Some important aspects of Medical and Nursing House Call sustaining Assisted Living of Ageing Population

B. Spyropoulos, A. Tzavaras, M. Botsivaly, M. Moschidis, K. Mertika,
P. Sochos, K. Koutsourakis

Medical Instrumentation Technology Department, Faculty of Engineering, Technological Education Institute of Athens, 12210 Athens, Greece, basile@teiath.gr

Abstract. Although the house call a decade ago was declared a vanishing practice, statistics show an upwelling of home visits by physicians, in the developed countries, during the last ten years. A major reason for this is the radical alteration of the contents of the physicians' black bag that beyond the stethoscope includes also, a Personal Digital Assistant with embedded Cell-phone safekeeping detailed patient-records, sophisticated point-of-care diagnostic equipment and reagents, along with other technical means, that allow for providing care, comparable to that of an emergency room, at home. It is the purpose of the present study to to present the technical and managerial means we have developed, in order to support the adaptation of an ancient medical ritual and a traditional intervention mode, to the 21st Century managed care needs.

Keywords: House call, homecare, point-of-care in vitro diagnostics, portable imaging equipment, medical record, continuity of care record, treatment plan.

1 Introduction

We define a house call as an encounter between a patient and a physician in a private residence [1]. Although house calls by physicians traditionally formed the core of home health care, their number has declined dramatically after World War II. From 40% of all patient–physician encounters in 1930, house calls made up only to 0.6% of such encounters by 1980, mainly reserved for the elderly [2]. However, during the last decade the house call is gradually going through a revival in the USA and elsewhere [3], [4], [5]. We experience presently the merging of Biomedical Technology, Information Technology Systems, and Medical Decision-Making Procedures, within a highly Computerized, Wireless, and Hi-Tec social environment, providing highly developed equipment, software, and communication resources for the General Physician.

It is the purpose of the paper to present the home-care related technical and managerial means, both, hardware and software, which we have developed, in order to contribute to the adaptation of an ancient medical ritual and a traditional intervention mode, to the 21st Century managed care needs.

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Contemporary house-call comprises, first, emergency situations, where the main task for the physician is to perform a diagnosis in complicated cases and to provide on site treatment wherever this is feasible, otherwise to initiate the further Hospital treatment, either immediately, or in due time, depending on the triage results. This process [7] requires accelerated procedures, the adoption of standard guidelines [8], and portable-equipment supported procedures by the physician.

Second, follow-up cases usually including persons discharged from a Hospital, after a major surgical or medical intervention, and follow-up periods that may vary from a few days up to several months. The major tasks to be performed usually lack the urgency of an emergency case; however, the nature of duties includes decisions pertaining to the medical supervision and the administration of a long-term treatment.

Third, palliative care [9], [10] aiming to relieve suffering and improve the quality of life for patients with advanced illnesses and their families. Allocating time for a house call is a major issue, however, the emerging technical and managerial means seem to be able to provide for the necessary human and material resources.

2 Adapting Biomedical Technology to contemporary House-call

We have developed a home-computer based monitoring system [12] that comprises of, the employment of low-cost commercially available components supporting patient's well-being observation, by enabling periodical or continuous vital-signs monitoring, at home. The hardware of the system comprises of, first, a custom-made ECG acquisition module, equipped with an RF link between amplifier and PC, second, a Nellcor finger pulse oximetry probe for typical plethysmography based Oxygen Saturation (SpO2) measurements and the estimation of Heart Rate (HR) and Respiration Rate (RR), and third, another custom-made Carotid Sounds (CS) acquisition module, for the extraction of Heart Rate (HR) and Respiration Rate (RR).

The *ECG module* is designed to acquire Eindhoven I, II or III leads. The system comprises of a preamplifier circuit, a band pass active filter in the range of 0.5 -150 Hz, an amplifier, an analog to digital converter, and a microcontroller circuit that collects and transmits digitally and wireless the ECG. The receiver end is composed of a Radio Frequency (RF) digital receiver tuned to transmitter frequency, and a controller that translates digital data to RS232 communication protocol.

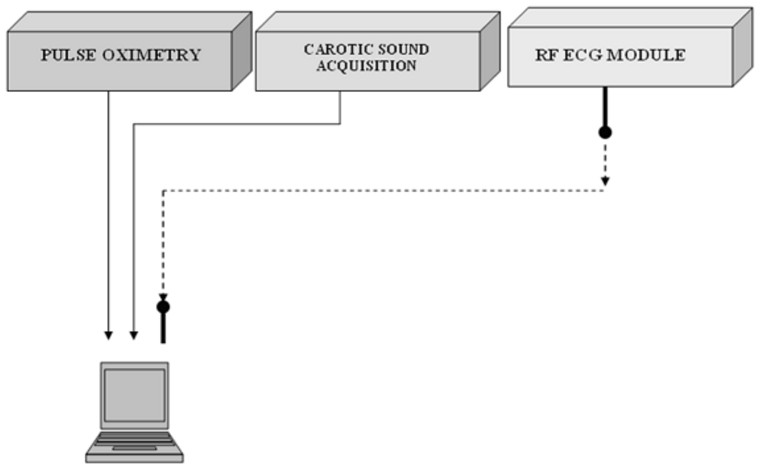


Fig. 1. Block diagram of the developed home-computer based monitoring system.

The *Pulse Oximetry module* measures non-invasively light absorbance of arterial blood as a basis of determining arterial oxygen saturation. The Oxygen Saturation module returns the data to the computer for further processing

The *Carotid Sound Acquisition module* is based on the arterial blood flow sound waveform, acquired by the stethoscope. The sound is captured with the aid of a microphone fitted to the stethoscope’s acoustic path, and then directed to the PC sound card input.

Although the system’s architecture is simple, and the implementation cost is minimal, the performance is very good, allowing not only for the acquisition of Heart Rate and Respiration Rate waveforms, but, furthermore, for full-scale tele-auscultation, in quasi real time mode. Obviously, other irrelevant bodily sounds and external noises may influence the recording. The acquired row data of the system described are appropriately processed to produce decision supportive data, and to allow for remote monitoring.

The home-computer is at the present in the course of replacement by a custom-made ECG (Eindhoven leads I-III) acquisition module based on a JFET Operational Amplifier TL074 (300 Hz sampling rate), equipped only optionally with a 433 MHz RF link between an amplifier and a PC, allowing for further miniaturization and flexibility of the system.

The comparison of the above described Biosignals determination options, with the Equipment available in a physician-staffed Ambulance-vehicle (Notarztwagen) [13], [14], in the Federal State of Baden-Württemberg, Germany, about five years ago, show that the available equipment located was much more.

Our own research and development experience, as well as, the published reports of similar attempts, and finally, the evaluation of commercially available products, argue for the gradual build-up of the house call physician’s in vivo diagnostics Instrumentarium that will allow for, either the life saving urgent intervention or the successful supervision of a long term condition.

Concerning home-based in vitro Diagnostics, Clinical Chemistry offers today a variety of products, covering the whole range of important parameters, like metabolites, enzymes, electrolytes etc. Beyond Diabetes daily strip-based monitoring, which is a routine for the last 2-3 decades, a variety of Home Diagnostic Tests is offered over the counter in the USA, in Europe and elsewhere. This fact virtually leads to a home-based in vitro diagnostics laboratory [15]-[26], that could be very useful, if combined with medical advice and supervision, before, during and after a house call, or a call to facilities offering medical care supported housing, for elderly people.

Concerning Home Imaging, portable, hand-carried ultrasound units, about the size of a laptop computer, have been developed for point-of-care cardiac assessment at the bedside or in the physician's office to extend the accuracy of the bedside physical examination [27], [28], [29]. Finally, external image and video transmission and processing capabilities, constitute another interesting and useful complementary imaging option, already available in high quality, for the physician on house call.

3 Software means supporting medical-managerial aspects of house calls Biomedical Technology to support contemporary house calls

Attempting to contribute to the elaboration of a multifarious, however, integrated approach for the development of software for the house caller physician, we have developed a prototype that includes, first, tools supporting the application of Medical Guidelines relevant to house call, second, means ensuring the continuity of care of the patient, between various care providers, third, tools supporting the allocation of the resources needed to sustain house calls, and finally, software enabling virtual house calls, by employing internet based approaches.

3.1 Applying Medical Guidelines in house call

We have already mentioned that decision making during a house call, especially due to an accident or another emergency requires accelerated procedures and this leads necessarily towards the adoption of standard guidelines and equipment supported procedures by the physician. Therefore, an application was developed that aims to support the General Practitioner, through the on-line display of the appropriate medical guidelines for the treatment of an emergency patient, according to the patient’s condition [30]. Commonly accepted European and American Emergency Medical Guidelines are employed in the developed software that defines the minimum standard of care to be provided to patients by the first responder, probably a General Practitioner on an emergency house call.

These protocols define the minimum standard of care to be provided in an Emergency, and the user interacts with the program through its main menu, which gives him the ability to switch to up to thirteen different screens, each one of which reflects a distinct emergency aspect. The first six screens represent the major emergency categories, as shown in Table 1:

Table 1. Major Emergency Categories of the on-line Guidelines [30].

Major Emergency Categories of the Guidelines		
Cardiopulmonary	Trauma	Obstetric-Neonatal
Medical	Behavioral-Environmental	Pediatric

Each of these six screens is divided in three parts. The first part comprises of the *Basic Life Support protocols* for the most common incidents, in a form of a list, from which the user can choose the desired one. The second part encompasses *Advanced Life Support protocols*, to be employed for the advanced life support of a patient. The last part of each screen includes instructions about *specific emergency operations* such as endotracheal intubation, AED etc. Some of these operations are also demonstrated through videos. The next seven screens support the following important issues:

- Primary survey (Airway, Breathing, Circulation, Disability, Exposure) and the proper management of the patient.
- Evaluation of the patient status (CPR, unstable patient, potentially unstable patient and stable patient).
- Secondary survey of an adult patient (Head, Neck, Chest, Abdomen, Pelvis, Assessment of the level of consciousness, Extremities, Back).
- Automatic External Defibrillation (AED).
- The Simple Treatment And Rapid Transport (S.T.A.R.T) flow diagram.
- An interactive drug management screen based on MS Access 2000 allowing for drug administration.
- A typical powerful patient-record data-entry menu.

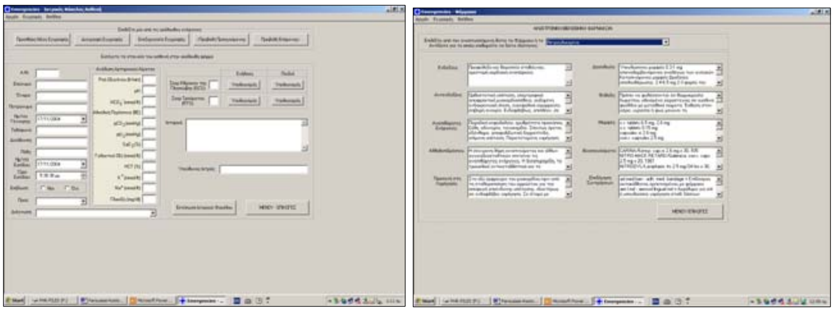
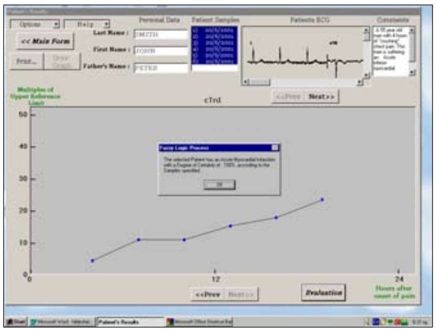


Fig. 2. The patient-record data-entry menu and the drug-management screen.

Since suspicion of Acute Myocardial Infarction (AMI) is a frequent situation, faced by the physician on house call, appropriate software based on fuzzy logic rules [31] was developed, supporting cardiac enzymes' evaluation, during the implementation of typical Acute Myocardial Infarction Treatment Guidelines. Only 10-15% of all patients with chest pain develop AMI. The diagnosis of AMI is based on the detection of at least two out of three infarction-specific findings, that is chest pain for more than

20 min, resistant to Nitro derivatives, infarction-specific ECG alteration in at least two leads of the standard 12-lead ECG, and finally, increased activity of cardiac specific enzymes.

The developed software is based on the fact that during an acute myocardial infarction, there is an increase of the concentration of the cardiac enzymes [32], which at some point after the onset of the chest pain, reaches a peak and passes on to a normalization phase.



DECISION SUPPORT DOCUMENT FOR DIAGNOSING AN AMI

First Name : G
Last Name : MAN

CARDIAC READERS TESTS

Date of Sample	Sample Number	AST (GOT)	LD-1 (HBD)	CK	CKMB mass	CKMB activity	Myoglobin	cTnI	cTnT	GPBB	H-FABP
20/6/2001	1	-	920	-	-	-	-	-	2,1	-	-
20/6/2001	2	-	748,8	-	-	-	-	-	1,86	-	-
20/6/2001	3	-	469	-	-	-	-	-	1,13	-	-
20/6/2001	4	-	345	-	-	-	-	-	0,76	-	-
Reference Values	Male: Female	16-41 U/L	<240 U/L	55-380 U/L 39-189 U/L	<5-8 ig/L	<10 U/L	<70-110 ig/L	0.1-2 ig/L	0.1 ig/L		<5 ig/L

Fig. 3. Temporal evolution graph of the enzyme activity and calculated AMI risk report of the system.

By inserting the measured (e.g. by employing Dry Chemistry strips) activity values and the corresponding sampling times, of at least one and up to, depending on availability, maximum ten specific enzymes, after the onset of the chest pain, the system calculates repetitively AMI risk probabilities for the "suspicious" patient. Temporal evolution graphs of the enzyme activity of every treated patient can be displayed anytime.

Other relevant clinical patient data, including also directly-recorded or scanned paper-strip ECG waveforms, can be stored in the system's database, and be also appropriately considered in the overall prediction.

It becomes gradually apparent that the employment of on-line Emergency Guidelines, combined with the diagnostic information extracted from measured crucial in vitro parameters, and from biosignals monitored within a hi-tec house call environment, can provide for the feeling of safety, through timely and reliable on site intervention for sensible and frail populations, even in rural and isolated regions.

3.2 Continuity of care through house call

As we move towards decentralization in Health-care, well argued concerns are raising about the fragmentation of patient's relevant information and the discontinuity in the delivered care. Furthermore, crucial questions emerge concerning the way this specific kind of care will be medically supervised and financially reimbursed. ASTM, an American National Standards Institute (ANSI) standard development organization, has recently approved the E2369-05, Standard Specification for Continuity of Care Record (CCR) [33]. CCR is intended to assure at least a minimum standard of health information transportability when a patient is discharged, referred or transferred, fostering thus and improving continuity in care.

We have developed and previously partially reported [34] the conceptualization and initial design of a CCR to be employed during a house call. Since Home-care and physician's house calls resources consumption must also be monitored, we have developed for this purpose, an appropriately adapted Continuity of Care Record.

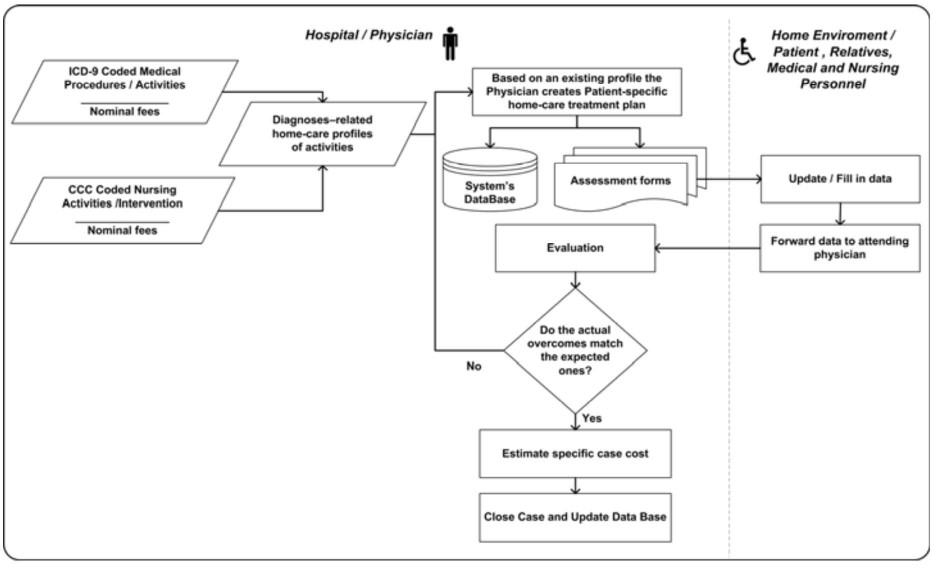


Fig. 4. Flow-chart of the developed system

The developed system consists of two modules. The first module is responsible for the creation of a typical CCR that contains the appropriate demographic and administrative data, as well as the relevant clinical information, while the second module is responsible for the creation of a homecare plan which will be included in the Care Plan section of the CCR. The system is intended to be used upon the transition of a patient from hospital to homecare, although the first module alone could actually be used in any case of transition or referral.

The typical–CCR module can either collect the necessary data from an already installed EHR system or allow the user to enter the data manually by filling special forms. In any case, the user decides which parts of the patient's medical record (electronic or paper) are the most significant ones or are the necessary ones for the description of the current health status of the patient and should be included in the CCR. The second module is responsible for the creation of the homecare plan by creating a structured subset of data, containing the monitoring, treatment, diagnostic and nursing activities that should be employed during the post-discharge homecare period. The actual flow diagram of the developed system is illustrated in Figure 4.

The developed model allows for every Hospital Department or Medical/Nursing group, to individually assign an appropriate set of homecare activities to specific diagnoses codes that are coded according to Diagnosis Related Group (DRG) codification. These activity sets consist of diagnostic, monitoring and treatment activities that can be actually performed in home-environment, together with appropriate General Practitioner house calls, as well as, nursing, and physiotherapy activities plan. These profiles of homecare activities are custom-made and every user, i.e. the physician responsible for discharging a patient from hospital, is actually allowed to set up his own profiles.

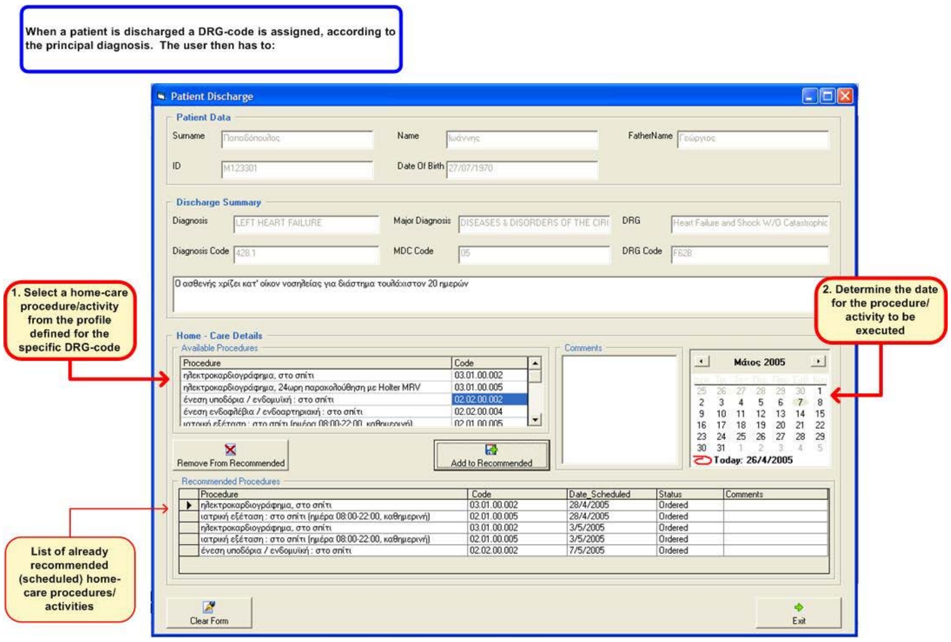


Fig. 5. Homecare activities selection for a specific patient.

During the formation of these profiles the user can attach to each activity a set of nominal fees. This set of fees consists either of the official Insurance Agencies reimbursement data, or of another currently valid financial rate. The later can be estimated by a software tool that we have already developed and allows for a rational approximation of the effective mean cost for several elementary medical activities, over different medical specialties [35], [36]. Thus, the developed system ignites, when relevant, the corresponding revision of an implicitly associated latent financial record that allows for an approximation of the individual case-cost.

Upon the actual discharge of a patient the physician can use one of the predefined profiles, create a new one or modify an existing one in order to adapt his homecare profiles to specific instances and to emerging new demands. The scheduled procedures are automatically inserted in the CCR in the section of Care Plan.

However, the system, apart from producing, electronically or in paper – format, the CCR, also produces a number of additional forms, including advisory and informational notes for the patient himself or for his relatives and diagrams of physiologic measurements, such as glucose, blood pressure etc. that the patient should monitor. The system also provides for the production of forms that will be filled by the nursing personnel during the care visits in order to document their activities.

The filled forms, both the ones regarding the nursing activities and interventions and the ones regarding the monitoring of physiological parameters, are returned to the physician who is responsible after the Hospital discharge, and he evaluates them and, depending on his evaluation, can modify the care – plan of the specific patient in any suitable way.

The structure and data of the produced CCR are complying with the ASTM E2369-05 Specification for Continuity of Care Record, while XML is used for the representation of the data. The XML representation is made according to the W3C XML schema proposed by ASTM [37]. The CCR that is produced by the system is currently automatically transformed to HTML format, using the Extensive Stylesheet Language (XSL), in order to be viewable and printable.

It should be mentioned here that the diagnostic and treatment activities are classified according to International Classification of Diseases Version 9 (ICD9), while the Australian Refined DRGs (AR-DRGs) have served for the case codification, and the Nursing Interventions taxonomy of the Clinical Care Classification (CCC) system [38] was used for the documentation of nursing activities.

The system developed is currently being laboratory tested with an EHR system that has been developed by our team. The laboratory implementation indicates that the system, whether interfaced to an EHR or not, is stable enough for practical use and it actually provides a simple, effective and easily expanded tool for the formation of both a CCR and a homecare plan, offering at the same time a good approximation of the individual case cost and a flexible HTML format for data representation, as it is illustrated in Figure 5.

3.3 Remote monitoring and treatment support of high risk groups

Given the amount of time that house calls require, the reimbursement is worldwide very low [11]. However, the emerging technologies could reverse the economics of house calls, and gradually, they can become part of low-cost but high-technology care for high-risk patients, averting expensive hospital admissions.

In our home-computer based monitoring system described previously, the acquired row data of the system are appropriately processed to produce decision supportive data. The ECG waveforms and the corresponding Heart Rate (HR) are directly exported from the ECG module, while HR can also be obtained directly from the Carotid Sound acquisition module. Respiration Rate can also be estimated directly from the Carotid Sound acquisition module, or be extracted by employing frequency analysis and filtering of the original Photo-plethysmography signal (PPG). The PPG taken from finger tip extends from 0.001Hz to 6Hz, with the DC content removed, and the range 0.5 – 2.0 Hz is related to the mean heart rate.

The data were collected in quasi real time mode, and undergone Fast Fourier Transformation in the frequency domain, by employing standard MatLab software. The estimation of Respiration Rate and Heart Rate respectively, was based on the identification of the local frequency peaks, in the ranges 0.01-0.50 Hz and 0.5-2.0 Hz.

The detection of shockable Ventricular fibrillation (VF) and malignant ventricular tachycardia (VT) and the closest responder alerting, for high risk patients, is achieved by employing two different techniques, introduced in earlier reports [39]. The techniques employed are first, the Image Analysis Technique, according to which the ECG record is considered to be an image, divided into a number of equal regions of interest (ROI), and second, the Cumulative Probability Distribution Function (CDF) and the coefficient of Skewness (SKEW) CDF-SKEW techniques.

Concerning home ventilation, it is widely accepted that is safe to treat stable, chronic ventilator-dependent patients in their homes [40], [41]. Home care is as much as 70% less costly than ventilation in an ICU bed and the patient has a better quality of life [42], enhanced social relationships, and less likelihood of nosocomial infection. Attempting to contribute to this multidisciplinary approach, we have designed and implemented a fuzzy logic algorithm [43], to support home Oxygen Therapy management. The Oxygen Saturation (SpO_2), the Heart rate (HR), and the Respiration Rate (RR) data, acquired by the described system, constitute the input of the fuzzy system. As internal indicator of the efficiency of oxygen therapy, Oxygen Saturation over time ($dSpO_2$) has been considered, serving as an evaluative factor, of the patient's condition.

The inputs are translated from crisp values to linguistic variables and the system's response is dictated by a set of fuzzy rules, which were derived based on well established respiration physiology principles. The system actually produces an advice on the percentage change of Oxygen flow to the patient and the translation of its output back to crisp values is performed with the centroid defuzziation method. This result in an improved control of the settings of the home ventilator employed, and the system allows for remote medical supervision and evaluation of both, long term respiratory data trends or short-term interventions, by phone to the patient or his family, if a preset alarm $dSpO_2$ level is reached.

Finally, the transmission of the data can be achieved through wireless point-to-point links, and over IP. Thus, there is the possibility of both, recording long term trends, without visiting the patient, and adjusting accordingly the treatment, or getting alarmed and reacting promptly, in the case of an emergency situation.

4 Concluding Remarks

The reviewed published reports, the mentioned commercially available products, and the presented own research and development outcomes, suggest that something new is emerging, related to house call Medical and Nursing Practice. Although, there is still a multifaceted set of technical, managerial, financial, social, and even legal and ethical problems, to be further investigated, and deeper researched, there is enough evidence that the age of the house calls has not yet passed away forever, it is still much more than nostalgia; it is rather the beginning of a new era, for the oldest way of practicing the Medical Profession in the human History.

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