DOI: 10.17816/PED9521-26

# EXPERIENCE USING INTERNET-ECG TO OPTIMIZE THE PATIENTS HOSPITALIZATION DURATION WITH ACUTE MYOCARDIAL INFARCTION

© E.V. Timofeev, Ch.A. Abdalieva, E.V. Zemtsovsky

St. Petersburg State Pediatric Medical University, Ministry of Healthcare of the Russian Federation, Russia

*For citation:* Timofeev EV, Abdalieva ChA, Zemtsovsky EV. Experience using internet-ECG to optimize the patients hospitalization duration with acute myocardial infarction. *Pediatrician (St. Petersburg)*. 2018;9(5):21-26. doi: 10.17816/PED9521-26

Received: 03.09.2018 Accepted: 19.10.2018

***The aim*** of this study was to examine the efficiency of on-line Internet-electrocardiography (ECG) in the practice of GP (therapist) to clarify the factors causing chest pain and make a decision about the necessity of emergency hospitalization. ***Materials and methods.*** 2022 ECG recording made by the patients at home by means of "Cardiometr" device ("Micard Lana", St. Petersburg) were registered by GP (therapist) with concern to identify heart rhythm disorders and make a differential diagnosis of chest pain. The decision to hospitalize was taken in view of automatic detention. ***Results.*** A high percentage of coincidence between automatic and medical conclusion on violation of heart rhythm and ischemic ECG changes was revealed. It also showed total match of automatic and expert opinions about the myocardial infarction stage and its localization. Use of on-line Internet ECG helps to substantially increase the amount of patients hospitalized in first 6 hours after the onset of chest pain (37,7% vs 19,4%, $\chi^2 = 3,65$, $p = 0,05$) and reduce the number of patients hospitalized in the late timeline (more 24 hours) (10,1% vs 27,8%, $\chi^2 = 5,42$, $p = 0,01$). ***Conclusion.*** ECG automatic analysis provides high accuracy of diagnosis of cardiac arrhythmias and acute focal changes and will promptly resolve the necessity of emergency hospitalization of patients with myocardial infarction. It is advisable to equip the similar devices GP (therapist) carrying out visiting patients at home.

**Keywords:** telemetric ECG; early diagnosis of myocardial infarction; automatic ECG analysis.

# ОПЫТ ПРИМЕНЕНИЯ ИНТЕРНЕТ-ЭКГ ДЛЯ ОПТИМИЗАЦИИ СРОКОВ ГОСПИТАЛИЗАЦИИ БОЛЬНЫХ ОСТРЫМ ИНФАРКТОМ МИОКАРДА

© Е.В. Тимофеев, Ч.А. Абдалиева, Э.В. Земцовский

ФГБОУ ВО «Санкт-Петербургский государственный педиатрический медицинский университет» Минздрава России

*Для цитирования:* Тимофеев Е.В., Абдалиева Ч.А., Земцовский Э.В. Опыт применения интернет-ЭКГ для оптимизации сроков госпитализации больных острым инфарктом миокарда // Педиатр. – 2018. – Т. 9. – № 5. – С. 21–26. doi: 10.17816/PED9521-26

Поступила в редакцию: 03.09.2018 Принята к печати: 19.10.2018

***Целью исследования*** явилось изучение возможностей использования телеметрической интернет-ЭКГ в практике участкового терапевта для уточнения причины развития болевого синдрома и принятия решения о необходимости экстренной госпитализации. ***Материалы и методы.*** Врачами-терапевтами городской поликлиники было зарегистрировано 2022 записи ЭКГ на дому с использованием устройства «Кардиометр» (ЗАО «МИКАРД-ЛАНА», Санкт-Петербург) по поводу нарушений сердечного ритма и с целью дифференциальной диагностики кардиалгий. Решение о госпитализации принималось с учетом автоматического заключения с последующим сопоставлением результатов автоматического и экспертного заключений. ***Результаты.*** Отмечен высокий процент совпадений автоматического и врачебного заключения по нарушениям ритма сердца и проводимости, а также очаговым изменениям ЭКГ. Показано также полное совпаде-

ние автоматического и экспертного заключений по стадии и локализации инфаркта миокарда. Использование при посещении врачом больного на дому интернет-ЭКГ позволяет существенно увеличить долю больных инфарктом миокарда, госпитализированных в первые 6 часов от начала болевого приступа, и уменьшить число больных, госпитализированных в поздние сроки (более 24 часов). ***Заключение.*** Комплекс автоматического анализа ЭКГ с автоматической обработкой обеспечивает высокую точность диагностики нарушений сердечного ритма и острых очаговых изменений, что позволяет оперативно решать вопросы об экстренной госпитализации больных с инфарктом миокарда. Целесообразно оснастить подобными устройствами врачей, осуществляющих посещения больных на дому.

**Ключевые слова:** интернет-ЭКГ; ранняя диагностика инфаркта миокарда; автоматический анализ ЭКГ.

Diagnosis of acute myocardial infarction (AMI) in the prehospital stage remains one of the urgent cardiological issues. Specifically, unjustified hospitalization of patients with cardiac pain due to difficulties in differential diagnosis of AMI during outpatient care as well as late hospitalization of patients associated with an atypical AMI course are two major concerns. Limited awareness of the course of cardiac pathologies and delay in seeking medical help are associated with late hospitalization of patients with acute coronary syndrome (ACS), whereas deficiencies in the organization of medical care by physicians at the time of first contact is another reason.

More than 2.5 million electrocardiograms (ECG) are obtained annually in St. Petersburg, more than one million of which are recorded within the outpatient network. However, the waiting time for ECG at city polyclinics ranges between one to two weeks, which is associated with late AMI diagnosis and unreasonable hospitalization of patients with cardiac pain. Performing ECG at home is limited, as it requires emergency medical services and increases the workload of the functional diagnostics departments at city polyclinics. The workload on the functional diagnostics department is regulated by a system that issues certain number of letters. A physician at the functional diagnostics department requests approximately 19–20 ECGs during a seven-h working day, whereas the nurse must register 25 ECGs per working day. The additional load on the ECG staff is associated with frequent emergency conditions. Patients presenting with typical signs of ACS can be hospitalized without prior ECG. However, patients with indistinct clinical picture or who are paucisymptomatic are forced to wait in line for ECG, which delays hospitalization.

Another issue related to obtaining ECGs at home is the necessity for medical personnel to visit with an electrocardiography device. Delays in AMI diagnosis in these cases are almost inevitable since house calls of the nursing personnel is fraught with difficulties including provision of vehicles and increase in the overload of the ECG services of the clinics. Rapid advances in medical technology has led to the development of portable electrocardiography devices that can be provided to individual primary care physicians; however, physicians at polyclinics are often not prepared to obtain an ECG independently or, more importantly, interpret the recording. One approach is the introduction of telemetric Internet ECG into the daily practice of primary care physicians.

ECG telemetry is a rapidly developing telemedicine field[1]. The first Russian portable 12-channel tele-electrocardiograph with cloud processing and ECG storage is the Cardiometer (hereinafter referred to as the device) by MIKARD-LANA (St. Petersburg), which weighs 300 g and enables the physician to take the Cardiometer to the patient visit, obtain the ECG, and transfer it to a mobile phone, smartphone, or personal computer with an Internet access via Bluetooth connection. ECG is transferred to a "cloud cardio server," where it undergoes computer processing, which generates an automatic ECG report. The automatic analysis results are stored in the user's individual archive on the server and can be sent to a mobile phone or computer as a brief computer report with preliminary ECG classification including normal, deviation from the norm, and pathology, based on a traffic-light model. Deviation from the norm includes ECG findings of minor changes in the heart rhythm and/or forms of the atrioventricular complex, which are not clinically significant. A fully automatic ECG report, which comprises a description of the cardiac rhythm and any associated disorders and the analysis of the atrioventricular complex form, can also be obtained. In addition to the report, the physician can also see common ECG on the smartphone.

[1] Order of the Ministry of Health of Russia dated October 13, 2017 No. 804n on approval of the nomenclature of medical services. A05.10.004.001 Decoding, description and interpretation of data of electrocardiographic studies with the use of telemedicine technologies.

A more detailed description of the technique and its comparison with similar systems are described in a review [2].

Identification and authentication of the users are used to protect anonymous personal data of the patients processed by the cloud cardio server. Anonymous personal data are transferred over the communication channels in the protected form.

The use of Internet ECG for examining patients in a large city hospital was previously reported to be associated with positive outcomes including a significant decrease in waiting time for the ECG report by the attending physician and a sufficiently high accuracy of the automatic analysis results in detection of sinus rhythm and atrial fibrillation as well as certain conduction disturbances including complete blockage of left His bundle branch and first-degree atrioventricular blockage [1]. However, the utility of Internet ECG in outpatient settings or the accuracy of the automatic analysis of focal ECG changes has not been evaluated. The timely registration of an ECG during an outpatient visit of a patient at home with subsequent rapid decoding has the potential to significantly reduce the time for decision-making regarding the need for hospitalization of the patient in specialized hospital departments.

Thus, we determined the utility of telemetric Internet ECG at a city clinic in identifying the causes of cardiac pain and determining the need for emergency hospitalization. Specific study objectives were to determine the need of the outpatient service for ECG registration at home, compare the accuracy levels of the medical and automatic ECG reports regarding cardiac rhythm and changes in the shape of the atrioventricular complex, and assess the potential impact of the Internet ECG utilization on the timing of hospitalization in patients with AMI.

## MATERIALS AND METHODS

The study was conducted at the City Polyclinic No. 37 in St. Petersburg. The four primary care general practitioners at the polyclinic received portable devices for recording 12-lead ECGs. 2014 to 2015, the physicians performed 2022 ECG examinations during house calls. The main reasons for ECGs were suspected heart rhythm disturbances and chest pain. After registering the ECG and sending the recording to the server, the physician received an automatic report within 1–2 min and decided on the need for hospitalization based on the results. All records were later evaluated by an expert physician at the functional diagnostics department of the polyclinic. Additionally, in patients who were detected to have AMI and hospitalized, the ECG data were retrospectively compared with the laboratory and imaging results included in the hospital discharge summary.

Statistical analyses were performed using the Statistica 8 software (StatSoft, Inc.). Significance of differences between qualitative signs was determined using non-parametric chi-squared test ($p < 0.05$).

## RESULTS

We first analyzed the need for ECG registration at an outpatient setting during house calls by general practitioners. According to the data obtained from the registration cards, an average of approximately 20,000 house calls were received during the calendar year. Majority of these patients complained from cardiac-related symptoms including chest pain, high blood pressure, cardiac arrhythmias, and signs of heart failure. ECG registration is required for all patients with such complaints to determine next stage of management, including the decision on hospitalization. In addition, according to the existing medical and economic standards, ECG should be obtained from patients with a protracted course of acute respiratory disease and those with neurological disorders including dystrophic-degenerative disorders of the spine for the differential diagnosis of chest pain. Thus, during a year, approximately 25,000 ECGs are performed during house calls by one city clinic. Conversely, the use of conventional ECG recording systems which involves the house call of a nurse using special transport allows ECG examination of no more than 2,0000 patients, which is only 10% of the usual volume.

We analyzed all 2022 ECGs obtained by primary care physicians during house calls and compared the cardiac rhythm analysis based on the automatic processing to that based on the medical expert review (Table 1). All instances where sinus rhythm and atrial fibrillation were recognized automatically were confirmed by the medical expert. A complete agreement between the automatic and medical analyses was also noted for the identification of both supraventricular and ventricular extrasystoles. Furthermore, in one case, atrial flutter was diagnosed mistakenly, which was likely due to the presence of artifacts which can sometimes be considered as flutter waves by the automatic analysis software.

We compared the assessment of pacemaker migration separately. In patients with a sinus rhythm and migration sites present in the same ECG recording, the automatic analysis report indicated only the pacemaker migration as the heart rhythm, whereas

*Table 1 / Таблица 1*

Comparison of the accuracy of the automatic analysis and medical analysis arrhythmias
Сравнение точности автоматического и врачебного анализа ритма сердца

| ECG syndromes / ЭКГ-синдромы | Automatic interpretation / Автоматическая интерпретация | Medical conclusion / Врачебное заключение |
|---|---|---|
| Sinus rhythm / Синусовый ритм | 1835 | 1836 |
| Atrial fibrillation / Фибрилляция предсердий | 171 | 171 |
| Atrial flutter / Трепетание предсердий | 9 | 8 |
| Wandering pacemaker rhythm/ Миграция водителя ритма | 7 | 2 |
| Sinus rhythm with episodes of wandering Pacemaker rhythm / Синусовый ритм с эпизодами миграции водителя | 0 | 5 |
| AV-block 1 degree / АВ-блокада 1-й степени | 165 | 161 |
| Extrasystole / Экстрасистолия | 237 | 237 |

the medical expert based their conclusion on both rhythms. As shown in the table, migration episodes a main sinus rhythm were detected in only five patients (0.2% of the entire cohort). Overdiagnosis of first-degree atrioventricular block was also noticeable, which was due to the absence of an algorithm within the automatic analysis software that takes into account the relationship between the duration of the *PQ* interval and the heart rate.

Our analysis of the changes in focal signs by ECG revealed that the ECG-based diagnosis of focal changes was based on the identification of a pathological *Q* wave by automatic analysis, implying the presence or absence of a *Q*-myocardial infarction. The term "unclear stage" was used for focal changes in the automatic report. The signs of focal changes were detected in 173 ECGs, acute stage AMI was diagnosed in 85 ECGs, and subacute stage was diagnosed in 54 ECGs. The diagnosis of myocardial infarction was unclear by the automatic reporting for 34 ECG, which were confirmed as acute focal changes by the medical expert evaluation. After discharge from the hospital, the ECG data were compared with the imaging and laboratory data, which revealed a complete agreement on the localization and the stage of focal changes on ECG determined by automatic analysis and the definitive clinical diagnosis.

In summary, comparison of the automatic software-based analysis and the medical expert evaluation regarding the form of the atrioventricular complex revealed a good agreement between the two methods. However, one limitation was the automatic analysis of low-quality recordings; in such cases, ECG interpretation could not be performed automatically due to poor signal quality.

Finally, we determined the time of hospitalization from the onset of the pain episode in patients with a clinically diagnosed ACS, which revealed that 105 of a total of 173 patients with focal ECG changes were hospitalized following a house call by a physician, whereas 12 patients refused hospitalization. In the remaining 56 patients, the detected focal changes were determined to be manifestations of cicatricial post-infarction changes based on previous ECG recordings. Given that the prognosis is significantly improved with early hospitalization of patients with AMI, within the first six h, we also compared the hospitalization duration of patients with AMI in 2013 when the Internet ECG was not used, and that of the patients with AMI in 2014–2015 when the Internet ECG system was used. As presented in

*Table 2 / Таблица 2*

The timing of the decision on hospitalization of patients with MI, depending on the use of the Internet-ECG
Сроки принятия решения о госпитализации больных острым инфарктом миокарда в зависимости от использования системы интернет-ЭКГ

| The timing of hospitalization / Сроки госпитализации | 2013 36–100% | | 2014/2015 69–100% | | *p* |
|---|---|---|---|---|---|
| 0–6 hours / 0–6 часов | 7 | 19.4 | 26 | 37.7 | 0.05 ($\chi^2 = 3.65$) |
| 7–12 hours / 7–12 часов | 19 | 52.8 | 36 | 52.2 | 0.95 |
| After 12 hours / Позднее 12 часов | 10 | 27.8 | 7 | 10.1 | 0.01 ($\chi^2 = 5.42$) |

Table 2, compared with the previous year, the number of patients with AMI who were hospitalized within the first six h after the onset of cardiac pain was increased approximately two folds, and the number of late hospitalizations was significantly lower during the period of Internet ECG use (27.8% and 10.1%, respectively, $p = 0.01$).

## DISCUSSION

This findings of this study revealed that the complex automatic ECG analysis with cloud processing and ECG storage provided high diagnostic accuracy that was comparable with the expert analysis. Given its small size and weight, the device should be included in the equipment list of general practitioners on house calls for patients with chest pain, which can aid in quick diagnosis and surveillance of patients with ACS. Additionally, use of the Cardiometer should lead to increased availability of ECG evaluation for patients who are evaluated on an outpatient basis and network, improve the diagnosis of various presentations of ischemic heart disease, reduce unreasonable hospitalization, and increase the rate of hospitalization of patients with atypical or painless AMI.

Thus, portable devices for ECG recording should be recommended for physicians who are the first contact at polyclinics without the involvement of the nursing staff to improve the early diagnosis of ischemic heart disease. The widespread introduction of telemetric Internet ECG into practice at city polyclinics, medical and obstetric centers, and emergency medical ambulance teams will contribute to significant improvements in the early diagnosis of cardiac pathologies as well as the prevention of AMI, and its complications. Obtaining recordings with Internet ECG at the prehospital stage will significantly reduce the time from the onset of ACS to definitive diagnosis, significantly improve diagnosis, and enhance timely hospitalization of patients with paroxysmal cardiac rhythm disorders.

## CONCLUSION

Over a one-year period, approximately 25,000 ECGs are recorded during house calls from on city clinic in St. Petersburg, and the traditional system used during these house calls covers only 10% of the number of ECGs needed in the city clinic. Internet ECG with subsequent automatic decoding significantly expands the possibilities for detecting heart rhythm disorders and focal changes, and the use of devices with automatic assessment of ECGs by local physicians can facilitate early diagnosis and timely hospitalization of patients with AMI.

## REFERENCES

1. Баллюзек М.Ф., Бугагин Д.В., Морозова Н.Н. Опыт унификации исследований ЭКГ-покоя с использованием облачной технологии для их автоматической интерпретации и хранения в многопрофильной больнице // Медицинский алфавит. – 2016. – Т. 1. – № 4. – С. 58–61. [Ballyuzek MF, Bugagin DV, Morozova NN. Experience of unification of ECG studies using cloud technology to automatically interpret and store in general hospital. *Meditsinskii alfavit*. 2016;1(4):58-61. (In Russ.)]
2. Земцовский Э.В., Абдалиева С.А., Баллюзек М.Ф., и др. Электрокардиограмма покоя в 12 общепри-

нятых отведениях. Настоящее и будущее // Российский кардиологический журнал. – 2015. – Т. 20. – № 9. – С. 84–87. [Zemtsovskiy EV, Abdalieva SA, Ballyuzek MF, et al. Resting electrocardiography in 12 common leads: the present and the future. *Russian journal of cardiology*. 2015;20(9):84-87. (In Russ.)]. doi: 10.15829/1560-4071-2015-09-84-87.

◆ Information about the authors

*Eugene V. Timofev* — MD, PhD, Associate Professor, Department of Propaedeutics Internal Medicine. St. Petersburg State Pediatric Medical University, Saint Petersburg, Russia. E-mail: darrieux@mail.ru.

*Cholpon A. Abdalieva* — Assistant Professor, Department of Propaedeutics Internal Medicine. St. Petersburg State Pediatric Medical University, Saint Petersburg, Russia. E-mail: 5119443@mail.ru.

*Eduard Veniaminovich Zemtsovsky* — MD, PhD, Dr Med Sci, Professor, Head, Department of Propaedeutics Internal Medicine. St. Petersburg State Pediatric Medical University, Saint Petersburg, Russia. E-mail: zemtsovsky@mail.ru.

◆ Информация об авторах

*Евгений Владимирович Тимофеев* — канд. мед. наук, профессор, доцент, кафедра пропедевтики внутренних болезней. ФГБОУ ВО «Санкт-Петербургский государственный педиатрический медицинский университет» Минздрава России, Санкт-Петербург. E-mail: darrieux@mail.ru.

*Чолпон Абдалиевна Абдалиева* — ассистент, кафедра пропедевтики внутренних болезней. ФГБОУ ВО «Санкт-Петербургский государственный педиатрический медицинский университет» Минздрава России, Санкт-Петербург. E-mail: 5119443@mail.ru.

*Эдуард Вениаминович Земцовский* — д-р мед. наук, профессор, заведующий, кафедра пропедевтики внутренних болезней. ФГБОУ ВО «Санкт-Петербургский государственный педиатрический медицинский университет» Минздрава России, Санкт-Петербург. E-mail: zemtsovsky@mail.ru.