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ABSTRACT

Tele-cardiology is the practice of cardiology which utilizes telecommunications, and as such is a new alternate and cost-effective means of providing cardiac care. During the last few years there has been a constant increase in the incidence of cardiovascular chronic pathologies, mainly due to the aging of population. Tele-cardiology services enable patients suffering from these pathologies to communicate their clinical parameters (i.e. ECG) to specialists in order to receive a constant monitoring and quick support in case of an emergency.

Tele-cardiology improves patients' assistance and can reduce the number and duration of hospitalizations. Tele-cardiology has two common goals in this work - first one is to reduce the healthcare costs of chronically ill patients while providing them access to healthcare providers and maintaining their quality of life. Second goal is to support with network software which satisfies share of necessary data and information for diagnosis of cardiology and to support communication between doctors who locate different locations.

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LIST OF ABBREVIATIONS

Ohm(Ω): Unitofelectricalresistance.

V: Voltage

C: Current

W: Watt

BPM: Beat Per Minute

Sec(S): Second

mS: Millisecond

µ: Micro

m:Milli

k: Kilo

Hz: Hertz

Mm: millimeter

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LIST OF KEY WORDS

Telecardiology: Teletransmission of ECG using indigenous methods.

Myocardial İnfarction: Myocardial infarction (MI; Latin: *infarctus myocardii*) or acute myocardial infarction (AMI), commonly known as a heart attack.

Tachycardia*:*Is a heart rate that exceeds the normal range.

Bradycardia: In the context of adult medicine, is the resting heart rate of under 60 beats per minute (BPM).

Cardiac arrhythmia:(also known as irregular heartbeat) is any of a group of conditions in which the electrical activity of the heart is irregular, faster, or slower than normal.

Ecg: An**electrocardiogram** (ECG) records the electrical activity of the heart.

GPRS:**G**eneral**P**acket**R**adio **S**ervice is a packet oriented mobile data service on the 2G and 3G

Wi-Fi: Is a local area wireless technology that allows an electronic device to participate in computer networking.

PCB: Printed Circuit Board

1 OVERVIEW

Telemedicine is a multimedia application that integrates a myriad of technologies (live video and audio, static DICOM-encoded, medical images and data, text, graphics and vital signs) into a time and space independent, medically relevant system. This is not a trivial matter, particularly for the underlying communication infi-astructure, because each of these information types has a different set of requirements.

The common technological aspect is that most Telemedicine applications require technology that is, today, high-end. It requires moderate to fast networks (medium to v e q high bandwidth and fastrouting), moderate to fast end-user workstations, so handling data types

from live-video and audio to fast image-processing tasks can be done at reasonable time and cost, and a high-resolution data encoding and display (diagnostic quality) for medical images. Patient vital signs monitoring requires low bandwidth but continuous transmission, and data queries and textual information operate in short bursts of moderate bandwidth, but require a powerful server to perform these queries. The Pennsylvania Medical Center has proved (1995) that ATM technology can successfully handle all of these data types at once, over continental distances as well as within a single facility or campus.

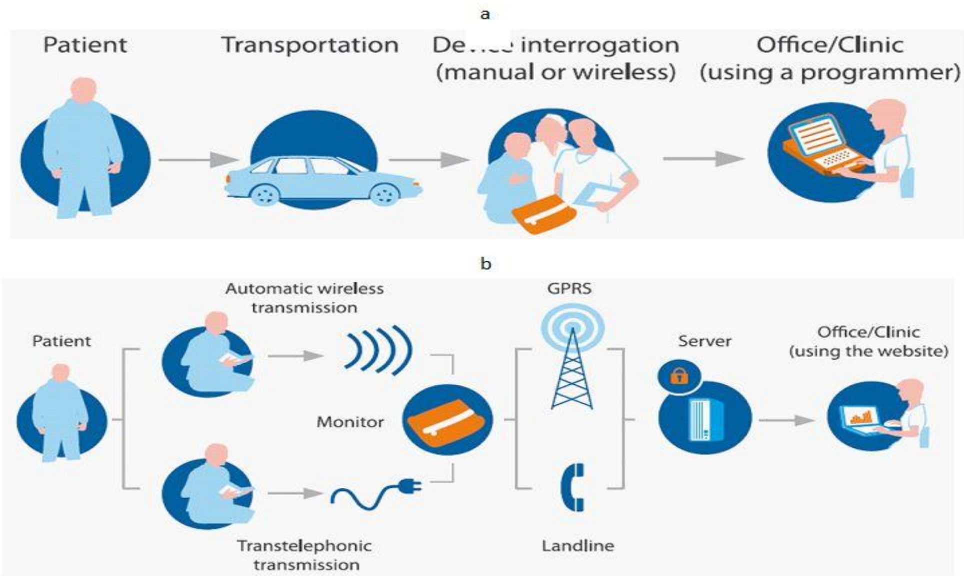


Figure 1-1 The past days and nowadays of the medicine

The telemedicine goals are:

- Improving patient care
- Improve access to health care for rural areas and underserved areas.
- Give physicians better access to tertiary consultation.
- Give physicians access to conduct remote examinations.
- Reduce health-care costs.
- Provide health care services of a physician or facility to a larger audience (larger geographic regions and populations).
- Reduce patient transfers to secondary and tertiary care centers.
- Build an atmosphere of managed-care at. hospitals and health-care facilities.

1.1 THE SHORT HISTORY OF TELEMEDICINE

While the explosion of interest in telemedicine over the past four or five years makes it appear that it’s a relatively new use of telecommunications technology, the truth is that telemedicine has been in use in some form or other for over thrrty years. The National Aeronautics and Space Administration (NASA) played an important part in the early development of telemedicine (Bashshur and Lovett, 1977) . NASA's efforts in telemedicine began in the early 1960s when humans began flying in space. Physiological parameters were telemetered from both the spacecraft and the space suits during missions. These early efforts and the enhancement in communications satellites fostered the development of telemedicine and many of the medical devices in the delivery of health care today. NASA provided much of the technology and funding for early telemedicine demonstrations, two of which are mentioned below. A book by Rashid L. Bashshur published in 1975 (Bashshur R.L. et al. 1975) lists fifteen telemedicine projects active at the time. There were several pioneering efforts not only in the US, but all over the world.

1.2 SERVICES OFFERED BY TELEMEDICINE

Telemedicine offers a growing number of services in the field of health-care and its delivery. These services can be roughly cut into three major topics:

Direct-patient examination, Patient-information sharing and Physician information gathering.

Telemedicine holds great promise to enhance health care delivery in rural areas by allowing a physician or other health professional to examine a patient while linked by video or other means to an expert consultant at a distant medical center [3]. Radiologists and other specialists can review medical images transmitted over telephone lines. And university-based pathologists can review biopsies done in a rural hospital while the patient is still under anesthesia. Without telemedicine, these services would require travel on the part of either the patient or the consultant, or would simply not be available at all.

- **Primary Delivery Methods:**

Telemedicine is practiced on the basis of two concepts: real time (synchronous) andstore-and-forward (asynchronous).

Real Time Telemedicine (synchronous) is also referred to as “two way interactivetelevision (IATV)”. It can be as simple as telephone calls or as complex as sophisticatevirtual reality (VR) robotic surgery or tele-surgery. In it providers/patients at distantlocations interact with each other using communication technology in the form ofaudiovisual and wireless or microwave signals. Apart from video-conferencing,peripheral sensing devices can also be attached to the patient or the equipment to aid ininteractive examination. For example, tele-stethoscope to monitor patients heartbeat ortele-otoscope to examine patients ear. It can also be used for monitoring of long term carepatients or patients at their home. In fact, due to the severe cost constraints, quality andcontinuity of care issues, mal-distribution of physicians in different geographic regionsand scarcity of the same, remote home care of chronically ill patients and of long termcare patients, is the fastest emerging use of telemedicine. Specialties for which it is usedmost often are psychiatry, internal medicine, rehabilitation, cardiology, pediatrics,obstetrics and gynecology, neurology.

Store and Forward (asynchronous) technology involves acquiring medical data (images,bio-signals) and transmitting this data to a medical specialist for consultation, evaluationor other purposes. It does not require simultaneous communication between both partiesin real time. Tele-radiology and tele-dermatology is the fastest emerging branch that usesuch kind of services. Overall radiology, pathology and dermatology are most conducive for utilizing this mechanism.

The above mentioned basic telemedicine technologies are utilized for providing variousservices that spawns numerous specialties and can be broadly categorized as:

- Telehome Home Health Care
- Telepsychiatry
- Teleradiology
- General Telemedicine
- Telecardiology
- Telemedicine Consulting
- Teledermatology
- Emergency Telemedicine
- Telepathology
- Teledentistry
- Telesurgery
- Telemedicine Structure

The telemedicine unit basically consists of four modules:

- Biosignal Acquisition Module: for biosignal acquisition through sensors andperipheral devices
- Digital Camera: for digital image or video capturing
- Processing Unit: comprised of computers of varying complexity
- Communication Module: GSM, satellite, POTS modem, Internet, WAN, PAN,etc.

2 TELECARDIOLOGY

Telecardiology is one of the most highly developed of the medical disciplines covered by telemedicine. In addition to the provision of care to patients with heart disease, it has a vital role in educating these patients on the nature of their conditions, improving their compliance to medical therapy, and guiding them in practicing healthy life habits. The benefit of telecardiology in rural communities is especially important because of its capability of overcoming the obstacle of the large distances that would have to be covered in order to access medical assistance. As such, hazardous and even unnecessary transportationof critically ill patients for the purpose of diagnosis canbe avoided by remote expert counseling. Finally, patients can receive second opinions and physicians can consult experts,capabilities that have proven to have a beneficial effect on bothpatient survival and recovery. While telecardiology has beenwidely applied, there are still limited prospective randomizeddata supporting its health care benefits.This review summarizes updated information on the useof telemedicine in cardiology and details its evidence-basedeffect on patient survival and quality of life.

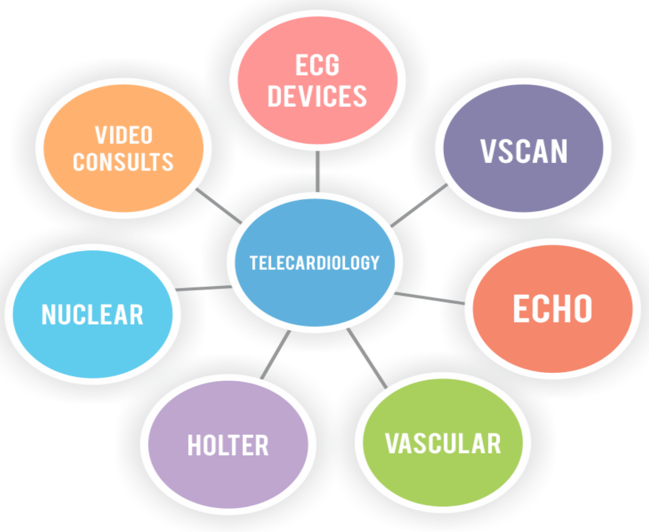


Figure 2-1 The Basis of Telecardiology

2.1 INTRODUCTION

Home monitoring of Pacemakers trans-telephonically was introduced in 1971 and remained until recently the main technology to remotely follow the performance of PMs. It was mostly aimed at ascertaining the integrity of the system especially with regard to battery performance and longevity, appropriate capture, and sensing.Modern Remote wireless communication from the Cardiac implantable electronic devices (CIED) to a home communicator allows the transmission of the information gathered by the device regarding programming, test and alerts, to the clinician. It became the new standard for remote follow-up.The current CIEDs being interrogated remotely include implantable cardioverter defibrillator (ICDs), pacemakers, implantable loop recorders and implantable haemodynamic monitors.

- **Definitions and principles of telecardiology applicable to ICDs**

Telecardiology or home monitoring of ICDs refers to remote communication technology in general. Different types of data transmission are available.

2.2 TYPE OF TRANSMISSIONS

Remote follow-up refers to programmable scheduled transmissions in which routine CIED parameters are collected remotely in a format similar to that obtained during a routine clinic visit. As opposed to trans-telephonically monitoring, practically all information available during traditional ICD interrogation with a programmer can be obtained via remote follow-up for a better outcome of patients

Remote monitoring is an alert function. It refers to data acquired automatically with unscheduled transmissions of any pre-specified alerts related to device functioning or to clinical events. The latter adds a new functionality to implanted devices, opening a new era of potentially beneficial pre-emptive interventions that may alter the natural history of a particular disease or condition.

Patient-initiated interrogations refers to non-scheduled follow-up interrogations as a result of a patient experiencing a real or perceived clinical event, for which the patient is seeking expert evaluation.

2.3 TECHNOLOGY OF TRANSMISSION

Unlike traditional follow up that implies a clinic appointment, transportation and face to face meeting, remote follow up is based on Data transmitted from the device to the home monitoring station by wireless communication or using a telemetry head (for older models) between device and home monitoring station. This home monitor is linked by telephone (*analogic line or GSM*) to a central server or website automatically to deposit encrypted data for further

In clinic follow up needs scheduling and transportation while Remote communication is performed by a radiofrequency transmitter circuitry integrated in the ICD utilizing telephone lines or cellular phone technology. The ICD transfers encrypted data via the Transmitter to a service centre using a cellular network. The service centre provides a cardiologic report accessible online by the physician via a secure Internet access

Alert notifications are sent to physicians via pager, fax, SMS, voice message, or email. Many systems require access to a dedicated (device or company specific) website to obtain detailed information on the interrogation.

Remote reprogramming of alert level (yellow or red) is possible but remote ICD programming is not yet available in clinical practice, mainly due to safety considerations regarding data protection and unauthorized control of device function.

ICD compatible with home monitoring use radiofrequency telemetry to send information to a home communicator. This feature allows also the device to be operated remotely on a short distance (3 to 7 meters) during implantation procedure hence more flexibility, shorter intervention time, and lower risk of infection.[8] Radiofrequency telemetry is also very useful during in person follow up, eliminating the need for patient preparation and ECG monitoring in most cases, all information being accessible via the programmer (figure 2). Unfortunately, this possibility of short distance remote ICD interrogation and programming is not fully available for all brands at this time. (table 1)

	Boston Scientific Latitude	Biotronik Home Monitoring	Medtronic CareLink	St Jude Merlin.net	Sorin SMARTVIEW
Network	Analogue phone line.	GSM network (Europe & USA), Analogue phone line (USA &Japan) 3G (Japan)	Analogue phone line and GSM network	Analogue phone line, cellular network and WiFi	Analogue phone line and GSM network
Physician notification	Fax, phone, email	SMS, email, fax	SMS, email	Fax, email, SMS and automated phone calls	Fax, email, SMS
IEGM (real-time at remote follow-up)	10 s	30 s	10 s	30 s	7 s
FDA and CE Mark system	Yes	Yes	Yes	Yes	CE yes FDA (in progress)

	Boston Scientific Latitude	Biotronik Home Monitoring	Medtronic CareLink	St Jude Merlin.net	Sorin SMARTVIEW
approval					
Short distance RF remote programming	Yes	Yes (available in 2012)	Yes	Yes with an antenna	no

TABLE 1.1Comparaison of communications features

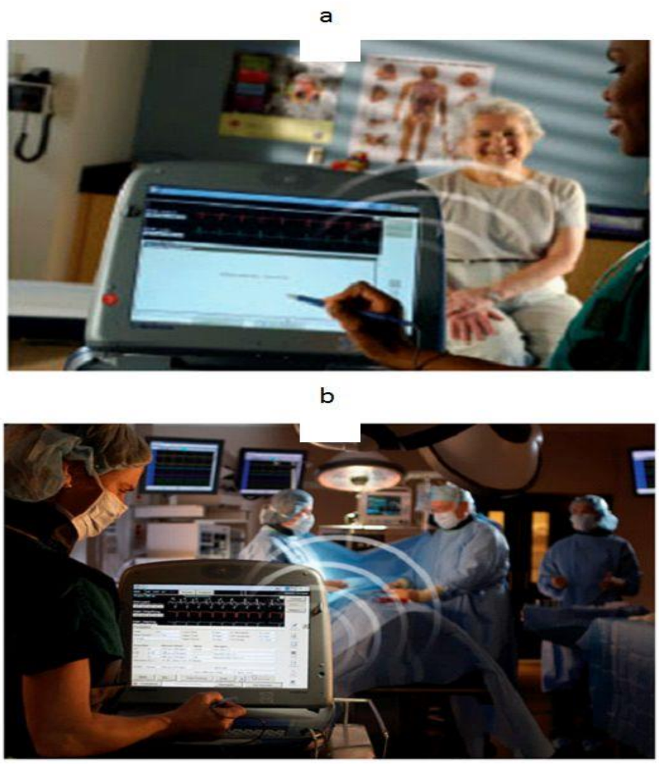


Figure 2-2 Some manufacturers use RF to interrogate and program remotely on a short distance. This is of particular interest during in person follow up (a) and during implantation procedure (b).

2.4 TYPES OF ALERTS

The ability of implantable devices to continuously monitor variables such as heart rate, the patient’s daily activities, intrathoracic impedance for the detection of fluid accumulation, the occurrence of arrhythmias and the integrity of the system may provide early warning of changes in cardiac status or of safety issues and allow timely management. When these patients have clinical events such as ICD shocks or device audible alert notifications of possible critical situations, they often visit the emergency department or clinic for an unscheduled examination.

ICD and lead dysfunction may be associated with severe consequences and could be anticipated thanks to home monitoring alerts. Patients could be contacted to correct the problem in office for reprogramming or in hospital if a procedure is needed.

Significant change in lead impedance, pacing or sensing thresholds, could be linked to lead failure and should be investigated thoroughly. It has been reported that remote monitoring helps prevent inappropriate shocks in a population at risk.

An hemodynamic measurement modification, a low rate of resynchronisation should lead physicians to look for an aetiology (e.g. atrial fibrillation, Av delay, crosstalk…) in order to avoid a cardiac heart failure.

Development of persistent atrial fibrillation with fast ventricular rate close to ventricular fibrillation (VF) zone, frequent episodes of ventricular tachycardia (VT) with delivery of frequent antitachycardiac pacing sequences, should also act as a trigger for a follow up visit in order to change ICD parameters (VT, VF Zones, discrimination algorithms), or drug therapy.

2.5 HOME MONITOR COMMUNICATOR

This is a remote telemetry device able to communicate with the ICD automatically in real time or at scheduled intervals, and that transmits the encrypted data over long distances utilizing telephone lines or cellular phone technology. The data are then entered and stored in dedicated servers that act as data repositories and communicate actively or passively with the caregivers of the patient. A specific home communicator was developed by each company: Medtronic Care- Link, Boston Scientific Latitude, Biotronik Home Monitoring, Sorin Smart View and St Jude Merlin@Home.net. In the near future, all systems will be compatible with GSM. Besides, Biotronik offers complete mobility of the home monitoring station with battery backup. Furthermore, frequency of remote follow up, and selection of remote monitoring alerts are fully programmable in all systems

3 ADVANTAGES AND CHALLENGES OF TELECARDİOLOGY

3.1 PHYSİCİANS

Because of the burden of follow-up of ICD patients, with regular in-office visits every 3-6 months, puts on specialized electrophysiology clinics Heidbuchel et al. retrospectively evaluated in 1739 ICD visits in a random set of 169 patients. The standard follow-up scheme consisted of in office visits 1 month after implantation and then every 6 months, unless approaching battery depletion. They conclude that ICD remote monitoring can potentially diagnose 99.5% of arrhythmia or device-related problems if combined with a follow-up by the local general practitioner and/or referring cardiologist. Its use may provide a way to significantly reduce in-office follow-up visits that are a burden for both hospitals and patients. A similar study was performed by Elsner et al.They investigated in a prospective, randomized, and multicentre comparison study the effect of ICD home monitoring against conventional follow-up in 115 MADIT II patients. The results prove that the simplified ICD follow-up scheme with additional home monitoring in MADIT II patients can reduce the number of visits and lead to time reduction.

In 2011 Boriani et al. published a survey indicating that in ‘real-world’ clinical practice, the follow-up of CIEDs requires important resources in terms of time dedicated by specialized personnel, corresponding to cardiologists, nurses, internal technicians, and also, external, industry-employed technicians.

More recently Cronin et al. found that analysis of remote monitoring transmissions has significant implications for device clinic workflow. Non-actionable transmissions are rapidly processed, allowing clinicians to focus on clinically important findings.

According to Theuns et al. “remote monitoring is feasible, may facilitate ICD follow up, and lead to early detection of system-related complications. Continuous monitoring of specific device parameters may avoid unnecessary replacements of devices or leads. However, as with every new technology, there are areas of uncertainty. Remote monitoring is associated with a redesigned organization of the care system, including physicians, allied professionals, and a dedicated remote monitoring service. Another area of uncertainty is related to the question of liability. The now “virtual patient” poses a paradigm shift. Physicians have the responsibility for responding to the new sources of data. How fast must a physician react to the transmitted alerts? Do we need 24 hours, 7 days a week coverage or is it legally acceptable not to check event notifications outside the office hours ? The development of practice guidelines on the appropriate role of remote monitoring of patients with implanted cardiac devices would help to address many of these issues.”

3.2 PATIENTS

Besides the decrease in number of in office follow up, safety and more rapid detection of actionable events compared with conventional monitoring in patients with implantable electronic cardiac devices were demonstrated in several studies:

In Lumos-T Safely Reduces Routine Office Device Follow-up (TRUST) multicentre trial authors concluded that home monitoring detected more device related issues and earlier compared with those following calendar-based or symptom-driven in-person interrogations. The results confirmed that conventional in-person follow-up methods underreport device malfunctions.

In the AWARE Study, Lazarus et al. analysed transmissions of 11624 recipients: 4631 pacemakers, 6548 single or dual chamber defibrillators and 445 cardiac resynchronisation therapy defibrillators (CRT-D) systems. The mean interval between the last follow-up and the occurrence of events notified by home monitoring was 26 days, representing a putative temporal gain of 154 and 64 days in patients usually followed up at 6 and 3 month intervals, respectively.

In 2010, the ALTITUDE registry showed that for the 69556 ICD and CRT-D patients receiving remote follow-up on the network, 1 and 5 year survival rates were higher compared with those in the 116 222 patients who received device follow-up in device clinics only (50% reduction; p=0.0001).

Another example of remote monitoring improving clinical outcomes is its potential to reduce symptomatic lead failures, consisting of inappropriate shocks and symptomatic pacing inhibition due to oversensing. A study of patients who underwent repeat surgery due to malfunctions of the ICD lead compared the rate of symptomatic lead failure in patients monitored remotely with those followed up in-clinic. Inappropriate shocks occurred in 27.3% of the remote group compared with 46.5% of the in-clinic group. This trend gains statistical significance if the compound endpoint of inappropriate shocks and symptomatic pacing inhibition due to oversensing is focused; 27.3% in the remote group compared with 53.4% in the in-clinic group. The remote monitoring system sent alert messages in 91% of all incidents, enabling intervention to prevent aninappropriate shock.

Mabo reported in the EVATEL study , a randomized trial that included 1500 patients implanted with single or dual chamber ICD that "Home monitoring leads to a decrease of 37% of inappropriate shocks.

Kacet reported similar results in the ECOST study : "home monitoring reduces by 76% the number of aborted ICD charges with a significant impact on battery status and device longevity".

Raatikainen et al. reported that over 90% of patients found the system easy to use. Marzegalli et al. also reported that the review procedure was successful. Its mean duration was 5 ±2 minutes per transmission and users indicated that both access and navigation were easy. Patients reported a general preference for remote versus in clinic follow-up and described a sense of reassurance created by the remote monitoring capacity. In a study of 379 patients implanted with pacemakers, Halimi et al. reported all differences in the SF-36 questionnaire scores to be non-statistically significant. Patient satisfaction was studied recently by Petersen et al. : of the 385 of the patients that answered the survey (81.2%), ninety-five percent were content with the remote Follow up. Only 25% had unscheduled transmissions and most unscheduled transmissions were for appropriate reasons. Eighty-four percent of the patients wished for a more detailed response and 21% wished for a faster reply after routine transmissions.

Current ICDs provide not only arrhythmia information but also several indicators of heart failure (HF). Studies are under way to evaluate the benefits of HF specifics diagnostics coupled with home monitoring.

3.3 HEALTH ECONOMICS

While remote monitoring (RM) may be able to reduce the time spent on device follow up it is not clear whether this relates to an overall reduction in costs. RM has its own costs including the cost of the transmitter, the setup and maintenance of the central server and database, patient and clinic staff education and staff time to read, interpret, import information into electronic medical records and act on transmission events/problems. The frequency of in office visits and the frequency of RM transmissions, proximity of the patient to the clinic and many other factors will affect the economic modeling as to the potential cost savings associated with RM. Beyond assessing the simple economic modeling is the assessment of cost effectiveness which also needs to consider the improvement in patient outcomes as well as the costs involved for each form of follow up.

3.4 LIMITS OF TELECARDIOLOGY

A network failure may delay transfer of data. Most of telecardiology departments do not have 24/7services. Thus, an alert message issued on a Friday night has a good chance not to be examined before the following Monday. In addition transferred data through the network are privileged, leading to legal considerations regarding reliability of the technology and confidentiality especially during emergency situations. To add another level of complexity, each country seems to have a different modus operandi at this point in time.

Health care providers and health care organizations that are involved in remote monitoring (RM) of ICDs will typically sign a ‘Terms of Use’ agreement with each of the ICD vendors. These legal documents outline the provisions of RM between the ICD vendor and the user. The patient needs to be informed of the purpose and limitations of RM, such as the fact that it does not replace an emergency service or absence of dealing with alert events outside office hours. Before initiating RM and follow-up, the patient may be requested to sign a written informed consent stating these points and authorizing transmission of personal data to third parties, respect of privacy, and confidentiality of patient data by device companies should be subjected to strict rules, described in contracts. Cardiac implantable devices record a wealth of information and as devices become more sophisticated the scope of information can be expected to grow. Guidelines need to be established to determine the periodicity with which ICD transmissions would need to be reviewed and documented.

Vulnerability of security breaches by hackers accessing devices with wireless capability must be tested in every system. There have been no reports to date of unauthorized reprogramming of implantable devices; however, unauthorized access to personal information stored on internet servers must be also considered.

In addition, transfer of ICD data would be impossible if the home monitoring station is not close to the patient at reasonable time intervals. This could be happening in case of hospitalization in another center. The patient could even experience serious system failure without any data transmission.

Logistics may also be a limit to the development of home monitoring: It is up to the implanting center to organize ordering, stock management and traceability of home monitoring stations as well as patient education. The Sorin group is the only one so far using a distribution network to handle all these tasks.

3.5 REIMBURSEMENT

Reimbursement is important to the manufacturer in order to compensate for some of the costs related to the home monitoring stations and the transmission network. It remains a major concern in most countries, limiting the increase of use of remote monitoring despite growing evidence in favor of this technology. Today's cost containment pressure requires increased reimbursement efforts with the burden of proof shifting to medical communities and manufacturers. Reimbursement assessments often begin with the presumption that a technology or service will not be covered unless its use is supported by scientific evidence of improved outcomes. Recent publications like the EVOLVO study are important milestones in this endeavor. It concludes that "remote monitoring can reduce emergency department/urgent in office visits and, in general, total healthcare use in heart failure patients with modern ICD/CRT-D. Compared with standard follow-up through in-office visits and audible ICD alerts, remote monitoring results in increased efficiency for healthcare providers and improved quality of care for patients". Another study is under way to develop a cost minimization analysis from the hospital perspective and a cost effectiveness analysis from the third payer standpoint, based on direct estimates of costs and QOL associated with remote follow-ups, compared with standard ambulatory follow-ups, in the management of ICD and CRT-D recipients Remote monitoring of ICDs represents a growing area with increasing numbers of patients being subject to these technologies but also more and more physicians involved in decision making on the indications for these technologies and the handling of data in the context of clinical decision making.Cardiac implantable device transmissions may occur either over telephone lines or over cellular network lines. These transmissions often only take less than a minute to a few minutes to complete. However, in the foreseeable future we can expect alternative methods of data transmission to become available with transmission rates that will make it possible for nearly continuous and instantaneous patient ICD data delivered to health care providers. There are, of course, limitations to how frequently ICD data can be reviewed by health care providers and battery longevity constraints will likely limit the transmission times as well.Technological advancements continue to structure our practice of medicine, but with it often new legal challenges emerge. In order to minimize risk to patient and liability to health care providers a clear discussion regarding the expectations and limitations of remote monitoring between patients and health care providers is recommended

4 CURRENT DEVICES

4.1 ECG (ELECTROCARDİOGRAM)

Heart disease is one of the major causes of death, especially for the elderly population inmany countries. A total of 42 million out of 84 million people in North America who haveone or more cardiovascular diseases are estimated to be older than 60 years old . Theexisting ambulatory ECG monitoring systems take a considerable amount of time andeffort, record ECG signals in patients through long-term hospitalization, and the ECGdata have to be sent to professionals for diagnostic analysis. However, a portable ECGdevice, which provides real time monitoring of heart disease, can help medical decisionmaking by detecting sporadic events of heart disease as early as possible. If the patientwith chronic diseases worn a ECG device without any real time monitoring function, theprimary defect of such solution is arise from lack of help when a major incident occursduring the monitoring. The device without real time analysis recorded ECG waveformbut no immediate response is taken to help the patient. The device with real time analysiscan support medical decision with captured ECG waveform during doubtful sections of incident as a black box. Therefore, a portable ECG device is required for monitoring andidentification of sporadic and chronic events of heart diseases.Representative ECGsignals of a normal ECG, in atrial fibrillation (AFib), and inmyocardialischemia, are shown in Figure 1. AFib, which is caused by a rapid and irregular heartbeat at a rate of 400 to 600 beats per minute, is a type of arrhythmia . AFib can bedetected by monitoring the heart beat and absence of the P wave. Myocardial ischemia,caused by blockage of coronary arteries, reduces oxygen supply from the heart ,andcan be detected by monitoring abnormal divergence in the PR and ST segments. Eventhough various detectionmethods have been proposed for AFib and myocardial ischemia, they can only detect a single disease. To simultaneously detect AFib and ischemia,a compact and efficient architecture for detecting heart disease is required.Developing a portable ECG monitoring device has been an active focus of research(Table 1). Most of the portable ECG device have simple metal contacts that the user canplace their thumbs or other fingers on or place against bareskin, such as on the chest. The metal contacts are much more convenient and faster to use than adhesiveskin electrodes. In general, there aremore artifact noise and artifacts called baseline wanderin the typical thumb contact. On the other hand, recordings using adhesive electrodesare much cleaner, consistent and more accurate .

4.2 THE HEART

4.2.1 Location of the Heart

- The heart is located between the lungs behind the sternum and above the diaphragm.
- It is surrounded by the pericardium.
- Its size is about that of a fist, and its weight is about 250-300 g.
- Its center is located about 1.5 cm to the left of the midsagittal plane.

Location of the heart in the thorax

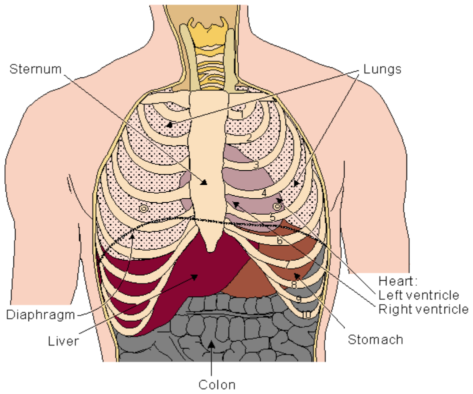


Figure 4-1 Location of the heart

4.2.2 Anatomy of the heart

- The walls of the heart are composed of cardiac muscle, called *myocardium*.
- It consists of four compartments:
    - The right and left atria and ventricles

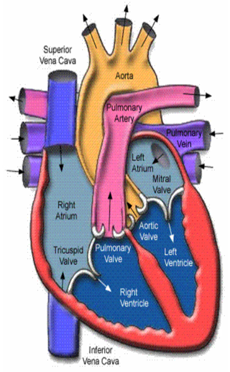


Figure 4-2 Anatomy of the Heart

4.2.3 The Heart Valves

- The tricuspid valve regulates blood flow between the right atrium and right ventricle.
- The pulmonary valve controls blood flow from the right ventricle into the pulmonary arteries
- The mitral valve lets oxygen-rich blood from your lungs pass from the left atrium into the left ventricle.
- The aortic valve lets oxygen-rich blood pass from the left ventricle into the aorta, then to the body

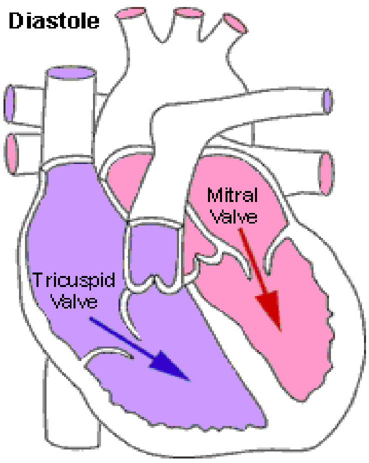


Figure 4-4 Atrioventricular Valves

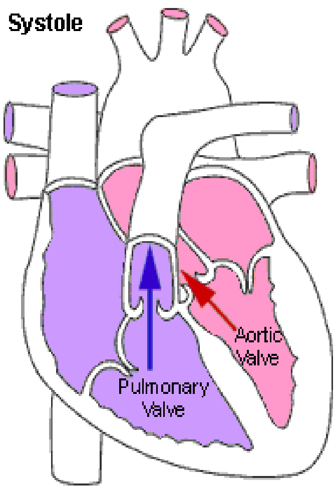


Figure 4-3 Semilunar Valves

4.2.4 Blood circulation via heart

- The blood returns from the systemic circulation to

the right atrium and from there goes through the

tricuspid valve to the right ventricle.

- It is ejected from the right ventricle through the

pulmonary valve to the lungs.

- Oxygenated blood returns from the lungs to the

left atrium, and from there through the mitral valve

to the left ventricle.

- Finally blood is pumped through the aortic valve to the

aorta and the systemic circulation.

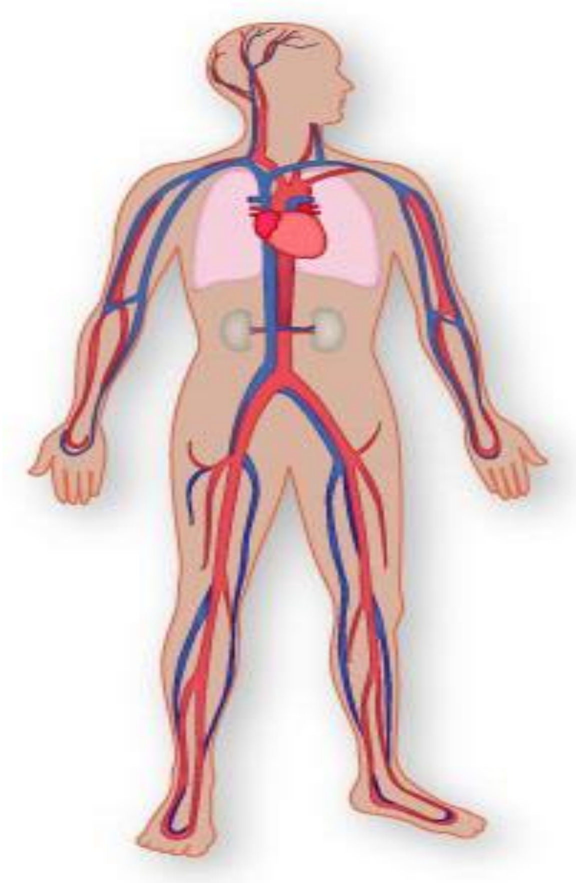


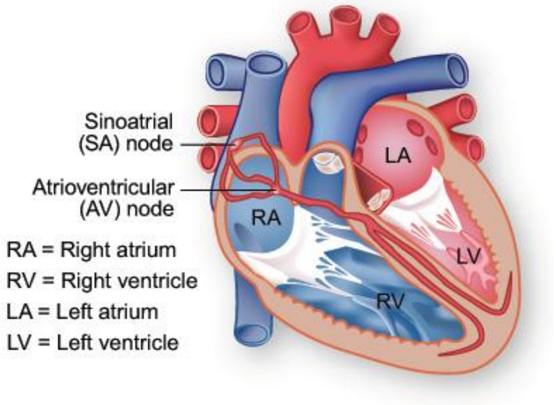
Figure 4-5 The Circulatory Way Of The Heart

4.2.5 Electrical activation of the heart

- In the heart muscle cell, or *myocyte*, electric activation takes place by means of the same mechanism as in the nerve cell, i.e., from the inflow of Na ions across the cell membrane.
- The amplitude of the action potential is also similar, being 100 mV for both nerve and muscle.
- The duration of the cardiac impulse is, however, two orders of magnitude longer than in either nerve cell or sceletal muscle cell.
- As in the nerve cell, repolarization is a consequence of the outflow of K ions.
- The duration of the action impulse is about 300 ms.

4.2.6 The Conduction System

- Electrical signal begins in the sinoatrial (SA) node: "natural pacemaker."
  - causes the atria to contract.
- The signal then passes through the atrioventricular (AV) node.
  - sends the signal to the ventricles via the “bundle of His”
  - causes the ventricles to contract.



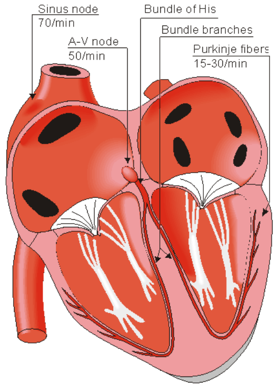


Figure 4-6 Anatomy of the conduction system

Figure 4-7 Normal conduction system of the heart

- The sinoatrial node in humans is in the shape of a crescent and is about 15 mm long and 5 mm wide.
- The SA nodal cells are self-excitatory, pacemaker cells.
- They generate an action potential at the rate of about 70 per minute.
- From the sinus node, activation propagates throughout the atria, but cannot propagate directly across the boundary between atria and ventricles.
- The atrioventricular node (AV node) is located at the boundary between the atria and ventricles; it has an intrinsic frequency of about 50 pulses/min.
- If the AV node is triggered with a higher pulse frequency, it follows this higher frequency. In a normal heart, the AV node provides the only conducting path from the atria to the ventricles.

- Propagation from the AV node to the ventricles is provided by a specialized conduction system.

Proximally, this system is composed of a common bundle, called the;

- Bundle of His (after German physician Wilhelm His, Jr., 1863-1934).
- More distally, it separates into two bundle branches propagating along each side of the septum, constituting the right and left bundle branches. (The left bundle subsequently divides into an anterior andposterior branch.)
- Even more distally the bundles ramify into Purkinje fibers (named after Jan Evangelista Purkinje (Czech; 1787-1869)) that diverge to the inner sides of the ventricular walls.
- Propagation along the conduction system takes place at a relatively high speed once it is within the ventricular region, but prior to this (through the AV node) the velocity is extremely slow.

Propagation on ventricular wall

- From the inner side of the ventricular wall, the many activation sites cause the formation of a wavefront which propagates through the ventricular mass toward the outer wall.
- This process results from cell-to-cell activation.
- After each ventricular muscle region has depolarized, repolarization occurs.

4.3 THE NORMAL ELECTROCARDIOGRAM

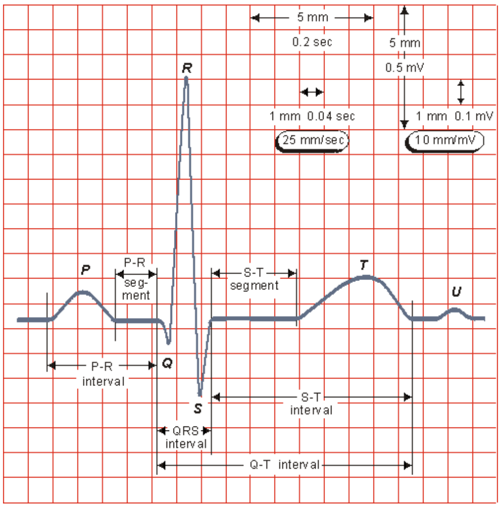


Figure 4-9 Waveforms on ECG paper.

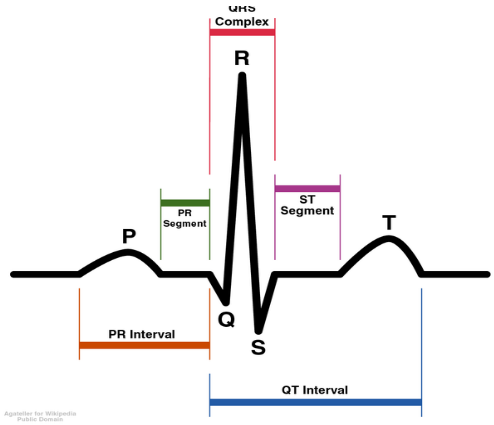


Figure 4-8 Waveforms of ECG.

P wave: Signal spread from SA node to make the atria contract.

P-Q Segment:signal arrives AV node stay for a instant to allow the ventricle to be filled with blood.

Q wave:After the Buddle of His the signal is divided into two branches and run through the septum.

R,S wave: Left and right ventricle contraction are marked by the R,S wave.

T wave: Ventricle relaxing

4.3.1 Electrical events in the heart

SA node	impulse generated	0		0.05	70-80
atrium, Right	depolarization *)	5	P	0.8-1.0	
Left	depolarization	85	P	0.8-1.0	
AV node	arrival of impulse	50	P-Q	0.02-0.05	
	departure of impulse	125	interval		
bundle of His	activated	130		1.0-1.5	
bundle branches	activated	145		1.0-1.5	
Purkinje fibers	activated	150		3.0-3.5	
endocardium					
Septum	depolarization	175		0.3 (axial)	20-40
Left ventricle	depolarization	190		-	
			QRS	0.8	
epicardium	depolarization	225		(transverse)	
Left ventricle	depolarization	250			
Right ventricle					
epicardium					
Left ventricle	repolarization	400			
Right ventricle	repolarization				
			T	0.5	
endocardium					
Left ventricle	repolarization	600			

*) Atrial repolarization occurs during the ventricular depolarization; therefore, it is not normally seen in the electrocardiogram.

Table 1.1.1 the electrical activity rates of the heart

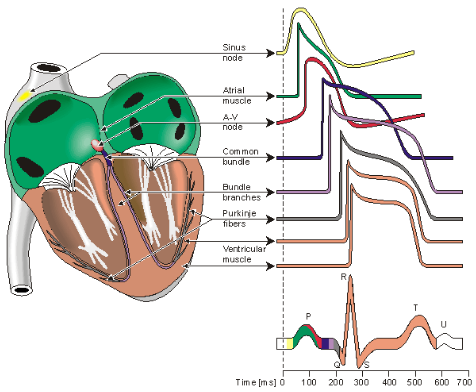


Figure 4-11

- **Isochronic surfaces of the ventricular activation**

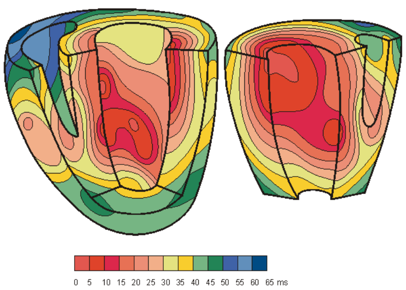


Figure 4-12 Model of ventricular activation.

- **Electric field of the heart on the surface of the thorax, recorded by Augustus Waller (1887)**

The curves (a) and (b) represent

the recorded positive and negative isopotential lines, respectively.

These indicate that the heart is a dipolar source having the positive and negative poles at (A) and (B), respectively.

The curves (c) represent the assumed current flow lines..

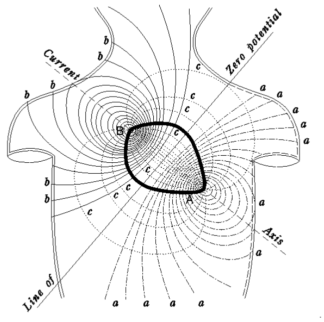


Figure 4-14 Electric field of the heart

- **Lead Vector**

The potential Φ at point P due to any dipole p can be written as the vector c is the *lead vector*. Note that the value of the lead vector is a property of the lead and volume conductor and does not depend on the magnitude and direction of the dipole p.

$$\phi = c_x p_x + c_y p_y + c_z p_z \qquad \phi = \bar{c} \cdot \bar{p}$$

- **Extending the concept of lead vector**
- Unipolar lead: measuring the voltage relative to a remote reference.
- Bipolar lead: formed by a lead pair and is the voltage between any two points.

- **THE 10 ECG LEADS OF WALLER.**

Einthoven limb leads (standard leads) and Einthoven triangle. The Einthoven triangle is an approximate description of the lead vectors associated with the limb leads.

- **Limb leads**
- The Einthoven *limb leads* (standard leads) are defined in the following way:
- Lead I: $V_I = \Phi_L - \Phi_R$

Lead II: $V_{II} = \Phi_F - \Phi_R$

Lead III: $V_{III} = \Phi_F - \Phi_L$

$$\phi_R = \bar{c}_R \cdot \bar{p}$$
$$\phi_L = \bar{c}_L \cdot \bar{p}$$
$$\phi_F = \bar{c}_F \cdot \bar{p}$$

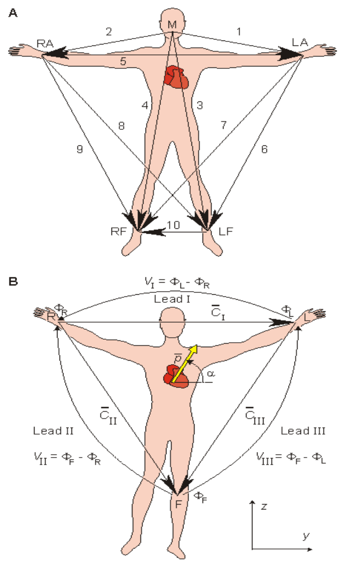


Figure 4-15Lead placement axis.

where V_I= the voltage of Lead I

V_{II}= the voltage of Lead II

V_{III}= the voltage of Lead III

Φ_L= potential at the left arm

Φ_R= potential at the right arm

Φ_F= potential at the left foot

- According to Kirchhoff's law these lead voltages have the following relationship:

$V_I + V_{III} = V_{II}$

hence only two of these three leads are independent

Standard lead vectors form an equilateral triangle

$$V_I = \phi_L - \phi_R$$
$$= (\bar{c}_L - \bar{c}_R) \cdot \bar{p} = \bar{c}_I \cdot \bar{p}$$

$$V_{II} = \phi_F - \phi_R$$
$$= (\bar{c}_F - \bar{c}_R) \cdot \bar{p} = \bar{c}_{II} \cdot \bar{p}$$

$$V_{III} = \phi_F - \phi_L$$
$$= (\bar{c}_F - \bar{c}_L) \cdot \bar{p} = \bar{c}_{III} \cdot \bar{p}$$

$$V_I + V_{III} - V_{II} = 0$$
$$\bar{c}_I + \bar{c}_{III} - \bar{c}_{II} = 0$$

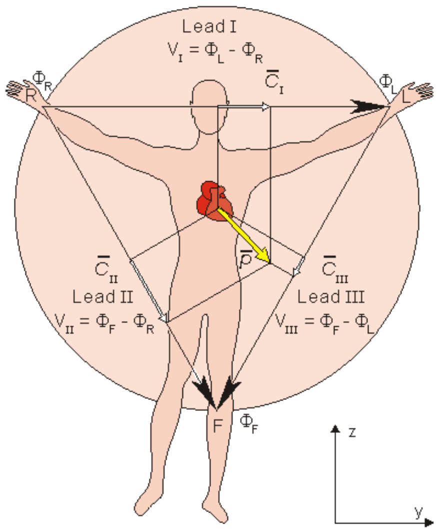


Figure 4-16 3-lead placement.

- **The generation of the ECG signal in the Einthoven limb leads - I**

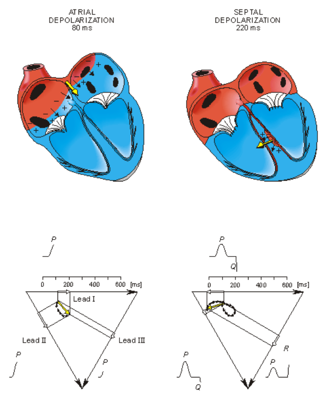


Figure 4-18 Electrical activity of the heart.

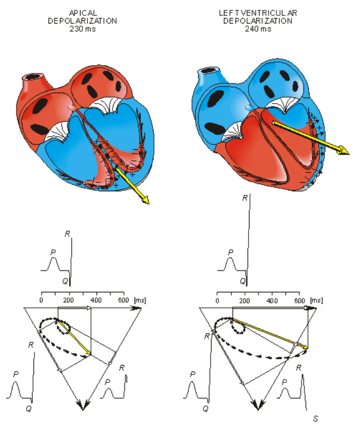


Figure 4-17 Electrical activity of the heart.

4.3.2 The generation of the ECG signal in the Einthoven limb leads - II

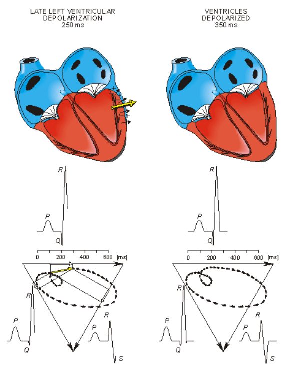


Figure 4-19 Electrical activity of the heart.

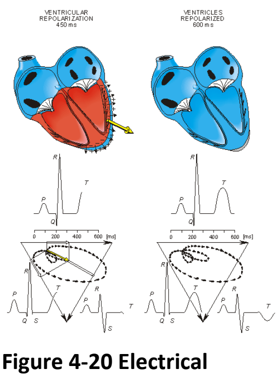


Figure 4-20 Electrical activity of the heart.

The Wilson central terminal (CT) is formed by connecting a 5 k resistance to each limb electrode and interconnecting the free wires; the CT is the common point. The Wilson central terminal represents the average of the limb potentials. Because no current flows through a high-impedance voltmeter, Kirchhoff's law requires that $I_R + I_L + I_F = 0$.

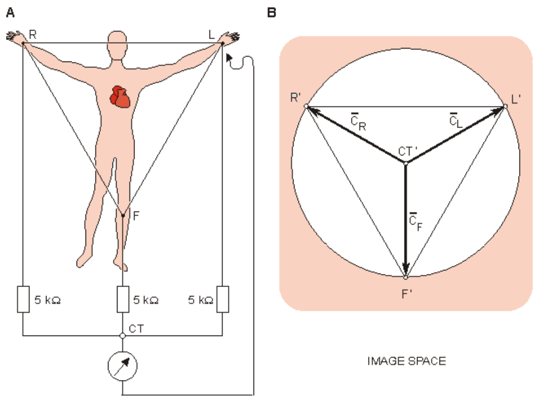


Figure 4-21 Lead placement.

(A) The circuit of the Wilson central terminal (CT).

(B) The location of the Wilson central terminal in the image space (CT'). It is located in the center of the Einthoven triangle

- **Additional limb leads**

- Three additional limb leads V_R, V_L, and V_F are obtained by measuring the potential between each limb electrode and the Wilson central terminal.

$$V_F = \phi_F - \phi_{CT} = \frac{2\phi_F - \phi_R - \phi_L}{3}$$

$$V_R = \phi_R - \phi_{CT} = \frac{-\phi_F + 2\phi_R - \phi_L}{3}$$

$$V_L = \phi_L - \phi_{CT} = \frac{-\phi_F - \phi_R + 2\phi_L}{3}$$

- **Goldberger Augmented leads**
- Goldberger observed that the signals from the additional limb leads can be augmented by omitting that resistance from the Wilson central terminal which is connected to the measurement electrode.
- The aforementioned three leads may be replaced with a new set of lead that are called augmented leads because of augmentation of the signal.
- The augmented signal is 50% larger than the signal with the Wilson ventral terminal chosen as reference.

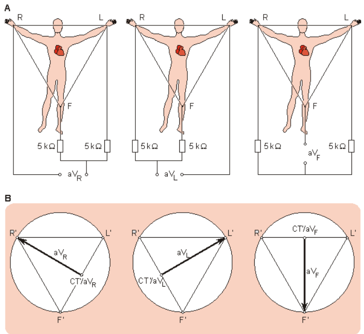


Figure 4-22 Lead placement.

(A) The circuit of the Goldberger augmented leads.
(B) The location of the Goldberger augmented lead vectors in the image space.

Precordial Leads

- For measuring the potentials close to the heart, Wilson introduced the precordial leads (chest leads) in 1944. These leads, V_1-V_6 are located over the left chest as described in the figure.

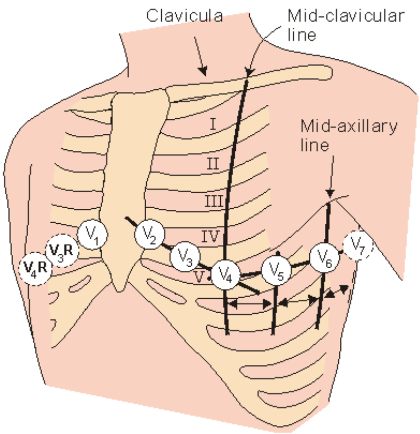


Figure 4-23 Lead placement.

- **THE 12-LEAD SYSTEM**

- The most commonly used clinical ECG-system, the 12-lead ECg system, consists of the following 12 leads, which are:

$$\begin{aligned}&I, II, III\\&aV_R, aV_L, aV_F\\&V_1, V_2, V_3, V_4, V_5, V_6\end{aligned}$$

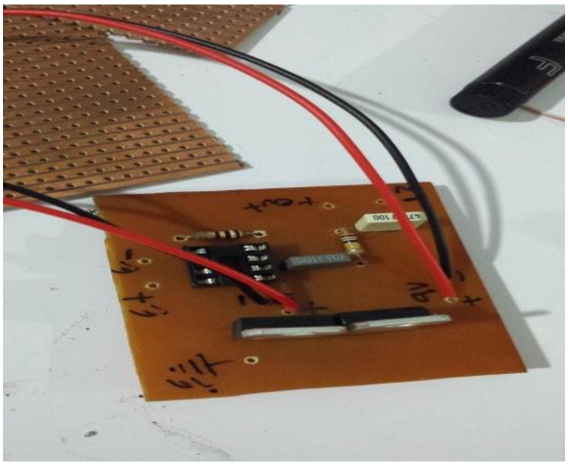
The projections of the lead vectors of the 12-lead ECG system in three orthogonal planes

(when one assumes the volume conductor to be spherical homogeneous and the cardiac source centrally located).

5 CONSTRACTION OF PRACTICAL APPLICATION

5.1 PRACTİCAL Circuit

Figure 6.2 shows the construction of practical circuit



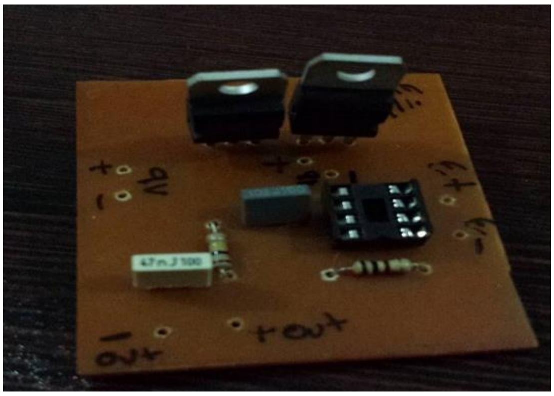


Figure 5-1

Figure 5-2 Performed circuit.

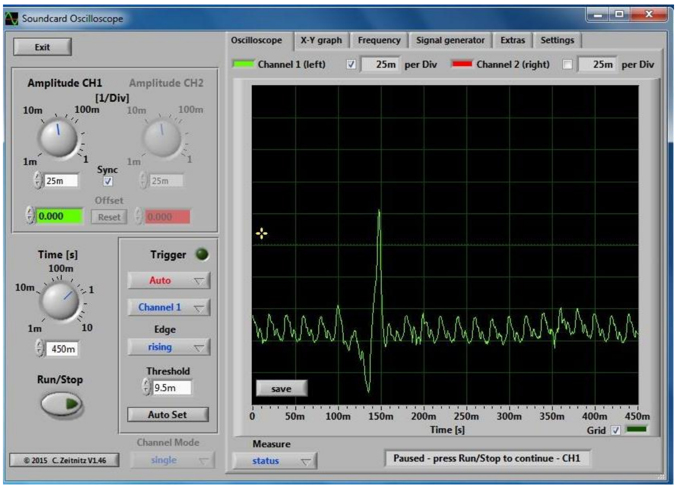


Figure 5-3 Obtained signal

Materials:

- INA 128 integrated circuit
- Resistors (100ohm, 100 kilo ohm)
- Capacitors (47nF, 10nF)

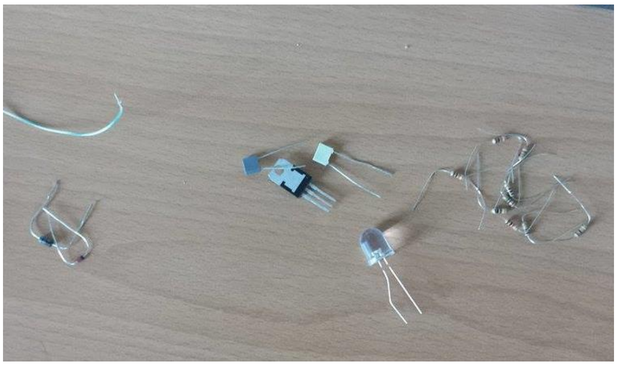


Figure 5-4 Materials that are used

Simulated Circuit

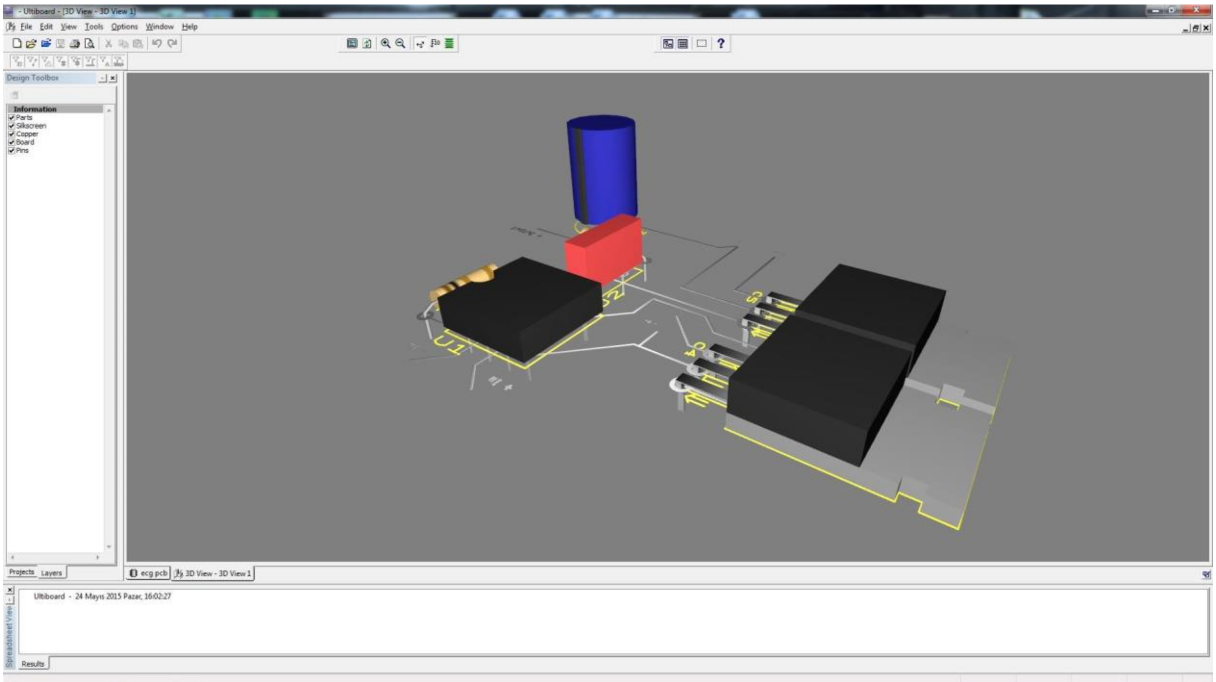


Figure 5-5 Circuit desing in ultiboard 12.0

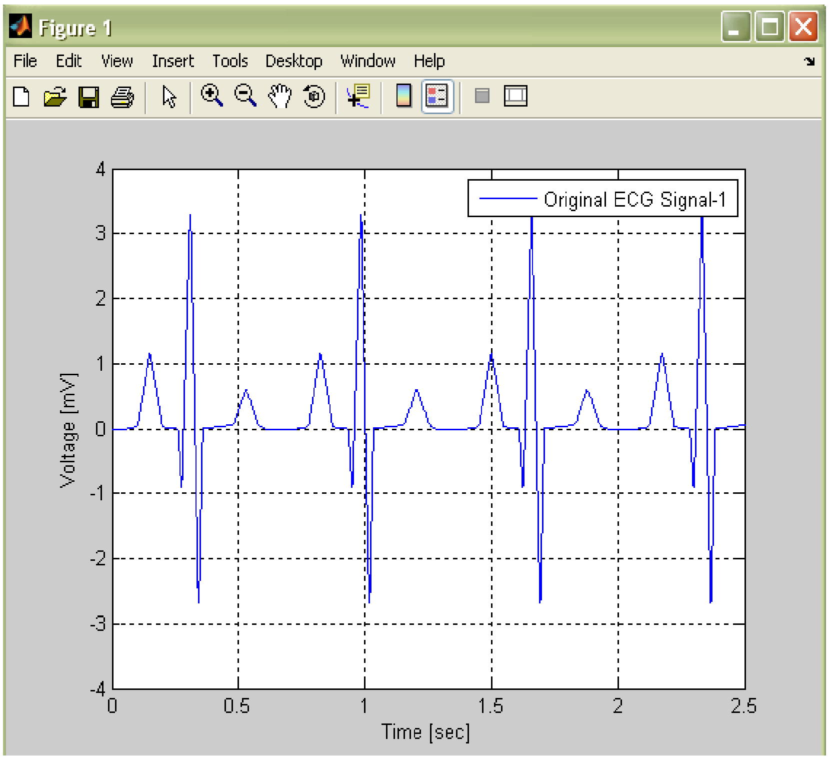


Figure 5-6 Signals taken from MatLab

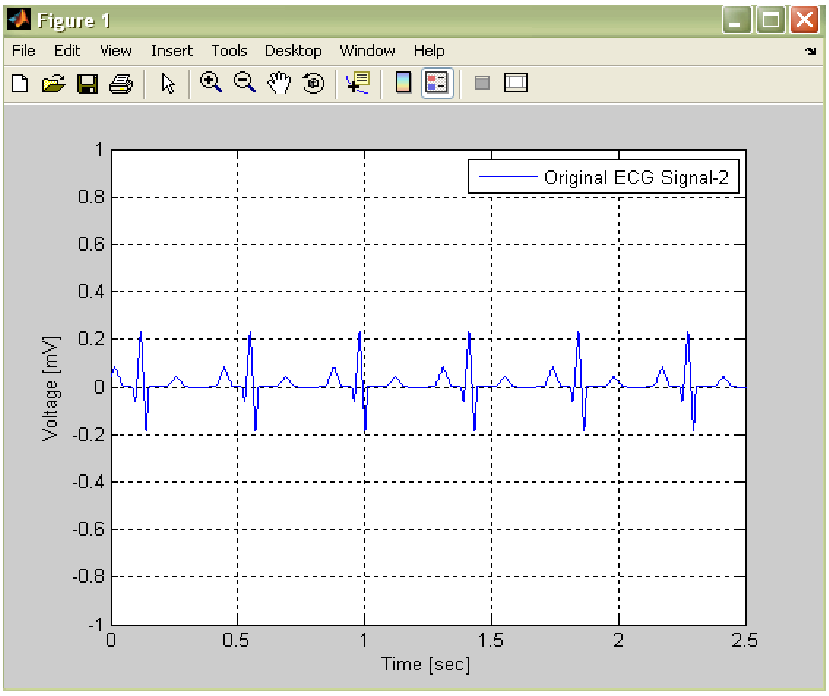


Figure 5-7 Signals taken from Matlab

5.2 PCB (Printed Circuit Board)

A printed circuit board (PCB) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. PCBs can be single sided (one copper layer), double sided (two copper layers) or multi-layer (outer and inner layers). Multi-layer PCBs allow for much higher component density. Conductors on different layers are connected with plated-through holes called vias. Advanced PCBs may contain components - capacitors, resistors or active devices - embedded in the substrate.

Printed circuit boards are used in all but the simplest electronic products. Alternatives to PCBs include wire wrap and point-to-point construction. PCBs require the additional design effort to lay out the circuit, but manufacturing and assembly can be automated. Manufacturing circuits with PCBs is cheaper and faster than with other wiring methods as components are mounted and wired with one single part. Furthermore, operator wiring errors are eliminated.

When the board has only copper connections and no embedded components, it is more correctly called a printed wiring board (PWB) or etched wiring board. Although more accurate, the term printed wiring board has fallen into disuse. A PCB populated with electronic components is called a printed circuit assembly (PCA), printed circuit board assembly or PCB assembly (PCBA). The IPC preferred term for assembled boards is circuit card assembly (CCA),[1] and for assembled backplanes it is backplane assemblies. The term PCB is used informally both for bare and assembled boards.

5.3 Materials that we used to make PCB :

- Printing appropriate benchmark copper or epoxy plaque to the circuit diagram7
- PNP or oily (coated) paper
- Iron
- Scouring pads
- Detergents (JIF, Sıvısab's)
- Asitat pen
- muriatic acid
- Perhydrol Acid
- Plaque horizontal frequently be a plastic container

Figure 5-8 Preparation of our PCB circuit

- **TeamViewer**

TeamViewer is a proprietary computer software package for remote control, desktop sharing, online meetings, web conferencing and file transfer between computers.

- **Features**

Versions are available for the Microsoft Windows, Mac OS X, Linux, iOS, Android, Windows RT, Windows Phone 8 and BlackBerry operating systems. It is also possible to access a machine running TeamViewer with a web browser. While the main focus of the application is remote control of computers, collaboration and presentation features are included.

TeamViewer can be used without charge by non-commercial users, and Business, Premium and Corporate versions are available.

TeamViewer GmbH was founded in 2005 in Uhingen, Germany. UK-based private equity firm Permira acquired TeamViewer GmbH from Durham, North Carolina-based software developer GFI Software in 2014. The company also host an online backup cloud service called Airbackup.

- **Establishing connections**

TeamViewer may be installed with an installation procedure, although the 'Quick Support' version will run without installation. To connect to another computer, TeamViewer has to be running on both machines. To install TeamViewer,administrator access is required, but once installed it can be run by any user. When TeamViewer is started on a computer, it generates a partner ID and password (user-defined passwords are also supported). To establish a connection between a local client and a remote client, TeamViewer generated ID and password of either client are required. The local client requires the remote client's ID and password to gain control over the remote client, whereas the remote client requires the local client's ID and password to gain control over the local client.

To start an online meeting, the presenter gives the Meeting ID to the participants. They join the meeting by using the TeamViewer full version or by logging on tohttp://go.teamviewer.com/ and entering the Meeting ID. It is also possible to schedule a meeting in advance.

- **Fraudulent uses**

TeamViewer and similar services have been used to commit fraud via telephone calls. People are called, either at random or from a list, by criminals claiming to represent a computer support service which has identified the victim's computer as being infected by malware, sometimes using the name of a company such as Microsoft. They then ask the victim to give them access to their computer via a remote control service. From this point they can do anything they want. Typically they confuse the user with spurious jargon and offer to "repair" the computer and supply several years' of service for a payment; in addition to a freely offered agreed payment, this gives them the victim's payment card details. They may also infect the computer with malware, delete files, and steal files.

6 CONCLUSION

Telemedicine can provide access to health care in previously unserved or underserved areas. These areas include both rural ‘and inner city or barrier locations. typically have lower healthcare services of specialty practitioners. Teleradiology services are often used to provide the services of a radiologist to multiple remote locations that do not have a radiologist on site.

An ECG was recorded with distinct R-peaks during sleep, regardless of body position and location on the bed.The waveforms varied according to the contact condition and position.Further study on analyzing the waveform is needed for the motion artifacts.Shows the feasibility of using IDC-ECG for long-term daily ECG monitoring during sleep with minimal intrusion.

The objective of this thesis was to take advantage of the modern day technology and create a tele-cardiology sensor network for remote ECG monitoring purposes. While technological advancements have seen changes to many aspects of the daily lives, there is still a significant gap between the existing solutions and the needs in the medical field. One of the most pressing issues in medical care today is the response time to patients in need. Although fully capable of providing cures, many patients pass away due to delays of treatments. Thanks to the recent developments in wireless sensor networks and wavelength signal analysis, such misfortunes may be avoided This thesis is an endeavor to suggest a solution utilizing these technologies and provide a remote ECG monitoring system designed for the medical environment. This system provides continuous vital sign monitoring capabilities without the exhaustion of any manpower. In fact, it is intended to give support to the current health care environments and free up medical professionals for more urgent functions. By automating the vital sign monitoring process, the most updated information for all patients are made available at all times.

This system is composed of two major components. Based on wireless sensor network technology, there are the wearable mobile platforms distributed to the patients of concern. These mobile platforms are responsible for gathering patient vital sign using a 3-Lead ECG monitoring system. The gathered data are transmitted wirelessly over radio to the receiving station connected to a workstation where the data are processed.

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8 Appendix

```
% % Creating ECG Signal
x1 = 3.5*ecg(2700).';
y2 = sgolayfilt(kron(ones(1,13),x1),0,21);
n = 1:30000;
del = round(2700*rand(1));
mhb = y2(n + del);
t = 0.00025:0.00025:7.5;
plot(t,mhb)
axis([0 2.5 -4 4]);
grid;
xlabel('Time [sec]');
ylabel('Voltage [mV]');
legend('Original ECG Signal-1');
```

```
x2 = 0.25*ecg(1725);
y2 = sgolayfilt(kron(ones(1,20),x2),0,17);
n = 1:30000;
del = round(1725*rand(1));
fhb = y2(n + del);
t = 0.00025:0.00025:7.5;
plot(t,fhb);
axis([0 2.5 -1 1]);
grid;
xlabel('Time [sec]');
ylabel('Voltage [mV]');
legend('Original ECG Signal-2');
```