



WHITE PAPER

**An Objective Approach
to Analysis of
Active Mattress Surfaces**

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Novis Healthcare is a specialist in the design, manufacture and supply of pressure care devices, assistive technology solutions and clinical training. A strong focus on clinical outcomes including pressure injury prevention and patient handling ensures Novis provide healthcare products that exceed clinical and therapeutic expectations.

Novis utilises best practice, gold standard procedures and clinical evidence to ensure our research, innovation and design facilitate clinical excellence. Novis maintains a strong focus on delivering successful patient outcomes in acute care, long term care, rehabilitation and in the community.

INTRODUCTION

A support surface is a mattress surface on which the patient is placed to manage pressure load, shear, friction and microclimate ¹.

An active (alternating/dynamic) support surface is a “powered support surface, with the capability to change its load distribution properties, with or without load” ².

Active support surfaces proactively remove the contact interface pressure between the body and the support surface. This process is referred to as ‘off-loading’ and is achieved by the use of air cells that are cyclically inflated and deflated using an external power source, such as an electronically controlled air pump. (Figure 1)

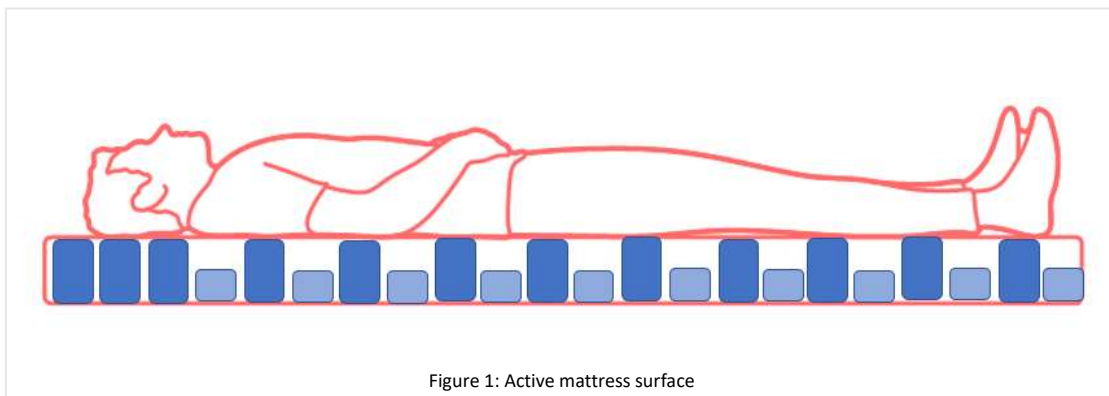
BACKGROUND

The components of the individual active mattress will determine the degree in which it provides a therapeutic solution for Pressure Injury Prevention and Management.

Active support surfaces vary by several objective parameters including the depth of air cells and cell cycle time. The ideal frequency, duration, amplitude and rate of inflation and deflation have not been conclusively determined by current available evidence. However, when comparing similar surfaces, this information is essential for defining its classification as an active surface and determining the potential of the cyclic offloading for treatment and prevention of Pressure Injury.

NPUAP published a list of performance criteria for all therapeutic support surfaces which considered that, alongside basic cell configuration, active surfaces have four clinically important, interdependent and measurable performance characteristics — cycle frequency, duration, amplitude and rate of change ².

An informed active surface prescription and differentiation between varied options requires knowledge of the varied mechanisms required for clinical performance of the mattress.



CELL AMPLITUDE

The most significant benefit of an alternating mattress is attributed to the cell cycle amplitude (depth), which ensures offloading for tissue reperfusion ^{3, 4}.

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 support the body in the highest amplitude position. The body must be held clear of the deflating cells by resting upon the fully inflated cells. (Philips).

The contact pressure of a deflating cell will be lower on a mattress that has a higher amplitude inflation ⁵.

Not all mattress systems stating to be “alternating” may achieve sufficient amplitude to provide enough variation between the inflated or deflated duration of the cycle. The amplitude may not be high enough in comparison to the deflating cell to achieve effective offload.

The Pan Pacific Guideline recommend avoiding use of cells less than diameter of 10 cm or overlays as they cannot be sufficiently inflated to ensure adequate pressure redistribution ¹. This is due to an inability of these options to create sufficient amplitude to support the body whilst other cells are offloading. They also increase the risk of ‘bottoming-out’ ¹.

‘Bottoming-out’ (Figure 2) is the descriptor used to explain the result when a person is no longer being supported by the surface and is potentially inappropriately reaching the bottom of the surface. According to the 2019 Clinical Practice Guideline ‘bottoming out’ is the state of support surface deformation beyond critical immersion whereby effective pressure redistribution is lost ⁶.

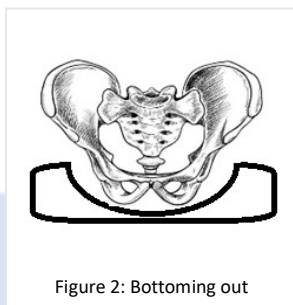


Figure 2: Bottoming out

Determination of effective cell amplitude can be achieved using the results of Interface Pressure in the inflated cells and the objective results of near to full offload in the deflated cells.

The Novis ProCair Plus was tested to have a maximum sacral interface pressure of 31.7 mmHg ⁷. This pressure is sufficient to retain cell amplitude, avoiding ‘bottoming out’ and facilitating full offload of the adjoining cell. The pressure of 30mmHg is also a value that represents occlusion of the arterioles, a necessary action to facilitate the body’s protective vascular response once offloaded. Once vessels are occluded the body produces metabolites that then create a physiological response for reperfusion of the tissue and clear waste as quickly as possible.

As such, following the period of controlled occlusion, a period of spontaneous vessel dilatation occurs, this serves to increase blood flow beyond that normally seen at baseline, the phenomenon known as reactive hyperaemia (Figure 3). This reverses the hypoxic state and restore cellular equilibrium ⁸.

Reactive hyperaemia is the transient increase in organ blood flow that occurs following a brief period of ischemia such as arterial occlusion from pressure. The physiological reaction first appears as a bright flush that lasts about one-half or three-quarters longer than the ischemic period ⁹.

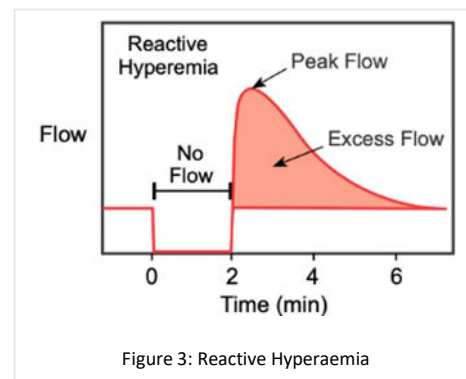


Figure 3: Reactive Hyperaemia

Although amplitude is important for perfusion, it does not mean that air pressures within the mattress need to be unduly high – inflation pressure needs only to be ‘high enough’ to lift the body clear of the deflated cell ¹⁰. Caution needs to surround exerting exceptionally high pressure at risk of tissue damage.

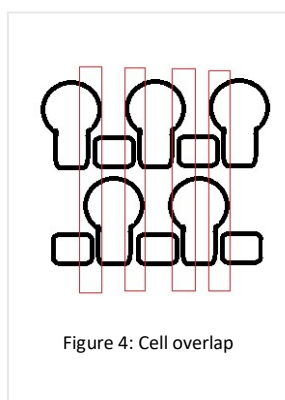
If the initial pressure applied is too high for too long, reactive hyperaemia fails to meet the demand for blood and tissue damage occurs ⁹. The balance between the occlusion and the offload becomes important. The pressure to create cell amplitude must support the body, facilitate offload of the

adjoining cell and must not be too large force to create Injury.

The ProCair Plus offers a conservative high pressure to ensure the body is not succumbing to unnecessary high levels of pressure associated with faster onset of pressure injury ¹¹. The ProCair Plus was measured to never exceed the 32mmHg level ensuring that the smallest possible amount of pressure is used to keep the amplitude high and activate the reactive hyperaemia, without adding undue risk ⁷.

CELL STRUCTURE

The ability for a cell to retain its amplitude when loaded is essential to the realisation of the actual cell height and width.



A cell that collapses under pressure will increase in width creating a zone of overlap with adjacent cells. This overlap zone on the skin will remain under pressure during all periods of the alternating cycle and will therefore not receive the offload at any time (Figure 4).

Novis ProCair Plus has cells designed to retain height and width when loaded. The internal construct of the cell ensures that the best possible alignment of the cell is maintained even when under load. This ensures that all sections of the skin are receiving the therapeutic occlusion and offload to facilitate reactive hyperaemia.

CYCLE TIME

Humans are exposed to varied degrees and durations of pressure as part of everyday life. The body physiologically adapts to compensate by alleviating pressure through movement to prevent exposure to Pressure Injury.

One such biological intervention is the complex, spontaneous, subconscious movement of the body at night that enables offload and redistribution of pressure during sleep. Even poor sleepers exhibit the same behaviours in both small and large movement

of their body whilst not consciously aware of their motion ¹².

During time in bed, people fully vary their position utilising a gross body movement allowing full offload of the skin surface. On average people spend 54.1% in the side position, 37.5% in the back position, and 7.3% in the front position with average of 1.6 gross body movements occurring per hour ¹³. The frequency of all body movements both gross and minor averages fourteen instances per hour with almost a minute spent moving each hour ¹⁴.

Understanding natural nocturnal movement guides us to use similar interventions on people who either have diminished or absent movement, or who are unable to perform the movement independently whilst in the bed.

As such when analysing Pressure Injury risk, studies of vulnerable patients have shown that those who make significant gross body movements every seven to twelve minutes are less likely to develop tissue damage ^{15, 16}.

A principal goal in the design of a mattress will therefore be to simulate the protective effect of normal repositioning by periodically offloading the body's exposure to pressure caused by contact with the mattress surface.

The Novis ProCair Plus mattress is programmed, utilising available evidence, to a 12 minute cycle, whereby each set of 2 cells complete an inflation and deflation period. This means that every 12 minutes every section of the body surface experiences reperfusion in lieu of this not occurring with spontaneous nocturnal movement ⁷.

Increasing the frequency of the alternation comes at the risk of tissue having inadequate time for reperfusion to occur sufficiently. This is particularly relevant for those who have vascular pathology or a longer oxygen recovery requirement ¹⁷.

Conversely increasing the duration between alternations comes at the risk of exposing the tissue to longer periods of pressure and would not be supported by the indicative evidence we have on the timing of nocturnal movement to prevent damage from pressure.

To ensure the mattress remains at this ideal therapeutic cycle time. The ProCair Plus has

engineered a fixed cycle time to ensure that care givers are not able to inadvertently alter this required parameter.

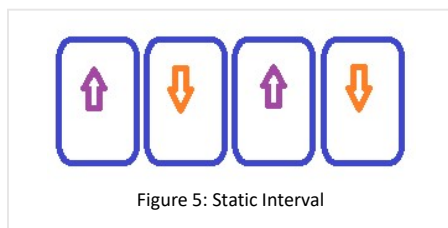
CELL CHANGEOVER

Achieving a static period where corresponding cells are both at maximum amplitude ensures that the person is not moving vertically as the cell exchange occurs. (Figure 5)

If the inflated cell begins to deflate prior to the deflated cell rising the person will drop with the deflating cells and re-rise with the inflating cells.

This experience can negatively impact the compliance in utilising the mattress as they can feel a sensation of 'motion sickness' from the ongoing movement the mattress is exerting on their body. This sensation is disliked by some patients and can cause feelings of nausea and affect sleep ¹⁸.

The ProCair Plus cycle time incorporates a static period between each alternation to ensure the person remains stationary and eliminate any undue effects from undesired motion (Figure 5)



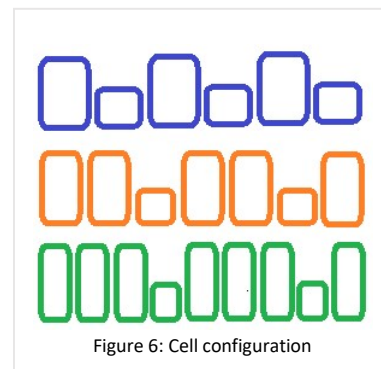
CONFIGURATION

Alternating mattresses can come in varied cell cycle stages. This includes a Single stage inflation: a 1 in 2 orientation (one cell up, one cell down), or multi-stage inflation: a 1 in 3 (two cells up, one cell down) or a 1 in 4 (three cells up, one cell down). (Figure 6)

The single stage inflation aims to align the time of pressure with as greater duration of offload to allow for the longest period of reactive hyperaemia possible. Ensuring that the duration of reactive hyperaemia (an increased 150 – 175% time relative to the time of occlusion ⁹) is maximised ensures that the greatest volume of blood is redirected to the occluded vessels and tissue for repair.

However, for those who clinically require, physiologically require or prefer more support, the multistage inflation offers effective relief of pressure whilst allowing the person to be supported by a greater proportion of the mattress surface, with smaller width cells.

Both alternating mattress types are equally effective to prevent pressure injury development. A mattress with multi-stage inflation does not result in a significantly lower pressure injury incidence compared to a mattress with a standard single-stage inflation of the air cells ¹⁹.



The Novis ProCair Plus offers a 1 in 2 cell orientation maximising the physiological vascular response, however the ProCair range also boasts a 1 in 3 (ProCair Trio) and 1 in 4 (ProCair Quad) for use when clinically indicated or preferred.

RATE OF CHANGE

A well designed active support surface results in a rapid drop in interface pressure to stimulate reactive hyperaemia, mimicking natural body movement ¹⁰.

The speed of offload is important to ensure maximised duration of tissue being offloaded. The more effectively the mattress can deflate to 0mmHg, the more time available for reactive hyperaemia and tissue reperfusion ^{20, 21}.

Active support surfaces designed to off-load vulnerable anatomical locations for as long as possible at each cycle have been shown to deliver optimal levels of tissue perfusion and lymph flow compared to both short interval and low amplitude cycles ^{4, 22, 23}.

The ProCair Plus is designed to deflate in a shorter period as possible and thus increase the duration of time the deflating cell imparts pressure of values below 30, 20 and 10mmHg at the sacrum 7. (Figure 7)

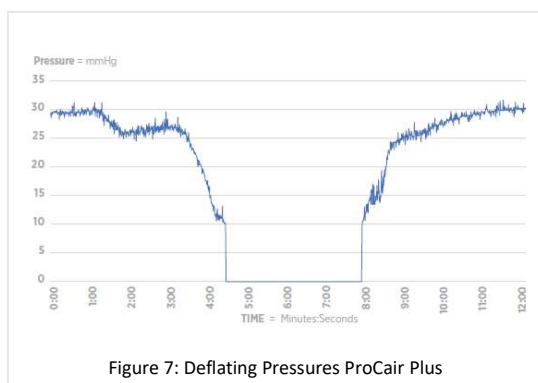


Figure 7: Deflating Pressures ProCair Plus

OFFLOAD PRESSURES

The function of an effective dynamic mattress is to hold contact pressures as low as possible for as long as possible, particularly under the most vulnerable areas such as the heel, sacrum and other bony prominences.

The essential and significant benefit of an alternating mattress is attributed to complete or near complete off-loading delivering superior tissue perfusion compared with partial offloading 3, 4.

The ability of a mattress to relieve pressure below clinically relevant thresholds is measured by calculating the Pressure Relief Index (PRI). Choosing thresholds close to arteriolar, capillary and venule

closing pressures (30, 20 and 10mmHg) indicate clinical performance. (Figure 8)

The goal is to maximise time spent below these pressures, in particular, the 20 and 10 mmHg thresholds are clinically of greater importance 22, 23.

The Novis ProCair Plus demonstrates high levels of clinical performance essential for the person to receive both the prevention and therapeutic impact of the cell offload duration 7.

Analysing the ProCair Plus utilising PRI, we are able to conclude that 29% of the 12-minute cycle (3 minute, 29 seconds) the interface pressure is below 10mmHg (approximate closing pressure of venules), and 39% of time below the 20mmHg (approximate closing pressure of capillaries). With the PRI threshold in the mattress set at 30mmHg the test subject recorded sacral pressure equal to or less than 30mmHg for 94% (11 minutes 17 seconds) of the 12-minute cycle time 7. (Figure 9)

PRI THRESHOLD (mmHg)	TIME (MINUTES:SECONDS)	PERCENTAGE OF 12-MINUTE CYCLE
Above 40	0:00	0%
Between 30 and 40	0:43	6%
Between 20 and 30	6:36	55%
Between 10 and 20	1:12	10%
Below 10	3:29	29%

Figure 9: Sacral PRI for ProCair Plus

To produce re-perfusion after periodic loading, complete or near complete off-loading needs to occur 24. These results demonstrate the ProCair Plus meets this criteria and maximises the offloaded period, encouraging the greatest timeframe for reperfusion and reactive hyperaemia.

PRESSURE RECALIBRATION

For optimum comfort and pressure redistribution, a mattress must be correctly inflated.

The pressure required in the air cells is directly proportionate to the weight and posture of the person 25. If the air cell pressure is too high, then the mattress becomes too hard, giving high interface pressures, and if it is too low then it will 'bottom out'. Maximum contact pressures on the sacrum are significantly lower on devices whose inflation pressure is adjusted according to subject's body mass 25.

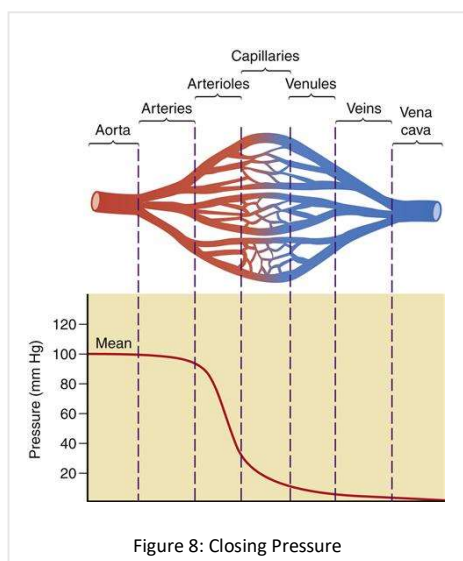


Figure 8: Closing Pressure

The ProCair Plus offers auto-calibration of pressure in real time. This means that the mattress is constantly adjusting for changes in weight and posture at all times in the cycle.

Some mattresses are only able to be calibrated upon set up, others recalculate at the end of each cycle or a predetermined time period. This can lead to delay in the mattress detecting and changing pressure, leading to period of increased risk of the pressure delivered being too high or too low.

When the bed enters the Fowler position (Figure 10), recommended to not exceed 30 degrees ¹, the proportion of torso weight is shifted from the back to the buttock region. The amount of force through the ischial tuberosities and/or sacrum (dependant on posture) is increased.

The mattress will therefore be required to deliver greater support pressure to the sitting region to ensure the person remains elevated by the mattress, that cell amplitude is maintained and the mattress does not bottom-out.

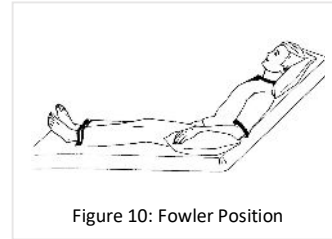


Figure 10: Fowler Position

Novis ProCair Plus offers an automatic fowler mode. When the head of the mattress is elevated to 30 degrees the mattress recalibrates delivering sufficient pressure to continue to deliver clinically effective offloading.

This auto response by the ProCair Plus is essential in removing the need to care givers to activate it manually, which inevitable can be forgotten during busy periods assisting the person in the bed. Absence of an auto fowler mode increases the risk of 'bottoming-out' and exposure to excessive, prolonged pressure.

SUMMARY

To ensure implementation of the best possible clinical solution it is imperative to have a thorough understanding of the mechanism of successful active mattress therapy. When prescribing this Assistive Technology, it must meet certain objective criteria in order to ensure that the results will meet the therapeutic expectations.

Metrics such as cell amplitude, structure, cycle time, changeover, configuration, rate of change, offload pressures and pressure recalibration will assist in comparing similar products to determine greatest suitability to achieve the clinical solution for the person.

Novis ProCair Plus has been designed utilising the best evidence available in lieu of no formal guidelines surrounding alternating mattress therapy.

Applying the objective metrics to the ProCair Plus mattress enables us to correctly ensure that the mattress system has been designed, engineered, constructed to perform at a level to which realisation of the best possible results will occur from implementation of active mattress therapy.



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