TECHNOLOGY UPDATE:

Defining 'active' pressure redistribution




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This paper will explore the design principles of 'active' (alternating) support surfaces, discuss how specific characteristics might influence physiology, pathophysiology and the prevention of pressure ulcers, and introduce the rationale for a standardised performance measurement.

INTRODUCTION

Pressure ulcer prevention guidelines routinely include the prescription of regular patient repositioning, and a pressure-redistributing surface for beds and chairs[1]. However, selecting a support surface from the rapidly expanding list of available options is difficult. Reliable information from high quality clinical trials is scant[2], the terminology for reporting support-surface performance is confusing and the measurements used to describe product performance are not, as yet, standardised.

Nevertheless, an informed prescription requires a basic understanding of support surface functionality and an appreciation that surfaces are not generic with respect to clinical performance.

WHAT IS 'ACTIVE' THERAPY?

Since 2007, the National Pressure Ulcer Advisory Panel (NPUAP)[3], and, more recently, the European Pressure Ulcer Advisory Panel (EPUAP)[1], has classified support surfaces into one of two functional categories, as determined by the primary method of pressure redistribution *[Fig 1]*.

Reactive surface

Included here for clarity, these range from simple foam, gel and non-powered, air-filled surfaces, through to powered low-air-loss and air-fluidised beds. Measurable performance characteristics include immersion into, and envelopment by, the supporting materials mentioned above[3]. By increasing the surface area that supports the body, the applied pressure is lowered, however, unless the patient is repositioned, the pressure remains constant and may still be sufficient to occlude the circulation to the tissue. This modality has been covered in a previous issue of this publication[4] and will, therefore, not be discussed further

Active surface

These are powered devices designed to periodically redistribute pressure by repeatedly loading and unloading the pressure beneath the body[3]. Unloading, or pressure removal, is typically achieved through the alternate inflation and deflation of a series of air-filled cells, giving rise to the more traditional description of 'alternating therapy' or 'alternating pressure air mattress'. Unlike reactive surfaces, cyclical pressure redistribution continues even in the absence of patient movement, although the degree of off-loading varies by device.

Why 'active'?

The purpose, form and function of active pressure redistribution can best be described by first revisiting standard physiology. Essentially, as terrestrial mammals, human beings are naturally exposed to periods of relatively high, non-uniform, pressure. Even so, most do not develop tissue injury thanks to complex and highly successful, protective physiological mechanisms, including spontaneous movement; a subconscious behavioural response, which redistributes

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Key Points

1. *Active (alternating) surfaces have a unique 'signature' described by cycle frequency, duration, amplitude and rate of change*
2. *Physiological outcome can differ significantly in response to unique performance characteristics*
3. *Evidence arising from one active surface cannot be automatically attributed to another surface*
4. *Standardised performance tests and field studies are required to enable informed selection*
5. *There is no single clinically safe pressure-time threshold*
6. *Design goals aim for time-sensitive, complete or near-complete off-loading*
7. *Active surfaces are recommended for both prevention and treatment*
8. *Active therapy is the modality of choice for patients who cannot be regularly repositioned.*

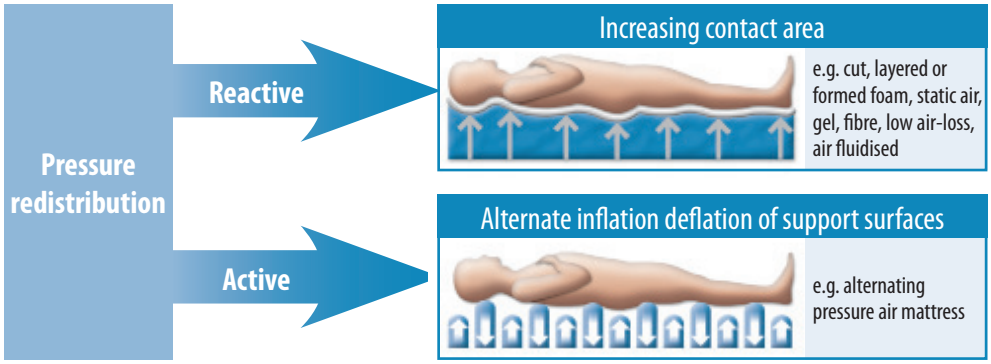

Figure 1. Principal modalities for pressure redistribution.

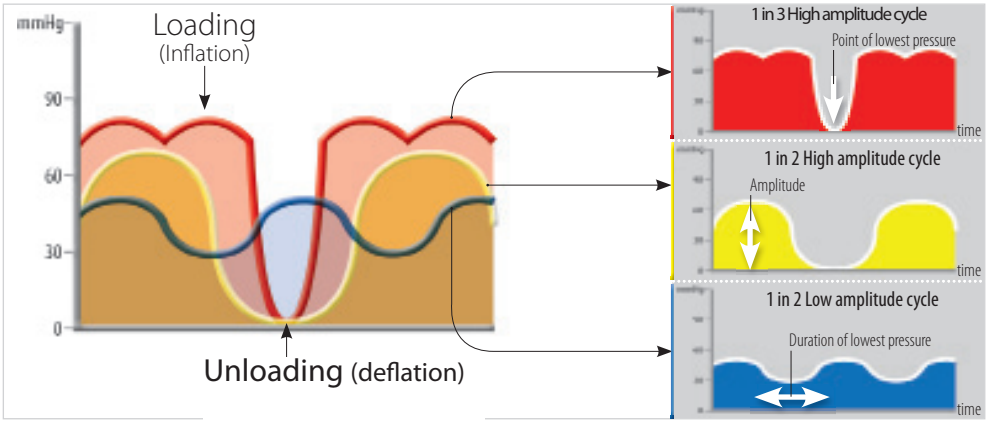

Figure 2. Key performance characteristics: cycle frequency, duration, amplitude and rate of change.

pressure several times each hour, even during sleep[5].

This periodic off-loading is followed by a period of vessel dilatation, which serves to increase blood flow beyond that normally seen at baseline (reactive hyperaemia), reverse the hypoxic state and restore cellular equilibrium[6]. However, when motor, sensory or cognitive pathology results in partial or total immobility, the patient is exposed to increasing risk[7,8].

The most accepted hypothesis is that pressure injury develops when tissue located usually, but not always, over a bony prominence is exposed to forces of sufficient magnitude, direction or duration to result in tissue ischaemia, cell disruption and cell death[9]. Severe pressure damage can occur in less than two hours in the most vulnerable patient[10], hence the importance of time in any preventative strategy.

As immobility is clearly a dominant risk factor, the foundation of preventative care has traditionally been focused on pressure redistribution through assisted repositioning — a relatively effective, if labour intensive, activity when carried out diligently. Whether assisted or spontaneous, this repeated application and removal of pressure is, in part, simulated by active support surfaces, given that both duration and magnitude of pressure are prioritised.

In 2007, NPUAP (USA) published a list of performance criteria for all therapeutic support surfaces[3], which considered that, alongside basic cell configuration, active surfaces have four clinically important, inter-dependent and measurable performance characteristics — cycle frequency, duration, amplitude and 'rate of change', ie the speed at which the cells shift between the inflated and deflated state *[Fig 2]*.

Cell configuration

Active surfaces typically operate on a one-in-two cycle giving a matched interval between the duration of loading (50%) and off-loading (50%). Less commonly, some devices operate a one-in-three or one-in-four sequence providing a larger supporting area either side of the single deflating cell. Other surfaces have different cell sequencing over different parts of the body, such as the sacrum and heel.

Individual air cells can be of different shape, depth and overall dimension and may be stacked in layers with variable functionality in each layer. Cells can be configured to such a depth as to replace the

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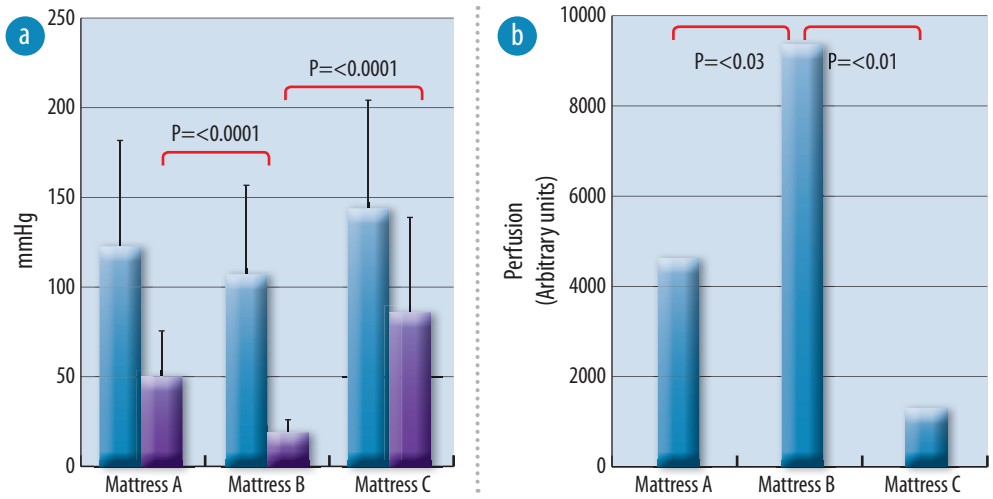

Figures 3a nd 3b. Comparing interface pressure (IP) and heel perfusion in three different active mattresses[17].

existing mattress or presented as a single-layer overlay to be placed on top of the existing foam mattress.

Cycle duration and frequency

Cycle duration is the time taken to complete one inflation-deflation cycle and will depend on both the speed of air transfer and the number of cells in each sequence. Typically, but not exclusively, cycle duration ranges from 7.5 to 20 minutes, with 10 minutes perhaps the most common. Cycle frequency is generally sequential in that one cycle follows another, but some devices have a 'periodic' active phase where one or more cycles are followed by a reactive or 'static' interval, hence, it is important to be able to differentiate between frequency and duration when selecting a device.

Cycle amplitude

Amplitude, or the range between the highest and lowest pressure applied to the skin during the inflation and deflation cycle *[Fig 2]*, is a primary design consideration and varies widely. In order to achieve the lowest pressure on the skin during cell deflation, the cells adjacent to the deflating cell need to contain sufficient air pressure to provide support to the patient. This will depend on the construction of the cells themselves, how the quickly the air flows between them and, critically, whether the pump has sufficient power to support the patient during the inflation phase.

At the same time, the deflating cell needs sufficient clearance to reduce contact with the skin. It is important to note that tightly fitted covers and sheets can create an artificial 'hammock' across the deflating cell, reducing the potential benefit derived from off-loading[11].

Rate of change

One important characteristic of the inflation-deflation process is the 'rate of change', or speed of the air transfer during the fill-empty-fill cycle, as this directly influences the duration of the off-loading phase. If air is moved slowly out of a cell, it takes longer to achieve the minimum pressure (off-loading) point, but slower air transfer does have the advantage that the cell movement is less noticeable for the patient. As with all surfaces, there has to be a balance between therapeutic performance and patient acceptability and comfort.

CLINICAL SIGNIFICANCE

As each patient presents with a unique and changing risk profile, it is not possible to determine a universally 'safe' pressure-duration threshold for each individual[9][12]. A principal design goal is, therefore, to mimic the protective effect of repositioning by periodically reducing contact with the support surface to a level that is as low as practically achievable for as long as possible. Off-loading cycles ideally occur several times each hour to reduce the risk of ischaemia-reperfusion injury; a condition associated with vessel occlusion (closure or blockage) for as little as one to two hours[13].

While the optimal cycle duration has yet to be determined, volunteer studies suggest shorter cycle times (five minutes) to be marginally favoured over longer cycles[14]. There will be a physiological cut-off point where the cycle is either too fast for the tissue to reperfuse or too slow to prevent ischaemia.

The cycle has to be long enough for full reperfusion, which is particularly important for patients with vascular pathology and a longer oxygen recovery index[13][15]. Similarly, patients with spinal injuries have been shown to require off-loading for up to five minutes to fully restore cellular function[16], making a minimum 10-minute

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cycle preferable. While cycle frequency and duration is important, the most significant benefit is attributed to cycle amplitude, with complete or near complete off-loading delivering superior tissue perfusion compared with partial off-loading[14][17].

STANDARDISED PERFORMANCE MEASUREMENT

One or more of the performance characteristics for each device, be it a mattress replacement, mattress overlay or chair cushion, will almost certainly be different. Even subtle changes, particularly those that control the duration and amplitude of the loading/off-loading cycle, have been shown to elicit very different physiological responses in systems, such as lymph flow[18] and perfusion[19]. A study comparing pressure and tissue perfusion at the heel *[Fig 3]*, while subjects lay on three virtually identical mattress replacements[17], clearly demonstrated a significant relationship between performance (amplitude and off-loading) and outcome.

It is clear that, despite similar physical construction (appearance), performance differences may have important implications for clinical prescription. These have yet to be fully investigated but are likely to depend on the underlying condition of the patient and the individual therapy goals. For example, if a patient has very slow reperfusion then a longer cycle might be preferable; if the patient has pain or muscle spasm then a low amplitude cycle might be better

Unfortunately, at present, clinicians cannot objectively assess how a support surface might perform, how 'active' the therapy actually is, how it might compare with their existing surfaces and how best to select the right surface for a specific clinical application in the future.

Once surfaces are properly described the results of clinical studies are more meaningful. Clinicians can select a device with the same or similar performance characteristics and have perhaps more chance of getting similar results than they do at present.

For example, if a surface with particularly good results in heel ulcer treatment is accurately described the clinician has a much greater chance of finding a similar product. Today they only have appearance, price and marketing brochures to guide them.

Data arising from, non-standardised test conditions can be unreliable and, therefore, misleading. Clinicians need access to information collected under controlled test conditions in order to tailor prescriptions, design and report clinical trials and make informed purchase decisions. In 2008, a European and Japanese working party affiliated to the NPUAP Support Surface Standardization Initiative[3], began the process of developing a controlled methodology for active surfaces. Phase 1, clinician consensus, has been published[20] and a standardised human analogue is under development. The concept phase is now complete and about to move into inter-lab validation.

CLINICAL PRESCRIPTION

Active surfaces in general, and mattress replacements in particular, have proven cost-effective for the prevention[21] and treatment[22,23] of pressure injury, although a continued lack of well-designed comparative studies complicates the selection of a specific device from the wide range available[2]. There are few restrictions on the use of active surfaces, aside from unstable fractures, particularly of the spine. However, a small number of patients, such as those with intractable pain or severe muscle spasm, may find that the air cell movement exacerbates their condition.

Active surfaces, by the very nature of their design, periodically off-load the tissue, meaning that they are considered the modality of choice for patients who cannot be regularly repositioned[1]. Examples might be end-of-life care, intensive care, long-term care where reduced sleep interruption is preferred, or simply patient choice. Active cushions might be particularly useful for patients with existing wounds, such as patients with spinal injuries[24], as some studies have shown ischial dermal perfusion to be similar to, or better than, that achieved by short duration 'push-ups'[16] and 'forward-lean' techniques[25].

That said, active surfaces, whether for bed or chair, are not designed to replace patient repositioning, but simply to complement a well-designed, holistic plan of care designed to reduce the risk of harm from prolonged pressure.

DECLARATION OF INTEREST

ArjoHuntleigh has provided an unrestricted grant to support work of the Active Surface Standards Group, including author compensation for meeting attendance and laboratory studies.

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