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A Respiratory Follow-Up and Warning System for Cleft Palate Infants

Berkant Talha CAN[1], Özge ÜSTÜNER[1], Melike EREN[1], Ceyda ÜLKER[1], Gür Emre GÜRAKSIN[1]*
[1]Department of Biomedical Engineering, Engineering Faculty, Afyon Kocatepe University, Afyonkarahisar, TURKEY

*Sorumlu Yazar:
E-mail: emreguraksin@aku.edu.tr

Abstract

Cleft palate is a disease which happens if the tissue that makes up the roof of the mouth does not join together completely for various reasons during the development of the baby in the mother's womb. In cleft palate babies, the upper and lower respiratory tracts are open to each other, and it is very likely that fluid may escape during vomiting or the baby's own spit may escape. Often babies are vomiting during sleep and are therefore at risk of suffocation. Under these conditions, parents have to keep watch and observe the baby while the baby is sleeping. Considering the daily sleep time of a baby, it is very difficult for a family with cleft palate to follow up the breathing of the baby. This situation prevents family members from fulfilling their personal responsibilities and prevents them from their daily lives. Given all these disadvantages, there is a need for a system that will support family and baby. In this paper a system with a bed was designed to follow up the respiratory of a baby with a cleft palate. If the infant stops breathing while sleeping, the bed will automatically be raised to the upright position and the family will be alerted with an alarm. The recommended system will greatly benefit the family for the care of the cleft palate infants and will reduce the risk of suffocation while the baby is sleeping.

Keywords: Cleft Palate, Cleft Palate Infants, Respiratory Follow-Up, Smart Bed

INTRODUCTION

Cleft lip and cleft palate are completely two different clinical situations which are presented with different clinical signs and symptoms because of their embryonic developments, pathogenesis and location. Their treatments are also completely different. Although cleft lip may be associated with a cleft palate and/or a part of sign of a syndrome [1-3]. The incidence of cleft lip and cleft palate varies in all over the world. But, the incidence of cleft lip and cleft palate in Turkey are 1/1000 and 1/2500, respectively [1]. The etiology of the cleft lip and palate may be multifactorial but it can be classified as environmental and genetic basically. In figure 1, illustration of laterality of oral clefts are given [4].

Life risk for cleft palate is more than cleft lip. In cleft palate babies, the upper and lower respiratory tracts are open to each other. Due to this condition, it is common for the infants to run out of fluid during the vomiting or to escape the spit of his / her own saliva. Often babies are vomiting during sleep and are at risk of suffocation. In this case, the risk of suffocation is quite high in children with cleft palate.

Treatment age for cleft lips in children is 10 to 12 weeks old age when the treatment age for cleft palate is 12 to 18 months old age [1,2,3,5]. Therefore, the family should keep a close watch on the baby during this period. Under these conditions, parents have to keep watch and observe the baby while the baby is sleeping. Considering the daily sleep time of a baby, it is very difficult for a family with cleft palate to follow up the breathing of the baby. This situation prevents family members from fulfilling their personal responsibilities and prevents them from living their daily activities. Given all these disadvantages, there is a need for a system that will support family and baby. In the literature Spillman et al. present the results of research aimed at the development of a 'smart' bed to non-intrusively monitor patient respiration, heart rate and movement using spatially distributed integrating multimode fiber optic sensors. The research is especially focused on allowing more automation of patient care, an especially important matter for the elder population, which is a rapidly growing fraction of much of the world population today [6]. In another study Yousefi et al. designed a smart bed platform that addresses one of the most costly, acute health conditions, pressure ulcers - or bed sores. The proposed platform collects information from various sensors incorporated into the bed. By the data collected from these sensors the system analyzes the data to create a time-stamped, whole-body pressure distribution map, and commands the bed's actuators to periodically adjust its surface profile to redistribute pressure over the entire body [7]. On the other hand, Hart et al. describes an approach to contact-free respiration monitoring that addresses these shortcomings by employing a highly sensitive capacitance sensor to detect variations in capacitive coupling caused by breathing. They built a prototype system that consisting of a synthetic-metallic pad, sensor electronics, and iPhone interface [8].

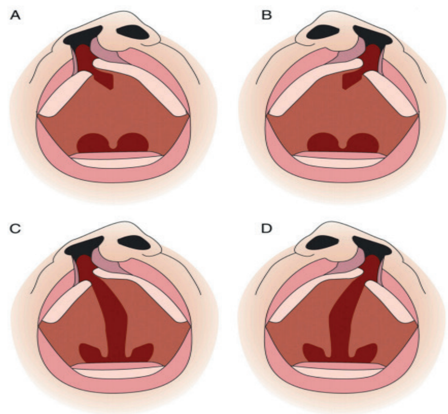

Figure 1. A-Right unilateral cleft of the lip and alveolus. B- Left unilateral cleft of the lip and alveolus. C-Right unilateral cleft of the lip and alveolus with cleft palate. D-Left unilateral cleft of the lip and alveolus with cleft palate [4].

In this paper a system with a bed was designed to follow up the respiratory of an infant with a cleft palate. If the infant stops breathing while sleeping, the bed will automatically be raised to the upright position and the family will be alerted with an alarm. The recommended system will greatly benefit the family for the care of the cleft palate infants and will reduce the risk of suffocation while the baby is sleeping.

MATERIALS AND METHODS

As we mentioned before the risk of suffocation is quite high in children with cleft palate. In order to prevent this and support the family, in this study a smart bed was designed as the flow chart of the system was given in figure 2. For this, first, the baby's breathing should be monitored. When babies breathe in, or inhale, their diaphragm contracts (tightens) and moves downward. This increases the space in their chest cavity, into which their lungs expand. The intercostal muscles between their ribs also help enlarge the chest cavity. They contract to pull their rib cage both upward and outward when they inhale. This event repeats for a certain period. If this period does not repeat for more than 15-20 seconds, the respiration is stopped [9]. Starting from this point of view in this study, respiratory movements are monitored from the baby's abdomen by using a flex sensor. The Flex Sensor patented technology is based on resistive carbon elements. As a variable printed resistor, the Flex Sensor achieves great form-factor on a thin flexible substrate. When the substrate is bent, the sensor produces a resistance output correlated to the bend radius-the smaller the radius, the higher the resistance value. Flex Sensors usable for many applications like automotive controls, medical devices, measuring devices, etc [10]. In this study, monitoring of respiration was performed with the help of a flexible sensor placed on the abdomen of the infant. When breathing stops according to the time reported in the [9], the alarm is triggered, and the head of the bed comes upright position by the help of servo engines. Thus, it is aimed to prevent the infant from having no more fluid flow to the trachea and it is intended to facilitate the excretion of the escaped fluid into the respiratory tract. In this study, a buzzer was used to alert the parents while breathing stops. Buzzer is a device that provides different audio signals according to the given voltage. They are used in many areas due to their low cost, simple production and very light structure. There are several kinds of buzzer. In this study we used the most basic one which is a piezoelectric buzzer. It is just a flat piece of piezoelectric material with two electrodes. Besides alerting the family, when the device alarms it brings the head position of the bed to the upright position by the help of servo engines. The servo circuitry is built right inside the motor unit and has a positionable shaft, which usually is fitted with a gear. The motor is controlled with an electric signal which determines the amount of movement of the shaft.

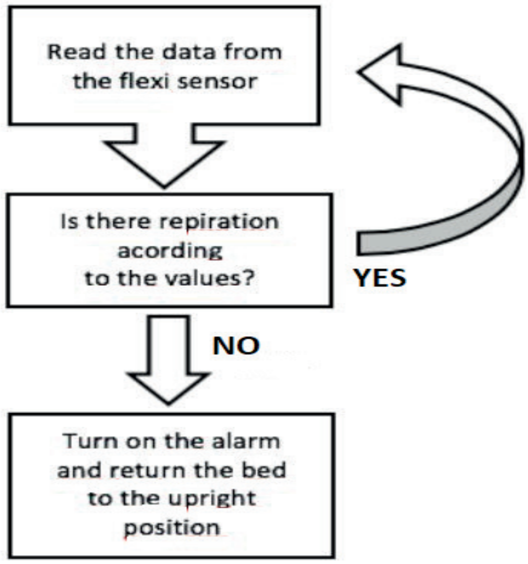

Figure 2. Flow Diagram of the System

Inside of servo there is a pretty simple set-up: a small DC motor, potentiometer, and a control circuit. The motor is attached by gears to the control wheel. As the motor rotates, the potentiometer's resistance changes, so the control circuit can precisely regulate how much movement there is and in which direction.

When the shaft of the motor is at the desired position, power supplied to the motor is stops. If not, the motor is turned in the appropriate direction. The desired position is sent via electrical pulses through the signal wire. The motor's speed is proportional to the difference between its actual position and desired position. So, if the motor is near the desired position, it will turn slowly, otherwise it will turn fast. This is called proportional control. This means the motor will only run as hard as necessary to accomplish the task at hand [11]. The system adjusts the angle of the bearing head using these features of the servo motor. The solidworks drawing of the system was given in figure 3. The position of the servomotors is given by the red color.

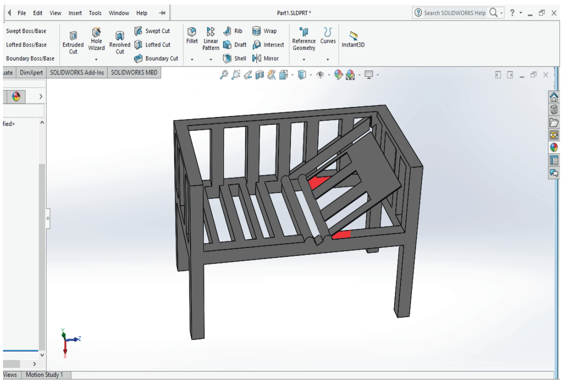

Figure 3. Solidworks design of the system

We used the Arduino as a microprocessor to control the servo motors and buzzer according to the data from the flex sensor. The Arduino Uno is a microcontroller board which has 14 digital input/output pins.

RESULTS AND DISCUSSION

In this paper a system with a bed was designed to follow up the respiratory of an infant with a cleft palate. If the infant stops breathing while sleeping, the bed will automatically be raised to the upright position and the family will be alerted with an alarm. The respiratory condition of the baby is monitored by using a flex sensor. When babies breathe in, or inhale, their diaphragm contracts (tightens) and moves downward. When each breath is completed, the lung still contains a volume of air which is called the residual volume. Each inhalation adds additional air to the lungs. As well each exhalation removes approximately the same volume as was inhaled. So, in the light of this information, the graph that should be a normal respiration by means of functional residual capacity is given in figure 4 [12]. In addition, the tidal volume graph of controlled mechanical ventilation is given in figure 5 [13]. Therefore, we expect a normal breathing to be the similar to the graph given in figure 4 and 5.

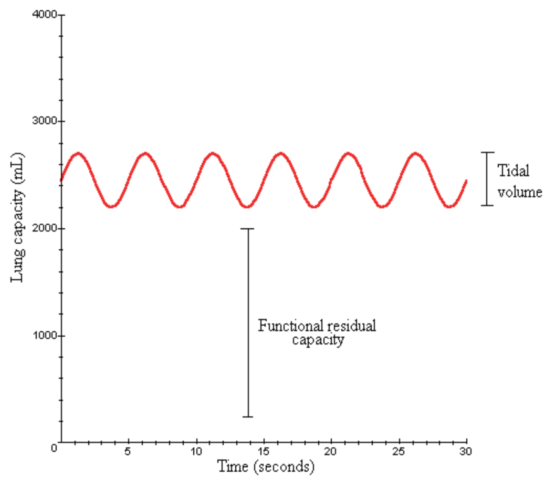

Figure 4. Time dependent, respiratory-volume graph

Figure 5. Controlled Mechanical Ventilation

In order to test the system, a model infant with artificial respiration (mechanical ventilation) was designed. For this purpose, using an air pump motor, air is fed into a cuff. When the air is supplied, the drain cover is closed and the cuff inflates. The air vent of the supplied air is provided by opening the drain cover. Artificial respiration was occurred by repeating this procedure at regular intervals. Arduino Uno was used as a microprocessor to determine how much and how many seconds this engine would pump air. This system was placed in the belly of a baby model. In this way, a model doll which makes artificial respiration was created to test the system. During the testing phase, a flex sensor was placed on the model's abdomen which makes artificial respiration. The data from this sensor is given as figure 5 by graphically from the serial plotter screen where Arduino can display the data as moving.

As shown in figure 6, the respiratory graph obtained from this system was consistent with the tidal volume graph of controlled mechanical ventilation given in figure 5. By using this model (artificial baby) the smart bed system we developed in this study was tested. As long as the artificial baby was breathing regularly, the system continued to monitor the baby's breathing. When breathing stops according to the time reported in the [9], the alarm is triggered, and the head of the bed comes upright position by the help of servo engines. As a result of the experiments it was seen that the system was working properly. By the way, it is aimed to prevent the infant from having no more fluid flow to the trachea and it is intended to facilitate the excretion of the escaped fluid to the respiratory tract.

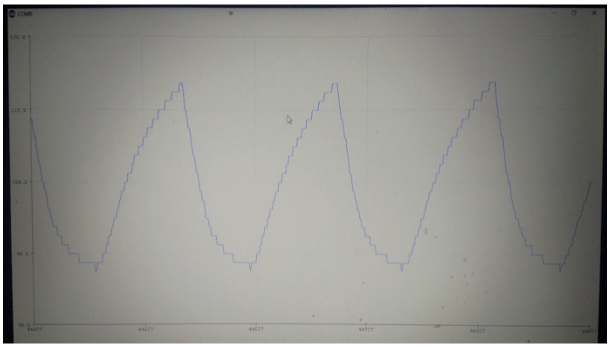

Figure 6. Respiratory-volume graph (with artificial respiration) according to the data from flex sensor

CONCLUSION

This paper provides a smart bed system for the cleft palate infants to follow up the respiratory of the infant and to alarm the family when the breathing of the infant stops. Often babies are vomiting during sleep and are at risk of suffocation. Children with cleft palate have an increased risk of suffocation. Considering that the age of treatment for children with cleft palate is 12 months at the earliest, we can see how difficult this process is for families. Given the daily sleep time of a baby, it is very difficult for a family to follow the baby's breathing during sleep. Therefore, in this study, the design of a smart bed to support the families in this situation was realized. The results show that the system works properly according to respiratory follow-up. In the future studies It is also possible to add a software that gives warnings in the mobile environment to the smart bed. In this way, the family may be aware of a negative situation even if the baby is away.

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