Issuing Electrocardiographic Reports Remotely: Experience of the Telemedicine Network of Santa Catarina

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Abstract

Background: **A growing use of telemedicine has been observed, especially as regards the sending and evaluation of electrocardiograms (ECG); this is a low-cost procedure with a high potential to save lives.**

Objectives: **To describe the form of systematic analysis and user profile of the Telemedicine Network of Santa Catarina during the time when the report was issued freely.**

Methods: **Observational cross-sectional study determining the associations between patient characteristics and electrocardiographic diagnoses issued among users of the Telemedicine Network of Santa Catarina during the time when the report was issued freely. This system was connected to 287 cities in Santa Catarina; the tests were done in the places of origin and the reports were issued in three tertiary-care hospitals. From 2005 to 2010 the reports were issued freely and a probabilistic method for data analysis was created. An experienced cardiologist evaluated all ECGs to assess the chances of abnormality.**

Results: **243,363 ECGs were evaluated. The majority (58%) was performed on patients older than 50 years from primary care services (72%). There were differences in the frequency per region; this was partly related to the number of cardiologists/region ($r = -0.551$), to the distance from tertiary-care centers and potential differences of acceptance of the method. Approximately 53% of the ECGs were abnormal with greater frequency with increasing age ($r^2 = 0.8166$) and with significant regional differences ($p < 0.0001$).**

Conclusions: **We built a data analysis system integrating prevalent terms, probabilistic analysis and specialized dictionaries. The system has covered a significant portion of the population of Santa Catarina, mainly elderly patients from the network of primary healthcare centers and remote regions of the State. (Arq Bras Cardiol 2012;99(5):1023-1030)**

Keywords: **Telemedicine; electrocardiography/methods; aged; health service.**

Introduction

There has been a growing use of telemedicine as regards the sending and interpreting of electrocardiograms (ECG)[1-5]. This growth has been even greater in Asynchronous Telemedicine, in which the tests are sent to a server for further analysis and reporting by a specialist. It is considered a low-cost timesaving technology with a potential to save lives[6], thus decreasing the distance between the primary care and secondary care[7].

Telecardiology is changing the primary care of patients with cardiovascular disease across the world[8]. When coupled with a proper computing and telecommunications infrastructure, this methodology assists family physicians in the management of acute and chronic heart conditions. It enables the preferential treatment of high-risk patients and decreases unnecessary hospitalizations, which reduces bottlenecks in the health system and provides a better quality of life to the users[9,10].

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Manuscript received November 16, 2011; manuscript revised November 21, 2011; accepted July 31, 2012.

Tests may be conducted in the patients' homes, which is especially interesting for elderly individuals[11]; they can also assist in the diagnosis of outpatients with arrhythmia, since they enable longer observation periods[12]. In ambulances, they may assist the monitoring and decision making in severely ill patients[13,14] and provide excellent service to patients with severe decompensated heart disease, even when the procedure is performed by paramedics or other health professionals[15].

In large countries like ours, the method can be especially useful if added to others – such as pulse, blood pressure, oxygen saturation and temperature monitoring, especially in critically ill patients and in remote areas[16]. Telemedicine is a technology that is beginning to be used in Brazil, and is well accepted[17].

Despite all the advantages presented above, it is suggested that further studies on Telecardiology are necessary to analyze the costs, impact and profile of the users assisted[18]. This study aims to present the construction of the analysis and profile of the users undergoing ECG — remotely and asynchronously — by the Integrated Telemedicine and Telehealth System of Santa Catarina — STT/SC[19-22], during the time when the reports were issued freely. It also aims to demonstrate the user profile of this system at this stage of the process.

Methods

The Telemedicine Portal is an electronic tool designed to aid health professionals who need to view and diagnose imaging tests remotely, and is an integral part of the technological infrastructure of the STT/SC. This model allows performing telediagnoses directly by the Internet[19-21].

The STT/SC system serves a center for collecting and issuing reports. It is administered by the Department of Regulatory Centers of the State Department of Health – GECOR/SES/SC, interconnected with more than 400 health institutions in 291 cities of Santa Catarina. Large state hospitals are integrated with more than 300 primary health care centers within the state. Data traffic between hospitals occurs in an encrypted and secure manner through the Government Network of the State of Santa Catarina. Access to primary healthcare centers and physicians, including via mobile applications, is offered through a point of convergence between the Internet and the State Government Network, at the Point of Presence - POP-SC. Both forms of traffic are performed via secure connection with standard digital certificate level 3 of the Public Key Infrastructure — ICP-Brazil, aligned to resolutions 1643/02 and 1821/07 of the Federal Council of Medicine. Technical details concerning structure, technology and modes of operation of TBS/BSA can be found in earlier publications of the group[20,21]. In order to raise the security level and offer additional *timeliness* and *irrefutability* guarantees to the tests generated, making them legally valid electronic document carrying time stamps, the system also runs the digital protocol of electronic documents of image and signal data of every test generated. Later, it does the same for the text combination of test report-data[22]. This time stamp is performed with a digital protocol of electronic documents (PDDE), which has a standard digital certificate ICP-Brasil installed in a Safe Room at Universidade Federal de Santa Catarina (UFSC). The certificate is aligned to the procedures adopted, such as in the Regional Labor Court of Santa Catarina[23]. The digital registration system makes it impossible to file an electronic document retroactively with respect to time, protocol number and original contents.

The cities were provided with equipment to collect digital electrocardiograms, and the health staff was trained to handle the system. The digital ECG tests are conducted in the places of origin and issued to the portal, which sends them to a team of cardiologists, who, then issue the report. The report, in turn, can be accessed at the place of origin to be properly managed by the team responsible for the patient.

The team of cardiologists in charge of issuing the reports is composed of professionals with over 10 years of practice in cardiology, all specialized in cardiology and involved with teaching in master's and doctor's programs in cardiology (master's and doctor's programs of UFSC), or other graduate programs (residency in cardiology in tertiary care hospitals).

From August 2005 to August 2010, 243,363 ECGs were performed in the STT/SC by Telemedicine, and at that stage, the reports were issued in the free form of writing. As there was a number of variants of ECG models, a method was created to retrieve the reports. This method was based on three steps: interviews with cardiologists related to the program; development of new techniques for extracting information from medical reports using probabilistic techniques; and the formation of a nomenclature using specialized dictionaries with the generation of the statistics derived during the application of the methodology conceived.

The first step was to specify the process of drafting an ECG report and define the process of classification of the findings. For this purpose, four cardiologists contributed to the methodological profile by drafting a report and mapping the words and sentences most frequently used by each one individually. Subsequently, new interviews with the same group of physicians were conducted with the objective of cataloging the categories in which the findings would be distributed.

The second step was to develop a tool to retrieve the information from the STT/SC database. This tool uses statistical analysis techniques to return the degree of similarity of one or more grammatical compositions[24]. These techniques include the Levenshtein distance, which uses the mathematical concept of matrices to insert, delete or substitute a single character in the expressions to be compared, with the aim of transforming one expression into another. This technique compares two expressions to obtain a degree of similarity between them[25].

The third step consisted of developing a nomenclature using specialized dictionaries to expand the vocabulary in the surveys. For this purpose, we used Portuguese language[26] dictionaries, a dictionary compiled from the Guidelines of the Brazilian Society of Cardiology on the Analysis and Issuance of Electrocardiographic Reports[27], as well as the dictionary of descriptors and synonyms of the Health Sciences Descriptors – DeCS[28]. In order to increase the quality of results, we created a specific dictionary of typical compositions used by the cardiologist who used the STT/SC, designed in the interview process of the first stage.

To add information from these dictionaries, thesauri and descriptors, we developed a mechanism to merge information from these various sources, generating a single file of synonyms appropriate to the tool developed.

Several independent variables were used for the univariate description of the tests performed during the period: age, type of health facility, macro-region of Santa Catarina, relationship between the population and the number of tests and relationship between the population and the estimated number of cardiologists, according to the Brazilian Society of Cardiology/Santa Catarina Section[29]. The reports were reviewed by an experienced cardiologist and were categorized for the likelihood of being normal or abnormal.

Nonparametric continuous data were described as median and interquartile range (IQR). We determined the absolute frequencies and percentages, according to the characteristics of the variables. The associations between variables were determined using the chi-square test for trend or independence, according to data characteristics; or using Spearman correlation when appropriate.

According to the consensus of the Ethics Committee on Human Research of UFSC, July 2009, there was no need to review the project because it involved secondary data from the STT/SC. The Medical Ethics Code, the Helsinki Declaration and the Resolution 196/96, especially related to data confidentiality, were respected.

Results

Distribution of users of electrocardiograms

We analyzed 243,363 ECG reports. The patients' ages ranged from 0 to 104 years, with a median of 53 years (interquartile range: 42 to 66 years). Table 1 shows the distribution of patients according to age, with the majority of users (approximately 58%) older than 50. Comparing the age distribution to the average population of Santa Catarina in these years[30], we observed a direct relationship between age and requests for ECG (p for trend < 0.0001, chi-square test).

We evaluated the distribution of ECGs according to the macro-region of Santa Catarina, shown in percentages in Figure 1. It was observed that the macro-region of Vale do Itajaí had the largest number of ECGs recorded in the database

Table 1 – Distribution of users' age, by age group — Telemedicine Network of Santa Catarina, from 2005 to 2010

Age (years)	Frequency (in thousands)	Percentage (%)	R P/E+
0 to 9	2.9	1.2	329.1
10 to 19	10.1	4.2	104.1
20 to 29	16.6	6.8	65.7
30 to 39	26.1	10.7	35.6
40 to 50	45.6	18.7	18.8
50 to 60	53.2	21.9	11
60 to 70	47.3	19.4	6.9
70 to 80	30.8	12.7	5.7
80 plus	10.7	4.4	6.7
Total	243.4	100	24.8

+R P/E: population/number of tests ratio.

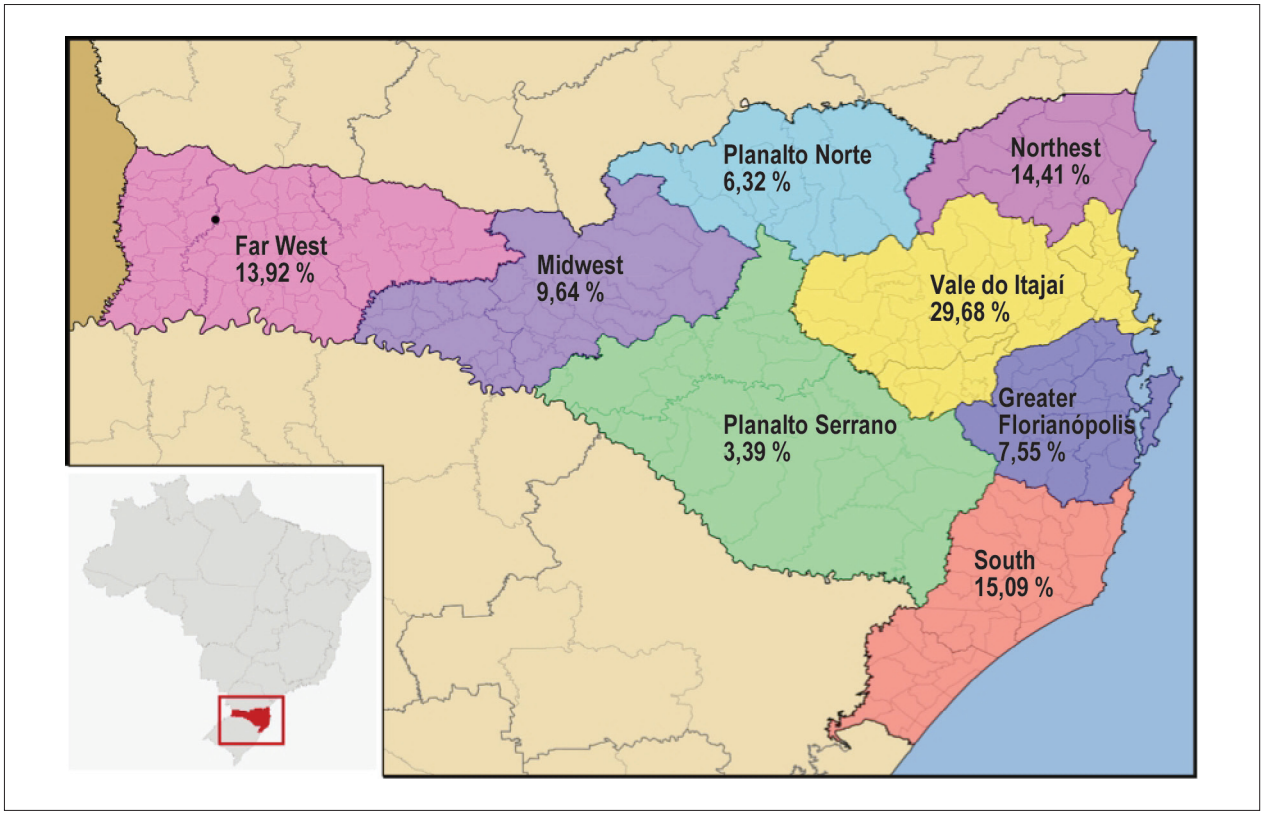

Figure 1 – *Distribution of ECGs in each region — Telemedicine Network of Santa Catarina, from 2005 to 2010.*

of STT/SC, with 29.68% of the total, while the macro-region of Planalto Serrano had the lowest concentration of tests, with 3.39%. When we analyze the relationship between the population and the number of tests, this ratio is higher in Florianópolis and lower in Vale do Itajaí, which is partly explained by the population/number of cardiologists ratio estimated for the macro-region[29], with r = - 0.551 by Spearman correlation and p = 0.1568, as presented in Table 2.

We also collected data about the institution that performed the test and the type of care received by the patients. Primary care included primary health care centers, secondary care included polyclinics, hospitals and emergency care centers, excluding the institutions of Florianópolis, São José and Joinville. The hospitals in these cities are tertiary care centers. Most tests were performed in primary care centers (72%), followed by secondary care (22%), and only 6% at the tertiary level.

Distribution of electrocardiogram diagnoses

By applying the method of search of terms and classification of diagnoses, we obtained the frequency distribution described in Table 3, represented in absolute data. A diagnosis containing more than one term mapped by the system was listed in more than one diagnosis.

Distribution of electrocardiograms according to the criterion of normality

Of all ECGs, 52.8% were considered abnormal. There was a strong positive linear correlation between age and percentage of abnormalities found on ECG, (r^2 = 0.8166, p = 0.0008, Spearman correlation). The distribution of data is presented in Table 4.

The relationship between the macro-regions of Santa Catarina and the percentage of abnormalities found on ECG was statistically significant (p < 0.0001, chi-square test for independence), being higher in the Northeast and lower in the South. There was no relationship between the percentage of abnormalities per macro-region and the ratio population/number of cardiologists (r = -0.1479, p = 0.7266, Spearman correlation). The distribution of data is presented in Table 5.

Discussion

This study shows, for the first time, the STT/SC experience regarding the preparation of ECG reports. It shows that a significant number of users from Santa Catarina have used the system, especially patients older than 50 years from regions lying far from tertiary-care hospitals and in primary care. Most reports showed statistically significant abnormalities, more frequent with increasing age and with a different spatial distribution. The relationship between the local population and the number of cardiologists could barely explain the total number of tests by macro-region. The more frequent ECG requests with increasing age can be explained by the increased frequency of cardiovascular diseases in older patients, and the consequent greater degree of suspicion in this age group[31].

The distribution of tests according to macro-region showed very peculiar characteristics, partly explained by the relationship between the local population and the number of cardiologists, and partly by the distance from tertiary-care hospitals (macro-regions of Florianópolis and Northeast). The macro-region of Vale do Itajaí presented a high frequency and Planalto Serrano, a low frequency, even if we consider the two aspects mentioned previously. This might be due to the strong dissemination and acceptance of the tool in the first macro-region, and weak dissemination and acceptance in the second one[10]. There is a need for further studies to check this hypothesis.

A more frequent execution of tests in primary care facilities was expected and does meet the main goals of the tool, to bring the primary care closer to the secondary or tertiary care, thus reducing bottlenecks in the system and facilitating the urgent care of severely ill patients[6-9,17].

When the possibility of cardiovascular abnormality detected by the ECG report is evaluated, most tests showed some abnormality. This was even more significant with advancing age, reaching more than three quarters of patients older than 70 years[31]; such findings also suggest some degree of repressed demand or delay in the degree of suspicion in these patients, which also requires elucidation in further studies. This user profile – and a potential repressed demand — may also be associated with a higher frequency of left bundle branch

Table 2 – Distribution of ECGs in each macro-region — Telemedicine Network of Santa Catarina, from 2005 to 2010

Macro-region	Frequency (in thousands)	Percentage (%)	R P/E+	R P/C (in thousands)§
Far West	32.4	13.9	21.2	40.1
Greater Florianópolis	19.2	7.6	56.6	11.1
Midwest	23.7	9.6	25.8	36.6
Northeast	34.8	14.4	23.8	18.6
Planalto Norte	15.4	6.3	23.5	31.5
Planalto Serrano	7.8	3.4	38.3	24.5
South	35.7	15.1	25.1	23.7
Vale do Itajaí	126.8	29.7	17.1	19.2
Total	243.4	100	24.8	20

+ R P/E: population/number of tests ratio; § R P/C: population/number of cardiologists ratio.

Table 3 – Distribution of ECG diagnoses — Telemedicine Network of Santa Catarina, from 2005 to 2010

	Total ECG Reports in MTCR	Reports
I	**Conduction Disorders and Formation of Cardiac Stimulus**	
	a) Arrhythmias	
	- Sinus bradycardia*	13,944
	- Atrial Fibrillation or Atrial Flutter	5,125
	- Sinus tachycardia	3,793
	- Ventricular extrasystoles or ventricular bigeminy	2,590
	- Sinus arrhythmia	1,792
	- Supraventricular extrasystoles	1,147
	- Short PR interval	1,032
	- Wolf-Parkinson-White Syndrome	261
	- Paroxysmal supraventricular tachycardia	87
	- Brugada syndrome	10
	- Nonsustained ventricular tachycardia	6
	b) Blocks	
	- Left bundle branch block	17,651
	- Left bundle anterior superior divisional block	14,059
	- Right bundle conduction disorder	6,951
	- Right bundle branch block	6,803
	- Atrioventricular block (1st, 2nd and 3rd Degree)	1,850
	- Junctional rhythm	288
	- Idioventricular rhythm	2
II	**Abnormalities compatible with ischemia/myocardial necrosis**	
	- Subepicardial ischemia	6,392
	- Fibrosis (lower/anterior septal/lateral/anterior)	3,939
	- Subendocardial ischemia	563
	- Myocardial infarction (acute or old) or ST elevation	166
	- Myocardial ischemia	9
	- Atrial infarction	4
III	**Overload of heart chambers**	
	- Left ventricular hypertrophy	7,585
	- Atrial enlargement (left or right)	713
	- Right ventricular hypertrophy	290
IV	**Nonspecific abnormalities**	
	- Diffuse abnormalities in ventricular repolarization, isolated	25,699
N	**Reports with no abnormalities**	
	- Normal electrocardiogram	114,893

Table 4 – Distribution of abnormal data, by age group — Telemedicine Network of Santa Catarina, from 2005 to 2010

Age (years)	Abnormal ECG (in thousands)	Percent of abnormal ECG (%)	Total (in thousands)
0 to 9	0.9	39.6	2.3
10 to 19	2.8	29.3	9.5
20 to 29	4.6	29	15.8
30 to 39	8.2	33.2	24.8
40 to 49	17.9	41.0	43.6
50 to 59	28.1	52.7	53.5
60 to 69	31.3	64.7	48.5
70 to 79	24.1	74.1	32.5
80 plus	10.5	81.3	12.9
Total	128.5	52.8	243.4

Table 5 – Distribution of ECGs classified as abnormal, by macro-region — Telemedicine Network of Santa Catarina, from 2005 to 2010

Macro-region	Abnormal ECG (in thousands)	Percent of abnormal ECG (%)	Total (in thousands)
Far West	17.1	52.7	32.4
Greater Florianópolis	9.8	50.9	19.2
Midwest	12.7	53.8	23.7
Northeast	20.9	59.9	34.9
Planalto Norte	8.1	52.5	15.4
Planalto Serrano	4.1	51.6	7.9
South	17.9	50.1	14.7
Vale do Itajaí	37.9	51.1	74.2
Total	128.5	52.8	243.4

block in the sample. More severely ill patients with heart failure may be more frequent among the study group than in the general population.

Although it is statistically significant, there was no explanation for the regional differences as to the percentage of abnormalities found in the reports. These may be associated with differences in regional incidences of cardiovascular disease, degree of suspicion from their doctors and different degrees of access to healthcare by region[10]. These associations must also be further tested.

Limitations

This is a retrospective study on users of the Telemedicine Network of Santa Catarina. Due to the nature of the sample, an epidemiological study of the State is not proposed. Instead, a convenience sample is proposed, because there are different degrees of accessibility and motivation that determined a user-based search in the system. All profile analyses are related specifically to users during the time interval of observation described.

As a limitation, we also observed the logistics and probabilistic approach required by the analysis of reports written in the free form. This limitation was corrected in August 2010, when there was a new report formatting using formulas according to the model of report following the DICOM Structured Reporting – DICOM SR[32], a model originally suggested for radiology reports by the American College of Radiology. The model was adapted for use in cardiology through the development of a controlled vocabulary according to the criteria and diagnoses suggested by the guidelines of the Brazilian Society of Cardiology.

Finally, we underline the difficulty of determining the association between reports, the user's history and follow-up, also corrected in 2010 when this information was added to the test in the system.

Conclusion

The system of "digging out" free data consisted of freely mapping the most common terms associated with statistical analysis based on the degree of similarity between the terms, and standardization of findings based on specialized dictionaries.

ECGs done in the STT/SC serve a significant portion of the population in all regions of Santa Catarina, especially those patients older than 50 years in regions far from tertiary

cardiologic care centers and primary care centers. Further studies are necessary – now using a more accurate and optimized information system — to elucidate more precisely the clinical characteristics of patients and their follow-up. Such precision will provide a more accurate determination of the impact of this tool on the cardiovascular health of users.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

This study was partially funded by por CNPq e CAPES.

Study Association

This article is part of the master dissertation submitted by Cloves Langendorf Barcellos Junior, from Universidade Federal de Santa Catarina.

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