



Cost-benefit of the Telecardiology Service in the State of Minas Gerais: Minas Telecardio Project

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Abstract

Background: Telecardiology is a tool that can aid in cardiovascular care, mainly in towns located in remote areas. However, economic assessments on this subject are scarce and have yielded controversial results.

Objective: To evaluate the cost-benefit of implementing a Telecardiology service in remote, small towns in the state of Minas Gerais, Brazil.

Methods: The study used the database from the Minas Telecardio (MTC) Project, developed from June 2006 to November 2008, in 82 towns in the countryside of the state. Each municipality received a microcomputer with a digital electrocardiograph, with the possibility of transmitting ECG tracings and communicating with the on-duty cardiologist at the University hospital. The cost-benefit analysis was carried out by comparing the cost of performing an ECG in the project versus the cost of performing it by patient referral to another city.

Results: The average cost of an ECG in the MTC project was R\$ 28.92, decomposed into R\$ 8.08 for the cost of implementation and R\$ 20.84 for maintenance. The cost simulation of the ECG with referral ranged from R\$ 30.91 to R\$ 54.58, with the cost-benefit ratio being always favorable to the MTC program, regardless of the type of calculation used for referral distance. The simulations considered the financial sponsor's and society's points-of-view. The sensitivity analysis with variation of calibration parameters confirmed these results.

Conclusion: The implementation of a Telecardiology system as support to primary care in small Brazilian towns is feasible and economically beneficial, and can be used as a regular program within the Brazilian public health system. (Arq Bras Cardiol. 2011; [online].ahead print, PP.0-0)

Keywords: Cost-benefit analysis; telemedicine; Brazil; health care assistance.

Introduction

Minas Gerais is a Brazilian state with a high number of municipalities with significant socio-economic heterogeneity, reflected in the epidemiological, profile, demographic structure, healthcare provider structure and, consequently, access to healthcare services^{1,2}.

In the context of large number of municipalities with small populations, the healthcare provider management may be compromised. The efficient provision of such services, both in terms of effectiveness and financial viability, depends on the population scale.

A healthcare technology that is relatively little known in Brazil, but can be a viable alternative to overcome the difficulties imposed by our geopolitical design, is the use of tele-healthcare services. Telemedicine is the practice of Medicine at distance by means of telecommunications³. Several countries have used the services of tele-healthcare as an alternative treatment^{4,5}, including cases of cardiovascular diseases⁶. However, the methodological quality of most studies in telemedicine and telecardiology has been considered questionable^{5,7} and are not enough to prove any eventual economic benefits of telecardiology⁷.

In 2006, in the state of Minas Gerais, the Minas Telecardio (MTC) project was initiated, which implemented the telecardiology service in 82 small towns in Minas Gerais⁸⁻¹⁰. The services were provided by establishing a telecardiology network consisting of 05 university hospitals that receive the transmission of electrocardiograms by the Internet and perform other telemedicine activities. The project was successful

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regarding its implementation and maintenance, and received good evaluations by town health teams, substantially reducing unnecessary referrals⁸.

The objective of this study is to evaluate the cost-benefit ratio of the MTC project, considering the hypothesis that there is economic benefit in performing the ECG through telecardiology, in comparison with patient referral to perform the examination in other reference institutions.

Methods

The Minas Telecardio Project

The project proposed to implement telecardiology activities in small municipalities in the state of Minas Gerais (MG) and assess the system effectiveness and cost in relation to ischemic cardiovascular diseases. The project methodology was described in detail in other articles and only essential aspects will be reviewed here⁸⁻¹⁰.

The project was created by public university hospitals in Minas Gerais under the Edict #008/2005 of *Fundação de Amparo à Pesquisa de Minas Gerais* (FAPEMIG), with support from the State Health Secretariat of Minas Gerais (SES-MG) and FINEP - *Financiadora de Estudos e Projetos*. The Edict requested research proposals to sponsor the implementation, development and evaluation of the effectiveness of a pilot telemedicine system in cardiology. Within this proposal, the Mineira Telecardiology Network was constituted, with the integration of 05 public universities that had a teaching hospital: *Universidade Federal de Minas Gerais* (UFMG), which holds the project coordination, *Universidade Federal de Uberlândia* (UFU), *Universidade Federal do Triângulo Mineiro* (UFTM), *Universidade Estadual de Montes Claros* (UNIMONTES) and *Universidade Federal de Juiz de Fora* (UFJF).

Each university originally constituted an implementation and monitoring center of the MTC activities. The cardiologists who perform the electrocardiogram analyses are stationed at the centers, using an on-duty system at the emergency services to provide care for the entire state of Minas Gerais.

A total of 82 towns from the countryside of the state of Minas Gerais was included in the study, according to the following eligibility criteria: attendance rate at the Family Health Program - PSF equal to or greater than 70.0%; population up to 10,500 inhabitants; needy municipalities with low morbimortality rates due to acute myocardial infarction, as a way to control the underreporting bias, usually more significant in needy regions⁹⁻¹⁰. Each municipality received an advanced-configuration PC, a webcam, a printer and a digital 12-lead electrocardiograph. The ECG software includes patient identification information, comorbidities and risk factors for cardiovascular diseases, use of medications, investigation of chest pain and diagnostic hypothesis.

The project attended to the municipalities for a period of 30 months, from June 2006 to November 2008, providing clinical activities in telemedicine by means of on-duty shifts carried out by specialists in cardiology, responsible for analyzing electrocardiograms sent by all municipalities and

online discussions of clinical cases. The cardiology duty shifts were divided among the campuses and attended to all the participating municipalities. A report was issued for each ECG, which was promptly returned to the town of origin. Communication software was used to interact via chat, voice, images and files between users, and a WEB system was developed by the project team to manage online and offline teleconsulting⁸⁻¹⁰.

Minas Telecardio project cost assessment

The assessment of the MTC project costs was conducted by accounting for all expenses incurred by it. In this case, the expenses and costs are equivalent, as expenditures were made using market prices and specific subsidies were not granted for project expenditures. The MTC project was funded by FAPEMIG (with contributions of funds from FINEP and SES / MG), with support from CNPq.

The institution that carried out the project was Universidade Federal de Minas Gerais, of which fund managing unit for research projects is *Fundação de Desenvolvimento a Pesquisa* - Fundep. Information on expenses related to the MTC project can be obtained from the Fundep website (www.fundep.br). The site has made all financial transactions related to the project available, which have been separated by item. For the analysis of the project costs, data were collected for each item, and the values were computed according to June 2008 prices, inflated according to the Broad Consumer Price Index (*Índice de Preços ao Consumidor Amplo* - IPCA). For reference purposes, one US dollar on June 15, 2008 was equivalent to R\$1.64 reais. Expenses related to the purchase of 30 computers and 05 video conference equipment for the university hospitals tele-health centers were excluded from the costs, as they were not directly related to the activities being evaluated in this study (nominal value of R\$ 191,099.98).

Cost typology

The MTC project costs were classified into three categories, implementation cost, maintenance cost and evaluation cost. This typology reflects the cost categories associated with different activities. The cost of implementation refers to the total expenditure made for the project implementation in 82 municipalities in the state of Minas Gerais. The project implementation took place between August 2006 and December 2006, so that all financial records included in this category have been made in this period. In calculating the implementation costs, for the purpose of cost-benefit assessment, we considered a depreciation rate of 20.0% / year. As technological changes in the telecommunication industry have been very intense, it is reasonable to assume that the equipment does not have a service life higher than 05 years.

The project maintenance costs include all expenditures to keep the project active and assessment costs refer to the amounts spent in the project evaluation study, consisting primarily of researchers' compensation.

Chart 1 summarizes the three categories of costs and its components.

Chart 1 - Cost typology and components of each category, Minas Telecardio project

Categories	Description
Implementation costs	Daily costs: daily wages related to technical visits, training and informatics support by technicians responsible for the towns/cities that are part of the program.
	Permanent equipment: healthcare and informatics equipment costs
	Aerial and terrestrial transportation costs: bus and plane tickets for technical visits
	Third-party Services: necessary services for program implementation.
	Grants: researchers involved in the program implementation.
	Software: software costs for the program implementation.
	Daily costs: travel costs of participants for monitoring and aiding the project activities.
Maintenance costs	Aerial and terrestrial tickets: travel costs associated with transportation to participant towns for monitoring and aiding the project activities.
	Third-party services.
	Consumables.
	Grants: researchers involved in the program implementation.
	Equipment maintenance.
	CPMF (Taxes).
Assessment costs	Grants: researchers involved in the program assessment
	Third-party services.

Cost-benefit analysis

The cost-benefit analysis (CBA) compares the costs of carrying out the intervention to achieving its benefits in currency values, being a customary tool in economic policy-decision making and consists in comparing the costs to the benefits of a particular intervention or program on the monetary metric. The main advantage of the CBA is that it directly generates an economic policy indication, as a negative cost-benefit ratio means that the benefits outweigh the intervention costs, therefore being favorable to its implementation.

This approach presupposes the need to perform ECG tests, and in this study, the cost-benefit analysis was performed according to established guidelines^{11,12}, comparing the cost of performing an ECG at the MTC project to the expected costs of performing the same test in another location, having the municipality as the analysis unit. The benefit of the program refers to ECG access in the municipality where the patients reside. To measure this benefit, it is necessary to calculate the cost of transportation that the individuals would generate to undergo the ECG in the absence of the program.

As the city of destination was not been empirically observed and there are no pre-determined institutional parameters in the Programação Pactuada Integrada for the specific case of ECG, we measured the program benefit by assuming two possible scenarios for patient transportation. In the first scenario, we considered that patients undergo the ECG in the closest city/town where the ECG examination and consultation with a cardiologist are provided. In the second scenario, we considered that patients would be treated at the micro-regional center, which, according to the parameters defined by the SES-MG, must provide medium-complexity healthcare services and procedures. This second scenario can be interpreted as the maximum patient transportation distance,

which allows us to infer the maximum cost of patient travel, which allows us to infer the maximum benefit of this program.

To calculate the cost of patient transportation, we included the following categories of expenditures: the cost of transportation, which is usually the responsibility of municipalities, the cost of food during the period of absence from home and the individual's cost of opportunity to miss a day of work. The cost of opportunity refers to the value of labor income the individual does not receive during the time spent going to another city, in search of a healthcare service. These categories refer to the direct costs associated with the displacement of the individual. The inclusion or not of certain categories of expenditure is associated with the study perspective^{11,12}. From the perspective of society, it is usual to include both the direct costs that are the government's responsibility (in this case, municipalities) and the costs that are the individual's responsibility. From the perspective of the government, which is equivalent to the perspective of financing, it is reasonable to include only the cost of transporting individuals to the next municipality. Thus, we evaluated the cost-benefit without the inclusion (situation A) and with the inclusion (situation B) of food and opportunity costs of individuals.

When calculating the program benefit, we considered, in addition to the cost of travel, the cost of food and the opportunity cost, the cost of the ECG that would be performed by the Brazilian Public Health System (SUS) in the absence of MTC project and a consultation with a medical specialist. The ECG examination using July 2008 values, is established by SUS at R\$ 5.15 (five reais and fifteen cents) and the medical consultation at \$ 10.00 (ten reais).

Chart 2 describes the cost categories included in the analysis. The transportation cost consists of fuel costs and the driver's remuneration cost. Rental car values were not

Chart 2 - Description of costs included in the cost-benefit analysis, Minas Telecardio project

Category	Parameter	Description	Source
Cost of Transportation	Driver's hour wage	Hourly wage* of a driver in June 2008†	PNAD 2007
	Driver's hours	Number of hours spent by the driver with the transportation and waiting for examination to be performed	PNAD 2007
	Number of transported people	Number of people transported to receive healthcare assistance in neighbor town	N.A.
	Gas price	Cost of gasoline for patient transportation between towns	Mercado Mineiro Site‡
	N. of Km per liter	Number of km per liter of gasoline	N.A.
Cost of ECG	ECG cost paid to SUS	ECG cost in SUS in July 2008	SIGTAP
Cost of consultation with specialist	Consultation with specialist in SUS	Cost of consultation with specialist in SUS in July 2008	SIGTAP
Food costs	Food costs	Food costs	N.A.
Cost of User's Opportunity	User's hours	Number of hours spent by the user with transportation and waiting for the examination	N.A.
	User's hour wage	Hourly wages* of user of the Public Health System in June 2008†	PNAD 2003

* Hourly-wages refer to the ratio between the individual's income in main job and the number of hours worked in the main job; † The disinflation of hourly wages was accomplished by using the Índice de Preços ao Consumidor Amplo; ‡ comparative price research since the beginning of Plano Real, 14 years ago, until June 2008 (www.mercadomineiro.com.br); PNAD - Pesquisa Nacional por Amostra de Domicílios (<http://www.ibge.gov.br/>); N.A. – Not applicable; SIGTAP - Sistema de Gerenciamento da Tabela de Procedimentos, Medicamentos e OPM do SUS, <http://sigtap.datasus.gov.br>.

considered, as in general, municipalities have their own vehicles for this type of service. In order to perform the cost-benefit analysis it is necessary to calculate the average cost of the ECG performed by the MTC project, including the cost of project implementation and maintenance. In this case, we did not include the costs of evaluation, as they are not directly related to the ECG production itself. Implementation costs, which with the depreciation rate of 20.0% per year would be dissolved in 05 years, were calculated proportionally for the 30-month period of project duration.

Benefit calculation

With the objective of establishing the program benefits, we initially selected the municipalities that did not have an electrocardiograph and cardiologist. For this analysis, we used two sources of information: the Sistema de Informações Ambulatorial - SIA-SUS regarding the second semester of 2006 to the second semester of 2007 and information from the Cadastro Nacional de Estabelecimentos de Saúde (CNES), for the period of November 2006.

The SIA provided information on ECG production in the municipality. The SIA is the payment system for outpatient procedures of the Brazilian Public Health System (SUS), so it has the most reliable information on the availability of a certain type of healthcare service in the town/city. Very often, the municipality declares the existence of the equipment to CNES, which is not being used due to lack of specialized labor to operate it, for instance. CNES verifies the existence of a cardiologist in the city. In this case, we use the most current

information. As the CNES is a dynamic system that receives data on a monthly basis, the information may vary depending on the variation in professional supply in the city. We used the CNES information regarding the November 2006 period, when the MTC project was implemented.

The second procedure when calculating the MTC benefit consists in identifying the neighboring city or town that is a member of the program and that has a cardiologist and ECG production. Once the municipality is identified, the distance between the towns was calculated. The calculation of the distance between the towns was made considering the municipal and state road networks in the State of Minas Gerais (INGE Database / Ministry of Planning, 2002). To calculate the cost of fuel needed to make the transportation, we parameterized the number of kilometers traveled with the vehicle. This parameter was calibrated considering the values of 8 to 10 kilometers per liter of gasoline.

The calculation of the driver's hourly wage was performed using the Pesquisa Nacional de Amostra de Domicílios (PNAD) 2007. Through PNAD, we obtained the value of the average hourly wage, which is the reference value for the parameter. The variation interval was built considering the range of one to 04 minimum wages as the monthly salary and considering a 40-hour work week. The number of hours necessary to perform the transportation of patients was calibrated using two values: 04 or 08 hours. The hypothesis is that the driver, depending on the distance, can make one or two transportations a day. Transportation costs were calculated considering that the

number of persons transported in the vehicle ranges from one to 04 people.

In the case of individuals' hourly wages, which is a proxy for the opportunity cost of missing a day's work, the reference value was calculated using the value of the average hourly wage for individuals living in Minas Gerais and that use the public health system. These data are only available in PNAD 2003. The values were inflated to June 2008. The range of the hourly wages of users was built considering the same range of the hourly wages for drivers, which is a monthly salary ranging from one to 04 minimum wages.

Chart 3 summarizes all the parameters used and the intervals that will be tested in the sensitivity analysis.

Ethical aspects

This study was approved by the Ethics Committee in Research of Universidade Federal de Minas Gerais, Edict #0507/2006, and all study participants gave their informed consent, including healthcare service managers, staff and patients. Every professional involved in handling data for this research signed a secrecy and confidentiality agreement regarding the information, assuring the safeguard of the electronic patient records. The Tele-health Center of Hospital das Clinicas of UFMG, responsible for the telecardiology system implementation, is registered at the Conselho Regional de Medicina, according to Resolution No. 1.643/2002 CFM.

Results

Cost results

Table 1 shows the total costs of the program from June 2006 to December 2008, discriminated by category at June 2008 prices, with implementation costs referring to the initial 06-month period. All values were inflated considering the

Chart 3 - Parameters of the Cost-Benefit Analysis, Minas Telecardio project

Parameter	Reference value	Variation interval
Driver's hour wage	Mean value R\$ 6.40	R\$ 2.59 to R\$ 10.37
Driver's hours	4 hours	4 to 8 hours
N. of Km per liter	8 km per liter	8 to 10
Food costs	R\$ 3.00	R\$ 3.00 to R\$ 5.00
User's hours	4 hours	4 to 8 hours
User's hour wages	Mean value R\$ 4.00	R\$ 2.59 to R\$ 10.37
Number of transported people	3	1 to 4 people
ECG cost in SUS	R\$ 5.15	R\$ 5.15
Consultation with specialist in SUS	R\$ 10.00	R\$ 10.00

SUS - Brazilian Public Health System.

Table 1 - Total cost of the Minas Telecardio project, according to cost typology, from August 2006 to December 2008

Type of Cost	Total value (R\$ June/2008)	Relative participation (%)
Implementation cost	508,037.75	23.81
Maintenance cost	1,310,245.08	61.40
Assessment cost	315,658.31	14.75
Total	2,133,941.18	100.00

IPCA. The total cost of the project is R\$ 2,133,941.18, of which the most relevant category is the program maintenance cost, accounting for 61.0% of the total cost.

In order to determine the average cost of each ECG test, we assessed the electrocardiograms performed in each municipality in the MTC project, from August 2006 to December 2008. Throughout the entire state of Minas Gerais, during the 30 months of the project, 64,000 ECGs were performed, of which 62,865 were available for analysis with complete data (97.0%). The mean cost of an ECG in the MTC project, from August 2006 to December 2008 was R\$ 28.92, with the implementation cost being R\$ 8.08 and the maintenance cost R\$ 20.84.

Cost-benefit analysis results

Tables 2 and 3 show the parameters calibrated for the reference values and the results found, considering the two scenarios for patient transportation. Table 2 shows the results when we suppose that the patients are transported to the closest municipality that offers ECG and cardiologist (Scenario 1). Table 3 shows the results when we suppose the patients are transported to micro-regional center (Scenario 2). In each table, we simulate two situations. In situation A, only the cost of transporting the patient is included in the benefit, and in situation B, the cost of transportation includes the cost components of the patient's opportunity and the food costs.

The results show that the cost-benefit ratio of the MTC program is always positive, regardless of the distance calculation. Considering that the transportation is directed to the closest municipality (Scenario 1), in situation A, when the program benefit included only the cost of transportation plus the cost of the ECG and consultation with the specialist, the cost-benefit ratio is favorable to the MTC project, but the difference is small, around R\$ 2.00.

In this case, the parameterized benefit for reference values is R\$ 30.91, while the cost of the ECG in the program is R\$ 28.92. In situation B, which included, in addition to the cost of transportation, the individual's opportunity costs and food costs, the cost-benefit ratio is quite favorable. In this situation, the benefit of the program is R \$ 49.83, i.e., much higher than the ECG cost in the program, which is R\$ 28.92. In scenario 2, which compares the MTC project with the transportation to the micro-regional center, the ratio is always more broadly favorable in both situations, A and B.

Table 4 shows the results of the sensitivity analysis, considering the transportation to the closest municipality. Each line shows the result by varying one of the parameters,

Table 2 - Cost-benefit analysis considering the reference values of parameters in scenario 1 - transportation to the closest town with available ECG and cardiologist

Cost of ECG in MTC	Benefit	Is the cost-benefit ratio in MTC favorable?	Parameters							
			Driver's hour wage	Driver's hours	Transported people	Gas price	N. of Km per liter	Food costs	User's hours	User's hour wages
Situation A: benefit including cost of transportation. Cost of ECG and cost of consultation										
Values of parameters in reference situation										
R\$ 28.92	R\$ 30.91	Yes	R\$ 6.40	4	3	R\$ 2.32	8	R\$ 0	0	R\$ 0.00
Situation B: benefit including cost of transportation. Cost of ecg. Cost of consultation. Cost of opportunity and food costs										
Values of parameters in reference situation										
	R\$ 49.83	Yes	R\$ 6.40	4	3	R\$ 2.32	8	R\$ 3.00	4	R\$ 4.00

Table 3 - Cost-benefit analysis considering the reference values of parameters in scenario 2 – transportation to the micro-regional center

Cost of ECG in MTC	Benefit	Is the cost-benefit relation in MTC favorable?	Parâmetros							
			Driver's hour wage	Driver's hours	Transported people	Gas price	N. of Km per liter	Food costs	User's hours	User's hour wages
Situation A: benefit including cost of transportation. Cost of ECG and cost of consultation										
Values of parameters in reference situation										
R\$ 28.92	R\$ 35.58	Yes	R\$ 6.40	4	3	R\$ 2.32	8	R\$ 0	0	R\$ 0.00
Situation B: benefit including cost of transportation. Cost of ECG. Cost of consultation. Cost of opportunity and food costs										
Values of parameters in reference situation										
	R\$ 54.58	Yes	R\$ 6.40	4	3	R\$ 2.32	8	R\$ 3.00	4	R\$ 4.00

while keeping the other parameters calibrated according to the values shown in Table 2, considering both situations. In situation A, which is constructed based on the perspective of the health system, i.e., considering the expenses incurred by the State, the cost-benefit ratio has a sensitivity to the parameters of the driver's hourly wage and number of persons transported. Only in extreme calibrations, when we consider the driver receiving a minimum wage per month, or when we consider the largest possible number of persons transported per vehicle, the cost-benefit ratio of the MTC is no longer favorable. In situation B, constructed from the perspective of society, which include the patient's opportunity costs and food costs, the cost-benefit ratio of MTC is always favorable.

Table 5 presents the sensitivity analysis when we suppose the transportation of patients to the micro-regional center. In this case, the cost-benefit ratio of the MTC project is also always positive, not being sensitive to any of the calibration parameters.

Discussion

The present study demonstrates that in the context of healthcare in small municipalities in the state of Minas Gerais, the use of a telecardiology system that includes electrocardiograms and at-distance consultation is favorable

in the originally evaluated scenarios and in almost all situations tested by sensitivity analysis. This result is extremely important for planning health service provision in the country, considering that it demonstrates that the implementation of telecardiology systems is feasible and can reduce costs related to performing electrocardiograms and providing cardiovascular care.

Cardiovascular diseases constitute the leading cause of death in Brazil, accounting for about 30.0% of deaths. Although commonly associated with the lifestyle of large cities, they are also the leading cause of death in small and medium-sized towns, where the high prevalence of cardiovascular risk factors can be observed¹³.

The ECG is a well-established, easy to perform, low-cost method of investigation of the cardiovascular system with a wide clinical usefulness in the detection and management of cardiovascular diseases. The ECG transmitted to distant locations by different methods, such telephone and internet can be used in different clinical situations. While there have been several experiences of tele-electrocardiography in Brazil and in the world^{5,6}, there are limited data about the feasibility and economic benefit of its implementation in the public health system as support to primary healthcare^{5,7}. Molinari et al¹⁴ described the experience with 106,942 patients in Italy, in which the ECG was performed to clarify the cardiovascular

Table 4 - Analysis of sensitivity of the calibrated parameters in scenario 1 – transportation to the closest town with available ECG and cardiologist

Cost of ECG in MTC	Benefit (cost of transportation + cost of ECG* cost of consultation) in R\$	Is the cost-benefit relation of MTC favorable?	Parameters							
			Driver's hour wage	Driver's hours	Transported people	Gas price	N. of Km per liter	Food costs	User's hours	User's hour wages
Situation A: benefit including cost of transportation. ECG cost and cost of consultation.										
Calibrated Parameters										
25.82 to 36.46	Depends	R\$ 2.59 to R\$ 10.57	-	-	-	-	-	-	-	-
39.44	Yes	-	8	-	-	-	-	-	-	-
26.96 to 62.42	Depends	-	-	1 to 4	-	-	-	-	-	-
29.46	Yes	-	-	-	-	8 to 10	-	-	-	-
Situation B: benefit including the cost of transportation. Cost of opportunity. Food costs. Cost of the ECG and cost of consultation.										
Calibrated Parameters										
R\$ 28.92										
44.82 to 55.46	Yes	R\$ 2.59 to R\$ 10.57	-	-	-	-	-	-	-	-
74.44	Yes	-	8	-	-	-	-	8	-	-
45.96 a 81.42	Yes	-	-	1 to 4	-	-	-	-	-	-
48.46	Yes	-	-	-	-	8 to 10	-	-	-	-
51.90	Yes	-	-	-	-	-	R\$ 3.00 to R\$ 5.00	-	-	-
44.26 to 76.18	Yes	-	-	-	-	-	-	-	-	R\$ 2.59 to R\$10.57

symptoms or in routine consultations, but they did not describe any eventual economic benefits. Scalvini et al¹⁵ studied 892 consecutive patients treated by general practitioners also in Italy, observing that the evaluation by consultant cardiologists was capable of significantly reducing referrals to emergency services and new cardiac tests, with significant cost reduction.

Our study is an original contribution to the subject, as it reports a successful, feasible experience, with favorable cost-benefit of the use of telecardiology in the public health system as support of the family health strategy, with the potential to improve cardiovascular care in the country.

An important aspect to be highlighted concerns the quality of published economic analysis studies in telecardiology. Hailey et al⁷ performed a systematic review of articles on telecardiology with clinical, economic or administrative outcomes and found 12 studies with economic outcomes. Analyzing the studies by the quality criteria of Drummond et al¹², the authors call attention to the low quality of the studies, which showed a mean score of 2.7 in a scale ranging from 0 to 10⁷. The present study intentionally followed the established recommendations^{11,12} and specifically addresses the quality questions evaluated in the economic analyses, especially the definition of the evaluated alternatives, with its clearly defined costs, measured and estimated in appropriate and credible units, and adjusted for different moments of

collection. It also highlights the sensitivity study, which allows the evaluation of the results with a variety of scenarios and the use of two perspectives: the government's point of view, from the perspective of funding and society's, which also includes patient costs¹⁶.

In this study, we considered as a benefit of the program the access to ECG, which was the main purpose of the program, but one must consider that the MTC project has other direct and indirect benefits resulting from the implementation of the tele-health system. In fact, it is recommended that economic analysis in tele-health consider the *social gain*, which is the sum of benefits and economic outcomes related to external effects, not considered in the initial analysis¹⁶.

In many of the assessed municipalities, the introduction of tele-health primarily meant the capacity to establish quick and direct communication of doctors and healthcare workers with renowned university centers, interrupting the geographic and social isolation of these locations. To establish the MTC office, the municipalities are prepared to obtain a stable and good quality internet connection, so that the first benefit was the digital inclusion of health centers where the MTC project was installed.

Improvements to the municipalities included in the project not evaluated in this study comprise other tele-health activities undertaken during the project, such as online and offline

Tabela 5 - Analysis of sensitivity of calibrated parameters in scenario 2 – transportation to the micro-regional center

Cost of ECG at MTC	Benefit (cost of transportation * cost of ECG* cost of consultation) in R\$	Is the cost-benefit relation of MTC favorable?	Parameters							
			Driver's hour wage	Driver's hours	Transported people	Gas price	N. of Km per liter	Food costs	User's hours	User's hour wages
Situation A: benefit including cost of transportation, ECG cost and cost of consultation.										
Calibrated parameters										
	30.50 to 41.14	Yes	R\$ 2,59 to R\$10,57	-	-	-	-	-	-	-
	R\$ 44.11	Yes	-	8	-	-	-	-	-	-
	R\$ 30.47 to R\$ 76.45	Yes	-	-	1 to 4	-	-	-	-	-
	R\$ 33.20	Yes	-	-	-	-	8 to 10	-	-	-
Situation B: benefit including cost of transportation, Cost of opportunity, food costs, ECG cost and Cost of consultation										
Calibrated parameters										
R\$ 28.92	R\$ 49.50 to 60.14	Yes	R\$ 2.59 to R\$10.57	-	-	-	-	-	-	-
	R\$79.11	Yes	-	8	-	-	-	-	8	-
	R\$ 49.47 to R\$ 95.45	Yes	-	-	1 to 4	-	-	-	-	-
	R\$ 52.20	Yes	-	-	-	-	8 to 10	-	-	-
	R\$ 56.58	Yes	-	-	-	-	-	R\$3.00 to R\$5.00	-	-
	R\$ 48.94 to R\$ 80.86	Yes	-	-	-	-	-	-	-	R\$ 2.59 to R\$ 10.57

teleconsulting (clinical case discussions with the on-duty physicians in real time or by later response, respectively), in cardiology and other specialties, in addition to the possibility of continuing education of health professionals in distant municipalities by means of participation in the program implementation workshops or courses offered by experts in tele-conference activities.

It is worth mentioning, however, some limitations of the associated analyses.

Regarding the assessment of the MTC project costs, it is important to emphasize that although all expenses incurred for the implementation of the tele-health system have been included in the study, there are costs required to implement the project that were not included in this analysis, either due to the difficulty to obtain real values, or the fact that they were closely related to other activities of the municipal health secretariats. It would be impossible, with the available data, to evaluate what fraction should be attributed to the performing of the electrocardiograms, such as administrative costs of municipalities and local staff involved in the project, as well as the costs of existing facilities that were used for the MTC project.

Similarly to the assessment of costs, there are difficulties in measuring the benefits of the program, specifically the calculation of patient transportation to another municipality. In this case, we chose not to include the cost of the car that

transports the patients, which may have been obtained by contracts with the federal or state government without direct costs to municipalities, but which is often purchased or rented by the municipality. Also included are the car maintenance costs, which are relevant. In general, the inclusion of these costs would result in even more favorable cost-benefit ratios than those observed in our results.

Another aspect that could be more accurately measured is the distance traveled to have the ECG performed in the absence of the program. In this study, we tested two different scenarios, the referral to the closest municipality, where there is a cardiologist and referral to the micro-region center, as the referrals were markedly reduced in the cities after the system implementation and the distance was not measured in real cases. This limitation was a result of the original edict by SES and FAPEMIG / MG that motivated the study, which indicated the need for prompt initiation of telemedicine activities, without enough time to establish a baseline.

In any case, the sensitivity analyses performed indicate significant benefit in almost all situations studied, indicating that the economic benefit is maintained with considerable variations in the studied parameters.

With the initial results achieved, the MTC project was transformed into a program by SES-MG, which has been expanded since 2007 and gradually extended their activities to other areas of Medicine as well as Nursing, Dentistry,

Nutrition, Psychology, Physical therapy and Pharmacy. Moreover, in 2007, the Ministry of Health National Tele-health Project was implemented in Minas Gerais, with the Tele-health Center of HC / UFMG being responsible for the telecardiology activities for the 100 municipalities included in the program and asynchronous teleconsulting activities for 50 of these municipalities. In 2007/2008, SES decided to expand the system to other 97 municipalities and in 2009, to 328, becoming thereafter a tele-healthcare service, called Tele Minas Saúde. In 2009, Universidade Federal de São João Del Rey (UFSJ) was integrated into the Minas Tele-healthcare Network, which now provides Tele-healthcare services to more than 650 healthcare centers.

The cost-effectiveness results reported in this study and the consolidated experience of the Minas Telecardio program, currently Minas Tele-health, strongly suggest that the use of telecardiology in the support of primary care can be cost-effective and feasible in other regions of Brazil and the world, allowing for the limits of variation of parameters considered in the sensitivity study and the studied scenarios. In fact, with the expansion of the program, the implementation costs tend to decrease and the costs to perform each ECG by the system will also decrease, making the cost-benefit ratio become even more favorable.

It should be emphasized that the program used commercially available and low-cost technology and health services provided by the Brazilian public health system, of which costs were computed. Thus, it is not guaranteed that the same positive economic results from the viewpoint of the manager and the society can be obtained in cases where the healthcare provider is private and includes a profit margin, or when using proprietary technology, which has higher costs.

Conclusions

The cost-benefit analysis performed demonstrates the feasibility and economic benefit of the MTC project, even when considering only the direct benefit of performing the ECG. As the implementation of the telecardiology system in

the municipalities brought other benefits not measured in this investigation, the project has a very favorable overall outcome. The implementation of a telecardiology system, in support of primary healthcare in small Brazilian towns can be transformed into a regular public health program with economic benefit, potential impact on cardiovascular disease care and eventually, on the morbimortality related to such diseases.

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Potential Conflict of Interest

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

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Study Association

This study is not associated with any post-graduation program.

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