Review Article

Risk Factors for Developing Pressure Ulcers in Neonates and Novel Ideas for Developing Neonatal Antipressure Ulcers Solutions

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Abstract

Pressure Ulcers (PU) are highly prevalent iatrogenic occurrences among hospitalized adults and neonatal patients. These decubitus ulcers are progressive in nature and are mostly seen in patients that are immobile for prolonged periods, either by virtue of being bedridden or chair bound. The continual pressure on the skin surfaces disrupts blood supply from the subcutaneous regions and leads to the development of PUs. Several treatment and prevention protocols have been defined for adult patients. However, there is a dearth of literature available for critically ill pediatrics or neonates and often adult practices are used to treat pressure injuries in them. There is a significant physiological and anatomical difference between the skin of newborns and adults or even older children. The dermal layer of a preterm neonate is <60% of the thickness of an adult and has a much higher susceptibility for developing pressure ulcers. The immune system of premature infants lacks an efficient antigenic specificity, diversity or immunologic memory, making them prone to lethal infections. The study was performed using search engines like PubMed, EMBASE and Google Scholar, with the focus of the search strategy being the breadth rather than the details of the study. Selected keywords were used alone or in combination with each other to retrieve relevant articles. This review focuses on the risk of developing PUs in neonates, explains the currently available solutions of PU prevention in adults, emphasizes the need for neonatal specific solutions and presents novel ideas for developing antisore bed for neonates.

Keywords: *Decubitus ulcer, mattresses, nasal septum, pressure ulcer*

Introduction

An increase in the occurrence of pressure ulcers (PUs) in the population that is strapped with medical devices and admitted to the neonatal intensive care unit (NICU) as opposed to the patients admitted in the intensive care unit (ICU), has sparked intensive research revolving around the causes and risk factors associated with such pressure injuries. Despite the physiological and anatomical distinction in the neonatal and adult skin, adopting adult practices to prevent or treat PUs in premature infants has questioned the cost, efficacy, and effectiveness of these measures.[1]

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Factors Involved in the Risk of Developing Pressure Ulcers

Extrinsic factors

Shear, friction, moisture, abnormal posture, undue, and prolonged pressure owing to numerous clinical devices and impaired mobility are some of the critical

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extrinsic factors associated with ulceration.[2] Friction and shearing are mainly the result of interaction between the skin and stationary surfaces such as bed clothes and intertissue plane movements such as gliding over. Accumulation of moisture due to urine, perspiration, and discharges leads to maceration of the skin surface, weakening of the skin barrier and blister formation making it more susceptible to breakdown. Abnormal body postures simply lead to unequal pressure distribution across various anatomical points in the body that often cause ulceration.

Intrinsic factors

The intrinsic factors include age at birth (weeks), weight at birth (grams), period of hospitalization (days), or gestational age (weeks).[3] It was observed that the rate of occurrence of PUs was low for premature infants as compared to the term infants. The distribution of PU severity mostly reached to stage II in case of premature infants, while the same severity extended to stage III in case of term infants. Hemoglobin levels (an indicator of nutrition management) in the body are a measure of tissue oxygenation. In case of anemic patients, the oxygen carrying capacity of blood vessels is reduced, which causes tissue necrosis due to excessive mechanical pressure, making the tissue more prone to ulceration. Conditions such as edema are the outcome of a compromised circulation and poor nutrition and often cause an accumulation of interstitial tissue fluid coupled with the decrease in tissue oxygenation. Therefore, poor nutrition management is also regarded as a significant risk for developing PUs.

Predicting the Risk of Pressure Ulcer in Pediatrics

Going by the medical doctrine, "Prevention is better than cure," an exact evaluation of risk for developing PUs is the initial step in designing suitable intervention that can impede its incidence. Out of the ten validated and published scales, the Braden Q, Neonatal Skin Risk Assessment Scale (NSRAS), and Glamorgan scales are the only ones tested for their sensitivity and specificity. If these scales denote a higher score, the risk is more and also the specifications of mattresses required are higher.

The neonatal Braden Q scale originally published in 1996 was adapted from Braden scale for adults used for predicting pressure sore risk (originally published in 1987).[4] It is a more detailed scale that includes factors such as mobility of body position, degree of physical activity, sensory perception, nutrition, tissue perfusion, oxygenation, and moisture among others, with each factor being graded from 1 to 4 (based on predefined guidelines) to calculate the total score.[5] And finally, the NSRAS scale that is based on the Braden Scale includes factors such as mobility, general physical condition, activity, and mental status to calculate a PU risk total.[6]

A study carried out in several of Spain's Pediatric Hospitals[7] built two sets of forms: one namely to assess the risk of developing PUs by patients admitted to the NICU and the other that enlisted and characterized the different preventive measures adopted by the hospitals such as skin monitoring, nutrition management, placement of pulse oximeter, and ulcer management in an attempt to study the efficacy of the said measures. It also further classified the risk of PUs based on their location within the body, number of contact surfaces within the body, and the gestational age of the admitted patient. It was revealed that 84.1% of PUs were caused by medical devices and that 54% among them were caused by noninvasive mechanical ventilation. The nasal area was highly prone to PUs followed by the occiput and other bony prominences such as heels, sacrum, elbows, and shoulder. Furthermore, each additional week of gestational age at birth reduced the risk of PUs by 20.1%. After a careful statistical analysis of all the adopted measures, kangaroo care method was the only method that fetched a significant protective effect, while other methods such as repositioning or use of support surfaces showcased nonsignificant effects. This review paper also includes studies conducted in other public care hospitals that statistically proved that a majority of PUs were caused by medical devices.[8] Adhesives used to connect clinical devices to the bodies of these neonates caused skin tissue injuries and abrasion of the stratum corneum layer when they were removed. However, silicone-based adhesives, such as RTV silicone 666, caused less skin lesions as compared to the standard acrylate-based adhesives.[8] A Cincinnati Hospital study called out several risk factors for the occurrence of PUs such as noninvasive ventilation (CPAP and ECMO), a longer period of hospitalization, medical device-related pressure injuries, excess moisture, and effect of gestational age on PU development. A greater prevalence and tendency of patients to develop stage II PUs was observed.[9] A study made from the biomechanical perspective[10] emphasized the importance of a medical device setup, arrangement, and its role in the development of PUs in the neonates and stated that higher stresses and deformation were induced in the contacting skin tissue surfaces when wires and electrodes of medical devices were wedged under the body of newborns. A US-based hospital study was carried out to determine the usefulness of pressure redistribution mattresses[11] specifically manufactured with the intention to reduce the risk of PUs in pediatric patients. This crib mattress had unique features such as movable side rails, built-in scale to measure the weight of the child, overhead features to prevent falls, and an adjustable head of the bed. A comparative analysis of the PU occurrences in patients using these mattresses and the ones that were not using them denoted that such mattresses along with bundled interventions[12] such as use of urinary catheters, acute elevation of the head of bed, use of disposable underpads and dry-weave diapers, and the use of blanket rolls, draw-sheets, and pillows along with repositioning by nurses whenever possible could potentially prevent PUs.

Methods

Search strategy

The literature survey was done and statistical findings were analyzed thoroughly. This literature is essentially broader and comparatively more explanatory in nature. However, it focuses on breadth rather than the details of each study and was performed using search engines such as PubMed, IEEE Xplore, EMBASE, and Google Scholar. After the analysis of keywords in abstract and title of the article, preliminary search was done in PubMed and ScienceDirect. The primary aim of the search strategy was to retrieve articles related to PU risk assessment and antisore bed. Selected keywords were used in particular or in combination with each other to retrieve relevant articles [Figure 1].

The search terms considered relevant were "Neonates or Preemies" and "Decubitus ulcers or Pressure sores" and "PU prevention protocol or PU risk assessment" and "Biocompatible or Biocompatibility."

Study selection

Resultant papers were evaluated based on the set criteria for inclusion or exclusion as listed in this paper. The primary screening of articles based on abstract was done for relevant articles based on their titles. The study was selected from all similar keywords used to retrieve relevant articles.

Inclusion criteria

Case controls, patent devices, and randomized controlled trials were included in this study. Articles from books, conference articles and review articles, and publications from all the countries were considered.

Exclusion criteria

Articles written in languages other than English and reported before 2000 were excluded from this review. Duplicate articles along with articles that did not have relevant titles and/or abstracts were excluded. Only the selected articles were fully reviewed.

Existing Solution

Broad classification of the study

Prevention of PUs constitutes a variety of mattresses, classified as low-tech devices or constant low pressure (CLP), high-tech devices or alternating pressure (AP), and other support surfaces. The CLP devices construct the body shape of the patient to distribute its weight over a large area and include standard and alternative foam mattresses/overlays such as convoluted and cubed, gel filled, air filled, water filled, fiber, or bead filled. The AP devices provide the pressure periodically beneath the patient's body with mechanical techniques and include air fluidized beds, low air loss beds, or AP overlays/mattresses. Based on the operation of these mattresses, they are classified as static mattresses, dynamic mattresses, and overlay mattresses.[13,14]

Static mattresses redistribute the pressure around the whole body and are very handy to use and to set up, while dynamic/ripple mattresses are designed as an alternative inflating and deflating strips bed underneath the patient. The noise of electric pumps and the breakdown of mechanical system owing to its rigorous use form some of its drawbacks. The third category includes the overlay mattress that is placed on a static mattress or on a dynamic mattress or sometimes even both. It is quick to install. However, it does not provide the same level of protection as a replacement mattress. It is suitable for a short period of time and also for acute illness. It prevents the patient to get in or out of the bed as it raises the height of the mattress.

Description of the study

The most acceptable way of preventing neonatal PUs is to get the patients moving often and prevent them from sleeping or lying in the same position for long period of time on a particular side of the body. Since there are no specified solutions designed for neonates, previously designed antisore beds for adults have been included in this study as a means to understand the technology gap and highlight the scope for future development.

A study done on sleeping mattresses of premature babies by Carol Turnage-Carrier[15] on 5 bed surfaces which includes crib mattress with foam, standard crib mattress, mattress with gel donut, mattress with gel, and mattress with water pillow stated that except the standard crib mattress all of the four surfaces had significantly lower interface pressures i.e., less than 100 mm Hg.

A patented device with multiple layers of sponge, air, and paper sheet layer used for reduction of pressure ulcers.[16] Depending on the patient's weight, the air mattress and sponge layers are arranged to enhance the patient's body's surface area in contact with the bed. The

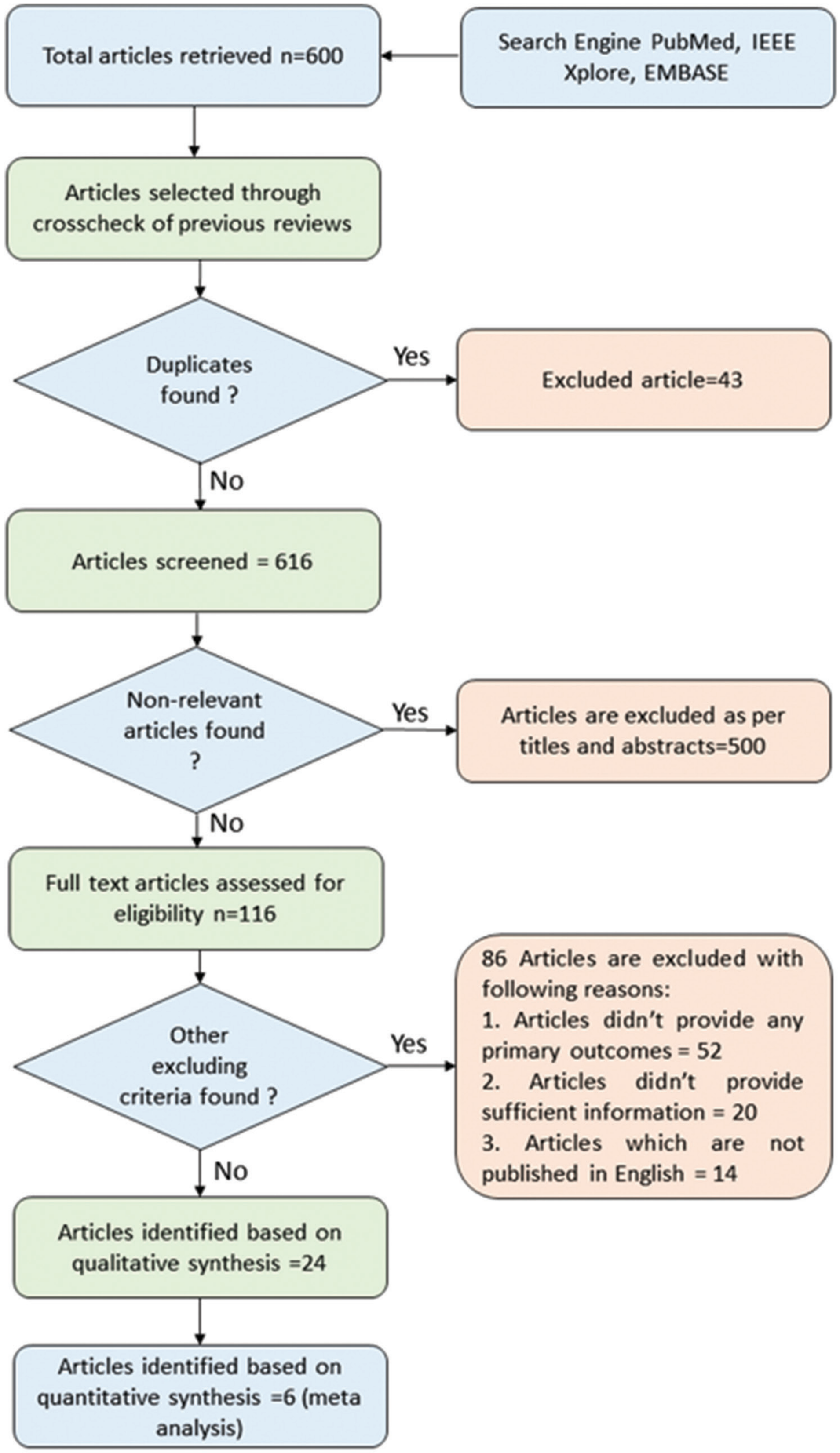

Figure 1: Flowchart of literature search

intermediate layer is a rubber layer designed to offer ventilation utilising dry air or dry air mixed with ozone gas, essential/volatile oil, and/or antibacterial vapours for parts of the mattress that come into contact with a patient's body. The purpose of the second sponge layer is to distribute air beneath the patient's body. If the mattress becomes wet from sweating or incontinence, the paper sheet layer is set up to sound an alert.

Smart bed platform developed by Yousefi *et al*.[17] evidently denotes a combination of machine intelligence, sensor network, and computers that is capable of providing support to the healthcare staff in improving patient care and PU prevention, also carrying out epidemiological analysis efficiently. The design beholds two types of sensors, resistive and capacitive over the entire bed surface in order to measure surface body pressure. Patient profile was generated based on initial and fused sensor data that capture matrices such as moisture content, pressure map, temperature, and blood pressure.

The Nimbus pediatric system,[18] designed for examined to be at risk of pressure injury or existing pressure damage provides alternating pressure relief with self-regulating weight, size, and position adjustment of the patient.

A patented device that is for relieving pressure invented by Jennifer B *et al*.[19] has several different layers that include -1. Sponge layer for conduction of electricity 2. Air electric conducting sheet 3. Intermediate layer having air release units 4. Second sponge layer having sensor matrix for the detection of mattress with second moisture.

Carrigan *et al*. have developed a sensor-based soft actuator array. Controlling interface pressure was accomplished by monitoring the internal pressure of the actuator. The said system automatically distributed the interface pressure using pressure-modulating algorithm. After applying the weight on the surface, there were changes in pressure at the center of the surface. Conclusively, a system with the interpolated surface achieves the best pressure distribution.[20]

An array of capacitor plate is used for sensing the pressure, as shown in Figure 2. Wherein, the applied pressure can be obtained based on the capacitance value.[21] Sensor-to-sensor variation and baseline drift were some of the limitations associated with this version.

Chenu *et al*. have developed seating system based on embedded system that measured the pressures in real time and estimates the risk for internal overstrains. The textile map is put onto the chair’s seat area, usually all around the cushion. The system has been intentionally developed for the paraplegic population, to monitor their interface pressures for prevention of ulcers as shown in Figure 3.[22]

Interface pressure, the loading between a patient’s skin and the support surface, is measured to determine the relative efficiency of performance of various support surfaces. All the above-discussed techniques are summarized in Table 1.

Limitations

Limitation of the study

Articles that did not report any primary outcomes of the review or that did not have the full text published in English were excluded from the scope of this study. The biggest limitation when studying neonatal PUs is the number of available datasets.[7-9] Usage of larger datasets when drawing conclusions to a conducted study helps in establishing a sense of credibility to the obtained results.

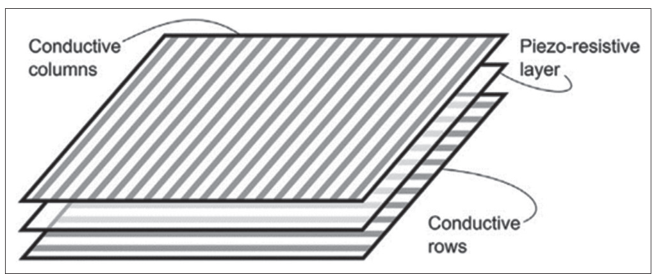

Figure 2: Schematic of the sensor array[21]

Table 1: Various mechanisms followed by antisore beds in articles included during the literature search

Anti-sore bed mechanism	Literature name/Patent name	Publishing year/ Patent year	F. Author/Inventor
Passive	Effect of visco-elastic foam mattresses on the development of pressure ulcers in patients with hip fractures	2000	L. Gunningberg[23]
	The QUATRO ACUTETM mattress and pressure ulcer prevention	2003	Sylvie Hampton[24]
	Hospital-acquired pressure ulcer prevalence-Evaluating low air loss beds	2011	Jane Johnson[25]
	Neonatal absorbency pad and related methods [Patent]	2015	Jennifer J. Bracci[19]
	Development of a bed centered telehealth system based on a motion sensing mattress	2015	Yu-Wei Liu[17]
Active	The theracute alternating pressure relieving mattress	2001	Heather Newton[26]
Both	A smart bed platform for monitoring and ulcer prevention.	2011	R. Yousefi[27]
	Design of Anti bed sore hospital bed	2014	Siva Soonthornkiti[28]
	Multi-Fowler techno bed: A solution for pressure ulcer patients	2015	Czar Czamwahyudy[29]

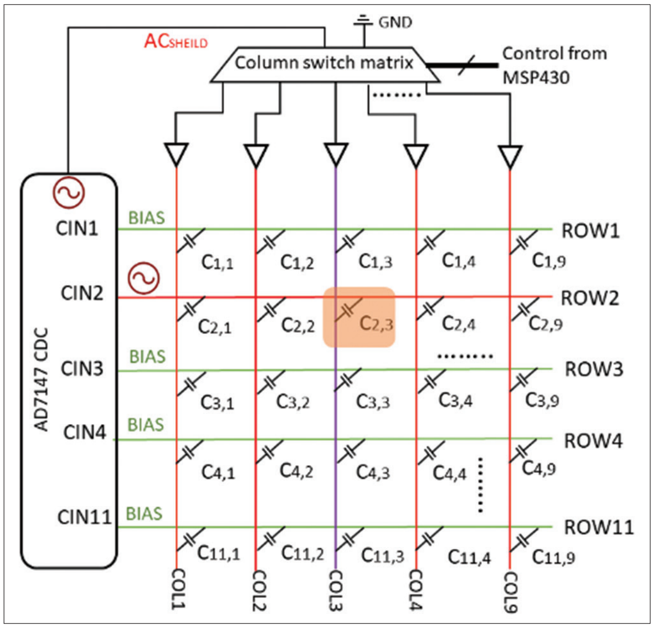

Figure 3: Three layers that constitute the TexiCare textile sensors[21]

Limitation of the solution

The incapability of measurement of factors such as nutrition levels, sleep, or friction and shear levels that are an integral aspect of the etiology of PUs is believed to be one of the major limitations of the existing solutions. The current methods employed to reduce the incidence of neonatal PUs also have certain inhibitions such as incapacity of repositioning (seen as somewhat effective way to protect ulcerations) owing to limitations in the availability of nurses. Support surfaces such as low air loss beds, sheepskin, gel pads, viscous fluid mattresses, heel suspension of the bed using pillows, and air, water, or gel mattresses are limited by their sheer availability, scientific evidence proving their overall efficacy for pediatric patients, and maintenance costs. Pressure injuries tend to include tissue damage inflicted on the skin due to mechanical forces and medical devices. Congenital pressure injuries or traumatic birth injuries[28] (due to significantly diminished or near absence of amniotic fluid presence in the mothers, skin injuries due to intrauterine transfusions or amniocentesis) are also an integral aspect of the cause of PUs in neonates. Thus, there is a pressing need for the development of pediatric specific anti-PU solutions to prevent the occurrence of neonatal pressure injuries.[30]

Future Perspective

A more comprehensive biomechanical model can be prepared to experimentally and computationally study the structural design and medical device arrangement and use of neonate compatible material to minimize the risk of PU development. Deeper study into the nature and properties of biomaterials involved in pediatric care as well as exploration of the possibility of new biomaterials could be potentially undertaken in this regard. Models or experimentation studies can be designed to scientifically evaluate the efficacy of these preventive measures. The effectiveness of kangaroo care method can be statistically and scientifically analyzed and specialized materials that procure skin-to-skin contact can also be incorporated in specialized neonatal antisore bedding.

Conclusion

Devices based on active mechanism are comparatively more successful in the prevention of PU because they have an associated moving part that periodically changes the pressure points of the patient.

The avoidance of exposure to the highest interpressure surface in premature babies can be regarded as one of the most effective ways of PU prevention. The ideal interface pressure to reduce tissue injury is uncertain but choosing a bed surface with the lowest interface pressure may prevent the surging risk of bedsores and will eventually reduce the period of hospitalization. When there are chances of a high risk of PU development, use of a higher specification foam mattress over the regular standard hospital foam mattress is preferred.

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Conflicts of interest

There are no conflicts of interest.

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