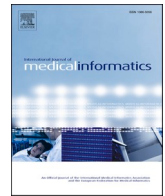




Contents lists available at ScienceDirect

International Journal of Medical Informatics

journal homepage: www.elsevier.com/locate/ijmedinf

Design and deployment of ODISEA, an application for the myOcarDial infarction SafEtytrAnsfer of patients

Antonio Rodríguez^a, Jaime Aboal^b, Pablo Loma-Osorio^b, Rafel Ramos^c, Imma Boada^{a,*}

^a Graphics and Imaging Laboratory, University of Girona, Girona, Spain

^b Hospital Universitari Josep Trueta, Girona, Spain

^c Department of Medical Sciences, School of Medicine, University of Girona, Spain

ARTICLE INFO

Keywords:

Acute ST-elevation myocardial infarction (STEMI)
Infarct protocol
Cardiology
Web and mobile-based applications

ABSTRACT

Background: Rapid primary angioplasty is the most effective reperfusion strategy for acute ST-elevation myocardial infarction (STEMI) patients. Since not all hospitals have a catheterization laboratory to perform this intervention, adequate coordination of all medical professionals involved in the management of STEMI patients from the emergency room to the hospital catheterization laboratory is necessary.

Objective: Present the design and deployment of ODISEA (acronym of myOcarDial Infarction SafEtytrAnsfer), a web-based environment plus an application created to complement and support the transfer and management of STEMI patients from the first medical contact to the catheterization laboratory where the primary angioplasty will be carried out.

Method: ODISEA is an application that has been designed to improve the coordination of all health personnel involved in the management of STEMI patients, i.e., primary care hospitals, Emergency Medical Services [EMS] and cardiology departments. The application provides: (i) functionalities to register relevant information of the patients' and the administered medications, (ii) a chat to coordinate all involved personnel; (iii) treatment recommendations for the first medical contact; and (iv) a GPS-SATELLITE monitoring system to know the exact position of the ambulance during patient transfer. These features improve the coordination in the catheterization laboratory, and optimize the equipment preparation time, and also the patient accommodation procedures after primary angioplasty. ODISEA registers all treated cases for a proper follow-up. The application has been tested from September 2021 to January 2022 in the context of a pilot study in Girona that involved 98 patients and 42 professionals (11 from hospital without Cath lab availability, 21 from EMS, and 10 from the main hospital). Professionals answered a questionnaire using a five-point Likert scale (satisfaction level from 1 to 5) to assess ODISEA regarding patient management, care quality, transfer coordination, transfer effectiveness, and usefulness. Collected data was analyzed using chi-square or Fisher's exact test. Statistical significance has been considered $p < 0.05$. To evaluate times of first angioplasty, relevant data from 98 patients was collected and compared with data of 129 STEMI patients not treated with ODISEA.

Results: For all the questions >70 % of answers are in the 3 to 5 range and from these, almost all the questions have 50 % of answers in the 4 and 5 range. Regarding groups of professionals only in the question related to coordination significant difference has been found for EMS professionals with respect to hospital without Cath lab availability and catheterization hospital professionals. Comparing ODISEA with no ODISEA patients it was observed an improvement in the times of first angioplasty as well as a reduction in the erroneous infarction codes activation. Patients treated with the ODISEA APP were further away from the PCI-capable center. A non-significant tendency was seen towards shorter primary angioplasty times (diagnostic electrocardiogram-guidewire passage) in the ODISEA compared to the NON ODISEA group (112 min vs 122 min; $P = .3$), a non-significant reduction of cases with times > 120 min (26.2 % vs 35.7 %, respectively; $P = .1$), and a tendency towards fewer cases eventually diagnosed as non-acute coronary syndrome (7.1 % vs 13.2 %; $P = .1$).

Conclusion: ODISEA is a very well-accepted application that improves the management of STEMI patients. The application is an appropriate complement to current infarction protocol.

* Corresponding author.

E-mail address: imma.boada@udg.edu (I. Boada).

1. Introduction

An acute ST-elevation myocardial infarction (STEMI) is an event in which transmural myocardial ischemia results in myocardial injury or necrosis [1]. Rapid myocardial reperfusion is decisive in the STEMI patients since the death risk increases by 7.5 % every 30 min of treatment delay [2]. To improve clinical outcomes, it is critical to reduce the total ischemic time being fundamental the assessment and treatment from the first moment. For this reason, a proper coordination of all medical services involved in the management of STEMI patients, from the emergency location to the catheterization laboratory of the hospital, is mandatory. Unfortunately such a coordination can be difficult because of different health profiles that intervene. On the one hand, the general practitioner that receives the emergency call after patient suffers chest pain. On the other hand, the ambulance paramedic that transfer the patient to the catheterization laboratory. Finally, the personnel from the catheterization laboratory that will perform a primary angioplasty. For the sake of correct treatment and patient security, it is necessary a proper communication between all them and web-based, smartphone, and tablet applications can be very valuable.

In the last years, several smartphone and tablet applications for cardiology have been proposed. Nguyen and Silva [3] reviewed the potential of smartphone technologies in cardiology care focusing on functionalities for the active patient participation in their own care, the raise patient awareness, the promotion of early diagnosis, and the accurately outcomes prediction. Hamilton et al. [4] presented a systematic review that examines smartphone interventions for comprehensive cardiac and heart failure rehabilitations, service and patient outcomes management, and control of cardiac patients in rural and remote locations. Dorje et al. [5] investigated whether a smartphone and social media-based home cardiac rehabilitation and secondary prevention program can facilitate risk factor monitoring and modification to improve disease self-management and health outcomes in patients with coronary heart disease after percutaneous coronary intervention therapy. Kotecha et al. [6] demonstrated the value of integrating novel digital technology into clinical practice, with the potential for patient engagement, optimization of pharmacological and interventional therapy in atrial fibrillation, and its contribution to patient outcomes improvements. Astarcioğlu et al. [7] assessed the efficacy of WhatsApp application as a communication method among the emergency physician in a rural hospital without percutaneous coronary intervention capability and the interventional cardiologist at a tertiary center. Similarly, Chao et al. [8] evaluated the use of a smartphone application to facilitate communication between the emergency physician and the interventional cardiologist in order to minimize the time to cardiac catheterization laboratory activation and the time to percutaneous

coronary intervention. Park et al. [9] evaluated how the use of a smartphone social network system in a regional STEMI network can reduce the ischemic time. Focused on STEMI management, Dickson et al. [10] proposed STOP-STEMI an application to improve the coordination of STEMI care and Krishnamoorth [11] proposed an HIPAA compliant app for the transfer of patients with STEMI.

Inspired by the satisfactory results of related applications, the ODISEA application, which stands for myOcarDial Infarction SafEtytrAnsfEr patients, is proposed. The application aims to complement the infarct code protocol of our country in order to support and control the management of STEMI patients from the emergency location to the catheterization laboratory where the primary angioplasty will be carried out. With this objective, the application will provide: (i) functionalities to improve the coordination of all health personnel involved in the management of STEMI patients via chat and registration of relevant information and administered medications; (ii) treatment recommendations to the first medical contact; and (iii) GPS-satellite monitoring system, enabling to know the exact position during patient transfer with the ambulance. These features will improve the coordination in the catheterization laboratory, and will optimize the equipment preparation time, and also the patient accommodation procedures after primary angioplasty. In addition, shorter primary angioplasty times will be achieved and unnecessary transfers will be avoided.

The aim of this paper is threefold: (i) Present the design and development process of ODISEA application; (ii) Evaluate the professional experience using the application in a pilot study; and (iii) Evaluate performance and effectiveness of the application comparing patients treated with ODISEA with no ODISEA patients.

2. Method and materials

In this section the different phases of the ODISEA design and development process will be described. Firstly, the general analysis and requirements gathering will be presented, secondly, the application design process, and finally, the application deployment, and testing.

2.1. General analysis and requirements gathering

To define the requirements of our application, the infarction code applied in our country [12] was considered. The infarction code is an urgent protocol that includes the activation of a series of assistive devices that allow emergency care in acute phase of disease when a patient is suspected of having a heart attack and is a candidate for immediate reperfusion. Since not all the hospitals of our country have a catheterization laboratory, the protocol aims to ensure the proper attention of the patient until the target hospital (the one with the laboratory) is reached.

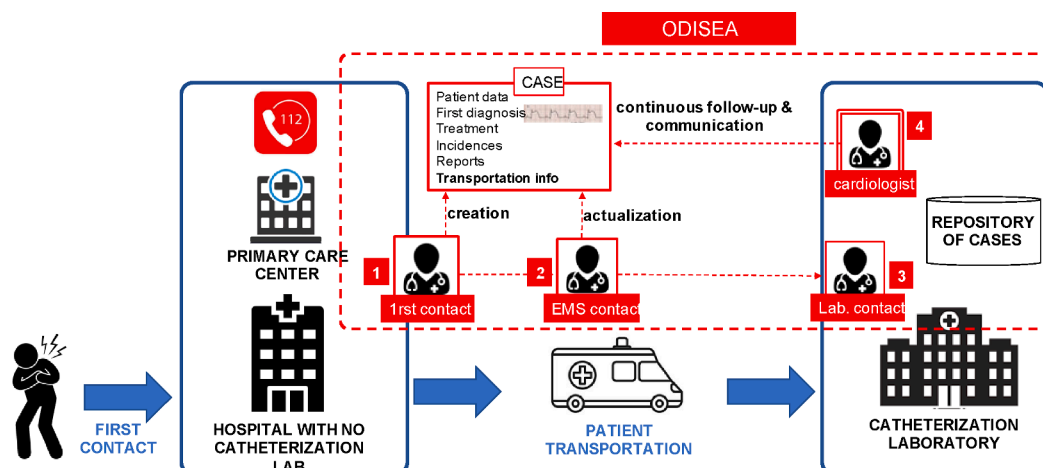


Fig. 1. The Infarction Code protocol with all involved actors and the support provided by the ODISEA application.

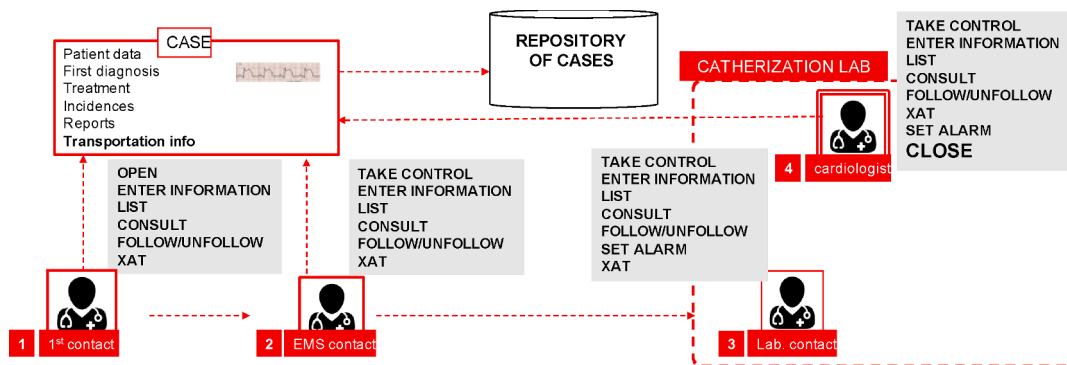


Fig. 2. The different actions that can be carried out using ODISEA application according to the user profile.

The aim of ODISEA is to complement this protocol with an application that provides expert physician oversight and support from the moment that the code is activated until the patient arrives to the catheterization laboratory to perform primary angioplasty. For this reason, to define the requirements of the application this protocol was our first focus of interest.

2.2. The infarction code protocol

The Infarction Code protocol, illustrated in Fig. 1, is activated from the moment a person who presents symptoms of a possible heart attack comes in contact with the Emergency Medical System (EMS), either because the patient calls the 112 or because of primary care or a hospital with no catheterization laboratory calls EMS. The EMS sends an advanced life support unit to the patient's location. Once with the patient, emergency medical professionals perform an electrocardiogram, which is the basic diagnostic test [13]. If the diagnostic suspicion is confirmed and the person has to be treated at the hospital with a catheterization laboratory, the EMS professionals transmit the results of the electrocardiogram to the Central Health Coordination, which, in turn, sends to the cardiologist of the catheterization laboratory to confirm STEMI case and starts the transfer to perform primary angioplasty. The EMS professional in the ambulance, following advice from the cardiologist, can administrate treatment if it is necessary inside the ambulance. If it has been previously agreed, in the hospital, the patient does not stop at the emergency department, but enters catheterization laboratory directly. There the doctor is waiting for the patient with the electrocardiogram, the case information, and ready to perform percutaneous coronary intervention to restore the flow in coronary artery.

2.3. Application user profiles

From the infarction code description, the three user profiles that have to be supported have been identified. ODISEA users will be: (i) the EMS professionals; (ii) the primary care professionals (from a primary care center of a hospital with no catheterization laboratory), and (iii) the nurses and doctors, from the catheterization laboratory of the infarction reference hospital. All these users will have access to the application via username and password.

2.4. The case

The main element of the application will be the case where all the relevant information of the patient, the diagnosis, and the treatment will be registered and recorded in the application database. Particularly, a case will be composed of five blocks:

- Patient data. This block will contain a form with different fields to enter the relevant data. To describe the fields for each one of them the information that has to be entered by the user is presented in

brackets. These fields are: the patient's name and surname (text); the birth date (date); the medical identifier (number); the EMS identifier assigned when the EMS takes the patient control of (number), and the patient sex (choose option). Note that depending on the status of the patient it may be difficult to fill some of the fields.

- Diagnostic. This block will contain the information of the first diagnosis. This will be entered in a form with the following fields: the image of the pre-hospital electrocardiogram (image); the place from where the first contact has been done (choose option from home or public space, primary care, or hospital with no hemodynamic unit); time of electrocardiogram diagnostic (date); the infarct location (choose option from anterior, posterior, inferior, lateral or no located); the Killip level at admission (choose option from I to V to classify the heart failure degree); previous bypass surgery (mark option); and sudden death (mark option). In this block there will also be an access to the chat of the case where the personnel involved in the case can text. The text of this chat will be recorded in the application database with the case.
- Treatment. This block will maintain the treatment that can be administered before hospital arrival and during transportation to the hospital. Treatments are grouped as: no treatment, primary angioplasty, and fibrinolysis. Once the case has been selected, a form is presented with different options including: defibrillator near of patient, oxygen therapy, nitroglycerine, opioids, control of blood glucose, antiaggregation treatment (aspirin or lysine aspirin, clopidogrel, prasugrel or ticagrelor), and anticoagulation treatment (unfractionated heparin).
- Incidences. This block will maintain incidences during transportation to the hospital. The incidences will be presented as mark options including: need for tracheal intubation; ventricular tachycardia; ventricular fibrillation; complete AV block; cardiorespiratory arrest; need for inotropic drugs; need for vasopressor drugs; cardiogenic shock; and acute pulmonary edema.
- Reports. This block will maintain an intermediate and a final report. The intermediate report will be generated when the user that controls the case left it. This report will contain the information related to EMS transfer, hospital arrival, code infarct cancellation, patient death, or if control has been passed to another user. The final report will be generated by the hemodynamic cardiology and will contain the following information: if it was an infarct code or not; if a primary angioplasty was performed in the culprit artery; type of stent implanted; and the final blood flow in the culprit artery (TIMI score); time of primary angioplasty (first medical contact to cross guire in culprit artery); patient destination; if fibrinolytic was the reperfusion option; needle time and the effectiveness of the treatment and if a rescue angiography has been necessary or not.
- Transportation information. This last block will maintain the location of the patient on the way to the hospital and also the remaining time to arrive. These information will be automatically obtained

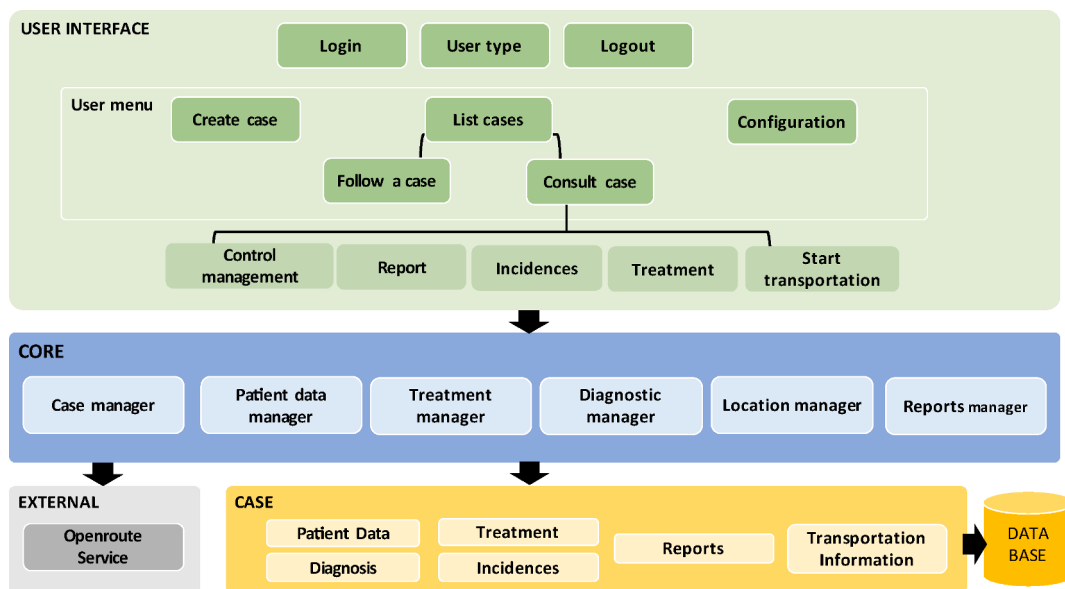


Fig. 3. The three-level architecture of ODISEA application with its main components.

from the application via GPS. Once the transportation of the patient starts, the Init option will initialize the route and also the GPS.

2.5. The case management

Since the case is the key element of the application, the provided actions will be related to the cases. To manage the cases the following actions will be supported (see Fig. 2):

- Open case. This action will create and register a new case in the application database. To enter the information of the case, as it was described, different forms will be presented to enter patient data, treatment, and diagnosis. This Open action will be carried out by personnel from the primary care center, from the hospital with no catheterization laboratory, or from the EMS. The user that opens the case will have the control of the case until another user takes it off. At each moment, only one owner of the case will be possible.

- List cases. This action will list the cases where the user has participated and also the unfollowed cases. To follow a case the Follow option has to be selected.
- Consult cases. This action will allow to consult the followed cases. The actions that can be carried out with the case will depend on the state of the case. Particularly, a user with the control of the case will be able to: left the control; modify the information, the treatment, the incidences, or the related chat; start the transfer to the hospital with catheterization laboratory (if the user is from EMS); and close the case (in case of being a cardiologist from the reference hospital). A user that has left the control of the case will be able to: take the control again; consult the information of the case; and consult the chat. A user that has lost the control will be able to: select the reasons of the lost from a list with different options such as hospital arrival, patient death, etc.; take the control; consult the information; and participate in the chat. Finally, if the case is closed the user will be able to consult the information of the case.

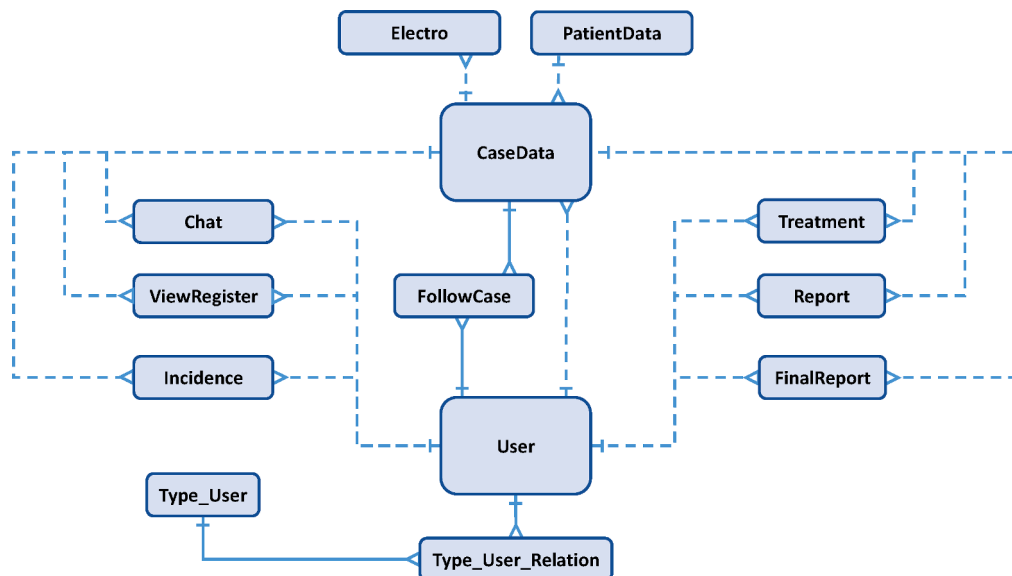


Fig. 4. The schema for the ODISEA data base.

- Take Control. This action will give the control of the case to another user. Remind that there will be a unique owner of the case, the unique that will be able to modify it.
- Close case. This action will be carried out by the cardiologist from the catheterization laboratory of the reference hospital to close the case. In this case the final report of the case will also be generated.

In addition, the cardiologist and nurses from the reference hospital can set the alarm to know when the patient is at some minutes far from the hospital. The number of minutes will also be set by these users. They can also list the cases that are on the way and consult their related information. The doctors can see all the information of the case and interact while the nurses only can consult the information.

2.6. Final considerations

As final considerations, our application has to be responsive, and with support to different languages. In addition, its design has to be modular to allow the integration of new functionalities in an easy way completely transparent to the users. The application has to ensure General Data Protection Regulation (GDPR) compliance as required in the European Union.

2.7. Application design process

Taking into account all these requirements and the different users profiles information, the three-level architecture illustrated in Fig. 3 and described below is proposed.

From top to bottom, the first level maintains the user interfaces where after identification and user profile selection, the main options of the application are available for the user.

These options include: Create case, List cases with two sub-menus one to follow a case and another to consult the case. The case consultation also provides a set of sub-options to control management, access to the case reports, the incidences, and the treatment. It can also access the transportation information to start transport. The Configuration option allows to define parameters such as language and also define the alarm to receive a message when the patient is a few minutes away from the hospital.

The second level is the core of the application where the modules to manage the cases, and the data, the treatment, and the diagnosis information of the patient are codified. In addition. there are the modules to control the GPS satellite to indicate at every moment the position of the patient. There is also a report manager to control the different reports that can be generated. Note that the GPS is controlled via an external module that provides the Openroute Service [14] via an https connection.

The third level maintains all the data of the application in a database. The schema of this database is illustrated in Fig. 4. The main tables of the database are: the User table which registers all the users that can access to the application. The users are classified according to their profile that determines the functions that they can carry out. The CaseData is the second table which maintains all the PatientData and also the electrocardiogram. The relationship between User and CaseData is stored in the Treatment and Final Reports, and also in the Chat, ViewRegister, and Incidence tables. Note that there is also a control via FollowCase table to identify the CaseData followed by a User.

For more details on the design and coding please see Appendix A.

2.8. Pilot trial and application evaluation

The first prototype, which supports Catalan, Spanish and English languages, has been tested simulating different cases and situations to ensure the robustness and the correct performance of the application and to guarantee that all identified requirements are met. Experts covering all the profiles involved in the STEMI procedure have

Table 1

The answers for each question grouped per question and participants profiles and the p-values.

	Hospital without Cath lab availability	Angioplasty Hosp.	EMS	p. overall
Participants	(N = 11)	(N = 10)	(N = 21)	
Q1. ODISEA provides a quicker management of CODI IAM patients?				0.29
1	0 (0.00 %)	0 (0.00 %)	4 (19.0 %)	
2	2 (18.2 %)	1 (10.0 %)	6 (28.6 %)	
3	2 (18.2 %)	1 (10.0 %)	5 (23.8 %)	
4	2 (18.2 %)	3 (30.0 %)	3 (14.3 %)	
5	5 (45.5 %)	5 (50.0 %)	3 (14.3 %)	
Q2. ODISEA improves my quality of STEMI patient care?				0.01
1	0 (0.00 %)	0 (0.00 %)	2 (9.52 %)	
2	0 (0.00 %)	1 (10.0 %)	6 (28.6 %)	
3	1 (9.09 %)	0 (0.00 %)	7 (33.3 %)	
4	3 (27.3 %)	3 (30.0 %)	3 (14.3 %)	
5	7 (63.6 %)	6 (60.0 %)	3 (14.3 %)	
Q3. ODYSEA improves the coordination of STEMI patients transfer?				0.10
1	0 (0.00 %)	0 (0.00 %)	1 (4.76 %)	
2	1 (9.09 %)	1 (10.0 %)	5 (23.8 %)	
3	2 (18.2 %)	0 (0.00 %)	3 (14.3 %)	
4	1 (9.09 %)	2 (20.0 %)	8 (38.1 %)	
5	7 (63.6 %)	7 (70.0 %)	4 (19.0 %)	
Q4. ODISEA enhances my effectiveness in STEMI patients transfer?				0.03
1	0 (0.00 %)	1 (10.0 %)	4 (19.0 %)	
2	1 (9.09 %)	0 (0.00 %)	6 (28.6 %)	
3	1 (9.09 %)	0 (0.00 %)	5 (23.8 %)	
4	3 (27.3 %)	3 (30.0 %)	3 (14.3 %)	
5	6 (54.5 %)	6 (60.0 %)	3 (14.3 %)	
Q5. ODISEA makes my job easier?				0.07
1	0 (0.00 %)	0 (0.00 %)	5 (23.8 %)	
2	1 (9.09 %)	0 (0.00 %)	4 (19.0 %)	
3	1 (9.09 %)	1 (10.0 %)	4 (19.0 %)	
4	3 (27.3 %)	2 (20.0 %)	5 (23.8 %)	
5	6 (54.5 %)	7 (70.0 %)	3 (14.3 %)	
Q6. ODISEA is useful in my job?				0.14
1	0 (0.00 %)	0 (0.00 %)	4 (19.0 %)	
2	0 (0.00 %)	1 (10.0 %)	2 (9.52 %)	
3	1 (9.09 %)	0 (0.00 %)	6 (28.6 %)	
4	4 (36.4 %)	4 (40.0 %)	4 (19.0 %)	
5	6 (54.5 %)	5 (50.0 %)	5 (23.8 %)	

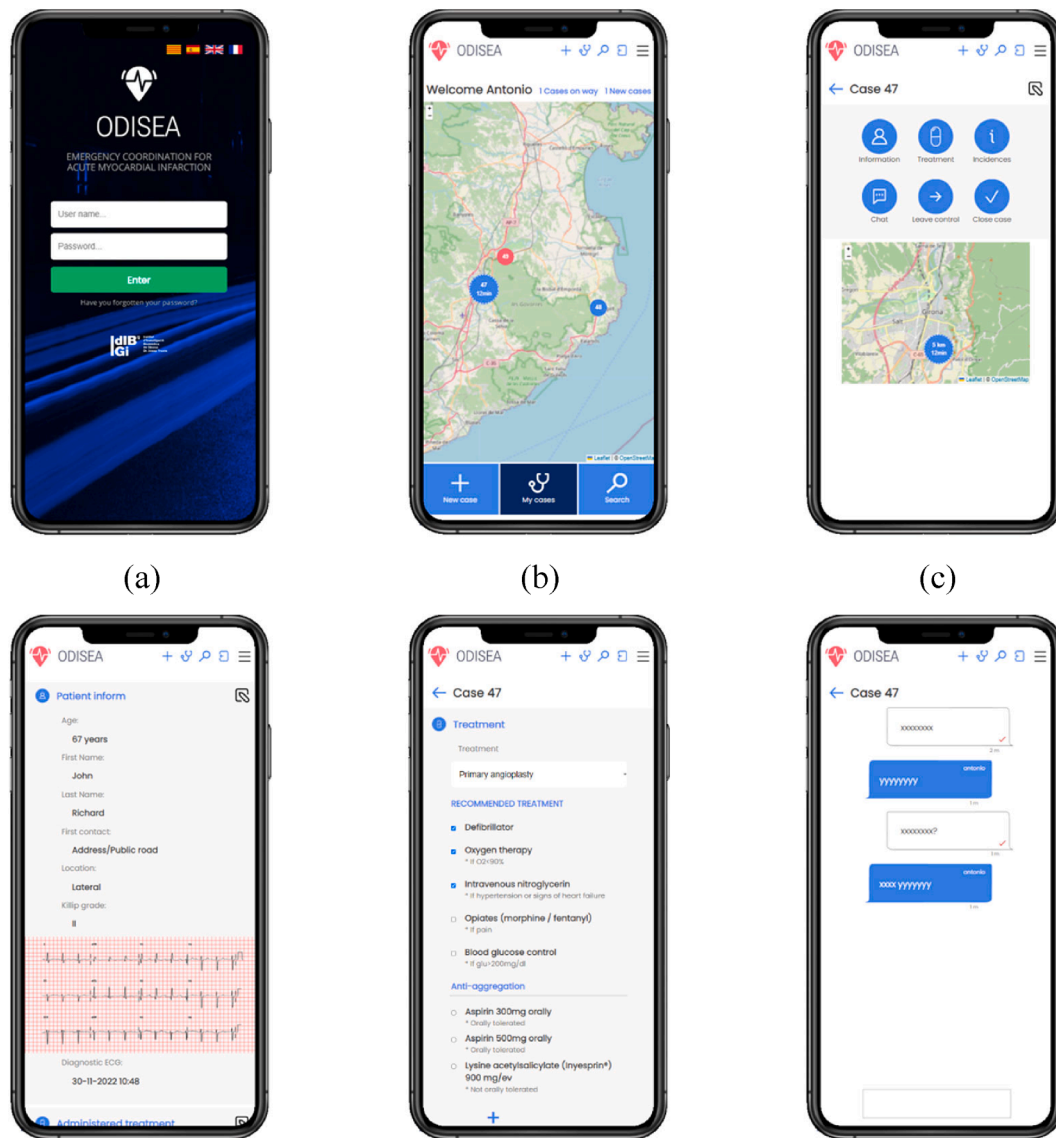


Fig. 5. ODISEA app screenshots of English version corresponding to simulated cases: (a) Identification screen to enter the application and select language; (b) Screen with the access to cases which are placed on the map. On road cases added to the identifier show the distance to the hospital in minutes. Color information indicates if the case is followed by the current user (blue) or not (red); (c) Menu to access to all the information of one selected case; (d) and (e), information and treatment of the patient; and (f) Chat between STEMI professionals. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

participated in this test phase. Once the correct performance has been proved the deployment and pilot trial in a real scenario has started.

ODISEA was deployed in a pilot trial conducted in Girona’s health area. This has six hospitals without catheterization laboratory, a Medical Emergency System to transfer patients, and one reference hospital capable to perform primary angioplasty, the Hospital Universitari de Girona Dr. Josep Trueta. The trial involved 42 participants from which 12 are professionals from hospitals without catheterization laboratories, 21 are EMS professionals, and 10 from the reference hospital. All the participants have a tablet or a cell phone with the app and also with access to the ODISEA web. They have all received a tutorial explaining the application and its features. The pilot trial period was from September 2021 to January 2022. At the end of this period participants answered a questionnaire (see Table 1) to evaluate ODISEA regarding patient management, care quality, transfer coordination, transfer effectiveness, and usefulness perceived usefulness of technological context. To answer the Likert scale (1. Strongly disagree; 2. Disagree; 3. It will not affect; 4. Agree; 5. Completely agree) was used.

2.9. Statistical analysis

Answers were analyzed with R software [20] using the Compar-eGroups module [21]. Categorical variables are expressed as frequencies and percentages and quantitative variables as mean and standard deviation (SD). The association between the categorical variables was analyzed using the chi-squared test or Fisher’s exact test, with continuity correction when necessary. Quantitative variables were analyzed using Student’s *t*-test.

Statistical significance has been considered $p < 0.05$.

3. Results.

ODISEA app screenshots of English version corresponding to a simulated case are presented in Fig. 5. From left to right, Image (a) is the identification screen where the user has to enter name, password and select the language. Previously, the administrator has registered and assigned a profile to this user. Image (b) illustrates a map with active

Table 2
Comparison of data from ODISEA versus NO ODISEA patients.

	ODISEA	NO ODISEA	p-value
Number of patients	98	129	
Age (Median, Standard deviation)	61 (13.9)	63 (13.1)	0.17
% Female	21.4 %	24.8 %	0.55
% Smoking	44.9 %	38.8 %	0.35
% Arterial Hypertension	49 %	45.7 %	0.62
Dyslipemia n%	34.7 %	41.9 %	0.27
Diabetes mellitus n%	18.4 %	24 %	0.30
Previous acute myocardial infarction	16.3 %	12.4 %	0.40
Previous Cardiac Surgery n%	2.1 %	1.6 %	0.44
Anterior Localization n%	39.8 %	33.3 %	0.31
Killip > 2n%	5.1 %	6.2 %	0.72
First contact place			0.58
Emergency Medical System	35.7 %	30.2 %	
Primary Care Center	28.6 %	27.9 %	
No cath lab hospital	35.7 %	41.9 %	
Distance in Km (media DE)	42(19.3)	36 (21.7)	0.21
Sudden death n%	1 %	0.8 %	0.84
Time of ECG STEMI diagnosis to wire crossing (minutes) (median/ standard deviation).	112 (28)	122 (24)	0.38
(Time ECG diagnostic- time wire crossing) > 120 min.	26.2 %	35.7 %	0.18
Erroneous acute myocardial infarction code	7.1 %	13.2 %	0.12

cases and its locations on a map. For each case, the application shows the code and for cases that are on road the distance in minutes to the hospital. A code of colors is used to show followed cases (in blue) and the unfollowed ones (in red). When the user selects a case by clicking on the map the menu of Image (c) to access case options appears. Images (d) and (e) correspond to information of the patients and the treatment, respectively. Finally, an example of the chat screen to communicate the STEMI professionals.

The results of the questionnaire are presented in Table 1 where for each question the percentages of answers in each group are shown. Note that p-value compares the frequency of responses according to the type of doctor. From Table 1, it can be seen that for all the questions >70 % of answers are in the 3 to 5 range. From these, almost all the questions have 50 % of answers in the 4 and 5 range. The best results are obtained in Question 3, participants considered that ODISEA improves the coordination of STEMI patients. The lower results, although being positive, are obtained in Question 1 which indicates that ODISEA could be more quicker. No significant differences have been detected between groups of experts except for Question 3. From the questionnaires of this first pilot study it has been seen that the best results have been obtained for the hospitals personnel from both the primary and the reference one. Focusing on the first, they commented that the application makes them to feel more supported and confident. It is reassuring for them having the direct contact with experts from the reference hospital. Personnel from reference hospital considered the application a good strategy to optimize resources and time. They specially highlight the possibility to know the relevant information previous to patient arrival and also the GPS functionality that makes planification easier providing a better attention. SEM personnel were receptive with ODISEA but they complain about the need of entering duplicate information. The fact is that EMS has its own application for the patient management and some of the fields required by ODISEA are coincident. For the final deployment both applications will be connected and redundant data will be avoided. In the pilot study, it was not possible. The results indicate that ODISEA is a good complement to current protocol.

In addition, since the application maintains a register of all the cases different performance metrics have been evaluated considering patients treated with ODISEA and the ones of the same period that have been treated with NO ODISEA. The most relevant data has been summarized in Table 2. It can be seen that no significant differences were reported between both groups regarding the patient's past medical history, the

infarction location, the Killip grade or the place where the first medical contact occurred. Statistically speaking, patients treated with the ODISEA APP were further away from the PCI-capable center. A non-significant tendency was seen towards shorter primary angioplasty times (diagnostic electrocardiogram-guidewire passage) in the ODISEA compared to the NON ODISEA group (112 min vs 122 min; $P = .3$), a non-significant reduction of cases with times > 120 min (26.2 % vs 35.7 %, respectively; $P = .1$), and a tendency towards fewer cases eventually diagnosed as non-acute coronary syndrome (7.1 % vs 13.2 %; $P = .1$).

4. Discussion.

Compared to state-of-the-art, two applications need to be mentioned. The first one is STOP STEMI, proposed by Dickens et al. [10] and developed to enhance the coordination and management of STEMI patients. Once a case is activated, the application alerts all the members of the STEMI care team giving access to the patient electrocardiogram and other relevant information. Although, this application does not provide information of patient position or communication channels between members of the team, an special mention has to be done for being the first one to be proposed to support STEMI management. The second application is STEMIcathAID, proposed by Krishnamoorthy et al. [11]. This mobile app optimizes care for STEMI patients and facilitates electronic extraction of relevant performance metrics to improve allocation of resources and reduction of costs. The application provides, among others, communication tools including phone and video calls, image transfer, and chat functionality, GPS tracking and different functionalities for the proper patient follow-up. It is a very complete application with functionalities very similar to the ODISEA ones. However, STEMIcathAID seems to be designed as a substitute for current STEMI management protocol while our application it has been designed to complement the current protocol of our medical region. The similarity of both applications and the good results achieved with STEMIcathAID encourages us to extend the use of our application to a greater territorial area. Our aim is to distribute ODISEA to the different medical regions of our country. These have their own infrastructures to maintain the application and hence no scalability limitations are expected. ODISEA uses a free version of the map to locate the patients which limits the number of queries to two thousand. This limitation can be solved with the paid version. Regarding security all required protocols have been applied.

5. Conclusions and future work

ODISEA is a new application created to complement the infarct code protocol of our country. It has been tested in a pilot study and it has been seen that professionals, specially from the hospitals with no catheterization laboratory, feel more confident with the application. Although an evaluation with more patients and professionals is required the first obtained results are very satisfactory intervention times are reduced.

6. Summary table

What was already known on the topic.

- The management of STEMI patients involves different health profiles
- Technology-based application can complement the management of STEMI patients

What this study added to our knowledge.

- A proper communication between all personnel involved in the management of STEMI patients reduces the times of first angioplasty and also the number of erroneous infarction codes.

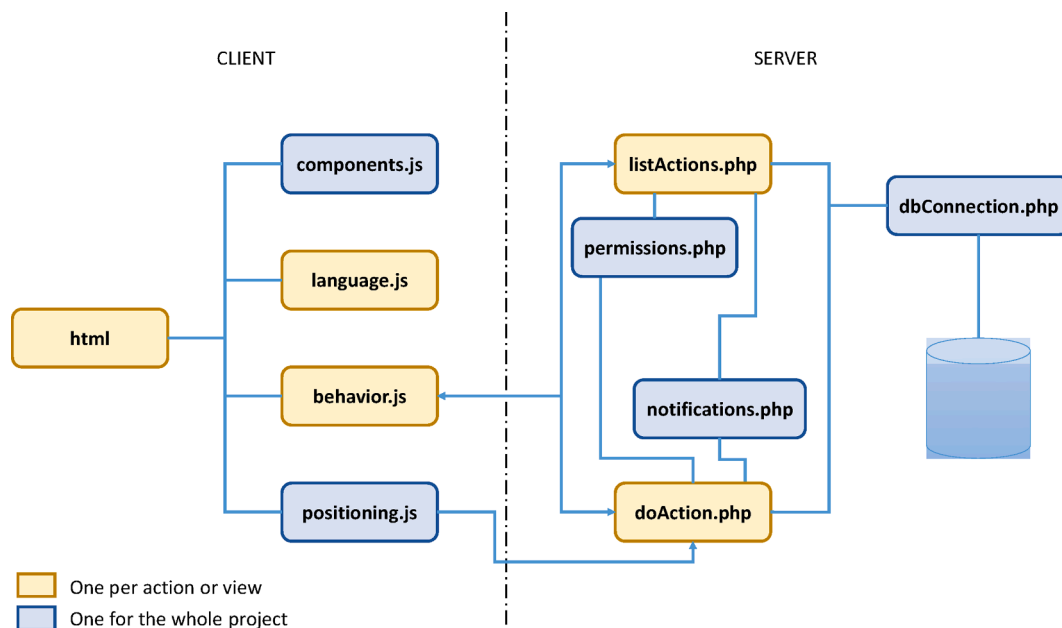


Fig. A1. The model-view-controller pattern applied for the ODISEA design.

- Professionals, specially from the hospitals with no catheterization laboratory, feel more confident with the support of mobile applications.

7. Ethics

The Ethics Committee of Research with Medicines (CEIM) approved the ODISEA study on the meeting of June 10, 2021.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This work was supported by the Spanish Government (Grant No. PID2019-106426RB-C31).

Appendix 1. .

Focusing on the design, as it is illustrated in Fig. A1, the application follows a model-view-controller design pattern. The view side maintains all the html files with the user views and a JavaScript file for each view. The language.js module maintains the different languages supported by the application. There is also a component.js module with the components of the different web pages. The controller side is composed of client and server parts. The client side maintains for each html file the behaviour.js file which is responsible of web page behaviour and server communication. When the web page is loaded it is asked to the server the information that has to be shown to the user. The communication is done via listActions.php, a PHP specific of each html page. Once the action has been selected by the user, the behavior.js file via doAction.php performs the action. This last file is also specific for each html file. For the correct server performance, there are two global files permissions.php and notifications.php that control the user permissions to perform the requested action and look for possible notifications, respectively. Finally, the positioning.js file updates GPS position in real time using its listActions.php and doAction.php files. The dbConnection.

php connects with the model part of the application, the database previously presented.

The application has been implemented using JavaScript [15], PHP [16], MySQL [17], HTML5 [18] and CSS [19].

HTML5 and CSS have been used to create and design the different web pages. JavaScript has been used for the control of the user side web. For the sake of simplicity, robustness and scalability the Vue.js library has been used for the web logic and to maintain the DOM values of the HTML always updated. In addition, this library has allowed to maintain different reusable components on the different web pages of the application.

For the server side, PHP has been used to program the logic of the server and MySQL for the data base access. For the sake of security in the access to the database the PHP PDO library has been used.

References

- [1] J.S. Alpert, K. Thygesen, E. Antman, J.P. Bassand, Myocardial infarction redefined—a consensus document of The Joint European Society of Cardiology/American College of Cardiology Committee for the redefinition of myocardial infarction, *J. Am. Coll. Cardiol.* 36 (3) (2000) 959–969, [https://doi.org/10.1016/s0735-1097\(00\)00804-4](https://doi.org/10.1016/s0735-1097(00)00804-4). PMID: 10987628.
- [2] G. De Luca, H. Suryapranata, J.P. Ottervanger, E.M. Antman, Time delay to treatment and mortality in primary angioplasty for acute myocardial infarction: every minute of delay counts, *Circulation* 109 (10) (2004 Mar 16) 1223–1225, <https://doi.org/10.1161/01.CIR.0000121424.76486.20>. Epub 2004 Mar 8 PMID: 15007008.
- [3] H.H. Nguyen, J.N. Silva, Use of smartphone technology in cardiology. *Trends Cardiovasc. Med.* 2016 May;26(4):376-86. 10.1016/j.tcm.2015.11.002. Epub 2015 Nov 19. 10.1016/j.tcm.2015.11.002 PMID: 26686266.
- [4] S.J. Hamilton, B. Mills, E.M. Birch, S.C. Thompson, Smartphones in the secondary prevention of cardiovascular disease: a systematic review, *BMC Cardiovasc. Disord.* 18 (1) (2018) 25, <https://doi.org/10.1186/s12872-018-0764-x>. PMID: 29415680; PMCID: PMC5803998.
- [5] T. Dorje, G. Zhao, A. Scheer, L. Tsokey, J. Wang, Y. Chen, K. Tso, B.K. Tan, J. Ge, A. Maiorana, SMARTphone and social media-based Cardiac Rehabilitation and Secondary Prevention (SMART-CR/SP) for patients with coronary heart disease in China: a randomised controlled trial protocol, *BMJ Open* 8 (6) (2018) e021908.
- [6] D. Kotecha, W.W.L. Chua, L. Fabritz, J. Hendriks, B. Casadei, U. Schotten, P. Vardas, H. Heidbuchel, V. Dean, P. Kirchhof, European Society of Cardiology (ESC) Atrial Fibrillation Guidelines Taskforce, the CATCH ME consortium and the European Heart Rhythm Association (EHRA). European Society of Cardiology smartphone and tablet applications for patients with atrial fibrillation and their health care providers, *Europace* 20 (2) (2018) 225–233, <https://doi.org/10.1093/europace/eux299>. PMID: 29040548; PMCID: PMC5834097.
- [7] M.A. Astarcioğlu, T. Sen, C. Kilit, H.I. Durmus, G. Gozubuyuk, M. Kalcik, S. Karakoyun, M. Yesin, H. ZencirkiranAgus, B. Amasyali, Time-to-reperfusion in STEMI undergoing interhospital transfer using smartphone and WhatsApp

- messenger, *Am. J. Emerg. Med.* 33 (10) (2015 Oct) 1382–1384, <https://doi.org/10.1016/j.ajem.2015.07.029>. Epub 2015 Jul 31 PMID: 26299691.
- [8] C.C. Chao, Y.C. Chen, C.M. Shih, S.K. Hou, R.R. Seethala, I.P. Aisiku, C.C. Huang, P. C. Hou, W.F. Kao, Smartphone transmission of electrocardiography images to reduce time of cardiac catheterization laboratory activation, *J. Chin. Med. Assoc.* 81 (6) (2018) 505–510, <https://doi.org/10.1016/j.jcma.2017.11.009>. Epub 2017 Dec 26 PMID: 29287703.
- [9] J.J. Park, C.H. Yoon, J.W. Suh, Y.S. Cho, T.J. Youn, I.H. Chae, D.J. Choi, Reduction of Ischemic Time for Transferred STEMI Patients using a smartphone social network system, *J. Am. Coll. Cardiol.* 68 (13) (2016) 1490–1492, <https://doi.org/10.1016/j.jacc.2016.07.733>. PMID: 27659471.
- [10] R. Dickson, A. Nedelcut, R. Seupaul, M. Hamzeh, STOP STEMI—a novel medical application to improve the coordination of STEMI care: a brief report on doorto-balloon times after initiating the application. *Crit. Pathw. Cardiol.* 13 (2014) 85–88. PMID: 25062390 PMCID: PMC4132040 10.1097/HPC.0000000000000019.
- [11] Parasuram Krishnamoorthy, Andriy Vengrenyuk, Brian Wasielewski, Nitin Barman et al. Mobile application to optimize care for ST-segment elevation myocardial infarction patients in a large healthcare system, STEMIcathAID: rationale and design *European Heart Journal - Digital Health*, Volume 2, Issue 2, June 2021, Pages 189–201, 10.1093/ehjdh/ztab010.
- [12] <https://scientiasalut.gencat.cat/handle/11351/2651?locale-attribute=en> (accessed February 2022).
- [13] Ibañez, Borja et al. “2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC).” *European heart journal* vol. 39,2 (2018): 119-177. doi:10.1093/eurheartj/ehx393.
- [14] <https://openrouteservice.org/>.
- [15] <https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference>.
- [16] <https://www.mysql.com/>.
- [17] <https://www.php.net/>.
- [18] <https://html.spec.whatwg.org/dev/>.
- [19] <https://developer.mozilla.org/en-US/docs/Web/CSS/Reference>.
- [20] <https://www.R-project.org/>), utilizando en paquete “CompareGroups”(1).
- [21] I. Subirana, H. Sanz, J. Vila, Building Bivariate Tables: The compareGroups Package for R, *J. Stat. Softw.* 57 (12) (2014) 1–16. <https://www.jstatsoft.org/v57/i12/>.