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## The Role of Standard 12-lead ECG in a Telecardiology Consultation Service

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### 1. Introduction

Electrocardiography (ECG), introduced in 1902 by Einthoven, is the most commonly used procedure for the diagnosis of heart disease. It is a frequently performed procedure by internists and family practitioners as well as by emergency department physicians and cardiologists. As a record of electrical activity of the heart, it is a technology that provides information not readily obtained by other methods. The 12-lead ECG has numerous potential clinical uses. It serves as the criterion standard for noninvasive diagnosis of arrhythmias and conduction disturbances, and occasionally it is the only marker for the presence of heart disease. Prior studies have shown that misinterpretation of the ECG can lead to inappropriate diagnoses and clinical decisions.

Telecardiology is one of the oldest applications in telemedicine, and has been largely applied during the last 10-20 years. Telecardiology encompasses a wide variety of applications and is one of the fastest-growing fields in telemedicine. Telecardiology in some fields such as emergency and chronic care undoubtedly improves the quality of health care and helps to contain rising costs. ECG consultations between general practitioners and specialists encompass a wider spectrum of clinical entities, including non-urgent patient care.

An internet-based telecardiology centre for ECG consultations was established in 2008. The centre provides physicians with comprehensive ECG consultations, including description of the ECG findings, case urgency, need for further examinations, and recommendations for therapeutic strategy, like changes in medication or need for hospital admission. The service was initially provided by a separate enterprise, which in 2010 was incorporated into the Tampere University Hospital Heart Centre, a tertiary cardiologic referral centre.

In this chapter, the patient material from the consultation service is presented, including age, sex, and estimated case urgency. The ECG findings are classified into clinical categories, like suspected acute coronary syndrome, and arrhythmias. Consultation response delays and technical aspects are reported, as well as recommendations provided by the cardiology experts.

The potential benefit of an ECG consultation service, which provides clinical recommendations, is discussed. There are quite a few challenges with the introduction of a new consultation model. Many physicians are unaware of their limitations and believe that

they can interpret ECGs well. Physicians may prefer telephone contact instead of an internet-based consultation service. Advantages and disadvantages of different consultation models are discussed; also cost issues are discussed.

## 2. Telemedicine

Telemedicine is the provision of healthcare services, through use of information and communication technology, in situations where the health care professional and the patient, or two health care professionals, are not in the same location. It involves the secure transmission of medical data and information, through text, sound, images, or other forms needed for the prevention, diagnosis, treatment and follow-up of patients (Saxena et al., 2003). Despite the potential of telemedicine, its benefits and the technical maturity of the applications, the use of telemedicine services is still limited, and the market remains highly fragmented. Integrating new types of services in healthcare services is a challenging task (Commission of the European Communities: COM(2008)689). Privacy and security related aspects are also major components of building trust and confidence in telemedicine systems. Interoperability and standardisation in telemonitoring are crucial to allow widespread use of the technologies. The societal and economic benefits from wider use of telemedicine are potentially huge. At the present moment, they are far from being fully appreciated or achieved (Edwards et al., 2008; Hämäläinen et al., 2008).

## 3. Telecardiology

Telecardiology is one of the oldest applications in telemedicine, and has been largely applied during the last 10-20 years (Hailey et al., 2004). Telecardiology encompasses a wide variety of applications. Over 200.000 patients worldwide are being managed via remote implantable electronic cardiovascular device monitoring to facilitate the recognition of abnormal device behaviour and verify the patient's immediate physiological response to the many programmable therapies the devices offer (Jung et al., 2008). Data collected in several completed and ongoing studies strongly suggest that this new technology will make important contributions, particularly with respect to the facilitation of device follow-ups, enhancement of patient safety and quality of life, and lowering of medical costs. Continuous home monitoring of vital parameters like weight, blood pressure and heart rate, using external telemedicine devices, can improve outcomes in heart failure patients (Cleland et al., 2005; Goldberg et al., 2003; Louis et al., 2003).

Telecardiology applications can be categorized as pre-hospital, in-hospital and post-hospital (Scalvini & Glisenti 2005). Coronary artery disease provides an ideal target for telehealth intervention because of its great and increasing financial cost, and the overrepresentation of heart disease in rural and remote communities (Hooper et al., 2001). The major purpose of pre-hospital 12-lead ECG diagnosis is the early detection of acute myocardial infarction with ST-segment elevation and the communication of that information to the receiving emergency physician before the arrival of the patient (Terkelsen et al., 2005). Transmission of prehospital 12-lead ECG directly to the attending cardiologist's mobile telephone decreased door-to-device time by >1 hour when patients with ST-elevation myocardial infarction were transported directly to invasive centres, bypassing local hospitals (Sejersten et al., 2008). Ambulance transport was safe despite longer transport times. On the other hand, long transport times may allow the catheterization suites more preparation time. The telephone display showed sufficient resolution for ECG interpretation.

In-hospital telecardiology is used between small hospitals in rural regions and main hospitals (Zaliunas et al, 2009). Telemedicine here has the potential to improve access to echocardiography diagnoses in the intensive care unit, emergency room and newborn nursery (Sekar & Vilvanathan, 2007). Post-hospital applications include teleconsulting between general practitioners and specialists, home telenursing for chronic cardiac diseases and the diagnosis of arrhythmias (Goh et al., 2006; Scalvini et al., 2006).

Publications related to telecardiology surveillance of coronary care unit monitoring data outside hospital are scarce and mostly deal solely with technical aspects (Nikus et al., 2009).

#### 4. Electrocardiology

The 12-lead ECG has been used in clinical medicine since the early 1900s as a first-line diagnostic tool in studying both acute and chronic cardiac diseases. The ECG is a noninvasive, relatively inexpensive diagnostic test that provides important information regarding not only the heart, but also non-cardiac events impacting the cardiac system.

Numerous studies have compared cardiologists and non-cardiologists in their ability to recognize ECG changes. A review of the literature showed a wide variety in skills among various specialities (Mele, 2008). Non-cardiologists were in disagreement with the cardiologist reference interpretations from 4 % to 64 % of the time, depending on the specific abnormality in question. Salerno et al suggested that up to one third of ECG interpretations have some error when compared to the expert reference (Salerno et al., 2003). The authors estimated that up to 11 % resulted in inappropriate management, e.g. anticoagulation for non-existent atrial fibrillation; close to 1 % had significant adverse outcomes or potentially preventable death. A screening study from 49 general practices in central England showed that many primary care professionals cannot accurately detect atrial fibrillation on an ECG, and interpretative software is not sufficiently accurate to circumvent this problem, even when combined with interpretation by a general practitioner (Mant el, 2007). Twenty per cent of cases of atrial fibrillation were missed by the general practitioners, and the probability that a positive diagnosis was correct was only 41 %.

There is wide variability in ECG over-reading, in part because of lack of standards for certifying individuals to over-read ECGs. According to a position statement by the American College of Cardiology and the American Heart Association, all ECGs should be over-read either by cardiologists or ECG-tested physicians (Kadish et al., 2001). The statement has good scientific background, but it is difficult to implement in many countries. Hongo and Goldschlager proposed telemedicine as a possible solution to improve ECG diagnostics (Hongo & Goldschlager, 2004). In an editorial, they discussed the difficulties of automated computer analysis to assess cardiac rhythm and concluded that physicians should become less reliant on computerized interpretations. A system with on-call ECG reading service that accepts tracings by fax or via electronic mail to handheld devices was suggested. ECGs performed in an outpatient setting could be sent for centralized interpretation that would then be returned to an office "in-box". The authors predict that this approach would ensure that ordering physicians, as a matter of routine, review finalized ECG interpretations and take responsibility for patient follow-up.

Correct ECG interpretation is extremely important in patients with a suspicion of acute coronary syndrome. Vijayaraghavan et al investigated ECG interpretation on site with core laboratory interpretation in acute coronary syndrome patients, focusing on ST elevation (Vijayaraghavan et al., 2008). Overall concordance between the core-lab and on site

interpretation was 62 % and the calculated kappa 0.49, indicating modest agreement. In an editorial referring to this article, Brady and O'Connor state that the physician receiving the ECG in the suspected acute coronary syndrome patient must be an expert in ECG interpretation (Brady & O'Connor, 2008). Studies have shown consistently high rates of agreement between the emergency physician and the cardiologist (Kuhn et al., 1992; Todd et al., 1996). However, at least in our country, patients with suspected acute coronary syndromes are likely to be treated by inexperienced junior doctors. This highlights the importance of the possibility to consult a specialist through telemedicine.

### 5. Tele-ECG consultation

In teleconsultation a representative of health care personnel approaches an expert in a remote place for advice. In the *Real time interactive mode* the patient is present with an attending physician or paramedical personnel and a specialist is present at a remote center. In the *Store-and-forward mode* all relevant information is transmitted electronically to the specialist, who generates a report within hours or days. The latter model is typical for teleradiology.

Molinari et al studied the role of telecardiology in reducing unnecessary hospital admissions of patients with suspected life-threatening cardiac events, evaluated by general practitioners. One hundred general practitioners in remote rural areas in Italy sent a trans-telephonic 12-lead ECG, mostly from the patients' home to a cardiologist on 24/7 duty (Telemedicine Institute, Genoa) (Molinari et al., 2002). The general practitioners used transportable ECG equipment. Before teleconsultation, the general practitioners recorded their own opinion (based on clinical evaluation only) about the presence of a cardiac event. Following transmission of the ECG, this opinion was compared with that of the cardiologist. In total there was agreement between the general practitioner and cardiologist about the presence of a cardiac event in 316 of the patients (69%) and disagreement in 140 patients (31%). This represents a specificity and sensitivity of the general practitioners' diagnosis of 76% and 47%, respectively. For 84 of 134 patients judged as having a cardiac event by the general practitioner, telecardiology avoided hospitalization. On the other hand, telecardiology identified a cardiac event in 56 of 322 patients judged as not having a cardiac event by the general practitioner. The authors concluded that telecardiology is a useful tool to reduce unnecessary hospitalizations in patients with suspected life-threatening cardiac events. The system presented seems to be useful in countries and regions with frequent use of home visits by physicians.

Investigators have reported their experiences with ECG transmission by patients to a telemedicine center. Chiantera et al compared two models of assistance (telecardiology versus usual care) for patients discharged after acute coronary syndrome in the assessment of angina pectoris (Chiantera et al., 2005). Two hundred patients were randomized either to telecardiology or to usual care. Patients randomized to usual care underwent a control visit 15 and 30 days after discharge. In the telecardiology group, the patients were provided with a portable device by means of which a 12-lead ECG could be recorded and transmitted to the service centre by fixed or mobile telephone. ECGs were sent either for symptoms, or as routine at 4 weeks follow-up. The service offered by the telemedicine institution was available 24 h per day. Early hospital readmission in the first month occurred in 16 patients (7 in the telecardiology Group and 9 in the usual care group). The authors concluded that telecardiology slightly reduced hospital readmissions and better identified true angina pectoris.

Experiences from the Shahal organization in Israel pointed to considerable cost savings by trans-telephonic ECG transmission by the service subscribers thanks to shorter delays from anginal symptom onset to call for medical help. In the majority of calls, an ambulance transport could be avoided (Roth et al., 2006).

## 6. Real time interactive tele ECG

Procardia Medical Center in Israel provides large volume on-line internet-based tele-ECG consultations to health care professionals around the country (unpublished data reported by one of the authors, Professor Samuel Sclarovsky, director of telemedicine at Procardia). Planning of a tele-ECG consultation service in Tampere University Hospital started in the mid-2000s. Basically, the logistics of the system should enable treating physicians to consult cardiology specialists about ECG-related medical topics, and get a swift response. The cardiologist should also give medical advice about additional tests needed, need for change in medication, patient urgency etc. In other words, the system should not provide technical ECG analysis only. In addition, the system should be easy to use, technically robust and adequately secure for the handling of patient data. Finally, the system should enable interactivity through messages in addition to the consultation requests and responses.

It was decided that the most urgent cases should not be handled through the telecardiology consultation service, because clinical decisions should be made within minutes in acute cardiac urgencies. The Heart Center at Tampere University Hospital provides telecardiology consultation service 24/7/365 for acute ST-elevation myocardial infarction patients. In that system, the ECGs are sent by fax or mobile phone to a handheld communicator and clinical decisions are made by telephone contact between the cardiologist on duty and the treating physician or emergency medical personnel. Delays from the first ECG to arterial puncture and to first device are well within recommendations from international guidelines (article published in Finnish).

## 7. Telecardiology pilot

During the planning phase for the tele-ECG service, a pilot study was performed in 2007. In the pilot, the Tampere University Hospital Heart Center provided tele-ECG consultation service for one health centre and for the emergency department of a regional hospital. The 12-lead ECGs were immediately stored at these 2 remote units into a digital ECG archive (GE Muse database), with immediate access for the cardiologist to the recordings and, if available, to previous recordings for comparison. The Personal Information Repository (PIR) document service was used in delivering consultation requests, responses and other related documents. The architecture of the PIR document service and the experiences from the pilot have been described in a previous article (Lähteenmäki et al., 2009). In a questionnaire, usability of the service was evaluated. Health care personnel estimated possible benefits for the patients as high. No major technical problems were encountered.

Based on the pilot phase, literature reviews and multidisciplinary planning, a telecardiology service company in close association with the Heart Centre was established. A business plan pointed to possibilities for the company to show positive results, providing the consultation service would be largely implemented in health centres in different parts of our country. In addition, other telecardiology applications were planned.

### **7.1 The consultation system**

During the final planning phase, the PIR document service was replaced by an internet homepage-based consultation system. Physicians from the health care units, who participate in the telecardiology service, typically general practitioners, have user names and passwords to enter the consultation program. A structured form is filled in and sent to the telecardiology centre. Arrival of a consultation request will alert the cardiologist by an SMS to a mobile phone. The cardiologist opens the consultation program by user name and password. Most health centres in the Pirkanmaa Hospital district store the ECGs digitally into the GE Muse database, from which the ECGs can be analyzed by the cardiologists in the hospital. Alternatively, the ECGs can be sent as a fax or as a scanned document.

The customers only pay a standard fee per consultation, no annual fee or payment for information and communication technology services exists. A small market analysis directed to potential customers indicated that pricing is dependent on case urgency. Doctors were ready to pay €20-40 if the expert response would be given within 2 days, but €40-60 for short response times.

### **7.2 Cardiology expertise**

For the first year of the study period, from June 2009 to May 2010, there was tele-ECG service from 8:00 to 20:00 Monday to Friday. Service was provided as real-time interactive consultation; responses were sent within 30 minutes from the arrival of the consultation request and the ECG. From June 2010 on, responses are provided within 4 hours as part of the Heart Centre cardiology consultation service.

### **7.3 The heart center**

The Tampere University Hospital is the only central hospital in the Pirkanmaa Hospital District, which has about 481.000 inhabitants. The Tampere University Hospital Heart Center is a tertiary cardiology and cardiac surgery referral centre for the neighbouring hospital districts. Heart Center Co. began its operations as a process-based organization dedicated to cardiac patients in 2004 when it merged with Tampere University Hospital's cardiac, cardiothoracic and cardiac-anesthesiology operations. In 2005, the Heart Center was made into its own financial unit and in 2007 Heart Center Co. began serving the public as a corporation. Close to 20 cardiologists work in the Heart Centre.

### **7.4 Customers**

By the end of the study period, 23 customers had signed a written agreement for telecardiology service. The majority are health centres within the Pirkanmaa Hospital District. Sales and marketing aimed at reaching agreements with health care providers, municipal and private, all around our country. Challenges met during the sales and marketing process will be covered in the Discussion.

## **8. Study results**

### **8.1 ECG consultation volume and response time**

In total, 505 ECG consultations were handled during the study period from June 2009 to the end of February 2011. The first consultation request was sent in June 2009. During the first 3 months, only a few consultations were handled. From September 2009 on, the number of consultations per month varied from 16 to 54. The maximum number was reached in

February 2010, 8 months after the introduction of the service. In June 2010 there was a drop in the number of consultations, and after that the maximal number of consultations per month was 27. When comparing the period of real-time interactive consultation service, excluding the first 3 months, to the period of a longer response time ("store-and-forward model"), the mean number of consultations per month were 35 (min 16 - max 54) and 21 (min 16 - max 27). Both periods represent 9 months.

There was wide variation in the number of consultations per customer. The highest volume, 91 requests, was provided by a health centre, which was involved already in the telecardiology pilot phase. Different time points for signing agreements for the service explains some of the variation between the customers.

For response time, only time from arrival of the consultation request was studied. This overestimates the response time as the ECG, if sent by fax, typically arrives later than the request. As expected, when comparing two 9 months periods, the response times were shorter during the first period with on-line consultation service. From the arrival of the consultation request, 52% of the responses were sent within 30 minutes and 75% within 45 minutes during the first 9 month period. During the second 9 month period, the corresponding numbers were 13% and 24%, respectively.

## 8.2 Consultation requests and responses

The reasons for consulting the telecardiologist are presented in Table 1. The treating physician did not always indicate a specific reason for consultation. In that case, patients are categorized as "pathological ECG". This category also includes cases, where the treating physician did not specify his or her interpretation of the ECG findings, but only indicated that the finding was abnormal. As mentioned, the consultation service is not intended for patients with acute myocardial infarction, neither for cases with acute coronary syndrome, where acute hospitalization is clearly indicated. This is also stated on the consultation form. In patients with accidental findings of Q waves without signs of acute coronary syndrome and in cases where the clinical picture is atypical, consultation is recommended.

In Table 2 the main ECG findings are presented. Only one classification per patient is used and the analysis was done by one of the authors (KN). Clinical importance was used when classifying the findings. For example, myocardial ischemia was considered as the main finding although first degree AV-block was present. On the other hand, if the patient's actual problem was arrhythmia, the category extrasystole was used, although a patient had ECG signs of left ventricular hypertrophy. The largest group, "miscellaneous" consists of many ECG findings, like left or right frontal axis shift and fragmented QRS complex. Also 5 cases with pre-excitation with delta waves, and 2 with electrode misplacement were included in this group. Due to the hierarchical classification, the numbers under-estimate the actual prevalence of the different subgroups of ECG findings.

In Table 3, the first-line recommendations by the cardiologist are presented. Again, only one recommendation per patient is presented. For example, if the cardiologist recommended a control ECG before definite decision about actions needed, the category ECG control was indicated. In case of suggested ECG control within hours, or laboratory tests, like troponin, the cardiologist usually presented alternatives for further measures in the consultation request, depending on the test results. This was considered as time saving, as the treating physician would not have to send additional consultation requests for the same patient.

| Reason for consulting             | N (%)    |
|-----------------------------------|----------|
| Arrhythmia                        | 174 (35) |
| Myocardial ischemia or infarction | 131 (25) |
| Pathological ECG                  | 114 (23) |
| Conduction disturbance            | 42 (8)   |
| Prolonged QT                      | 26 (5)   |
| Pacemaker                         | 8 (2)    |
| Perimyocarditis                   | 10 (2)   |

Table 1. Reasons for consulting the cardiologist.

| ECG findings                          | N (%)    |
|---------------------------------------|----------|
| ECG pathology, miscellaneous          | 107 (21) |
| Conduction disturbance                | 84 (17)  |
| Normal ECG                            | 84 (17)  |
| Tachyarrhythmia                       | 74 (15)  |
| Left ventricular hypertrophy          | 41 (8)   |
| Extrasystole                          | 39 (8)   |
| Myocardial ischemia                   | 33 (6)   |
| Ectopic atrial rhythm                 | 19 (4)   |
| Myocardial infarction (old or recent) | 17 (3)   |
| Short PQ interval                     | 7 (1)    |

Table 2. Main ECG findings during the study period.

| Recommendation                      | N (%)    |
|-------------------------------------|----------|
| No measures needed                  | 105 (21) |
| Change of medication                | 95 (19)  |
| Cardiology consultation, non-urgent | 93 (18)  |
| Holter                              | 70 (14)  |
| Stress test                         | 36 (7)   |
| Control ECG                         | 34 (7)   |
| Urgent hospitalization              | 33 (7)   |
| Blood tests                         | 26 (5)   |
| Cardiology consultation, urgent     | 13 (2)   |

Table 3. First line recommendations to the treating physician by the telecardiologist.

Figure 1 shows the age distribution of the patients. The youngest patient was 2 years and the oldest 96 years old. The mean age was 60 years. There were slightly more males (n=263, 52 %) than females (n=242, 48 %).

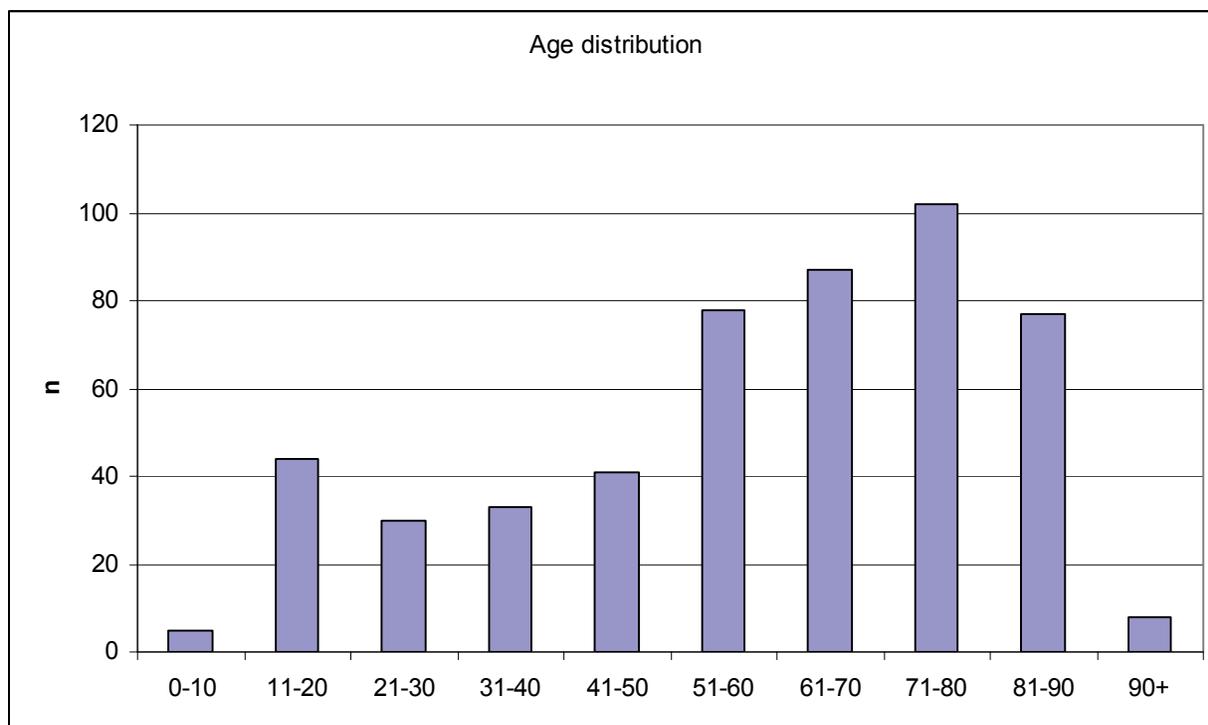


Fig. 1. Age distribution of the study patients

### 8.3 Technical aspects

Detailed analysis of the technical performance of the consultation system has not been done so far. In general, the system was well-functioning. In five patients, the cardiologist was not able to read the ECG and/or the consultation request due to technical problems. In these cases, the cardiologist responded based on the clinical data and the ECG analysis made by the treating physician.

The fax system poses the greatest challenge to the consultation system. The technical quality of the faxed ECGs is sometimes poor. Also, one has to check for possible height (mV) or length (ms) distortion in the faxed ECGs. Sometimes, fax transmission is slow and it may be difficult for the cardiologist to know how soon after the arrival of the consultation request to check with the treating physician whether the ECG has been faxed or not.

## 9. Discussion

### 9.1 Real time interactive tele-ECG consultation

It is apparent that a real time interactive tele-ECG consultation service has a number of advantages. This is also supported by experiences elsewhere as reported by one of the authors (SS). The treating physician gets an expert opinion about the ECG findings, and possible actions needed, based on the findings, while the patient is in the doctor's office or in the emergency department. In some cases, potentially life-threatening conditions can be identified. In many more cases medication can be modified. Also, indications for additional tests, like holter, stress tests and echocardiography can be better appreciated by a specialist than by a general practitioner. In a small pilot study, we found that planned referrals for cardiology consultations could be avoided by the telecardiology consultation service (Lähtenmäki et al, 2009). In many cases, the physician wants a second opinion from a

specialist before making treatment decisions, and that is possible through the consultation service.

Compared to traditional telephone consultation, exact documentation of the consultation process is a clear advantage of our telecardiology consultation service. The consultation requests and responses with their exact timing are stored. It is well known that telephone consultations are not always documented in the patient files, although this should be done. At least in our country, there are no studies to show how frequently documentations are left out. Related to patient security, when the system is built on user name and password, it is possible to identify individuals, who have entered the system.

Our system enables interactivity through messages. Both the medical professional asking for advice and the expert may add comments or questions related to a specific consultation through the internet-based system. For example, the expert may ask for additional clinical data. Messages are used rather frequently in our consultation service. Messages may also aid in avoiding misunderstandings between the two parts.

## 9.2 Telemedicine processes

The planning phase of our telecardiology service to a large part dealt with telemedicine processes. Telemedicine service platforms are typically focused to limited telemedicine areas and measurement devices. The Personal Information Repository (PIR) document service provides a generic platform with the objective to support an extremely wide spectrum of different applications in the field of telemedicine (Lähteenmäki et al, 2009). Application specific support is obtained by specific components, which can be easily connected by using open interfaces. During the planning phase of our telecardiology service, the proposed document-based approach was assessed as attractive in many respects. The HL7 CDA R2 document model used is an international standard, which is widely being adopted for Electronic Patient Record (EPR) systems. This provides potential for semantic interoperability between the telemedicine system and other patient information resources. On the other hand, the document-based approach allows complete recording of the service process (in the form of a document archive) at both the customer and the service provider side. By adding digital signatures to the documents, non-repudiation of all interactions can be achieved. However, interoperability remains a challenge also with this service. There is only limited support for integration with other systems. Improvement in this respect is needed as centralised health information archives ("national EPRs") are being established in many countries, including Finland. The national EPRs are providing standard interfaces through which health information can be inserted and accessed, along with the consent provided by patient.

The pilot phase showed that a cardiac consultation service is useful even without full integration with the EPR. In the pilot, the EPR could be opened in another window while providing the consultation response. On the other hand, the necessary texts could be moved to the EPR by using the clipboard. Both the Heart Centre cardiologists and the physicians of the remote units considered the benefits of the consultation service to be high. In the consultation cases, cardiology diagnostics and medication could be refined and guidance for patient logistics was provided. The pilot comprised thirty consultations. In ten patients, there was a recommendation for change in medication. In five cases, the patient was sent to the emergency department of the Tampere University Hospital, in two of the cases, the physician who asked for consultation had not identified case urgency. It was estimated that in five cases, a planned consultation to cardiologist was avoided thanks to telemedicine consultation, although the pilot process did not involve exact appreciation of how the

handling of patients was affected. In four cases, non-urgent referral to a cardiologist was recommended. In most of these cases, the treating physician had planned to send the patient to a specialist. In two patients, an arrhythmia was identified: one necessitated change of medication, and one was potentially fatal (ventricular tachycardia). Two cases with silent myocardial infarction and one with unrecognized acute ischemia were noted. The physicians participating in the pilot considered it feasible to use a commercial consultation service when available.

The PIR document service was replaced by an internet homepage based telecardiology service model in the final part of the planning phase. Although the PIR document service has potential advantages in a comprehensive telemedicine service with different types of telemedicine applications, an internet-based system was considered easier to maintain for the simpler model of consultations between health care professionals. For example, new program versions are easy to introduce, as no changes are needed locally in the health care organizations involved in the service.

### 9.3 Challenges

Based on our experience, there are many challenges with a telecardiology ECG consultation service. In our country, the biggest challenge is to make the service profitable. During the sales and marketing process, potential customers liked the system, but at the end preferred to consult specialists in their own region. One reason for this was that the local specialist service was considered as free of charge. Hence, the telecardiology consultation system was considered as expensive. Actually, regional systems proved to cost about the same or were more expensive, at least as reported by the local authorities. Pricing of the telecardiology service was accommodated to the prevailing pricing level of telephone consultations in our country. Also, experiences from a market analysis and from the pilot study were exploited when the pricing level was determined. Transparency was also sought for by charging only for the consultation with no annual fee or payment for ICT services.

It was appreciated already in the planning phase that regional consultation systems have certain advantages over a system, where the consultation response is provided from a central organization. It seemed, though, that regional and central hospitals would not be able to provide specialist service with response times comparable with the telecardiology service. The cardiology speciality in Finland is invasive. Hence, many cardiologists are busy in catheterization suites during routine working days. In many regions, ECG interpretation as a consultation service is probably provided by specialists in internal medicine familiar with cardiology. The level of ECG interpretation skill of internists has not been studied in our country.

In the Finnish health care system, local authorities provide primary health care ([www.kunnat.fi](http://www.kunnat.fi)). Municipal public-health work is the foundation of the Finnish health system. Local authorities run about 172 health centers. Alongside municipal health care, there is an occupational health service system, financed by employers and the State, which is responsible for much of the health care for the workforce. There is also a relatively extensive system of private medical services, partly financed by the sickness insurance system. Hospitals run by joint municipal authorities provide 95 per cent of all specialist medical care; the remaining 5 per cent is provided by the private sector. Every local authority is required by law to be a member of a joint municipal authority administering a hospital district. There are 20 hospital districts in all.

One can also see the Finnish health care system as rather fragmented with small units deciding about how to organize specialist consultations. As all actors in the field have their

own budgets, it is many times difficult to appreciate total savings with new innovations. Also, decisions about what ECG equipment to use and how the ECGs are stored are decided by the local authorities. In the health centers in the Pirkanmaa hospital district area, there are ECG machines from many different companies. For that reason, ECGs have to be transmitted either by fax or as scanned documents to the specialist in the telecardiology service.

#### **9.4 ECG analysis**

In Finland, there are no specific competence requirements for physicians who interpret ECGs. The way of documenting ECG findings varies, as there are no strict recommendations. Typically, possible pathological findings are documented as part of the patient records, or the finding is stated as normal. A more structured way of reporting findings could improve the level of ECG analysis. ECG interpretation is incorporated in the medical studies, but in practice, the skills are far from sufficient in the beginning of the career as a practicing physician. As previously discussed, many studies have shown that non-cardiologists fare worse than cardiologists in ECG interpretation, and that false interpretation may result in even fatal events. Many physicians are unaware of their limitations and believe that they can interpret ECGs well. This is probably one reason for not using the consultation system.

A tele-ECG consultation system has the potential to serve as a learning environment. Actually, this could be one reason for diminishing consultation volumes in our study. One does not need to ask the specialist many times about a particular ECG pathology. The best for the patient should, of course, always be what medical professionals are striving for.

Outsourced health care also proved to be a challenge for our consultation service. In many places in our country, health care service is partly outsourced. A large pool of younger physicians is responsible for the acute and to some part also for elective, patient care in health centers. Information about the existing consultation service and user name and password handling proved to be very challenging, and these physicians rarely used our service.

#### **9.5 Potentials for ECG consultation in non-urgent situations**

In urgent cases, the value of telecardiology service consists of better patient outcome and more optimal usage of resources. There is much potential to be gained in the individual case. In non-urgent cases, the diagnostic and prognostic information contained in the ECG is clinically important in many cases, although the benefits of correct interpretation are not as evident as in the acute situations. However, the volume of ECG recordings is much larger in non-urgent situations, and the superiority of expert interpretation compared to non-cardiologist analysis is evident. From the standpoint of the treating physician, the need for consultation may arise from different scenarios. It is not unusual to have accidental ECG findings during regular controls for chronic disease like diabetes. General practitioners and specialists in occupational medicine may not have the knowledge to either make a correct diagnosis from the ECG or to draw the right clinical conclusions from the unexpected findings. Many times, patients who seek for acute or subacute symptoms do not fit into established guidelines for patients care. The symptoms may be atypical, the ECG findings difficult to interpret and the laboratory tests may not provide definite answers concerning the disease process. Also in risk evaluation before surgery or fitness programs, pathological ECG findings may set in motion a process, where the telecardiologist has a central role.

### 9.6 ECG screening

Ashley et al. performed a literature review related to the use of ECG as a screening tool for cardiovascular disease for large populations (Ashley et al, 2001). They found that no study directly approached the question, so no direct answer to whether ECG screening is useful or not is available. However, the authors suggested that high-risk asymptomatic people in middle age should undergo a screening ECG. They justified their conclusion by specific ECG findings, especially left ventricular hypertrophy, new Q waves, atrial fibrillation, and ST-segment depression, which may affect patient prognosis. ECG left ventricular hypertrophy is a well recognized risk factor for cardiac death. Left ventricular hypertrophy is potentially reversible with antihypertensive therapy with potential for improved prognosis. In the Losartan Intervention For Endpoint Reduction in Hypertension (LIFE) study, less-severe ECG left ventricular hypertrophy by Cornell product and Sokolow-Lyon voltage criteria during antihypertensive therapy was associated with lower likelihoods of cardiovascular morbidity and mortality, independent of blood pressure lowering and treatment modality in persons with essential hypertension. Hence, antihypertensive therapy targeted at regression or prevention of ECG left ventricular hypertrophy may improve prognosis (Okin et al, 2004). Ashley et al. in their review article stressed that clinicians should have a low threshold for performing a screening ECG in patients with known predisposing conditions for ECG left ventricular hypertrophy (age, hypertension, obesity, stature, and glucose intolerance).

Atrial fibrillation is the most prevalent sustained cardiac arrhythmia in adults, affecting > 1% of general population and up to 10% of those aged > 80 years. Atrial fibrillation is commonly associated with structural heart disease and is a major cause of significant cardiovascular morbidity and mortality. Individuals who have not been properly anticoagulated remain at risk of stroke which may result from thromboembolic phenomena. Portable devices may help in recognizing episodes with paroxysmal atrial fibrillation through telemedicine. However, it seems equally important to improve the ECG diagnosis of this particular arrhythmia from 12-lead ECG. As pointed out earlier, diagnosis of atrial fibrillation is not optimally diagnosed by primary care professionals, even with the aid of interpretative software (Mant el, 2007). A telecardiology consultation service has the potential to improve diagnostic quality as part of a screening program.

Q waves noted on screening ECGs are important as markers for unrecognized cardiac disease. Estimates regarding the proportion of actual infarctions that go unrecognized, the syndrome of painless myocardial infarction, vary, but the average is between 15% and 30%, increasing with age (Nadelmann et al., 1990). Study data suggests that for the age group 40 to 59, even 1 silent myocardial infarction in 100 patients could be identified by routine screening (Ashley et al, 2001). On the other hand, false positive myocardial infarction diagnosis by the treating physician, may result in unnecessary anti-thrombotic and anti-ischemic medication.

### 9.7 Findings from the study

Our study indicates that the real time interactive consultation model (within about half an hour) is superior to a system with delayed response. The number of consultations dropped after the response time was prolonged. This came as no surprise, as one of the main ideas with the service was to provide a specialist response with the patient still in the doctor's office or in the emergency department. Rapid response time enables the physician to immediately inform the patient about diagnostic tests, change of medication etc. Otherwise the doctor and the patient need to be in contact through telephone or mail.

The reason for delaying the response time was to a large part economical. In a nation-wide perspective, the sales and marketing process did not result in enough customers within reasonable time. It was not considered profitable to provide the service via a separate company dedicated mainly to ECG consultations. The consultations were incorporated into the Heart Centre's cardiology consultation service.

As expected, electrophysiological problems constituted a large part of the consultation requests. Arrhythmias, conduction disturbances, including AV-block and sick sinus syndrome, pacemaker ECGs and prolonged QT represent half of the reasons for consultation. Modern pacemaker technology with different technical solutions from different companies represents a great challenge for ECG interpretation by non-cardiologists (Figure 2). General practitioners who see patients with a suspicion of pacemaker dysfunction will ask a cardiologist for advice in the vast majority of cases.

The group with suspected myocardial ischemia was large taking into account that clear acute coronary syndrome cases are not included in the telecardiology service. However, less than half of the cases with a suspicion of ischemia were classified as ischemic by the ECG expert. We think that there is potential for cost savings here, as a considerable proportion of patients with suspected ischemia did not need immediate hospitalization according to the tele-cardiologist. However, cost issues were not part of the study protocol.

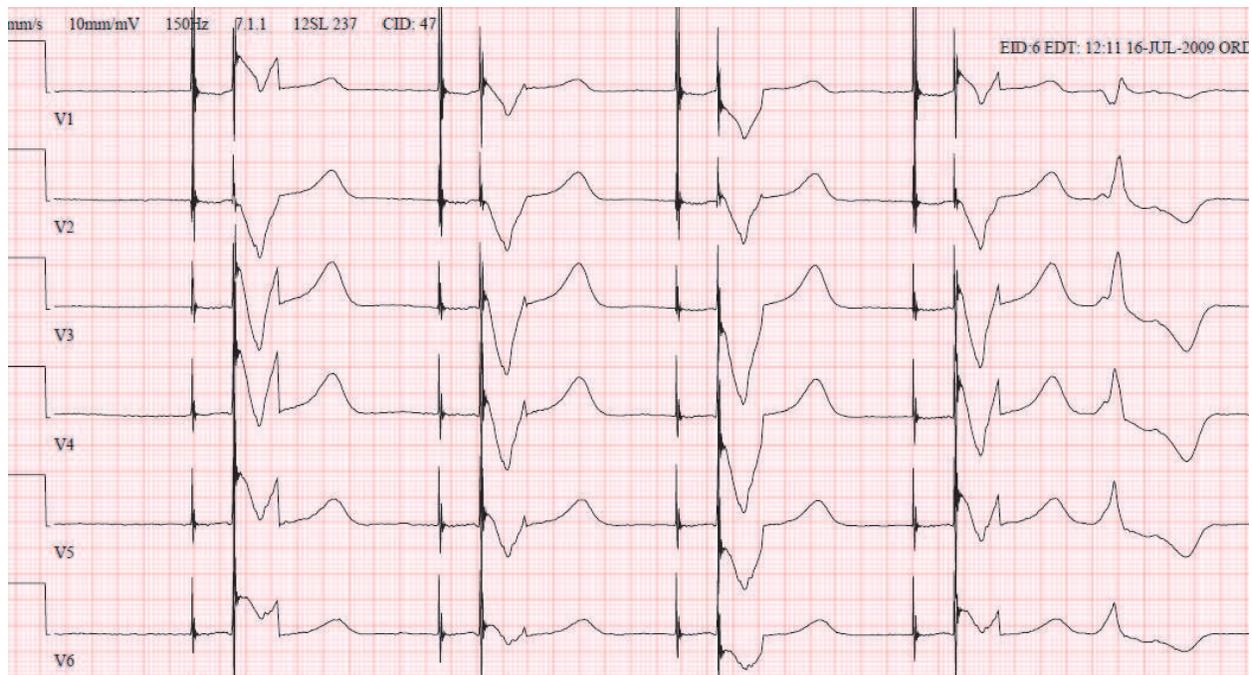
Regional guidelines and logistic systems both for acute ST-elevation myocardial infarction and non-ST elevation acute coronary syndrome were established already quite a few years ago in our hospital district. Only 3 patients with acute ST-elevation myocardial infarction were encountered in the study. In these cases, the treating physician was contacted per telephone to speed up the therapeutic process. Fourteen patients showed "silent" myocardial infarction; new pathological Q waves without a diagnosis of myocardial infarction.

Normal ECG was found in 17 % of the cases. In these instances, the treating physician was uncertain whether findings represented normal variants or needed further investigations. Benign early repolarization was often encountered, and was classified as a normal variant (Figure 3). In many cases, it was evident from the consultation request that the automated ECG analysis had alerted the physician about possible pathology. One typical case was ectopic atrial rhythm, which may be difficult to diagnose for inexperienced interpreters (Figure 4). We had 39 cases (8 %) with consultations related to extrasystoles. The number may seem high as the diagnosis often is easy. However, our system always includes clinical interpretation of the ECG findings, not only ECG diagnostics. Therefore, it is evident that treating physicians send consultation requests to get advice about handling of the patients.

The distribution of first-line recommendations (Table 3) show that, at least primarily, the patients' treatment could continue in the referring unit, not in specialist care. If the health care unit provided stress tests and hollers, which is the typical case, no referral to specialist care was recommended in 73 % of the cases. In 18 % of the cases, a non-urgent cardiology consultation was recommended. The main reason for this was rule-out of organic heart disease by echocardiography. It is well known that some ECG findings are associated with organic heart disease. For example, the S1S2S3 pattern may be a normal variant, but it may also indicate pulmonary artery hypertension. Left bundle branch block may be a primary intraventricular conduction defect, or it may be secondary to structural heart disease. Left axis deviation is typical for increased left ventricular mass in hypertensive heart disease. Children with left axis deviation should undergo further cardiology evaluation.

Not surprisingly, the age group 71 – 80 years was the largest. Patients with coronary artery disease, heart failure, atrial fibrillation, sick sinus syndrome and AV-block typically belong to this age group in many countries. The wide age variation also mirrors the wide spectrum of patients treated in the health centers.

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Fig. 2. Normal dual chamber pacing with atrial and ventricular pacemaker spikes. ECG recorded at 50 mm/sec.

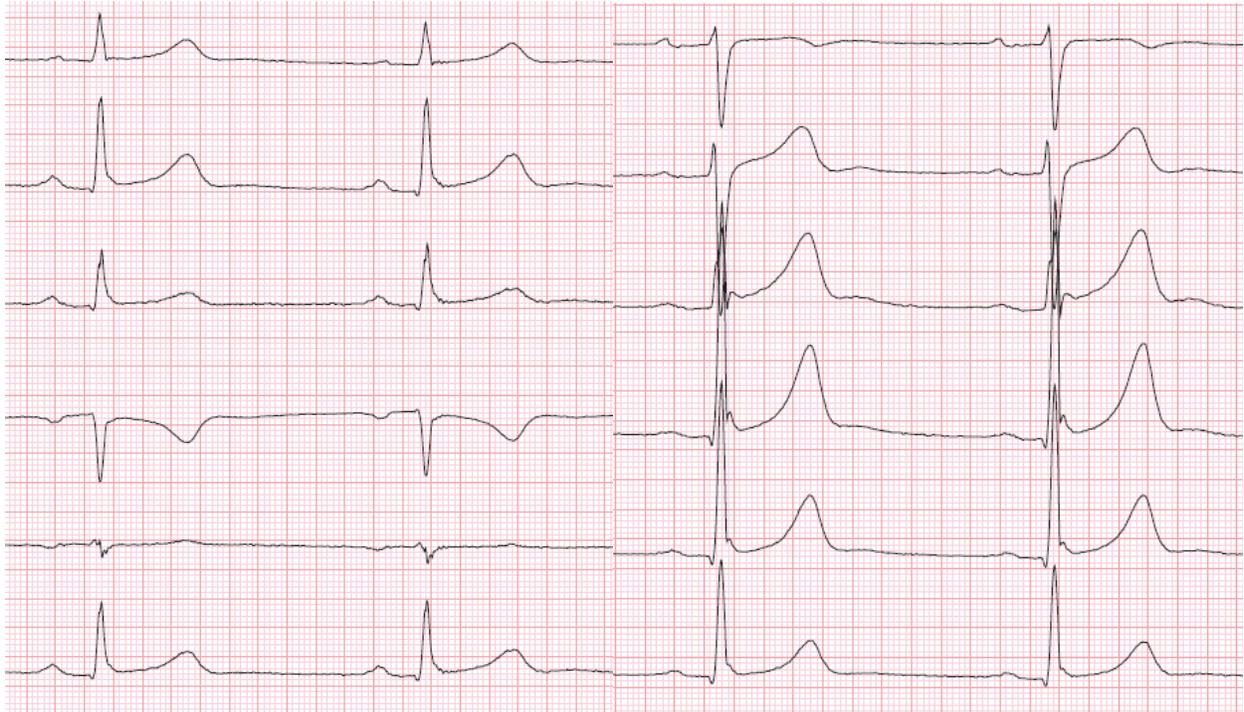


Fig. 3. Typical early repolarization findings in a 22 year old male patient with atypical chest pain. The J point is elevated with ST segment elevations and prominent T waves in many leads. Leads V3-V5 show the most prominent changes. ECG recorded at 50 mm/sec. Extremity leads I, II, III, aVR, aVL, aVF to the left and chest leads V1-V6 to the right.

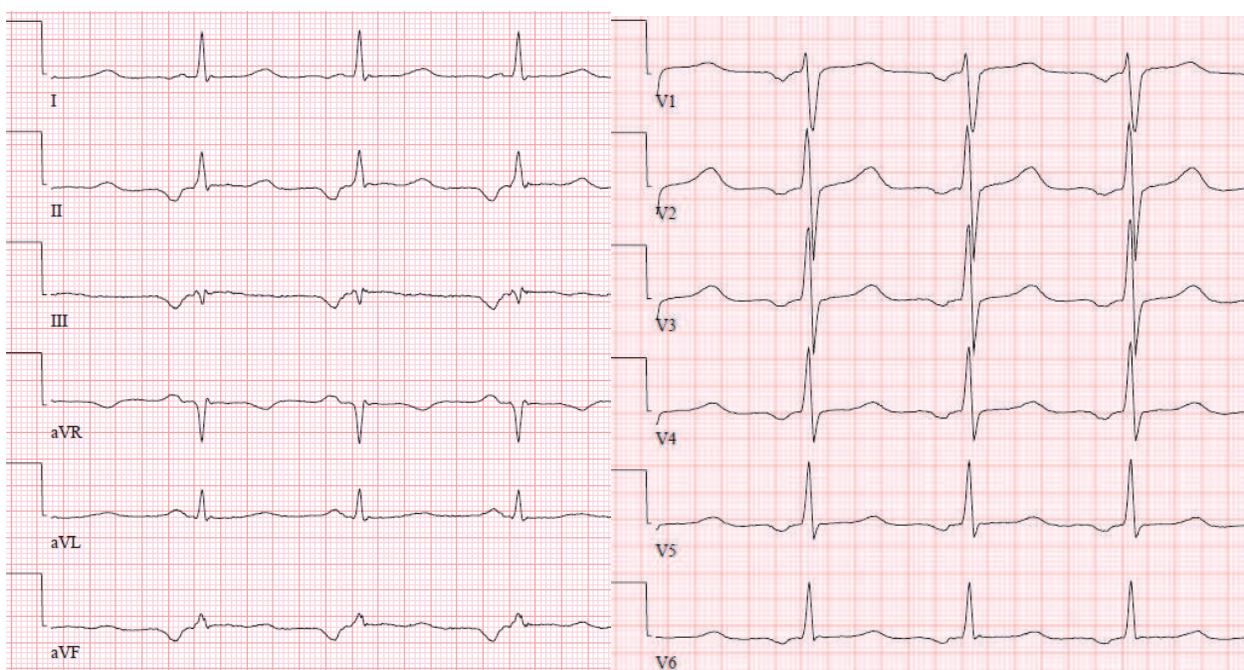


Fig. 4. Ectopic atrial rhythm in a 59 year old female. The P waves are negative in leads II, III and aVF, and in all the precordial leads. Lead aVR shows positive P waves. ECG recorded at 50 mm/sec.

## 10. Conclusions

We have presented our experiences with a tele-ECG consultation system in Finland. The system was created as a user-friendly, low-cost alternative to traditional specialist consultation. We believe that there is a place for telemedicine also in this field. However, many obstacles were encountered during the process. Success of a real time interactive consultation model probably depends on many factors, like the structure of the health care organization, systems of reimbursement and ECG equipment.

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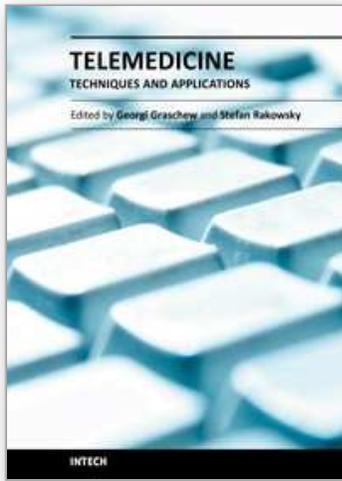
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