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Telecardiology applied to a region-wide public emergency health-care service

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Abstract *Aim* To assess feasibility and reliability of telecardiology technologies applied to a region-wide public emergency health-care service. *Methods* About 27,841 patients from all over Apulia (19.362 km^2, 4 million inhabitants) were referred from October 2004 until April 2006 to public emergency health-care number "118" and underwent ECG evaluation according to a previously fixed inclusion protocol. Data recorded were transmitted with mobile telephone support to a telecardiology "hub" active 24-h a day. Hospitalization or further examinations were arranged by emergency physicians on the basis of ECG diagnosis and consultation. *Results* Thirty-nine percent of patients complained of chest pain (CP) or epigastric pain, 26% loss of consciousness, 10% breathlessness, and 7% palpitations. Atrial fibrillation (AF) was diagnosed in 11.68% of patients and ST-elevation acute myocardial infarction (STEMI) in 1.91%. Among patients with CP, ECG showed STEMI in only 3.84% of cases, theoretically eligible for fibrinolysis or primary PCI; patients with STEMI complained of CP in 78.94% of cases. Of the patients, 65.28% with STEMI were from small towns without coronary care units, thus benefiting from an immediate pre-hospital diagnosis. Among patients with palpitations, only 10.27% of subjects showed ECG signs of supra-ventricular tachycardia and 25.18% of AF; other subjects avoided further improper hospitalization or emergency department monitoring. *Conclusions* This first region-wide leading experience shows the feasibility and reliability of telecardiology applied to a public emergency health-care service. Telemedicine protocols would probably be useful in lowering the number of improper hospitalizations and shortening delay in the diagnosis process of some heart diseases.

Keywords Telecardiology · Emergencies · Public health care

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Background

Emergency physicians have to face challenging difficulties in interpreting symptoms complained of by patients with suspected ischemic disease. Sensitivity and specificity of signs and symptoms might be very low, as reported by several case studies [1, 2]. Fewer data, moreover, are available with regards to new scenarios drafted by telecardiology technologies, nowadays involving a growing number of areas of medicine [3]. Cardiology could particularly benefit from telemedicine support, thanks to distance wireless data transmission of ECG. Telecardiology technologies have been increasingly applied in the recent past to small isolated community contexts needing distance monitoring for patients with chronic heart failure [4] or family practitioner activity [5, 6].

We report data from the first, the largest and the longest Italian region-wide experience of telecardiology applied to the public emergency health-care service; previous studies generally reported about early diagnosis of cardiac disease managed by general practitioners [6–8].

Methods

This study involved 27,841 patients from all over Apulia (19.362 km^2, 4 million inhabitants, Fig. 1), who were referred from October 2004 to April 2006 to the public emergency free health-care number "118." The number "118" is the Italian public free service for general medical or surgical emergencies, whose aim is an immediate diagnosis of critical diseases in order to avoid emergency room delay-to-diagnosis. Final hospitalization is arranged by teams of physicians and "118" district central, connected by mobile phone: direct admission to a critical care unit is arranged according to the level of care. Patients are discharged from the ambulance and not transported at all in case of normal findings.

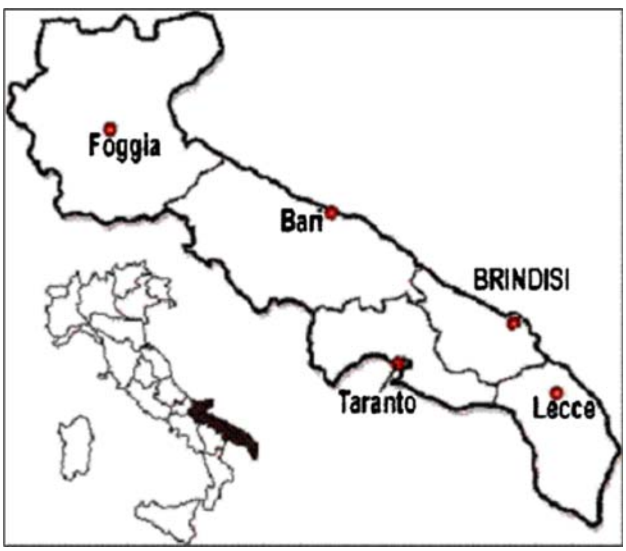


Fig. 1 Apulia and its administrative districts

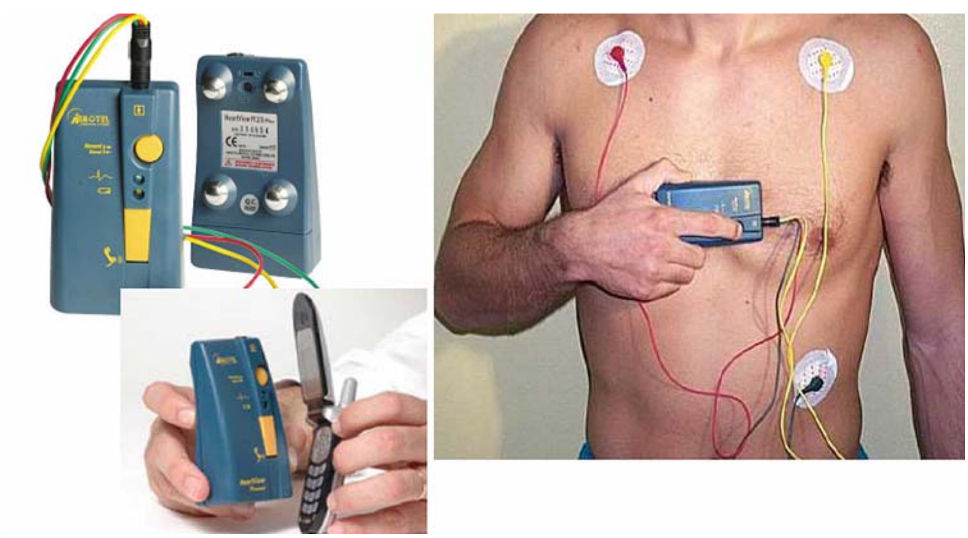
About 154 crews of the "118" emergency number were equipped in this study with special devices for recording and telephone transmission of 12-lead ECG: Cardio Vox P12 heart-line receiving system by Aerotel^{TM} (Figs. 2 and 3). Logistic support was furnished by Cardio-on-line Europe S.r.l. thanks to a grant by Pfizer^{TM}. According to Italian legislation, "118" crews usually include a physician skilled in emergency medicine and nurses. The Cardio Vox device does not allow the "118" crew members to be shown the ECG record.

Data recorded by "118" physicians (emergency medicine specialists) were immediately transmitted by mobile phone to a "hub" center with a consultant cardiologist available 24-h a day, 365 days a year. About 20 cardiologists cooperated with Cardio-on-line Europe S.r.l., providing cardiologic consultancy. The hub center was furnished with 12 computer terminals, 25 telephone lines, 2 telephone operators 24-h a day, and emergency power in order to provide for a 24-h service even in case of black-out.

Indications for ECG recording were presence of chest pain or epigastric pain, breathlessness, palpitations, loss of consciousness, or anyway suspected acute cardiovascular disease. After ECG recording (<2 min), mobile telephone transmission (<2 min), and ECG diagnosis (few seconds), hospitalization in a coronary care unit or for primary coronary angioplasty was arranged by "118" district central when necessary. A physician-to-physician (emergency medicine—hub cardiologist) report about patient's history and physical examination immediately followed ECG transmission. Patients without either evidence of anomalies at ECG or clinical signs of increased risk for cardiovascular disease were not hospitalized. ECG data were archived on paper and CD ROM support.

ST segment elevation was considered as significant for myocardial infarction according to AHA/ACC/ESC criteria

Fig. 2 Cardiovox P12 and its application on patient's chest wall



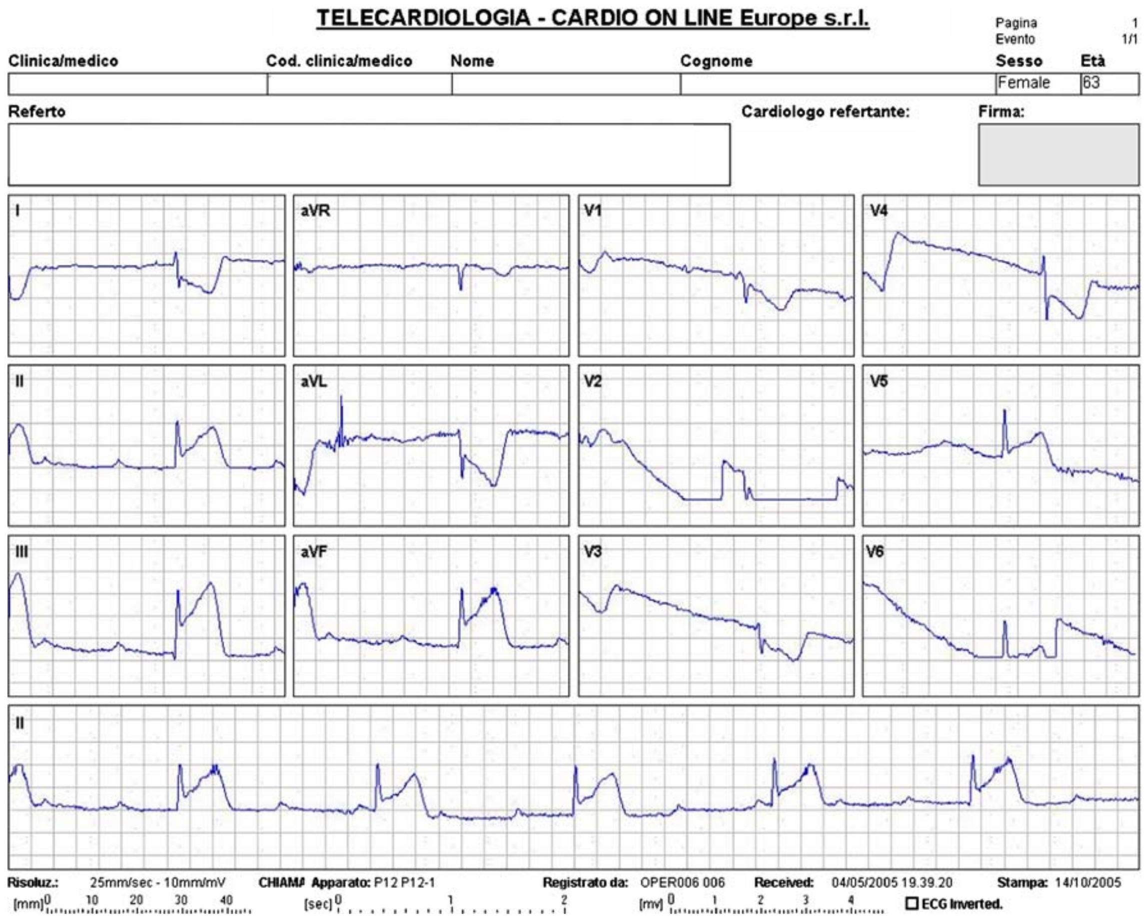


Fig. 3 Telecardiology ECG

published in 2000 (new or presumed new ECG alterations: ST segment elevation at the J point in two or more contiguous leads with the cut-off points ≥0.2 mV in leads V1, V2, or V3 and ≥0.1 mV in other leads) [9].

Results

The telecardiology call center received 27,841 calls from all over Apulia from October 2004 until April 2006: the trend drafted by calls month by month is reported in Fig. 4. After first 3 months of training, the hub-center received about 1,000 calls per month; peaks were observed in February–March and in August, probably coinciding with flu outbreaks and the summer tourist season. Of the patients who called "118" and underwent telecardiology evaluation, 50.76% were male, and mean age was 65 ± 19 years; 39% of patients complained of chest pain or epigastric pain, 26% loss of consciousness, 10% breathlessness, and 7% palpitations. Atrial fibrillation (AF) was diagnosed in 11.68% of patients, supra-ventricular tachycardia (SVT) in 1.61%, and ST elevation acute myocardial infarction (STEMI) in 1.91%. Peak in incidence of STEMI was observed in December, while AF was more commonly diagnosed in winter months. Seasonal incidence and trends by age of calls, STEMI, and AF are reported in Figs. 5–9.

Among patients with chest or epigastric pain, in 8.01% of cases ECG showed AF, in 0.98% SVT, and in 3.84% STEMI; among patients with breathlessness, in 22.16% of cases ECG showed AF, in 1.84% SVT, and in 0.93% STEMI; among patients with loss of consciousness, in 10.04% of cases ECG showed AF, in 0.85% SVT, and in 0.61% STEMI (Figs. 10 and 11). Sensitivity, specificity, and positive and negative predictive power of each symptom are reported in Table 1.

Patients with STEMI complained of chest pain in 78.94% of cases, breathlessness in 4.74%, palpitations in 0.57%, loss of consciousness in 8.36%, and other symptoms in 7.40%; 45% of subjects with STEMI were referred to "118" crews within 30 min after onset of chest pain, 41% between 30 min and 3 h, 4.86% between 3 and 6 h, 3.82% between 6 and 12 h, and 5% later than 12 h. Out of 11,000 patients with chest or epigastric pain, 3.84% ($n = 416$) of patients were theoretically eligible for

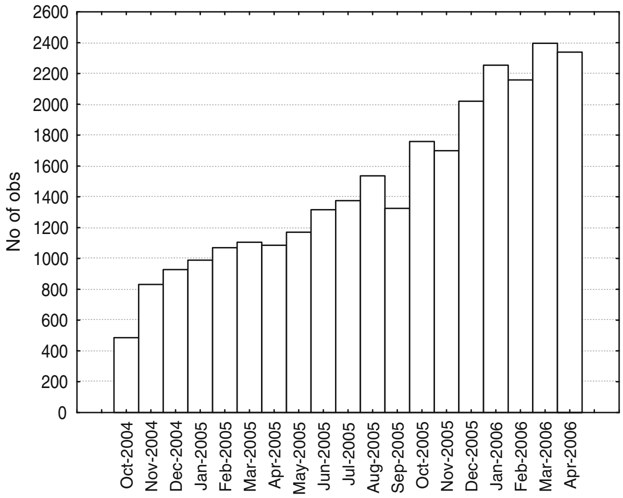


Fig. 4 Calls by month

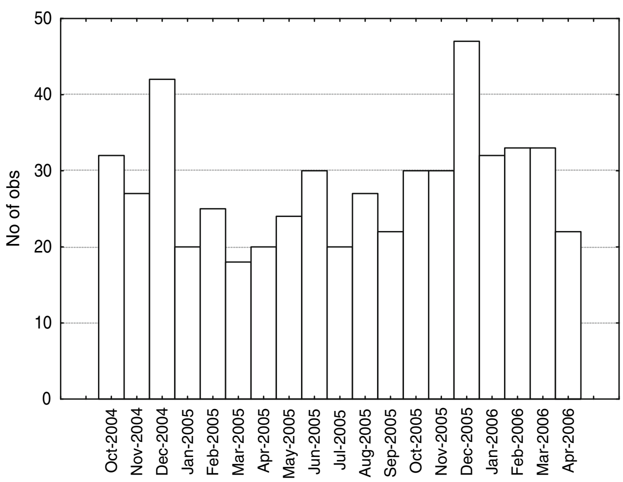


Fig. 5 ST elevation ACS by month

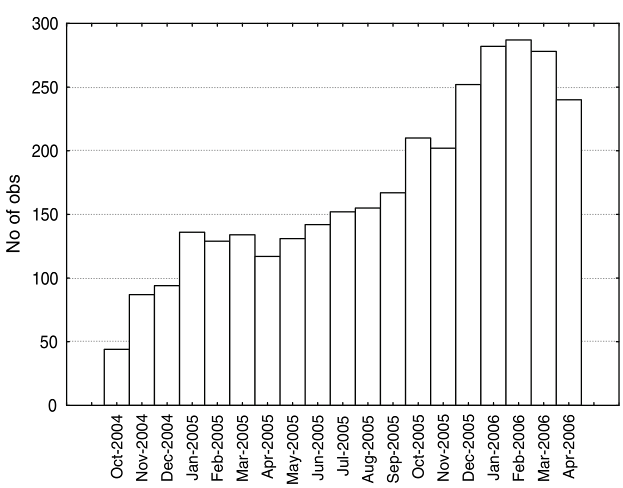


Fig. 6 Atrial fibrillation by month

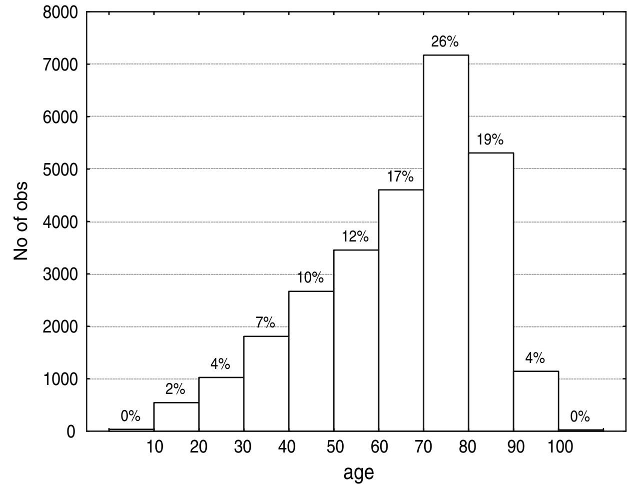


Fig. 7 Calls by age

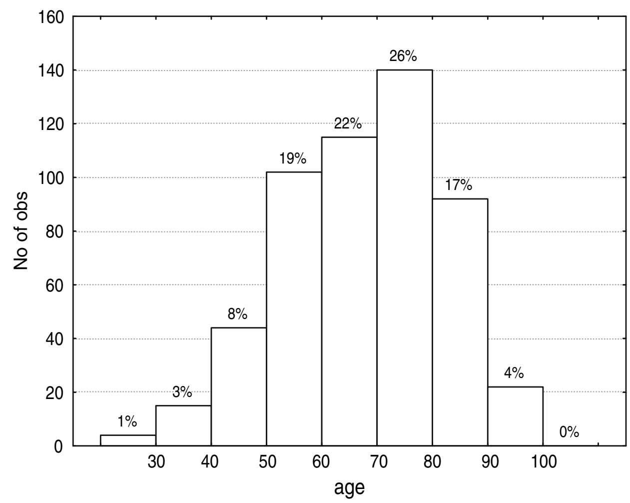


Fig. 8 ST elevation ACS by age

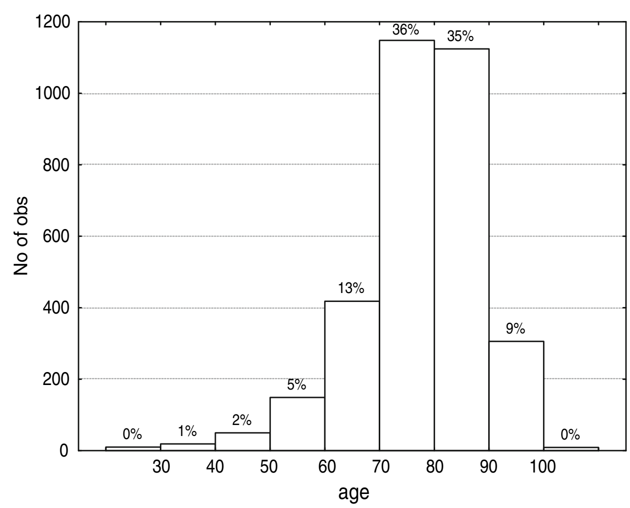
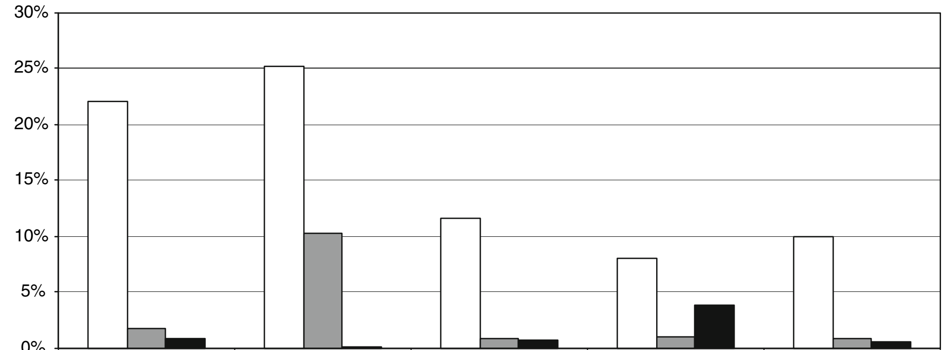


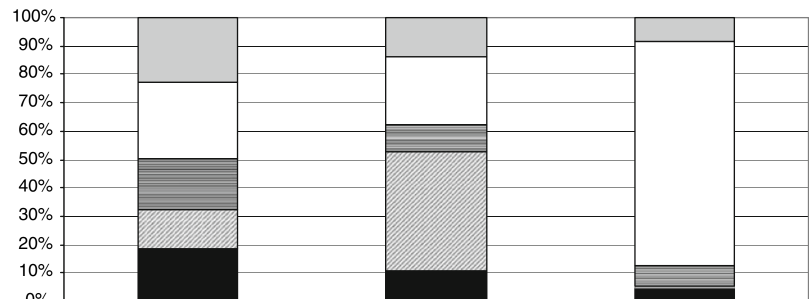
Fig. 9 Atrial fibrillation by age

Fig. 10 Symptoms and ECG diagnosis



	breathlessness	palpitations	other	chest pain	loss of consciousness
□ AF	22,16%	25,18%	11,58%	8,01%	10,04%
■ SVT	1,84%	10,27%	0,88%	0,98%	0,85%
■ STEMI	0,93%	0,17%	0,78%	3,84%	0,61%

Fig. 11 ECG diagnosis and symptoms



	AF	SVT	STEMI
loss of consciousness	22,56%	13,74%	8,35%
chest pain	26,99%	23,87%	78,94%
other	18,01%	9,91%	7,40%
palpitations	14,05%	41,44%	0,57%
breathlessness	18,39%	11,04%	4,74%

Table 1 Symptoms analysis

	Sens (%)	Spec (%)	Ppp (%)	Npp (%)	Acc (%)	
Palpitations	14.05	94.48	25.18	89.26	85.09	AF
Breathlessness	18.39	91.46	22.16	89.45	82.93	
Chest pain	26.99	59.00	8.01	85.94	55.26	
Loss of consciousness	22.56	73.26	10.04	87.74	67.34	
Other	18.01	81.81	11.58	88.30	74.36	
Palpitations	0.57	93.32	0.17	97.97	92.55	STEMI
Breathlessness	4.74	90.19	0.93	97.98	88.56	
Chest pain	78.94	61.43	3.84	99.34	61.77	
Loss of consciousness	8.35	73.41	0.61	97.62	72.17	
Other	7.40	81.64	0.78	97.84	80.22	
Palpitations	34.91	94.06	10.27	98.67	92.92	SVT
Breathlessness	9.30	90.33	1.84	98.08	88.78	
Chest pain	20.11	60.38	0.98	97.49	59.61	
Loss of consciousness	11.57	73.54	0.85	97.71	72.36	
Other	8.35	81.69	0.88	97.86	80.29	

Sensitivity (Sens), specificity (Spec), positive predictive power (Ppp), negative predictive power (Npp), and accuracy (Acc) of each symptom for ECG diagnosis (AF: atrial fibrillation, STEMI: ST elevation myocardial infarction, SVT: supra-ventricular tachycardia) fibrinolysis or primary PCI. More than 47% of subjects with STEMI were older than 70 years. More than 60% of patients with STEMI received "118" assistance in towns without an immediately accessible coronary care unit (CCU), thus benefiting from an immediate diagnosis of STEMI. Among these patients from small towns, 47% called "118" within 30 min of onset of chest pain and 87% within 3 h, thus further benefiting from a very early diagnosis of STEMI; similar time delays were found in bigger towns with CCU (42% within 30 min, 84% within 3 h).

Among patients complaining of palpitations (about 2,000), only 10.27% of subjects showed ECG signs of SVT and 25.18% of AF; other subjects avoided further improper hospitalization or emergency department (ED) monitoring. Almost 80% of subjects with AF were older than 70 years.

Discussion

This first region-wide leading experience showed feasibility and reliability of telecardiology technology applied to a public emergency health service. A presumable lower number of improper hospitalizations and shorter delay in diagnosis process may be inferred applying telemedicine protocols also to large public emergency health-care networks.

The one we are reporting is the largest and the longest experience of telecardiology applied to a region-wide public emergency health-care network. Other experiences have been in even larger settings, as in the Georgia Statewide Academic and Medical System Network [10], which was however characterized by only 516 teleconsultations and fewer than 50 telecardiology consultations. Smaller although very interesting experiences have been held in Italy by Scalvini et al. [11], reporting lower incidence of rehospitalization in patients with heart failure, thanks to telecardiology support. The same authors reported data about telecardiology applied to settings of emergency cardiology [12] or family practitioner medicine [13].

Telecardiology met the expectations of a region-wide public emergency health-care service involving more than 4 million inhabitants. More than 21,000 ECGs submitted for telecardiology diagnosis in about 18 months of activity testify to the relevance attributed by physicians of the emergency number "118" to this diagnostic tool. Telecardiology examination is particularly useful in remote or isolated areas where qualified assistance of a cardiologist was not immediately available. A single hub-center network is essential for conciliating a high quality assistance with cost reducing, since, according to present Italian practice, cardiologist consultation is required for STEMI diagnosis, but a cardiologist cannot be included in all "118" crews.

Seasonal trends in the incidence of symptoms suggesting heart disease could be observed analyzing telecardiology databases; trends from our study are similar to those reported by other studies for incidence of heart disease or heart failure [14–17], albeit not all authors share these same conclusions [18]. A higher rate in incidence of heart disease has been reported by several authors in winter and fall. This has been explained by the influence of several factors such as flu epidemics during winter months.

Low numbers of abnormal ECG findings reported presumably documents a tendency of emergency physicians to overrate the risk of heart disease in patients complaining of symptoms such as chest pain or breathlessness. This behavior could be explained by the modern increasing risk of legal implications related to emergency diagnostic procedures [19]. On the other hand, this consistently elevated number of normal ECG findings corresponds to a lower number of patients needing further examinations or ED monitoring. A considerable number of patients complaining of symptoms suggesting heart disease would probably be sent for cardiologist examination or hospitalized if they had not been screened with telecardiology diagnostics. Overuse of telecardiology support by emergency physicians is however justified by the very low specificity of symptoms commonly related to heart disease. As reported by Pope et al. [20], the positive predictive power of a common symptom such as chest pain does not exceed 8%. Telecardiology support could dramatically reduce the number of false positives as reported in Table 1; more than 60% of subjects with palpitations might reasonably avoid further urgent examinations in ED or hospitalizations after ECG screening with telecardiology, since they are without any ECG evidence of arrhythmias. Telecardiology support could help in reducing diagnostic errors and improving quality of diagnosis. Probable reduction of improper hospitalization and ED monitoring could therefore provide a significant reduction of health-care costs.

Nowadays, the impact of telecardiology on health-care costs is not well determined: available data are still controversial since telecardiology has been reported by some authors as reducing costs of health-care assistance [21], while some others described increased costs [22]. For certain, telecardiology assistance improves the quality of health care [10] and, in a special way, of emergency health care.

Furthermore, telecardiology support could reduce delay to treatment of heart diseases. Delay in treatment has been reported as one of the principal outcome determinants in coronary heart disease, both in the case of primary PCI [23, 24] and in the case of fibrinolysis [25]. Nevertheless, remarkable delays in treatment have still been reported in several areas also of developed countries. In a paper by Nallamothu et al. [26], total door-to-balloon times for transfer patients undergoing primary PCI in the United

States rarely achieved guideline-recommended benchmarks. The authors concluded by suggesting that, for the full benefits of primary PCI to be realized in transfer patients, improved systems are urgently needed to minimize total door-to-balloon times. Terkelsen et al. [27] hence recently reported how telecardiology significantly lowered time to PCI in patients with STEMI. According to Ortolani et al., pre-hospital diagnosis is associated with a two-thirds reduction of in-hospital mortality in the case of STEMI complicated by cardiogenic shock [28]. Telecardiology technologies together with an effective network of tertiary care centers ready for primary PCI and adequately spread across the territory could thus suitably meet suggestions by Nallamothu et al. [26]. Data reported by these authors showed times to diagnosis for STEMI were rather higher if compared to those reported by our study: 53% of patients were admitted within 2 h after onset of chest pain and 74% within 6 h, while our data show how more than 40% of patients with chest pain and STE-ACS referred to "118" within 30 min after onset of symptoms and about 80% within 3 h. A consistent number of ischemic patients could thus benefit from telecardiology support since that could presumably reduce delay to treatment, in adherence with international society guidelines.

Study limitations

These are preliminary data needing confirmation in larger prospective and randomized trials. We actually presumed a reduction in improper hospitalization, costs, and delay to treatment since these patients diagnosed with STEMI or arrhythmias avoided ED triage. In a recent report by Solinas et al., the mean ED triage cost in Italy was 189 ± 237 euros per patient. Sixty-eight percent of patients needing ED triage were sent back home only 69 ± 60 min from admission and 32% required a brief clinical observation lasting 10 ± 6 h and including serial electrocardiographic and myocardial injury marker assessment [29].

Conflict of Interest Drs. Brunetti, De Gennaro, and Pellegrino cooperated with Cardio-on-line Europe as consultants.

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