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Review

Telemedicine for cardiovascular disease continuum: A position paper from the Italian Society of Cardiology Working Group on Telecardiology and Informatics ☆

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ABSTRACT

Telemedicine is the provision of health care services, through the use of information and communication technology, in situations where the health care professional and the patient, or 2 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 a patient.
First data on implementation of telemedicine for the diagnosis and treatment of acute myocardial infarction date from more than 10 years ago. Telemedicine has a potential broad application to the cardiovascular disease continuum and in many branches of cardiology, at least including heart failure, ischemic heart disease and arrhythmias. Telemedicine might have an important role as part of a strategy for the delivery of effective health care for patients with cardiovascular disease.
In this document the Working Group on Telecardiology and Informatics of the Italian Society of Cardiology intends to remark some key-points regarding potential benefit achievable with the implementation of telemedicine support in the continuum of cardiovascular disease.

1. Introduction

Telemedicine is the provision of health care services, through the use of information and communication technology, in situations where the health care professional and the patient, or 2 health care professionals, are not in the same location [1]. According to the World Health Organization, telemedicine is defined as "the delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities" [2].

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 a patient.

Telecardiology applications can be categorized as pre-hospital, in-hospital and post-hospital. The major purpose of pre-hospital 12-lead electrocardiographic 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 [3]. In-hospital telecardiology is used between small hospitals in rural regions and main hospitals, with the aim to improve access to echocardiography diagnoses in the intensive care unit, emergency room and newborn nursery. Post-hospital applications include teleconsulting between general practitioners and specialists, home telenursing for chronic cardiac diseases and the diagnosis of arrhythmias.

First data on the implementation of telemedicine for the diagnosis and treatment of acute myocardial infarction date from more than

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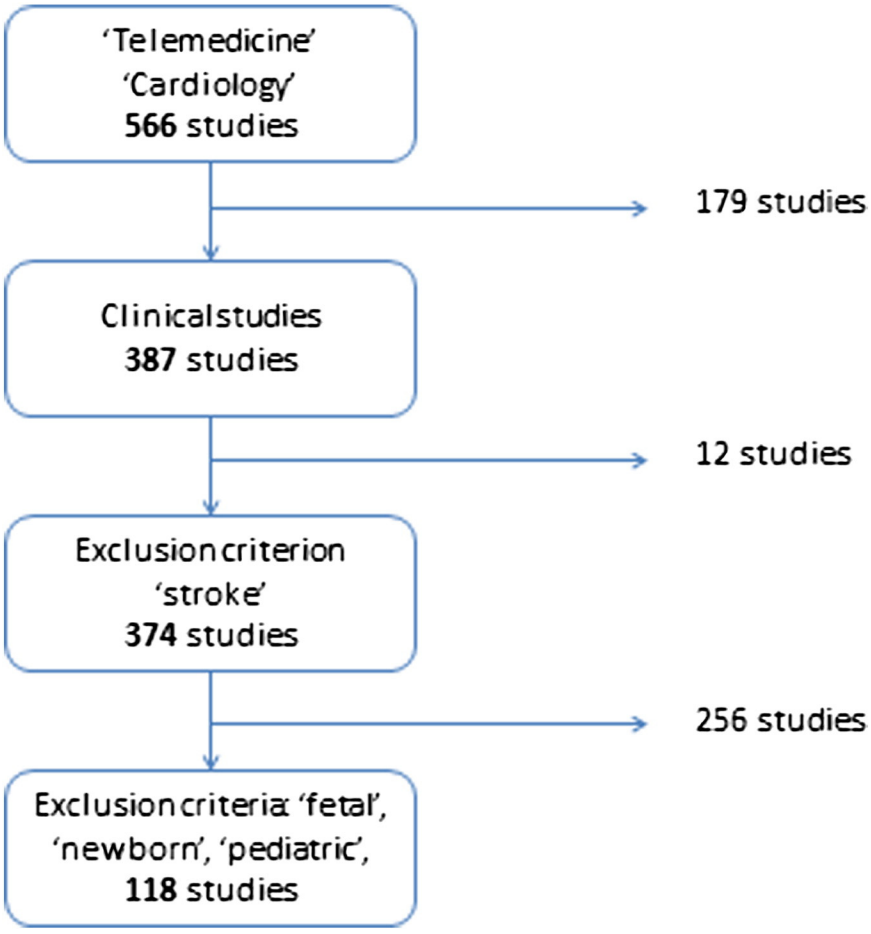

Fig. 1. Study selection.

10 years ago [4]. Studies on the transmission of electrocardiograms from a moving ambulance were reported even before [5]. Up to July 1, 2014 more than 540 references could be retrieved from a PubMed research by typing the key-words "telemedicine" and "cardiology" [6].

In this document the Working Group on Telecardiology and Informatics of the Italian Society of Cardiology intends to remark some key-points regarding potential benefit achievable with the implementation of telemedicine support in the continuum of cardiovascular disease. The present study does not aim to be a comprehensive review nor to summarize all the available literature on the topic of telemedicine support for cardiologists. Therefore, the aim of this Position Paper by the Italian Society of Cardiology Working Group on Telecardiology and Informatics is to provide recommendations for an aware use of telemedicine support in every-day practice for cardiologists, with the aim of increasing the likelihood of success in translating these new technologies into improved clinical outcomes.

2. Methods

2.1. Data sources and searches

The PubMed database was systematically searched for studies published from January 1990 through December 2014. Our PubMed search query was 'telemedicine' and 'cardiology' or 'telecardiology' or 'pre-hospital electrocardiogram', specifically focusing on title/abstract (Fig. 1).

All references from selected studies were therefore assessed for relevant articles.

2.2. Selection criteria

Studies retrieved from the preliminary database search were examined: studies focusing on pregnancy pediatric cardiology or including the term 'newborn', 'pregnancy', 'pediatric', or 'fetal' were excluded from the study. Non-clinical studies not involving humans and patients were also excluded. Studies on stroke diagnosis and treatment were excluded. Original studies were preferred over review papers.

We have restricted the citations to, in our view, the most relevant and informative publications (Table 1).

3. Telemedicine for primary and secondary prevention of cardiovascular disease

Telemedicine support was used for the early diagnosis of cardiovascular disease. Several studies addressed the feasibility of remote support by a cardiologist for general practitioners [7,8]. Telemedicine could be a useful tool in the diagnosis of chest pain in primary care. When two-hundred general practitioners were equipped with a portable electrocardiograph which could transmit a 12-lead electrocardiogram via a telephone line and a cardiologist was available 24 h a day for an interactive tele-consultation, the telecardiology service showed a sensitivity of 97.4%, a specificity of 89.5% and a diagnostic accuracy of 86.9% for the assessment of chest pain [9].

A telecardiology service may provide a useful tool in the home management of chronic atrial fibrillation and in the first detection of new cases of atrial fibrillation [10]. Telemedicine is particularly useful in

Table 1
Studies showing potential role of telemedicine support in principal fields of cardiology.

First author	Provenance	Participants	Conclusions
Primary and secondary prevention			
Bernocchi et al.	Italy	640	Telemedicine can ensure care continuity in chronic diseases
Scalvini et al.	Italy	1396	Telemedicine is effective in second-opinion consultation by general practitioners
Scalvini et al.	Italy	5073	Telemedicine could be a useful tool in the diagnosis of chest pain in primary care.
Scalvini et al.	Italy	7516	A telecardiology service may provide a useful tool in the home management of chronic atrial fibrillation and in the first detection of new cases of atrial fibrillation
Brunetti et al.	Italy	27,841	Tele-cardiology improves sensitivity of diagnosis of atrial fibrillation in elderly EMS patients
Scalvini et al.	Italy	2183	In elderly subgroup patients there was a reduction in ED referrals and in number of request for cardiological consultation
Molinari et al.	Italy	456	Telecardiology reduce unnecessary hospitalizations in patients with suspected cardiac events
Molinari et al.	Italy	106,942	Telecardiology may improve the decision making of general practitioners, avoid unnecessary hospitalizations, reduce the time before treatment in cardiac emergencies
Acute coronary syndrome			
Terkelsen et al.	Denmark	250	Prehospital diagnosing had shorter door-to-needle time
Giovas et al.	Greece		ECG transmission from a moving ambulance reduces in-hospital delays and allows faster triage
Terkelsen et al.	Denmark	161	In primary PCI, those diagnosed pre-hospitally had shorter treatment delay
Sejersten et al.	Denmark	565	Transmission of a pre-hospital 12-lead electrocardiogram directly to the attending cardiologist's mobile telephone decreased door-to-PCI time when patients were transported directly to PCI centers, bypassing local hospitals.
Sorensen et al.	Denmark	759	Pre-hospital electrocardiographic diagnosis and direct referral for primary PCI enables ST-elevation acute myocardial infarction patients living far from a PCI center and in rural areas to achieve a system delay comparable with patients living in close vicinity of a PCI center.
Brunetti et al.	Italy	27,841	Pre-hospital electrocardiographic diagnosis enables ST-elevation acute myocardial infarction diagnosis in patients living far from a PCI center and in rural areas to achieve a system delay comparable with patients living in close vicinity of a PCI center.
Brunetti et al.	Italy	297	Pre-hospital electrocardiographic diagnosis and direct referral for primary PCI enables ST-elevation acute myocardial infarction patients living far from a PCI center and in rural areas to achieve a system delay comparable with patients living in close vicinity of a PCI center
Brunetti et al.	Italy	27,841	On field electrocardiogram screening may lower the rates of false negative diagnosis in the case of STEMI with atypical presentation
Sanchez-Ross et al.	USA	142	The early triage of patients with STEMI with telemedicine shortens door to balloon times, reduces infarct size, limits ejection fraction reduction, and shortens length of stay
Chan et al.	Canada	594	Pre-hospital triage was associated with improved survival rate in patients undergoing primary PCI in STEMI
Da Waure et al.	Italy	863	Telemedicine may reduce in-hospital mortality from acute myocardial infarction (meta-analysis)
Rehabilitation and chronic heart failure			
Scalvini et al.	Italy	47	Telemedicine based rehabilitation after cardiac surgery increases the 6-min walking test distance
Chiantera et al.	Italy	200	Telecardiology after acute coronary syndrome slightly reduced hospital readmissions
Roth et al.	Israel	4598	Telemedicine subscribers had significantly higher survival rates
Giordano et al.	Italy	358	In patients with chronic HF home-based tele-management was associated with a favorable effects on hospital readmission for cardiovascular reasons and on quality of life
Giordano et al.	Italy	602	In chronic HF patients, tele-management and home-based tele-surveillance programs, a significant improvement in New York Heart Association class, left ventricular ejection fraction, 6-min walking distance, and Minnesota Living with Heart Failure Questionnaire was observed.
Sohn et al.	Germany	1124	In chronic HF telemedicine support reduced hospital stays, optimized medical therapy, improved quality of life, and reduced mortality.
Pekmezaris et al.	USA	488	Remote patient monitoring was not significantly different from live nursing visits in the management of HF in home care
Dendale et al.	Belgium	116	In HF patients, telemonitoring-facilitated collaboration between general practitioners and a HF clinic reduces mortality and number of days lost to hospitalization, death, or dialysis
Chiang et al.	Taiwan	63	Tele-health care could reduce family caregiver burden, improve stress mastery, and improve family function in HF after discharged
Kurtz et al.	France	138	Automated home telephone self-monitoring reduces hospitalization in patients with advanced HF
Giordano et al.	Italy	460	Home-based tele-management was associated with a decrease in hospital readmissions and hemodynamic instability
Inglis et al.	Australia	8323	Tele-monitoring and structured telephone support reduced chronic HF-related mortality and hospitalizations (meta-analysis)
Koehler et al.	Germany	710	In stable chronic HF patients remote telemedicine monitoring had no significant effect on all-cause mortality or on cardiovascular death or HF hospitalization
Chaudhry et al.	USA	1653	In patients who had recently been hospitalized for HF tele-monitoring did not improve outcomes
Klersy et al.	Italy	5715	Remote patient monitoring was associated with lower number of hospitalizations for HF and for any cause (meta-analysis)
Takeda et al.	UK	5942	Case management type interventions led by a HF specialist nurse reduces HF related readmissions, all cause readmissions and all-cause mortality (meta-analysis)
Arrhythmias and cardiac implantable electronic devices			
Landolina et al.	Italy	200	Remote monitoring reduces emergency department/urgent in-office visits
Guédon-Moreau et al.	France	433	Home monitoring lowered the number of appropriate and inappropriate shocks delivered
Nielsen et al.	Germany	260	Home monitoring is associated with an early detection of medical and technical events
De Ruvo et al.	Italy	99	Office visits without a daily remote monitoring system had higher risk of delayed detection of adverse events
Cost-analysis			
Sohn et al.	Germany	1124	Reduction of costs in patients with chronic HF and telemedicine support
Giordano et al.	Italy	460	Home-based tele-management was associated with mean cost for hospital readmission significantly lower
Inglis et al.	Australia	8323	Tele-monitoring and structured telephone support reduced chronic HF-related costs
Brunetti et al.	Italy	109,750	A cost per quality-adjusted life year gained of €1927 was calculated for pre-hospital electrocardiogram diagnosis of STEMI
Roth	Israel	1608	An 83$ individual cost saving per year was figured in an emergency setting using telemedicine support
Ricci et al.	Italy	209	Costs for care-giver reduced by remote monitoring
Scalvini et al.	Italy	426	Home-based telecardiology on management of chronic HF lowered costs by 24%
Thokala et al.	UK	182	Structured telephone support via human to machine was the most cost-effective strategy and yielded an estimated incremental cost-effectiveness ratio

the case of asymptomatic atrial fibrillation [11]. Elderly frail patients may specially benefit from telemedicine support [12].

Telecardiology may reduce unnecessary hospital admissions of patients with suspected life-threatening cardiac events, evaluated by general practitioners. Over one month, 456 consecutive patients complaining of typical or atypical chest pain, palpitations, dyspnea or syncope were enrolled, assessed by electrocardiogram and teleconsultation: in total there was agreement between the general practitioners and cardiologist about the presence of a cardiac event in 69% of the patients [13]. For 63% of patients judged as having a cardiac event by the general practitioner, telecardiology avoided hospitalization; on the other hand, telecardiology identified a cardiac event in 17% of patients judged as not having a cardiac event by the general practitioner.

In another study, over nine years, about 7000 peripheral medical users (mainly general practitioners), who were experienced in using transtelephonic electrocardiography and who were spread throughout Italy, conducted tele-consultations with a telecardiology center (total 106,942 patients evaluated) [14]. After tele-consultation, 58% were reported to have no heart disease, 26% had their drug dose adjusted and remained at home, 11% were sent to their cardiologist for further investigations and 5% were urgently hospitalized. Among the hospitalized patients, an ST-elevation coronary syndrome was found in 32%, a non-ST-elevation coronary syndrome in 40% and a life-threatening arrhythmia in 24%. Telecardiology may improve the decision making of general practitioners, avoid unnecessary hospitalizations, reduce the time before treatment in cardiac emergencies, rationalize health-care costs and promote home care.

Key-points

- Telemedicine support could be extremely useful for the management of suspected or overt cardiovascular disease by the general practitioner (IIB).
- Frail elderly subjects particularly benefit from telemedicine support (IIB).

4. Telemedicine for acute coronary syndrome

Early diagnosis of acute coronary syndrome and pre-hospital management of acute myocardial infarction is one of the fields with the larger body of evidence supporting the use of telemedicine. There is a more than 10-year experience with the use of telemedicine and pre-hospital electrocardiogram sent by the ambulance and used for the alert of cath-lab for primary PCI [15,16]. The agreement between tele- and standard-electrocardiogram concerning alterations of the ST segment is usually very good (kappa = 0.99) [17].

Patients with acute myocardial infarction, diagnosed pre-hospitally had shorter treatment delay compared with those diagnosed in the hospital, both in the setting of initial admission to a local hospital, and to an even larger extent in the setting of referral directly to the interventional center [18]. Transmission of a pre-hospital 12-lead electrocardiogram directly to the attending cardiologist's mobile telephone decreased door-to-PCI time by >1 h when patients were transported directly to PCI centers, bypassing local hospitals [19]. Pre-hospital electrocardiographic diagnosis and direct referral for primary PCI enables ST-elevation acute myocardial infarction patients living far from a PCI center and in rural areas to achieve a system delay comparable with patients living in close vicinity of a PCI center [20–22]. Immediate on field electrocardiogram screening may lower the rates of false negative diagnosis in the case of ST-elevation acute myocardial infarction with atypical presentation [23].

The early evaluation and triage of patients with ST-elevation acute myocardial infarction with telemedicine technologies shortens door to balloon times, reduces infarct size, limits ejection fraction reduction, and shortens length of stay [24]. A dramatic 60% reduction in early and late mortality was observed in large registries on acute myocardial infarction with the use of pre-hospital electrocardiogram supported by telemedicine [25]; pre-hospital triage was an independent predictor for survival at 1 year (hazard ratio: 0.37, 95% confidence interval: 0.18–0.75). Even data from meta-analysis studies show that the relative risk for in-hospital mortality from acute myocardial infarction was 0.65 (95% confidence interval, 0.42–0.99) for the telemedicine group when compared to standard treatment [26].

Current European Society of Cardiology guidelines warmly recommend the use of pre-hospital electrocardiogram for the earliest diagnosis of ST-elevation acute myocardial infarction [27]. Networks should be established with regionalization of primary PCI treatment to address the challenges regarding pre-hospital diagnosis and treatment, triage and transport of ST-elevation acute myocardial infarction patients and collaborations between hospitals and Emergency Medical Services.

The use of pre-hospital electrocardiogram, telemedicine support and networks for the treatment of acute myocardial infarction has been already implemented in several regions so far, in Italy [28,29] and worldwide [30,31].

Pre-hospital electrocardiogram should be interpreted by a cardiologist, given the poor accuracy of trained personnel emergency medical service personnel and automated algorithms. In a study based on 380 transmitted and 323 non-transmitted cases, the sensitivity and specificity of emergency medical service personnel detecting ST-elevation acute myocardial infarction were 99.6% and 67.6%, respectively; the positive and negative predictive values for ST-elevation acute myocardial infarction were 59.5% and 99.7%, respectively [32]. The accuracy of automated software is even poorer with a false diagnosis rate slightly below 30% [33,34]. Current guidelines therefore always recommend a physician confirmation of electrocardiogram interpretation [35].

Key-points

- The use of pre-hospital electrocardiogram for the diagnosis of ST-elevation acute myocardial infarction is warmly recommended, since it can shorten the delay to reperfusion (IA) and lower mortality (IB).
- Pre-hospital electrocardiogram should be preferably interpreted by a cardiologist, given a large number of incorrect diagnoses with automated algorithm (IIB).

5. Telemedicine for rehabilitation and chronic heart failure

The use of telemedicine support may be useful in rehabilitation after a cardiac event (acute myocardial infarction, PTCA, post-cardiac surgery and chronic heart failure (HF)). Telemedicine based rehabilitation after cardiac surgery is feasible and safe [36]. When two models of assistance (telecardiology versus usual care) for patients discharged after acute coronary syndrome were compared in the assessment of angina, telecardiology slightly reduced hospital readmissions (44% versus 56%) [37]. In a large population who survived hospitalization after sustaining an acute myocardial infarction, subjects followed by telemedicine support had significantly higher survival rates at 1 year [38]. The direct 12-week comparison of a conventional and a telemedicine approach showed the suitability of telemedicine for delivering cardiac rehabilitation for risk factor modification and exercise monitoring to patients who otherwise would not have access to it [39].

The largest experience is available on subjects with chronic HF. During an eight-year period, in 358 patients with chronic HF, a six-month home-based tele-management program was associated with favorable

effects on hospital readmission for cardiovascular reasons and on quality of life [40]. In 602 chronic HF patients, tele-management and home-based tele-surveillance programs, a significant improvement in New York Heart Association class, left ventricular ejection fraction, 6-min walking distance, and Minnesota Living with Heart Failure Questionnaire was observed [41].

In the retrospective, matched-pairs study "Telemedicine for the Heart", besides a reduction of costs, patients with chronic HF and telemedicine support experienced a reduced number of hospital stays, optimized medical therapy, better quality of life, and reduced mortality [42]. Remote patient monitoring, when utilized in conjunction with a robust management protocol, was not found to significantly differ from live nursing visits in the management of HF in home care [43]. Shorter hospitalization times and lower associated costs may be due to earlier identification of exacerbation. In 116 chronic HF patients, telemonitoring-facilitated collaboration between general practitioners and a HF clinic reduces mortality and number of days lost to hospitalization, death, or dialysis in chronic HF patients [44]. Tele-health care combined with discharge planning could reduce family caregiver burden, improve stress mastery, and improve family function during the first 30 days at home after HF patients are discharged from the hospital [45]. Automated home telephone self-monitoring reduces hospitalization in patients with advanced HF [46].

Even in multicenter randomized trials home-based tele-management with patients receiving a portable device, transferring, by telephone, a one-lead trace to a receiving station where a nurse was available for interactive tele-consultation, the intervention was associated with a 36% decrease in the total number of hospital readmissions and a 31% decrease in the total number of episodes of hemodynamic instability; the rate of HF-related readmission was 19% vs 32% and the mean cost for hospital readmission was significantly lower [47].

In a large meta-analysis tele-monitoring and structured telephone support reduced chronic HF-related hospitalizations [48]. Both interventions improved quality of life, reduced costs, and were acceptable to patients. Improvements in prescribing, patient-knowledge and self-care, and functional class were observed.

Controversies still persist since other studies did not confirm such encouraging findings. In 710 stable chronic HF patients in New York Heart Association functional class II or III with a left ventricular ejection fraction ≤35% and a history of HF decompensation within the previous 2 years or with a left ventricular ejection fraction ≤25%, remote telemedicine monitoring had no significant effect on all-cause mortality or on cardiovascular death or HF hospitalization compared with usual care [49]. Among 1653 patients who had recently been hospitalized for HF to undergo either tele-monitoring or usual care, tele-monitoring did not improve outcomes [50].

However, in a meta-analysis of 21 randomized control trials (5715 patients), remote patient monitoring was associated with a significantly lower number of hospitalizations for HF [relative risk 0.77, 95% CI 0.65–0.91] and for any cause (relative risk 0.87, 95% CI: 0.79–0.96) [51]. In a budget impact analysis, the adoption of a telemedicine based strategy entailed a progressive and linear increase in costs saved. In another a meta-analysis including 6.000 patients from 25 trials, case management type interventions led by a HF specialist nurse reduces HF related readmissions after 12 months of follow-up, all cause readmissions and all cause mortality [52].

Key-points

- The use of telemedicine may be useful for the large implementation of rehabilitation programs (IB).
- Remote telemedicine monitoring of patients with chronic heart failure is recommended for the reduction of re-hospitalization (IIB).

6. Telemedicine for arrhythmias and cardiac implantable electronic devices

This paper is not specifically aimed at the evaluation of remote control for implantable cardioverter–defibrillators. Notwithstanding, some aspects of interest intertwining telemedicine and cardio-stimulation must be considered.

The field of telemedicine provides the opportunity for highly individualized medical management in a way that has never been possible before. Evolving medical technologies using cardiac implantable devices with capabilities for remote monitoring permit evaluation of multiple parameters of cardiovascular physiology and risk, including cardiac rhythm, device function, blood pressure values, the presence of myocardial ischemia, and the degree of compensation of congestive HF [53,54]. Cardiac risk, device status, and response to therapies can now be assessed with these electronic systems of detection and reporting.

Remote monitoring reduces emergency department/urgent in-office visits and, in general, total healthcare use in patients with implantable cardioverter–defibrillators or defibrillators for resynchronization therapy [55]. 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. Long-term home-monitoring of implantable cardioverter–defibrillators is at least as safe as standard ambulatory follow-ups with respect to a broad spectrum of major adverse events [56]. It also lowered significantly the number of appropriate and inappropriate shocks delivered, and spared the device battery. Home monitoring is feasible and associated with an early detection of medical and technical events [57].

Remote monitoring was assessed also in subjects with cardiac-resynchronization therapy device (CRT-D). CRT-D patients followed with quarterly in-office visits without a daily remote monitoring system had an 86% higher risk of delayed detection of clinical adverse events, during a median follow-up of 7 months [58]. In a large dataset of patients implanted with ICDs and CRTDs, however, younger age and small clinical size were important predictors of noncompliance to remote monitoring [59]: there is room for improvement in remote monitoring usage.

Key-points

- Home monitoring of cardiac implantable electronic devices is feasible and associated with an early detection of medical and technical events (IA).

7. Telemedicine: considerations on cost-efficacy

The cost-effectiveness of telemedicine is still a matter of debate. Nevertheless, recent evidence shows some potential cost reduction associated with the implementation of telemedicine support. A cost per quality-adjusted life year gain of €1927 was calculated in a regional registry for pre-hospital electrocardiogram diagnosis of ST-elevation acute myocardial infarction [60]. Similarly, an 83$ individual cost saving per year was figured in another emergency setting using telemedicine support [61].

Data from patients enrolled in the TARIFF registry confirm that there are social and economic impacts to patients attending routine device checks in hospital which can be significantly reduced by using a remote monitoring strategy [62]. The effect of home-based telecardiology on management of chronic HF was lower costs by 24% [63]. In a decision analysis modeling to examine the cost-effectiveness of different remote monitoring technologies by Thokala et al., structured telephone support via human to machine was the most cost-effective strategy and yielded

an estimated incremental cost-effectiveness ratio compared to usual care [64]. The issue however still needs further investigations.

Key-points

- The use of telemedicine may favor cost reduction (IIB).

8. Conclusions

Telemedicine has a potential broad application to the cardiovascular disease continuum and in many branches of cardiology, at least including HF, ischemic heart disease and arrhythmias [65]. Telemedicine might have an important role as part of a strategy for the delivery of effective health care for patients with cardiovascular disease. Adequately powered multicentre, randomized controlled trials are required to further evaluate the potential benefits and cost-effectiveness of such strategy.

Key-points

- The use of telemedicine is useful in delivery of effective health care for patients with cardiovascular disease.

Conflict of interest

The authors report no relationships that could be construed as a conflict of interest.

References

[1] K. Nikus, J. Lähteenmäki, P. Lehto, M. Eskola, The role of continuous monitoring in a 24/7 telecardiology consultation service—a feasibility study, J. Electrocardiol. 42 (2009) 473–480.

[2] WHO, A health telematics policy in support of WHO's Health-For-All strategy for global health development, Report of the WHO Group Consultation on Health Telematics, 11–16 December, Geneva, 1997, World Health Organization, Geneva, 1998.

[3] S. Scalvini, F. Glisenti, Centenary of tele-electrocardiography and telephonocardiography — where are we today? J. Telemed. Telecare 11 (2005) 325–330.

[4] C.J. Terkelsen, B.L. Nørgaard, J.F. Lassen, J.C. Gerdes, J.P. Ankersen, F. Rømer, T.T. Nielsen, H.R. Andersen, Telemedicine used for remote prehospital diagnosing in patients suspected of acute myocardial infarction, J. Intern. Med. 252 (2002) 412–420.

[5] P. Giovas, D. Papadoyannis, D. Thomakos, G. Papazachos, M. Rallidis, D. Soulis, C. Stamatopoulos, S. Mavrogeni, N. Katsilambros, Transmission of electrocardiograms from a moving ambulance, J. Telemed. Telecare 4 (Suppl. 1) (1998) 5–7.

[6] http://www.ncbi.nlm.nih.gov/pubmed/?term=telemedicine+cardiology2014 (July 1st).

[7] P. Bernocchi, S. Scalvini, C. Tridico, G. Borghi, P. Zanaboni, C. Masella, F. Glisenti, M. Marzegalli, Healthcare continuity from hospital to territory in Lombardy: TELEMACO project, Am. J. Manage Care 18 (2012) e101–e108.

[8] S. Scalvini, C. Tridico, F. Glisenti, A. Giordano, S. Pirini, P. Peduzzi, F. Auxilia, The summa project: a feasibility study on telemedicine in selected Italian areas, Telemed. E Health 15 (2009) 261–269.

[9] S. Scalvini, E. Zanelli, C. Conti, M. Volterrani, R. Pollina, A. Giordano, F. Glisenti, Boario home-care investigators. Assessment of prehospital chest pain using telecardiology, J. Telemed. Telecare 8 (2002) 231–236.

[10] S. Scalvini, M. Piepoli, E. Zanelli, M. Volterrani, A. Giordano, F. Glisenti, Incidence of atrial fibrillation in an Italian population followed by their GPs through a telecardiology service, Int. J. Cardiol. 98 (2005) 215–220.

[11] N.D. Brunetti, L. De Gennaro, P.L. Pellegrino, G. Dellegrottaglie, G. Antonelli, M. Di Biase, Atrial fibrillation with symptoms other than palpitations: incremental diagnostic sensitivity with at-home telecardiology assessment for emergency medical service, Eur. J. Cardiovasc. Prev. Rehabil. 19 (2012) 306–313.

[12] S. Scalvini, E. Zanelli, Telecardiology: a new support for general practitioners in the management of elderly patients, Age Ageing 31 (2002) 153.

[13] G. Molinari, G. Reboa, M. Frascio, M. Leoncini, A. Rolandi, C. Balzan, A. Barsotti, The role of telecardiology in supporting the decision-making process of general practitioners during the management of patients with suspected cardiac events, J. Telemed. Telecare 8 (2002) 97–101.

[14] G. Molinari, A. Valbusa, M. Terrizzano, M. Bazzano, L. Torelli, N. Girardi, A. Barsotti, Nine years' experience of telecardiology in primary care, J. Telemed. Telecare 10 (2004) 249–253.

[15] C.J. Terkelsen, B.L. Nørgaard, J.F. Lassen, J.C. Gerdes, J.P. Ankersen, F. Rømer, T.T. Nielsen, H.R. Andersen, Telemedicine used for remote prehospital diagnosing in patients suspected of acute myocardial infarction, J. Intern. Med. 252 (2002) 412–420.

[16] P. Giovas, D. Papadoyannis, D. Thomakos, G. Papazachos, M. Rallidis, D. Soulis, C. Stamatopoulos, S. Mavrogeni, N. Katsilambros, Transmission of electrocardiograms from a moving ambulance, J. Telemed. Telecare 4 (Suppl. 1) (1998) 5–7.

[17] B. Schwaab, A. Katalinic, J. Riedel, A. Sheikhzadeh, Pre-hospital diagnosis of myocardial ischaemia by telecardiology: safety and efficacy of a 12-lead electrocardiogram, recorded and transmitted by the patient, J. Telemed. Telecare 11 (2005) 41–44.

[18] C.J. Terkelsen, J.F. Lassen, B.L. Nørgaard, J.C. Gerdes, S.H. Poulsen, K. Bendix, J.P. Ankersen, L.B. Gøtzsche, F.K. Rømer, T.T. Nielsen, H.R. Andersen, Reduction of treatment delay in patients with ST-elevation myocardial infarction: impact of prehospital diagnosis and direct referral to primary percutaneous coronary intervention, Eur. Heart J. 26 (2005) 770–777.

[19] M. Sejersten, M. Sillesen, P.R. Hansen, S.L. Nielsen, H. Nielsen, S. Trautner, D. Hampton, G.S. Wagner, P. Clemmensen, Effect on treatment delay of prehospital teletransmission of 12-lead electrocardiogram to a cardiologist for immediate triage and direct referral of patients with ST-segment elevation acute myocardial infarction to primary percutaneous coronary intervention, Am. J. Cardiol. 101 (2008) 941–946.

[20] J.T. Sørensen, C.J. Terkelsen, B.L. Nørgaard, S. Trautner, T.M. Hansen, H.E. Bøtker, J.F. Lassen, H.R. Andersen, Urban and rural implementation of pre-hospital diagnosis and direct referral for primary percutaneous coronary intervention in patients with acute ST-elevation myocardial infarction, Eur. Heart J. 32 (2011) 430–436.

[21] N.D. Brunetti, G. Amodio, L. De Gennaro, G. Dellegrottaglie, P.L. Pellegrino, M. Di Biase, G. Antonelli, Telecardiology applied to a region-wide public emergency health-care service, J. Thromb. Thrombolysis 28 (2009) 23–30.

[22] N.D. Brunetti, G. Di Pietro, A. Aquilino, A.I. Bruno, G. Dellegrottaglie, G. Di Giuseppe, C. Lopriore, L. De Gennaro, S. Lanzone, P. Caldarola, G. Antonelli, M. Di Biase, Prehospital electrocardiogram triage with telecardiology support is associated with shorter time to balloon and higher rates of timely reperfusion even in rural areas: data from the Bari-BAT public Emergency Medical Service 118 registry on primary angioplasty in STEMI, Eur. Heart J. Acute Cardiovasc. Care 3 (2014) 204–213.

[23] N.D. Brunetti, L. De Gennaro, G. Amodio, G. Dellegrottaglie, P.L. Pellegrino, M. Di Biase, G. Antonelli, Telecardiology improves quality of diagnosis and reduces delay to treatment in elderly patients with acute myocardial infarction and atypical presentation, Eur. J. Cardiovasc. Prev. Rehabil. 17 (2010) 615–620.

[24] M. Sanchez-Ross, G. Oghlakian, J. Maher, B. Patel, V. Mazza, D. Hom, V. Dhruva, D. Langley, J. Palmaro, S. Ahmed, E. Kaluski, M. Klapholz, The STAT-MI (ST-Segment Analysis Using Wireless Technology in Acute Myocardial Infarction) trial improves outcomes, JACC Cardiovasc. Interv. 4 (2011) 222–227.

[25] A.W. Chan, J. Kornder, H. Elliott, R.I. Brown, J.F. Dorval, J. Charania, R. Zhang, L. Ding, A. Lalani, R.A. Kuritzky, G.J. Simkus, Improved survival associated with pre-hospital triage strategy in a large regional ST-segment elevation myocardial infarction program, JACC Cardiovasc Interv. 5 (2012) 1239–1246.

[26] C. de Waure, C. Cadeddu, M.R. Gualano, W. Ricciardi, Telemedicine for the reduction of myocardial infarction mortality: a systematic review and a meta-analysis of published studies, Telemed. J E Health 18 (2012) 323–328.

[27] Task Force on the management of ST-segment elevation acute myocardial infarction of the European Society of Cardiology (ESC), P.G. Steg, S.K. James, D. Atar, L.P. Badano, C. Blömstrom-Lundqvist, M.A. Borger, C. Di Mario, K. Dickstein, G. Ducrocq, F. Fernandez-Aviles, A.H. Gershlick, P. Giannuzzi, S. Halvorsen, K. Huber, P. Juni, A. Kastrati, J. Knuuti, M.J. Lenzen, K.W. Mahaffey, M. Valgimigli, A. van 't Hof, P. Widimsky, D. Zahger, ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation, Eur. Heart J. 33 (2012) 2569–2619.

[28] N.D. Brunetti, L. De Gennaro, G. Dellegrottaglie, D. Amoruso, G. Antonelli, M. Di Biase, A regional prehospital electrocardiogram network with a single telecardiology "hub" for public emergency medical service: technical requirements, logistics, manpower, and preliminary results, Telemed J E Health. 17 (2011) 727–733.

[29] A. Martinoni, S. De Servi, E. Boschetti, R. Zanini, T. Palmerini, A. Politi, G. Musumeci, G. Belli, M. De Paolis, F. Ettori, E. Piccaluga, D. Sangiorgi, A. Repetto, M. D'Urbano, B. Castiglioni, F. Fabbiocchi, M. Onofri, N. De Cesare, G. Sangiorgi, C. Lettieri, F. Poletti, S. Pirelli, S. Klugmann, Lombardima Study Group, Importance and limits of prehospital electrocardiogram in patients with ST elevation myocardial infarction undergoing percutaneous coronary angioplasty, Eur. J. Cardiovasc. Prev. Rehabil. 18 (2011) 526–532.

[30] K. Kalla, G. Christ, R. Karnik, R. Malzer, G. Norman, H. Prachar, W. Schreiber, G. Unger, H.D. Glogar, A. Kaff, A.N. Laggner, G. Maurer, J. Mlczoch, J. Slany, H.S. Weber, K. Huber, S.T.E.M.I. Vienna, Registry Group. Implementation of guidelines improves standard of care: the Viennese registry on reperfusion strategies in ST-elevation myocardial infarction (VIENNA-STEMI Registry), Circulation 113 (2006) 2398–2405.

[31] J.G. Jollis, M.L. Roettig, A.O. Aluko, K.J. Anstrom, R.J. Applegate, J.D. Babb, P.B. Berger, D.J. Bohle, S.M. Fletcher, J.L. Garvey, W.R. Hathaway, J.W. Hoekstra, R.V. Kelly, W.T. Maddox Jr., J.R. Shiber, F.S. Valeri, B.A. Watling, B.H. Wilson, C.B. Granger, Reperfusion of Acute Myocardial Infarction in North Carolina Emergency Departments (RACE) Investigators. Implementation of a statewide system for coronary reperfusion for ST-segment elevation myocardial infarction, JAMA 298 (2007) 2371–2380.

[32] R.A. Ducas, A.W. Wassef, D.S. Jassal, E. Weldon, C. Schmidt, R. Grierson, J.W. Tam, To transmit or not to transmit: how good are emergency medical personnel in detecting STEMI in patients with chest pain? Can. J. Cardiol. 28 (2012) 432–437.

[33] E. Clark, M. Sejersten, P. Clemmensen, P.W. Macfarlane, Effectiveness of electrocardiogram interpretation programs in the ambulance setting, Comput. Cardiol. 36 (2009) 117–120.
[34] E.N. Clark, M. Sejersten, P. Clemmensen, P.W. Macfarlane, Automated electrocardiogram interpretation programs versus cardiologists' triage decision making based on teletransmitted data in patients with suspected acute coronary syndrome, Am. J. Cardiol. 106 (2010) 1696–1702.
[35] P. Kligfield, L.S. Gettes, J.J. Bailey, R. Childers, B.J. Deal, E.W. Hancock, G. van Herpen, J.A. Kors, P. Macfarlane, D.M. Mirvis, O. Pahlm, P. Rautaharju, G.S. Wagner, M. Josephson, J.W. Mason, P. Okin, B. Surawicz, H. Wellens, American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; American College of Cardiology Foundation; Heart Rhythm Society. Recommendations for the standardization and interpretation of the electrocardiogram: part I: the electrocardiogram and its technology a scientific statement from the American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; the American College of Cardiology Foundation; and the Heart Rhythm Society endorsed by the International Society for Computerized Electrocardiology, J. Am. Coll. Cardiol. 49 (2007) 1109–1127.
[36] S. Scalvini, E. Zanelli, L. Comini, M.D. Tomba, G. Troise, A. Giordano, Home-based exercise rehabilitation with telemedicine following cardiac surgery, J. Telemed. Telecare 15 (2009) 297–301.
[37] A. Chiantera, S. Scalvini, G. Pulignano, M. Pugliese, L. De Lio, A. Mazza, M.S. Fera, L. Bussolotti, S. Bartolini, L. Guerrieri, A. Caroselli, E. Giovannini, Role of telecardiology in the assessment of angina in patients with recent acute coronary syndrome, J. Telemed. Telecare 11 (Suppl. 1) (2005) 93–94.
[38] A. Roth, N. Malov, D.M. Steinberg, Y. Yanay, M. Elizur, M. Tamari, M. Golovner, Telemedicine for post-myocardial infarction patients: an observational study, Telemed J E Health. 15 (2009) 24–30.
[39] L.C. Dalleck, L.K. Schmidt, R. Lueker, Cardiac rehabilitation outcomes in a conventional versus telemedicine-based programme, J. Telemed. Telecare 17 (2011) 217–221.
[40] A. Giordano, E. Zanelli, S. Scalvini, Home-based telemanagement in chronic heart failure: an 8-year single-site experience, J. Telemed. Telecare 17 (2011) 382–386.
[41] A. Giordano, S. Scalvini, A.M. Paganoni, S. Baraldo, M. Frigerio, C. Vittori, G. Borghi, M. Marzegalli, O. Agostoni, Home-based telesurveillance program in chronic heart failure: effects on clinical status and implications for 1-year prognosis, Telemed J E Health. 19 (2013) 605–612.
[42] S. Sohn, T.M. Helms, J.T. Pelleter, A. Müller, A.I. Kröttinger, O. Schöffski, Costs and benefits of personalized healthcare for patients with chronic heart failure in the care and education program "Telemedicine for the Heart", Telemed J E Health. 18 (2012) 198–204.
[43] R. Pekmezaris, I. Mitzner, K.R. Pecinka, C.N. Nouryan, M.L. Lesser, M. Siegel, J.W. Swiderski, G. Moise, R. Younker Sr., K. Smolich, The impact of remote patient monitoring (telehealth) upon Medicare beneficiaries with heart failure, Telemed J E Health. 18 (2012) 101–108.
[44] P. Dendale, G. De Keulenaer, P. Troisfontaines, C. Weytjens, W. Mullens, I. Elegeert, B. Ector, M. Houbrechts, K. Willekens, D. Hansen, Effect of a telemonitoring-facilitated collaboration between general practitioner and heart failure clinic on mortality and rehospitalization rates in severe heart failure: the TEMA-HF 1 (TElemonitoring in the MAnagement of Heart Failure) study, Eur. J. Heart Fail. 14 (2012) 333–340.
[45] L.C. Chiang, W.C. Chen, Y.T. Dai, Y.L. Ho, The effectiveness of telehealth care on caregiver burden, mastery of stress, and family function among family caregivers of heart failure patients: a quasi-experimental study, Int. J. Nurs. Stud. 49 (2012) 1230–1242.
[46] B. Kurtz, M. Lemercier, S.C. Pouchin, E. Benmokhtar, C. Vallet, A. Cribier, F. Bauer, Automated home telephone self-monitoring reduces hospitalization in patients with advanced heart failure, J. Telemed. Telecare 17 (2011) 298–302.
[47] A. Giordano, S. Scalvini, E. Zanelli, U. Corrà, G.L. Longobardi, V.A. Ricci, P. Baiardi, F. Glisenti, Multicenter randomised trial on home-based telemanagement to prevent hospital readmission of patients with chronic heart failure, Int. J. Cardiol. 131 (2009) 192–199.
[48] S.C. Inglis, R.A. Clark, F.A. McAlister, S. Stewart, J.G. Cleland, Which components of heart failure programmes are effective? A systematic review and meta-analysis of the outcomes of structured telephone support or telemonitoring as the primary component of chronic heart failure management in 8323 patients: Abridged Cochrane Review, Eur. J. Heart Fail. 13 (2011) 1028–1040.
[49] F. Koehler, S. Winkler, M. Schieber, U. Sechtem, K. Stangl, M. Böhm, H. Boll, G. Baumann, M. Honold, K. Koehler, G. Gelbrich, B.A. Kirwan, S.D. Anker, Telemedical Interventional Monitoring in Heart Failure Investigators. Impact of remote telemedical management on mortality and hospitalizations in ambulatory patients with chronic heart failure: the telemedical interventional monitoring in heart failure study, Circulation 123 (2011) 1873–1880.
[50] S.I. Chaudhry, J.A. Mattera, J.P. Curtis, J.A. Spertus, J. Herrin, Z. Lin, C.O. Phillips, B.V. Hodshon, L.S. Cooper, H.M. Krumholz, Telemonitoring in patients with heart failure, N. Engl. J. Med. 363 (2010) 2301–2309.
[51] C. Klersy, A. De Silvestri, G. Gabutti, A. Raisaro, M. Curti, F. Regoli, A. Auricchio, Economic impact of remote patient monitoring: an integrated economic model derived from a meta-analysis of randomized controlled trials in heart failure, Eur. J. Heart Fail. 13 (2011) 450–459.
[52] A. Takeda, S.J. Taylor, R.S. Taylor, F. Khan, H. Krum, M. Underwood, Clinical service organisation for heart failure, Cochrane Database Syst. Rev. 9 (2012) CD002752 (Sep 12).
[53] S. Dubner, A. Auricchio, J.S. Steinberg, P. Vardas, P. Stone, J. Brugada, R. Piotrowicz, D.L. Hayes, P. Kirchhof, G. Breithardt, W. Zareba, C. Schuger, M.K. Aktas, M. Chudzik, S. Mittal, N. Varma, ISHNE/EHRA expert consensus on remote monitoring of cardiovascular implantable electronic devices (CIEDs), Europace 14 (2012) 278–293.
[54] A. Hernández-Madrid, T. Lewalter, A. Proclemer, L. Pison, G.Y. Lip, C. Blomstrom-Lundqvist, Scientific Initiatives Committee, European Heart Rhythm Association. Remote monitoring of cardiac implantable electronic devices in Europe: results of the European Heart Rhythm Association survey, Europace 16 (2014) 129–132.
[55] M. Landolina, G.B. Perego, M. Lunati, A. Curnis, G. Guenzati, A. Vicentini, G. Parati, G. Borghi, P. Zanaboni, S. Valsecchi, M. Marzegalli, Remote monitoring reduces healthcare use and improves quality of care in heart failure patients with implantable defibrillators: the evolution of management strategies of heart failure patients with implantable defibrillators (EVOLVO) study, Circulation 125 (2012) 2985–2992.
[56] L. Guédon-Moreau, D. Lacroix, N. Sadoul, J. Clémenty, C. Kouakam, J.S. Hermida, E. Aliot, M. Boursier, O. Bizeau, S. Kacet, ECOST trial investigators. A randomized study of remote follow-up of implantable cardioverter defibrillators: safety and efficacy report of the ECOST trial, Eur. Heart J. 34 (2013) 605–614.
[57] J.C. Nielsen, H. Kottkamp, M. Zabel, E. Aliot, U. Kreutzer, A. Bauer, A. Schuchert, H. Neuser, B. Schumacher, H. Schmidinger, G. Stix, J. Clémenty, D. Danilovic, G. Hindricks, Automatic home monitoring of implantable cardioverter defibrillators, Europace 10 (2008) 729–735.
[58] E. De Ruvo, A. Gargaro, L. Sciarra, L. De Luca, L.M. Zuccaro, F. Stirpe, M. Rebecchi, A. Sette, E. Lioy, L. Calò, Early detection of adverse events with daily remote monitoring versus quarterly standard follow-up program in patients with CRT-D, Pacing Clin. Electrophysiol. 34 (2011) 208–216.
[59] L.E. Rosenfeld, A.S. Patel, V.B. Ajmani, R.W. Holbrook, T.A. Brand, Compliance with remote monitoring of ICDS/CRTDS in a real-world population, Pacing Clin. Electrophysiol. 37 (2014) 820–827.
[60] N.D. Brunetti, G. Dellegrottaglie, C. Lopriore, G. Di Giuseppe, L. De Gennaro, S. Lanzone, M. Di Biase, Prehospital telemedicine electrocardiogram triage for a regional public emergency medical service: is it worth it? A preliminary cost analysis, Clin. Cardiol. 37 (2014) 140–145.
[61] A. Roth, N. Malov, Z. Carthy, M. Golovner, R. Naveh, I. Alroy, E. Kaplinsky, S. Laniado, Potential reduction of costs and hospital emergency department visits resulting from prehospital transtelephonic triage—the Shahal experience in Israel, Clin. Cardiol. 23 (2000) 271–276.
[62] R.P. Ricci, A. Vicentini, A. D'Onofrio, A. Sagone, A. Vincenti, L. Padeletti, L. Morichelli, A. Fusco, F. Vecchione, F. Lo Presti, A. Denaro, A. Pollastrelli, M. Santini, Impact of in-clinic follow-up visits in patients with implantable cardioverter defibrillators: demographic and socioeconomic analysis of the TARIFF study population, J. Interv. Card. Electrophysiol. 38 (2013) 101–106.
[63] S. Scalvini, S. Capomolla, E. Zanelli, M. Benigno, D. Domenighini, L. Paletta, F. Glisenti, A. Giordano, Effect of home-based telecardiology on chronic heart failure: costs and outcomes, J. Telemed. Telecare 11 (Suppl. 1) (2005) 16–18.
[64] P. Thokala, H. Baalbaki, A. Brennan, A. Pandor, J.W. Stevens, T. Gomersall, J. Wang, A. Bakhai, A. Al-Mohammad, J. Cleland, M.R. Cowie, R. Wong, Telemonitoring after discharge from hospital with heart failure: cost-effectiveness modelling of alternative service designs, BMJ Open 3 (2013 Sep 18) e003250.
[65] R. Sutton, Remote monitoring as a key innovation in the management of cardiac patients including those with implantable electronic devices, Europace 15 (Suppl. 1) (2013) i3–i5.