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DEVELOPMENT OF A MOBILE APPLICATION FOR ASSESSMENT OF PERIPHERAL OBSTRUCTIVE ARTERY DISEASE

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ABSTRACT

Peripheral Arterial Disease (PAD) is a serious problem for the health system. It is expected that PAD cases follow the increase of the prevalence of diabetes mellitus, hypertension, dyslipidemia, obesity, as well as other conditions that are known risk factors for this pathology. The impact on health expenses as well as on the social security system is undeniable, not to mention the stigma that the loss of a leg brings to the psychological status of the patient. It is therefore important to perform the correct stratification of these patients in order to ensure the best treatment for each case. At the same time, the use of technology and mobile devices has helped human practice, which can be observed by an exponential increase of these technologies in the health area. The development of a mobile application capable of assisting in the assessment and treatment of this group of patients is imperative, as it directly impacts treatment and the prognosis improvement. This study aims to develop an application for a mobile device capable of correlating the type of trophic lesion with the pattern of arterial lesion in the lower limb to predict the risk of amputation, the benefit and the type of revascularization to be performed in patients with PAD. The processes continue to improve the functioning of the application, with probable use of Artificial Intelligence for image recognition in subsequent studies.

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INTRODUCTION

Peripheral Arterial Disease (PAD) is defined as a chronic disease resulting from reduced arterial blood supply to the lower limbs due to chronic atherosclerotic lesions. The symptoms occur during situations of increased metabolic energy demand on the lower limbs, for example, when walking. Since the arterial blood supply is reduced, ischemic pain, also known as intermittent claudication, occurs during ambulation. In advanced stages, it can evolve into Critical Ischemia. This term refers to patients with typical chronic ischemic rest pain or patients with ischemic skin lesions (either ulcers or gangrene) (Norgreen, 2007). It is estimated that more than 200 million people worldwide have PAD (Fowkes, 2013). A meta-analysis revealed a prevalence of 6.5% in men aged 60 to 69 years, increasing to 29.4% in individuals over 80 years. The prevalence in women is similar and, due to the higher life expectancy in women, the amount of affected women exceeds the male population (Hirsch, 2012). The risk factors for PAD are the same as those for the development of atherosclerosis. Among the main ones, Diabetes Mellitus and smoking stand out, since they are the risk factors with the highest relative risk for developing PAD (Criqui, 2015). All demographic changes (aging population and increasing prevalence of diseases that predispose to atherosclerosis) contribute to an expected increase in the prevalence of PAD in the coming decades. The treatment of PAD is clinical, where risk factor control measures, dietary and lifestyle changes, as well as foot care are indicated for all groups of patients regardless of their stage of disease. For cases of Critical Ischemia, as well as cases of disabling intermittent claudication that does not improve with clinical treatment and rest pain, interventional treatment is indicated (Norgreen, 2007).

The interventional treatment consists of revascularization of the lower limb, a procedure that aims to restore adequate blood supply to the affected limb. The invasive procedure can be performed by endovascular intervention or by conventional surgery. Classically, the choice of interventional treatment method is based on the anatomical evaluation of atherosclerotic lesions through the classification of the *Trans-Atlantic Inter-Society Consensus Document on Management of Peripheral Arterial Disease* associated with the clinical evaluation of ischemic lesions of the lower limbs. Lesions are classified as A, B, C, or D according to location, extent, or prevention of obstruction. Extensive atherosclerotic lesions as well as large lower limb injuries tend to require conventional surgery, otherwise endovascular intervention takes precedence. After the development and improvement of endovascular techniques, clinical cases previously treated only with conventional surgery are being resolved by endovascular approach, there has been a progressive abandonment of the use of the transatlantic consensus as a guide to define conduct. However, decision making for the interventional method occurs, in most cases, subjectively, which is subject to interobserver variations. The subjective character of the evaluation generates a wide range of behaviors depending on the location and available resources, often not compatible with what is proposed in the medical literature, having as a direct impact increased patient morbidity and mortality (Goodney, 2013).

At the same time, the accelerated technological development has provided emergence of a wide variety of high-cost endovascular devices for treatment of atherosclerotic lesions (Perez-Favila, 2019). This development is evidenced by a large number of publications related to the term Critical Ischemia since the year 2000. The large number of devices available for treatment is not associated with better outcomes, but increases the bias in the choice of interventional method (Goodney, 2014). In 2013, several societies of Vascular Surgeons came together to create Global Guidelines for the treatment of Critical Ischemia with the intention of improving quality in the care of these patients, as well as identifying aspects related to diagnosis and treatment that need further study. A protocol for the evaluation of ischemic wounds and atherosclerotic lesions was created based on the current scientific evidence available. Therefore, the *Global Vascular Guidelines on the management of chronic limb threatening ischemia* was created (Conte, 2019). The global guideline is based on the main scientific evidence available in the literature and aims to optimize the care of patients with Critical Ischemia, and the Vascular Surgeon must be familiar with this study. The present study, through the creation of a mobile application, aims to help physicians standardize the evaluation and treatment of patients with Chronic Limb-Threatening Ischemia (Critical Ischemia), according to the best scientific evidence available in the literature and improve the care and treatment results in the short and long term in these patients.

METHODS

Study Type: Mobile application development and application.

Research Ethics Committee: Waived, because it is not an experimental study (in living beings) and does not use human beings for proof and/or validation.

Sample: Global Vascular Guidelines on the Management of Chronic Limb-Threatening Ischemia was used as a source of information to make the calculators for the application.

Application Name: The name chosen for the application is Salve Pé. It is short and easily assimilated with the project's objective.

Application Logo: The logo of the application consists of a shell-shaped hand holding a foot with a white background which directly refers to the sense of caring for the feet. We used Canva ®, which is a free graphic design tool. (Figure 1)

Figure 1. Logomarca.png. Source: Author himself

Application Development (Figure 2): To make the front-end (user interaction interface with the application), Figma ® was used. Figma ® is a tool used to create user flows, *wireframes,* user interface simulations, prototypes and mobile application design. For storing information in the database, Firebase ® was used. To make the *back-end*, where all the programming protocol for the application's operation is done, Heroku® was used. Heroku® is an online cloud programming platform. It uses several programming languages, such as Java, Node.js, Scala, Clojure, Python, PHP and Go. For the application to work, therefore, an Internet connection is required for use on the device. The project consists of developing a Web application. This type of software allows the development of projects at a more accessible cost and in a shorter time.

RESULTS

Internal error research of the application was performed by 2 members of the research team. The errors identified were fixed and revised. No Usability Test was performed, because the application consists of an intermediate stage of a larger project, where Artificial Intelligence resources for image classification of lower limb wounds and Digital Subtraction Angiography are used.

Figure 2. Page *Login*. Source: Author himself

Figure 3. Application functioning test. Source: Own author

Practical example (clinical case created by the researchers): (Figure 3).

A 63-year-old patient with DM and former smoker, comes to the emergency department due to an injury on the fifth right pododactyl which arose after trauma from inadequate footwear two months ago. Previous surgeries: Cataract surgery 2 months ago (patient had a low cardiology risk report from his cardiologist).

Physical Examination:

- General: Good general state, oriented, cooperative, eupneic, hydrated, normochorous, anicteric, acyanotic, afebrile.
- Extremities: Femoral and popliteal pulses palpable in the lower limbs. Dorsalis pedis and posterior tibial pulses absent in lower limbs. Wet necrosis of the fifth right pododactyl and lateral of the right foot with bony exposure of the affected pododactyl and with signs of fluctuation in the sole of the foot. Ankle-brachial index: 0.5 (pedal artery).

He underwent digital subtraction angiography that found stenosis of less than 50% in the middle third of the superficial femoral artery, segmental occlusion of 1cm length in the proximal third of the anterior tibial artery, occlusion of the posterior tibial and fibular arteries in all their extensions, adequate filling of the tarsal arteries by the dorsalis pedis artery. The app test results are consistent with the global guideline protocol.

Chronic Limb-Threatening Ischemia, formerly called Critical Limb Ischemia, includes a broad and heterogeneous group, in which patients with documented PAD and at least one of the following conditions are considered: Ischemic rest pain with confirmatory hemodynamic tests for ischemia assessment, diabetic foot ulcer or any other lower limb ulcer more than 2 weeks in progress, gangrene involving any region of the lower limb or foot. Patients with purely venous ulcers, acute limb ischemia, atheroembolism, acute trauma or mutilated extremity, and lower limb wounds related to non-atherosclerotic conditions (such as vasculitis, collagenosis, Thromboangiitis Obliterans, neoplasms, dermatoses, and actinic arteritis) are excluded (Conte, 2019). The importance of identifying patients with advanced disease is justified by the completely different prognosis in relation to asymptomatic patients or those with intermittent claudication. Once the risk of amputation in patients in the early stage of the disease is around 3% in 5 years, which is lower than the risk of death from cardiovascular events, the focus of treatment is on the control of risk factors, both to avoid progression to advanced stages and to prevent cardiovascular events. In advanced stages, the risk of limb loss is high, which justifies interventional treatment by lower limb revascularization.

The high rates of morbidity, mortality, and amputation generate not only a social but also an economic impact on health policies (Norgreen, 2007). With regard to lower limb wounds, preexisting classification systems are limited. The classifications of Rutherford *et al*. (1997) and Fontaine *et al*. only consider the degree of ischemia, neglecting the impact of the extent of tissue loss and the severity of infection on decision making. Wagner's classification, does not help in differentiating between ischemic and infectious lesions. The old classification systems have limited usefulness by focusing on only one specific aspect. The global guideline, with regard to interventional treatment, makes use of current classification systems for lower limb injuries and atherosclerotic lesions, as well as clinical data for decision making in patients with limb-threatening Chronic Ischemia. The WIfI classification was developed by the *Society for Vascular Surgery* in 2013. It addresses the 3 main pillars that put a limb at risk for amputation: the wound (characteristic of the wound), the presence of ischemia (degree of ischemia), and the presence of foot infection (degree of foot infection) (Mills, 2014). In 2015, a prospective study of 201 patients with Critical Ischemia was followed for a period of 2 years. Amputation-free survival at 1 year was inversely proportional to WIfI stage. The limb salvage rates at each stage were 25%, 31%, 31%, and 13, respectively (Zhan, 2015). Other studies have shown similar data, thus reporting the ability of the WIfI classification to predict the risk of amputation at 1 year (Beropoulis, 2016; Darling, 2016; Ward, 2017). Among the primary endpoints of the WIfI classification is the assessment of the need for revascularization for the threatened limb. In most publications, revascularizations were more common with increasing WIfI stage. Revascularization accelerates wound healing time in stage 3, as well as reduces the risk of amputation by 25% in stages 3 and 4. (Zhan, 2014). The benefit of revascularization is low for stages 1 and 2, except in selected cases of stage 2. Regarding mortality, most publications found that WIfI classification is not a good predictor of mortality and in one cohort modified WIfI scores were suggested to be consistent predictors of mortality.[16] Considering exclusively the non-diabetic population revascularized by endovascular approach, the WIfI classification produces good correlation with mortality rate.[17] Novak *et al* showed that the wound grade (*Wound*) is a predictive factor of patient survival (Beropoulis, 2016). With regard to hospital costs, which is important with regard to public health policy, it has been shown that WIfI Stages 3 and 4 are correlated with higher hospital costs (Hicks, 2018). The WIfI classification is therefore a safe classification system for decision making regarding the benefit of revascularization or risk for amputation, assisting in clinical decision making and avoiding excessive procedures in patients, which directly impact morbidity and mortality. The GLASS classification considers both the complexity of the lesions and uses the concept of target arterial pathway (target artery for treatment, which is the least affected artery that will provide perfusion to the foot).

It provides a foundation for clinical practice and support for future research. However, it correlates primarily with endovascular interventions. It does not address factors such as venous conduit, which are important for treatment by conventional surgery (Conte, 2019). The WIfI and GLASS classifications together with the patient's clinical data provide scientifically based evidence for correct decision making in patients with Chronic Limb Threatening Ischemia. Although they have scientific basis, being able to guide conduct as to interventional treatment, the WIfI and GLASS classifications are complex in terms of the amount of information contained. There is a difficulty of memorization by the physician, making the use of these classifications unfeasible in many cases, which can negatively impact the outcome of patients. An alternative to facilitate the implementation of new knowledge in medical practice is the use of mobile applications. Mobile applications consist of a true revolution in people's lives. In 2019, a survey by the Brazilian Institute of Geography and Statistics (IBGE) showed that 81% of the Brazilian population aged 10 or more years have a mobile phone for personal use. The main characteristic of mobile applications is versatility, the user has no limitation of mobility of the device. Another important aspect is that the fact that the device is for personal use makes it easier to adapt to the use of different applications, because the user is already used to the device's operating system (Tibes, 2014).

Mobile health applications are *softwares*related to health knowledge and research, used by health professionals and patients with the aim of improving knowledge and treatment, enabling indirect impact on public health. These applications transform a mobile platform into a regulated medical device (Pires, 2020). Sensors available on mobile devices, in combination with artificial intelligence algorithms, allow for the collection of data such as patients' vital signs. However, a study from Columbia University found that most mobile apps aimed at healthcare professionals are primarily focused on medical diagnosis (Mosa, 2012). To date, only 1 application with the calculators from the global guideline has been found in the literature. The application is in English, was developed by the *European Society for Vascular Surgery,* and is called *ESVS Clinical Guidelines*. There is no mobile application in Portuguese with the calculators of the global guideline. The application developed in this study is therefore pioneering in the area of PAD, facilitating the application of the current guideline in medical practice in an area where the Portuguese language is predominant, having a direct impact on the care of patients with PAD, improving morbidity and mortality, and reducing healthcare costs. Currently, some medical centers have already applied data science, more specifically by developing devices with artificial intelligence (*machine learning*) / deep *learning (deep learning)* to automate lesion analysis, material selection, and diagnosis for coronary artery disease [22, 23] as well as aortic artery disease (Elsevier, 2019; Raffort). Machine learning, more specifically deep learning, has shown remarkable performance in computer vision and medical image analysis, and is increasingly used in acute stroke neuroimaging, for example, in infarct and penumbra core segmentation. In these situations machine learning algorithms have demonstrated high accuracy compared to manual annotations by experts or commercial software (Chen, 2017; Litjens, 2012; Mckinley *et al.,* 2018; Litjens *et al.,* 2012; Zhang *et al.,* 2018). In some cases, such as for Melanoma diagnosis, the use of information technology coupled with Artificial Intelligence is superior to human diagnostic capability (Goyal, 2020). The application of data science, coupled with Artificial Intelligence and Machine Learning, provides new resources in the era of contemporary medicine, with the goal of proposing individualized and more accurate patient care, likely to be the future in health care. There are no mobile apps using Artificial Intelligence features for image recognition in WIfI and GLASS calculation. The common goal of using Artificial Intelligence for image recognition is to classify objects into different categories. The use of Artificial Intelligence for WIfI and GLASS calculation can eliminate inter-observer variation, standardizing the classification (Lebedev, 2018). Therefore, there is opportunity for innovation and upgrading for applications using WIfI and GLASS calculators in the near future.

CONCLUSION

The construction of the application has been successfully accomplished. The researchers continue to improve the functioning of the application, with likely use of Artificial Intelligence for image recognition in subsequent studies.

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