







The New Era of Technology Applied to Cardiovascular Patients: State-of-the-Art and Questionnaire Applied for a System Proposal

María Vanessa Villasana¹ , Juliana Sá^{2,3} , Ivan Miguel Pires^{4,5,6} ,
and Carlos Albuquerque⁶ 

¹ Centro Hospitalar do Baixo Vouga, 3810-164 Aveiro, Portugal
72152@chbv.min-saude.pt

² Faculty of Health Sciences, Universidade da Beira Interior, 6200-506 Covilhã, Portugal
julianasa@fcsaude.ubi.pt

³ Centro Hospital e Universitário do Porto, 4099-001 Oporto, Portugal

⁴ Instituto de Telecomunicações, Universidade da Beira Interior, Covilhã, Portugal
impires@it.ubi.pt

⁵ Computer Science Department, Polytechnic Institute of Viseu, Viseu, Portugal

⁶ UICISA: E Research Centre, School of Health, Polytechnic Institute of Viseu, Viseu, Portugal
calbuquerque@essv.ipv.pt

Abstract. The advance of technology allows daily monitoring of people with cardiovascular diseases. It enables patient empowerment, making them increasingly autonomous and responsible for their health by using digital tools and solutions. The purpose of this study is to idealize a system individualized to the patient with cardiovascular diseases, including monitoring, follow-up, treatments, and communication with healthcare professionals. A review of the existing literature was carried out, identifying the need to understand patients' needs and preferences to adapt the digital solutions. Therefore, a questionnaire was developed to characterize patients' preferences, showing that patients prefer to use their personal devices, such as mobile phones, due to their ease of use and commodity. Most patients would like to receive information through a mobile application. They also agreed that teleconsultation and telemonitoring helped to improve their health status.

Keywords: Patient-empowerment · Cardiovascular diseases · Mobile devices · Telemonitoring

1 Introduction

According to World Health Organization (WHO), cardiovascular diseases have a high prevalence worldwide, particularly in the middle- and low-income countries [24]. These diseases are mainly related to unhealthy behaviors that lead to the emergence of chronic

diseases, such as hypertension, diabetes, obesity, and cardiac failure [10]. Several reports describe the positive impact of technological equipment to promote the control of these diseases showing positive health results [4, 13], and this use is increasingly recommended for clinical practice.

Technology is currently entering daily lives, taking part in daily routines and behavior habits [5, 6]. The advancement of technology enables the possibility to monitor patients daily and promote the creation of medical assessment tools that are continuous, reliable, and accurate [1]. Thus, the medical assessment is not limited to a punctual evaluation in the clinic but translates the real values of [22]. The use of technology and telemonitoring also allows patients to have greater autonomy to manage their own health, with greater empowerment and a patient-centered approach [11, 23].

There is extensive research around this topic, but no combined technologies are used for a specific group of diseases. However, the number of studies related to remote patient monitoring, patient care using telemedicine, and the development of patient literacy is increasing [9].

Mainly, small research studies created systems for specific diseases, but they are not available in the market. For example, the authors of [16–18] argued about developing a system for blood pressure telemonitoring. They verified that it promotes the compliance to treatment, intensification, and optimization of medication use, improvement of life quality, reduction of risk of developing cardiovascular complications, and cost-saving with the help of mobile devices (i.e., Smartphones and smartwatches).

Regarding heart failure, some studies promoted the use of e-Health technologies for the telecare, remote monitoring of hemodynamic implantable devices, home monitoring of cardiovascular implantable electronic devices, and telerehabilitation, revealing robust capabilities for life-threatening deterioration, helping heart failure patients to avoid seeking medical assistance in hospitals, and revealing that home-based telerehabilitation is effective with high adherence and reduced mortality [7, 21].

Due to the high cost of the medical solutions and the rare validation of the developed solutions, the current solutions for monitoring blood pressure have limited value and benefits in hypertensive patients related to the less acceptance of these solutions [3].

This study aims to understand users' preferences in a system to monitor and control cardiovascular diseases. Furthermore, it intends to create a system as adapted as possible to patients with cardiovascular diseases, where each module can be adapted to individual patient preferences and healthcare needs. Thus, the focus is on the empowerment of patients and promote health literacy through individualized technological approaches.

2 Related Work

A literature review was performed to verify the different options for using telemonitoring technologies to promote e-Health solutions.

The study [8] proposed an electronic system for monitoring cardiac patients using the development board LinkIt ONE. It measures and analyses the cardiac pulse for the detection of arrhythmias. The system has an intelligent module that identifies the arrhythmias and activates an alarm to report the health conditions for the healthcare provider closer to the patient. The system also includes an Arduino and a GPS module

connected to the virtual platform UBIDOTS by Wi-Fi. The platform provides visual information about the patient's state.

In [15], the authors recruited 80 Heart Failure patients with New York Heart Association (NYHA) functional classes II or III. The latter was hospitalized in Intensive Care patients for a study for eight weeks to compare telemonitoring intervention with usual care. The patients are separated into a control group and an intervention group. The study consisted of an educational trial to measure the application of the Iranian version of the European Heart Failure self-care questionnaire and the heart failure-related readmission rates. The mean scores showed differences between the two groups demonstrated significant differences at the baseline for self-care behaviors. Related to the covariance analysis, the differences between the groups are also significant. However, related to the readmission rates, it is low for the intervention group. Thus, it proved that telemonitoring improved self-care behaviors, but the results are not significant.

The authors of [19] implemented a telemedicine platform for pulse-wave analysis and ambulatory blood pressure monitoring. The data was recorded with a computer for the investigation, uploading it to their Web-based telemedicine platform to process the sensors' signals with proprietary mathematical algorithms. Unfortunately, a detailed analysis of the algorithms was impossible because the source code was not available.

In another work [14], the Smartphone and cardiography devices were used to identify some health rate conditions, including normal sinus rhythm, atrial fibrillation, coronary artery disease, and possibly ST-segment elevated myocardial infarction with artificial intelligence techniques. In addition, it proved that it could be used in self-monitoring systems with a mobile device.

The authors of other work [2] analyzed 340 patients with heart failure in NYHA functional class III with a remote system named CardioMEMS HF that includes a CardioMEMS PA sensor to measure Pulmonary Artery pressure. The system consists of an implantable wireless sensor with a delivery catheter, a patient and hospital electronics system, and a patient database. With this system, the medical doctors were remotely informed about the Pulmonary Artery pressure of the patients via Merlin.net. The system also evaluated the efficacy and cost-effectiveness of hemodynamic monitoring in patients with chronic heart failure. However, the authors do not report the results, and more experiments are needed to report reliable conclusions.

In other research [12], the patients with atrial fibrillation used the short continuous heart rhythm monitoring (i.e., Holter device), and the long-term intermittent heart rhythm monitoring (i.e., AliveCor Kardia device), revealing a high accuracy in the detection of the different symptoms. The authors also used the System Usability Scale and a four-item questionnaire to evaluate the system through the other patients. As a result, it was verified that long-term intermittent monitoring effectively detects atrial fibrillation recurrences after atrial fibrillation ablation. In addition, long-term periodic monitoring has more reported usability than short continuous heart rhythm monitoring. Finally, the long-term intermittent monitoring reported a high accuracy to detect atrial fibrillation.

Table 1 presents the analysis of the different studies, verifying that few studies related to telemonitoring for cardiovascular patients. However, portable devices are starting to be used with other sensors to monitor these patients constantly.

Table 1. Analysis of the related work.

Study	Data Acquisition Method	Acquired Data	Devices	Tool used for Data Analysis
[8]	Virtual platform UBIDOTS	Cardiac pulse	Arduino and a GPS module	Virtual platform UBIDOTS
[15]	Telemonitoring through phone	The Iranian version of the European Heart Failure self-care questionnaire	Mobile device	Statistical software
[19]	Web-based telemedicine platform	Pulse, blood pressure, ambulatory arterial stiffness, and central hemodynamics	Computer, BPLab device, and oscillometric BPLab device	Web-based analysis software (THOLOMEUS, Biotechmed Ltd., Somma Lombardo, Varese Italy)
[14]	Mobile application	Health rate	Smartphone and cardiography devices	Artificial intelligence techniques
[2]	CardioMEMS HF	Pulmonary Artery pressure	Implantable wireless sensor with delivery catheter and CardioMEMS PA sensor	Hospital electronics system - Merlin.net
[12]	Holter device, and AliveCor Kardia device	Heart rhythm	Holter device, and AliveCor Kardia device	System Usability Scale (SUS) and statistical methods

3 Methods

3.1 Study Design

This research started with the research about the related work using a scientific database (*i.e.*, PubMed Central) related to using technology for cardiac patients. Then, the analysis was performed with the following keywords: “cardiovascular”, “e-Health”, and “telemonitoring”. The research was limited between 2016 and 2021, where 17 research articles were retrieved. However, only the original research articles were analyzed, which included only six studies.

A questionnaire was designed, including nine multiple-choice questions related to the patient’s preferences for disease management and interaction with the healthcare provider. The questions analyzed the different studies available in the literature and previous work [20]. Patients from an Arterial Hypertension outpatient clinic voluntarily participated. Thus, 12 patients anonymously answered the questionnaire after the acceptance of the informed consent. The Ethics Committee of the Universidade da Beira Interior previously approved the study protocol with the reference CE-UBI-Pj-2021-041:ID969.

3.2 Structure of the Study

As presented in Fig. 1, this study was born from recognizing the necessity for a system to allow patient empowerment in monitoring and controlling cardiovascular diseases.

After that, the questionnaire was created and distributed to the participants. Finally, the questionnaire was designed, distributed, and analyzed to evaluate the expectations of the patients.

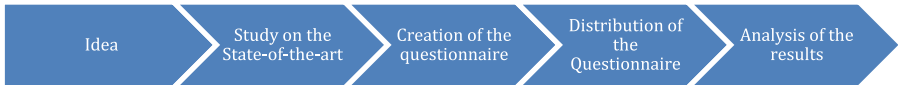


Fig. 1. Structure of the study

3.3 Statistical Analysis

Based on the data acquired, the responses were filtered and grouped by categories. Thus, the frequencies were analyzed, and different conclusions have been achieved to develop further and analyze a patient-centered innovative system for cardiovascular diseases.

4 Results

Based on the analysis of the distributed questionnaires, it was possible to verify different conclusions. The answers in the question “Which of the following instruments would you prefer to use to collect your health data?” presented in Fig. 2 show that the participants in the study do not have a consensual preference for collecting the data. We grouped

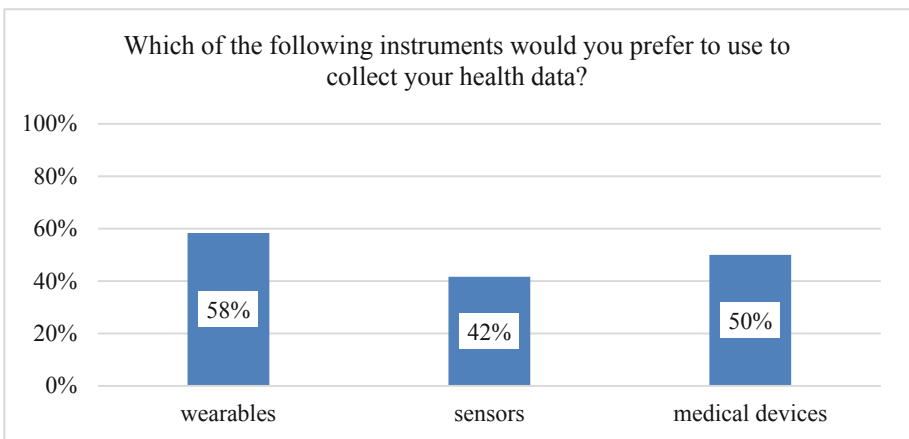


Fig. 2. Answers to the question “Which of the following instruments would you prefer to use to collect your health data?”

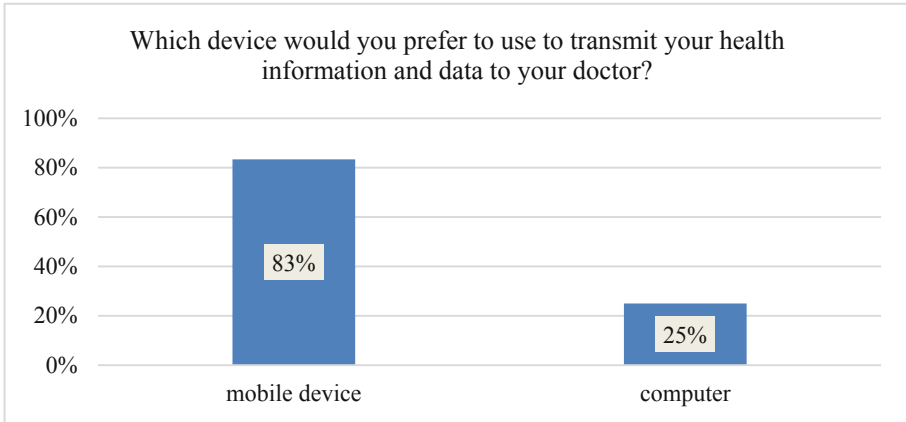


Fig. 3. Answers to the question “Which device would you prefer to use to transmit your health information and data to your doctor?”

the answers in three groups, including wearables (i.e., Smartphones and smartwatches), sensors (i.e., Clothing with built-in sensors, Sensors glued to the skin, and Sensors placed under the skin), and medical devices (i.e., blood pressure measuring device, scale, among others). A slight preference is revealed for the wearables.

Regarding the answers in the question “Which device would you prefer to use to transmit your health information and data to your doctor?”, presented in Fig. 3, the answers showed a clear preference for the use of mobile devices, and only 2 of the participants do not want to use the mobile devices for this function.

Considering the answers to the question “What tools would you use to analyze/visualize your health data?” presented in Fig. 4, patients prefer mobile applications. Furthermore, only 2 participants would not like the use of mobile devices.

Regarding the question “How would you like to receive feedback from your doctor about your health status?” presented in Fig. 5, it shows a clear preference for mobile applications.

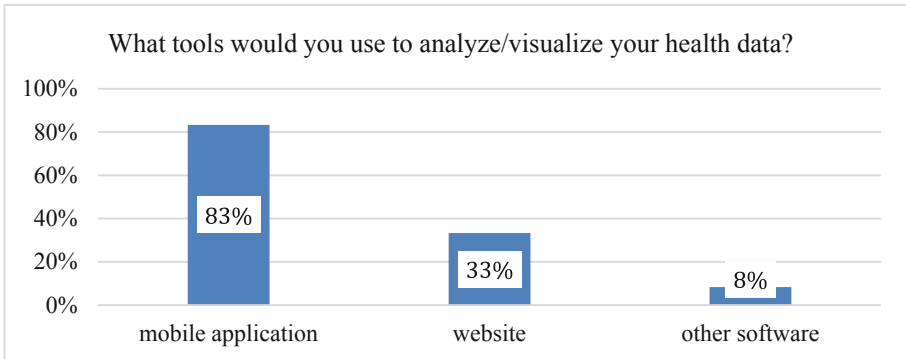


Fig. 4. Answers to the question “What tools would you use to analyze/visualize your health data?”

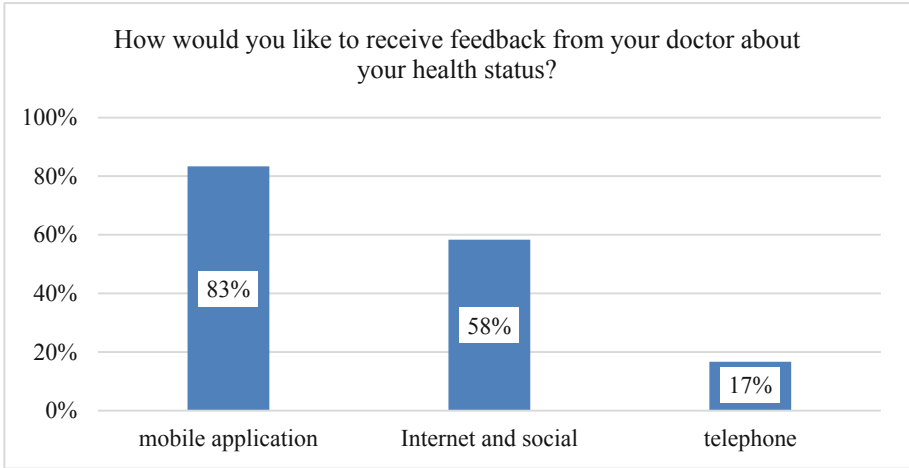


Fig. 5. Answers to the question “How would you like to receive feedback from your doctor about your health status?”

Sequentially, the question “What biological parameters do you think are important to evaluate?” presented in Fig. 6 shows that blood pressure measurement is essential for the patients. In addition, the other features critical in the patients’ viewpoint for the different measures are the electrocardiographic monitoring, the peripheral oxygen saturation, and the heart rate.

Analyzing the answers in the questions “What do you value most when using medical measuring devices?” and “What do you value most in the use of computer systems in

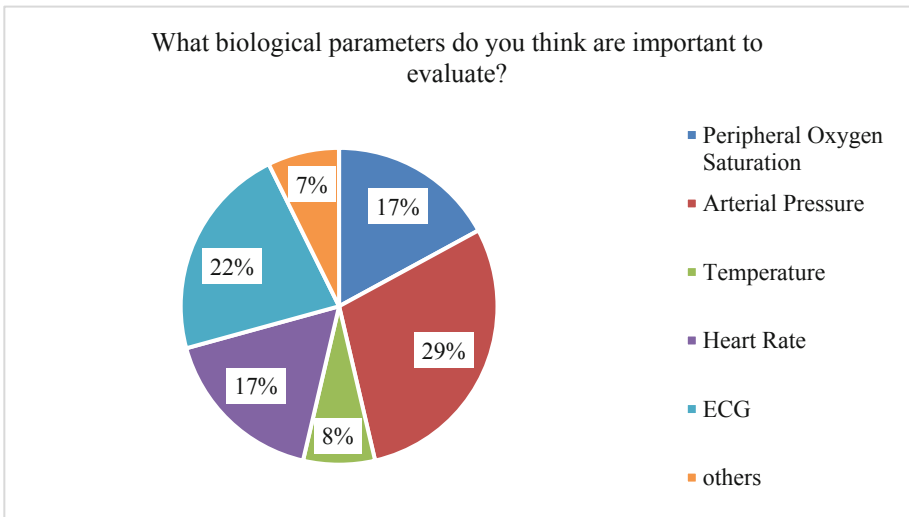


Fig. 6. Answers to the question “What biological parameters do you think are important to evaluate?”

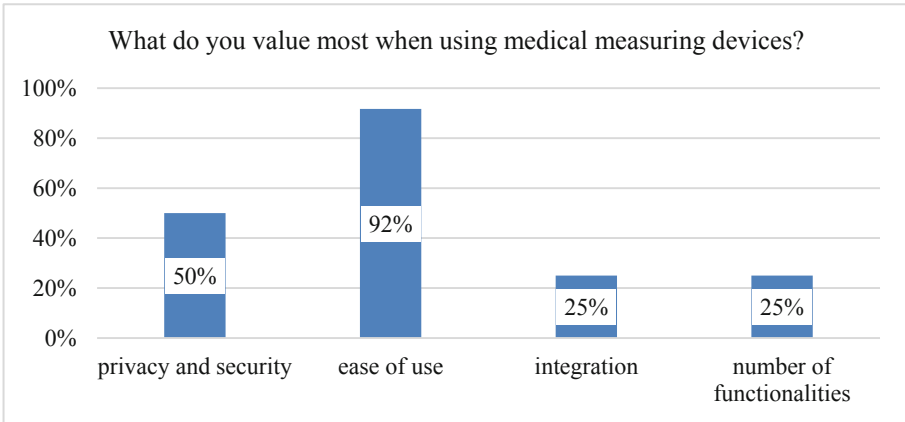


Fig. 7. Answers to the question “What do you value most when using medical measuring devices?”

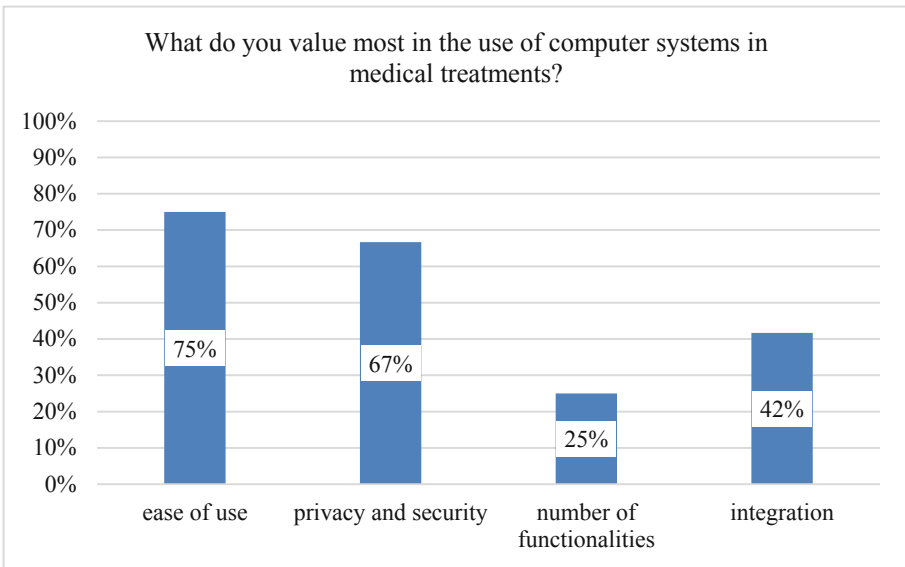


Fig. 8. Answers to the question “What do you value most in the use of computer systems in medical treatments?”

medical treatments?” presented in Figs. 7 and 8, respectively, revealed that most patients considered that the most important feature would be the ease of use and the security and privacy important for the medical treatments.

Related to the question “Would you like to contact your doctor in times of need using technology?” presented in Fig. 9, the answers showed that the patients would like to contact their doctor using technological equipment.

Finally, the question “Would you use teleconsultation/remote consultation?” presented in Fig. 10 showed that most patients would use teleconsultation/remote consultation.

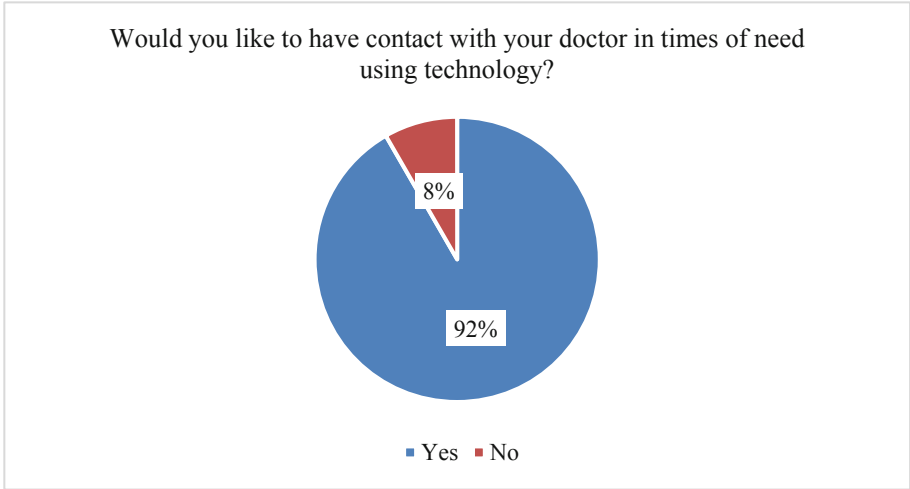


Fig. 9. Answers to the question “Would you like to have contact with your doctor in times of need using technology?”

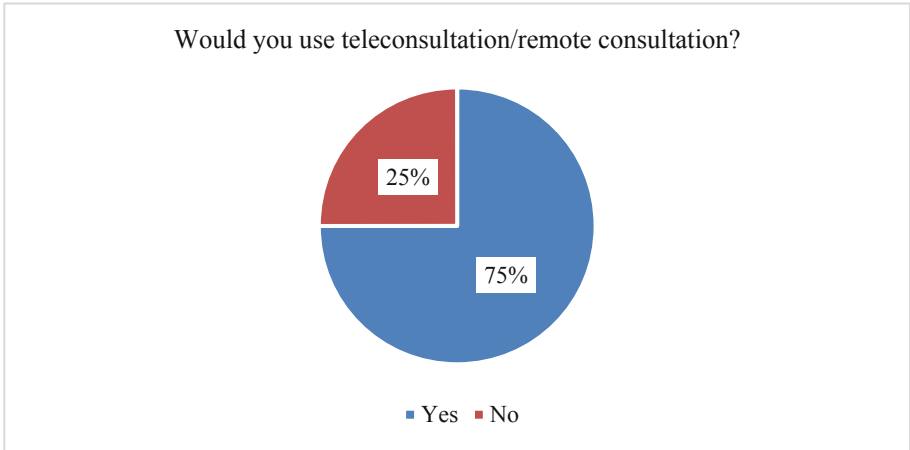


Fig. 10. Answers to the question “Would you use teleconsultation/remote consultation?”

5 Discussion and Conclusions

This study intends to analyze the use of remote technologies for improving the care of cardiovascular patients. It started with the analysis of previously developed studies regarding this subject.

The different studies analyzed were related to data acquisition and patient monitoring. However, the various authors did not present the data, applied methods, and data analysis methods. Furthermore, the different studies did not provide details about the contacts with the patients. Therefore, as part of this paper, the literature analysis was performed to plan a system for patient empowerment and monitoring, provide patient feedback, and educate the patients. However, as the significant intention of our study is related to the development of a system to promote patient autonomy, there are no studies related to this point. However, other authors already did a questionnaire to infer the patients' preferences presented in [20].

Based on the questionnaires, and similarly to the literature review, it is possible to verify that the preferred devices for the data acquisition are wearables/medical devices. Only mobile devices are chosen for data transmission, visualization, analysis, and the reception of feedback from healthcare professionals. Thus, the essential parameter selected by the patients is arterial pressure. However, two persons choose the use of computers as the preferred method of data transmission, and these persons also prefer alternative methods for visualization. However, for data visualization, one of them would like the use of mobile applications. Still, they would prefer the help of a website. Regarding the reception of feedback, one chooses mobile applications and websites to receive feedback, and the other prefers e-mails.

The previously analyzed work closely related to our work is presented by the authors of [14], which uses a standard mobile device to monitor the heart rate. In addition, other vital parameters should be monitored for the correct patient empowerment.

This study has some limitations since the questionnaire was self-administered. It may be an answer bias because some of the concepts of ignorance of some technologies' potential may not be understandable by the participants in the study. It may be one of the reasons that they are not selected. The questionnaire lacked the request for more patient data. Thus, we have a general idea of opinions with the data provided. Also, we cannot individualize the system as the knowledge about age would impact preferences.

Based on the opinions collected with the questionnaire, a system will be created to exploit technological equipment to help cardiovascular patients, promoting the patients' empowerment. The questionnaire results revealed that an informed patient would act in a specific moment of life and their treatments. Also, collecting a more significant number of subjects' variables should be considered, including technological habits.

Acknowledgements. This work is funded by FCT/MEC through national funds and, when applicable, co-funded by the FEDER-PT2020 partnership agreement under the project **UIDB/50008/2020**. (*Este trabalho é financiado pela FCT/MEC através de fundos nacionais e cofinanciado pelo FEDER, no âmbito do Acordo de Parceria PT2020 no âmbito do projeto UIDB/50008/2020*). This work is also funded by National Funds through the FCT - Foundation for Science and Technology, I.P., within the scope of the project **UIDB/00742/2020**. This article is based upon work from COST Action IC1303-AAPELE—Architectures, Algorithms, and Protocols for Enhanced Living Environments and COST Action CA16226—SHELD-ON—Indoor living space improvement: Smart Habitat for the Elderly, supported by COST (European Cooperation in Science and Technology). COST is a funding agency for research and innovation networks. Our Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. It boosts their research, career, and innovation. More information in www.cost.eu. Furthermore, we would like to thank the Politécnico de Viseu for their support.

References

1. Appelboom, G., et al.: Smart wearable body sensors for patient self-assessment and monitoring. *Arch. Public Health* **72**, 28 (2014). <https://doi.org/10.1186/2049-3258-72-28>
2. Brugts, J.J., et al.: A randomised comparison of the effect of haemodynamic monitoring with CardioMEMS in addition to standard care on quality of life and hospitalisations in patients with chronic heart failure Design and rationale of the MONITOR HF multicentre randomised clinical trial. *Neth. Hear. J.* **28**(1), 16–26 (2019). <https://doi.org/10.1007/s12471-019-01341-9>
3. Choi, W.S., Choi, J.H., Oh, J., Shin, I.-S., Yang, J.-S.: Effects of remote monitoring of blood pressure in management of Urban hypertensive patients: a systematic review and meta-analysis. *Telemed. E-Health* **26**, 744–759 (2020). <https://doi.org/10.1089/tmj.2019.0028>
4. Chow, C.K., Ariyaratna, N., Islam, S.M.S., Thiagalingam, A., Redfern, J.: mHealth in cardiovascular health care. *Heart Lung Circ.* **25**, 802–807 (2016). <https://doi.org/10.1016/j.hlc.2016.04.009>
5. Consolvo, S., McDonald, D.W., Landay, J.A.: Theory-driven design strategies for technologies that support behavior change in everyday life. In: *Proceedings of the 27th International Conference on Human Factors in Computing Systems - CHI 09*, p. 405. ACM Press, Boston, MA, USA (2009)
6. Cook, D.J., Augusto, J.C., Jakkula, V.R.: Ambient intelligence: technologies, applications, and opportunities. *Pervasive Mob. Comput.* **5**, 277–298 (2009). <https://doi.org/10.1016/j.pmcj.2009.04.001>
7. Di Lenarda, A., et al.: The future of telemedicine for the management of heart failure patients: a consensus document of the Italian association of hospital cardiologists (A.N.M.C.O), the Italian society of cardiology (S.I.C.) and the Italian society for telemedicine and eHealth (Digital S.I.T.). *Eur. Heart J. Suppl.* **19**, D113–D129 (2017). <https://doi.org/10.1093/eurheartj/sux024>
8. Escobar, L.J.V., Salinas, S.A.: e-Health prototype system for cardiac telemonitoring. In: *2016 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, pp. 4399–4402. IEEE, Orlando, FL, USA (2016)
9. Farias, F.A.C.D., Dagostini, C.M., Bicca, Y.D.A., Falavigna, V.F., Falavigna, A.: Remote patient monitoring: a systematic review. *Telemed. E-Health* **26**, 576–583 (2020). <https://doi.org/10.1089/tmj.2019.0066>
10. Francula-Zaninovic, S., Nola, I.A.: Management of measurable variable cardiovascular disease' risk factors. *Curr. Cardiol. Rev.* **14**, 153–163 (2018). <https://doi.org/10.2174/1573403X14666180222102312>
11. Griffin, P.M., Nembhard, H.B., DeFlitch, C.J., Bastian, N.D., Kang, H., Munoz, D.A.: *Healthcare Systems Engineering*. John Wiley & Sons, Hoboken (2016)
12. Hermans, A.N.L., et al.: Long-term intermittent versus short continuous heart rhythm monitoring for the detection of atrial fibrillation recurrences after catheter ablation. *Int. J. Cardiol.* **329**, 105–112 (2021). <https://doi.org/10.1016/j.ijcard.2020.12.077>
13. Hickey, K.T., et al.: A single-center randomized, controlled trial investigating the efficacy of a mHealth ECG technology intervention to improve the detection of atrial fibrillation: the iHEART study protocol. *BMC Cardiovasc. Disord.* **16**, 152 (2016). <https://doi.org/10.1186/s12872-016-0327-y>
14. Iftikhar, Z., et al.: Multiclass classifier based cardiovascular condition detection using smart-phone mechanocardiography. *Sci. Rep.* **8**, 9344 (2018). <https://doi.org/10.1038/s41598-018-27683-9>
15. Negarandeh, R., Zolfaghari, M., Bashi, N., Kiarsi, M.: Evaluating the effect of monitoring through telephone (Tele-Monitoring) on self-care behaviors and readmission of patients with

- heart failure after discharge. *Appl. Clin. Inform.* **10**, 261–268 (2019). <https://doi.org/10.1055/s-0039-1685167>
16. Omboni, S.: Connected health in hypertension management. *Front. Cardiovasc. Med.* **6**, 76 (2019). <https://doi.org/10.3389/fcvm.2019.00076>
 17. Omboni, S., Caserini, M., Coronetti, C.: Telemedicine and M-Health in hypertension management: technologies, applications and clinical evidence. *High Blood Press. Cardiovasc. Prev.* **23**(3), 187–196 (2016). <https://doi.org/10.1007/s40292-016-0143-6>
 18. Omboni, S., Panzeri, E., Campolo, L.: E-Health in hypertension management: an insight into the current and future role of blood pressure telemonitoring. *Curr. Hypertens. Rep.* **22**(6), 1–13 (2020). <https://doi.org/10.1007/s11906-020-01056-y>
 19. Omboni, S., et al.: Vascular health assessment of the hypertensive patients (VASOTENS) Registry: study protocol of an international, web-based telemonitoring registry for ambulatory blood pressure and arterial stiffness. *JMIR Res. Protoc.* **5**, e137 (2016). <https://doi.org/10.2196/resprot.5619>
 20. Parati, G., Dolan, E., McManus, R.J., Omboni, S.: Home blood pressure telemonitoring in the 21st century. *J. Clin. Hypertens* **20**, 1128–1132 (2018). <https://doi.org/10.1111/jch.13305>
 21. Piotrowicz, E.: The management of patients with chronic heart failure: the growing role of e-Health. *Expert Rev. Med. Devices* **14**, 271–277 (2017). <https://doi.org/10.1080/17434440.2017.1314181>
 22. Smyth, J.M., Smyth, J.M.: Ecological momentary assessment research in behavioral medicine. *J. Happiness Stud.* **4**, 35–52 (2003). <https://doi.org/10.1023/A:1023657221954>
 23. Vogt, H., Hofmann, B., Getz, L.: The new holism: P4 systems medicine and the medicalization of health and life itself. *Med. Health Care Philos.* **19**(2), 307–323 (2016). <https://doi.org/10.1007/s11019-016-9683-8>
 24. WHO (2016) Cardiovascular diseases (CVDs). [https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-\(cvds\)](https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)). Accessed 5 April 2021