

Implementation of international transtelephonic ECG platform for patients with ischemic heart disease

Remigijus Žaliūnas, Rimantas Benetis^{1, 2}, Giedrius Vanagas³,
Rimvydas Šlapikas, Alfonsas Vainoras²

Department of Cardiology, ¹Department of Cardiac, Thoracic and Vascular Surgery,
²Institute of Cardiology, ³Department of Preventive Medicine, Kaunas University of Medicine, Lithuania

Key words: telemedicine; telecardiology; teleconsultations.

Summary. Ischemic heart disease in European countries over decades causes up to 55% of all cases of sudden death and also has a high rate of mortality, morbidity, and hospital admission. Patients with such chronic diseases also require intensive home care facilities from community nurses.

The aim was to establish international multilingual platform for transtelephonic ECG system as an alternative solution for home care and assess its performance.

Methods. During this pilot study, the international toll-free line between Lithuania and Germany was established, and practical applicability of the tele-ECG device was tested. Transtelephonic ECG system was implemented between Telemedicine Center in Bad Segeberg (Bad Segeberg Clinic, Germany), the Call Center in Kaunas at the Hospital of Kaunas University of Medicine, and a patient residence.

Results. Over a 6-month follow-up period, 34 patients were recruited. Following the ECG transmission, 86 teleconsultations were done. During the study, a total of 329 ECGs were sent by the patients; out of them, 14 ECGs were with clinical changes. Technical problems due to insufficient patient training, telecommunication systems, acoustic data transmission, and device itself were reported. Up to 23% of ECGs sent by patients were unreadable and not applicable for further clinical analysis.

Conclusions. Our study showed the potential of telemedicine facilities to overcome the problems of access that makes the technique so potentially useful, but for telemonitoring application at patient homes in a wider population, it needs to be improved in terms of technical performance, transmission and analysis automatization.

Introduction

Ischemic heart disease (IHD) in European countries over decades has been a common cause of sudden death (up to 55% of all cases) and also has a high rate of mortality, morbidity, and hospital admission and requires long and intensive hospital care (1, 2). The first idea of transtelephonic transmissions of electrocardiograms (ECGs), ballistocardiograms (BCGs), and electroencephalograms (EEGs) in the former Soviet Union was developed by Prof. Zigmantas Januškevičius and implemented in 1962, when transmissions from Kaunas to Moscow were performed (3). This was the first telemedicine service trial in the former Soviet Union. However, only in late 1980s, tele-ECG screening program using Hewlett Packard system was initiated, aiming to transmit ECGs from rural areas to Kaunas University of Medicine for further analysis.

Over 10 000 ECGs were received in the framework of that program. Unfortunately, the program was cancelled due to political and financial issues. Later telecardiology services were used during the Olympic Games in Sydney in 2000 for remote monitoring of the heart function and reaction to the physical load as well as for the analysis of acclimatization processes and for efficient recovery of cardiovascular system after competitions.

The continuing improvement in computer technologies, image resolution, data compression methods, audiovisual data, and communications allows us to use it for the convenient and efficient management of medical data, images, graphics, movies, and voice recognition. The integration of on-line processing of clinical data for medical consultation follows naturally. These technological advances are now being

acknowledged as beneficial in medicine, health and social care, enabling the application of specialized medicinal care in the home environment. Numerous studies have shown that the diagnostic quality of such a system can be equal to that of a traditional hospital examination (4–7).

However, recent developments in data transmission capability, such as the miniaturization of equipment components and improved image compression, offer further extension of remote cardiac diagnostics (8). A trained patient can perform ECG recording in the home environment and transfer it to a referral hospital, where a cardiologist could serve as a consultant. To improve diagnostic precision and transmission quality, it would be useful to use automatic transmission for the method to be applied clinically (9).

Empowering patients to record himself/herself ECG and to transmit it via a regular telephone line allows nurses and physicians to follow up patients with chronic heart diseases at their homes by comparing emergency ECGs with reference ECGs stored in database and consulting them at home by phone. This could help us to select patients having pathologic ECG changes and transfer them for urgent surgery or examination in emergency unit (5, 9–11). Transtelephonic health care services should also contribute to higher accessibility of health care services and increase the safety of our patients (12).

The aim was to establish international multilingual platform for transtelephonic ECG (TTECG) system as an alternative solution for home care and to assess its performance.

Methods

Setting

During this pilot study, the international toll-free line between Lithuania and Germany was established. Transtelephonic ECG system was implemented among Telemedicine Center in Bad Segeberg (Bad Segeberg Clinic, Germany), the Call Center in Kaunas at the Hospital of Kaunas University of Medicine, and a patient residence.

Device and application description

One day before discharge from hospital, patients were equipped with a personal 12-lead recorder (model CG 7100G manufactured by Card Guard AG) (Fig. 1). This device has easy electrode placement. Only three wires are used to record the modified bipolar leads (9, 13). The device should be placed on three different chest locations in order to record V1–V2, V3–V4, and V5–V6. The first recording phase



Fig. 1. Positions of transtelephonic ECG device application

Table 1. Technical specifications of device CG-7100

Specification	Parameter value
ECG	12 leads
Transmission	Acoustic, not automatic
Modulation	FM tone
Recording period	41 s
Transmission period	43 s
Input impedance	100 MΩ
CMRR	80 db
Input dynamic range	±5 mV
DC offset correction	±300 mV
Band width	0.05–100 Hz
Carrier frequency	1700 Hz
Frequency deviation	100 Hz/mV

CMRR – common-mode rejection ratio;
DC – direct conversion.

records lead I, II, III, aVR, aVL, aVF, V1, and V2. The recording time of the first phase is 20 seconds. The second phase records V3 and V4 for 7 seconds, while during the third phase, V5 and V6 for 7 seconds are recorded (Fig. 1). The total recording time is 41 seconds.

The bandwidth is 0.05–40 Hz, and the analogue to digital sampling rate is 500 Hz at 10-bit resolution. FM tone modulation is used for the transmission over any telephone set and line. A built in loudspeaker works like an acoustic coupler at 1700 Hz carrier frequency plus / minus 100 Hz deviation per mV amplitude change (Table 1) (9).

Patients were trained by a nurse how to use the device, place the electrodes correctly, and send the ECG via toll-free line and regular phone to the Telemedicine Center in Germany, from which ECGs are retransmitted to referral 24-h Call Center.

Call Centre

Call Centre is equipped with database “Kardioregistras” based on Oracle software. Each patient treated at the Hospital of Kaunas University of Medicine

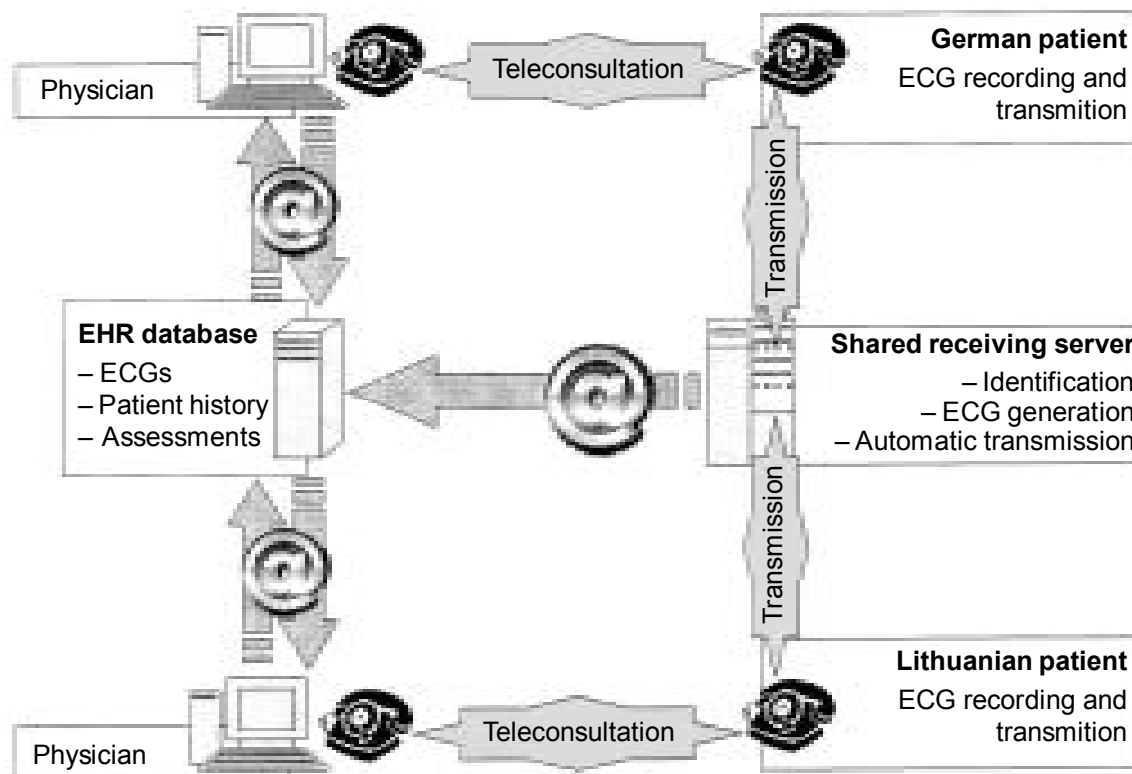


Fig. 2. Schematic representation of the telemedicine system work model

(HKMU) in the database has his/her own file with a set of protocols for patient data from previous treatments, anamnesis, ECG records, risk assessment, echocardiography, etc. Transtelephonic ECG records from Telemedicine Center in Bad Segeberg were transferred via the e-mail and directly uploaded to database "Kardioregistras." Physicians on duty were able to receive all information about a patient when an emergency event occurs and when a patient calls to the Call Centre.

The Call Centre works based on 24 hours, 7 days per week; a board-certified cardiologist was available on duty. Whenever a patient has any symptoms, he/she can call to the center by phone and get a consultation from cardiologist. There was also the possibility for second opinion as specialists of Hospital of Kaunas University of Medicine and Bad Segeberg Clinic were consulting each other. The system allows ECG to be compared on the computer with reference ECGs recorded earlier.

System management

A follow-up study design was used. Basic medical and personal patient data including reference ECG, disease severity, and quality of life were collected during the initial hospital stay and follow-ups (Table 2).

After completed follow-up period, each patient filled in questionnaires to assess compliance, quality of life, acceptability, and satisfaction within the TT ECG system.

All patients included into the study after 3-hour training were able to use the transtelephonic ECG system and recognize heart attack symptoms in daily living situations and in the home environment. The patients were also requested to send a routine ECG every week and to send an urgent ECG when they experienced any alarming symptoms of heart attack. The patients were also requested to consult the cardiologist in our Intensive Care Unit at the Clinic of Cardiology in case of heart attack symptoms. Patients' diaries were distributed to the patients, and they were asked to fill in them by reporting his/her symptoms, duration of symptoms, whether the symptoms had interrupted his/her daily activities, and the actions taken: addressing to GP, calling ambulance or community nurse, and transmitting the ECG to the database at the Clinic of Cardiology.

The advisory report by the physician was based on "evidence-based medicine" principles and guidelines were prepared according to the European Society of Cardiology (ESC) and American Heart Association (AHA/ACC) recommendations. Physician advice to

Table 2. Source of data and variables

Basic variables	Follow-up variables
<p><i>Source: Hospital database</i></p> <ul style="list-style-type: none"> – age – gender – risk factors relevant family history arterial hypertension diabetes smoking hyperlipidemia – body mass index – angina – previous myocardial infarction – congestive heart failure – ejection fraction – valvular heart disease (ischemic/nonischemic) – previous PTCA and/or stent – previous CABG – Risk stratification (DUKE, TIMI, EuroSCORE) – reference ECG 	<p><i>Source: TC-Call Center</i></p> <ul style="list-style-type: none"> – number of calls – calling hour – calling duration <p><i>Source: questionnaire</i></p> <ul style="list-style-type: none"> – quality of life (CORE) – disease severity (Scale) – patients satisfaction (PSQIII) – patients compliance (TCQ) – acceptability – costs – cause of call (diary) – TC advice (diary) <p><i>Source: Hospital database</i></p> <ul style="list-style-type: none"> – hospital stays (number, cause, duration, interventions) – emergency hospital admission – death and cause of death – use of drugs – ECG changes

CABG – coronary artery bypass grafting; PTCA – percutaneous transluminal coronary angioplasty.

the patient could be different: stay at home, repeat ECG after 20 min, invite a community nurse, consult a GP, or call the ambulance. The same system also gives the possibility for nurses visiting patients at home to get a second opinion from a board-certified cardiologist about the ECG changes and make further arrangements if necessary.

Participants

According to inclusion and exclusion criteria, patients with a history of myocardial infarction and at high risk for future IHD events, patients waiting for elective coronary artery bypass grafting (CABG) surgery at their homes with supervision by a community nurse and family physician were included.

The inclusion criteria were as follows: patient's informed consent, hospitalization because of acute coronary syndrome, stable angina pectoris, and coronary artery disease confirmed by coronary angiography. The patients who had had a history of sustained ventricular tachycardia, ventricular fibrillation, had survived myocardial infarction or undergone CABG within 1 month prior to enrollment, also the patients at risk for life-threatening arrhythmia defined as measured left ventricle ejection fraction of <30% with complex ventricular ectopy, and the patients unable

to handle the telemetric device or in any condition or situation, which according to the opinion of the investigator, might have posed a risk to the patient or interfere with participation in the study, were excluded from the study.

Clinical and technical performance assessment

All received ECGs were classified by their quality to use them in clinical practice into following categories: good, moderate, and bad quality, i.e., impossible or almost impossible to analyze. In addition, we compared ECG-specific changes with reference or normal ECGs according to the guidelines of ESC and AHA/ACC.

Consultations were considered beneficial when patients called because of cardiac symptoms or patients' daily treatment was modified. Patients' diaries were used to analyze patients' needs for medical care and to assess the adequacy of their complaints for the study objectives.

User acceptance

After completion of this pilot study, patients and physicians were interviewed by structured interview protocol to assess clinical and technical acceptance of the international transtelephonic ECG system.

Data collection and statistical analysis

Baseline data are documented within database forms at initial hospital stay and within the questionnaires during follow-up period. A detailed descriptive analysis of collected data was made.

Results

According to inclusion and exclusion criteria of our pilot study, we applied transtelephonic ECG system to patients at high risk for future IHD events. During a 6-month follow-up until May 1, 2007, 34 patients were recruited. All descriptive characteristics of study participants are presented in Table 3.

Table 3. Main descriptive characteristics of study participants

Characteristic	Value
Male gender	61.8%
Mean age	63.8±9.0
Left ventricular ejection fraction	0.45±0.12
Previous myocardial infarction	53.3%
Nonstable angina	80.0%
Previous coronary intervention	41.2%
Diabetes mellitus	8.8%
Hypertensive disease	85.3%

Clinical and technical performance of the system

During follow-up, we have received a total of 329 ECGs sent by the patients; 14 ECGs showed clinical changes. Following the ECG transmission, 86 telephone consultations were performed. There were 254 (77%) good-quality, 9 (3%) moderate-quality, and 66 (20%) bad-quality (impossible or almost impossible to analyze) ECGs.

Out of 263 clinically evaluated ECGs, 14 (4%) were classified as abnormal, i.e., had specific ECG changes recorded, and 249 (76%) ECGs were considered normal. In 4 (5%) cases of abnormal ECGs, premature beats were recorded.

Our pilot study highlighted that some of our cardiovascular patients experienced difficulties to manage such device application. We observed some technical problems arising due to insufficient patient training, telecommunication and technical device characteristics (Table 4).

Patients' acceptance of the system

The main disadvantages of the system mentioned

by our patients were problems in transmissions of the ECGs and technical problems they have faced using the system.

The main advantages of the system seen by our patients were as follows: 1) such application is the progress in medicine; 2) with this system they get faster access to health care services than in usual way.

Physicians' acceptance of the system

The main disadvantages mentioned by physicians using tele-ECG system were as follows: 1) application of this system has not reduced physicians' job demand in practice and rarely had a positive impact on effective use of working time; 2) communication process by phone with patient is rarely effective and constructive as half of the calls was not related to heart attack or emergency; 3) 23% of ECGs received were unreadable and not applicable for clinical analysis.

Main advantages of the system mentioned by physicians were as follows: 1) it is easy to learn how to use the system; 2) it is seen as the progress in medicine; 3) it can help to identify patients with heart attack symptoms; and 4) consultation with physician by phone is the same comfortable as consultation given in the department.

Discussion and conclusions

Cardiovascular disease remains the leading cause of morbidity and mortality in developed and developing countries, while health services in these countries are experiencing a number of conflicting influences. Development of technology and imaging techniques has greatly increased a diagnostic power. These developments have been widely reported, creating widespread acceptance both in society and among patients. This has increased public expectations not only for high-technology health care but also for rapid, unimpeded access to health care services. On the other hand, hospital diagnostic services have expanded slowly, while the debate regarding the future funding and provision of health services still continues (8). According to our experience, it would be more favorable for cardiovascular patients to use technologies based on automatic ECG registration and transmission, which are already available in the market. On the other hand, this system has proved rapid, unimpeded access to health care services for the study participants, and further technological adaptation of the system and telemedicine has ability to overcome the problems that will make the technique so potentially useful (8, 14).

Table 4. Examples of practical problems during pilot implementation with elderly cardiovascular patients

Case description	Problem cause	Proposed solution
Patient sent ECG from home with 6 leads	Patient placed device upside-down during ECG record session	Train patient how to place device
Patient sent the same ECG several times	Device memory full	Train patient to start recording from pressing "Clear Memory" button
Transmission was corrupted	Device microphone too far from phone microphone	Train patient to place phone with device microphone
ECG received with very dense spikes	Device microphone too close from phone microphone	Train patient to place phone with device microphone
ECG received with very high noise	1. Electrodes not properly attached, because of thoracic hairs 2. Reuse of electrodes	1. Propose to cut thoracic hairs 2. Use only new electrodes, do not reuse.
Patient could not enter PIN code	Old phone, pulse dialing regimen	Check and switch phone from pulse to tone regime if not buy new
Patient asked teleconsultations due to non cardiac complaints (e.g. cold in the chest)	NA	Explain carefully tasks of study to the patients before enrolling
ECGs from several patients did not arrive the whole day	Problem caused by German telecom provider. Receiving server had no internet connection	No solution

The telecardiology service can help to identify patients with urgent problems requiring immediate assessment at hospital or even emergency admission (9). The system is portable, so it can be used in patients' homes, facilitating the emergency evaluation of chest pain. In a number of cases, we are able to diagnose acute myocardial infarction, arrange immediate transfer to hospital, and begin thrombolytic therapy within a few minutes of arrival. It gives more information about patients to nurses as they can get direct recommendations from physicians. We have described a home care-based telecardiology consultation service limited to previously collected clinical data, cardiac risk assessment, and tele-ECG assessment. It is incorporated into a comprehensive, non-invasive telecardiology consultation service, and this approach was expected to have a positive impact on cardiac service accessibility and both clinical and economical effectiveness comparing to regular cardiology services. In the field of cardiology, the incorporation of data, such as electrocardiograms, echocardiograms, heart sounds and murmurs, vocal messages and images, opens new possibilities for interactive computing and remote consultations (4). Transtelephonic monitoring has been also proved to be an effective

alternative for hospital-based care (8, 9).

Our data showed very high acceptance and expectations of our patients to clinical telecardiology services we provided. Such services can be regarded as meeting patients' expectations and showing high satisfaction with such application (12). The system had also a positive impact on reducing the number of consultations in department, but it was less accepted by physicians due to high numbers of unneeded consultations by phone. Technical performance of international multilingual system was also insufficient as up to 23% of the received ECGs were of low quality and were not applicable for clinical analysis. Such tele ECG application, of course, is beyond of state of the art as mentioned by both physicians and patients, but it also needs to be improved in terms of technical performance and needs higher patients' compliance, vigilance, and objective expectations as such system is designed only to help and fasten diagnostics of the IHD events, not for treatment purposes.

Acknowledgement

This study as a part of project "eHealth for Regions" was partly financed by EU Interreg IIIb program in 2004–2006.

Tarptautinės telefoninių EKG telekonsultacijų sistemos įdiegimas išemine širdies liga sergantiems pacientams

Remigijus Žaliūnas, Rimantas Benetis^{1, 2}, Giedrius Vanagas³,
Rimvydas Šlapikas, Alfonsas Vainoras²

Kauno medicinos universiteto Kardiologijos klinika, ¹Širdies, krūtinės ir kraujagyslių chirurgijos klinika, ²Kardiologijos institutas, ³Profilaktinės medicinos katedra

Raktažodžiai: telemedicina, telekardiologija, telekonsultacijos.

Santrauka. Išeminė širdies liga Europos Sąjungos valstybėse lemia iki 55 proc. visų mirčių, taip pat didelę dalį sergamumo bei hospitalizavimo atvejų. Išemine širdies liga sergantiems ligoniams reikalinga intensyvi medicinos priežiūra. Šio tyrimo tikslas – sukurti tarptautinę telekonsultacijų sistemą išemine širdies liga sergantiems ligoniams ir įvertinti šios sistemos tinkamumą.

Metodai. Pilotinio tyrimo metu tarptautinė telekonsultacijų sistema sukurta tarp Lietuvos ir Vokietijos gydymo įstaigų ir įvertinti telemedicinos įrangos praktiniai pritaikymo aspektai. Telefonu siunčiamos kardiogramos buvo registruojamos ir siunčiamos pačių pacientų į Bad Segebergo telemedicinos centrą, o vertinamos Kauno medicinos universiteto klinikose.

Rezultatai. Šešių mėnesių stebėsenos laikotarpiu tyrime dalyvavo 34 pacientai. Iš 329 ištirtų EKG, 14 EKG su klinikiniais pokyčiais buvo registruotos. Suteiktos 86 telekonsultacijos. Tyrimo metu buvo registruoti techniniai sistemos trūkumai, susiję su pacientų gebėjimais naudotis sistema, telefoninio ryšio, akustinio duomenų perdavimo ir paties aparato problemomis. Iki 23 proc. pacientų siustų kardiogramų buvo netinkamos klinikiniam įvertinimui.

Išvados. Mūsų tyrimas parodė, kad telemedicinos priemonės galėtų būti panaudojamos klinikinėje praktikoje, tačiau sistemos turėtų būti orientuojamos į duomenų perdavimo ir analizės automatizavimą, pacientų mokymą ir paklusnumo didinimą.

Adresas susirašinėti: G. Vanagas, KMU Profilaktinės medicinos katedra, Eivenių 4, 50009 Kaunas
El. paštas: giedrius.vanagas@kmu.lt

References

- Babarskienė MR, Vencloviėnė J, Lukšienė D, Šlapikienė B, Milvidaitė I, Šlapikas R, et al. Prognostication of late left ventricular systolic dysfunction in patients with acute coronary syndrome during the acute period. *Medicina (Kaunas)* 2007;43(5):366-75.
- Žaliūnas R, Babarskienė MR, Kavoliūnienė A, Šlapikienė B, Lukšienė D, Šlapikas R, et al. Lethal outcomes in patients with symptomatic heart failure developed after Q-wave myocardial infarction. *Medicina (Kaunas)* 2004;40(2):141-8.
- Januškevičius ZI, Stasiūnas AS. Transmission of physiological information by telephone. *Cor Vasa* 1963;5:152-5.
- Balogh N, Kerkovits G, Horvath L, Punys J, Punys V, Jurkevičius R, et al. Cardiac digital image loops and multimedia reports over the internet using DICOM. *Stud Health Technol Inform* 2002;90:148-51.
- Berdusis K. The state of the art: tele-echocardiography and telecardiology. *Telemed Today* 1999;7(3):25-6.
- Crowe B, Hailey D. Cardiac picture archiving and communication systems and telecardiology – technologies awaiting adoption. *J Telemed Telecare* 2002;8 Suppl 3:S3-11.
- Fogliardi R, Frumento E, Rincon D, Vinas MA, Fregonara M. Telecardiology: results and perspectives of an operative experience. *J Telemed Telecare* 2000;6 Suppl 1:S162-4.
- Shanit D, Cheng A, Greenbaum RA. Telecardiology: supporting the decision-making process in general practice. *J Telemed Telecare* 1996;2(1):7-13.
- Schwaab B, Katalinic A, Riedel J, Sheikhzadeh A. Pre-hospital diagnosis of myocardial ischaemia by telecardiology: safety and efficacy of a 12-lead electrocardiogram, recorded and transmitted by the patient. *J Telemed Telecare* 2005;11(1):41-4.
- Bolz A, Schaldach M. Telecardiology – a service performance option for the physician. *Biomed Tech (Berl)* 1998;43 Suppl: 212-3.
- Chiantera A, Scalvini S, Pulignano G, Pugliese M, De Lio L, Mazza A, et al. Role of telecardiology in the assessment of angina in patients with recent acute coronary syndrome. *J Telemed Telecare* 2005;11 Suppl 1:93-4.
- Vanagas G, Kinduris S, Vaičiūnaitė L, Žaliūnas R, Benetis R, Šlapikas R, et al. Acceptance and patients' satisfaction with international trans-telephonic emergency ECG system in cardiology clinical practice. *Ukr J Telemed Med Telemat* 2006;4(2):145-52.
- Schwaab B, Katalinic A, Riedel J, Kiepe W, Huhmann W, Sheikhzadeh A. Feasibility and reliability of a transtelephonic 12 leads ECG. *Z Kardiol* 2003;92(1):31-8.
- Roth A, Kajiloti I, Elkayam I, Sander J, Kehati M, Golovner M. Telecardiology for patients with chronic heart failure: the 'SHL' experience in Israel. *Int J Cardiol* 2004;97(1):49-55.

Received 17 January 2008, accepted 5 February 2009
Straipsnis gautas 2008 01 17, priimtas 2009 02 05