenge for healthcare professionals in translating complex concepts into easily comprehensible formats, particularly for new generations. This challenge is further compounded by the need to tailor these educational materials to meet the diverse information needs of the general public.[28-30]

CONCLUSIONS

It is imperative to develop outreach materials focused on national public health problems, such as hypertension, with a focus on the target audience, understanding the specific needs of the population, and selecting the most effective methods or media for conveying the information. In the near future, patients and their caregivers may share the knowledge they have gained with others, thereby contributing to a reduction in the incidence of this condition and other chronic diseases.

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