
Air Mattresses as Prevention for Pressure Ulcer - An Interdisciplinary Overview

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ABSTRACT

Pressure Ulcers (PUs) are one of the most common medical problems in hospitalized immobile patients and elderly patients in nursing homes. PU occurs due to cell necrosis which tends to develop when a soft tissue is broken by a prominence bone or a hard surface for a long period of time. Currently available techniques and or protocols designed to prevent pressure ulcers are mainly based on the improvement of the skin- support interface and on a postural and behavioral education¹. This paper surveys the literature on the pressure ulcer incidences from three different viewpoints. First view point is study of different foam as well as air mattresses. The second view point focuses on effectiveness of air mattresses based on PU incidence and contact interface pressure and blood perfusion. Third viewpoint focuses on comfort and cost effectiveness. Ten RCTs analyzed the PU incidence.

Key words: PUs, HAPU, APAMs

INTRODUCTION

Pressure ulcers (PUs) are one of the most important and frequently occurring medical problems that occur in patients with reduced mobility and poor health. They are caused by unrelieved pressure and shearing forces on soft tissue overlying bony prominence when patient lying on hospital bed². These two forces can interrupt the blood circulation to underlying tissues. This result in oxygen depletion in soft tissues and muscles³. Pressure ulcers are difficult to cure, treat and are a major cost factor in the health care system⁴. Classical treatment involves extended periods of bed rest, which is believed to cause further deterioration of the patient's general condition^{5,6}.

Japanese statistics indicate that the frequency of PUs is 23.1% for in-hospital patients and the frequency is even higher for patients with severe illness⁷. In USA, the prevalence rate range from 4.7 to 32.1% in hospital settings and from 8.5 to 22% in nursing homes.⁸ In Canada, the prevalence rate is reported to be 25.1% and PU is associated with an increased risk of death in the elderly^{9,10}.

The American National Pressure Ulcer Advisory Panel (NPUAP) reported prevalence rates ranging from 10% to 18% in general acute care¹¹. Effective preventive measures reduce the

intensity and/or the duration of pressure and shearing forces and consequently guarantee a sufficient oxygen supply to tissues¹². The duration can be reduced by alternating the area under pressure. This can be achieved by repositioning or by using alternating pressure air mattresses (APAMs)¹³.

Literature on different support surfaces to prevent PUs is available, but a thorough analysis of air mattresses, their cost effectiveness and their technical problems are not been found.

COMPARATIVE STUDIES OF DIFFERENT FOAM AND AIR MATTRESSES

A study conducted biomechanical comparison of four “top of the line” mattresses from four different manufacturers using two different measurements by pressure distribution pattern and by quantifying the degree of spinal distortion induced when side posture position is taken and study shows that one mattress did induce significantly lower maximum pressure than the other three in both pelvic and thoracic regions.^[15] James W. DeVocht et al. in measured interface pressure with healthy volunteers lying in different kinds of mattresses and found that a Tempur polyethylene-urethane mattresses induced 20-30% lower pressure than a standard hospital mattresses¹².

A time-based analysis technique is devised for comparing performance assessment of mattresses by Shyam V (2004) in which, ten healthy volunteers were recruited to evaluate the pressure-relieving characteristics of two different designs of APAMs. Results indicated significant differences between the products. During the deflation phase of the cycle contact pressures on the heel were significantly lower ($p < 0.0001$) on the device whose inflation pressure was significantly higher, although there was no significant difference in deflation pressure. Therefore, it is important to note that low APs do not necessarily produce lower IPs under the heel, contrary to the intuitive classical notion. These techniques could assist in the selection of alternating or dynamic surfaces of any description confirmed by further clinical validation¹⁶

The prevalence of Hospital Acquired Pressure Ulcer (HAPU) over 3 quarters in 2008 ranged from 1.0% to 3.3% (overall rate 2.4%). Eighty-three percent of patients with HAPUs were cared for on low-air-loss beds. Of 12 patients with 16 HAPUs during this time, 75% were aged 70 years or older and 25% were managed in critical care units. Over half of patients who developed HAPUs had been hospitalized for 20 days or more. Half of the patients with HAPUs were scored as no-low risk on the Braden Scale. On the paired medical-surgical units, no statistically significant differences were found when patients with low-air-loss beds were compared to standard hospital mattresses supplemented by a variety of pressure redistribution devices. Seven of 11 HAPUs (63%) occurred in patients placed on low-air-loss beds¹⁷

A study reported that the use of alternating-pressure surfaces significantly reduced the incidence of pressure ulcers compared with standard hospital mattresses. The report of this large trial,

involving 482 patients who were defined by the authors as being at high-risk of pressure ulcers, gave no indication that either allocation concealment or blinded outcome assessment had been used. In an underpowered and unblinded study conducted on patients requiring head elevation, compared a single layer air cell overlay (the Air Doctor), a double-layer cell overlay (the Tricell) (both with five-minute alternating air pressure) and a standard hospital mattress (Paracare). In the Sanada trial, both the experimental groups and control group had a two-hourly change of position and skin care. In the Air Doctor group 4/29 (13.8%) participants developed grade 2 pressure ulcers, in the Tricell group 1/26 (3.8%) participants developed grade 2 pressure ulcers; and in the standard hospital mattress group 6/27 (22%) participants developed grade 2 pressure ulcers. The number of grade 1 ulcers was also reported in the study. The denominators are numbers presented by the authors after withdrawals and attrition, and the study was not analyzed by intention-to-treat (in that withdrawals were excluded from the analysis). For the purpose of meta-analysis, this three-armed trial was merged into two groups receiving AP overlay.^{18,19}

EFFECTIVENESS OF AIR MATTRESSES

Pressure ulcer incidences

A study conducted shows that a surface shear force decreases the blood flow more than a normal force of the same magnitude. Earlier, Bennett et al.^{20,21} had constructed a sensor that could measure pressure, shear force, and blood flow on the skin. The sensor was first tested on the soft tissue in a hand²⁰ and then later used for experiments underneath the buttocks of normal individuals, geriatric individuals, and paraplegics²¹. It was found that the shear force in seated geriatric and paraplegic patients was roughly three times higher than typical values for healthy individuals. The median rates of pulsatile skin blood flow for geriatric and paraplegic patients were only one-third of the normal values. The seated posture of the test subjects was not registered.^{20,21,22}

A study was conducted “To estimate the frequency of use of pressure-redistributing support surfaces (PRSS) among hip fracture patients and to determine whether higher pressure ulcer risk is associated with greater PRSS use”. Patients (n = 658) aged ≥ 65 years who had surgery for hip fracture were examined by research nurses at baseline and on alternating days for 21 days obtained. The result was a PRSS was observed at 36.4% of the 5,940 study visits. The odds of PRSS use were lower in the rehabilitation setting (adjusted odds ratio [OR] 0.4, 95% confidence interval [CI] 0.3-0.6), in the nursing home (adjusted OR 0.2, 95% CI 0.1-0.3), and during readmission to the acute setting (adjusted OR 0.6, 95% CI 0.4-0.9) than in the initial acute setting.²³

Contact interface pressure and blood perfusion

The results of Zhang and Roberts²⁴ and Goossens et al.²⁵ show that applied pressure and shear forces decrease the blood flow in the skin and some time after the pressure is relieved

the blood flow will return to its previous level. It is possible that this recovery time may prolong hypoxia enough to cause necrosis. This was studied by Meijer et al.²⁶ in an investigation of 109 elderly individuals, and it was concluded that the blood-flow recovery time is a direct measure of susceptibility to pressure ulcers.

A recent study by Deitrick et al.²⁷ worked from the hypothesis that spinal cord injured (SCI) patients get insufficient exercise due to the paralyzed muscle mass in the lower extremities and therefore are prone to poor circulation in the legs, which represents an increased arteriosclerotic risk factor.

A study used a transcutaneous oxygen/CO₂ monitoring system to investigate the influence of combined pressure and shear loading on ischemia. The sensor was indented into the skin either by pure normal pressure or by a combination of normal pressure and shear stress of 3.1 kPa, and the skin oxygen pressure was measured simultaneously. With pure normal loading, a mean applied pressure of 11.6 kPa was required to obtain a skin oxygen pressure of 1.3 kPa, which was presumed to be the ischemic limit. When a shear stress of 3.1 kPa was included in addition to the normal pressure, a normal pressure of only 8.7 kPa was necessary to reduce the oxygen pressure to 1.3 kPa, thus indicating that shear has an influence on ischemia²⁸

A tissue temperature increase of 1°C gives an approximately 12% increase in metabolism, meaning that the tissue will need more nutrition and oxygen, therefore requiring an increased blood flow. The relative humidity in the skin-support surface interface could be raised owing to perspiration, urine and faeces. Moderate moisture increases the skin friction, whereas a high degree of moisture decreases the friction, but makes the skin more sensitive to damage from robbing. Prolonged skin wetness increases the vulnerability to pressure-induced blood flow reduction. This effect appears to be caused mainly by the wetness, but urine could aggravate the effect. Thus the support surface has an important role in the dissipation of heat and moisture away from the skin-surface interface, to maintain an acceptable microclimate. Using plastic covers to protect mattresses in hospital is common practice; however, the plastic cover limits the mattress's ability to maintain a good microclimate. To summarize this Section, the extrinsic parameters we consider most essential to measure when evaluating antidecubitus mattresses are interface pressure in combination with blood flow and microclimate. Ideally, these parameters ought to be measured in conceivable users, i.e. individuals prone to pressure sore formation. It is also important to take into consideration the individual conditions that differ between subjects.^{29, 30, 31}

Comfort and cost effectiveness

Patients in a 257-bed acute care facility were included. One hundred, ten patients (110) were randomized into a control group using either a micro fluid static overlay (MSO) or a low-air-loss dynamic mattress (LALDM) with pulsation (n = 55) or into an experimental group using

an inflated static overlay (ISO) (n = 55). Head-to-toe assessments were performed 3 times a week for a maximum of 14 days to determine presence of pressure ulcers and comfort; Fisher's exact and chi-square tests were used to assess categorical data, and unpaired t-test and Mann-Whitney statistic tests were used to compare continuous variables. Comparative cost of support surface use was determined at the end of the study. Study found that in the control group, 50 patients used an MSO and 5 patients used an LALDM; in the experimental group, 55 patients used an ISO. No significant difference in pressure ulcer incidence was found between the control (n = 6) and experimental groups (n = 2) (11% versus 4%, respectively; $P = 0.2706$), and there was no significant difference in comfort (90% versus 85%; $P = 0.7129$). However, a significant difference was noted in total cost (\$13,606 CAD versus \$3,364 CAD, $P \leq 0.001$); the ISO was less expensive.³² To evaluate the cost-effectiveness of pressure-redistribution mattresses (PRMs) compared to standard mattresses (SMs) on emergency room stretchers and beds for the prevention of pressure ulcers (PrUs) in patients admitted to hospitals via emergency departments. A Markov history model of PrUs was developed. Input data for prevalence of hospital-acquired (H-A) PrUs, health utility and costs were derived from population-based data sources. A cost-utility analysis was conducted according to the Ontario health system perspective and 1-year time horizon. Approximately 1 in 6 emergency-admitted patients experienced H-A PrUs. PRMs reduced the prevalence of H-A PrUs by 2.2% (range: 1.7%, 2.6%); on average, 47 patients need to be on PRMs to prevent one H-A PrU. The mean cost saving associated with PRMs was \$74 per patient for the 258,000 targeted cases per year in Ontario. PRMs had a 68% chance of improving health while saving costs. The aggregate direct cost saving to hospitals' budgets would be \$17 million per year.³³

CONCLUSIONS

This paper provides overview of literature published on the use of air mattress as a means of pressure ulcer prevention. The literature is mainly focused on Pressure ulcer incidences and effectiveness and comfort of air mattresses. From the literature review we can conclude that, while comparing effectiveness of different foam and air mattresses it is found that alternating pressure air mattresses (APAMs) are more effective. Further it is found that the problem highlighted in the review is that the mattresses' effectiveness in preventing and treating pressure sores has not been sufficiently evaluated. When antidecubitus mattresses are evaluated, it is often only with regard to aspects of the interface pressure and the mattresses ability to redistribute the pressure. The review points out the important observation that, to evaluate the efficacy of the antidecubitus mattress, the mattress's effect on tissue viability needs to be studied. A number of technical problems associated with APAMs are related to nurses' improper use of devices.

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