

## **Pressure ulcers and shear.**

This month's pressure ulcer references cover publications cited in EMBASE that consider shear and pressure ulcers – shear in wound aetiology will form a major focus at this year's Tissue Viability Society conference.

Bansal, C., R. Scott, et al. (2005). "Decubitus ulcers: A review of the literature." *International Journal of Dermatology* 44(10): 805-810.

Decubitus ulcers are a worldwide health care concern affecting tens of thousands of patients and costing over a billion dollars a year. Susceptibility to pressure ulcers comes from a combination of external factors (pressure, friction, shear force, and moisture), and internal factors (e.g. fever, malnutrition, anaemia, and endothelial dysfunction). Often, enough damage is done to create the basis for a decubitus ulcer after as little as 2 h of immobility, a situation which may be difficult to avoid if the patient must undergo prolonged surgery or remain bedridden. Damage owing to pressure may also occur hours before the patient receives medical attention, especially if the patient falls or becomes immobilized owing to a vascular event. Several classification systems for decubitus ulcers have been described, based on where injury first occurs. The histologic progression of decubitus ulcers is a dynamic process involving several stages, each having characteristic histologic features. A team-focused approach integrating all aspects of care, including pressure relief, infection control, nutrition, and surgery, may improve healing rates. With accurate risk assessment and preventative care, we can hope to minimize complications and mortality owing to decubitus ulcers. copyright 2005 The International Society of Dermatology.

Barbut, F., B. Parzybut, et al. (2006). "Pressure sores in a university hospital: Prevalence, risk factors, and management. [French]." *Presse Medicale* 35(5 I): 769-778.

Objectives > To determine the prevalence of pressure sores, their risk factors, and the responsible microbial agents in an acute-care hospital and to evaluate their management. Method > A prevalence survey was conducted from 5 July through 9 July 2004. Investigators completed a standardized questionnaire for each hospitalized patient, including demographic data (age, sex, previous hospitalizations,

etc.) and Braden scale risk factors (sensory perception, humidity, activity, mobility, nutrition, and friction and shear). Two experts in skin care detected pressure sores by physical examination of the patients. Each pressure sore was swabbed and inoculated on selective media. Management was evaluated by reviewing the clinical charts of each patient with a pressure sore. Results > The study included 535 adult patients (aged 59 +/- 19 years): 75 ulcer sores were observed in 37 patients (prevalence = 6.9%). Stage I sores accounted for 24% of the total, stage II for 29%, stage III 31%, and stage IV 16%. The most frequent site was the heel (41%), followed by the sacrum (20%), elbow (11%), back (7%) and ischial tuberosities (7%). Sixty (80%) were acquired while hospitalized. Age-adjusted multivariate analyses found that the risk factors significantly associated with pressure sores were Braden score [less-than or equal to]15 (OR = 5.9, 95% CI: 2.4-13.7, p <0.0001) and previous pressure sores (OR = 5.0 95% CI: 2.2-11.6, p < 0.0001). Eleven sores (24.5%), mostly stage III and IV, were colonized by multiple-drug-resistant bacteria (i.e., methicillin resistant *Staphylococcus aureus*, extended spectrum beta-lactamase Enterobacteriaceae). Seven (9.3%) of the 75 ulcers were diagnosed only during the survey, by the experts; of the 68 diagnosed before the survey, 57 (83.8%) had been under treatment. Treatment was considered inappropriate according to French guidelines in 31.6% of the cases. Conclusion > This prospective prevalence study resulted in better awareness of the patients at risk for pressure sores. It also made the recently created mobile geriatrics unit better known within the hospital. copyright 2006, Masson.

Caswell, M. and L. E. Kanj (1999). "Pressure ulcers [2] (multiple letters)." *Journal of the American Academy of Dermatology* 40(1): 131.

Chronakos, J. and D. M. Nierman (2003). "Managing pressure ulcers in critically ill patients." *Journal of Respiratory Diseases* 24(8): 365-371.

Critically ill patients are at increased risk for the development of decubitus ulcers as a result of impaired mobility, blunted sensation, and decreased serum albumin levels. Therefore, patients in the ICU need careful daily inspection of skin for early evidence of breakdown, with special attention to pelvic, sacral, elbow, and heel areas. Existing ulcers should be examined and staged. Preventive measures that can reduce the potential for decubitus ulceration include repositioning every 2 hours

and minimization of friction and shear forces. Special bedding options range from foam to air-fluidized beds. For established ulcers, nutritional supplementation with ascorbic acid or zinc appears to promote healing. Mechanical, chemical, and surgical debridement are options for deeper wounds. Exogenous cytokines are useful adjuncts to medical and surgical care. Growth factors and cultures of human keratinocytes may have an expanded role in the future.

Dabnichki, P. and D. Taktak (1998). "Pressure variation under the ischial tuberosity during a push cycle." *Medical Engineering and Physics* 20(4): 242-256.

The present study is devoted to the variation of the magnitude of the compressive loading acting on the soft seating parts of a disabled person and the related pressure distribution under the ischial tuberosity during wheelchair propulsion. A combined experimental and computational approach was designed to predict correctly the change in magnitude of the maximum internal shear and compressive stresses produced by different propulsion speeds, cushion characteristics and body position of the subject. The results obtained show that the vertical force acting on the seating parts increases with the propulsion speed and exceeds the body weight by more than 100%. The related pressure under the ischial tuberosity shows a significant increase of 125% on the tissue/seat interface and an estimated increase of 185% in the peak compressive stress. It is concluded that computer modelling using a quasistatic approach provides a reliable estimate of the pressure values by the observed loading frequencies of 0-4 Hz. It can also be noted that the time independent material model utilised for the bulky soft tissue proved adequate for the estimate of the pressure level occurring under the ischial tuberosity during a push cycle.

Edlich, R. F., K. L. Winters, et al. (2004). "Pressure ulcer prevention." *Journal of Long-Term Effects of Medical Implants* 14(4): 285-304.

The purpose of this collective review is to outline the predisposing factors in the development of pressure ulcers and to identify a pressure ulcer prevention program. The most frequent sites for pressure ulcers are areas of skin overlying bony prominences. There are four critical factors contributing to the development of pressure ulcers: pressure, shearing forces, friction, and moisture. Pressure is now viewed as the single most important etiologic factor in pressure ulcer formation.

Prolonged immobilization, sensory deficit, circulatory disturbances, and poor nutrition have been identified as important risk factors in the development of pressure ulcer formation. Among the clinical assessment scales available, only two, the Braden Scale and Norton Scale, have been tested extensively for reliability and/or validity. The most commonly used risk assessment tools for pressure ulcer formation are computerized pressure monitoring and measurement of laser Doppler skin blood flow. Pressure ulcers can predispose the patient to a variety of complications that include bacteremia, osteomyelitis, squamous cell carcinoma, and sinus tracts. The three components of pressure ulcer prevention that must be considered in any patient include management of incontinence, nutritional support, and pressure relief. The pressure relief program must be individualized for non-weight-bearing individuals as well as those that can bear weight. For those that can not bear weight and passively stand, the RENAISSANCE Mattress Replacement System is recommended for the immobile patient who lies supine on the bed, the stretcher, or operating room table. This alternating pressure system is unique because it has three separate cells that are not interconnected. It is specifically designed so that deflation of each individual cell will reach a ZERO PRESSURE during each alternating pressure cycle. The superiority of this system has been documented by comprehensive clinical studies in which this system has been compared to the standard hospital bed as well as to two other commercially available pressure relief mattresses. The most recent advance in pressure ulcer prevention is the development of the ALTERN8\* seating system. This seating system provides regular periods of pressure relief and stimulation of blood flow to skin areas while users are seated. By offering the combination of pressure relief therapy and an increase in blood flow, the ALTERN8\* reportedly creates an optimum pressure ulcer healing environment. Foam is the most commonly used material for pressure reduction and pressure ulcer prevention and treatment for the mobile individual. For those immobilized individuals who can achieve a passive standing position, a powered wheelchair that allows the individual to achieve a passive standing position is recommended. The beneficial effects of passive standing have been documented by comprehensive scientific studies. These benefits include reduction of seating pressure, decreased bone demineralization, increased bladder pressure, enhanced orthostatic circulatory regulation, reduction in muscular tone, decrease in upper extremity muscle stress, and enhanced functional status in general. In the absence

of these dynamic alternating pressure seating systems and mattresses, there are enormous medicolegal implications to the healthcare facility. Because there is not sufficient staff to provide pressure relief to rotate the patient every 2 hours in a hospital setting, with the exception of the intensive care unit, the immobile patient is prone to develop pressure ulcers. The cost of caring for these preventable pressure ulcers may now be as high as \$60,000 per patient. The occupational physical strain sustained by nursing personnel in rotating their patients has led to occupational back pain in nurses, a major source of morbidity in the healthcare environment.

Elena Sorando, E., P. Benito Duque, et al. (2005). "Prevention of pressure sores in Palliative Care: Recomendations in evidence based medicine. [Spanish]." *Medicina Paliativa* 12(1): 47-54.

Pressure sores affect patients who are unable to change position regularly, usually cronic, elderly and advanced disease patients. We review pressure sores literature, searching into evidence based medicine. Evidence based medicine proposes the best clinical and scientific evidence available relative to pressure sores, so it affirms, prevention is a very important goal in this problem. Outcomes emphasize: patients require general approach with preventive strategies include recognizing risk, decreasing the effects of pressure, assessing nutritional status, avoiding excessive bed rest and preserving the integrity of the skin. Our study concludes that effective actions in pressure sores prevention are: assessing the severity of the ulcer, reducing pressure and shear forces, optimising skin care, avoiding excess moisture due to incontinence and correcting nutritional deficits. Copyright copyright 2005 ARAN EDICIONES, S.L.

Ferrarin, M., G. Andreoni, et al. (2000). "Comparative biomechanical evaluation of different wheelchair seat cushions." *Journal of Rehabilitation Research and Development* 37(3): 315-324.

The aim of the present study was to perform a comparative biomechanical analysis of four antidecubitus wheel-chair cushions. Thirty wheelchair users were considered divided into three groups: paraplegic subjects (with no cutaneous sensation), neurologic subjects (with intact cutaneous sensation), and elderly subjects. The biomechanical evaluation was performed using a piezoresistive sensor matrix system to quantify parameters referred to pressure distribution, seating

surface and posture. Dedicated software was developed for the automatic elaboration of the raw data and the computation of the parameters of interest. Differences among cushion types and subject groups were analyzed. An analysis of time-transient behaviors was also performed. Results showed that no significant differences in pressure peak reduction were found among the four cushions. Moreover, no time-transient behavior was shown by any cushions. However, both the location of pressure peaks and posture were dependent on cushion types. Comparison of the three subject groups showed that elderly subjects had the highest mean pressure and the lowest contact surface, while paraplegics presented the highest pressure peaks. This procedure appears indicated for individualizing the prescription of a wheelchair cushion and even for customizing a cushion to induce a specific posture.

Feuchtinger, J., R. J. G. Halfens, et al. (2005). "Pressure ulcer risk factors in cardiac surgery: A review of the research literature." *Heart and Lung: Journal of Acute and Critical Care* 34(6): 375-385.

**BACKGROUND:** Pressure ulcer incidence in patients undergoing cardiac surgery is reported to be up to 29.5%. Common known risk factors for pressure ulcer development include compressive and shearing forces. However, knowledge about the specific risk factors in a defined population is helpful in the development of an effective prevention management. This literature review is part of a quality improvement project to reduce pressure ulcer incidence in the cardiac surgery population. **OBJECTIVES:** The objective is to determine "which specific risk factors for pressure ulcer development in the cardiac surgery population are identified in the literature." **RESULTS:** The results of this literature review indicate a high-risk potential in the tissue tolerance for oxygen as temperature manipulation, vasoactive drugs, hypotensive periods, and reduced hemoglobin and hematocrit levels. Time on the operating room table, frequency of repositioning, immobility time, older age, low albumin level, and corticosteroid are also found as significant risk factors in this population. **CONCLUSION:** Diseases that influence oxygen supply in older patients in combination with the special demands of temperature and circulation regulation during the cardiac surgical procedure place the patient at risk for pressure ulcer development. Prevention measures should be aimed at supporting tissue tolerance for pressure and tissue tolerance for oxygen. These measures should be additional

to pressure-relieving devices on the operating room table and, postoperatively in bed, a defined minimum frequency of postoperative turning and early mobilization after the surgical procedure should be considered. Copyright copyright 2005 by Mosby, Inc.

Garcia, A. D. and D. R. Thomas (2006). "Assessment and Management of Chronic Pressure Ulcers in the Elderly." *Medical Clinics of North America* 90(5): 925-944.

Pressure ulcers remain a complex and costly problem to the health care system. As the population ages, a greater number of individuals will be at high risk for developing pressure ulcers. An understanding of the physiologic changes that occur with aging skin is important in preventing and treating chronic wounds. Risk factor assessment and modification, when possible, can help to reduce the development of pressure ulcerations. Although the goal continues to be prevention, once a pressure ulcer does occur, a systematic and comprehensive approach to assessment and treatment is necessary to reduce healing times. copyright 2006 Elsevier Inc. All rights reserved.

Gefen, A. (2007). "Risk factors for a pressure-related deep tissue injury: A theoretical model." *Medical and Biological Engineering and Computing* 45(6): 563-573.

Pressure-related deep tissue injury is the term recommended by the United States National Pressure Ulcer Advisory Panel to describe a potentially life-threatening form of pressure ulcers, characterized by the presence of necrotic tissue under intact skin, and associated with prolonged compression of muscle tissue under bony prominences. In this study, a theoretical model was used to determine the relative contributions of the backrest inclination angle during prolonged wheelchair sitting, the muscle tissue stiffness and curvature of the ischial tuberosities (ITs) to the risk for injury in the gluteus muscles that pad the IT bones during sitting. The model is based on Hertz's theory for analysis of contact pressures between a rigid half-sphere (bone) and an elastic half-space (muscle). Hertz's theory is coupled with an injury threshold and damage law for muscle - both obtained in previous studies in rats. The simulation outputs the time-dependent bone-muscle contact pressures and the injured area in the gluteus. We calculated the full-size (asymptotic) injured area in the gluteus and the time for injury onset for different sitting angles  $\alpha$  (90-50degrees), muscle tissue long-term shear moduli  $G$  (250-1,200 Pa) and bone

diameters  $D$  (8-18 mm). We then evaluated the sensitivity of model results to variations in these parameters, in order to determine how injury predictions are affected. In reclined sitting ( $\alpha = 150^\circ$ ) the full-size injured area was [similar to]2.1-fold smaller and the time for injury onset was [similar to] 1.3-fold longer compared with erect sitting ( $\alpha = 90^\circ$ ). For greater  $G$  the full-size injured area was smaller but the time for injury onset was shorter, e.g., increasing  $G$  from 250 to 1200 Pa decreased the full-size injured area [similar to]2.5-fold, but shortened the time for injury onset 6.2-fold. For smaller  $D$  the time for injury onset dropped, e.g., decreased [similar to]1.5-fold when  $D$  decreased from 18 to 8 mm. Interestingly, the full-size injured area maximized at  $D$  of about 12 mm but decreased for smaller or larger  $D$ . The susceptibility to sitting-acquired deep tissue injury strongly depends on the geometrical and biomechanical characteristics of the bone-muscle interface, and, particularly, on the radius of curvature of the IT which mostly influenced the size of the wound, and on the muscle stiffness which dominantly affected the time for injury onset. copyright International Federation for Medical and Biological Engineering 2007.

Gefen, A., N. Gefen, et al. (2005). "In vivo muscle stiffening under bone compression promotes deep pressure sores." *Journal of Biomechanical Engineering* 127(3): 512-524.

Pressure sores (PS) in deep muscles are potentially fatal and are considered one of the most costly complications in spinal cord injury patients. We hypothesize that continuous compression of the longissimus and gluteus muscles by the sacral and ischial bones during wheelchair sitting increases muscle stiffness around the bone-muscle interface over time, thereby causing muscles to bear intensified stresses in relentlessly widening regions, in a positive-feedback injury spiral. In this study, we measured long-term shear moduli of muscle tissue in vivo in rats after applying compression (35 KPa or 70 KPa for 1/4-2 h,  $N = 32$ ), and evaluated tissue viability in matched groups (using phosphotungstic acid hematoxylin histology,  $N = 10$ ). We found significant (1.8-fold to 3.3-fold,  $p < 0.05$ ) stiffening of muscle tissue in vivo in muscles subjected to 35 KPa for 30 min or over, and in muscles subjected to 70 KPa for 15 min or over. By incorporating this effect into a finite element (FE) model of the buttocks of a wheelchair user we identified a mechanical stress wave which spreads from the bone-muscle interface outward through longissimus muscle

tissue. After 4 h of FE simulated motionlessness, 50%-60% of the cross section of the longissimus was exposed to compressive stresses of 35 KPa or over (shown to induce cell death in rat muscle within 15 min). During these 4 h, the mean compressive stress across the transverse cross section of the longissimus increased by 30%-40%. The identification of the stiffening-stress-cell-death injury spiral developing during the initial 30 min of motionless sitting provides new mechanistic insight into deep PS formation and calls for reevaluation of the 1 h repositioning cycle recommended by the U.S. Department of Health. Copyright copyright 2005 by ASME.

Goldstein, B. and J. Sanders (1998). "Skin response to repetitive mechanical stress: A new experimental model in pig." *Archives of Physical Medicine and Rehabilitation* 79(3): 265-272.

Objectives: To develop a new animal model for investigating the relations between interface stresses at the skin, adaptation, and breakdown. There were two hypotheses. (1) In skin subjected to varying types of repetitive mechanical stress, the tissue response depends on the direction and magnitude of the load. As the shear stress increases, tissue breakdown occurs earlier. (2) In skin subjected to repetitive mechanical stress of longer duration, there will be evidence of tissue adaptation. Design: Multiple case control, single-blind. Interventions: Varying combinations of normal and shear mechanical loads are applied to pig's skin for short durations (breakdown studies) or longer durations (adaptation studies). Main Outcome Measures: Gross evidence of breakdown (visual inspection of skin) and microscopic changes (eg, histologic features of breakdown; thickness of epidermis and dermis; the length and shape of the basement membrane; concentration of inflammatory cells, mast cells, and fibroblasts; and quantity of elastin fibers). Results: The instrumentation was reliable and a significant improvement over past models in that shear forces were delivered and measured in a controlled manner. The animal model and tissue methodology provided consistent results, and it was found that skin breakdown occurred earlier as shear forces were increased. Evidence of tissue adaptation occurred in the long-term experiments, although corresponding morphologic changes have been difficult to elucidate. Conclusions: To address the problem of skin breakdown, new animal models are strongly needed to better understand basic biologic processes related to pressure ulcer development.

Goossens, R. H. M., C. J. Snijders, et al. (1997). "Shear stress measured on beds and wheelchairs." *Scandinavian Journal of Rehabilitation Medicine* 29(3): 131-136.

Local shear is understood to be one of the principal risk factors for the development of pressure sores. There is a need for a small deformable sensor that can measure the shear force between skin and deformable materials without disturbing the shear phenomenon. In the present study a new shear sensor is introduced with a contact area of  $4.05 \text{ cm}^2$ . A series of validation experiments was performed with ten healthy young subjects. It was demonstrated that with a forward-tilted seat, the sum of the local shear forces between skin and sensormat is equal to the resultant shear force measured with a force plate. This result serves as a validation of the new sensor. The shear values recorded are 4.8 kPa in the longitudinal direction and 8.5kPa in the transversal direction while sitting in a wheelchair, and 5.6kPa in the longitudinal direction and 3.1 kPa in the transversal direction on a mattress of a hospital bed, while in sitting position in bed.

Grey, J. E., S. Enoch, et al. (2006). "Pressure ulcers." *British Medical Journal* 332(7539): 472-475.

Gunningberg, L., C. Lindholm, et al. (2001). "Risk, prevention and treatment of pressure ulcers - Nursing staff knowledge and documentation." *Scandinavian Journal of Caring Sciences* 15(3): 257-263.

The aims were to investigate (i) registered nurses' and nursing assistants' knowledge of risk, prevention and treatment of pressure ulcer before implementing a system for risk assessment and pressure ulcer classification for patients with hip fracture (ii) interventions documented in the patient's records by registered nurses, and (iii) to what extent reported and documented interventions accord with the Swedish quality guidelines. Nursing staff (n = 85) completed a questionnaire, and patient's records (n = 55) were audited retrospectively. The majority of the nursing staff reported that they performed risk assessment when caring for a patient with hip fracture. These risk assessments were, however, not comprehensive. The most frequently reported preventive interventions were repositioning, use of lotion, mattresses/overlays and cushions for the heels. These interventions were to some extent documented in the patient's records. Nutritional support, reduction of shear

and friction, hygiene and skin moisture, and patient's education were reported to a small extent and not documented at all. The Swedish quality guidelines regarding prevention and treatment of pressure ulcers were not fully implemented in clinical practice. It was concluded that nursing staff's knowledge and documentation of risk, prevention and treatment of pressure ulcers for patients with hip fractures could be improved.

Ho, K., S. Warriar, et al. (2006). "A prepelvic tunnel for the rectus abdominis myocutaneous flap in perineal reconstruction." *Journal of Plastic, Reconstructive and Aesthetic Surgery* 59(12): 1415-1419.

Background: The use of the transpelvic vertical rectus abdominis myocutaneous (VRAM) flap in pelvic reconstruction is well documented. It can be used to fill large defects after pelvic exenteration, reconstruct the vagina and provide skin coverage in perineal reconstruction. This study examines an alternate prepelvic pathway for the flap to enhance its versatility and reliability. Patients and method: A female patient with recurrent squamous cell carcinoma in the pelvis, who underwent radical pelvic exenteration and a successful VRAM flap reconstruction with a prepelvic tunnel. Results: The patient experienced a small area of epithelial tip necrosis over the sacral promontory from shear forces. This healed with dressings within two weeks. There were no major flap complications and the patient had good flap integrity at one-year follow-up. The prepelvic pathway for the VRAM flap is advantageous to the conventional transpelvic course in perineal reconstruction. The more direct, shorter path to the defect allows for a more reliable skin paddle design without the need for de-epithelialisation. A greater area of skin paddle is available and creates a more versatile flap with no tension on the pedicle. This is especially in cases where a skin paddle is needed for vaginal reconstruction or when pelvic organs such as bladder and uterus are left in situ. These advantages may result in less flap complications. copyright 2006 The British Association of Plastic Surgeons.

Houwing, R. H. and E. M. H. Mathus-Vliegen (2007). "Dietary supplements such as nutrient drinks have no role in the prevention of pressure sores. [Dutch]." *Nederlands Tijdschrift voor Geneeskunde* 151(18): 1015.

Pressure sores are the result of primary intrinsic factors like pressure, shear and friction forces combined with secondary extrinsic factors such as old age,

malnutrition, immobility, incontinence, and poor physical and mental health. A cause-and-effect relationship between malnutrition and decubitus ulcers has never been established. There is insufficient evidence that dietary interventions can decrease the incidence of pressure sores.

Hughes, C. (2001). "Obstetric care. Is there risk of pressure damage after epidural anaesthesia?" *Journal*.

Anecdotal evidence suggests that there is an increase in the incidence of pressure damage to women in labour. This appears to be associated with epidural anaesthesia. Epidural anaesthesia used to control pain in childbirth causes loss of sensation and a degree of motor block, which removes the women's reflexes and ability to reposition to prevent pressure damage. The large amount of fluids present during childbirth may also increase the risk of pressure damage, especially in association with shear and friction. A combination of unfamiliarity of pressure ulcer prevention techniques among midwives, and the type of delivery room equipment, that is currently available, may leave young healthy women at risk of developing pressure ulcers. copyright copyright 1992-Feb 2001 by SMTL.

Ichioaka, S., N. Ohura, et al. (2003). "Treatment for intractable pressure ulcers. [Japanese]." *Japanese Journal of Plastic and Reconstructive Surgery* 46(5): 485-490.

Management for intractable pressure ulcers remains one of the most challenging problems facing plastic surgeons. Factors that complicate ulcer treatment are usually associated with a patients' poor general status and an unfavorable local condition of the wounds. We should treat pressure ulcers in accordance with the clinical and social situation of each individual patient. Major local factors associated with difficult ulcers incorporate persistent harmful external forces (i.e. normal stress and shear stress), infection, necrosis, and subcutaneous pocket formation. Besides these local unfavorable factors, various situations that affect each case usually reject surgical treatment even in cases where a surgical operation may provide the best result. This article describes various management methodologies to counteract these troublesome situations that may lead to difficult ulcers. Concrete procedures include the release of external forces, debridement, irrigation, and treatment for subcutaneous pockets. We also demonstrate less

invasive surgery based on regenerative wound bed preparation using newly developed biomaterials and drugs.

Jastremski, C. A. (2002). "Pressure relief bedding to prevent pressure ulcer development in critical care." *Journal of Critical Care* 17(2): 122-125.

One major risk for the critically ill patient is the development of pressure ulcers during the intensive care unit (ICU) stay. These patients have many of the risk factors for the development of pressure ulcers including reduced mobility/activity, medications, neurologic deficits, increasing age, incontinence, decreased mental status, poor nutrition, pressure, shear forces, and friction. Pressure ulcers are known to be costly for the health care system and delay recovery in many patients. Different strategies have been advocated for the prevention of pressure ulcers, and the Agency for Healthcare Research and Quality (AHRQ) has identified the use of pressure relief bedding as a means to prevent the development of pressure ulcers during hospitalization. The use of pressure relief bedding has received the most research attention to date. The focus of this article is to describe the state of the current research in this area and how this applies to critical care. Development of protocols and guidelines for the use of pressure ulcer preventing strategies are important to improve the quality of care in the ICU. There is still a need to examine the impact of the evidence of pressure ulcer prevention in the ICU and this review should help to build a framework for future research and protocol development. Copyright 2002, Elsevier Science (USA). All rights reserved.

Jonsson, A., M. Linden, et al. (2005). "Evaluation of antidecubitus mattresses." *Medical and Biological Engineering and Computing* 43(5): 541-547.

Pressure sores are a current problem in hospitals and care of the elderly, leading to protracted hospital stays and a high care burden. The trauma for the patients is severe, and the cost of pressure sore prevention and treatment, is considerable. Antidecubitus mattresses are used for prevention and in treatment, but they also contribute to the cost of treating pressure sores. 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 be able to evaluate the efficacy of the antidecubitus mattress, the mattress's effect on tissue viability needs to be studied. The parameters that ought to be considered when evaluating a support surface are: interface pressure, pressure and blood flow distribution, temperature and humidity in the skin-support surface interface. The authors propose that the effect on tissue viability of external loading can be assessed by simultaneous measurement of the interface pressure and tissue perfusion. copyright IFMBE: 2005.

Kemppainen, B. W., D. W. Urry, et al. (2004). "Bioelastic membranes for topical application of a thromboxane synthetase inhibitor for protection of skin from pressure injury: A preliminary study." *Wound Repair and Regeneration* 12(4): 453-460.

A previous study showed that topical exposure to bioelastic-thromboxane synthetase inhibitor-matrix resulted in local tissue concentrations of thromboxane synthetase inhibitor sufficient for thromboxane synthetase inhibition. The objective of this research was to use an animal model to determine if a dressing having controlled release of thromboxane synthetase inhibitor (dazmegrel) could be used to prevent tissue breakdown over pressure points, i.e., lesion at the assistive device-skin interface. The animal model studies utilized the greyhound, a dog that has thin skin, angular conformation, limited body fat and is predisposed to pressure ulcers similar to those occurring in humans. The model uses a short-limb walking cast on one pelvic limb with the severity of the dermal pressure lesions induced over the medial malleolus controlled by the amount of padding in the cast and length of time the cast is in place. The bioelastic matrix loaded with dazmegrel provided protection from shearing and pressure skin injury over the medial malleolus, as evidenced by a decrease in epidermal abrasion/ulceration as measured with planimetry. Histopathologic evaluation of the skin over the medial malleolus indicated a protective function of the bioelastic matrix as measured as lower numbers of neutrophils, lymphocytes, and decreased collagen density compared to such numbers when no bioelastic matrix was present. These studies provided evidence that bioelastic-thromboxane synthetase inhibitor-matrix helps in preventing or reducing the severity of pressure lesions, e.g., assistive device-skin interface wounds.

Kikuchi, M., Y. Kai, et al. (2005). "Control of depressurization and seating are effective for a case of ischial pressure ulcer. [Japanese]." *Skin Research* 4(5): 448-452.

A 70-year-old woman with paraplegia sitting on wheelchair, had repeated ischial pressure ulcer for 10 years. The left ischial ulcer was getting worse, and ischial bone was exposed. So, she was admitted to our hospital and got treatment nonetheless the ulcer was hard to cure. MRSA infection was repeated despite using antibiotics. Debridements and several topical therapy could not make healthy granulation tissue. We think the cause of the ulcer was pressure and shearing force at the ischial region, so started strict control of depressurization after debridement. Under strict control of depressurization, MRSA infection had disappeared and the ulcer size got smaller with red granulation tissue. Then perforator flap were done. After operation, the control of depressurization were gradually removed, and we taught the patient how to seat on wheelchair to reduce the pressure at the ischial region. As a result, the patient has no recurrence of ulcer for 13 month after operation.

Kirkland, L. R. (1997). "Preventing shear-induced decubitus ulcers." *Consultant* 37(2): 272.

Klitzman, B., C. Kalinowski, et al. (1998). "Pressure ulcers and pressure relief surfaces." *Clinics in Plastic Surgery* 25(3): 443-450.

Pressure ulcer incidence has been reduced but not eliminated. A few patients still develop pressure ulcers despite using air-fluidized beds and other specialty beds. In the future, very high-risk patients may possibly be sent to space clinics to recuperate in zero gravity for extended periods. Another possibility is the creation of suspension devices to keep a patient off the areas of the body where pressure sores might occur. Being informed of what is available and aware how to use it optimally is currently the best solution.

Kolnaar, B. G. M. and V. G. M. Chel (2000). "Summary of the guideline 'Decubitus' [pressure ulcer] of the Dutch College of General Practitioners. [Dutch]." *Nederlands Tijdschrift voor Geneeskunde* 144(14): 646-649.

The guideline 'Decubitus' published by the Dutch College of General Practitioners contains guidelines with instructions for prevention, diagnosis and treatment of pressure ulcers in primary care. - The classification used for severity is: redness of the skin, superficial damage, superficial ulcer, deep ulcer. This classification follows the one used internationally and the one in the consensus of the Dutch Institute for Health Care Improvement CBO. - For each patient who becomes (totally or partly) immobile measures to prevent pressure ulcers are necessary, with emphasis on minimizing pressure and shearing forces acting upon the skin. After a pressure ulcer has developed these measures remain important. - Guidelines for treatment are given for each level of severity of the pressure ulcer; the main aim is to keep the ulcer moist, to remove necrosis and exudate and to treat infection.

Levi, B. and R. Rees (2007). "Diagnosis and Management of Pressure Ulcers." *Clinics in Plastic Surgery* 34(4): 735-748.

Pressure ulcers represent a significant health issue and cost for the growing number of elderly and debilitated patients. The plastic surgeon, as part of the wound care team, has the ultimate responsibility of forming a plan to allow for the eventual closure of the wound. This plan should start with breaking the cycle and eliminating the risk factors that led to the development of the wound. Simultaneously, the surgeon should order an MRI and erythrocyte sedimentation rate and take a bone biopsy to diagnose the extent of the wound and the bacteria present. If more than 10<sup>5</sup> bacteria are present, surgical debridement should be performed, followed by 6 weeks of intravenous antibiotics. Once the bacterial load has been lessened, a 6-week course of Regranex should be applied. Finally, after the wound bed has been prepared adequately, definitive surgical closure should be planned and performed. copyright 2007 Elsevier Inc. All rights reserved.

Lindgren, M., M. Unosson, et al. (2004). "Immobility - A major risk factor for development of pressure ulcers among adult hospitalized patients: A prospective study." *Scandinavian Journal of Caring Sciences* 18(1): 57-64.

Objective: To identify risk factors associated with pressure ulcer development among adult hospitalized medical and surgical patients. Design: A prospective comparative study including 530 adult patients from medical and surgical wards.

Registered Nurses made the data collection on admission and once a week for up to 12 weeks. The risk assessment scale used was the Risk Assessment Pressure Sore (RAPS) scale, including the following variables; general physical condition, activity, mobility, moisture, food intake, fluid intake, sensory perception, friction and shear, body temperature and serum albumin. Results: Sixty-two (11.7%) patients developed 85 pressure ulcers. The most common pressure ulcer was that of nonblanchable erythema. Patients who developed pressure ulcers were significantly older, hospitalized for a longer time, had lower scores on the total RAPS scale, had lower weight and lower diastolic blood pressure than nonpressure ulcer patients did. In the multiple logistic regression analyses using variables included in the RAPS scale immobility emerged as a strong risk factor. When adding remaining significant variables in the analyses, mobility, time of hospitalization, age, surgical treatment and weight were found to be risk factors for pressure ulcer development. Conclusion: It is confirmed that immobility is a risk factor of major importance for pressure ulcer development among adult hospitalized patients. The results also indicate that the RAPS scale may be useful for prediction of pressure ulcer development in clinical practice. copyright 2004 Nordic College of Caring Sciences.

Lowthian, P. T. (2005). "Trauma and thrombosis in the pathogenesis of pressure ulcers." *Clinics in Dermatology* 23(1): 116-123.

Lyder, C. H. (2003). "Pressure ulcer prevention and management." *Journal of the American Medical Association* 289(2): 223-226.

Mess, S. A., S. Kim, et al. (2003). "Implantable Baclofen Pump as an Adjuvant in Treatment of Pressure Sores." *Annals of Plastic Surgery* 51(5): 465-467.

Currently, the success of ulcer treatment is limited by the high recurrence and complication rates. Spasticity is an important contributing factor to ulcer recurrence, and intrathecal baclofen is an effective method to reduce spasticity. Spasticity creates friction, shear, and mobility impairment resulting in wound dehiscence, flap loss, infection, and hematoma. Spasticity can be managed pharmacologically and surgically; baclofen is the drug of choice. Baclofen inhibits spasticity by blocking excitatory neurotransmitters in the spinal dorsal horn. Intrathecal baclofen maximizes the dose delivered to spinal receptors and minimizes the side effects associated with

oral baclofen. Case reports of intrathecal baclofen used in patients with pressure sores demonstrate the use of intrathecal baclofen to improve reconstructive outcomes in spastic patients.

Olyae Manesh, A., K. Flemming, et al. (2006). "Electromagnetic therapy for treating pressure ulcers." *Cochrane Database of Systematic Reviews* (2)(CD002930).

Background: Pressure ulcers are defined as areas "of localized damage to the skin and underlying tissue caused by pressure, shear, friction and/or the combination of these". In the UK, pressure ulcers occur in 5 to 32% of District General Hospitals people and in 4 to 7% of people in community settings. Electromagnetic therapy, in which electrodes produce an electromagnetic field across the wound, may improve healing of chronic wounds such as pressure ulcers. Objectives: To assess the effects of electromagnetic therapy on the healing of pressure ulcers. Search strategy: For this first update, we searched the Cochrane Wounds Group Specialised Register (last searched October 2005); CENTRAL (The Cochrane Library 2005, Issue 4); MEDLINE (1966 to October 2005); EMBASE (1980 to October 2005); and CINAHL (1982 to October 2005). Selection criteria: Randomised controlled trials comparing electromagnetic therapy with sham electromagnetic therapy, or other (standard) treatment. Data collection and analysis: For this first update, two authors independently scrutinized the results of the search to identify relevant RCTs and obtained full reports of potentially eligible studies. For the original review, details of eligible studies were extracted and summarised using a data extraction sheet. Attempts were made to obtain missing data by contacting authors. Data extraction was checked by a second author. Meta-analysis was applied to combine the results of trials when the interventions and outcome measures were sufficiently similar. Main results: This update identified no new trials. Two RCTs were identified for inclusion in the original review (total of 60 participants). One was a three-armed study comparing electromagnetic therapy with electromagnetic therapy in combination with standard therapy, and with standard therapy alone, on 17 female and 13 male with grade II and III pressure ulcers. The other study compared electromagnetic therapy with sham therapy in 30 male participants with a spinal cord injury and a grade II or grade III pressure ulcer. Neither study found a statistically significant difference between the healing rates of pressure ulcers in people treated with electromagnetic therapy compared with those in the control group. Authors' conclusions: The results provide

no evidence of benefit in using electromagnetic therapy to treat pressure ulcers. However, the possibility of a beneficial or harmful effect cannot be ruled out, due to the fact that there were only two included trials both with methodological limitations and small numbers of participants. Further research is recommended. Copyright copyright 2006 The Cochrane Collaboration. Published by John Wiley & Sons, Ltd.

Oura, T. (2003). "New concepts for understanding pressure ulcers. [Japanese]." *Japanese Journal of Plastic and Reconstructive Surgery* 46(4): 343-352.

1. As far as the prevalence of pressure ulcers are concerned, there are a few reliable reports available in Japan. In summary, the incidence of pressure ulcers in Japan is as follows: a) Inpatients (hospital and facility) 4.2%, 7.6% b) Homecare patients; 7.0%, 14.6% 2. Present state of pressure ulcers A nation wide study was performed and supported by the Japanese healthcare department. As a result, 655 cases of pressure ulcer protocols were collected from 205 hospitals and long-term care (LTC) facilities. The following results were obtained regarding the present state of pressure ulcer conditions: "an ulcer mental state 52%", "incontinence (feces) 88%", "incontinence (urine) 83%", "limited mobility 98%", "morbid bony prominence 80%". As for the distribution of pressure ulcers, 47% were located in the area of sacrum, 13% in the lower legs and 11% in the ischium. Furthermore, the depth of pressure ulcer was Stage III in 39% and Stage II in 28% of the evaluated cases. Space dose not permit me to report on other results of the collected data. 3. Shear force is the second key factor in the development of pressure ulcers, as was indicated by Bennet and Lee (1985). In fact, shear force occurs when tissues of different density move along each other, causing a decrease in circulation due to a mechanical deformation of local blood vessels. In Japan, mechanical stress combinations (compression stress, sheer force, tensile stress) by time by frequency is considered the underlying formula for defining pressure ulcers, not just pressure by time of past formula. The mechanism for the above mechanical stress and the relationship between mechanical stress and the three types of pressure ulcers are shown in this report. 4. Numerous intrinsic and extrinsic factors contribute to the development of pressure ulcers. Our nationwide study detected four risk factors: an altered level of consciousness, a morbid bony prominence, edema, and limitation of joint movement. It also showed that when patients had compound risk factors, pressure ulcer onset probability would change according to the level and category of

the risk factors. The results of this study also emphasized that both the warning factors (potential risk factors) and the intervention factors contributed extraordinarily to the development of pressure ulcers.

Palevski, A., I. Glai, et al. (2006). "Stress relaxation of porcine gluteus muscle subjected to sudden transverse deformation as related to pressure sore modeling." *Journal of Biomechanical Engineering* 128(5): 782-787.

Computational studies of deep pressure sores (DPS) in skeletal muscles require information on viscoelastic constitutive behavior of muscles, particularly when muscles are loaded transversally as during bone-muscle interaction in sitting and lying immobilized patients. In this study, we measured transient shear moduli  $G(t)$  of fresh porcine muscles in vitro using the indentation method. We employed a custom-made pneumatic device that allowed rapid (2000 mm/s) 4 mm indentations. We tested 8 gluteus muscles, harvested from 5 adult pigs. Each muscle was indented transversally (perpendicularly to the direction of fibers) at 3 different sites, 7 times per site, to obtain nonpreconditioned (NPC) and preconditioned (PC)  $G(t)$  data. Short-term ( $G_S$ ) and long-term ( $G_L$ ) shear moduli were obtained directly from experiments. We further fitted measured  $G(t)$  data to a biexponential equation  $G(t) = G_1 \cdot \exp(-t/\tau_1) + G_2 \cdot \exp(-t/\tau_2) + G_\infty$ , which provided good fit, visually and in terms of the correlation coefficients. Typically, plateau of the stress relaxation curves (defined as 10% difference from final  $G_L$ ) was evident [similar to] 20 s after indentation. Short-term shear moduli  $G_S$  (mean NPC: 8509 Pa, PC: 5711 Pa) were greater than long-term moduli  $G_L$  (NPC: 609 Pa, PC: 807 Pa) by about an order of magnitude. Statistical analysis of parameters showed that only  $G_2$  was affected by preconditioning, while  $G_L$ ,  $G_S$ ,  $G_\infty$ ,  $\tau_1$ ,  $\tau_2$ , and  $G_1$  properties were unaffected. Since DPS develop over time scales of minutes to hours, but most stress relaxation occurs within [similar to] 20 s, the most relevant property for computational modeling is  $G_L$  (mean [similar to] 700 Pa), which is, conveniently, unaffected by preconditioning. Copyright copyright 2006 by ASME.

Polliack, A. A., D. D. Craig, et al. (2002). "Laboratory and clinical tests of a prototype pressure sensor for clinical assessment of prosthetic socket fit." *Prosthetics and Orthotics International* 26(1): 23-34.

Lower limb prosthetic socket fabrication is a highly refined process relying on the prosthetist's skill and experience. Despite their best efforts, patients often return with complications. Additionally, clinical application of technological advances for the quantification of biomechanical factors at the socket interface has not changed in practice. Measuring pressure levels at the stump/socket interface could provide valuable information in the process of prosthetic socket fabrication, fit and modification. This paper presents findings on the performance of a prototype capacitance pressure sensor designed for prosthetic socket use. Bench tests using compressed air were performed to measure accuracy, hysteresis and drift responses in both a flatbed chamber and a custom-modified pressure vessel. For the contoured testing, the sensors were placed on nine sites on a positive trans-tibial stump mould and enveloped with a silicone liner. Additionally, a preliminary clinical evaluation was performed with two trans-tibial amputee subjects at the nine sites during normal ambulation. Bench test results showed that the prototype capacitance sensor performed well in all categories, exhibiting a 2.42% (flatbed) and 9.96% (contoured) accuracy error, a 12.93% (flatbed) and 12.95% (contoured) hysteresis error, and a 4.40% (flatbed) and 6.20% (contoured) drift error. The clinical study showed that after three hours of continual use, no noticeable sensor drift occurred between pre and post-test calibration values. The results from this study were encouraging and the authors hope to conduct further laboratory and clinical trials to assess the influence of shear force and dynamic loading on sensor response.

Ragan, R., T. W. Kernozek, et al. (2002). "Seat-interface pressures on various thicknesses of foam wheelchair cushions: A finite modeling approach." *Archives of Physical Medicine and Rehabilitation* 83(6): 872-875.

Objective: To investigate the effect of cushion thickness on subcutaneous pressures during seating by using a finite element modeling approach. Design: Seat-interface pressure measurements were used in a computational model. Setting: Biomechanics laboratory. Participant: A single healthy man (weight, 70kg). Interventions: Subject sat upright either with or without cushions of various heights. Seat-interface pressures measured by using a sensor mat interfaced to a personal

computer sampling at 15Hz. Main Outcome Measures: Peak seat-interface pressure; finite-element software was used to model the buttock, ischial tuberosity, and seat cushion. Subcutaneous stresses were calculated from the model. Results: The region of highest subcutaneous stress in the soft tissue was concentrated within 1 or 2cm of the ischial tuberosity, with the maximum compressive stress inferior to the bottom surface of the ischial tuberosity. The maximum subcutaneous stress, maximum seat-interface pressure, and maximum subcutaneous shear stress each changed with cushion thickness. Subcutaneous pressures decreased with thicker cushions, but almost all of the reduction was obtained with an 8-cm cushion. The amount of subcutaneous shear stress increased slightly for thicker cushions. The maximum subcutaneous stress was greater than the maximum interface pressure but not by a constant factor. Instead, the former was consistently larger by 0.7 to 0.8N/cm<sup>2</sup>. Conclusions: Cushion use reduced the maximum subcutaneous stress inferior to the ischial tuberosity. However, increasing the cushion thickness beyond 8cm was ineffective in further reducing subcutaneous stress. It was also found that seat-interface pressures were a good indicator of the subcutaneous stress reduction in seating. copyright 2002 by the American Congress of Rehabilitation Medicine and the American Academy of Physical Medicine and Rehabilitation.

Rubayi, S. and Y. Kiyono (2001). "Flap surgery to cover olecranon pressure ulcers in spinal cord injury patients." *Plastic and Reconstructive Surgery* 107(6): 1473-1481.

In the quadriplegic patient, the periolecranon region is subjected to continuous and permanent mechanical shearing and pressure forces. As the sensation of this region is partially impaired secondary to the level of the spinal cord injury, this anatomical area is prone to develop bursitis and then a chronic open draining wound. This type of wound is refractory to conservative measures. Surgical closure of this functional area can represent a challenge to the plastic and reconstructive surgeon because not all of the surgical options available are suitable for spinal cord injury patients. Therefore, we describe our clinical experience, which consists of seven patients with traumatic complete quadriplegia treated between 1989 and 1998 (all patients were male) who presented with an open olecranon ulcer, septic bursitis, or aseptic bursitis, and who underwent surgical closure by direct closure, local arm fasciocutaneous flap, or cross-chest flap to cover the periolecranon soft-tissue

defects. The follow-up period ranged from 3 months to 8 years (mean, 44 months). All types of flaps achieved wound closure without losing range of motion at the elbow; however, at 10 to 12 months after surgery, an olecranon pressure ulcer or septic bursitis recurred in three of seven patients. These three patients required surgical revision. The local fasciocutaneous rotational flap was found to be effective for closing periolecranon soft-tissue defects and can be reused in instances of recurrence. Patient education is essential to prevent re-ulceration in that functional area in the spinal cord injury patient.

Sanders, J. E., J. L. Garbini, et al. (1997). "A bidirectional load applicator for the investigation of skin response to mechanical stress." *IEEE Transactions on Biomedical Engineering* 44(4): 290-296.

Instrumentation was developed to apply controlled biaxial (normal and shear) forces to the skin of a human or animal subject. The instrument mimicked any reference waveform within the constraints of a bandwidth of 15 Hz, a maximum force of 20 N, and displacement ranges of 15 mm for the normal direction and 18 mm for the shear direction. Two shaker motors, positioned with their axes parallel, were used with a low effective mass linkage and small-angle rotational joints to deliver the force. A digital feedback controller independently controlled the instantaneous normal and shear forces and recorded the resultant displacements. Evaluations on human and animal (pig) subjects demonstrated mean absolute errors between the applied and reference waveforms of less than 1.2% full-scale output for both the normal and shear directions. No degradation in performance was apparent over the course of a 1-h loading session. The instrument is to be used for the investigation of skin adaptation to mechanical stress, information that could be used to design new therapeutic methods to encourage skin load-tolerance.

Schoonhoven, L., D. E. Grobbee, et al. (2006). "Prediction of pressure ulcer development in hospitalized patients: A tool for risk assessment." *Quality and Safety in Health Care* 15(1): 65-70.

Objectives: To identify independent predictors for development of pressure ulcers in hospitalized patients and to develop a simple prediction rule for pressure ulcer development. Design: The Prevention and Pressure Ulcer Risk Score Evaluation (prePURSE) study is a prospective cohort study in which patients are

followed up once a week until pressure ulcer occurrence, discharge from hospital, or length of stay over 12 weeks. Data were collected between January 1999 and June 2000. Setting: Two large hospitals in the Netherlands. Participants: Adult patients admitted to the surgical, internal, neurological and geriatric wards for more than 5 days were eligible. A consecutive sample of 1536 patients was visited, 1431 (93%) of whom agreed to participate. Complete follow up data were available for 1229 (80%) patients. Main outcome measures: Occurrence of a pressure ulcer grade 2 or worse during admission to hospital. Results: Independent predictors of pressure ulcers were age, weight at admission, abnormal appearance of the skin, friction and shear, and planned surgery in coming week. The area under the curve of the final prediction rule was 0.70 after bootstrapping. At a cut off score of 20, 42% of the patient weeks were identified as at risk for pressure ulcer development, thus correctly identifying 70% of the patient weeks in which a pressure ulcer occurred. Conclusion: A simple clinical prediction rule based on five patient characteristics may help to identify patients at increased risk for pressure ulcer development and in need of preventive measures.

Sharp, C. A. and M. L. McLaws (2005). "A discourse on pressure ulcer physiology: The implications of repositioning and staging." *Journal*.

This paper aims to promote discussion on the physiology of pressure ulcer development and the impact this may have on clinical intervention and the allocation of resources. It argues against the use of both the Australian Wound Management Association's [1] and the New South Wales Department of Health's [2] method of staging pressure ulcers, which is similar to the grading system established by the European Pressure Ulcer Advisory Panel (EPUAP) [3], as a tool for assessing the risk of pressure ulcer development and the only tool for evaluating the severity of pressure damage. It proposes a new model, 'the middle model', whereby tissue damage may start anywhere between, and including, the skin surface and bone interface, concurrently or haphazardly, to produce a pressure ulcer. copyright 1992-Feb 2001 by STML.

Stekelenburg, A., G. J. Strijkers, et al. (2007). "Role of ischemia and deformation in the onset of compression-induced deep tissue injury: MRI-based studies in a rat model." *Journal of Applied Physiology* 102(5): 2002-2011.

A rat model was used to distinguish between the different factors that contribute to muscle tissue damage related to deep pressure ulcers that develop after compressive loading. The separate and combined effects of ischemia and deformation were studied. Loading was applied to the hindlimb of rats for 2 h. Muscle tissue was examined using MR imaging (MRI) and histology. An MR-compatible loading device allowed simultaneous loading and measurement of tissue status. Two separate loading protocols incorporated uniaxial loading, resulting in tissue compression and ischemic loading. Uniaxial loading was applied to the tibialis anterior by means of an indenter, and ischemic loading was accomplished with an inflatable tourniquet. Deformation of the muscle tissue during uniaxial loading was measured using MR tagging. Compression of the tissues for 2 h led to increased T2 values, which were correlated to necrotic regions in the tibialis anterior. Perfusion measurements, by means of contrast-enhanced MRI, indicated a large ischemic region during indentation. Pure ischemic loading for 2 h led to reversible tissue changes. From the MR-tagging experiments, local strain fields were calculated. A 4.5-mm deformation, corresponding to a surface pressure of 150 kPa, resulted in maximum shear strain up to 1.0. There was a good correlation between the location of damage and the location of high shear strain. It was concluded that the large deformations, in conjunction with ischemia, provided the main trigger for irreversible muscle damage. Copyright copyright 2007 the American Physiological Society.

Theaker, C. (2001). "Special mattresses - Are they value for money?" *Care of the Critically Ill* 17(4): 116.

Then, C., J. Menger, et al. (2007). "A method for a mechanical characterisation of human gluteal tissue." *Technology and Health Care* 15(6): 385-398.

The most common complication associated with immobilization is pressure sores caused by sustained localized tissue strain and stress. Computational simulations have provided insight into tissue stress-strain distribution, subject to loading conditions. In the simulation process, adequate soft tissue material parameters are indispensable. An in vivo procedure to characterise material parameters of human gluteal skin/fat and muscle tissue has been developed. It employs a magnetic resonance imaging (MRI) device together with an MRI compatible loading device. Using the derived data as constraints in an iterative

optimization process the inverse finite element (FE) method was applied. FE-models were built and the material constants describing skin/fat and muscle tissue were parameterized and optimized. Separate parameter sets for human gluteal skin/fat and muscle were established. The long-term shear modulus for human gluteal skin/fat was  $G_{\infty}$ ,  $S/F = 1182$  Pa and for muscle  $G_{\infty}$ ,  $M = 1025$  Pa. The Ogden form for slightly compressible materials was chosen to define passive human gluteal soft tissue material behaviour. To verify the approach, the human skin/fat-muscle tissue compound was simulated using the derived material parameter sets and the simulation result was compared to empirical values. A correlation factor of  $R^2 = 0.997$  was achieved. copyright 2007 - IOS Press and the authors. All rights reserved.

Thomas, D. R. (2006). "The New F-tag 314: Prevention and Management of Pressure Ulcers." *Journal of the American Medical Directors Association* 7(8): 523-531.

An extensive revision of the guidelines for prevention and management of pressure ulcers is now in effect. Overall, the guidelines are an improvement over the previous version. Much more of the current guidelines rests on evidence-based data and is more consistent with current standards. However, there are still areas where the evidence does not yet answer all of the questions.<sup>14,15</sup> Until future research more clearly defines the evidence, clinicians will still have to interpolate the data to manage the difficult problem of prevention and management of pressure ulcers. copyright 2006 American Medical Directors Association.

Thomas, D. R. (2006). "Prevention and treatment of pressure ulcers." *Journal of the American Medical Directors Association* 7(1): 46-59.

Pressure ulcers are complex chronic wounds for which no gold standard for prevention or treatment has yet been established. Several attempts at developing guidelines has been undertaken by different organizations. Pressure ulcers are devastating comorbidities for patients and difficult to prevent or manage. Whether or not pressure ulcers are preventable remains controversial. The strategy for prevention includes recognizing the risk, decreasing the effects of pressure, assessing nutritional status, avoiding excessive bed rest and prolonged sitting, and preserving the integrity of the skin. The principles of treatment of pressure ulcers

include assessing severity, reducing pressure, friction and shear forces, optimizing local wound care, removing necrotic debris, managing bacterial contamination, and correcting nutritional deficits. Copyright copyright 2006 American Medical Directors Association.

Zhang, J. D., A. F. T. Mak, et al. (1997). "A large deformation biomechanical model for pressure ulcers." *Journal of Biomechanical Engineering* 119(4): 406-408.