ABSTRACT

As pressure ulcer incidence continues to rise, there is an ongoing search among caregivers for improved methods of prevention and treatment. Support surfaces remain key factors in both areas, yet with so many product choices and variations, the selection process can be overwhelming. pressure ulcer development is a combination of pressure, friction and shear forces. These forces cause soft tissue distortion that results in reduction of blood flow to an area. Gaining an understanding of the body's cellular response to ischemia can greatly simplify the tasks of support surface selection and comprehensive prevention. As the scientific and physiologic principles relating to support surfaces are addressed, one must question the past concepts used in support surface selection such as relying on interface pressure readings and accepting reactive hyperemia as a beneficial event. The purpose of this article is to review the basic concepts of microcirculation, cellular physiology, and reperfusion injury. Emphasis will be placed on the importance of selecting products based on scientific principles and research. The conclusion offered is that low-cost support surfaces that prevent soft tissue distortion by flotation with true static fluid (i.e. air, gas) should be selected, and the money saved should be utilized for proper nutrition.

Support Surface Principles Based on Scientific Fact

A cell is the complex structural unit of all animals and plants. Cells and cellular products compose all tissues of the body. Intercellular communication and cell division regulate all body functions and tissue development, therefore, injury to cells can lead to significant tissue destruction or result in a diseased state to the body.[1] Cellular injury and death often result from events such as hypoxia and mechanical stress, which cause ischemia, and lead to impairment of normal cellular permeability, metabolism, protein synthesis or phagocytosis.[2]

As patients lie or sit on a support surface, the surface media (i.e. gas, liquid, solid) and delivery method (i.e. non-powered-static; powered-dynamic) dictate the amount of pressure and shearing forces that are created. These mechaniccal stresses cause distortion of the soft tissue and will most likely result in crimping of the blood vessels, which then leads to decreased blood supply- ***ischemia,*** and a lack of oxygen to the cells- ***hypoxia***.[3] Hypoxia is the most common cause of cellular injury.[2] Therefore, in choosing support therapy, we must select products that minimize shear, thus prevent soft tissue distortion.

If a state of hypoxia is interrupted, meaning that blood supply and oxygen are restored, an increase in blood flow and oxygen is rushed out to the hypoxic area as a compensatory reaction to the ischemic event. This reaction is called **reactive hyperemia**.[2] Although this seems a logical solution to the problem, we must realize that tissues temporarily deprived of their blood supply do not achieve complete restoration of blood flow when reconnected to a normal supply.[3]

It is also known that during ischemia, an enzymatic conversion of xanthine dehydrogenase to xanthine oxidase occurs within the cells, resulting in a dangerous superoxide anion.[6] This "free radical" is toxic to tissues and may generate other types of free radicals if blood flow is restored. The free radical is a highly reactive molecule with unpaired electrons, thus it seeks reactions with other molecules to achieve more electrical stability. As these reactions take place, the free radicals multiply, thereby increasing the risk for tissue damage and cell death. Therefore, a sudden restoration of oxygen and blood supply can actually cause damage. The resultant damage is known as **reperfusion injury**.[2, 3]

With this scientific data in mind, one must question why it would be beneficial in prevention or treatment efforts, to place our patients on support surfaces that are being advertised as enhancing reactive hyperemia. An example of such a surface is an alternating pressure mattress. This type of therapy inflates and deflates air cells intermittently and can be quite expensive. Consider the tissue distortion that must be occurring secondary to shearing stress as the cells deflate. As stated earlier, this is where the hypoxia begins.

A hypoxic event may cause reversible or irreversible damage.[2] Reactive hyperemia is the body's attempt at saving the cells when blood flow is restored. What happens, however, if blood flow is not restored and the cell injury is irreversible as in cases of prolonged soft tissue distortion? A damaging cascade of events will likely occur.

Normal laminar blood flow allows leukocytes, erythrocytes, and platelets to flow freely and smoothly within the center of a vessel. They are surrounded by plasma and the outermost layer of cells called the endothelium, which is covered by a basement membrane.[2] As soft tissue distortion occurs,blood vessels may crimp or become blocked, resulting in decreased laminar flow and decreased velocity of flow. As the laminar flow is disrupted, a turbulent flow begins, causing neutrophils to come in contact with the endothelium. Also, as the flow velocity decreases, the neutrophils will come in contact with the endothelium. This process called **marginization**, results in an inflammatory response developing free radicals and stasis.[2, 3] Junctions between the endothelial cells then begin to develop and allow the blood cells to leak out into the tissues. Once again, the enzymatic conversion that occurs during ischemia creates free radicals. As the neutrophils leak into the tissues, they attract to the free radicals, causing a "respiratory burst" with their further release of free radicals, thus causing cellular damage.[6, 7] This cascade of events can progress if no circulation is restored, if incomplete circulation is restored, or if a reperfusion injury occurs due to the body's inability to neutralize free radicals. This is called oxidative stress and it is a balancing act dictated by an individual's general health, age, nutritional status, and quantity of free radicals.[7]

Aging, itself plays a very significant role in pressure ulcer susceptibility. In aging skin, the epidermis and dermis thin and elasticity decreases. There is a decrease in collagen synthesis, tensile strength, and moisture, making the skin stiffer.[4, 5] These changes increase the skin's susceptibility to ulcer development and decrease its ability to repair.

Now with all this data in mind, one must realize that perhaps our first line of defense in pressure ulcer prevention is to select support therapy and repositioning schedules that will eliminate soft tissue distortion secondary to shear stress, as well as relieve pressure to ultimately prevent ischemia. How do we do this? Simply by keeping the scientific principles in mind and understanding the true effects of support surface media being chosen.

The basic principles of physics, chemistry, and mechanics define why this predictable outcome of soft tissue strain occurs with support surface stress (stress to strain reaction). These principles are the kinetic molecular theory, the ideal gas law, Archimedes principle, Hooke's Law, and the physical properties relating to a static fluid, dynamic fluid, and solid media, and the mechanical advantage of the simple inclined plane machine as relating to a wedge-shaped structure.[10] Utilizing these basic scientific principles, one can explain the clinical presentation of ischemic necrosis (pressure ulcer) occurring secondary to placing a human body on an improper surface.

Maintaining volumetric three-dimensional configuration of the soft tissue at risk can be accomplished by delivering non-gradient perpendicular pressure by floating the body in a static fluid media. Flotation therapy is the most effective therapy to prevent and treat pressure ulcer problems. The benefit of maintaining volumetric support by utilizing flotation therapy is that the bony prominence is not allowed to sink into the surrounding soft tissue. If this unwanted impaling occurs, then vertical shearing occurs with subsequent tissue distortion, ischemia, tissue injury and ultimate cellular necrosis. This sequential event explains the crater-like wounds occurring around, not only under, the bony prominence. Thus, the impaling of the wedge-like bony prominence into the surrounding soft tissue creates force amplification following the mechanical advantage of a wedge inclined plane machine.

This mechanical advantage is better understood when one compares a high heel shoe versus a flat heel shoe. The pressure under the high heel shoe is greater than that of the flat heel shoe based on the smaller area of support contact. But the force of the high heel shoe is magnified when the high heel impales into a viscoelastic material (i.e. asphalt). Upon impaling of the wedge-like structure, the smaller surface of contact becomes a surface into which a wedge is being driven with the force amplification of the weight of the body. This above explanation is comparable to the unwanted occurrence when a bony prominence impales into the surrounding viscoelastic soft tissue when shear strain (distortion), not volumetric support (equalized compression), is delivered to the body by a support surface. This is why a static fluid system is the ideal media to float the body.

We have relied on interface pressure readings for some time now. Interface pressure is the intensity of the perpendicular mechanical stress which is being applied externally to the skin.[4] Relying solely on these pressure readings in support surface selection can be dangerous and misleading due to the fact that the body is three-dimensional, not two-dimensional.[7] We must consider the depth in addition to length and width when assessing support surface needs. Ulcers develop at the bony prominence level. Therefore, we need to know what is happening at that level. Is the bony prominence impaling into the soft tissue? Is shearing causing the soft tissue to stretch over the bony prominence? For example, if we place a body on a board, the interface pressure will most likely be fairly high. Whereas, if we place a body on a foam surface, we would expect the interface pressure to be lower. However, as discussed earlier, the other major component causing ischemia and tissue damage is shearing stress resulting in soft tissue distortion. An interface pressure reading does not tell us anything about these factors.

Therefore, in the above example, although the foam may deliver less interface pressure than a board, does that mean it will meet our goal of eliminating soft tissue distortion and shearing? The answer is no.
Perhaps the only way to eliminate all pressure and tissue distortion would be to float in space where there is no gravity. Due to the laws of gravity (Newton's Third Law), there will always be some mechanical stress between a body and the surface supporting it.[7,8] So we must then choose a surface which will provide equalized pressure over the greatest area of contact with the body without delivering shear aand causing distortion of the soft tissue. A brief review of physics will help us choose.

A **solid** material is composed of many tightly bound molecules that adhere together. This physical property allows shear forces to be sustained, which means they can also be delivered.[7,8,10] Foam is an example of a solid. A **fluid**, which may be a gas or a liquid, is composed of loosely bound molecules that tend not to adhere so closely together, resulting in no shearing forces sustained or delivered.[7,8,10] Air is an example of a fluid. So in a pursuit of a surface that will deliver the least shear, it is scientifically clear that an air product will be the best choice.

Now again, keeping in mind our goal of eliminating tissue distortion secondary to shear, we must consider the delivery method of the air. The delivery may be dynamic (i.e. alternating pressure, low air loss) or static. We discussed earlier, how alternating air cells can actually cause tissue distortion.

Dynamic air means that the air is moving or being pumped into a container.[8,10] If air is being pumped into an empty container, it must provide enough air to make the container taut, otherwise, a body would sink into the center, which is obviously not therapeutic with our goal. Therefore, this taut container now may actually be delivering shear forces much like a solid would. Again, we must think then about what is happening at the bony prominence level. Also, moving air actually causes shearing of the tissue due to the physical properties of a dynamic fluid system.

Low air loss therapy not only fills a container taut, thus delivering shear forces, but also blows air out of the container. So in addition to the high risk of tissue distortion and ischemia, we now introduce new risks caused by circulating air. For example, continuous airflow on a patient's skin can have a dangerous drying effect on already dry skin. Also, in cases of incontinence, the drying effect of the air must actually increase the concentration of the urine and feces directly on the skin, thus increasing the likelihood of irritation and breakdown. Lastly, consider the existing contamination risk as bacteria is being blown into the air.

Static air is motionless or non-powered air.[8, 10] The loose molecules of static air actually disperse when a body is placed on it. The molecules redistribute in a manner providing non-gradient or equalized support to the entire surface area of contact with the body. Thus, minimizing the chance of shearing and resultant soft tissue distortion. So, based on the basic principles of physiology and physics, static air is the media and delivery of choice in our goal of prevention. Incidentally, this non-powered air is also much cheaper than devices utilizing pumps or fancy filling.

So why is so much money being spent on support surfaces that may or may not help us reach our goals of prevention and may even contribute to pressure ulcer development? We actually need to be spending more money on nutrition, which is often overlooked by caregivers. Numerous studies have indicated poor nutrition is a significant factor in the development of pressure ulcers.[4, 5] In addition, nutrition plays an integral part in wound healing. The strength and integrity of tissue repair depend heavily on collagen formation.[6] Vitamins A, C, and B-complex along with protein glucose, and minerals are necessary for proper cellular health as well as collagen production and synthesis. Vitamin E helps prevent tissue damage from free radicals. Adequate calories provide the energy needed for tissue defense and wound repair.[4, 5, 6] This confirms the importance of increasing our efforts in assessing the nutritional needs of our patients. We must utilize comprehensive nutritional assessment tools and provide requirements and supplements deemed necessary. Registered Dietician referrals should be made when possible to promote quality management of nutritional intake and requirements.

As pressure ulcer incidence and treatment costs continue to increase while reimbursement dwindles, we must revise our protocols and get these numbers down. It is imperative that we do not misuse funds or time in our efforts. As caregivers, it is our responsibility to make informed decisions based on outcome studies and scientific principles. Making product utilization choices based on the aforementioned principles should free up many dollars in the future, allowing us to focus more on the culprit of malnutrition, which is often downplayed. Remember that prevention is the key. It has been reported that pressure ulcer treatment costs are 2.5 times greater than prevention costs.[11] If we budget our funds appropriately and make wise decisions early in targeting the key contributing factors to pressure ulcer development, we should make an enormous impact in saving the money, and more importantly, the lives that are taken by this problem.

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