Telecardiology

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ABSTRACT: Telemedicine is the application of advanced telecommunication technology for diagnostic, monitoring and therapeutic purposes. It enables data transmission from the patient's whereabouts or his/her primary care provider to a specialized medical call center. Telecardiology is a highly developed medical discipline involving almost every aspect of cardiology, including acute coronary syndromes, arrhythmias, congestive heart failure, sudden cardiac arrest and others. Israel is one of the leading countries in the use of telecardiology, achieving extended survival, improvement of the patient's quality of life, and significant reduction in health costs.

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Telemedicine is the application of advanced telecommunication technology for diagnostic, monitoring and therapeutic purposes in almost every medical subspecialty. Telemedicine involves live, bi-directional audio and video interaction between patients and medical professionals and among medical professionals. It transmits real-time or recorded data and verbal reporting from a patient's whereabouts to a medical call center, as well as medical files and output data from medical devices from the facilities of a primary care provider to a designated specialist. Telemedicine was approved by the Israel Medical Association Ethics Committee in a position paper in which it recognized the capabilities of telemedicine to meet the growing need for enhancing the delivery of medical care. In addition to enabling better and more extended health services worldwide, the implementation of telemedicine systems was shown to substantially reduce health costs.

Among the vast range of medical disciplines in which telemedicine has been successfully applied are cardiology, psychiatry, dermatology, radiology, neurology, ophthalmology, otolaryngology, rheumatology, pulmonary, urology, wound care, obstetrics, pediatrics and neonatology, pathology, emergency medicine and trauma. Home telehealth is provided by licensed health care providers including, but not limited to, physicians, nurses, physical therapists, social workers, speech therapists, psychologists, occupational therapists and nutritionists. Consultations and extra services for accommodating special needs can be incorporated into the system as needed.

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 transportation of critically ill patients for the purpose of diagnosis can be 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 both patient survival and recovery. While telecardiology has been widely applied, there are still limited prospective randomized data supporting its health care benefits [1].

This review summarizes updated information on the use of telemedicine in cardiology and details its evidence-based effect on patient survival and quality of life.

TELECARDIOLOGY IN THE TREATMENT OF HEART FAILURE

Heart failure constitutes the most frequent and expensive hospital discharge diagnosis in the United States, costing over $23.7 billion in direct medical expenditures, with over 980,000 hospital admissions in 2004 and an average of 3.2 hospital admissions annually per patient [2]. Effective use of telemedicine in the treatment of HF patients has been expanding considerably worldwide. Many studies have demonstrated a substantial reduction in hospital admission and in the length of hospitalization, and an increase in survival among HF patients who were managed by telemedicine [3]. In a recently published meta-analysis that summarized 96 studies (with a total of 6258 patients), Klersy et al. [4] reported that remote patient moni-

HF = heart failure

toring significantly reduced the risk of death and the length of hospitalization for any cause, including HF, compared with usual care. Roth et al. [5] telephonically followed 118 patients with New York Heart Association functional class II-IV who had at least two past hospitalizations due to HF. The patients' vital signs and weight were transmitted daily to the system's monitor center, and the monitor center's nurse telephoned the patient twice monthly to assess a number of parameters, including well-being, frequency of specific symptoms, adherence to treatment, and to remind him/her of the importance of maintaining a salt-free diet and of the regular use of medication. The nurse instructed patients with "red alarms" (e.g., weight gain > 1.5 kg compared to baseline, diastolic blood pressure > 180/110 mmHg or systolic < 90 mmHg) to increase the furosemide dose. Mobile intensive care units were dispatched according to the protocol for action taken in given cases. In addition to the significant decrease in the absolute number of hospitalizations during the study period compared to the year preceding it (558 versus 1623 days/year, respectively), there was also a remarkable decrease in the average length of in-hospital stay (from 13.75 to 3.06 days). These changes were typical for all NYHA functional groups.

In a large randomized study published in 2010, Chaudhry et al. [6] assigned 1653 patients with recent hospitalization for HF failure to undergo either telemonitoring (826 patients) or usual care (827 patients). The median age of those patients was 61 years. The study results failed to show any significant difference between the two groups in the composite rate of readmission for any reason or death from any cause within 180 days after study entry. However, only 78% of the patients used diuretics and 30% had an ejection fraction of 40% or more. Moreover, a total of 85.6% of patients in the telemonitoring group made at least one call, and only 55.1% of them had adhered to the study protocol by week 26. This study had other limitations, including the use of an automated telemedicine tool, a short follow-up period, and a relatively young population. The findings of a recently published Cochrane review on telemedicine practice for congestive HF patients [7], which included only peer-reviewed, randomized controlled trials, contradicted those results by showing a 44% reduction in the death rate from any cause and a 21% reduction in HF hospitalization, with a substantial improvement in quality of life together with cost reduction.

Finally, in the COMPASS-HF Study, Bourge et al. [8] examined the efficacy of an implantable monitor that continuously measures and stores hemodynamic information of CHF patients and can be reviewed remotely. In this prospective, multicenter, randomized, single-blind, parallel-controlled trial, 274 HF patients with NYHA functional class III or IV received an implantable continuous hemodynamic monitor. The patients were then randomized to a control group and to the Chronicle® monitor group. Clinicians had access to the hemodynamic information only in the Chronicle group, and the pressure information was reviewed at least once a week for the 6 months of follow-up. There was a non-significant reduction of 21% in all HF-related events (hospitalizations, emergency department and urgent clinic visits requiring intravenous therapy) among the Chronicle monitor group compared with the control group ($P = 0.33$). A retrospective analysis showed a 36% reduction in the relative risk of an HF-related hospitalization in the Chronicle monitor group. This reduction in the relative risk of an HF-related hospitalization was comparable in the groups with ejection fraction < 50% and > 50% ($P = 0.03$).

Telemedicine exploits cutting-edge communication technology to provide rapid contact between a patient in need and a source of medical assistance

TELECARDIOLOGY IN DIAGNOSING ACUTE ST ELEVATION MI

Increasing the treatment efficacy in ST elevation myocardial infarction and reducing the door-to-balloon time, defined as the time between the arrival at the hospital and the first balloon inflation during percutaneous coronary intervention, are major targets of contemporary patient management [9]. The importance of the door-to-balloon time cannot be overemphasized: it is one of the core quality measures collected and reported by the Centers for Medicare and Medicaid Services and the Joint Commission on Accreditation of Healthcare Organizations [9]. Yet, only a minority of hospitals treats patients with ST elevation MI within 90 minutes after their arrival [10,11], and hospital performance has not improved substantially in recent years [10]. Many attempts have been made to implement telemedicine technology in order to reduce this crucial time period. Carmody [12] reported a simple approach to transmit out-of-hospital electrocardiograms by means of cellular phone cameras, alerting catheterization teams prior to patient arrival at the hospital. In addition, there are devices that transmit 12-lead ECG tracings via regular and mobile telephones, and even some that have the capability of interpreting the ECG findings [13,14]. In order to reduce the time to catheterization, Sejersten et al. [15] transmitted the prehospital ECG of patients suffering from chest pain to the cardiologist's mobile telephone. After evaluation of their ECG tracings, 168 patients (30%) were referred directly for PCI, and 146 of them (87%) underwent emergent catheterization. The median time of the study group from the ambulance call to PCI was significantly shorter than in the historic control group

NYHA = New York Heart Association
CHF = congestive heart failure

MI = myocardial infarction
PCI = percutaneous coronary intervention

(74 vs. 127 minutes, $P < 0.001$). Specifically, door-to-PCI time was 34 minutes for the study patients compared to 97 minutes for the controls ($P < 0.001$).

Lastly, telemetry may enable the use of prehospital thrombolytic treatment in ST elevation MI, thus reducing the call to treatment times, especially in a rural setting. However, this benefit must be balanced against the very small proportion of eligible patients identified as suitable for prehospital thrombolysis [16].

TELECARDIOLOGY AND THE REDUCTION OF SUDDEN CARDIAC DEATH

Patients suffering from an acute ischemic event are at risk of sudden cardiac death [17]. Roth et al. [18] followed patients who survived hospitalization after an acute MI, comparing the one-year survival rate among participants of the Acute Coronary Syndrome Israel Survey (ACSIS) 2004 and SHL-Telemedicine subscribers. Even though the SHL cohort was significantly older than the ACSIS cohort, had significantly more past MIs, more past strokes and more HFs, the one-year mortality was significantly lower among the SHL patients (4.4% vs. 9.7% for ACSIS). The authors concluded that availability of medical call centers in the out-of-hospital setting improves patient motivation to seek timely and appropriate medical assistance and thus improve survival. Müller et al. [19] collected information on the circumstances of sudden cardiac death in order to tailor preventive and educational measures. Most of the sudden cardiac death patients had multiple high-risk symptoms: 25% suffered from angina symptoms (for a mean period of 120 minutes) prior to the cardiac arrest, 17% had dyspnea, and 7% had nausea or vomiting. Only 25% of the patients were asymptomatic before the event. The poor survival rate after out-of-hospital cardiac arrest and the knowledge that the majority of patients had exhibited some definitive symptoms prior to the event emphasize the importance of educating patients about the nature of warning symptoms and of providing them with accessible medical service. The same conclusion was reached by another study [20] that compared the 15% survival rate of patients with sudden cardiac death among patients with out-of-hospital cardiac arrest treated by a telemedicine service to the 7% rate of the national ambulance service. Those authors noted that the telemedicine call center routinely initiates calls to subscribers, thereby reinforcing their awareness of relevant symptoms and of the need to seek medical assistance without delay. This vigilance together with awareness and accessibility of the medical service were shown to have raised the survival rate after out-of-hospital cardiac arrest: of 1810 patients who underwent out-of-hospital resuscitation, 597 were hospitalized and 279 (15.4%) were ultimately discharged.

Delay in treatment of heart conditions is directly associated with patient survival. Telecardiology instantly mobilizes all the required resources to advise, treat and transport patients according to specific, individual requirements

TELECARDIOLOGY IN DIAGNOSIS AND TREATMENT OF ARRHYTHMIAS

Symptoms secondary to arrhythmias, such as palpitations and syncope, can be documented on ECG tracings, but many ECG changes are transient or paroxysmal, and the search for corroboratory evidence of these arrhythmias can be lengthy and problematic and missed even by long-term Holter ECG recordings [21]. The detection of these arrhythmias has crucial therapeutic implications, such as the provision of anti-arrhythmic and anticoagulation treatment for high-risk atrial fibrillation patients, permanent pacemakers for patients suffering from high-degree atrioventricular nodal block, ablation for patients suffering from recurrent supraventricular tachycardia, and others [21,22]. The diagnostic yield increases substantially with the use of patient-activated short-term ECG recordings [21]. Singh and Hsiao [23] described the development of a remote device that enables real-time cardiac arrhythmic monitoring with very high sensitivity and specificity (100% and 99.62%, respectively, in the absence of arrhythmia, and 99.34% and 99.31%, respectively, in the presence of arrhythmia). This device provides a specific diagnosis and recommendations of actions to be taken immediately, and may raise the rate of diagnosis and the efficacy of treatment. Olson et al. [24] reviewed the records of 122 patients using continuous mobile cardiac outpatient telemetry as part of evaluating palpitations, presyncope/syncope, or as part of evaluating the efficacy of a specific anti-arrhythmic therapy. Ten of 17 patients studied for presyncope/syncope were diagnosed by the monitor device: 8 of them had a previous negative evaluation and 5 had an event correlated with their heart rhythm during the monitoring period. One-third of the patients monitored for medication titration had dosage adjustments during outpatient monitoring. Those authors concluded that continuous mobile cardiac outpatient telemetry can detect clinically significant arrhythmias, and that it was especially useful for identifying the cause of presyncope/syncope. In addition, it enabled patients to undergo dose titration or change of their medication in the outpatient setting, thus reducing the rate of hospitalization.

The use of telemedicine can ensure urgent provision of medical treatment for potentially life-threatening arrhythmias. Retrospective studies have shown that significant changes in heart rate variability indices occur prior to cardiac arrest. Based on these studies, Singh et al. [25] recently

ACSIS = Acute Coronary Syndrome Israel Survey

designed a handheld remote ECG monitor that detects the QRS complex and calculates short-term heart rate variability indices in real time. Those authors believe that this device may provide early warnings of impending cardiac conditions. Roth et al. [26] reported their experience with self-injected intramuscular lidocaine injections for treating SHL-Telemedicine subscribers who experienced sustained ventricular tachycardia unassociated with an MI that was registered transtelephonically. Following orders via telephone while a mobile intensive care unit was en route, sinus rhythm was regained within 10 minutes in 27 of 76 patients (36%), while rhythm was slowed by > 30% in an additional 7 patients (9%). Thus, telemedicine has the capability of identifying the malignant arrhythmic event and deploying treatment in a substantially shortened period.

TELECARDIOLOGY IN PATIENTS WITH IMPLANTABLE ELECTRONIC DEVICES

A recently introduced technology allows remote monitoring and continuous interrogation of implantable electronic devices in order to detect adverse events earlier than is possible with standard follow-up visits and to decrease the number of ambulatory follow-up visits. The experience thus far has been in patients with implantable cardioverter defibrillators and in those undergoing cardiac resynchronization therapy [27]. Transmissions from the implanted device are made every day at a specific programmable time (generally during the night) or immediately upon detection of preselected critical events of which the physician is directly alerted and can respond without delay. The transmissions are automatically triggered and the patients play no role in initiating them [27]. Theuns and colleagues [28] followed 146 patients who received an ICD device with home monitoring and in whom a total of 57,148 transmissions were recorded. The authors concluded that remote monitoring of ICD patients is feasible, and despite the large number of transmissions, remote monitoring imposed only a minimal additional burden on the clinical workload and showed a potential to limit the frequency of scheduled ambulatory visits.

Knowledge of the nature of a cardiac condition and its warning symptoms and of the importance of adherence to treatment and maintaining a healthy lifestyle is vital for prolonging the best possible quality of life. This is one of the fundamental services of a telecardiology system

Spencker and co-researchers [29] used a remote monitoring device to follow 11 patients who had undergone reimplantation due to malfunctions of the ICD lead. The rate of inappropriate shock and symptomatic pacemaker inhibition due to oversensing was compared with that in 43 patients without remote monitoring who underwent the same invasive procedure. The home monitoring device sent alert messages in 91% of all incidents. There was a significant difference between the remote monitoring group and the control group in the composite outcome of symptomatic lead failure consisting of inappropriate shocks and symptomatic pacemaker inhibition (27.3% of patients vs. 53.4% of controls, respectively, $P = 0.04$). The authors concluded that the automatic remote monitoring surveillance system enables physicians to detect serious lead problems early and to intervene quickly. In their opinion, the system might potentially avoid inappropriate shocks due to lead failure and T-wave oversensing.

In another prospective, randomized multicenter clinical trial, the "TRUST" study, Varma et al. [30] compared the safety and usefulness of automatic remote monitoring in ICD recipients with standard in-clinic follow-up. A total of 1450 patients were randomized, 977 to the remote monitoring treatment group and 473 patients to the conventional follow-up group. The mean number of in-clinic and hospital visits was 2.1 per patient-year in the remote monitoring group compared with 3.8 per patient-year in the conventional group ($P < 0.001$). Thus, the total in-office visits were reduced by 45% in the home monitoring group at 12 months. Eighty-six percent of all the remote monitoring group follow-ups were performed using remote monitoring only, indicating that this method provided sufficient assessment in these cases. There was no difference in the adverse events rate between the two treatment groups. There was no significant difference in the mortality rates between the groups after 12 months of follow-up. The authors concluded that the home remote monitoring allows a safe extension of face-to-face encounters, improves adherence to scheduled checks, and significantly reduces the need for in-hospital device evaluation (without a detrimental effect on safety), thus reducing clinic load.

We anticipate that these remote monitoring implantable devices will have many more functions that will be operable in the near future.

TELECARDIOLOGY IN THE DIAGNOSIS AND MANAGEMENT OF HYPERTENSION

Hypertension is one of the leading causes of death worldwide and affects almost one in three adults in the United States [31]. Although hypertension is among the most common reasons for an outpatient medical visit [32], several studies have shown that only 25% of the patients with hypertension have adequate blood pressure control, resulting in an elevated risk of coronary artery disease, CHF, renal insufficiency, peripheral vascular disease, and stroke [32]. Home blood pressure monitoring is a well-established practice that has been shown

ICD = implantable cardioverter defibrillator

to improve patient adherence to treatment regimens and to achieve target blood pressure levels [33].

Many studies have been conducted on the effectiveness of telemedicine in the treatment of hypertension. In a multicenter, prospective study of 111 patients whose hypertension was uncontrolled despite monotherapy, Bobrie et al. [33] assessed the effects of self-drug titration via instructions provided by telemedicine on blood pressure treatment outcome. Overall, 58% of patients were satisfied and 23% were very satisfied with the program, and 78% of the patients fully complied with self-measurement instructions. Home blood pressure measurements decreased significantly without any untoward events. In another randomized control study, Green et al. [31] enrolled 778 participants with uncontrolled essential hypertension and randomly assigned them into three groups: a) usual care, b) home blood pressure monitoring and secure patient Web training only, and c) home blood pressure monitoring and secure patient Web training plus pharmacist care management delivered through Web communications. After one year of follow-up, there was a non-significant increase in the percentage of patients with controlled blood pressure among those assigned to the home monitoring and Web training-only group. Adding Web-based pharmacist care to home blood pressure monitoring and Web training, however, significantly increased the percentage of patients with controlled blood pressure compared with the other two groups. Another interesting feature about telemedicine is its ability to provide measurements of blood pressure without provoking the 'white coat' effect [34].

TELEMEDICINE IN THE CARDIAC SUBSPECIALTIES OF ECHOCARDIOLOGY AND CORONARY CT

When ordinary echocardiology is not feasible, it is now possible to substitute it with a robotic system that enables the sonographer to perform the echocardiographic examination by remotely controlling the robotic arm and the ultrasound equipment. This can be followed by a videoconference between the general practitioner, the patient, the sonographer, and the cardiologist [35]. Recent advances in technology allow the carrying out and transferring of computed tomography images, including those of the coronary arteries. LaBounty et al. [36] recently described their success in performing coronary CT angiograms for the detection and exclusion of significant coronary artery stenosis: they were remotely interpreted on a mobile handheld device with a high rate of accuracy.

TELEMEDICINE AND REDUCTION OF HOSPITALIZATION HEALTH COSTS

One of the ongoing challenges facing the USA and other western countries is the increasing cost of health care. Part of the solution is to identify strategies for slowing the growth of health care spending without compromising access, effectiveness and safety of the medical service. A comprehensive review of the literature suggests that there is a lack of concrete evidence to assess the economic impact of telemedicine [37], but there is mounting evidence of the cost-effective and even cost-reduction effects of telemedicine. In a recent study, Wennberg and team [38] followed 174,120 patients to assess the effect of a telephone-based care management strategy on medical costs and resource utilization. The patients were randomly assigned to a usual support group (three outreaches) and an enhanced support group (five outreaches). The intervention in the enhanced support group reduced total health care costs by 3.6%, and this was accompanied by a 10% reduction in population-based admission rates. Roth et al. [39] followed 1600 subscribers to a telemedicine system and found that a considerable number of potential applications to the emergency department were safely avoided (a reduction of 31 emergency department visits for every 100 calls) because of the availability of a telemedicine service. The approximate savings to the national economy were $830,000 per 10,000 members per year. In another study, the same authors showed that the vast majority of the telemedicine subscribers (89%) reported an improvement in their self-confidence as well as in their quality of life [40]. In our opinion, the reduction of health costs made possible by the use of telemedicine, without compromising and even enhancing the quality of medical service, is highly underestimated.

CONCLUSIONS

The application of telemedicine in the field of cardiology has been shown to substantially reduce the number of hospitalizations of patients with a wide range of heart diseases and conditions, and to lower mortality after MI compared to the general acute MI population and probably in a variety of other cardiovascular entities as well. Its capabilities in the diagnosis, follow-up and treatment have extended the possibilities of providing the kind of care required by these individuals and of lowering health costs considerably.

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"It is the mark of an educated mind to be able to entertain a thought without accepting it"

Aristotle (384-322 BCE), Greek philosopher

"A bore is a man who deprives you of solitude without providing you with company"

Gian Vincenzo Gravina (1664-1718), Italian writer and philosopher