

# Telemedicine in pre-hospital emergency care: literature review and implementation of a pilot project



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Abstract

*The incorporation of telemedicine in emergency medical system is expanding, with successful results in several countries. The objective is to analyze the opinion of experts about using of telemedicine tools in emergency medicine and to evaluate their technical viability in the pre-hospital care in Belo Horizonte, Brazil. Design: Application of a questionnaire to 40 specialists in emergency medicine from different countries. Assessment of average time of sending, processing and receiving 12-lead EKG data transmission via 3G from different regions of the city. Prospective analysis of telemedicine use in 14 pre-hospital care situations. There was heterogeneity in responses and a large number of unanswered questions by the experts. All regions of the city have shown good technical feasibility in data transmission, with data transmission maximum time of 56 seconds. Similarity between average and mode of analyzed values highlights the homogeneity of the mobile internet coverage. The questionnaire was considered reliable by analyzing the consistency of answers. The experts' feedback heterogeneity may reflect the innovative character of telemedicine. However, there were not positions contrary to the implementation of tele-urgency and tests showed technical viability of this resource in this city. This pilot project testified the viability of telemedicine in the emergency medical system in Belo Horizonte and preceded other initiatives in this field.*

**Keywords:** Telemedicine; Emergency Medical System; Prehospital Care.

Resumen

**Telemedicina en la atención prehospitalaria de urgencias: revisión de la literatura y ejecución de un proyecto piloto**  
*La incorporación de la telemedicina en los servicios de urgencia se encuentra en expansión y demuestra resultados exitosos en varios países. Lo objetivo es analizar la opinión de expertos del área sobre el uso de las herramientas de telemedicina en la medicina de urgencia y evaluar su viabilidad técnica en la atención pre-hospitalaria en Belo Horizonte, Minas Gerais. Diseño: Aplicación de un cuestionario a 40 expertos en medicina de urgencias de diferentes países. Análisis técnico de transmisiones de datos de ECG de 12 derivaciones de diferentes regiones del municipio respecto del tiempo promedio de envío, procesamiento y recepción de los datos por conexión 3G. Se realizó una análisis prospectivo del empleo de la telemedicina en 14 situaciones reales de atención prehospitalaria. Se observó una heterogeneidad en las respuestas y muchas no fueron contestadas por los expertos. Todas las regiones del municipio demostraron una buena viabilidad técnica en la transmisión de datos, con un tiempo máximo de envío de 56 segundos. La cercanía entre los valores promedios y modales evidencia la homogeneidad de la cobertura de Internet móvil en la ciudad. La fiabilidad del cuestionario quedó demostrada por el análisis de la consistencia de las respuestas. La heterogeneidad de opiniones obtenidas reflejó el carácter innovador de la telemedicina. Sin embargo, no hubo posiciones contrarias a la aplicación de la teleurgencia y las pruebas señalaron la viabilidad técnica de este recurso en el municipio. Este proyecto piloto comprobó la factibilidad de la telemedicina en el escenario de urgencia en Belo Horizonte y precede otras iniciativas en el área.*

**Palabras-clave:** Telemedicina; Sistema Médico de Emergencia; Atención Prehospitalaria.

**Telemedicina no atendimento prehospitalar de urgência: revisão da literatura e implantação de um projeto piloto**  
*A incorporação da telemedicina em serviços de urgência encontra-se em expansão, com resultados bem-sucedidos em diversos países. O objetivo é analisar a opinião de especialistas da área sobre o uso das ferramentas de telemedicina na medicina de urgência e avaliar a sua viabilidade técnica no atendimento pré-hospitalar em Belo Horizonte, Minas Gerais. Desenho: Aplicação de um questionário a 40 especialistas em medicina de urgência de diferentes países. Análise técnica de transmissões de dados de ECG 12-derivações, de diferentes regiões do município, quanto ao tempo médio de envio, processamento e recebimento dos dados via 3G. Análise prospectiva do emprego da telemedicina em 14 situações reais de atendimento pré-hospitalar. Observou-se heterogeneidade nas respostas e grande número de questões não respondidas pelos especialistas. Todas as regiões do município demonstraram boa viabilidade técnica na transmissão de dados, com tempo máximo de envio de 56 segundos. A proximidade entre a média e a moda dos valores analisados evidencia a homogeneidade da cobertura de internet móvel no município. O questionário aplicado mostrou-se confiável pela análise da congruência das respostas. A heterogeneidade das opiniões obtidas pode refletir o caráter inovador da telemedicina. Contudo, não houve posições contrárias à implantação da teleurgência e os testes sinalizaram uma viabilidade técnica desse recurso no município. Esse projeto-piloto atestou a viabilidade da telemedicina no cenário de urgência em Belo Horizonte e antecedeu outras iniciativas na área.*

**Palavras-chave:** Telemedicina; Sistema Médico de Emergência; Assistência Pré-Hospitalar.

## INTRODUCTION

The telemedicine can be defined as the delivery and sharing of medical information of a patient at a distance, using telecommunication means. The recent development of telecommunications and new information technologies has improved the availability of a telemedicine system in treatment care.<sup>1</sup>

France, with a very solid experience of Emergency Medical Service structuring, served as pre-hospital care model for Europe and distinct countries in Latin America (including Brazil). In this country, it has been tried several models of incorporating resources of Telemedicine in pre-hospital care, ranging from handheld devices with multiparameter monitors of vital signs until the incorporation of images and video. The French experience shows that the use of telemedicine contributes to improving the care provided to the patient.<sup>2</sup>

The Technical University of Madrid, in activities carried out with the Emergency Medical Service, compared the prehospital attendance held in equipped ambulances with telemedicine resources (electrocardiograph, static imaging equipments and video of the patient and the accident scene) to conventional care, noting significant differences in favor of that relating to the cost and time of attendance.<sup>3</sup>

Japanese experiences with the telemedicine use from ambulances, boats and planes have shown the efficiency of the use of these technologies.<sup>4</sup> The problems identified relate more to the legal dimension of the procedures than the technical aspects.<sup>5</sup>

Since the 90s, in the United States, several solutions have been tested, including video transmissions, medical images and electrocardiographic signals, to allow the trauma specialist to be virtually present at a remote location

and participate in pre-hospital care. In a study conducted by the University of Massachusetts, it was concluded that the use of telemedicine resources increases the quality of the trauma support, reducing morbidity/mortality.<sup>6</sup>

American Heart Association and the American College of Cardiology have recommended the routine use of 12 Lead ECG and an advanced form of notification to the emergency departments in cases of myocardial infarction with ST elevation (STEMI).<sup>7,8</sup> Even though, most US ambulances is not equipped with this technology, reducing the chances of early diagnosis and appropriate treatment. It is known that the time taken to perform a percutaneous coronary intervention in patients with ST segment elevation is crucial in reducing mortality.<sup>9,10</sup> The optimization of this variable can happen with the transmission of ECG to the emergency department before the patient arrives, allowing early identification of the clinical picture and better preparation for the hospital staff, being the telemedicine superior to conventional communication by phone on the question "treatment decision" (use or not use of thrombolytics).<sup>11-13</sup>

In Taiwan, it was tested the transmission via 3G of 12 Lead ECG directly from the ambulance to the doctor on duty at the hospital and a consultant cardiologist and can both simultaneously interpret the test. This made more agile the prehospital diagnosis and optimized the interventions in case of Acute Coronary Syndrome.<sup>14</sup> Similar Danish study confirmed the reduction in time to treat patients with STEMI by prehospital diagnosis aided by telemedicine.<sup>15</sup>

One of the most important indicators of microvascular injury in STEMI is the duration of ischemia. The recovery of left ventricular function after primary percutaneous coronary intervention occurs more pronouncedly in patients with

premature coronary reperfusion (<2 hours). In a prospective observational study in Italy, it was evaluated the impact on the pre-hospital care of ambulances equipped with telemedicine tools, compared to the traditional model. The results have a shorter time between the EKG and the referral to the center of percutaneous coronary intervention; shorter time between the EKG and the intervention; lower total ischemia time. In general, the use of telemedicine allowed a better recovery of left ventricular function, decreased the risk of in-hospital death and increased survival rate after one year.

Experiences in countries such as The USA<sup>6</sup>, Spain<sup>17</sup>, England<sup>18</sup>, Sweden<sup>19</sup>, Japan<sup>4,5</sup>, Korea<sup>20</sup>, Taiwan<sup>14</sup> and Denmark<sup>15</sup> serve as a model for others, such as Brazil, where the incorporation of telemedicine technologies in the Emergency Medical Service (SAMU) is still incipient.

In Belo Horizonte, Minas Gerais, SAMU is responsible for the mobile service, prehospital to traumatic, clinical, psychiatric and obstetric emergencies and count, since 2003, on basic Support Units (USB), Advanced Support Units (USA) and vehicles for simple removal of patients. Through a telephone switch the population has access to the services.

Considering all these well-established experiences with the telemedicine use in the emergency pre-hospital environment, this study aims to evaluate the impact of telemedicine tools in the SAMU in Belo Horizonte city. For this purpose, the opinions of experts from many countries were consulted on the use of telemedicine in emergency medicine; it was held prospective analysis of the technical viability of using this feature in 14 real situations of pre-hospital care; and it was tested the technical feasibility of data transmission via 3G throughout SAMU service territory in the city.

## MATERIALS AND METHODS

This is an exploratory research on the use of telemedicine in pre-hospital emergency care in Belo Horizonte city-MG/Brazil through a case study and quantitative and qualitative approach of experts' opinion in the field through a questionnaire built by the authors. It is not intended thus to test or confirm hypotheses, but probing the concepts of teleurgency and if they could be applied in this particular situation.

### Analysis of experts' opinion on teleurgency

From the reading and discussion of literature available in international databases such as BIREME and PUBMED,

it was used the DELPHI methodology to formulate questions and graded response options on the proposed themes. These statements were sent to experts in the field from all over the world in order to judge and punctuate them according to pre-established graduation by the researchers. The choice of these experts happened from the experience of them in the studies, in the incorporation process and in the use of telemedicine resources in pre-hospital care. Experts from England, France, Colombia and Brazil answered 15 states from the questionnaire, being these ones elaborated in Portuguese, English and French and graduated from 1 to 10, with 1 being equivalent to "strongly disagree" and 10 to "strongly agree". It was obtained a total of forty questionnaires answered: 16 Brazilians, 15 French, 4 Colombians and 5 English. After the return of these questionnaires, it was carried out a descriptive analysis of the answers using frequency tables, bar graphics, Person's Chi-squared test and Fisher's exact test, with a significance level of 0,05. It was used the SPSS software for such analyzes.

### Pilot analysis of teleurgency implementation in the SAMU of Belo Horizonte.

The pilot project was consisted of patients' data transmission attended by a SAMU ambulance of Belo Horizonte via 3G mobile technology. For this purpose, it was used a DX 2021 portable multiparameter monitor, Dixtal@ which features: digital oximetry, automated external defibrillator, a 12-lead digital electrocardiograph, non-invasive intracranial pressure gauge and capnography. The teams from this ambulance were trained by instructors to use such equipments.

### Analysis of the technical feasibility of data transmission via 3G in SAMU service territory of Belo Horizonte

Three transmission of EKG data from each of the 25 different regional from Belo Horizonte, that correspond to the coverage area of the service provided by the SAMU in the study period (2010), were analyzed concerning the average sending time, processing and receiving data.

It was used GPS monitoring pointers of ambulance bases, HCT smartphone for data transmission and a ZOLL brand multiparameter monitor, M Series model.

The acquisition of EKG tests was performed on the spot and the transmissions were made from the same local mobile operator.

The data collected from the smartphone with the Windows CE operating system and Zoll application owner, were sent by email to the Zoll data server, which turns the information into an image file (PDF) and sent to the city hall system by e-mail service through samubh@mail.pbh.gov.br e-mail address. The basic architecture of an e-mail service consists of user agents (MUA – Message User Agents), which are programs used by users for creating and receiving messages, and by a message transfer agent (MTA - Message Transfer Agents), which aims to forward messages from source to destination.<sup>21</sup>

The protocol used for sending messages by e-mail is the SMTP (Simple Mail Transfer Protocol - Simple Protocol of Message Transfer), used both for sending messages from an MUA to an MTA, and for sending messages between two MTA servers. The SMTP aims to transfer reliable and efficient messages.

The information processed in the SAMU system application server provide real-time updates through a Home Page with beep. These procedures do not generate any significant delay between processing and availability of information.

## RESULTS

### Analysis of experts' opinion on teleurgency

From the answers of the experts' questionnaire, it was conducted a descriptive analysis, which is shown in Table 1.

In order to check if there is agreement between the answers, two pairs of similar questions were selected and analyzed the responses of one interviewed (Table 2 – just one pair present). The results obtained indicate a high degree of consistency in the answers.

### Analysis of the teleurgency pilot project in the SAMU of Belo Horizonte

Within the pilot project, fourteen service data were transmitted conducted by the ambulance to different types of calls, as follows: six clinical care (1 case of convulsion, two cases of acute coronary syndrome, two cases of altered level of consciousness and one case of

exogenous intoxication), five inter-hospital transport and three trauma care (one case of automobile rollover, one case of motorbike accident and a pedestrian run over). These patients were referred to hospitals of Belo Horizonte city. All data (vital parameters and EKG, when necessary) were transmitted without losses and in a timely manner by telemedicine resources, and they showed that in this small group tested, the technical feasibility of using this technological resource in real calls.

### Analysis of the technical feasibility of data transmission via 3G service throughout the territory of the SAMU of Belo Horizonte

Analyzing the shipping times of these different areas of Belo Horizonte, each in charge of a SAMU unit, it was noticed that, on average, the time between the sending and receiving of data was 1 minute and 10 seconds. It was also found that in the region with the highest transmission delay, the time was 1min 23s, while in another one in which the transmission was faster, it was 1min 1s. Note the Tables 3.

The speeds prevailing in the data transmission through the mobile Internet of the cellular telephony are:

1. GPRS (General Packet Radio Service), which uses 14,4 kbits/s rate per channel until 57 Kbits/s;
2. EDGE (Enhanced Data rates for GSM evolution), which allows that the data rate reaches more than 384 kbit/s;
3. CDMA EV-DO (Evolution, Data-Optimized) ou 3G, which allows data rates up to 2,4Mbps.

It was found that the majority of transmissions was performed in the EDGE standard and in some cases in the GPRS standard. It was not identified transmissions in the 3G standard. Despite this finding, even in more peripheral regions of the city, with little mobile phone signal coverage, it was possible the data transmission in a quickly and effectively way.

## DISCUSSION

For the Table 1, it can be observed a great heterogeneity of answers and a great number of unanswered questions by experts. As the teleurgency is not yet currently a quite widespread process, with situation even worse in 2010, especially in our community, this heterogeneity may derive from ignorance or insecurity of professionals in relation to its use.

**Table 1 - Descriptive analysis of the answers to questions about teleurgency provided by experts interviewed (n=40)**

Issues	Answer			
	Disagree	Partially Agree	Agree	Total
1. The higher the team's training level of the mobile medical emergency service, lower the sequelae caused by AMI.	0 (0.0%)	8 (20.0%)	32 (80.0%)	40 (100.0%)
2. The higher the team's training level of the mobile medical emergency service, the lower the mortality rate due to AMI.	2 (5.0%)	10 (25.0%)	28 (70.0%)	40 (100.0%)
3. The transmission of the EKG to the center or hospital, minimizes the damage caused by AMI.	13 (32.5%)	13 (32.5%)	13 (32.5%)	39 (97.5%)
4. The transmission of vital data of the victim, acquired in public road and / or in the ambulance on the move, may suffer interference occurring with a mistaken analysis of the same.	13 (32.5%)	16 (40.0%)	8 (20.0%)	37 (92.5%)
5. Once having access to patient care images, as well as his tests, the regulator doctor is legally authorised to guide a medical management.	4 (10.0%)	14 (35.0%)	17 (42.5%)	35 (87.5%)
6. Once having access to patient care images, as well as his tests, the hospital medical staff prepares better for the emergency to be met.	1 (2.5%)	5 (12.5%)	34 (85.0%)	40 (100.0%)
7. The impact of telemedicine on the mobile medical emergency service is higher for polytrauma patients than for patients in clinical emergency.	19 (47.5%)	11 (27.5%)	9 (22.5%)	39 (97.5%)
8. Images and audios captured in the ambulances can become invasion of privacy, since sites like YOUTUBE and MYSPACE, enable the dissemination of materials like this.	14 (35.0%)	11 (27.5%)	12 (30.0%)	37 (92.5%)
9. Consultants via telemedicine can help little in the diagnosis of acute myocardial infarction in cases of atypical manifestations.	10 (25.0%)	16 (40.0%)	12 (30.0%)	38 (95.0%)
10. Nurses and paramedics are not able to differentiate the urgency criteria without medical support, and may underestimate the actual clinical picture of the patient.	10 (25.0%)	14 (35.0%)	16 (40.0%)	40 (100.0%)
11. The sending of 12 Lead EKG decreases the start time of intra-hospital procedures.	8 (20.0%)	12 (30.0%)	15 (37.5%)	35 (87.5%)
12. The acquisition of real-time images and various vital data in the SAMU service site and the sending of these to the central favors the better preparation of hospitals to receive the injured patients – the medical staff can have a better understanding of the severity of the accident through images.	2 (5.0%)	10 (25.0%)	28 (70.0%)	40 (100.0%)
13. The mobile medical emergency service with motorcycles, which has external defibrillator, portable oxygen, basic airway equipments and care to traumas, sphygmomanometer, stethoscope, capillary glucose meter and thermometer and the ability to send such data to the center, has well trained professional and able to equipment handling which leads to a reduction in time to the patient's care when compared to traditional medical service.	7 (17.5%)	14 (35.0%)	18 (45.0%)	39 (97.5%)
14. Considering that the mobile medical emergency service with motorbikes will have faster access to the accident site when compared to the ambulance, the beginning of the attendance time will be reduced.	3 (7.5%)	13 (32.5%)	22 (55.0%)	38 (95.0%)
15. The use of this technology allows greater reliability of clinical patient data, avoiding transmission bias, and consequently, optimizing the conduct, reflecting positively on the clinical outcome.	4 (10.0%)	16 (40.0%)	17 (42.5%)	37 (92.5%)

**Table 2 - Analysis, according to Fisher's exact test to evaluate the correlation between the answers to similar questions**

Question	N total	Question			"p" Value
		Disagree	Partially Agree	Agree	
6. Once you have access to patient care images, as well as the tests of the same, the hospital medical staff prepares better for the emergency to be met.	40	12. The acquisition of real-time images and various vital data in SAMU attendance site and the shipping of these ones to the central favors the better preparation of hospitals to receive the injured patients – the medical staff can have a better understanding of the severity of the accident through images.			
Disagree	1	0	1	0	
Partially agree	5	1	4	0	<0.01
Agree	34	1	5	28	



The evaluation of the reliability of the answers, displayed in Table 2, in which the p-value for the pair of 6x12 and 3x11 questions is significant, it indicates consistency and agreement between these answers. Therefore, it reflects credibility and robustness of the questionnaire and, by extension, its validity in the capture of these opinions.

From Table 3, it is clear that all regions of Belo Horizonte have good mobile internet coverage, with a maximum time of 56 seconds shipping. Although it does not fit the 3g pattern, this coverage is efficient and enables the use of teleurgency resources. The close proximity of the mean and mode of the values shows that the quality of coverage is homogeneous among the regions, being possible, then, the deployment of teleurgency resources globally between the SAMU units in the city.

**Table 3 - Statistics of shipping time of the data obtained in the pre-hospital care, including vital signs and 12 Lead ECG**

Statistics	Average time of shipping, in seconds	Average time of processing, in seconds	Average time of receiving, in seconds
Mean	46	24	70
Mode	44	22	68
Standard Deviation	05	03	06
Maximum	56	31	83
Minimum	39	21	61

The teleurgency is in an expanding process, which is proven by several studies currently published in the scientific literature about the subject. Thus, it is understandable obtaining a variety of opinions on the use of this technology in pre-hospital emergency care. However, numerous studies<sup>4-6,14-20</sup> reveal unequivocally the benefits of the telemedicine use in this pre-hospital emergency setting.

The city of Belo Horizonte has an organized structure of mobile emergency service and prehospital medical emergencies. The measurement of the potential positive impacts of the use of this technology in the care provided by the SAMU until now can not be performed due to the sample size obtained. However, the efficient transmission of data from 14 patients treated by the unit tested in this study and experiences of literature indicates benefits to the patient in the emergency pre-hospital care.

Through the questionnaire applied to the experts in medical emergencies, it was not observed a resistance to the adoption of these resources, although still exist some ignorance.

The introduction of telemedicine resources in pre-hospital care is a reality in many developed countries and this incorporation is taking place gradually in other locations. The transmitted information can be obtained by means of multiparametric monitors and / or imaging devices such as the ultrasound. It has already been described several technologies that allow this process to send information, such as WI Max, satellite and cellular telephony (3G and GSM / GPRS), 22 which guarantee the confidentiality of medical and assistance database, and the selection of priority information and initial shipping of these ones in case of transmission failures.<sup>23</sup>

After five years of this pioneering project, the technological advances have facilitated and expanded the use of telemedicine opportunities in the prehospital medical service of urgency and emergency. It was already proved the benefits of data transmissions through telemedicine to assist the pre-hospital care and direct the medical centers that will receive the patients. However, it was not observed in the city of Belo Horizonte the effective adhesion of these tools in emergency mobile services. In Emergency Care Units, however, the AMI Care Line with tele-electrocardiogram resources allowed greater access of the population to appropriate treatment and, consequently, reduction in hospital mortality through AMI.<sup>24</sup>

With feasibility of using the resources in the demonstrated city in this study, it is clear that the deployment of these resources in the mobile service units would be an important gain for the health service and for the local population. Projects on a larger scale are needed to assess, at this moment, the clinical results and impacts of the telemedicine tools.

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