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How to Improve Emergency Information Systems to Optimize the Care of Acute Stroke

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Abstract

The quality of the healthcare provided in the context of cerebrovascular accident (stroke) is closely linked to the celerity of the diagnosis, so the action of health professionals must be coordinated, and all the processes should proceed as quickly, efficiently, and effectively as possible. In turn, the crowding of emergency services contributes for considerable high delay times. The research study reported by this paper aimed to identify features to include in the emergency services information systems to improve the contribution of the medical imaging within acute stroke diagnosis and treatment. Medical imaging processes related to Head Computed Tomography and Angio Computed Tomography in a medium-size Portuguese were analyzed to identify possible improvements. Moreover, semi-structured interviews were conducted involving a group of health care professionals with experience in pre- and intra-hospital emergency services to identify the needs that can be satisfied with innovative technological solutions and to assess the viability to introduce additional features in the information systems supporting the emergency services. The results show that additional features might be considered to improve acute stroke diagnosis and treatment and the health care professionals are receptive to these improvements.

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1. Introduction

Waiting times in hospital emergency services are sometimes considerably high, contributing to poor patient outcomes, and poor patient and family experiences [1,2]. Possible contributions for high waiting times in the emergency services include an overall increase in patient volume and rise complexity and acuity of the clinical situations, and the lack of infrastructures [3,4], including short age of nursing and administrative staff, limited physical space, and restrictions in terms of beds for patients' admission. Moreover, organizational issues also contribute for the waiting times in the emergency services, including ineffective communication [5], delays in receiving results from medical imaging, laboratory and ancillary services, and complexity of medical record documentation [4].

The crowding of emergency services effects the care of patients with acute cerebrovascular accident (stroke). The first hours after the onset of symptoms are essential for the treatment, which means that there is a time window that allows the clinical procedures to be effective [6]. This means that the action of the healthcare professionals must be optimized and a sequence of diagnostic tests, imaging studies, and interventions must be accomplished in an efficient and timely manner [7,8], which has motivated several studies to evaluate the acute stroke care management [8-10].

Medical imaging workflows are supported by several information systems, including Hospital Information Systems (HIS), Electronic Health Record (EHR) systems, Radiological Information Systems (RIS), Picture Archiving and Communication Systems (PACS), and, in some cases, Teleradiology systems [11-13]. Much of the pertinent information related to the stroke patients is distributed by these various information systems, so their database are very relevant data resources for the optimization of the care processes over time [14,15].

The research study reported by this paper aimed to identify possible features to include in the emergency services information systems to improve the contribution of the medical imaging within acute stroke diagnosis and treatment. For that, the authors characterized the medical imaging procedures being performed in the context of acute stroke diagnosis and treatment of an emergency service of a Portuguese medium-size hospital and analyzed medical imaging studies data to identify points of improvement. The analysis highlighted the need to create alert mechanisms that might be based on data already available in the existing information systems. Finally, semi-structured interviews were conducted to gather the opinions of a group of healthcare professionals experienced in pre- and in-hospital emergency services about the feasibility of adding new alert mechanisms to the existing information systems, aiming to improve the care of patients with suspicious of acute stroke.

Five sections compose this paper: the section two is based on a literature review and analysis current research related to the optimization of emergency services to guarantee the time window required for acute stroke diagnosis and treatment. Sections three and four respectively present the methods and the results of the study reported by this paper. Finally, section five is devoted to the discussion of the results and to draw a conclusion.

2. Background

According to the World Health Organization (WHO), stroke is a focal or global neurological impairment, of vascular origin, which can lead to death, caused by an interruption of blood supply to the brain [16].

In the world, it is estimated that 15 million people suffer a stroke each year, and of those, six million do not survive [17], which justifies the worldwide concern of improvement of the care of acute stroke patients. Stroke remains among the leading causes of long-term disability due to the countless physical, mental, and social sequelae [10,18].

Reperfusion therapies have revolutionized the treatment of acute ischemic stroke and they present significant improvement in mortality and functional outcomes [10,19,20]. However, the benefits of reperfusion therapies are clearly time-dependent: the possibility of achieving a favorable outcome among patients treated with intravenous thrombolysis compared to placebo, decreases with the increase of delays in the treatment [21]. Thus, reducing the onset-to-treatment time it is of paramount importance [21]. In this respect, the guidelines for early management of acute ischemic stroke of the American Heart Association/American Stroke Association (AHA/ASA) recommend the administration of reperfusion therapies within 4.5 hours of symptom onset and within one hour of arrival at a hospital [22].

As a result, given the prevalence of stroke, one of the most important quality indicators of health care is the percentage of patients with stroke who receive timely treatment. The optimization of this indicator is dependent on the management of an important set of barriers.

The first barrier to stroke treatment is the accurate and timely recognition of the onset of stroke symptoms. Since most patients experience symptoms in the community and not in a medical setting, this may represent the greatest delay in some cases [8]. Implementing strategies to address this barrier falls within the responsibilities of public health (e.g., to increase lay people's awareness of stroke) and, therefore, it is important to educate general population on common stroke presentations and how to effectively activate emergency medical services [8].

Once the patient arrives at the hospital, efforts are necessary to streamline in-hospital sequence of diagnostic tests, imaging studies, and interventions pathways [21]. However, this sequence requires the cooperation of multiple specialties into interdisciplinary teams, and adequate infrastructures, including the ones of the medical imaging services, which means that effective stroke treatment must be systematically planned to optimize workflows and maximize expeditious treatment with an emphasis on communication and teamwork [8,21].

Different strategies and protocols that affect emergency services response and coordination of patient presentation to the hospital have been shown to reduce delay times. A key to factor is the ability to fulfill multiple tasks while the patient may be otherwise occupied or in transit. These include prenotification, rapid triage protocols, rapid realization of laboratory and medical imaging evaluations, prompt feedback, and a dedicated interdisciplinary "stroke code" team with members from emergency medicine, neurology, and medical imaging to expedite diagnoses and treatments [8,23]. The comprehensive nature of these strategies requires an institution-wide culture of active quality improvement, and emergency services should seek out opportunities for continuous improvement, namely by gaining knowledge about best practices [8].

The research related to the optimization of the medical imaging services in the acute stroke treatment is extensive but focused on process-specific (e.g., using process mining [24] to enhance the clinical pathway [24]) and patient-specific factors. However, recent studies focused on how operational environments of care, including the crowding of emergency services, may affect the management of acute stroke patients [9].

Long waiting times related to a large flow of patients in need of care are also a common problem in medical imaging services [25]. The lack of response capacity of medical imaging services in carrying out the request of the emergency services can have a significant impact on patients' waiting times [6]. Since inefficient management of workflows generates inefficient responsiveness in the provision of healthcare [26], the use of software tools to manage workflows might allow the balancing of workloads and can increase the efficiency and effectiveness of the available medical imaging services [27].

In Portugal, given the relevance of a rapid provision of care to victims of stroke in the acute phase, it was implemented in 2005 a stroke code mechanism at the national level, the Stroke Green Way (SGW) [28]. It intends to be a coordinated strategy to improve the referral and treatment of emerging patients with a suspicious stroke clinical condition, in the pre-hospital, intra-hospital and inter-hospital phases [29]. Until the year 2020, more than 38 thousand patients were able to benefit from the SGW for a better and faster treatment [26].

In the presence of any of the stroke warning signs, the patient, or whoever watches the occurrence, should immediately contact the European Emergency Number 112. According to the regulations and guidelines, after contact with 112, the Urgent Patients Orientation Center (Centro de Orientação de Doentes Urgentes – CODU) must confirm the suspicion of stroke, activate the stroke code and the emergency transport [30]. Referral from the CODU must be directed to the emergency service of the nearest hospital with a specialized SGW team.

In a hospital emergency, the SGW team must provide immediate attendance, perform the ABC assessment (i.e., A - Airway maintenance with cervical spine control, B – Breathing, and C - Circulation with haemorrhage control), and confirm the acute stroke diagnosis, including review of the time and circumstances of symptom onset, previous medical history, general and neurological objective examination, as well as the quantification of the neurological impact, using the National Institute of Health Stroke Scale (NIHSS) [30]. Regarding the use of complementary means of diagnosis, those normally used refer to i) medical imaging, ii) electrocardiogram (ECG), and iii) laboratory evaluation, namely blood count with platelets, coagulation study and blood glucose. In turn, the medical imaging evaluation may include Head Computed Tomography (Head CT) and Angio Computed Tomography (Angio CT) [31].

In general, the EHR systems are connected to the RIS, so that the later systems present an update list of the medical imaging studies being requested. Moreover, the results of the imaging studies carried out are stored in the PACS.

When an acute stroke is suspected, computed tomography studies must be analyzed by a neuroradiologist. As hospitals often lack neuroradiologists, Teleradiology systems have been adopted to allow neuroradiologists to remotely access imaging studies (stored in PACS) to be able to carry out their reports. Whatever the option, in person or remote, the reports produced by neuroradiologists are stored in the RIS.

3. Methods

Considered the objective of the study reported by this paper (i.e., identifying features to include in the emergency services information systems to improve the medical imaging services within acute stroke diagnosis and treatment), a mixed method research was performed:

- Processes mapping techniques [32] were applied to understand the operation of medical imaging services to support acute stroke care in a medium-size Portuguese hospital. Mapping techniques allow both the analysis of workflows already implemented and their restructuring, as well as the identification of new workflows in order to determine all stages and decisions of a process so that it can be continuously improved [3,25,33].
- The existence of multidisciplinary protocols when performing medical imaging studies in the context of acute stroke seems to contribute to the reduction of response time, providing an improvement in clinical results [34]. Therefore, data related to medical imaging studies were used to characterize the procedures being performed, as well as to identify points of improvement.
- Semi-structured interviews were conducted involving a group of health care professionals with experience in pre- and intra-hospital emergency services. The interviews aimed at identifying the needs that can be satisfied with innovative solutions based on information technologies and to assess the viability to introduce additional features in the information systems supporting the emergency services.

The research study reported by this paper was authorized by the board of directors of the selected medium-size hospital after being approved by the respective ethics committee. The anonymity of the healthcare professionals and patients involved in the study was fully guaranteed.

4. Results

4.1. Processes Mapping

In the scope of healthcare services, processes mapping (i.e., an exercise to identify all stages and decisions of a process so that it can be continuously improved [33]) is important as good processes tend to be translated into an overall improvement in the provision of healthcare [35]. On the other hand, processes mapping allows to understand the reality of the services through the description of their functionality and workflows management [36]. Moreover, the use of modelling and simulation tools for workflows allows both the analysis of workflows already implemented and their restructuring, as well as virtual simulation of new workflows [3,25].

Since the stroke imaging evaluation may include Head CT and Angio CT, the authors performed the mapping of the processes and information systems used to support the carry out of Head CT studies and Angio CT studies. Therefore, two processes were considered (Fig. 1):

- P1 - Head CT process characterized by the time interval elapsed from the moment the study is requested and the moment it is validated in the RIS, that is, when the medical report is available (Figure 1).
- P2 - Angio CT Process characterized by the time interval between the moment when the Head CT study is performed and the end of the Angio CT study (including images post-processing).

The Head CT process (P1) was divided into:

- P1.1 - Patient transport to the imaging department: time interval elapsed from the moment the Head CT is requested, and the moment the study starts on the CT equipment, which might be obtained by the field [Routine Study Requisition Time] of the RIS and the field [Routine Study Requisition Time] of the PACS.
- P1.2 - Perform Head CT: time interval between the beginning of the acquisition of images on the equipment and the closure of the study at RIS, which might be obtained by the field [Routine Study Execution Time] of the RIS and the field [Routine Study Acquisition Time] of the PACS.
- P1.3 - Head CT reporting execution: time interval elapsed between the moment of study archive completion at the Teleradiology system and the study validation moment at the RIS, which might be obtained by the field [Routine Study Validation Time] of the RIS and the field [Teleradiology Storage Time] of the Teleradiology system.
- P1.4 - Head CT Report Validation: time interval elapsed between the moment of the study execution and its validation at the RIS (i.e., the moment when the report is obtained), which might be obtained by the field [Routine Study Validation Time] and the field [Routine Study Execution Time] of the RIS.

In turn, the Angio CT process (P2) was further divided into:

- P2.1 - Angio CT decision time: time interval that elapses between the execution of Head CT and the request of an Angio CT, which might be obtained by the field [Angio CT Study Requisition Time] and the field [Routine Study Execution Time] of the RIS.
- P2.2 - Angio CT procedure: time interval that elapses between the start of image acquisition from Angio CT and the completion the post-processing of the images, which might be obtained by the field [Angio CT Post Processing Time] and the field [Angio CT Study Acquisition Time] of the PACS.

4.2. Characterization of the Processes

One of the aspects to be highlighted is the fact that within of the acute stroke diagnosis and treatment several information systems are used (i.e., HIS, EHR, RIS and PACS and the Teleradiology system). This distributed nature of information systems makes it difficult to identify situations of delay in the different SGW processes. In turn, data fields belonging to RIS, PACS and Teleradiology systems can be used to characterize the process and sub-processes associated to medical imaging workflow, namely in the context of suspected stroke in the acute phase.

Head CT studies carried out over a year on patients with suspected stroke, integrated into the hospital SGW, were analyzed in the period from August 1, 2017, to July 31, 2018, aiming to identify the duration of the different processes and sub-processes.

Head CT studies conducted on 464 patients were analyzed: 245 (52.8%) males and 219 females (47.2%). Of these patients, 198 (42.7%) also performed Angio CT.

In terms of process characterization, the request for the Head CT study carried out at RIS was considered the starting point. When the patient arrives at the CT room, requisition data is sent to the imaging equipment and the study is performed. At the end of the image acquisition, the study is considered completed being registered in the RIS as "executed". After the transmission of the images to the PACS database, the study is sent to the Teleradiology system. Depending on the results of the Head CT, the patient may be a candidate for Angio CT and endovascular treatment. Therefore, when an Angio CT is also required, it is performed after the realization of the Head CT.

Concerning the process analysis, Table 1 shows the statistical results of the time spent in Head CT studies (P1) and Angio CT procedures (P2). Surprisingly, minimum values of zero minutes were identified. However, these situations occur when the process is considered complete in one information system (e.g., RIS), but has not yet completed in another information system (e.g., PACS).

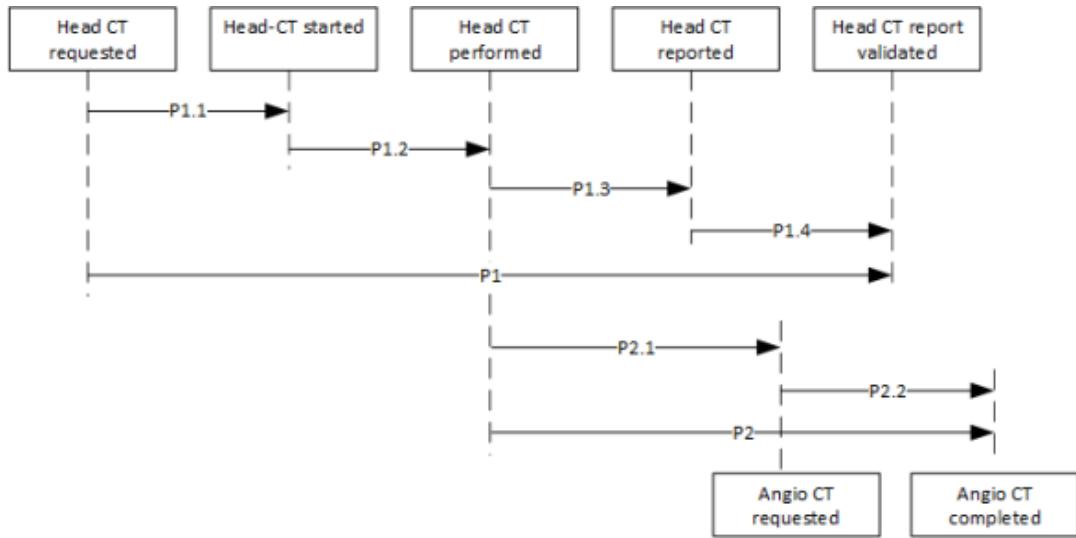


Fig. 1. Processes mapping.

Table 1. Descriptive Statistical analysis results over the processes being considered (hours:minutes).

	P1	P1.1	P1.2	P1.3	P1.4	P2	P2.1	P2.2
Average	00:47	00:19	00:05	00:16	00:24	00:23	00:09	00:10
Median	00:38	00:14	00:05	00:12	00:17	00:13	00:02	00:10
SD	00:37	00:28	00:03	00:17	00:24	00:55	00:46	00:03
Max	05:47	05:24	00:27	03:38	03:41	10:51	10:16	00:28
Min	00:12	00:00	00:00	00:01	00:06	00:00	00:00	00:05
1st Quartile	00:30	00:07	00:04	00:08	00:13	00:10	00:00	00:08
3rd Quartile	00:52	00:23	00:06	00:18	00:25	00:19	00:05	00:12

From the results, it is possible to identify the maximum time values of both processes carried out within the scope of the SGW. Although the maximum time values are high, 25% of the patients that underwent a Head CT study obtained the respective report in less than 30 minutes. In the case of patients whose clinical decision determined the need for an Angio CT, this process was completed in less than ten minutes for 25% of the patients. Moreover, 25% of the patients that performed Head CT waited for the report for more than 52 minutes, and of those who performed Angio TC, 75% completed this process in less than 19 minutes (Table 1).

According to Table 1, 25% of the patients wait less than seven minutes before the respective studies were performed, the images were acquired in less than four minutes and the reports were delivered in less than eight minutes. In some cases, significant standard deviations were identified, namely regarding the waiting time to enter to the CT room and the waiting time for the report, which has repercussions on the mean and median values. Regarding the decision times for performing Angio CT, for 75% of the patients, this time was less than five minutes (Table 1).

However, also in Table 1 it is possible to identify significant maximum time values. For example, a patient waited five hours and 24 minutes to enter to the CT room and another patient waited three hours and 38 minutes for the report. These abnormal situations could be identified by the aggregation of data stored in the different information systems.

4.3. Semi-Structured Interviews

The interviewees are multidisciplinary health professionals, physicians and nurses of emergency services pre-hospital emergency technicians from the National Institute of Medical Emergency (Instituto Nacional de Emergência Médica – INEM), diagnostic and therapeutic technicians, and developers of healthcare information systems. The interviewees were chosen due to their experience within the SGW, namely, in terms of the CODU, the first entity to activate SGW, and in the triage, diagnostic and treatment, including intensive medicine, neurology and medical imaging.

The interview guide included an introduction to the presentation of the interviewer and the interviewee, an explanation of the study and the respective ethical and regulatory framework, as well as the reading, presentation, and clarification of informed consent that each participant had to read and sign before the interview. Regarding the questions, they sought to determine: i) the opinions of the interviewees regarding the organization of the SGW and the role of information systems in its different processes; ii) the key aspects to be improved in terms of organization, management and resources, namely in terms of information systems, as well as the barriers that may condition these changes; iii) how the different interviewees are using solutions based on information technologies to optimize their performance, as well as the difficulties they face; iv) how aspects related to information management, interoperability, internal and external communication, quality, certification, or ethical and transparency are being addressed; and v) suggestions regarding additional features that could be implemented to improve the information systems that support the SGW.

The interviews were organized to have an estimated duration of approximately 60 minutes and to be carried out in a place with conditions to allow the audio recording, which was authorized by each of the interviewees, with signing the informed consent.

Considering the statements and opinions of the interviewees, in general the procedures have already been improved in recent years and “there has been an effort made by the institutions, both INEM and hospitals to improve the SGW processes”. Moreover, the interviewees revealed that they themselves optimize the procedures to the extent that they could do.

Regardless of their areas of expertise, all the interviewees agreed that information systems are an essential asset for operation and coordination of the SGW. One of the interviewees mentioned that “there are flaws that could be easily solved with technological solutions and a better information management”, while another said that “the institutions realized that it is necessary to improve the information management and systematically articulate the procedures between professionals from different specialties in line with the main objective of SGW (i.e., help, identify and treat the patient with an acute stroke)”.

Particularly, in the pre-hospital emergency, the articulation with the referred hospital could be optimized, since “the activation of stroke code continues to be done by telephone, which means that a computerized and automatic activation system could be implemented”. Also, in the hospital emergency, new technological solutions could be introduced “in the emergency, a sticker is affixed to the patients waiting for Head CT to distinguish them as the highest priority patients, because in the list of Head CT orders, the radiographer does not know if within the higher priority patients, there are patients with the stroke code activated, and the sticker is used to identify, manually, these patients”. In the opinion of one interviewee “automating this process could put the SGW patients in the top of the radiographer priorities”.

On the other hand, “the monitoring of the patient who suffered a stroke does not end with the hospital discharge, and after that, it is important to introduce applications to support both the stroke patients and their informal caregivers”. To consolidate what was achieved in the acute phase treatment during the patient recovery, the extension of the features of the hospital information systems, namely in terms of interoperability, were considered key aspects.

During the interviews, it was noticeable that some interviewees revealed a self-taught way of circumventing and optimizing the points they identified as “overcome”, that is, they identified points that could make a difference in their performance. For example, “there are small, simple things that could be done, however, I am not waiting for an institutionalized solution, and I simply adopt self-agility and optimization measures that I can implement”. It should be noted that some interviewees have already looking for specific information-based applications: “at the level of information systems, I use them for the benefit of my professional performance and to optimize the management and

treatment of the patient. I have identified several mobile applications that I use to measure the duration of the different processes, namely from the street to the Head CT medical imaging study”.

5. Discussion and Conclusion

Within the scope of the research study reported by this paper, the processes mapping of the requisition and the realization of medical imaging studies of acute stroke victims enabled a better understanding of the paths taken by the patients in the hospital, particularly in the medical imaging department and regarding the SGW initiative.

In the case of the Head CT characterization, it was possible to identify procedures that can promote delays, which might negatively impact the diagnosis and treatment of patients with suspected acute stroke. From the moment of the request of a Head CT study until the patient enters the CT room, there is significant variability in the time spent (SD - 28 min), and 25% of the patients wait more than 20 minutes before the beginning of the study. In particular, the identification of a patient that wait five hours and 24 minutes entering the room may deserve special attention. The same reasoning can be used for the analysis of the other sub-processes.

Regarding the studies' execution time, the values obtained show that, in general, the processes are efficient, both in the Head CT study (average of five minutes) and in the Anglo CT studies (average of ten minutes). However, for some patients, it was identified delays much longer than the average.

The time associated with some sub-processes carried out within the scope of the SGW initiative, namely before the patient's arrival at the medical imaging department (e.g., patient transportation and laboratory data acquisition) contributes significantly to higher waiting time to diagnosis. The fact that the processes are all dependent on each other, a punctual poor performance in a specific sub-process can compromise the whole process, since it is the sum of the time spent in all processes that give the relevant data to determine how long it takes to conclude a diagnosis.

The data collected allowed the identification of situations that may negatively impact the timely treatment of patients with acute stroke. In this respect it was anticipated the relevance of automatic and real-time alert systems to facilitate the adoption of best practices, as well to identify of situations that may promote the deterioration of the health conditions of the patients as well as compromising their prognosis in multiple clinical contexts, namely beyond stroke.

The study allowed to conclude that the data available in the different systems supporting the medical imaging services might be used by alert systems. Moreover, the interviews that were conducted involving a group of health care professionals with experience in pre- and intra-hospital emergency services show that the professionals that work daily in the diagnosis and treatment of acute stroke are very receptive to the improvements of the existing hospital information systems.

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