Airmed-Cardio: A GSM and Internet Services-Based System for Out-of-Hospital Follow-Up of Cardiac Patients

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Abstract—A platform built around three information entities (patient, health-care agent, and central station) was designed to enable patients with chronic heart disease (in stable condition; emergency situations were excluded deliberately) to complete specifically defined protocols for out-of-hospital follow-up and monitoring. The patients belonged to one of four specific risk groups: arterial hypertension, malignant arrhythmias, heart failure, and postinfarction rehabilitation. They were provided with portable recording equipment and a cellular phone that supported data transmission [electrocardiogram (ECG)] and wireless application protocol (WAP) (remaining parameters and ad hoc questionnaires).

The central station was an automatized platform, with no human operator. The information received was organized chronologically in patient folders. The health-care agents had continuous and secure access to the patient folders, through tools based on the world wide web and WAP, and to short messages sent by their patients.

A pilot project was conducted with 89 patients (mean length of participation: 50.1 days). A total of 2168 ECGs (mean duration transmission = 2 min/30 s; network errors < 0.1%) and 4011 short messages (none lost, in 95% of cases 30 s < delay < 1 min) were transmitted; 6083 WAP sessions (mean duration = 3 min 11 s; network failures < 0.1%) were held.

The functionality of the platform was also evaluated, analyzing the subjective component of usability, showing the evolution of patient acceptance over time.

Index Terms—Electrocardiography, global system for mobile communication (GSM), short message service (SMS), telecardiology, wireless application protocol (WAP), world wide web (WWW).

NOMENCLATURE

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>CS-E</td>
<td>Central_station entity.</td>
</tr>
<tr>
<td>GIF</td>
<td>Graphics interchange format.</td>
</tr>
<tr>
<td>GSM</td>
<td>Global system for mobile communication.</td>
</tr>
<tr>
<td>HcA-E</td>
<td>Health-care_agent entity.</td>
</tr>
<tr>
<td>IT</td>
<td>Information technologies.</td>
</tr>
<tr>
<td>Pat-E</td>
<td>Patient entity.</td>
</tr>
<tr>
<td>RAS</td>
<td>Router access server.</td>
</tr>
<tr>
<td>SCP</td>
<td>Standard communication protocol (computer-assisted electrocardiography).</td>
</tr>
<tr>
<td>SMS</td>
<td>Short message service.</td>
</tr>
<tr>
<td>WAP</td>
<td>Wireless application protocol.</td>
</tr>
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</table>

I. INTRODUCTION

THE PROGRESSIVE adoption of new paradigms in cardiovascular disease care, such as primary/secondary prevention and patient empowerment, promote the development of novel care approaches [1]–[3] in which out-of-hospital monitoring and follow-up are basic aspects [4], [5]. Therefore, the development and utilization of telematic systems that provide new modes of patient contact with the health-care system is of increasing interest [6]–[11]. It is also necessary to study the viability and efficacy of the new value-added services [12]–[14] as applied to medical attention for patients at risk for cardiovascular disease [14]–[19].

This paper describes a platform targeting patients with chronic heart disease who are in stable condition, belonging to one of four specific risk groups: arterial hypertension, malignant arrhythmias, heart failure, and postinfarction rehabilitation. The major objective of the system is to provide an attractive contact between patients and the health-care agents (HcAs) directly involved in their care, and complete specifically defined protocols for follow-up and monitoring. The management of emergency situations has been excluded intentionally since the health-care system is considered to deal with them with firmly established and validated ad hoc resources that have been shown to be extremely effective and reliable.

Section II presents the general platform requirements, sub-systems description, the security measures adopted, functional description of the services and application, and the evaluation methodology. Section III describes patient electrocardiogram (ECG) recording/transmission, patient WAP session, short messages, patient–user acceptance, and other aspects of interest.

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Fig. 1. Airmed-Cardio information entities.

TABLE I
PARAMETERS AND EQUIPMENT ACCORDING TO RISK GROUPS

<table>
<thead>
<tr>
<th>Risk Group</th>
<th>Parameters</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial hypertension</td>
<td>Blood pressure</td>
<td>Sphygmonomanometer</td>
</tr>
<tr>
<td></td>
<td>Questionnaire1</td>
<td>Mobile telephone</td>
</tr>
<tr>
<td>Malignant arrhythmias</td>
<td>ECG (6 leads)</td>
<td>Portable ECG recorder</td>
</tr>
<tr>
<td></td>
<td>Blood pressure</td>
<td>Sphygmonomanometer</td>
</tr>
<tr>
<td></td>
<td>Questionnaire2</td>
<td>Mobile telephone</td>
</tr>
<tr>
<td>Heart failure</td>
<td>Blood pressure</td>
<td>Sphygmonomanometer</td>
</tr>
<tr>
<td></td>
<td>Pulse oximetry</td>
<td>Pulse oximeter</td>
</tr>
<tr>
<td></td>
<td>Weight</td>
<td>Scale</td>
</tr>
<tr>
<td></td>
<td>Questionnaire3</td>
<td>Mobile telephone</td>
</tr>
<tr>
<td>Postinfarction</td>
<td>ECG (12 leads)</td>
<td>Portable ECG recorder</td>
</tr>
<tr>
<td></td>
<td>Pulse</td>
<td>Pulse meter</td>
</tr>
<tr>
<td></td>
<td>Questionnaire4</td>
<td>Mobile telephone</td>
</tr>
</tbody>
</table>

B. Platform Description

The equipment assigned to each patient varied according to risk group; the distribution is shown in Table I. All the devices utilized were commercially available: the Biolog3000i ECG monitor, from Micromedical Industries, Inc., the Nokia 7110 mobile telephone from Nokia, Inc., the Omron-M4 sphygmonomanometer from OMRON, Inc., the MiniSPO2T—503Dx pulse oximeter from Criticare Systems, Inc., and the M21-GRI-Antra pulse meter from Polar, Inc.

The previously recorded ECG, stored in the Biolog3000i, was sent to the CS-E by means of the internal GSM modem of the Nokia 7110 cellular phone. The remaining parameters and the personalized questionnaire were manually introduced by the patient and transmitted via WAP sessions.

There were two scenarios for transmission: according to the protocol or upon request. In the first case, each group of patients was subject to a protocol in which the type of information to be sent and the periodicity were specified (see Table II).

In the second scenario, upon request, the transmission of information could take place at any time, on the initiative of the patient. A transmission of this type occurred when the patient felt ill, but did not consider it an emergency.

The Biolog3000i and CardioView3000MITU system (Micromedical Industries, Inc.) were chosen because they conform to ENV 1064 CEN standard [20] for ECG transmission. The Nokia 7110 was chosen as the cellular phone because, in addition to fulfilling the essential requirements (internal GSM modem, WAP microbrowser, and a large display), its NaviTM Roller navigation button was considered, by a selected group of users, to be the most user-friendly interface when compared to a number of other models (e.g., Alcatel One-Touch Pocket, Ericsson R320s, Siemens C35, and Motorola v8088).

The CS-E was composed of a nucleus and a set of satellite systems that were interconnected by an intranet based on the Ethernet 100BaseT local network. The nucleus was supported by a PC-based platform to which the following modules (see

<table>
<thead>
<tr>
<th>Risk Group</th>
<th>Protocol (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial hypertension</td>
<td>- Every day: 3 WAP sessions</td>
</tr>
<tr>
<td></td>
<td>(morning/afternoon/night)</td>
</tr>
<tr>
<td>Malignant arrhythmias</td>
<td>- Every day: 1 WAP session</td>
</tr>
<tr>
<td></td>
<td>1 ECG (lead II/200s)</td>
</tr>
<tr>
<td>Heart failure</td>
<td>- Every day: 1 WAP session</td>
</tr>
<tr>
<td></td>
<td>1 ECG (lead II/20bs)</td>
</tr>
<tr>
<td>Postinfarction</td>
<td>- Every day:</td>
</tr>
<tr>
<td></td>
<td>- Pre-exercise: 1 ECG (12-leads)</td>
</tr>
<tr>
<td></td>
<td>- Post-exercise: 1 ECG (12-leads)</td>
</tr>
<tr>
<td></td>
<td>1 WAP session</td>
</tr>
</tbody>
</table>

(*) Questions such as initial treatment to be administered, procedure in case of a change in treatment, etc., were also addressed.
Fig. 2. Block diagram of the central station entity. Nucleus: PC-based, LINUX RedHat 6.0 OS, with (a) MySQL 3.22.32 database server, (b) Apache 1.3.12 WWW server, (c) ECG gateway, (d) SMSLink 0.48b SMS gateway, and (e) e-mail client. Satellite systems: (f) R-EGCi systems; (g) Cisco 4500 internet router; (h) Cisco 2509 remote access server; (i) Nokia WAP Server 1.1.1/Security Pack 1.0 WAP gateway.

Fig. 3. Security scenario. (1) Pat-E/CS-E secure Wireless Transport Layer Security (WTLS) WAP sessions (RSA 768 bits/RC5 56 bits/SHA-80 bits MAC). (2) HcA_WAP_application work sessions are secure WTLS WAP sessions (RSA 768 bits/RC5 56 bits/SHA-80 bits MAC). (3) HcA_application work sessions are secure HTTPS SSLv3 (RSA 512 bits/RC4 56 bits/MD5 MAC).

Fig. 2) had been added: a) database server; b) world wide web (WWW) server; c) ECG gateway, developed in the project, as the interface between the nucleus and the ECG receiver; d) SMS gateway; and e) e-mail client, used only to alert the CS-E administrator to some circumstance (e.g., notification of events about internal processes status, periodical analysis of CS-E activity, etc.).

The satellite systems surrounded the nucleus: f) \( R - ECG_i \) systems, which received the ECGs in an SCP—Computer-assisted electrocardiography SCP format [20] and automatically reported on the ECG tracings and the tables of ECG measurements, both in JPEG image format; g) the Internet router; h) the RAS; and i) the WAP gateway.

The HcA-E included three software applications: the HcA_application, developed within the project, for managing patient folders (e.g., hospital admissions and discharges, follow-up, etc.), performing messaging tasks, and processing stored information (e.g., curves illustrating parameter’s evolution, etc.); the HcA_WAP_application, developed within the project, for consulting patient folders (limited to viewing the questionnaires) and messaging to and from patients (transmission of predetermined messages); and the CardioView3000R, from Micromedical Industries, Inc., for the detailed inspection of the ECGs in SCP format.

C. Security

The security measures adopted involved two aspects: to protect the information during transmission through public networks and storage, and security at the system level (legitimate use, availability, and physical and logical access control).

Aside from the encryption that the GSM network itself introduced into the wireless communication interface, secure WAP sessions took place between the Nokia 7110 and the WAP gateway [see Fig. 3, sessions type (1,2)]. The HcA_application work sessions were secure WWW sessions [see Fig. 3, session type (3)]. At no time was sensitive information that could be directly associated with the patient included in the transmission.
of the ECG. The patient-ECG association was established in the CS-E, which was a controlled setting.

To control access to the stored information, the HcA_application established a hierarchy of privileges that mapped the two roles that an HcA could play: a) responsible user, with all the existing privileges over the folders of the group, and b) authorized user, who could only inspect the folder of the patients for which he had been authorized; he was not allowed to employ services like messaging, data validation, or reporting. Three levels of access were established: application, health-care_agent, and patient (Fig. 4). The first two levels were gained by means of predetermined login-password pairs, while the third had a dynamic configuration depending on the work context. As the user progressed from one level to the next, his privileges in terms of access to information were established. Physical control access to the systems was subject to the security policy of the hospital and logical control access was protected by the following mechanisms: a firewall in the Internet access router, a password authentication protocol in the RAS, an access restricted by IP address, and ECG_measurements, both in JPEG format. Once the three files were available (the ECG in .scp format and the two .jpg documents), the patient whose ECG was being dealt with was located [Fig. 5(4)]. The patient identification process differed depending on whether the transmission involved a single patient or an HcA (several patients, e.g., nurse at a primary health center). These documents were sent [Fig. 5(5)] to the CS-E nucleus and were introduced into the database, resulting in the update of the patient folder. Finally, the ECG gateway sent a command [Fig. 5(6)] to the SMS gateway ordering it to send a short message to the patient, informing him that the new information had been added to his folder.

2) Patient WAP Session: The Nokia 7110 was configured so that a secure WAP session could be automatically established with the simple touch of a button. The following processes were triggered (Fig. 6, Steps 1–4): A call was made [Fig. 6(1)] to the remote access server and the establishment of an IP session was negotiated; a secure connection was established [Fig. 6(2)] with the WAP gateway; pages were requested [Fig. 6(3)] of the WWW server, and interaction [Fig. 6(4)] with the database server took place.

Each patient WAP session (see Fig. 6) consisted of three parts:

a) Identification stage, the CS-E was presented to the patient and, two seconds later, personal identification was requested; if this was satisfactory, the system proceeded to the next stage.

b) Filling-in stage in which the patient was presented with a questionnaire (Table III) personalized according to the protocol; once this had been completed, it was sent to the CS-E to update the patient folder, and the system proceeded to the next stage.

c) Finalization stage, in which the patient received confirmation that the session was over.

3) HcA_Application: The appearance of the patient folder managed by the HcA-application is shown in Fig. 7. It had two parts.

The narrow frame on the left contained the set of operations that potentially could be applied to the folder, which were activated or not, depending on the role assigned to the HcA: patient data (e.g., personal description, clinical history prior to enrollment in the pilot study, and initial pharmacological treatment), trends, treatment (modification of the patient’s drug treatment), annotations, send message, report (edition of the final report
The wide frame on the right contained the collection of documents sent by the patient from the time he was included in the project. The documents were presented as icons in chronological order (date/time of register/receipt of the transmission). The background color of the icon (gray/red) indicated the type of transmission (protocol/on request), and the light/dark tone indicated whether or not they had been validated by an HcA. The description of the icons is provided on the right-hand side of Fig. 7.

A document could be viewed by selecting its icon with the mouse (superposition/clicking). The contents appeared by the following. 1) Superposition: A floating panel appeared in the left-hand frame of the folder with data ON. 2) Clicking: using a local viewer a) CardioView3000R for ECGs in .scp format, or b) a standard .jpg image viewer (e.g., MS Imaging) for ECG-strips or ECG-measurements (Fig. 8).

For trends and follow-up studies, the HcA_application provided facilities for dynamic graphics generation in GIF format (Fig. 9). These images were based on the data from the patient folder, relating one or more parameters to the time elapsed, drug doses, etc. Floating panels that responded to the movement of the cursor over the GIF image were employed in order to increase the amount of visible information (see Fig. 9).

Finally, the HcA-E was capable of sending short messages to patients via the SMS gateway, and of maintaining a secure WAP session only for consulting completed patient questionnaires.

4) Short Messages: Airmed-Cardio provided two SMS-based services: a) automatic notification of the incorporation of an ECG into the patient folder (during the ECG transmission phase, the patient already received a first notification of the correct receipt of the ECG), and b) messages from the HcA which, in turn, could be one of two types: “operative,” related to care and follow-up (e.g., change of treatment, notification of the need to perform another transmission, setting up an appointment, etc.), and “supportive,” the purpose of which was to maintain regular contact with the patient (e.g., to encourage him, to let him know everything is going well, etc.).
III. PILOT PROJECT RESULTS

A. Evaluation

A pilot project was carried out in Health Area no. 6 (over 500,000 inhabitants) in Madrid. The following material was employed: 14 Biololog300i ECG monitors (10 for the patients in risk Groups II and IV and 4 located in primary health centers in the area); 30 GSM Nokia 7110 cellular phones (20 for patients, 9 for HcAs, and 1 for the administrator of the CS-E); 20 sphygmomanometers, 5 pulse oximeters, and 5 pulse meters. Four cardiologists from three different centers in the area participated over a ten-month period.

The patients were enrolled in the project once their informed consent had been obtained. They remained in the study population for varying periods of time, depending on their disease and general condition. Their inclusion and discharge from the project were decided directly by the cardiologists, who disregarded issues such as age and previous experience with cellular phones, basing their selection exclusively on suitability in terms of health care.

Upon being chosen, each participant was asked to attend a learning session in which he was instructed in the use of the equipment, which he received, together with a “rapid learning guide” to all the devices to be employed. This was followed by a “preliminary phase” of varying length (maximum ten days), during which the patient, from his home, sent all the ECGs and WAP transmissions he wanted to. The cardiologist and patient agreed on the date on which the participation of the latter was to begin, and all the data transmitted prior to that moment was deleted.

Our major aims in this trial were to determine the attitude of the patients toward the system and ensure that the developed platform fulfilled the requirements for all four disease entities, searching only for coarse performance problems. The purpose of both was to acquire enough experience to enable us, in the future, to design a much more elaborate procedure for selecting and enrolling patients and, ultimately, to introduce Aimed-Cardio into the real health-care activity of our health area.

The evaluation plan consisted of assessing the functionality of the platform, using a methodology designed for the analysis of the subjective component of usability (user attitude) [21], [22]. It was not considered necessary to examine in depth the objective component of usability (efficiency) based on direct observation of the interactions of the users with the system. We did not include a control group of patients not implicated in telemedicine and, given the small number of participants and cardiologists, we did not propose to evaluate the efficacy of the platform in terms of cost or the purely health-care context [23].

For the patient–user subjective component, a questionnaire inspired by and designed according to the work of other researchers [24]–[26] was to be completed twice (during the first week of participation in the project and at the end). It was based on a Likert-type scale to assess patient agreement with six statements (see results, Table IV, patient acceptance). The scale ranged from 1 (strongly agree) to 5 (strongly disagree), and compiled only general aspects of patient acceptance and satisfaction. The changes observed in the first and final responses to the six statements were analyzed using the Wilcoxon signed rank test for paired data.
B. Participants and Results

A total of 89 patients, with a mean participation time of 50.2 days were included in the pilot project. Table V summarizes the findings.

The most noteworthy results were as follows.

1) ECG Recording/Transmission: The degree of difficulty varied widely depending on whether or not electrodes were employed. When they were not used, the learning session was never longer than 30 min and subsequent aid in the operation of the Biolog3000i on the part of the family was not necessary. When electrodes were employed, the mean duration of the learning session increased to 55 min.

To record and transmit the information themselves, approximately 56% of the patients required substantial aid from their families for the first ten days (preliminary phase), 20% required a certain amount of familial aid, and 24% required none. Once the preliminary phase was over, only nine patients continued to need help.

Connection with the CS-E was successful on the first attempt in 92% of cases; the second attempt was successful in 100% of the remaining cases (patients were advised to change location if the connection failed). The time required to establish the connection for data transmission between patient phones and CS-E (Public Switched Telephone Network modems were used) was 30–35 s.

With regard to the establishment of calls and the frequency of interrupted or lost connections, the results of transmission were excellent. The fact that the patient transmitted the information while stationary helped considerably since it avoided the problems that arise at times during data transmission via GSM when the sender is moving and changes from one cell to another.

Two network failures during ECG transmission were reported (one per thousand).

The size of the files ranged between 30 and 90 Kb, depending on the duration of the recording and the number of leads (Table II).

ECG reception was highly satisfactory and the analysis of the results of this test proved to be very extensive and valuable (Fig. 8).

2) Patient WAP Session: The learning session was more tedious than expected, requiring an average of 1.14 h (range 22 min to 1.52 h) of instruction per patient. Seventy-seven percent of the patients required substantial aid from their families during the preliminary phase, 14% required a certain amount of familial aid, and 9% required none. After the preliminary phase, 18 patients continued to need help for a time, and 4 throughout
their entire period of participation. The time required to learn depended mainly on previous familiarity with cellular phones and very little on patient age (mean: 61.4 years; range: 45–73 years). Previous familiarity was more closely related to professional obligations than to any cultural threshold.

The mean duration of the WAP sessions ranged from 5 to 6 min on the first 4 or 5 days (preliminary phase), after which it remained between 3 and 4 min (Table IV). These times do not include the 30 to 35 s required for negotiation between modems (telephone-remote access server).

Six network failures during WAP sessions were reported (one per thousand).

3) Short Messages: The central station sent a total of 4011 short messages to patients: 2168 acknowledging received ECGs and 1843 sent by the cardiologists.

The delay in receipt of a message by the patient was the responsibility of the operator (in this case, Vodafone). During the ten months of the pilot study, the delays observed (mean: 36 s; in 95% of cases 30 s < delay < 1 min; in the remainder, delay < 5 min; maximum: 3 h due to a breakdown) were generally valid for a scenario involving stable patients.

There were no reports of physicians receiving notification of unsent messages.

Despite the limitation of 160 characters of text imposed by this service, it proved to be sufficient for the needs of the different types of messages that the HcAs freely chose to send.

4) Patient–User Acceptance: Table V shows the six statements and the responses of the patients; only 88 cases are presented because, due to an error, the second response of one patient was not received.

1) A large number of patients (n = 35, 40%) considered the equipment difficult to use at the start of the project, a proportion that had decreased significantly to 12 (13.6%) by the end (p < 0.001). Of the 18 patients (20.4%) who had
no opinion in this regard at the start, 17 (19.3%) considered it easy to use by the end; moreover, none of those who found it easy at the beginning changed their opinion at the end.

2) Ten of the 22 patients (25%) who felt uneasy with the equipment when they began to participate in the project changed their attitude by the end. Of the 25 patients (28.4%) who had no opinion at first, 20 clearly declared that they felt little unease, leaving 6 (6.8%) with their initial opinion. None of the 41 patients (46.6%) who felt a little or very little uneasy at the start changed their minds at the end.

3) Most of the patients (n = 74, 84.1%) had a positive attitude toward the project at the outset, and by the end, this number had increased to 79 (89.8%) as 5 (5.7%) of the 12 patients (11.3%) who expressed no opinion at the beginning, adopted a positive attitude by the time the project had finished.

4) The certainty that the equipment had functioned properly in each session was high from the start and had improved at the end. Of the 20 patients (22.7%) who had no opinion when the project began, 9 (10.2%) ended up considering it easy to determine, while 11 (12.5%) maintained their original opinion. Of the 10 patients (11.3%) who considered it difficult to ascertain at the beginning, 6 (6.8%) had changed their minds by the time the project was over, finding it easy.

5) The responses concerning their impression with respect to whether or not the project violated their privacy did not vary significantly when the initial questionnaire was compared with the final one, 52 (59.1%) versus 60 (68.2%), indicating that the question was probably poorly presented. The number of patients who still had no opinion at the end of their participation in the project was very high, making it evident that they did not have the information necessary to respond properly.

6) Most of the patients (n = 71, 80.7%) agreed from the start that, in this specific case, the technology was beneficial. This number had risen to 80 (90.9%) by the end of the project as 8 (9.1%) of the 14 participants (15.9%) who had no opinion initially came to consider it beneficial when completing the final questionnaire.

Finally, three patients asked to drop out of the project: one at the end of the preliminary phase because of problems with the use of the phone, especially in the WAP session; another in the first week due to difficulties in recording the ECG; and the third in the third week because she felt that the obligation of measuring her own parameters increased her general stress. All three received support from their families.

### TABLE IV
**Patient Acceptance Questionnaire**

<table>
<thead>
<tr>
<th></th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Is the equipment difficult for you to use?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First time (first week project)</td>
<td>7</td>
<td>8.0</td>
<td>28</td>
<td>31.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second time (end of participation)</td>
<td>2</td>
<td>2.3</td>
<td>10</td>
<td>11.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Do you feel uneasy when using these devices?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First time</td>
<td>5</td>
<td>5.7</td>
<td>17</td>
<td>19.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second time</td>
<td>0</td>
<td>0.0</td>
<td>12</td>
<td>13.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Is your general attitude toward the project positive?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First time</td>
<td>20</td>
<td>22.7</td>
<td>54</td>
<td>61.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second time</td>
<td>32</td>
<td>36.4</td>
<td>47</td>
<td>53.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Is it easy to know whether the equipment has functioned correctly?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First time</td>
<td>13</td>
<td>14.8</td>
<td>45</td>
<td>51.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second time</td>
<td>22</td>
<td>25.0</td>
<td>50</td>
<td>56.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Can participation in the project violate your privacy?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First time</td>
<td>1</td>
<td>1.1</td>
<td>6</td>
<td>6.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second time</td>
<td>1</td>
<td>1.1</td>
<td>6</td>
<td>6.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. In this case, do you consider the technology beneficial?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First time</td>
<td>25</td>
<td>28.4</td>
<td>46</td>
<td>52.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second time</td>
<td>32</td>
<td>36.4</td>
<td>48</td>
<td>54.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE V
**Pilot Project Results**

<table>
<thead>
<tr>
<th>No. of patients</th>
<th>Days in the project (mean)</th>
<th>No. of ECGs sent</th>
<th>No. of short messages</th>
<th>No. of WAP sessions</th>
<th>Mean duration of ECG transmission (min:sec)</th>
<th>Mean duration of WAP session (min:sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial hypertension</td>
<td>39</td>
<td>31.6</td>
<td>182</td>
<td>749</td>
<td>3,584</td>
<td>2:28</td>
</tr>
<tr>
<td>M. arrhythmias</td>
<td>23</td>
<td>30.8</td>
<td>715</td>
<td>1,056</td>
<td>698</td>
<td>3:09</td>
</tr>
<tr>
<td>Heart failure</td>
<td>15</td>
<td>76.3</td>
<td>164</td>
<td>737</td>
<td>1,087</td>
<td>0:50</td>
</tr>
<tr>
<td>Postinfarction</td>
<td>12</td>
<td>61.5</td>
<td>1,107</td>
<td>1,469</td>
<td>714</td>
<td>(x2) 2:28</td>
</tr>
<tr>
<td>Total</td>
<td>89</td>
<td>50.1</td>
<td>2,168</td>
<td>4,011</td>
<td>6,083</td>
<td>2:34</td>
</tr>
</tbody>
</table>

Authorized licensed use limited to: Queens University. Downloaded on June 22, 2009 at 00:41 from IEEE Xplore. Restrictions apply.
5) **Other:** Transmission “on request” was utilized on 29 occasions (less than 1% of all the contacts). In one case, the phone had to be replaced due to malfunction (a broken antenna).

There were no reports of malfunction in the ECG monitors or in the display screens of other equipment: sphygmomanometers, pulse oximeters, and pulse meters.

Two patients resorted to the telephone number provided for technical help on five occasions.

### IV. DISCUSSION

Airmed-Cardio is a platform built around three information entities that integrate services and applications to support ubiquitous contact between patients presenting cardiovascular risk and the HcAs (especially cardiologists) directly involved in their follow-up. Since emergency situations are not included in the project, the term “ubiquitous” refers exclusively to the fact that contact can be made outside the home.

The proper intensity of contact between patient and HcA and how to implement it are by no means obvious, even in an ideal scenario with sufficient available resources [27], [28]. At the end of the pilot project, our conclusion was that the follow-up of heart disease patients is developing quite similarly, although with some years of delay, to that of diabetics [29]–[31]. It is very likely that nearly the same can be said for the management of other pathologies such as respiratory diseases [32]–[34], and definitely for the out-of-hospital follow-up of chronic patients [35].

Here we point out the most significant aspects of the functionality of Airmed-Cardio.

1) **Equipment:** It was impossible to find a device that simultaneously allowed: a) the recording of the desired cardiovascular parameters, b) incorporation of a configurable questionnaire, and c) transmission of all the information via GSM. Moreover, the difficulties did not only concern the patient since the devices that incorporate transmission capacity require receiving systems at the other end that cannot be unlinked from the sending device, and these receiving systems present a highly variable degree of opening: proprietary databases, networking, mandatory presence of human operators, etc.

The final decision to adopt a design that distinguished between the ECG (data transmission) and the remainder of the parameters together with the questionnaire (WAP session) and conveyed them all by GSM provided a solution with a very high degree of opening as compared to other options.

2) **WAP Sessions:** The difficulties faced by developers of WAP applications are well known: small displays, limited languages for their development, limited phone memory, limited bandwidth and, very importantly, different user interfaces depending on the cellular phone being employed (the buttons, their functionality, etc.). In addition to the general rules of style, three criteria were met in the design: a) minimize the number of interactions with the CS-E (identification, completion, and transmission of the questionnaire and confirmation of receipt); b) minimize the number of buttons to be used (only two), and c) minimize the number of interventions required for the progress of the session (preference for selecting one of several options rather than introduction of data by the user, hyperlinks for progress, and transmission of information, etc.).

3) **Short Messages:** One requirement was that there be no direct contact between the patient and the HcA. This limitation, which was only a recommendation in the HcA-to-patient direction, was technically ensured in the direction patient to HcA; the patient did not have the HcA’s phone number since he received all messages through the CS-E. This procedure was adopted because the HcAs had no desire to convey to the patient the impression that he had total access (especially in terms of time) to his cardiologist. We consider this a realistic position, better accommodated to the reality of today’s world and possibly to that of the near (at least) future, when dealing with patients who are not in an emergency situation.

The use of short messages in physician-to-patient direction was found to be useful and necessary, the added value being evident (e.g., treatment changes). The patient awaited the message from his physician and his confidence in the system grew when it arrived.

4) **Patient–User Training and Equipment Operation:** The enrollment of patients in the project was a tedious task that obviously could not involve the cardiologist or nurses; it had to be carried out by other professionals familiar with IT. The design employed for enrollment of patients, their instruction, and the preliminary phase were fundamental in terms of the level of approval of the system on the part of the patients.

The results obtained (Table V) indicate a positive course in terms of patient acceptance, as was expected. In general, comprehension on the part of the patients is demonstrated by the marked decrease in the number of neutral responses at the end of the trial.

### V. CONCLUSION

Airmed-Cardio could be included in an emerging scenario encompassing medical devices, products, and services that converge to deliver convenient user-friendly out-of-hospital care [36]–[38]. A major priority in cardiac patients is the performance of a more regular and intensive follow-up than usual and the completion of more effective secondary prevention protocols aimed at maintaining or improving the level of medical care, e.g.: 1) notably reducing the frequency with which the patient uses the services of the health-care provider, thus diminishing the inconvenience and expense to patient and the system alike; 2) shortening the time required for the adaptation of treatment to individual needs; 3) introducing drugs that are more effective but that require a more intensive follow-up of the disease course for dosage adjustment, etc.

Although the numbers of patients in each group and of HcAs involved were too small to allow the evaluation of the efficacy of the system within the health-care context, the results of the evaluation made of its functionality and patient acceptance show that Airmed-Cardio is an excellent tool for the following: 1) evaluating the viability and efficacy of services and technologies based on mobile communications (data transmission, SMS, WAP, etc.) as instruments of new outpatient health-care and
follow-up services not linked to the home, in specific groups of patients presenting cardiovascular risk; 2) evaluating the possibilities of widespread use of solutions of this type in this healthcare field and others, both public and private; 3) exploring new uses for the mobile terminal as a device for personal communications, and undertaking the evaluation and/or development of new telecardiology applications through the new mobile communications networks.

The type of out-of-hospital follow-up made possible by platforms like Aired-Cardio is being configured as one of the great strategies to be implanted in the near future to simultaneously improve health-care and control costs. However, projects like those described here present two serious problems that must be earnestly addressed: 1) the associated logistical changes generated by the new modes of providing health-care services and their coexistence with traditional methods, and 2) their integration into existing information systems, which impede a progressive “slimming down” of the patient’s clinical record.

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REFERENCES


patients.

server (DICOM 3) and telemedicine applications for the follow-up of chronic

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