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CLINICAL STUDY

The importance of internal strain as opposed to interface pressure in the prevention of pressure related deep tissue injury

C.W.J. Oomens [a,*], Sandra Loerakker [a], D.L. Bader [b]

[a] *Department of Biomedical Engineering, Eindhoven University of Technology, P/O Box 513 5600 MB Eindhoven, The Netherlands*
[b] *Dept. of Engng. & IRC in Biomedical Materials, Queen Mary University of London, Mile End Road, London, E1 4NS, United Kingdom*

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Abstract For pressure ulcer prevention an ambitious goal would be the establishment of a mechanical threshold for tissue damage. In the past, several researchers have sought to establish such a threshold often involving the loading time. However, they have not resulted in a unique reliable value that could be used in practice. This limitation is probably due to the focus on interface pressure. The objective of this paper is to clarify to an audience with no conventional background in mechanics, why interface pressure is not the appropriate parameter to define a damage threshold, whereas internal local deformations (strains) may prove more suitable. The paper reveals that it may be possible to identify a damage threshold for healthy skeletal muscle tissue based on local internal deformations.

Introduction

In the preamble for the recently published guidelines for prevention and treatment of pressure ulcers, developed by the European and American Pressure Ulcer Advisory Panels (EPUAP and NPUAP) the following definition is given: ''A pressure ulcer is localized injury to the skin and/or underlying tissue usually over a bony prominence, as a result of pressure or pressure associated with shear''. The definition is followed by a section on the definition of mechanical terms such as pressure, shear, friction. However, the terminology that is used to describe mechanical concepts in scientific papers and textbooks on pressure ulcers are written in a form that often causes confusion and misunderstanding in the target audience of nurses. In some cases ambiguous definition of terms by authors may lead to misinterpretation of data. For a nurse practitioner it is necessary to know exactly

* Corresponding author. Tel.: +31 402472818; fax: +31 402447355.
E-mail addresses: c.w.j.oomens@tue.nl (C.W.J. Oomens), s.loerakker@tue.nl (S. Loerakker), d.l.bader@qmw.ac.uk (D.L. Bader).

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how to act to prevent or treat a wound. This means that he/she has to appreciate the distinction between pressure, shear forces and friction and how they can be minimised in a clinical setting. By contrast, a researcher interested in the aetiology of pressure ulcers, or a bed manufacturer wanting to design a novel patient support system needs a more comprehensive view on the mechanical state of tissues and thus will require a more detailed knowledge of mechanics.

For pressure ulcer prevention an ambitious goal would be the establishment of a mechanical threshold for tissue damage. This would provide an objective measure that allows the clinical practitioner to evaluate the magnitude and exposure of the mechanical load, which tissues can tolerate before they become damaged. In the past, several researchers have sought to establish such a threshold often involving the loading time. However, they have not resulted in a unique reliable value that could be used in practice. This limitation is probably due to the focus on interface pressure, which can be measured, as the only causation factor for tissue damage.

Pressure ulcers can start to develop in the skin and may subsequently progress to deeper tissue layers. However it is also possible that ulcers can start in deeper tissue, adjacent to bony prominence, and progress to the skin surface, where they constitute a grade 3 or 4 ulcer. These ulcers are often associated with spinal cord injured subjects or patients who have been unconscious and thus insensate for some time. The current paper focuses on this pressure related deep tissue injury (DTI).

The objective of this paper is to clarify to an audience with no conventional background in mechanics, why interface pressure is not the appropriate parameter to define a damage threshold, whereas internal local deformations (strains) may prove more suitable. This approach will be used to explain recent state-of-the-art developments on the development of a damage threshold for pressure related deep tissue injury (DTI).

Why was the quest for a damage threshold for tissues in the past in vain?

Much of the seminal work on aetiology of pressure ulcers has been based on animal experiments, as reviewed by Stekelenburg et al. [1]. These studies differed widely in their choice of animal models and their mode of load application. Nonetheless their basic principles were similar in that they each employed an external indenter to compress the skin and underlying tissues against a bony prominence. By dividing the force on the indenter by its surface area, the resulting externally pressure, which varied with magnitude and application time, could be estimated. Following a period of load removal, the animal was sacrificed and the previously loaded tissue examined by either visual inspection or using histological techniques. The latter approach resulted in a fairly detailed description of the type and extent of damage in skin and skeletal muscle. It also enabled the investigators to construct a ''risk curve'' of applied pressure against time. Fig. 1 shows a graph with data from of a number of these studies. It also includes a retrospective study by Reswick and Rogers where they measured skin-cushion interface pressures in 800 human volunteers and estimated the magnitude of pressure and exposure times for patients with and without ulcers. Below the curve, the tissue is considered to be able to safely tolerate the applied load with no predicted damage. By contrast, a load/time combination above the curve will be predicted to result in tissue damage.

1. Daniel (swine, 1981) [2]
2. Kosiak (dog,1959) [3]
3. Rogers (human,1973) [4]
4. Kosiak (rat,1961) [5]
5. Dinsdale (swine,1973) [6]
6. Salcido (rat,1994) [7]

All curves in Fig. 1 reveal a hyperbolic form. Thus relatively low loads that are applied for a prolonged time appear as harmful as high loads

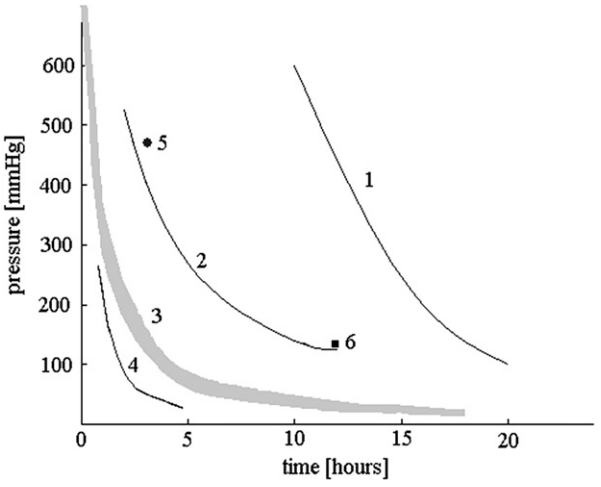

Figure 1 Risk curves with regard to pressure ulcers. Time/pressure combinations above the curve result in tissue breakdown.