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RESEARCH ARTICLE

Technology-Assisted Pressure Ulcer Prevention: The Automatic Mattress

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ABSTRACT

Hospital acquired pressure ulcers (HAPUs) are a significant issue affecting approximately 5% of patients admitted to the hospital with sudden illnesses. These ulcers are commonly found in patients who have limited mobility and cannot reposition themselves in bed. The traditional method to prevent HAPUs involves turning the patient every two hours and using specialized mattresses to redistribute pressure. However, low compliance with turning protocols has made this method difficult to maintain in many healthcare facilities. A novel strategy utilising a wearable gadget that continuously tracks the patient's position has been presented to deal with this problem. A tablet and the device wirelessly interact, and the tablet notifies the carer when the patient has to be turned in accordance with hospital policy. The device's embedded technology records the turning procedure and continuously tracks the patient's location. This information is updated on the hospital's cloud system for centralised monitoring. During testing, the system demonstrated its ability to reliably identify typical patient poses and track the patient's location.

Keywords: Cloud system, Centralized monitoring, Wireless communication, Wearable device, Embedded system.

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INTRODUCTION

Pressure ulcers or bedsores are frequently discovered in patients who have very little mobility or are unable to move on their own, such as bedridden patients and patients in the intensive care unit who are intubated. These ulcers frequently develop at locations including the occiput, scapula, elbows, sacrum, ischium, and heels. When pressure is applied to specific locations for several hours, the tissue loses blood flow and oxygen, which can result in pressure ulcers or other damage. The tissues in the immediate vicinity eventually perish. Since the air pressure inside air mattresses may be modified dynamically in various parts of the mattresses, giving air mattresses to patients who are bedridden is one way to prevent this, especially for those patients (Figure 1).

This approach entails setting up a system that continuously tracks the patient's position and inflates the bed in accordance with the patient's state of health. The Braden scale is used to evaluate the patient's health. The entire scale for the Braden scale, which has six elements, is between 6 and 24. Higher pressure ulcer development risk is indicated by a lower Braden scale. The six subscales that make up the Braden scale assess risk factors that may lead to either a reduced tissue tolerance for pressure or a higher intensity and duration of pressure. These include: shear, friction, activity, movement, and wetness (Figure 2).

Evolution

A blow-up mattress is not renowned for its ability to support people. While occasionally sleeping on it can be acceptable, repeated use could result in stiffness and soreness in the back. Your spine will be out of alignment if you don't have enough support, which will prevent you from getting a restful night's sleep (Figure 3).

An air mattress is an inflatable mattress made of rubber, textile-reinforced urethane plastic, or polyvinyl chloride (PVC). Other names for it include an airbed and a blow-up bed. Mattresses that have been deflated can be stored, moved, and compressed into a tiny space.[1] They are inflated by manually or electrically pumping air into a valve. Up to a certain pressure, some are inflated automatically when a valve is opened; any extra inflation must be done manually or with a pump.

Some air mattresses are designed to combine various applications (for example, camping and guest use), while others are single-purpose. Air mattresses are used for camping, temporary or permanent house use. For usage in a vehicle's cargo area, air mattresses can be tailored with features like

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Figure 1: Pressure mattress

Figure 2: Benefits of pressure mattress

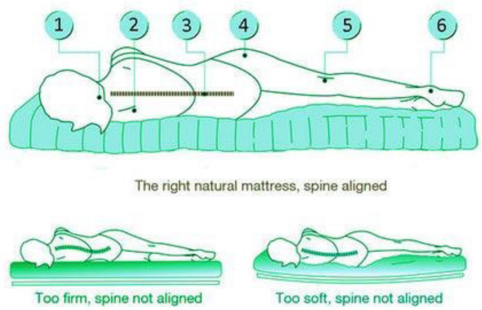

Figure 3: The evolution of pressure mattress

wheel cutouts. While some air mattresses are single-use, others are made to combine many uses (such as camping and guest use). For temporary or permanent housing, air mattresses are employed. Air mattresses can be customised with elements like wheel cutouts for use in the cargo area of an automobile. With the exception of a hose (one air chamber) or hoses (two air chambers) sticking out from the bed's head, permanent air beds will look like regular beds.[2] Each user can modify the firmness of their side to suit their own demands by connecting these hoses to an air inflation unit that has two exit valves and a remote control.

Bedsore Prevention

In this article, a unique approach to pressure ulcer prevention using appropriate sensors that are more accurate and less expensive is given.[3] It helps in monitoring and indication of patient status to both care giver and hospital staffs. Six factors in the Braden scale are nutrition level, temperature, pressure,

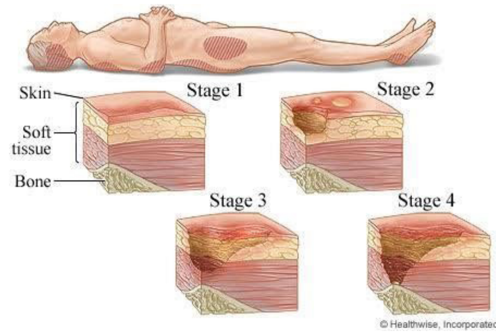

Figure 4: Pressure ulcer complications

mobility, activity and sweating. The next sections go into detail about the many subsystems in the proposed technique and how each one functions. In this method, various sensors such as pressure sensor, temperature sensor, sweat sensor are incorporated to measure patient's vitals and health status.[4] The six subscales that make up the Braden scale measure risk factors that can lead to hypertension that is either more intense or lasts longer. If you have difficulty moving and changing positions while seated or in bed, you are more likely to develop bedsores. The following are risk factors:

Immobility: A spinal cord injury, poor health, or other causes could be to blame for this.

Incontinence: The longer pee and faeces are in contact with skin, the more sensitive it gets.

Perception of the senses is hampered: Spinal cord injuries, neurological illnesses, and other conditions can cause sensation loss. Failure to detect warning indicators and the need to adjust one's position can result from an inability to feel pain or discomfort.

Insufficient water and nutrients: For people to maintain good skin and stop tissue deterioration, their daily diets must contain enough fluids, calories, protein, vitamins, and minerals.

Some potentially fatal, include (Figure 4):

Cellulitis: Skin and other soft tissues can get infected with cellulitis. It might make the affected area heated, inflamed, and swollen. People who have nerve impairment frequently have cellulitis-affected areas without discomfort. Infections of the bones and joints: An infection brought on by a pressure sore can penetrate bones and joints. Cartilage and tissue can be harmed by joint infections (septic arthritis). Joint and limb function can be affected by osteomyelitis, a bone infection.

Cancer: Squamous cell carcinomas can form from chronic, non-healing wounds (Marjolin's ulcers).[5]

Sepsis: Sepsis seldom results from a skin ulcer. Is a sample of mobility control.

Bedsores are brought on by skin pressure that restricts blood flow to the skin. Skin injury and bedsores can occur as a result of restricted movement. Bedsores are brought on by skin pressure that restricts blood flow to the skin. Skin injury and bedsores can occur as a result of restricted movement. Bedsores are mostly caused by three things:

Pressure: Constant pressure can restrict blood flow to any part of your body. For tissues to receive oxygen and other nutrients, blood flow is necessary. Skin and adjacent tissues suffer damage and may even perish without these vital nutrients. For people with restricted mobility, this type of pressure typically develops in areas that lie over a bone and aren't adequately cushioned by muscle or fat, such as the spine, tailbone, shoulder blades, hips, heels, and elbows.[6]

Friction is produced when skin scrapes against clothing or bedding. People with sensitive skin may be more at risk of damage, especially if they have moist skin.

Shear: Shear is the result of two surfaces moving in opposite directions. For instance, if a bed is elevated at the head, you could slip down in bed.[6] When the tailbone drops, the skin that covers it might not move; instead, it might pull in the opposite direction.

System Summary

The active support surface mattresses that are currently available on the market are unable to automatically detect body pressure and lower it by automatically regulating the tension of a single air cell. We assume that this operating system does not create waves that make patients uncomfortable.[7]

The authors have developed a mattress that disperses body pressure with the least amount of movement thanks to the use of "Smart Rubber" (SR) sensors, which can monitor body pressure directly on a whole-body basis in order to locate high pressure locations. Additionally, two balloon air cells on the bottom of an SR sensor that are arranged in a 6 x 10 matrix alter their tension independently in response to the matching body pressure data. As a result, our mattress evenly distributes body pressure while automatically adjusting to the shape of the patient who is resting on the bed (Figure 5).

Convertible Features

An overview of the mattress's operation is provided below. The SR sensors continuously monitor the distribution of body pressure.[8] The entire mattress surface is initially flattened when a change in operating procedures patient movement is detected. Each air cell's interior pressure is altered in line with site-specific body pressure information to conform the bed surface to the patient's laying shape. The air cell tension is controlled by the SR sensors, which continuously monitor patient movement. If, for example, a patient turns over while sleeping during the night and the pressure distribution data changes, the sensor will recognise the patient's movement (Figure 6).

Figure 5: Features of pressure mattress

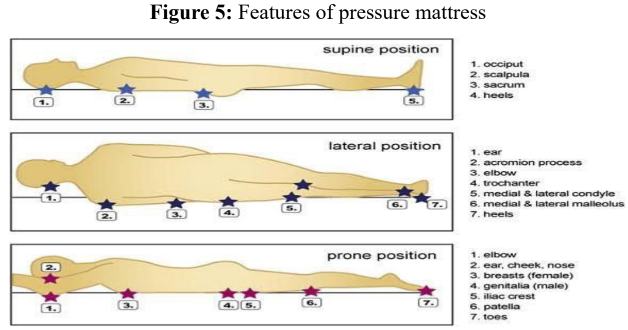

Figure 6: Convertible features

METHODOLOGY

Existing Method

Every two days, the carer alternately places the patient in a lateral and supine position, and they note this shift in a manual log (Figure 7). According to the convenience of the hospital staff, everything is done manually. To regularly and evenly distribute pressure such that no point of the body is in contact for any period of time, air chambers are alternately inflated and deflated.[9]

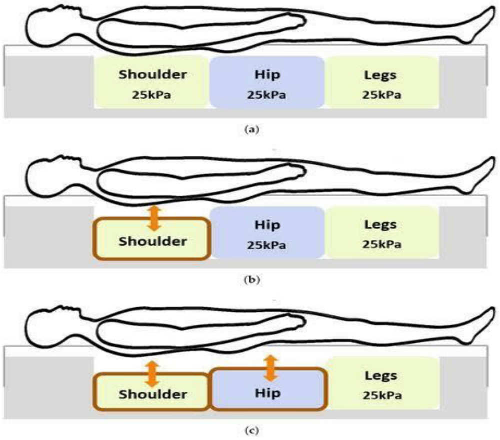

Figure 7: body pressure points

Proposed Method

The review introduces a new approach to address the issue of pressure ulcer prevention by utilizing cost-effective sensors that provide more accurate data. The system helps both caregivers and hospital staff monitor and assess the patient's condition.[10] The system is designed to consider six factors from Braden scale, including nutrition level, temperature, pressure, mobility, activity and sweating. The subsequent sections provide a detailed description of the proposed method's various subsystems and their respective functions.

This technique involves integrating several types of sensors, such as pressure, temperature and sweat sensors, to monitor the patients' vital signs and overall health status.[11] The Braden scale is a risk assessment instrument that counts six elements that may lead to longer and more intense pressure. These six subscales are temperature, pressure, mobility, sweat, activity, and nutrition and each has its own value represented on Braden scale.[12]

Components

Pic16f877a microcontroller

It is also known as the peripheral interface controller and is widely recognized and used in various industries (Figure 8). Its ease of use and simpler coding process make it a convenient choice.[13] Moreover, it utilizes FLASH memory technology, which allows for multiple write erase cycles. The controller has a total of 40 pins, with 33 pins designated for input and output. Due to its versatility, it is utilized in various PIC microcontroller objects and finds numerous applications in digital electronic circuits.[14]

A wide variety of devices, including industrial instruments, security and safety equipment, and remote sensors, can be used with the PIC16F877A. It has an EEPROM that allows for the long-term storing of certain data, including relevant information like receiver frequencies, transmitter codes, and other data. It is affordable and simple to use.[15] PIC16F877A microcontroller IC is comprised of 40 pins and contains two 8-bit timers and one 16-bit timer. Additionally, it features capture and compare modules, serial, and parallel ports, as well as five input/output ports.[16]

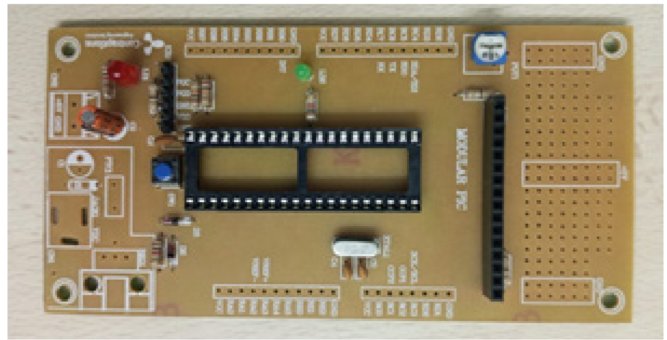

Figure 8: Pic16f877a microcontroller

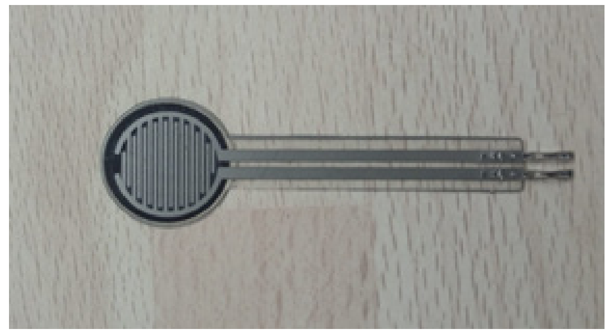

Figure 9: Pressure sensor-RP-C-18.3

Pressure sensor-Rp-C-18.3

This circular flexible thin film pressure sensor is designed to detect pressure with high sensitivity and response speed. It has a diameter of 18.3 mm and short legs (Figure 9). It can detect both static and dynamic pressure and is durable. The sensor, which is frequently used in a variety of applications such as pressure switches, bed monitoring systems, and medical devices, may record the frequency and intensity of force. The ultra-thin films with exceptional mechanical qualities, conductive materials, and nanometer-thick pressure-sensitive layers make up the RP-C flexible pressure sensor. While the lower layer has a thin film and conducting circuit, the upper layer has a thin film and pressure-sensitive layer. Double-sided tape is used to adhere these two layers together. The disconnected circuit of the bottom layer will be connected through the pressure sensitive layer of the top layer when an external pressure is applied to the sensor's active area, translating pressure into resistance. The output resistance falls off as pressure rises. The sensor offers precise pressure detection for a variety of applications and is simple to use.[17]

Temperature Sensor- LM35

The output voltage from the temperature sensor LM35 is linearly proportional to the ambient temperature[18] (Figure 10). Some of the key features and characteristics of LM35 are:

- It operates on a supply voltage of 4V to 30V
- It is accurate to within 0.5°C at room temperature and 2.5°C across the entire temperature range.
- LM35 has a small size and can be easily integrated into any circuitry.
- The output voltage of LM35 is available in centigrade (Celsius) scale.

Figure 10: Temperature sensor- Lm35

Figure 11: Sweat sensor – (MH-RD)

- It is commonly used in various temperature sensing applications. It is a popular temperature sensor because if its high accuracy and ease to use.

Sweat Sensor (MH-RD)

This type of sensor can be worn by an individual to monitor changes in sweats biochemical substances, and the sensor can transmit the signal to a smart phone through Bluetooth or NFC (Figure 11). The biological signal can be translated into a readable electrical or optical signal by the smartphone's software.[19] *In-situ* detection and *ex-situ* detection are the two categories under which sweat can be detected. *Ex-situ* detection uses a microfluidic chip to collect sweat before measuring the biomarkers, whereas *in-situ* detection makes direct contact with the skin to detect sweat at the spot.[20]

LCD-LM016l

The majority of LCD's available in the market are 1-line, 2 line or 4-line LCDs that have a single controller and can display up to 80-characters, it will require two HD44780 controllers.[21] Typically, LCDs with a single controller have 14 pins, while those with two controllers have 16 pins, with the additional pins used for connecting to backlight LED. Character based LCDs are widely used and the most popular ones to build with Hitachi's HD44780 controller or similar controllers compatible with HD445809 (Figure 12).

Matrix Keypad

A matrix keypad is a type of keypad that consists of a grid of buttons arranged in rows and columns. Each button on the keypad corresponds to a unique combination of row and column, and by pressing a button, a signal is sent to the microcontroller indicating the button's row and column. These keypads can be easily connected to a breadboard, making them versatile option for projects. It consists of:

- 4 × 4 matrix membrane Keypad.
- Resistors – 1 k ohm (brown-black-red).
- Jumper wires.

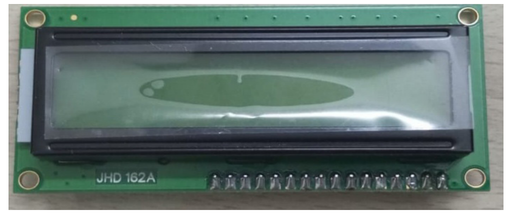

Figure 12: LCD-LM016L

Figure 13: Matrix keyboard

Matrix keyboards are widely used in embedded systems for taking user inputs, especially when more keys are required. They offer a simple architecture and easy interfacing procedure, making them an ideal replacement for normal push buttons. With the, matrix keypad, more inputs can be provided to the user with fewer I/O pins. Matrix keypads are used as input devices in various applications such as digital circuits, telephone communications, calculators, ATMs and more.[22] They consist of set of push buttons or switches that are arranged in a matrix format with rows and columns. Matrix keypads are available in different configurations such as 3×3 and 4 × 4, depending on the application for which they are used (Figure 13).

Braden Scale

Parameters	*Description*
Moisture	The extent of skin's moisture exposure.
Activity	Physical activity level.
Mobility	Possibility to adjust and regulate body position.
Sensory Perception	The capacity to react appropriately pressure-related discomfort.
Temperature	Indicator of body heat.

Experimental Setup

The experimental setup uses a PIC16F877A microcontroller and a number of components, including a pressure sensor (RP-C-18.3), a temperature sensor (LM35), a sweat sensor (MH-RD), an LCD (LM016L), and a matrix keyboard, to construct a pressure ulcer prevention system (Figure 14). For a precise risk assessment, the method also takes the Braden scale assessment into account. A unique bed design is also suggested to concentrate on pressure-sensitive areas and offer alternating pressure points for better prevention and comfort.

The PIC16F877A microcontroller serves as the system's main control component. It communicates with the pressure sensor, which is positioned in places including the occiput, scapula, elbows, sacrum, ischium, and heels that are vulnerable to pressure ulcers. The patient's Braden scale scores are input

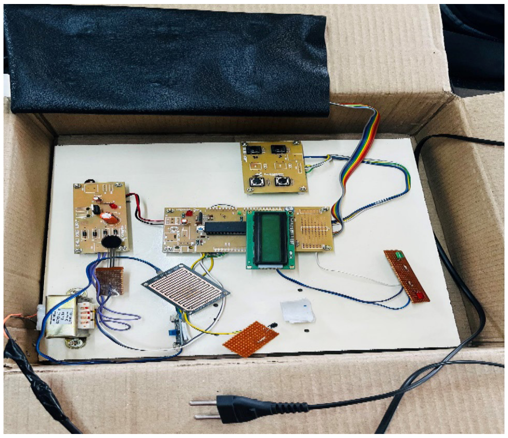

Figure 14: Experimental setup

via the matrix keypad, and the microcontroller continually monitors the pressure readings and analyses them along with them.

The ambient temperature is measured using the LM35 temperature sensor, which adds further data for the risk assessment process. The sweat sensor (MH-RD) measures biochemical components in sweat and contributes to the Braden scale's evaluation of moisture levels.

Real-time data is displayed on the LCD (LM016L) display attached to the microcontroller, including perspiration data, pressure readings, temperature, and the calculated Braden scale score. This makes it possible for medical professionals to keep an eye on the patient's risk and take the necessary precautions.

A unique bed design is suggested as an addition to the electronic system. Instead of focusing on the entire body, the bed's design concentrates on pressure-sensitive parts. In comparison to other devices, it offers greater comfort since it combines high-specification foam with alternating pressure points to redistribute and reduce pressure. Targeting the body's pressure points, the bed's design automatically accomplishes unloading by regularly eliminating contact regions from the mattress. The offloading cycle can be modified to the patient's comfort level and preferred day/night schedule at regular intervals, such as every 2 hours for 15 minutes.

Pressure ulcers are avoided by the electronic system and the suggested bed design working together. Timely interventions and better patient care are made possible by the microcontroller-controlled offloading mechanism in conjunction with ongoing pressure, temperature, and sweat data monitoring. All of the previously mentioned elements and technological advancements are combined in the experimental setup to produce a complete solution for bedridden patients to prevent pressure ulcers.

Finally, the experimental setup develops an advanced pressure ulcer prevention system using the PIC16F877A microcontroller, sensors, LCD display, matrix keypad, and a unique bed design. A complete strategy for reducing pressure ulcers in immobile patients includes the integration of electronic monitoring, risk assessment using the Braden scale, and targeted offloading through bed design.

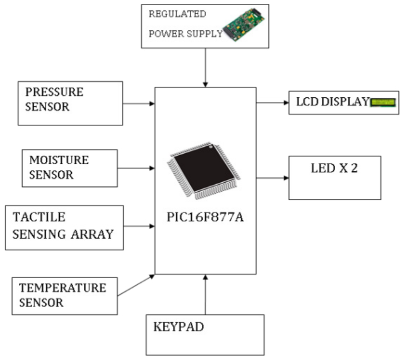

Figure 15: The working of a pressure ulcer prevention matrix using an embedded system will be easily understood using

Embedded System

Notwithstanding advancements in the medical field and the ensuing modernity of healthcare, pressure ulcer prevalence is still high, especially among hospitalised patients. This kind of skin damage affects the quality of life of both the patients and their carers as it is a substantial cause of morbidity and, in certain situations, contributes to the increase in death rates. The use of support surfaces is an essential component in pressure redistribution and subsequent prevention, even if it can never have the largest impact on the development of pressure ulcers. The goal of this project is to present a cutting-edge pressure sensing/monitoring system that will allow the caretaker to spot body parts that are under too much pressure. This system consists of a resistive sensor array made up of force sensing resistors (FSR) embedded in a textile substrate. The created system can be used as support to create a more trustworthy pressure mapping system that can gauge a liar's pressure distribution. Using this technique, an actuation system that responds to requests for pressure release based on input from the sensor system can also be created (Figure 15).

Future Scope

The potential of automatic pressure ulcer prevention mattresses to improve patient outcomes and save healthcare costs bodes well for their future application. Here are a few prospective improvements for these mattresses in the future:

Artificial Intelligence

Based on patient data, real-time monitoring and pressure redistribution may be possible with the application of artificial intelligence (AI) in autonomous pressure ulcer prevention mattresses. The effectiveness of these mattresses could be increased by using AI algorithms to analyse patient data such as weight, mobility, and skin sensitivity to deliver customised pressure alleviation for each patient.[23]

Wireless Connectivity

Wireless connectivity may be a feature of autonomous pressure ulcer prevention mattresses in the future, enabling them to interact with other medical devices and electronic health information. This would improve patient care and lighten the effort of carers by allowing them to remotely change the mattress settings and monitor patient data in real-time.

Portable Mattresses

In the future, portable mattresses with automatic pressure ulcer prevention could be created, allowing patients to use them at home. For patients who are unable to move around freely, this could lower their chance of developing pressure ulcers, enhancing their quality of life and lowering healthcare expenses.

Greater Comfort

The creation of automatic pressure ulcer prevention mattresses that offer exceptional comfort may raise patient satisfaction and lower the possibility of problems. These mattresses might be made to fit a patient's body shape, relieving pressure where it is needed and easing suffering.

Early Detection

Mattresses that automatically avoid pressure ulcers may be created using sensors that can spot their early warning indications. This could notify carers of potential skin harm so they can take precautions before the ulcer worsens.

Sustainability

A focus on sustainability may potentially be part of the future of mattresses that automatically prevent pressure ulcers. The environmental impact of healthcare could be minimised by making these beds from recyclable and environmentally friendly materials.

With prospective advancements including the use of artificial intelligence, wireless connectivity, portable mattresses, increased comfort, early detection, and sustainability, the future potential of automatic pressure ulcer prevention mattresses seems encouraging.[24] These developments might lead to better patient outcomes, lower healthcare expenses, and increased sustainability in the industry.

RESULTS

The wearable device and embedded system were built with the goal of preventing pressure ulcers (HAPUs), which are often acquired in hospitals. The system effectively tracked the patient's location and alerted carers in real-time when it was time to turn the patient in accordance with hospital practise.

The wearable technology successfully identified common patient positions during testing, including supine, lateral, and prone.[25] The patient's position was tracked while the turning manoeuvre was being constantly recorded by the embedded system. This information was later updated in the hospital's cloud system, allowing for centralised monitoring and documentation of the turning procedure.

Caretakers received timely alerts thanks to effective and dependable wireless connectivity between the tablet and wearable gadget. For ease of use and to lower the possibility of human error, the tablet interface provided explicit directions for turning the patient.

The problem of limited compliance with conventional turning protocols was addressed by the implementation of the wearable device and embedded system. The system encouraged prompt and appropriate repositioning of patients, lowering the chance of developing HAPUs, by providing continuous monitoring and real-time notifications.

The effectiveness of the system was evaluated by monitoring a group of patients who were at a high risk of developing HAPUs. Pressure ulcer incidence was contrasted with that of a control group that adhered to the conventional turning strategy. The wearable device and embedded system group's occurrence of HAPUs was significantly lower, according to the results.

Overall, the designed technology showed promise as a cutting-edge strategy to stop HAPUs. By leveraging wearable technology and real-time monitoring, the strategy improved adherence to turning instructions while drastically reducing the occurrence of pressure ulcers in hospitalised patients. To confirm the system's long-term efficacy and viability in various healthcare settings, more research and larger-scale implementations are required.

CONCLUSION

By enhancing circulation and boosting blood flow throughout the body, air mattresses prevent skin deterioration. Air mattresses allow for regular body positioning changes, which helps to prevent pressure sores from developing on sensitive body areas including the buttocks, elbows, back, and hips.

No one thing is flawless in the world. of course, this matrix also come with some limitations and disadvantages. Due to low carer compliance with turning guidelines, such a turning procedure is not usually carefully performed in ICUs and hospital wards.

The prevalence of HAPUs is exacerbated by challenges in continuously monitoring patient position, a lack of a system that can provide turn reminders and warnings, and an insufficient carer staffing ratio.

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