

Original Article

Dan Med J 2020;67(7):A10190570

Evaluation of telemedicine in patients suspected of acute coronary syndrome at a non-invasive centre

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Dan Med J 2020;67(7):A10190570

ABSTRACT

Introduction: The benefits of prehospital electrocardiograms (ECG) for patients with ST-elevation myocardial infarction (STEMI) are well-known. Evaluation of the present algorithm for prehospital ECG transmission is important to ensure correct and expeditious patient care. The purpose of this study was to evaluate ECGs transmitted from the prehospital setting to a non-invasive department of cardiology.

Methods: At Lillebaelt Hospital, the cardiologist on-call evaluated and entered the transmitted ECGs and the associated transmission criteria into the Clinical Measurement System database (KMS). Furthermore, data from the KMS and the diagnoses at discharge were obtained from 2012 to 2015.

Results: A total of 9,751 ECGs were included in the study. ECG transmission increased by 35% from year one to year three ($p < 0.05$). A total of 362 patients (3.7%) had STEMI. 25% of all ECGs were transmitted without any obvious cardiac symptom but produced a diagnosis of other cardiac illnesses than acute coronary syndrome in 28% of these patients. The number of ECGs sent per adult inhabitant in the area per year was 1:85.

Conclusions: A large number of ECGs are transmitted annually and at an increasing rate, and STEMI only comprises a very limited proportion of all transmitted ECGs to a non-invasive centre in Denmark. The high number of ECGs challenge the available resources, which are limited and should be used effectively, particularly in a period characterised by increased healthcare demands.

Funding: none.

Trial registration: not relevant.

Prehospitally transmitted electrocardiograms (ECGs) were introduced in Denmark in 1999 [1] and implemented nationally in 2002 after the DANAMI-2 study [2, 3]. The organisation of telecardiology in Denmark is well established as recommended and described elsewhere [4, 5].

The total number of ECGs transmitted and patients admitted via prehospital ECG in Denmark remains unknown. Continuous evaluation of the ECG transmission algorithm is important to secure correct and expeditious patient care without overloading available human resources in the hospital setting.

The catalyst for our local study from a non-invasive department of cardiology was a voiced concern from clinicians that the number of ECGs sent seemed to be increasing rapidly, while most of the patients suspected of cardiac illness in the prehospital setting were discharged from hospital with non-cardiac diagnoses.

In this study, we prospectively report on the total number of ECGs transmitted from the prehospital setting, the symptoms that led to the transmission of the ECGs, and the discharge diagnoses from the hospital after evaluation of the patients.

METHODS

Study population

Included in the study were all patients within the catchment area of the Lillebaelt Hospital (consisting of three individual hospitals and counting approximately 360,000 inhabitants equalling 6.3% of the Danish population [6]) who had a prehospital ECG transmitted to the hospital within the three-year period from 1 May 2012 to 30 April 2015.

Data collection and measurement

The Department of Cardiology at Vejle Hospital supports all ambulances in the catchment area of the Lillebaelt Hospital via telemedicine. The ambulance can be requested by the citizen via the emergency number 112 (analogue of 911) or by a general practitioner. The Emergency Medical Services (EMS) are guided by the internal defibrillator analysis algorithm, which is provided in every 12-lead ECG. The criteria for transmitting an ECG in Southern Denmark [7] are shown in **Table 1**.

TABLE 1 / Prehospital electrocardiogram transmission criteria used in Southern Denmark.

Chest pain, ongoing for > 15 min.
Chest pain for > 15 min within 12 h
New onset, unexplained dyspnoea
Clinical myocardial infarction
Syncope
Cardiac arrest
Clinical suspicion of acute cardiac illness: symptoms not matching the other transmission criteria

The cardiologist on call 24 hours a day receives and evaluates the ECGs on a smartphone, calls the ambulance crew and clarifies the medical history. The time spent on each patient evaluation is approximately ten minutes in our institution. Patients with ST-elevation myocardial infarction (STEMI) or left bundle-branch block (LBBB) and symptoms of acute coronary syndrome (ACS) are admitted directly to a primary percutaneous coronary intervention centre, and patients with a STEMI- or LBBB-negative ECG are admitted to emergency departments, departments of internal medicine or departments of cardiology in the catchment area. All ECGs (including those with STEMI and LBBB) in the study period were initially sent to the on-call cardiologist in our institution and not to the invasive centre as a standard procedure. However, on the authority of a prehospital doctor (*rendez vous*), an ECG could be sent directly to the invasive centre. According to the prehospital director in our region, the number of times this occurred is unknown but considered to be low.

Finally, the on-call cardiologist enters the interpretation of the transmitted ECGs into the Clinical Measurement System (KMS) database, including registration of the ECG transmission criteria. If the cardiologist has not listed an assessment, it is registered as *Not listed*.

Data were obtained from KMS and compared with the discharge diagnoses listed in discharge papers according to the tenth version of the International Classification of Disease (ICD-10) [8]. If the ICD-10-code was not listed, the discharge paper and the file were read by the investigators and a more suitable code was added. Every ECG transmitted in the study period in combination with ICD-10 and KMS data were entered into a database regardless of the number of hospitalisations per patient.

Before our study, data entry into the KMS database was very poor at 18%. Extra resources in the form of a secretary were allocated in the study period to help with data entry and to secure a

more complete dataset.

After these initiatives, data entry increased to 57% and 63%, respectively, in the following two months. During our study, we followed up on data completeness, which was 92% overall (89%, 99% and 90% for the three years, respectively).

The papers of all patients discharged with an ACS diagnosis and having undergone coronary angiography in the study period were reviewed to validate the diagnosis.

Statistical analysis

Descriptive statistics were used to summarise patient information comparing year one and year three. The association between observations at year one and year three were tested using the chi-squared test and Fisher's exact test for categorical data, and Student's two-tailed t-test for normally distributed data. p-values < 0.05 were considered statistically significant. Data were analysed by a statistician using STATA version 14.2.

Ethics

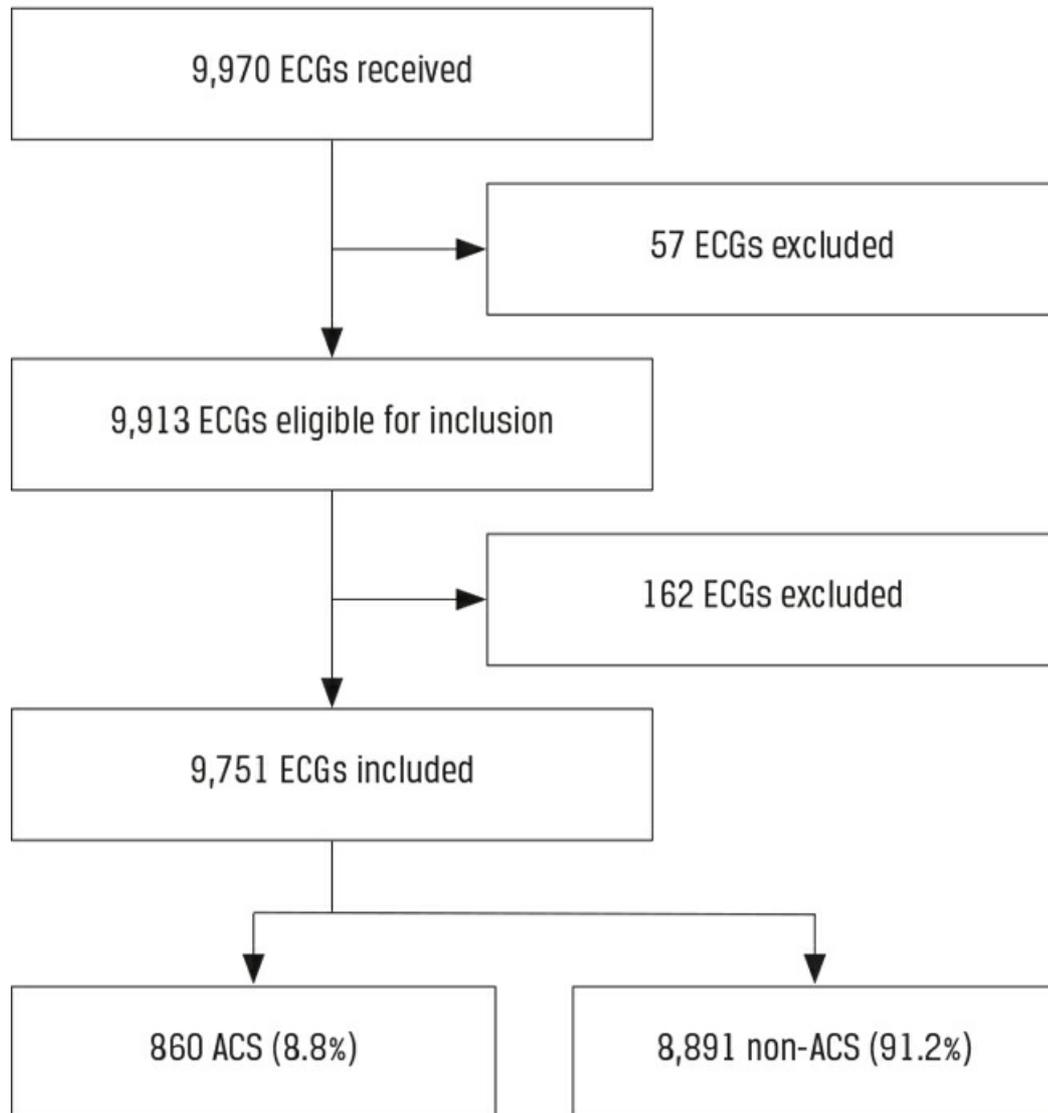
According to Danish law, this study did not need approval by the Regional Ethics Committee. This was confirmed by the chair of the South Danish Regional Ethics Committee. The research database was approved by the Danish Data Protection Agency (R. no. 18/3330).

Trial registration: not relevant.

RESULTS

A total of 9,970 prehospital ECGs were sent via telemedicine in the study period. In all, 57 ECGs were double-indexed and therefore excluded, and 162 ECGs were excluded because no hospitalisation occurred or because of an invalid personal identification number. Thus, 9,751 ECGs were included in the study, see **Figure 1**.

FIGURE 1 / Flow chart of received prehospital telemedicine electrocardiograms in the area of the Lillebaelt Hospital – part of Region of Southern Denmark, during the three-year period from 1 May 2012 to 30 April 2015.



ACS = acute coronary syndrome; ECG = electrocardiogram.

The cardiologist evaluated one ECG per 85 adult inhabitants per year and an average number of nine ECGs daily (the total adult population is approximately 280,000 [6]).

The total number of included ECGs increased significantly by 34.3% from year one to year three ($p < 0.05$). The most frequent ECG transmission criterion was *ongoing chest pain*, corresponding to 4,429 patients (45.4%), see **Table 2**. The second most frequent ECG transmission criterion was

clinical suspicion of acute cardiac illness (symptoms not matching the other transmission criteria), corresponding to 2,649 (27.2%) patients. The number increased significantly from 25.5% to 30.2% ($p < 0.001$) from year one to year three. Analysis of this transmission criterion revealed that 28.5% were discharged with a cardiovascular diagnosis (e.g., ACS, pericarditis, aortic dissection, heart block) (Table 3), but ACS and STEMI comprised only 1.8% and 0.5%, respectively. Moreover, a significantly increasing number of the patients admitted via prehospital ECG had psychiatric diagnoses ($p = 0.026$) or diagnoses related to the musculoskeletal system ($p < 0.001$) at discharge.

TABLE 2 / Prehospital telemedicine electrocardiograms (ECGs) received during the three-year study period. The values are n (%).

	Year 1	Year 2	Year 3	Total	p-value ^a
ECGs included in the study	2,786	3,223	3,742	9,751	< 0.05
<i>ECG transmission criteria</i>					
Chest pain, ongoing for > 15 min	1,223 (43.9)	1,496(46.4)	1,710 (45.7)	4,429 (45.4)	0.148
Chest pain for > 15 min within 12 h	480 (17.2)	564 (17.5)	568 (15.2)	1,612 (16.5)	0.026
New onset, unexplained dyspnoe	110 (3.9)	144 (4.4)	144 (3.8)	398 (4.1)	0.836
Clinical myocardial infarction	18 (0.6)	15 (0.5)	19 (0.5)	52 (0.5)	0.461
Syncope	140 (5.0)	135 (4.2)	131 (3.5)	406 (4.2)	0.002
Clinical suspicion of acute cardiac illness: symptoms not matching the other transmission criteria	710 (25.5)	808 (25.1)	1,131(30.2)	2,649 (27.2)	0.001
Cardiac arrest	13 (0.5)	17 (0.5)	13 (0.3)	43 (0.4)	0.449
Not listed	92 (3.3)	44 (1.4)	26 (0.7)	162 (1.7)	0.001
Acute coronary syndrome, total	252 (9.0)	309 (9.6)	299 (8.0)	860 (8.8)	0.129

a) Between year 1 and year 3.

TABLE 3 / Discharge diagnoses made for patients with the electrocardiogram transmission criterion clinical suspicion of acute cardiac illness: symptoms not matching the other transmission criteria, according to the tenth version of the International Classification of Disease. The values are n (%).

	Year 1	Year 2	Year 3	Total	p-value ^a
Abdominal pain	56 (7.9)	58 (6.9)	105 (9.3)	219 (8.3)	0.302
Musculoskeletal system	33 (4.6)	27 (3.3)	107 (9.5)	167 (6.3)	0.001
Hypertension or orthostatic hypotension	9 (1.2)	8 (1.0)	14 (1.2)	31 (1.2)	0.955
Cardiovascular	229 (32.3)	221 (27.4)	306 (27.1)	756 (28.5)	0.017
Observation for heart disease	157 (22.1)	223 (27.6)	181 (16.0)	561 (21.2)	0.001
Endocrinology, haematology, nephrology, urology, ENT	37 (5.2)	48 (5.9)	55 (4.9)	140 (5.3)	0.738
Pulmonal	79 (11.1)	79 (9.8)	132 (11.7)	290 (10.9)	0.721
Neurology	24 (3.4)	34 (4.2)	44 (3.9)	102 (3.9)	0.572
Psychiatric	13 (1.8)	23 (2.8)	41 (3.6)	77 (2.9)	0.026
Other	73 (10.3)	87 (10.8)	146 (12.9)	306 (11.6)	0.090
Total	710	808	1,131	2,649	0.001

ENT = ear, nose and throat.

a) Between year 1 and year 3.

Total STEMI accounted for 362 patients (3.7%), non-ST elevation myocardial infarction for 472 (4.8%) and unstable angina for 26 (0.3%). The total number of patients evaluated per verified ACS and STEMI was 11:1 and 27:1, respectively. The number of ACS did not change significantly from year one to year three ($p = 0.129$) (Table 2), even though the number of transmitted ECGs increased significantly ($p < 0.05$).

DISCUSSION

Our aim was to evaluate the transmitted ECGs over a three-year period from a non-invasive centre in Denmark. We found that patients presented very atypical symptoms but, even so, had serious cardiologic illness. The number of transmitted ECGs increased significantly in the study period without an increase in the number of diagnosed ACS, and less than one in every ten patients with transmitted ECGs had ACS.

Atypical presentation of cardiovascular disease

About a quarter of the patients who met the EMS transmission criterion *clinical suspicion of acute cardiac illness* (symptoms not matching the other transmission criteria) were discharged with cardiovascular diagnoses, suggesting that patients with time-dependent cardiovascular diseases are admitted to the right department with the present algorithm. Consequently, the criterion *clinical suspicion of acute cardiac illness* seems to be relevant as an indication for prehospital ECG transmission even though a low percentage had ACS (1.8%). However, if the only purpose is to find STEMI patients, then only very few STEMI patients (0.5%) out of a very large number of sent ECGs (one in 220) will be found using this criterion.

Other studies have demonstrated that atypical presentation constitutes a considerable percentage; a study found that 11% of patients presenting with atypical symptoms for acute myocardial infarction (nausea, vomiting, atypical chest pain, palpitations, hypertension syncope or dizziness) had STEMI [9]. Another study demonstrated that over a quarter of patients with STEMI presenting without chest pain did not have prehospital ECG recorded [10].

Increasing number of transmitted electrocardiograms

The study showed a significant increase in the total number of transmitted ECGs from year one to year three (34.3%). However, our institution saw no increase in the number of admissions to the Department of Cardiology; nor did the number of diagnosed ACS increase. This implies that although an extraordinarily large number of ECGs were sent, the patients' symptoms were not deemed to be of cardiac cause and the patients were evaluated either in the emergency departments or at the departments of internal medicine. The population in the catchment area of the Lillebaelt Hospital increased by 1.3% during the study period [6]. Thus, a population increase does not seem to be a determining factor in the increase observed in the total number of ECGs.

Previous studies suggest that over time, the total number of evaluated patients per verified STEMI increases ranging from 3:1 to 174:1 [11-15] and increases in areas with more ECG transmission criteria and in larger populations. In some areas, the prehospital ambulance service transmits the ECG directly to an invasive centre on high suspicion of STEMI. Thus, the proportion of patients with STEMI in these centres may be higher than in our local non-invasive centre.

The escalating number of ECGs may also be due to an increasing familiarity with telemedicine and therefore a more extensive use of the technology, which may produce a frequent disruption in the on-call cardiologist's day-to-day workflow.

In our study, the cardiologist evaluated one ECG per 85 inhabitants per year and an average number of nine ECGs daily corresponding to an approximate evaluation time of 90 minutes – this besides other on-call assignments. The average number may be higher in regions with greater population density, thereby challenging the cardiologist on call and the human resources in the hospital wards in general.

The management of prehospital transmitted electrocardiograms

Prehospital ECG transmission is important in order to ensure correct and expeditious patient care. The growing number of ECGs is, however, a challenge to Danish healthcare. The resources are limited and should be used effectively. Optimising the organisation should not affect the quality of rapid diagnostics and it should avoid misdiagnoses. Two focus areas should be considered: 1) Working to reduce the number of sent ECGs that are not well-founded, and 2) creating a system that is better equipped to deal with the increasing number of ECGs.

Computational methods using ECG alone to detect ischaemia and myocardial infarction have not been successful without the physicians and the patient context [16].

The future focus in our area should be on educating the primary healthcare system and providing further training to paramedics. In addition, further development of prehospital point-of-care-biomarkers may be helpful [17, 18]. As ECGs transmitted by telemedicine become an integral part of everyday work, the indications for transmitting an ECG to the cardiologist seem to be slipping and the cardiologist on-call becomes an advisory doctor for the prehospital system in general. This can lead to better prehospital patient triage but may also increase the strain on the cardiologist on call. A centralisation of the ECG evaluation regionally at the invasive centres in Denmark may also be worth considering. Dedicating a cardiologist in every region who is not on call is a possibility. This would free resources in the smaller centres and bring more uniform triage to an entire region.

An alternative may be to remove the task from the cardiologist and let the transmitted ECGs be evaluated by Cardiac Care Unit nurses [19] or paramedics [20]. However, in our opinion, a cardiologist is overall better equipped for the task.

After analysing the data in our study as described, we held a meeting with the EMS and plan to meet frequently in the future to build and maintain a strong cooperative relationship in order to achieve optimum and effective patient care. Moreover, after our study concluded, ECGs with suspicion of STEMI are now transmitted directly to the invasive centre.

Limitations

Our analyses depend on data from the KMS database and any lack of registration and registration error may influence the analyses. We did not read all discharge papers, and any registration error relating to ICD-10 codes in the discharge papers may therefore also influence our data. Possible readmissions were not included.

The total number of ECGs performed but not transmitted via telemedicine remains unknown despite considerable effort to retrieve these figures.

Our study is a single non-invasive centre study, and it is not representative of other Danish regions or other countries. However, the hospital consists of three individual hospitals, which should strengthen the results compared to a single-hospital study.

CONCLUSIONS

A large number of ECGs are transmitted annually at an increasing rate and STEMI only constitutes a very small proportion of all ECGs transmitted to a non-invasive centre in Denmark. The high numbers of ECGs challenge available resources, which are limited and should be used effectively in a time characterised by increased demands on Danish healthcare.

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Accepted: 18 May 2020

Conflicts of interest: none. Disclosure forms provided by the authors are available with the full text of this article at Ugeskriftet.dk/dmj

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