Proposal of a System for Intracranial Pressure Telemonitoring

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***Abstract*— The Intracranial Hypertension (ICH) is a neurological condition that affects patients with head injury, stroke and hydrocephalus. Currently, the most suitable treatment for this clinical condition requires continuous monitoring of cerebral function by the analysis of clinical parameters associated with cerebral perfusion. In this context, two parameters are relevant for clinical decision: the analysis of the waveform of intracranial pressure and the temperature. Ideally, a neurosurgeon should have access to this information during the whole period of treatment. However, in most cases this is not possible, because of the limited number of available professionals in this area. Possible consequences for this are delays in clinical interventions and the application of misleading procedures that may result in the death of patients or in worse prognostics. This research proposes the development of a system for temperature and intracranial pressure (ICP) monitoring. It will be developed a computer program that estimates and presents online and continuous relevant information regarding the ICP waveform and intracranial perfusion. This system will contain a remote evaluation module in addition to continuous monitoring at bedside, allowing the provision of periodic information about the evolution of the parameters of ICP, cerebral perfusion pressure (CPP) and intracranial temperature (ICT) via software application available in the mobile phone of the specialist. The software will be validated with synthetic and experimental data. Furthermore, it will be employed in a clinical study with 50 patients in order to compare the performance of two distinct types of equipment commonly used in the monitoring of the ICP. The results of this study will contribute to the improvement of current ICP monitoring systems, which may contribute to the reduction in morbidity and mortality of neurocritical patients.**

Keywords-Intracranial Pressure; Cerebral Perfusion; Telemonitoring.

I. INTRODUCTION

The Intracranial Pressure (ICP) is the measured pressure inside de skull that is influenced by the cerebrospinal fluid (CSF), blood and cerebral tissue volumes, which are maintained at a constant rate under normal conditions. The ICP is the sum of the pressure on the internal wall of the skull. Any volume alteration in the brain and its structures may cause the raise of the ICP, and consequently, changes in the cerebral perfusion [1-3].

In this context, the assessment of intracranial hypertension is of paramount relevance. From literature, it is known that intracranial hypertension occurs when the ICP remains above 15 mmHg measured with the patient in supine position for a prolonged period of time [4].

The ICP monitoring is an important parameter in the area of neurosurgery because in events such as head injury there is a large possibility of ICP increasing. This is proved by studies reporting that 40% of patients suffering from head injury and admitted in an unconscious state have an increased ICP. In addition, 50% of the patients die because of the raise of the ICP [5].

Furthermore, ICP must be monitored because it provides a reliable way of confirming or excluding intracranial hypertension [6]. Unfortunately, the monitoring of the ICP is limited to hospitals that have access to advanced technology and multidisciplinary teams, making the process of ICP monitoring expensive.

The high costs involved in continuous monitoring of ICP have called attention of a number of organizations in the area of telemonitoring, mainly, because it allows for a single professional, i.e., the neurosurgeon, to monitor a number of patients in distinct hospitals simultaneously and remotely.

Thus, the telemonitoring of ICP in neurocritical patients is crucial because it promotes a fast and reliable assessment of the state of patients while reducing the cost of having the presence of a specialist in all locations.

In this context, the main aim of this research is to develop a system for remote monitoring of ICP. This system should to be able to capture, process, monitor and send online information regarding the main parameters estimated from the ICP waveform to a remote device, i.e., a smart phone available to the professional. In addition the whole information will be stored in an online database for further analysis and visualization.

The structure of this paper is as follows: In Section 2 we describe the methodology that will be used to develop the tool, including the block diagram of the project and the steps of development. In section 3 we discuss the system dependability of the system. In section 4 we outline the implications of this approach and the future directions of our research.

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II. METHODOLOGY

The methodology used in the execution of this research will employ modern software engineering concepts and system design. The diagram depicted in Fig. 1 shows the main steps that will be applied in this project. It is important to note that the system development process is iterative and non-sequential. In this way, the knowledge obtained in any of the stages shown in Fig. 1 can be used as feedback in the development of any of the steps.

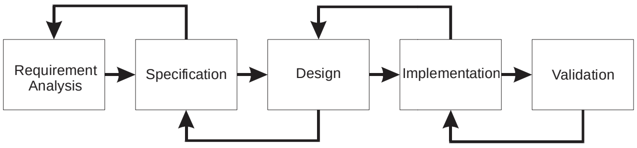

Figure 1. Main steps for developing the system for intracranial pressure telemonitoring.

In the *Requirement Analysis* stage will be identified the specific requirements regarding the monitoring of neurocritical patients in a joint action between the research groups in Neurosurgery and Biomedical Engineering of the Federal University of Uberlândia, Uberlândia, Brazil. The results of this step will guide the development of computational tools.

The *Specification* stage consists in the development of a documentation that describes as accurately as possible the architecture of the proposed system. Use-case diagrams will be used in order to assist the communication between the developers and the end user. These types of diagrams describe the scenario that shows the functionality of the system from the user's point of view. In addition the Unified Modeling Language (UML) [7] will also be employed for the specification and documentation of the system. The main block diagram of the proposed system is shown in Fig. 2.

The *Design* step consists in modeling the (i) interfaces for interaction with the user, as showed in Fig. 3, (ii) database (iii) reports, indicators and queries. The following information will be available in the conclusion of this step: entity and relationship diagrams, data flow diagrams and Graphical User Interface (GUI) design, detailing menus and sub-menus as well as their sequence of operation.

The step *Implementation* is the use of computational tools (e.g. compilers and programming languages) for the implementation of the system design as defined in the step "*Design*".

The *Validation* will be focused on the following aspects: (i) validation of the graphical interface with the end user; (ii) validation of the information generated by the system; and (iii) clinical validation of the system, i.e., the system will be used in a clinical study, with 50 patients, for comparing the performance of two distinct methods for measuring the ICP.

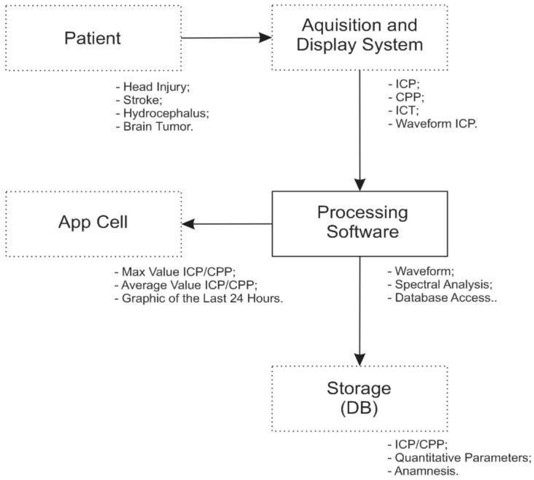

Figure 2. General structure of the system.

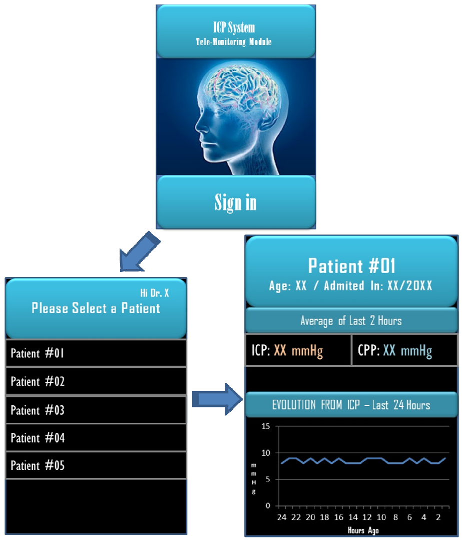

Figure 3. Model of a possible graphical user interface of the system.

Figures 4 and 5 depict typical user case scenarios for the proposed system. When the ICP is normal, the alarm is off (Figure 4) and both the specialist and the staff are following the routine parameters of the patient. In contrast, when the ICP is abnormal (Figure 5), the firing of an event will set off the alarm so that the specialist and staff can act promptly.

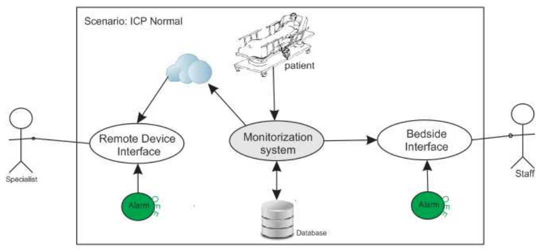

Figure 4. User case scenario when the intracranial pressure is normal.

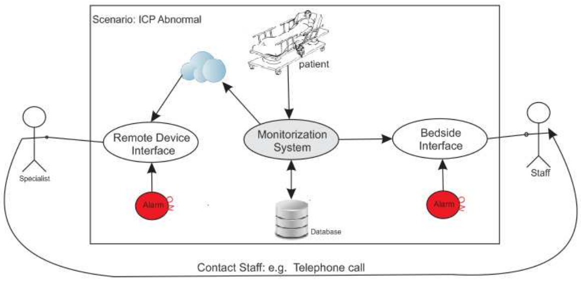

Figure 5. User case scenario when the intracranial pressure is abnormal.

III. SYSTEM DEPENDABILITY

Dependability assesses the quality and reliability in the service provided by a system [8]. This parameter is even more desirable when it comes to biomedical systems for monitoring or life support, due to stringent requirements regarding the availability and reliability of the system, as it is for health maintenance.

It is known that failures are inevitable, but the consequences of the failures, the interruption in the supply of the service and data loss can be prevented by proper use of some techniques that tolerate failures [9]. It is important to note that these tools have a certain cost, thus, users and developers should assess the cost-benefit in each case [10]. The system proposed in this research provides the specialist with further mobility; however mobility can put the patient at risk in the event of a failure in the communication about the state of the patient to a specialist.

For ICP monitoring is necessary a high reliability and availability of the system, in order to minimize the impact in the event of faults, e.g., loss of network connection. A possible mechanism to address these issues would be to include in the system additional alarms, and also distinct communication service providers, so that failures are perceived immediately, and communication can be guaranteed or reestablished as quick as possible.

IV. CONCLUSION

ICP monitoring is a very useful tool, particularly for patients suffering from head injury, mainly because, in this condition, a high measure of ICP reduces brain perfusion. For this reason, we propose to develop a tool for data processing, analysis and remote visualization of ICP parameters and waveform.

The use of the proposed tool in clinical practice allows the continuous monitoring of the ICP and hence of the state of patients. This will be a relevant tool for both the clinical staff at bedside and also for the neurosurgeon that might assess the condition of the patient remotely.

The next steps of the work will be: Finishing the conditioning system and digitalizing the analog signal of the ICP and posteriorly, the development of tools for the digital processing of information from ICP. After, will be implemented the databases. On the last stage, we will develop tools for communication between mobile systems and the bedside systems of information processing and storage.

V. ACKNOWLEDGEMENTS

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REFERENCES

[1] N. Lundberg, "Continuous recording and control of ventricular fluid pressure in neurosurgical practice," in *Neurosurgical Classics II*, R. Wilkins and G. Wilkins, Eds.: THIEME, 1960, pp. 66-185.

[2] I. Piper, "Intracranial Pressure and Elastance," in *Head Injury - Pathophysiology and management of severe closed injury*, P. Reilly and R. Bullock, Eds. London: Chapman & Hall, 1997, pp. 101-120.

[3] R. Hamilton, P. Xu, S. Asgari, M. Kasprowicz, P. Vespa, M. Bergsneider, and X. Hu, "Forecasting Intracranial Pressure Elevation Using Pulse Waveform Morphology," in *31st Annual International Conference of the IEEE EMBS* Minneapolis, Minnesota, 2009, pp. 4331-4334

[4] H. M. Shapiro, "Anestesia Neurocirúrgica e Hipertensão Intracraniana," in *Tratado de Anestesia*. vol. 2, R. D. Miller, Ed. San Francisco, Califórnia: Manole, 1989.

[5] J. D. Miller, D. P. Becker, J. D. Ward, H. G. Sullivan, W. E. Adams, and M. J. Rosner, "Significance of Intracranial Hypertention in Severe Head Injury," *Jornal of Neurosurgery*, 1997, pp. 503-516.

[6] B. North, "Intracranial Pressure Monitoring," in *Head Injury - Pathophysiology and management of severe closed injury*, P. Reilly and R. Bullock, Eds. London: Chapman & Hall, 1997, pp. 209-216.

[7] R. S. Pressman, *Software Engineering: A Practitioner's Approach*, 6 Edition ed.: McGraw-Hill Science/Engineering/Math, 2004.

[8] D. K. Pradhan, *Fault-Tolerant System Design*. New Jersey: Prentice Hall, 1996.

[9] F. L. Vargas, D. V. Lettnin, D. B. d. Brum, and D. P. Prestes, "A New Learning Approach to Design Fault Tolerant ANNs: Finally a Zero HW-SW Overhead.," in *Proceedings of the 11th IEEE Asian Test Symposium - ATS'02*, Los Alamitos - CA, USA, 2002, pp. 218-223.

[10] T. S. Weber, *Tolerância a falhas: conceitos e exemplos*. Porto Alegre - RS, Brazil. Editora da Universidade Federal do Rio Grande do Sul, 2000.