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Implantation of a Boarding System for Supervision and Angulometric Tilt Adjustment of beds in the ICU of the Adriano Jorge Hospital Foundation in Manaus-AM

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Abstract*—Concern about the high mortality rates in ICU beds in Brazil, as a result of the acquisition of Pneumonia associated with Mechanical Ventilation (PAV), triggered a series of movements in an attempt to establish procedures for its prevention. Studies indicate that the maintenance of decubitus between 30 ° and 45 ° of inclination, attenuates the invasive effects of mechanical ventilation equipment and promotes the favoring of diaphragmatic performance, significantly reducing the hospitalization time of patients submitted to mechanical ventilation. However, the Hospital Infection Control Committee (CCIH) of the Hospital Adriano Jorge Foundation (FHAJ), through its collaborators, found difficulties in the regulation of ICU beds, due to the lack of adequate measurement equipment for regulation. Through the implantation of an embedded system in Arduino microcontroller and the association of several components of sensing and communication, the development of the inclination measuring device became possible. Equipped with an alphanumeric LCD display and an Ethernet network module, the auxiliary supervision and adjustment device proved to be the solution for the decubitus regulation process, since besides allowing local real-time gauging and visualization, the module provided the sending of information to the Hospital's internal network (LAN), enabling general monitoring from the computer screen. With the built-in audible alert system for improper slopes, the correct angulation for PAV prevention could be maintained at optimal levels, eliminating human failures from carelessness and giving patients greater treatment safety.*

Keywords*—*Clinical engineering, hospital automation, pneumonia.

I. INTRODUCTION

The Adriano Jorge Hospital Foundation (FHAJ), belonging to the Indirect Administration of the Executive Branch, belongs to the health institutions of the State of Amazonas, linked to the Unified Health System (SUS). Currently has 188 beds, available to the Surgical, Medical and Orthopedic Clinics; 12 beds for the Intensive Care Unit (ICU) and the Surgical Center for Orthopedics and General Surgery [1].

The anousy infrastructure and the limitation of resources destined to the acquisition of new medical equipment of high technological value, makes it impossible to follow up and support the new discovered procedures, and consequently the appropriate treatment to patients hospitalized in these hospital units. The current picture differs from private hospitals, where supplies are abundant and equipment with state-of-the-art technology. However, for both cases, the absence of important functions in hospital equipment becomes clear when analyzing the relevance of the application, although there is the possibility of implanting such systems.

Through the application of microcontroled hardware, the present work aimed to offer, at low cost, the necessary assistance tool for the treatment of patients submitted to mechanical ventilation, aiming at reducing mortality rates and providing the required security in the process of Angulometric adjustment.

II. THEORETICAL REFERENCE

2.1 The problem of pneumonia associated with mechanical ventilation (PAV)

Pneumonia can be defined as an inflammation of the lung tissue that affects the small air sacs called pulmonary alveoli[2]. There are several factors that lead to the

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development of respiratory infection, among them is Ventilation Associated Pneumonia - PAV. The onset of this infection is directly related to the use of artificial mechanisms for oxygen supply, the affected part being the majority of the patients found in intensive care units.

PAV is the main nosocomial infection in patients requiring mechanical ventilation (MV). In fact, it is not associated with ventilators, but rather with the artificial ducts that persist during the treatment with invasive mechanical ventilation. MV prolongation is a complicating factor for the increase in mortality and morbidity in ICUs, since the risk factor for nosocomial pneumonia increases from six to twenty times in patients with orotracheal intubation and MV [3].

In a database analysis comprising more than 8,000 patients on mechanical ventilation for more than 24 hours, 9.3% of pneumonia was reported, with the mean time being between intubation and the diagnosis, of 3.3 days. In a study conducted in 99 Brazilian hospitals, pneumonia accounted for 28.9% of all nosocomial infections, and of these approximately 50% occurred in mechanically ventilated patients. An increase of 13.3 days in ICUs was estimated due to the acquisition of VAP, being rated as the second most common infection and the third in the field of mechanical ventilation, accounting for 63.7% of the cases[4].

2.2 Angulometric adjustments in ICUleeds for pav reduction

The disposition of the patient in the bed is one of the factors that can intervene directly in respiratory mechanics in patients submitted to mechanical ventilation (MV). Depending on the positioning imposed on mechanically ventilated patients, there may be a favor in diaphragmatic performance [5]. In addition to reducing the risk of pneumonia, some postural arrangements may directly affect the possibility of better distributed alveolar ventilation, as well as the possible reduction of the risk of lung injury induced by ventilation [6].

According to the *IIIConsensoBrasileiro de VentilaçãoMecânica*[7], an important intervention that can be used to attenuate the PAV is the elevation of the head of beds between 30 and 45 degrees of inclination, avoiding the probability of aspiration of enteral nutrition and of the gastric substance during reflux. The degree of random elevation of the backrest and the length of stay in the horizontal position are aggravating factors for VAP, since low elevations are intrinsically associated with increased gastric content aspiration [8]. In this way, it is recommended to raise the head in the 30 ° to 45 ° range.

A studyentitled "*Impacto de ação educativa na manutenção do decúbito elevado como medida preventiva de pneumonia associada à ventilação mecânica em Unidade de Terapia Intensiva*" [9], developedattheUniversity Hospital of Londrina, proposedaneducationalaction for 49 healthprofessionals. At the time, it was found that the lack of clarity about the importance of maintaining high decubitus was shown to be the main risk factor for patients undergoing mechanical ventilation. In order to remedy the problem, educational interventions were promoted with health officials in order to alert the severity of hospital pneumonia and the need to implant and supervise daily maintenance of the elevated decubitus.

According to the study, after the educational action and the insertion of illustrative posters above the beds, showing the importance of angulation adjustment, an increase in the mean of backrest angulation was observed between the pre-intervention period (27.85 ± 6,76º) and the first month after intervention (30.71º ± 9.06º), with progressive reduction of this average in the subsequent periods when the poster was withdrawn. The observation of the progressive decline in adherence to this recommendation was also confirmed by another study [10], where it was observed a decrease in inclination from 28º to 22º in a few weeks.

III. METHODOLOGY

Scientific research was based on the imminent need for a real-time angles measurement equipment, pointed out by the Director of Teaching and Research of the Hospital Adriano Jorge Foundation. From the literary research, which pointed to the global problem of Pneumonia Associated to Mechanical Ventilation, a prototype was developed in order to aid in the regulation and adjustment to optimal levels.

The starting point for the elaboration of the prototype was the identification of possible elements that could meet the needs of the project. As a fundamental element, the GY-541 Module that uses the MPU6050 IC was the one chosen for measuring slope angles, because it presents versatility and good price. However, because it is characterized as accelerometer and gyroscope and not an angulometric sensor, the variables of measures had to be manipulated through mathematical relations to reach the ends.

Knowing that the sensor has 3 axes of measures agreed as axis x, y, z, and that the sensor has 16-bit accuracy, totaling 216 = 65,532 measured analogue levels in unit of measure "g", was made from the acceleration of the gravity, calibrations with the sensor positioned horizontally (Fig.1).

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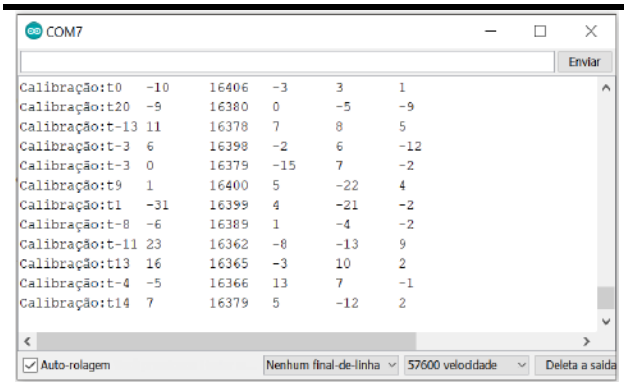

Fig. 1: Sensor Calibration
Source: Arduino IDE Serial Monitor

From the transformation of variables, it was possible to obtain the readings at practical levels for the angulometric calculation. All the received responses are represented in accelerations in the 3 axes of the sensor and, through the mathematical relationship listed below(1).

$$\theta_x = \tan^{-1}\left(\frac{a_x}{\sqrt[2]{{a_y}^2 + {a_z}^2}}\right) (1)$$

It was possible to transform the acceleration into angulometric values (Fig.2).

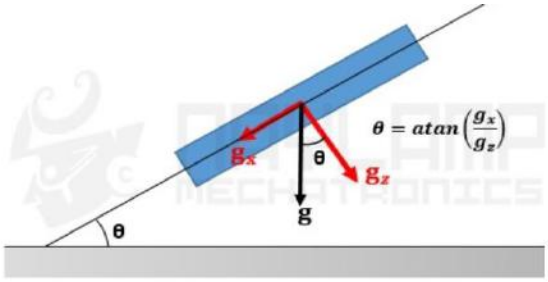

Fig. 2: Two-dimensional transformation relation
Source: www.naylampmechatronics.com

Once the angles were obtained, the next step was the interconnection between all elements for sampling and communication. All values, then controlled by the Arduino Nano microcontroller, were manipulated to provide the man-machine interface. The data needed to be shown to the user, therefore, LCD display for local sampling and Ethernet module were used to send information to the internal network of the hospital, being possible the monitoring and supervision from any computer connected to the network.

In addition to the elements described, also included were the audible alert items, for angles outside the specified range, and potentiometer for adjusting the contrast and brightness of the LCD display (Fig.3). Subsequently, the angulometric sensor was separated from the set by USB cable, in order to provide greater malleability in positioning below bed headers.

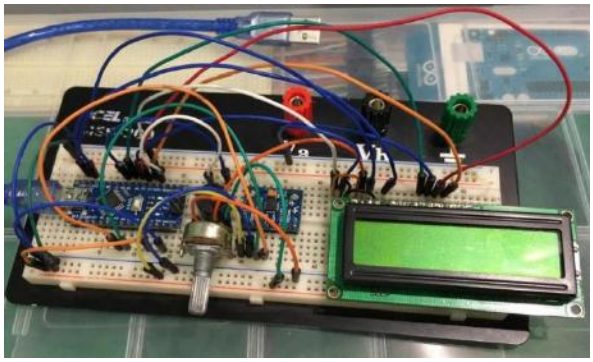

Fig. 3: Prototype in protoboard test
Source: Author, 2019

IV. ANALYSIS AND DISCUSSION OF RESULTS

Faced with the need of the Adriano Jorge Hospital Foundation, studies on possible solutions to the problem were put in focus. Considering the existence of such functionalities in beds of high monetary and technological value, the possible proposal should use two perspectives: efficiency and low cost. Both have been achieved, in addition to paving the way for possible implementations. All the components used in the elaboration of the model have undergone adjustments - both in the physical characteristics and in the logics - to obtain the best arrangement among the elements.

With the arrangement made, the communication between the subsystems became effective, allowing the heat dissipation and easy removal of components for possible maintenance. The device was subdivided into two sets: the first for visualization and control, consisting of microcontroller, display, battery, keys, buzzer, potentiometer, wires and connectors; the second restricted for measuring measurements, consisting of sensors, boards, wires and cables connected via USB. The conditioning and the final arrangement have two forms of power: mobile (battery) and fixed (electric grid), and buttons for sectioning and switching, costing $ 44.25 (Fig. 4).

Fig. 4: Final prototype
Source: Author, 2019

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Methods previously adopted by the Hospital Infection Control Commission (CCIH) team could be considered archaic and ineffective. In the first attempt to obtain adequate adjustment (Fig. 5), a goniometer (medical instrument for measuring angles) was used, and a blue tape attached to the wall behind the bed for calibration of the slope. The intention was to raise the headboard until it was positioned above the blue ribbon. The applied method failed because it was necessary to elevate and front view simultaneously, requiring two employees for the procedure.

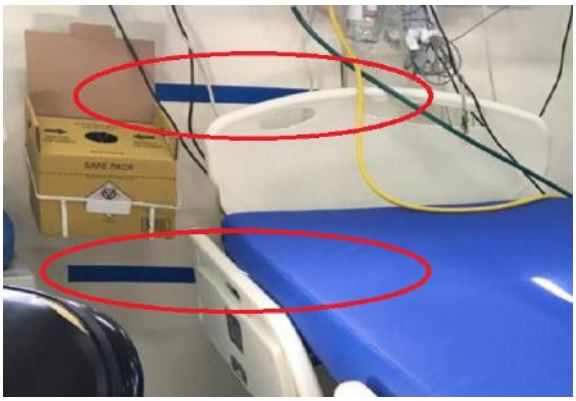

Fig. 5: First adjustment attempt
Source: Author, 2019

In the second attempt (Fig. 6), two small-sized ribbons were interposed between the lateral body support and the lateral bed support. By means of the lifting process, it is known that at some point the ribbons would align, indicating the predetermined correct angulation. The method made it impossible to select angles of inclination, since it was necessary for this purpose, the application of several tapes in the same place, besides making the work exhaustive and difficult to visualize.

Fig. 6: Second adjustment attempt
Source: Author, 2019

The angulation accuracy acquired by the accelerometer sensor was ± 0.05 degrees, making the module highly effective for the desired application. In addition, the sensory measurement levels were the best, and the device could operate in adverse conditions such as: lack of light, high levels of vibration and humidity, and temperatures between -20ºC and 85ºC. These characteristics added to practicality and mobility allowed the device to be adjusted in all places near the ICU beds (Figures 12,13).

Fig. 7: Device under ICU bed test
Source: Author, 2019

After performing tests at the Hospital Adriano Jorge ICU and proving its effectiveness by local servants, it was possible to perceive that the proposed solution would also cure the difficulty found in the research carried out at the University Hospital of Londrina[8], where the progressive reduction in the angulometric levels of beds after the educational action could be noticed. Through the technological application, the ability to visualize values and the sound signals embedded in the device - similar to the car seat alert system - corroborated with the elevated decubitus, since for positioning below 30 ° and above 40º, sound signals were issued, "obliging" the regulation.

Through the Ethernet interface and the RJ45 network connection port, the device has been enabled to connect to the Hospital's local network, and data can be read from any computer in the foundation. With this increase, and subsequent replication of the device for each ICU bed, it will be possible to create a bed supervision system in real time, with a history of measurements, calculation of averages of elevation of decubitus in the treatment of the disease, identification of each patient in the period of hospitalization and, monitor positioned in the therapy center for general visualization of angulometric levels.

At the end of the results, the Hospital Adriano Jorge Foundation started using a device capable of accurately expressing the values obtained in the bed slope adjustment process, making it the only public hospital in the region to use the technology. And, as a result of the visibility achieved, feasibility studies are being carried out for possible implantation in other Public Health Units.

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V. CONCLUSION

The use of engineering for the purpose of treating patients in hospital units was always present. A hospital complex is endowed with numerous assistance tools, which together enhance the clinical treatment and reduce the average time of hospitalization of patients. However, like all new technology introduced in the market, the investment required to acquire these modern equipment is extremely high, making the implementation of these devices in public health institutions, considering the current Brazilian political scenario.

Given the social perspective, the care given to low-income patients must be equated with those received by the wealthiest population. Although there is no possibility of obtaining all the equipment found in large private hospitals, alternatives with reduced costs need to be idealized and developed for medical treatment in public health networks. In this sense, this work was presented as an alternative accessible to the current means of life support, exhausting all the deficiencies of angulometric regulation and enabling the insertion of new components of sensing and communication in a single module.

At present, the beds found in the ICU of the FHAJ, are equipped with mechanical systems for lifting the set of platforms. Motors associated with the gear set can be manipulated from manual and selective control and the user can select the correct incline from the display on the designed measuring device. In a second stage of work, the independent subsystems that now function in a mutual and complementary way, could be converged to a single monitoring and control system, due to the fact that the designed hardware has a built-in microcontroller.

In short, through the use of care equipment used to prevent pneumonia, the reduction of the average time of hospitalization of patients can be achieved, as well as the consequent reduction of costly costs to the public coffers, thus allowing the redirection of resources to related areas.

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