PRESSURE INJURY PREVENTION

The Science behind the Support Surface

Fundamental principles and product performance characteristics

INTRODUCTION

Arjo Pressure Injury Prevention & Management Solutions

At Arjo we have been working for more than 60 years to help reduce the risk of pressure injuries. As a global leader in this area, we leverage our specialist expertise to bring you best-in-class solutions that are designed to support mobility and help to reduce both the incidence and severity of healthcare acquired pressure injuries.

Our support surface technologies combine clinical performance and technological innovation to address the management of pressure, shear, and microclimate – key aspects of effective pressure injury prevention and treatment. Our solutions align to best practice guidelines[1] which draw upon multi-disciplinary expertise, industry experts, and developmental research from around the world.

The following clinical summary offers an introduction to the principal pathology underlying pressure injury development. It considers the role of the support surface in pressure injury prevention and management strategies, examines how surface design characteristics can affect overall product performance, and highlights the importance of measuring critical performance characteristics to help support and inform clinical decision making at the bedside.

Pressure Injury Pathophysiology: Key Factors

To understand some of the key design principles related to the various support surface technologies offered by Arjo, it is important to understand how pressure injuries develop. ***A pressure injury is defined as localised damage to the skin and/or underlying tissues as a result of pressure or pressure in combination with shear***[1]. Although the underlying cause and formation of pressure injuries is complex and multifaceted, generally they cannot form without loading, or pressure on the soft tissues[2].

Damage develops gradually and sequentially over a period of minutes to hours due to sustained mechanical loads applied to the skin and soft tissues[1, 3, 4]. These mechanical loads originate from an individual's own bodyweight, or they can be the result of external forces such as from a medical device or other object[1]. The accepted model for pressure injury pathology recognises two interdependent pathways (Figure 1). One pathway involves mechanical loading, which relates to the type, duration and magnitude of the load applied to the tissues. The other pathway relates to those factors that influence the susceptibility and tolerance of the tissues to withstand the applied mechanical load[1, 5].

Whether injury occurs largely depends upon two physiologically relevant thresholds. One is a lower threshold associated with a complete or partial blockage of a blood vessel, which can reduce or even stop the flow of oxygen-rich blood to the tissues, leading to necrosis (tissue death). The other is a higher threshold which alters the shape and structure of the tissues leading to stress and strain and, ultimately, tissue damage (referred to as direct deformation induced cell damage)[1].

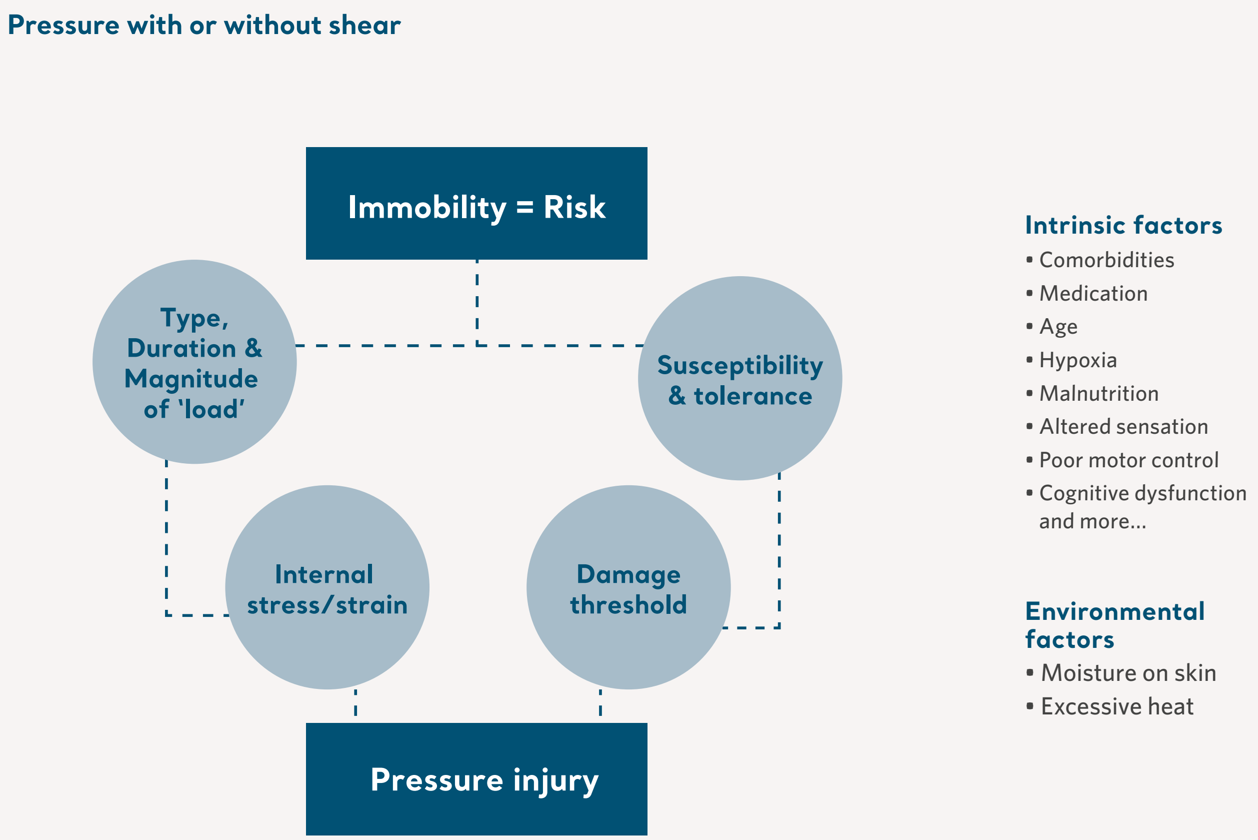


Figure 1: Pressure Injury Pathology: Mechanical Loading & Tissue Tolerance

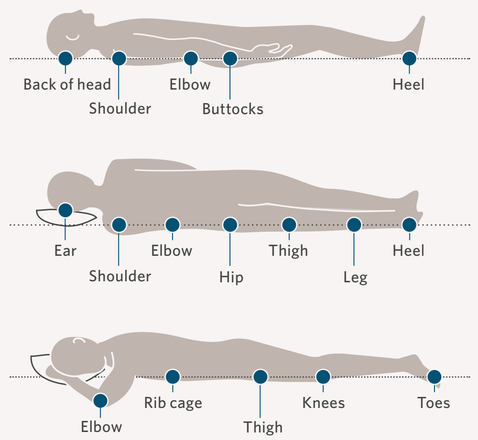
The Impact of Pressure & Shear on the skin & underlying Tissues

Pressure

Pressure is defined as **the amount of perpendicular force applied to the skin**[3]. While pressure is a completely natural phenomenon, it can become problematic when it is excessive or prolonged (e.g. when someone is immobile or very ill and unable to move themselves). When an individual is exposed to prolonged or sustained periods of lying or sitting on a particular part of the body, displacement or distortion of the soft tissues occur (Figure 2), resulting in small blood vessel collapse and ischemia[6] (restricted or reduced blood flow).

This hinders perfusion and lymphatic flow to the tissues, whilst also limiting the elimination of cellular by-products. Tissue damage is often more common over the bony prominences where sharp bony structures come into contact with easily deformable muscle, adipose (body fat) or skin tissues[4]. Pressures are three to five times higher internally near a bony prominence than the pressure applied to the skin over the prominence[7].

At risk areas for pressure ulcer development



Key anatomical locations associated with pressure injury development

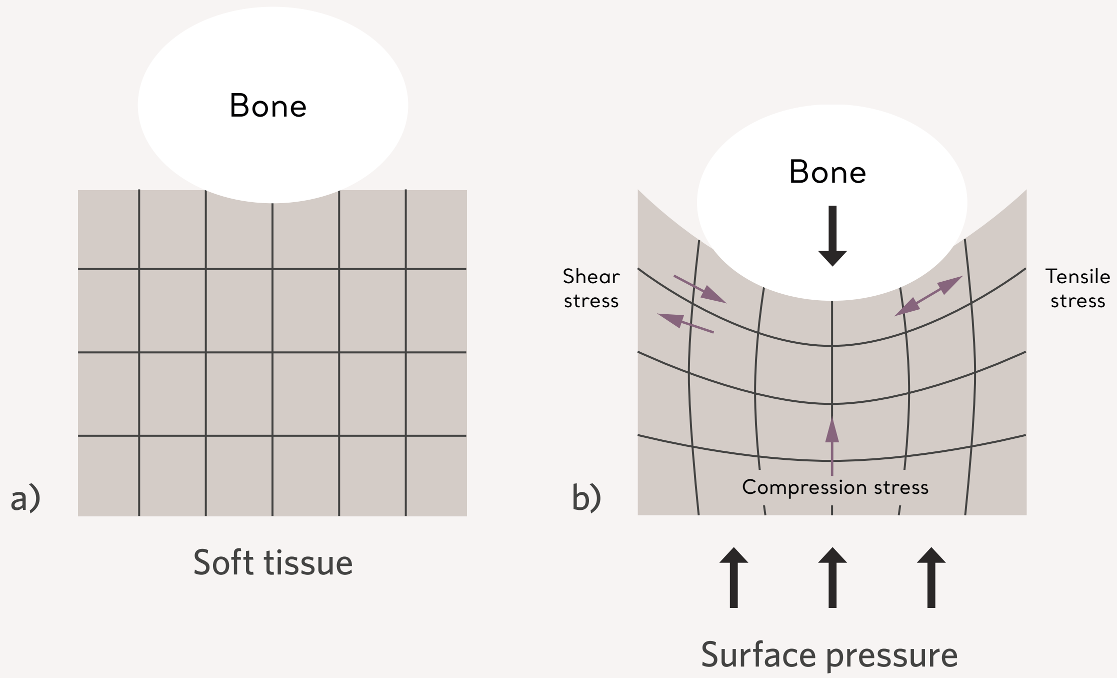


Figure 2: Pressure applied over a bony prominence. Illustration adapted from Pressure ulcer prevention: pressure, shear, friction and microclimate in context. A consensus document. London: Wounds International (2010).

Shear

Shear is **a diagonal force that coexists with pressure** (Figure 3). Lateral shear forces frequently exacerbate the effects of pressure. It causes deep horizontal stress by stretching and distorting tissue and blood vessels[8, 9] (Figure 3). Compression of tissue over bony prominences occurs concurrently with shear forces, which are key factors in pressure injury formation[10].

For example when a patient is in a semi-recumbent position, the effect of gravity is to pull the patient downwards. The skin does not move due to the resistance generated by the surface, however the skeleton and deep tissues slide downwards, thus creating a shear force that distorts the soft tissues beneath the skin (Figure 4). This can cause a significant reduction in blood flow to the skin as small blood vessels stretch, kink or tear.

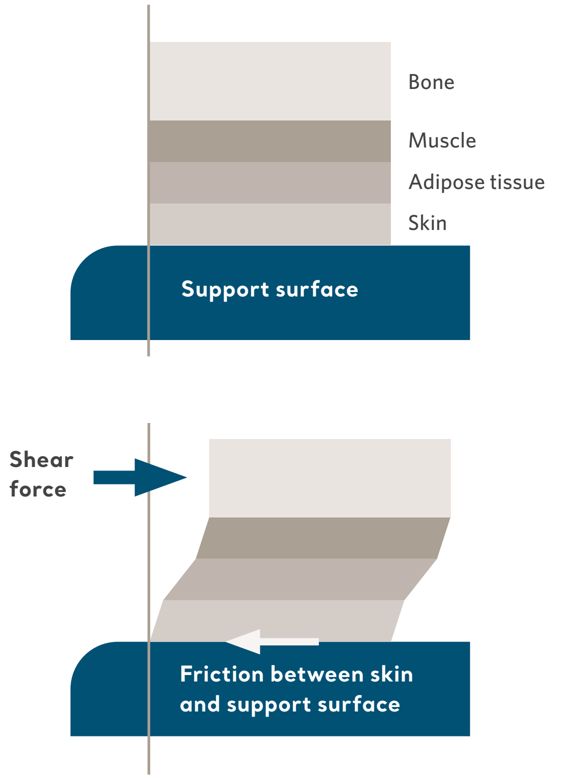


Figure 3: illustrative example of shear force & its impact within the tissues. Illustration adapted from Pressure ulcer prevention: pressure, shear, friction and microclimate in context. A consensus document. London: Wounds International (2010).

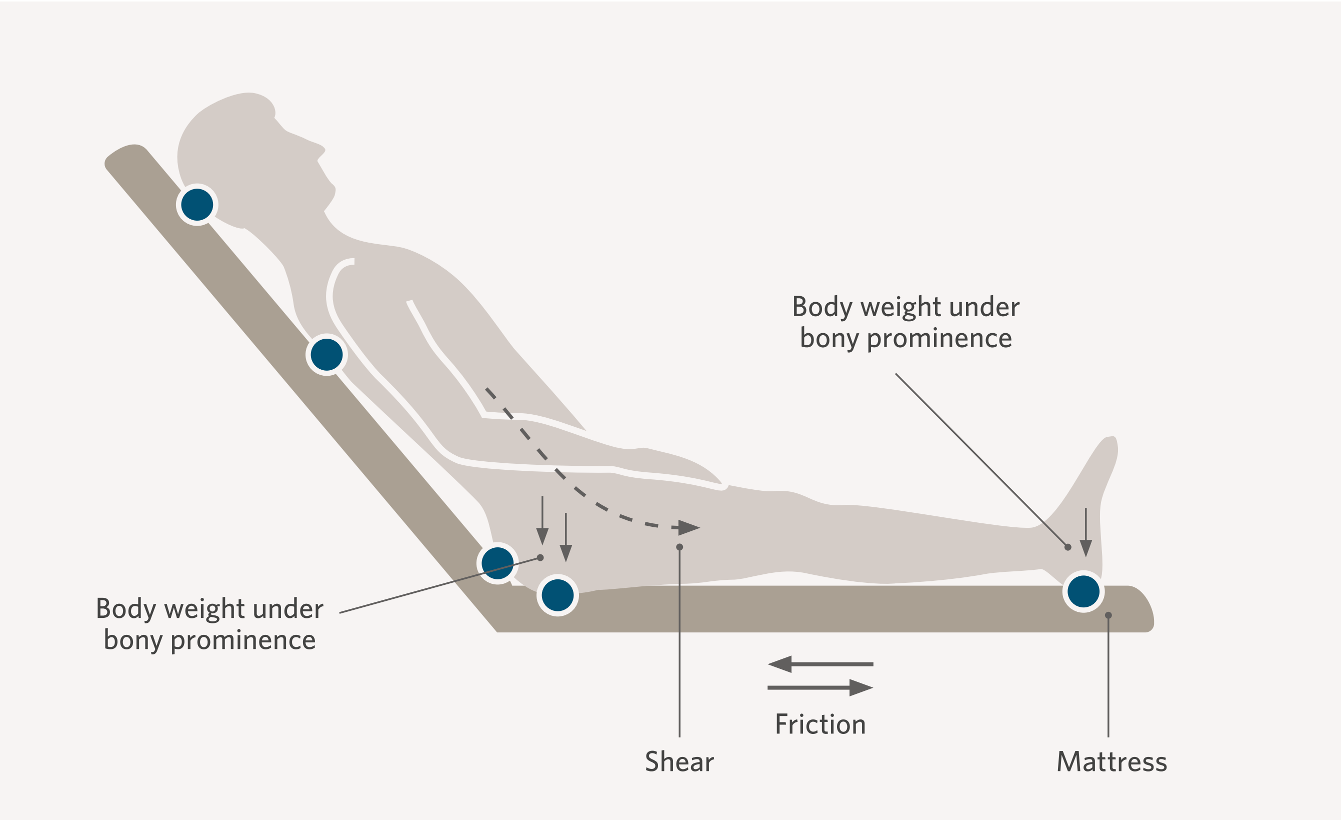


Figure 4: Lateral Shear Force

The Importance of Time in Pressure Injury Development

The relationship between pressure and time are critical factors in pressure injury development. Research conducted over many years has demonstrated that the magnitude of the mechanical load which may lead to tissue damage depends on the duration of time during which the loads are applied to the skin and tissues[11]. Generally the established principle is that tissue can withstand higher pressures for a short period of time and lower pressures for a longer period[1, 3, 12] (Figure 5).

Sufficiently high mechanical loads can lead to tissue damage at a microscopic level within minutes, although it can take hours of sustained loading for the damage to become clinically visible on the skin surface[11].

There is no universally 'safe' pressure threshold, and it is difficult to determine an absolute time period beyond which a patient will go on to develop a pressure injury[1]. The speed and severity of the onset of a pressure injury will depend on many internal and external factors including individual anatomy, tissue tolerances and confounding factors[11].

Tissue Tolerance

The development of a pressure injury also depends upon tissue tolerance, which is affected by many physical and environmental risk factors unique to each individual. When immobile and/or insensate these factors determine vulnerability to pressure injury and the speed and severity of tissue damage[1, 13].

Tissue tolerance is impacted further by environmental conditions at the skin, in particular the microclimate. Temperature has been found to have a profound effect on tissue tolerance, by raising metabolic demand at a time when the blood supply may be limited by pressure related occlusion of the microcirculation; this can be particularly problematic when higher pressures are experienced[5]. Furthermore, pressure alone can trigger a temperature rise.

In association with temperature, increased heat may trigger a natural diaphoretic (sweat) response creating a continually moist skin environment that can lead to skin maceration and an increased vulnerability to damage[1].

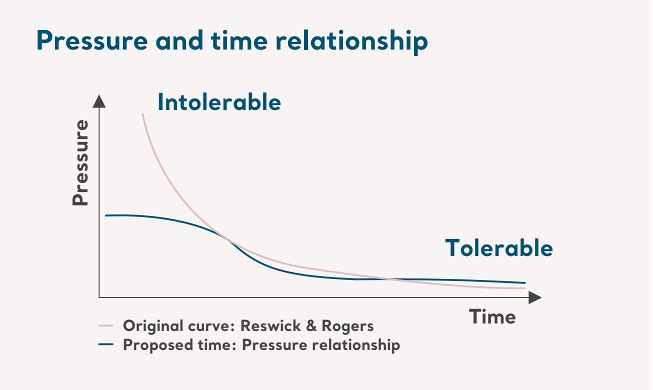
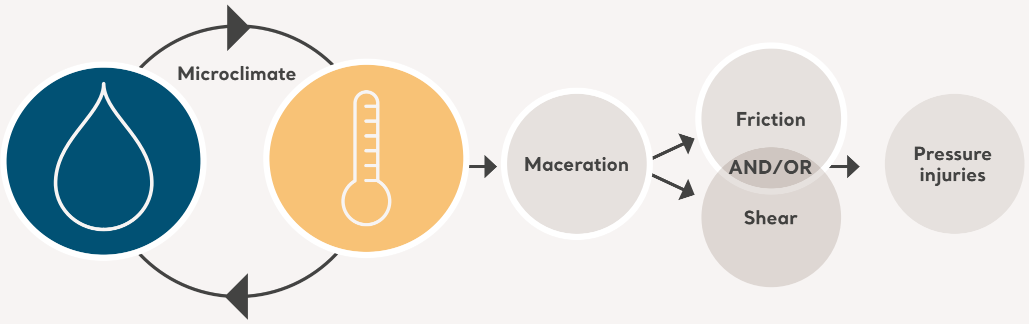


Figure 5: Pressure & Time Curve

Microclimate Management the critical link to skin integrity

- Microclimate refers to the conditions of moisture and temperature at the point(s) of skin/surface interface[1]
- Microclimate is a key factor for patients at risk of maceration and skin breakdown
- Excess variation in moisture and/or temperature increases skin sensitivity to the damaging effects of pressure, shear, and friction[6]



Microclimate as a contributing factor to the development of pressure injuries

Pressure injury damage cascade

When tissue tolerance is exceeded, this initiates a cascade of events[1, 15], comprising three main stages, **tissue deformation, inflammatory oedema and Ischaemic damage**, and described as follows (Figure 6):

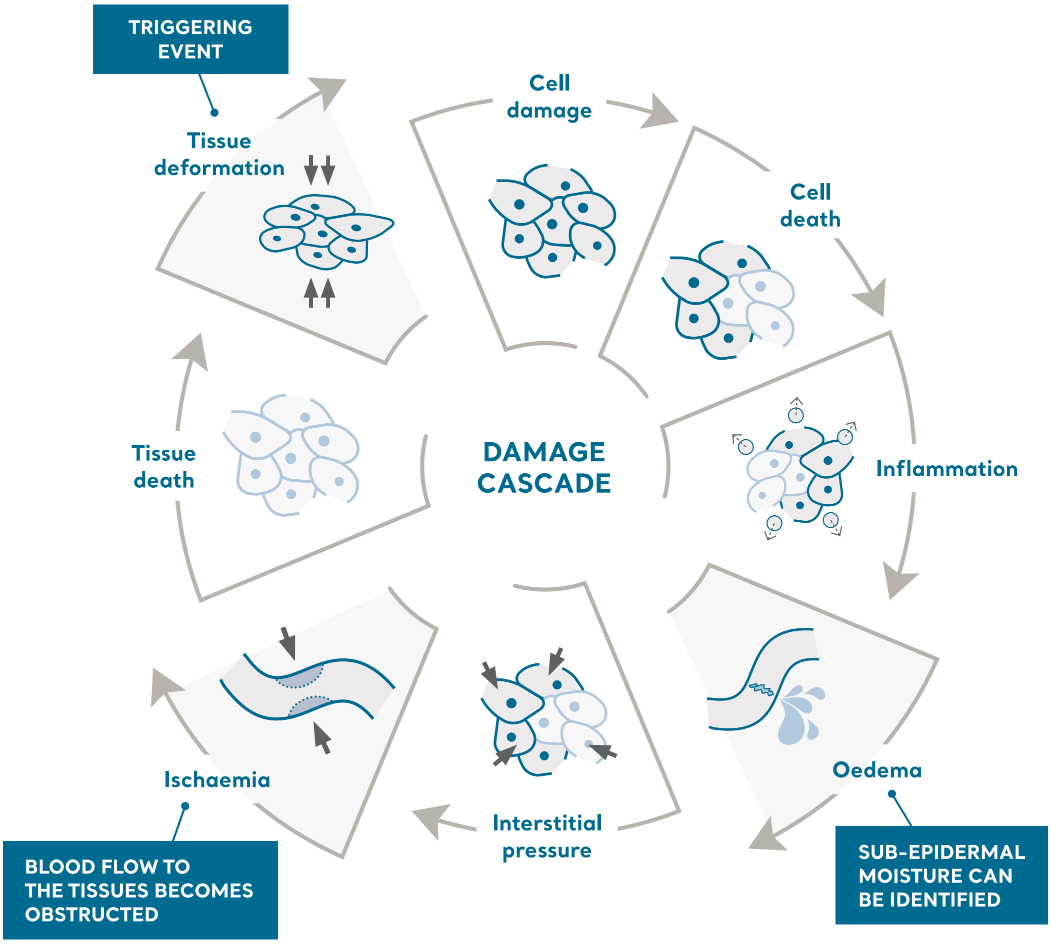


Figure 6: Pressure Injury Damage Cascade, adapted with kind permission from Wounds International Limited. Gefen 2020: The SEM Scanner for Early Pressure Ulcer Detection: A 360 degree Review of the Technology. Wounds International. Vol. 11, issue 3, p.22–30.

Direct Deformation: Sustained loading by mechanical forces can initiate damage at a microscopic level, provoking an inflammatory response.

Inflammatory Oedema: Increased blood flow and cellular porosity result in an accumulation of interstitial fluid below the epidermis (sub-epidermal moisture)[16, 17]. The subsequent rise in interstitial pressure further loads the tissues and is considered a potential contributor to progressive tissue damage[16, 17]. These inflammatory changes in the skin and underlying tissues may precede skin surface changes by 3 to 10 days[18].

Ischaemic Damage: The combined effects of deformation caused by bodyweight and/or other external forces, the intensifying effects of oedema, and the associated high interstitial pressure, obstruct the blood vessels and impair tissue perfusion at the damage site[19]. The subsequent reduction in the supply of oxygen and micronutrients, combined with the failure to remove toxic metabolites (lymph obstruction) can lead to tissue ischaemia and irreversible necrotic injury[18], particularly if prolonged.

Section Summary

There are many factors which can lead to pressure injury development, the primary of which include mechanical forces such as pressure and shear. Support surface design principles therefore aim to minimise the damaging effects of these mechanical forces by using a variety of different technologies to manage and reduce tissue load.

Support Surface Design Principles in Pressure Injury Prevention & Management

In order to reduce the likelihood of pressure injury development, successful prevention methods focus on reducing exposure to sustained tissue deformation (pressure & shear) by regularly off-loading or reducing loading on the tissues. Interventions, such as assisted repositioning regimens, help to reduce risk and are most effective when used in combination with pressure redistributing support surfaces.

The Support Surface Standards Initiative (S3I) has defined support surfaces as; ***'Specialised devices for pressure redistribution designed for management of tissue loads, microclimate and/or other therapeutic functions'***[20].

The Role of Support Surfaces in Pressure Injury Prevention & Management

The principal aim of support surfaces is to reduce the interface between the body and sustained pressure from a surface. The international pressure injury prevention and treatment guidelines[1] view support surface technologies as an important component in pressure injury prevention and treatment protocols, since they can help prevent the effects of damaging tissue deformation and provide an environment that enhances perfusion of at-risk or injured tissues[21]. They further recommend that the key characteristics to consider when selecting a support surface are those features that affect **pressure redistribution, friction, shear force management and microclimate**[21].

These key characteristics however will vary substantially between the different surface technologies available, and this can often make appropriate surface selection in the clinical setting challenging.

Two distinct generic types of support surface are defined, based upon their primary mode of action (how they redistribute pressure) and by the addition of supplemental functionality to manage microclimate and/or shear (Figure 7):

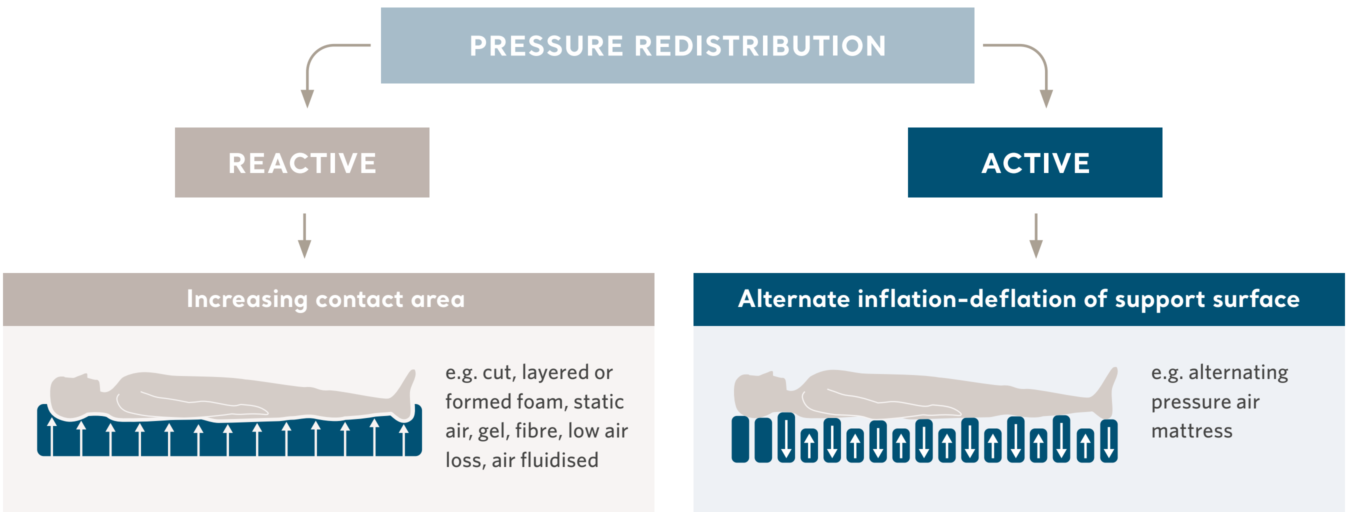


Figure 7: Active and Reactive Pressure Redistribution Surfaces & mode of action

Reactive Pressure Redistribution

Reactive pressure redistribution surfaces (formerly known as constant low pressure, static or pressure reducing) are defined as ***a powered or non-powered support surface with the ability to change its load distribution properties, only in response to an applied load*** (Figure 8)[20]. Reactive surfaces typically include, foam, gel, air/foam combination products and low air loss systems.

Reactive surfaces frequently incorporate additional features such as low air loss; this is clinically indicated in patients who might benefit from the active management of heat and moisture (microclimate) at the skin-mattress interface. Low air loss systems are inflated air support surfaces powered by a pump which allow air to escape via small holes in the mattress cells to facilitate the slow release of air around the patient. The Arjo Therakair Visio mattress (Figure 9) offers a high level of pressure redistribution and microclimate control, with the added benefit of a pulsation mode.

Design Principals: Reactive Pressure Redistribution

The principal purpose of a reactive surface is to minimise the magnitude of the applied force by reducing or redistributing pressure across the whole body in order to increase the surface area over which the individual is supported[4, 22]. This is achieved through the process of immersion and envelopment (Figure 10). Immersion relates to the ability of the body to sink into the support surface[23], and envelopment refers to how well a support surface conforms or moulds around the shape of the human body[23]. High levels of immersion and envelopment will help to reduce interface pressure and shear by redistributing body weight more uniformly across a wider contact surface area and hence reducing localised cell and tissue deformation[4].

Whilst high pressure gradients are reduced with reactive surfaces, the pressure applied to the skin and underlying tissues remains constant unless the patient moves or is repositioned.

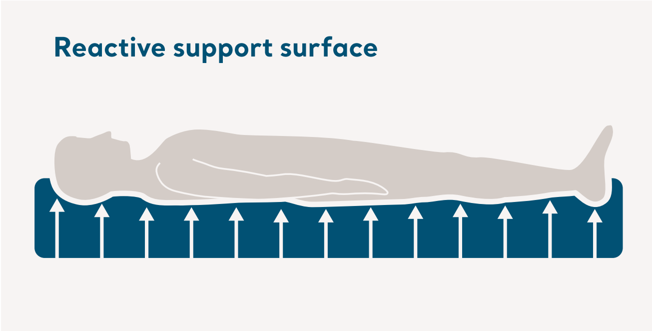


Figure 8: Reactive Pressure Redistribution

Figure 9: Therakair Visio low air loss system

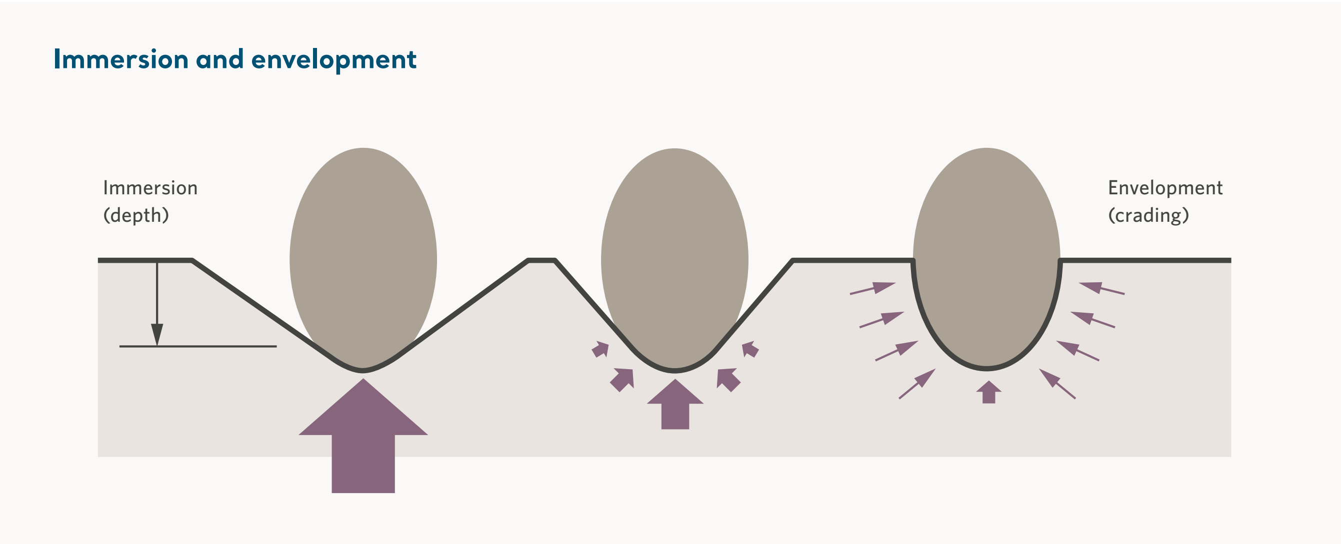


Figure 10: Illustrative example of how immersion and envelopment support pressure redistribution

Active Pressure Redistribution

Active pressure redistributing surfaces (formerly known as alternating pressure, dynamic mattresses, or pressure relieving surfaces) are defined as ***a powered support surface that has the ability to change its load distribution properties, with or without an applied load*** (Figure 11)[20].

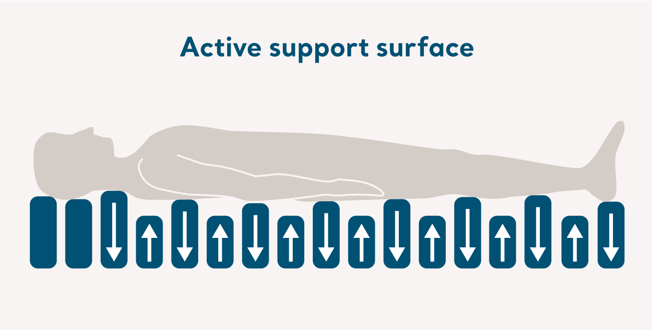


Figure 11: Active Pressure Redistribution

Design Principles: Active (alternating) Pressure Redistribution

Active (alternating) support surfaces are designed to closely mimic the natural protective environment of regular spontaneous movement by redistributing pressure beneath the body several times each hour. This is typically achieved through cyclical changes in loading and unloading of the body through the inflation and deflation of a series of air cells within the mattress. This helps to balance the application and removal of pressure to support tissue recovery and to allow tissue reperfusion (restoration of blood flow) to occur[21, 24].

Since pressure and time are critical factors in pressure injury development, it is important that active surfaces provide pressure redistribution for long enough periods in order to make a clinical difference[25]. This has an impact on support surface design characteristics and product performance parameters, with the most effective surfaces likely to be those able to **hold pressure as low as possible for as long as possible**. It is important to recognise that whilst design characteristics may be critical to clinical outcome, not all active (alternating) surfaces will perform the same despite being similar in appearance.

Since the goal of active support surfaces is to off-load and relieve the mechanical loading on the tissues, important technical performance characteristics focus on:

- The frequency and duration of off-loading
- The amplitude of the pressure wave
- How quickly pressure is applied and removed from the interface between the patient and the support surface.

These factors produce a 'cycle signature', which is likely to be different for each support surface.

Cycle Signature

Short Interval cycle

Systems with a high amplitude (the difference between maximum and minimum interface pressure) that achieve a low pressure but only for a short duration (Figure 12), are unlikely to allow sufficient reperfusion time, particularly in those individuals who because of their age and/or underlying medical condition have compromised or prolonged tissue oxygen recovery times e.g. those with diabetes, stroke or peripheral vascular disease.

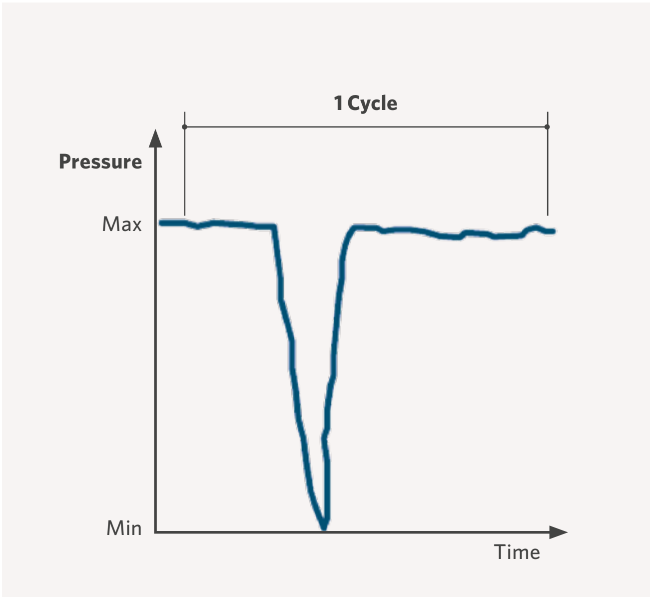


Figure 12: Short interval, high amplitude cycle. For illustration purposes only

Low Amplitude cycle

Active systems with a low amplitude cycle are likely to lower the contact pressure, but are unlikely to achieve tissue off-loading (Figure 13). Due to the lower difference between adjacent cell pressures, some patients may find this option more comfortable.

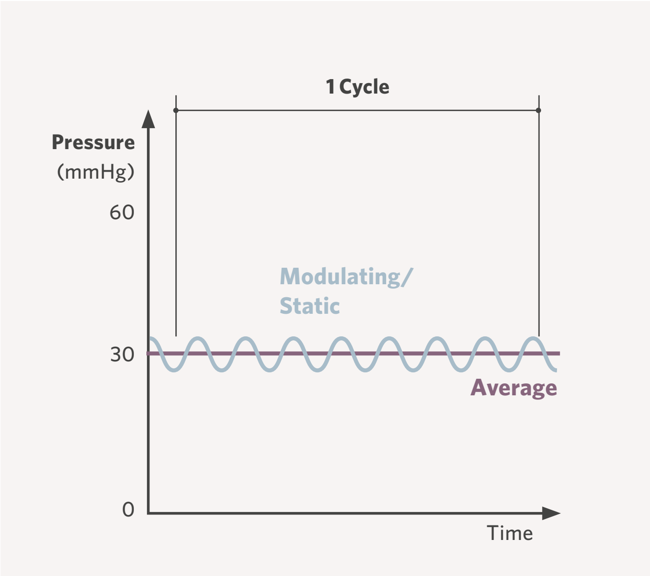


Figure 13: Low amplitude cycle. For illustration purposes only

Optimised Cycle

Active support surfaces designed to off-load vulnerable anatomical locations for as long as possible at each cycle (Figure 14) have been shown to deliver optimal levels of tissue perfusion and lymph flow compared to both short interval and low amplitude cycles[26, 27, 28]. Clinically the cycle needs to be of sufficient amplitude and duration to efficiently 'lift' the body clear of the deflating cell for long enough to allow tissue reperfusion to occur[24, 25]. This is the principle that all Arjo Active (alternating surfaces) are designed to achieve.

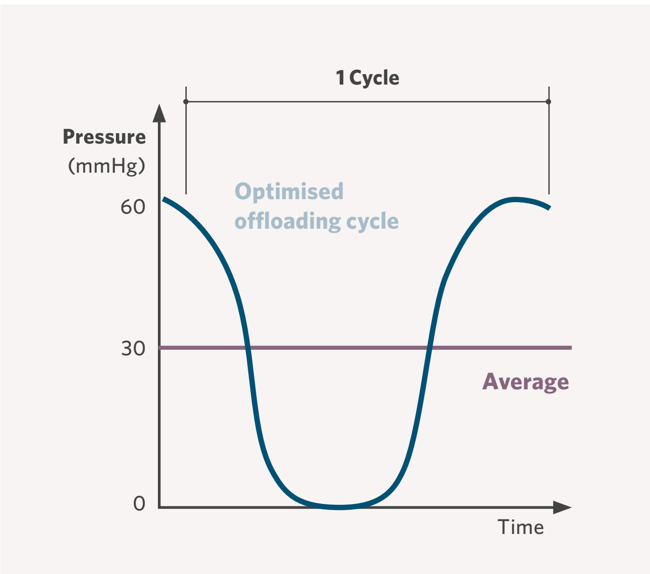


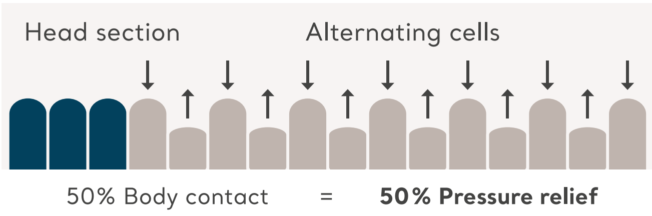
Figure 14: Optimised cycle. For illustration purposes only

Cycle Configuration (alternation sequence)

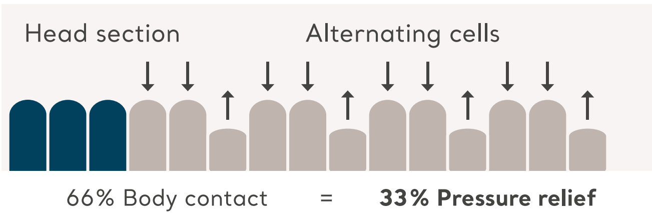
Cell configuration is particularly important for managing tissue integrity and in reducing mechanical loading. Support surfaces typically operate on an alternating cycle whereby every second (1-in-2) or every third (1-in-3) or fourth (1-in-4) cell deflates whilst keeping the body supported across the remaining inflated cells (Figure 15).

Arjo Active support surfaces are designed to operate on a 1-in-2 cell cycle in order to provide a balanced regime of tissue loading matched with off-loading and tissue recovery time.

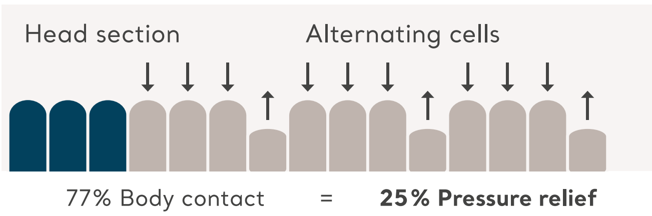
1 in 2 Cell cycle



1 in 3 Cell cycle



1 in 4 Cell cycle



Benefits of a 1-in-2 Cell Cycle:

- 50% of the body remains supported at any point in time
- 50% of the body is off-loaded at any one point in time
- Allows sufficient time for blood flow and tissue reperfusion to occur

Cell Alternation – Cycle Duration

Healthy individuals have a natural protective mechanism and manage pressure by moving spontaneously at approximately 5-minute intervals, even during sleep[29]. Similarly, studies of vulnerable patients have shown that those who make significant body movements every seven to twelve minutes are less likely to develop tissue damage[30, 31]. These principles form the basis for Arjo active pressure redistribution surfaces with the premise that a 10 minute cycle (5 minutes loaded and 5 minutes off-loaded) most closely resembles natural movement and hence is likely to lead to optimal outcomes.

Comfort & Support

A support surface should be considered a therapeutic modality prescribed to prevent and manage pressure injuries and hence the design must ensure there is a careful balance between pressure redistribution (efficacy) and comfort[32]. There is little point in developing a surface that is highly effective, but unacceptable to patients, and by the same token, there is little point in prioritising comfort over efficacy. As an example in active alternating air systems, comfort is related primarily to cell inflation pressure and the rate of inflation and deflation during the cycle. A high inflation pressure prevents bottoming out, but risks comfort for the patient through high peak contact pressure.

At the same time, a very soft surface will increase comfort, but may hinder independent movement and increase the likelihood of 'bottoming out' on the surface (Figure 16).

Arjo active support surfaces range from those that have fully automatic cell pressure adjustment to increase or decrease the air in the cells in response to a change in body-mass distribution (Nimbus range®, Auralis range), to those that require manual adjustment each time the patient alters position (Alpha Active range). Arjo surfaces have been designed to balance efficacy with comfort.

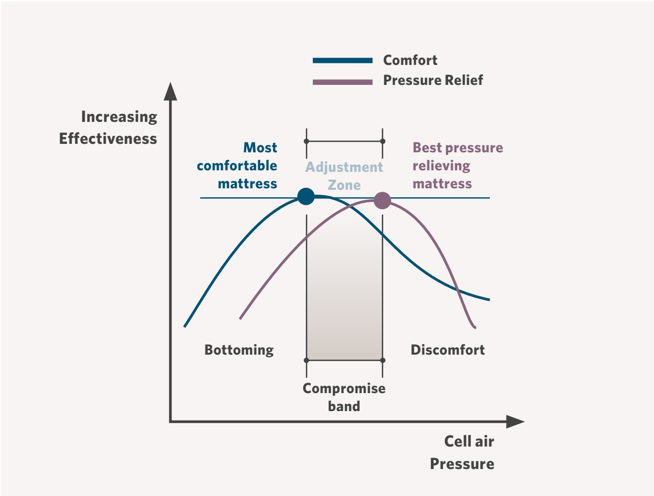


Figure 16: Optimising Comfort & Performance. For illustration purposes only

Manual vs. Automatic Cell Adjustment

Manual Adjustment

Manually adjusted active support surfaces, such as the Alpha Active 4, are most appropriate for patients who might be less vulnerable to harm should the device be set incorrectly. For example, lower risk patients who are able to make some independent position changes.

However, clinicians are still responsible for setting the device up correctly and this is likely to have implications for training, particularly in areas where staff turnover is high, where the environment of care is unsupervised (e.g. home care), or where patient acuity may divert attention (e.g. intensive care).

Alpha Active 4 Manually adjusted system

Automatic Adjustment

The safest option and the one most likely to deliver optimal outcomes in the most vulnerable patient, is the fully automated surface. Automatic active surfaces optimise internal cell pressures in order to maintain high levels of comfort and effective pressure redistribution regardless of weight or patient positioning.

Active support surfaces such as the Nimbus® range with Auto Matt sensor pad technology and the Auralis range® with Self Set technology (SST) are both fully automated mattress replacement systems.

Nimbus Professional with Automatt Sensor Pad Technology

AutoMatt Sensor pad Technology (Nimbus Range)

The Nimbus range consists of a pressure sensitive pad located beneath the cells of the torso section to automatically set cell pressures according to patient positioning and body weight distribution in order to ensure optimal cell pressures.

Self-Set Technology (SST) (Auralis Range)

The Auralis range uses sensing technology within the pump to detect patient weight and changes in body position to automatically and continually adjust cell pressure settings.

Auralis Mattress Replacement system with Self Set Technology

Adaptable Alternating Pressure (Velaris Range)

The Velaris support surface range combines the comfort of foam and the pressure offloading capability of air cells to maximise the benefits offered by both a reactive and active alternating support surface.

The Velaris pump offers fully adaptive technology to transform the surface into an alternating system with full pressure off-loading capabilities. Unique AltoVac® technology in the pump vacuums air out of the cells to provide a faster off-loading profile, whilst keeping interface pressure as low as possible for as long as possible.

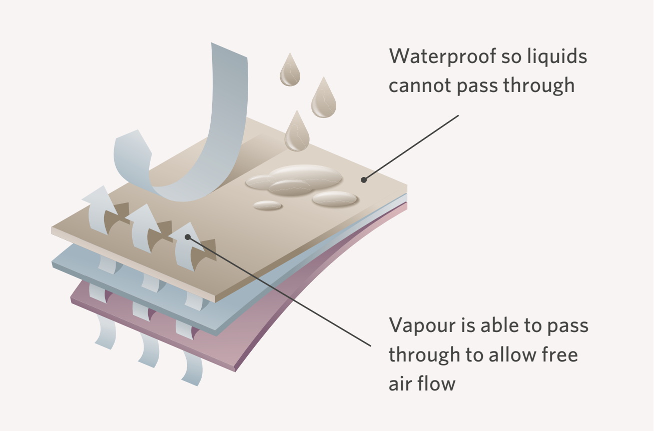
Velaris Adaptable Alternating Pressure mattress replacement

Cover Fabrics

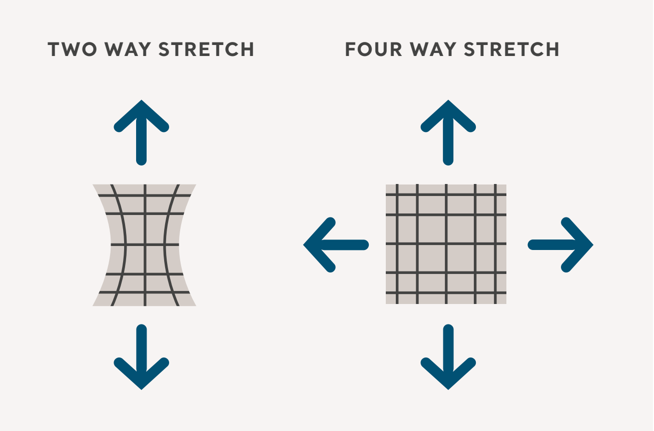
Cover fabrics are a key component in support surface design. Fabrics must have the ability to stretch and conform back to their original properties, without being too tight to cause a 'hammocking' effect.

The surface of the fabric should also have a low coefficient of friction in order to reduce local shear and strain on the skin during patient movement or repositioning.

In addition to these parameters it is important to ensure fabrics are breathable to allow air and water vapour to pass through and to prevent temperature and moisture build up against the patient's skin. This is achieved by measuring the fabric's MVTR (Moisture Vapour Transmission Rate).



Top covers & vapour permeability



Stretch properties of cover fabrics: 2 way or 4 way Stretch options

Enhancing Design and Product Performance Features

In addition to a full range of alarms, cable management and premium cover fabrics, many of the active and reactive surfaces within Arjo's product portfolio have additional design features aligned closely to patient and care giver safety:

6° Active Heel Slope (Velaris range)

A 6° heel slope allows for pressure redistribution in the vulnerable heel area (Figure 17a).

Figure 17a: Velaris Adaptable Alternating Pressure mattress replacement with Heel Slope

Heel Guard (Nimbus & Auralis range)

Uses very simple yet effective cell design to provide off-loading over the most vulnerable heel area to keep pressures as low as possible for as long as possible.

Wound Valve Technology (Nimbus 4)

International guidelines recommend that heels should be free from the surface of the bed and to off-load the heel in such a way as to distribute the weight of the calf without placing pressure on the Achilles tendon and popliteal vein[33]. The use of Wound Valve technology (Figure 17b) helps caregivers to provide a targeted intervention to the vulnerable heel area enabling cells in the heel zone to be deflated for as long as necessary.

Zoned Wound Valve Technology (Nimbus Professional)

Nimbus Professional wound valve technology allows caregivers to completely deflate individual cells under the patient's body, providing an adaptable support surface for the management of highly vulnerable areas even during prone positioning procedures (Figure 17c). Individual cell deflation can be targeted at sensitive body areas at particular risk of pressure injury.

Figure 17c: Nimbus Professional with Zoned Wound Valve Technology for individual cell deflation

Patient Turn Feature (Citadel Patient Care System)

Patient Turn can assist with manual repositioning by turning the patient up to 20° towards the caregiver (Figure 17d). It can be used on an ad hoc basis to help reduce the physical effort required of the caregiver during some nursing interventions.

A Continuous Patient Turn function automates patient repositioning by turning the patient laterally up to 20° to the left and right with pauses in each lateral and at the reclined position. The frequency of the pause at each bed position can be pre-programmed.

Figure 17b: Nimbus 4 with Wound Valve Technology in the heel zone

Figure 17d: Citadel Patient Care System with Patient Turn & Continuous Patient Turn Functionality

Measuring Support Surface Product Performance Characteristics

How do we assess the performance of Arjo support surfaces?

All Arjo support surfaces undergo rigorous testing to ensure they deliver the desired pressure redistribution characteristics under clinically relevant conditions (different weights, body mass distribution and head of bed elevations). In addition to internal bench testing, Arjo surfaces are also tested in independent laboratories to meet national and international standards such as the American National Standards Institute/Rehabilitation Engineering and Assisted Technology Association (ANSI/RESNA). This section will provide an overview of the test methods employed by Arjo and how such tests can generate valuable data to help guide clinical decision making and surface selection at the bedside.

Traditionally two methods have been used when evaluating support surface performance characteristics and these depend upon the specific type of surface being tested. The Pressure Area Index (PAI) is used to assess the pressure redistribution properties of a reactive surface and the Pressure Redistribution Index (PRI) is used to evaluate active (alternating) support surfaces[34]. Both methods produce data to help measure and evaluate relevant surface performance.

Measuring Pressure Area Index (PAI) for Reactive surfaces

PAI testing involves the measurement of interface (contact) pressure and pressure redistribution using flexible pressure sensor mat technologies. A pressure mat is placed between the individual or mannequin to be measured and the surface to be tested, in order to quantify and visualise the pressure between the two contacting objects (the individual and the support surface) (Figure 18).

Figure 18: Pressure Area Index flexible sensor mat technology

The interface (contact) pressure is measured at a single point in time to produce a pressure map similar to that shown in Figure 19. The overall aim is to establish the lowest possible peak pressures and the largest body surface contact area between the individual and the surface being tested[35].

Clinical Relevance of PAI testing

Reactive surfaces which provide a higher patient contact area and a lower pressure area index are likely to provide better levels of pressure redistribution.

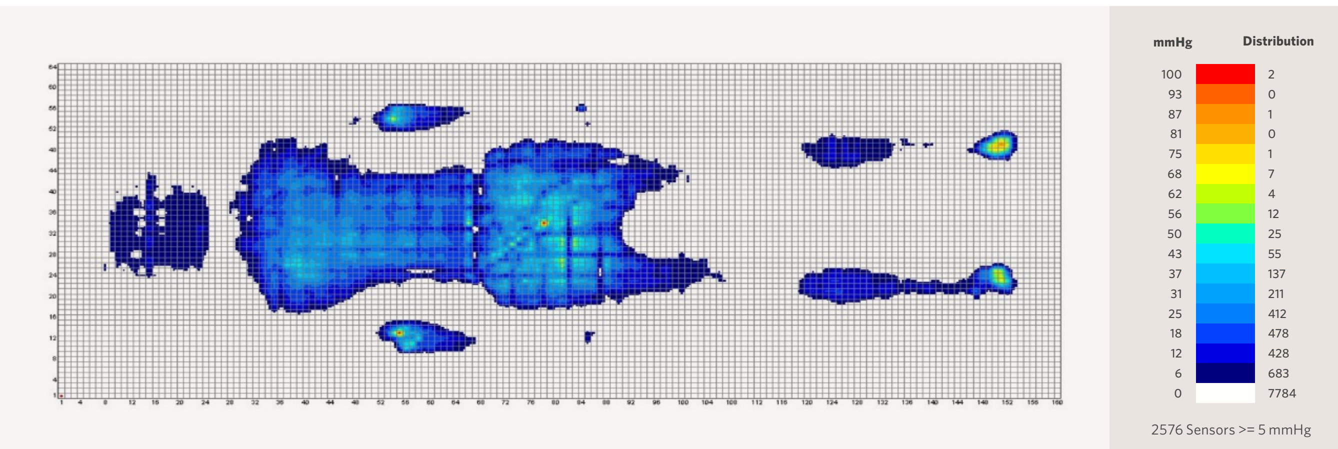


Figure 19: Pressure Area Index Mapping

Measuring Pressure Redistribution Index (PRI) for Active (alternating) surfaces

PRI testing is typically measured using a small calibrated sensor that is placed directly between the apex (top) of a cell and a mannequin or bony prominence, usually in the heel or sacral region. The pressure is tracked at this single point over time to measure the off-loading characteristics of the surface. In order to achieve this, Arjo use weighted mannequins and a standardised test protocol which replicates test procedures published in a consensus document by the Tissue Viability Society[34] in 2010 (Figure 20).

Figure 20: Active Pressure Redistribution 50th Percentile Mannequin Test Set Up (For illustrative purposes only)

Although it is difficult to determine an absolute safety threshold in the clinical setting, the goal is to achieve interface pressures as low as possible for as long as possible below arbitrary thresholds (30 mmHg, 20 mmHg & 10 mmHg) for each cycle. At Arjo, we look beyond these traditional thresholds and include the measurement of below 1 mmHg, which we describe as off-loading.

PRI can be reported as the percentage of time below certain thresholds for each cycle, this enables comparison between surfaces with different cycle times. In basic terms PRI evaluates how much pressure is removed and for how long from the mannequin that is lying on the surface.

Clinical Relevance of PRI testing

Support surfaces which are able to provide a good PRI performance in keeping lower pressures for longer during the off-loading cycle are likely to provide better product performance (Figure 21). Removing contact pressure from the body will encourage the movement of blood and essential nutrients and will greatly reduce the risk of developing a pressure injury. Figure 22 illustrates PRI performance of Arjo active surfaces with different cycle profiles and cell design.

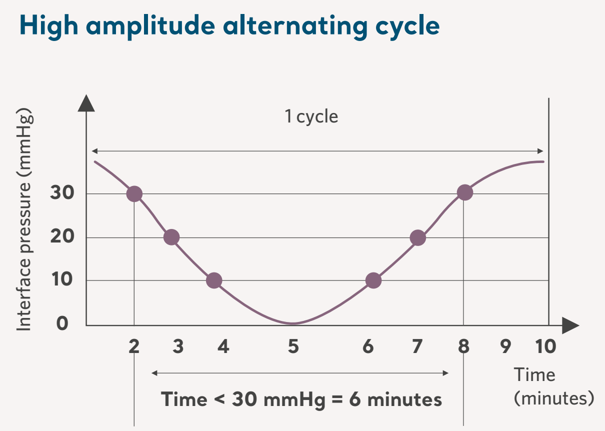
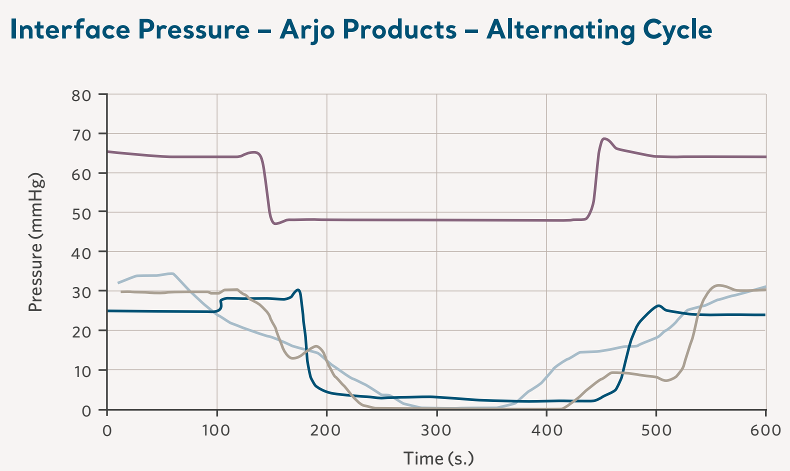


Figure 21: Illustration of a typical Pressure Redistribution (PRI) Curve



Citadel Pulsation Mode: A lower amplitude cycle that offers a gentle alternation in a 'reactive' (immersion & envelopment) environment

Citadel in Alternating Mode: Delivers a lower pressure profile for a longer period of the cycle, similar to that delivered by the Auralis

Nimbus: Different cell design results in lower maximum pressures followed by rapid deflation to hold pressures as low as possible for as long as possible

Auralis: Typical cycle profile with relatively higher pressures during inflation followed by rapid deflation to hold low pressure as long as possible

Figure 22: Illustrative example of PRI performance with different Active (alternating) surfaces within the Arjo Support Surface Portfolio

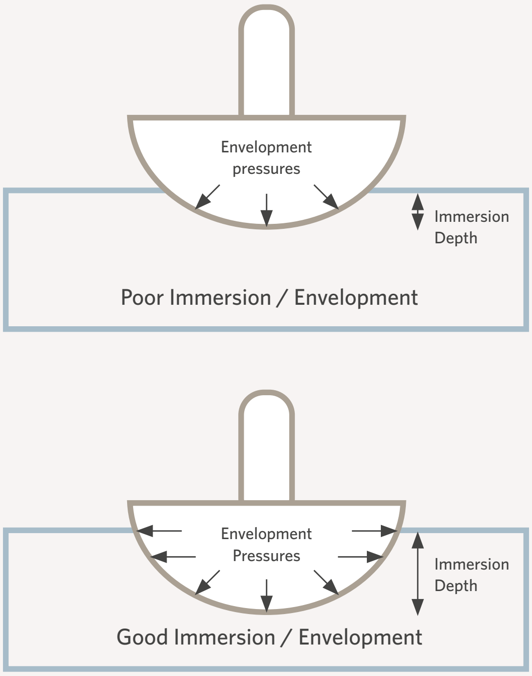
In addition to the traditional test methodologies described above, more recently Arjo support surfaces have also been tested in independent laboratories to meet the new US based ANSI/RESNA SS-1:2019 standard[36]. This standard has been developed and published by the Support Surface Standards Committee, a sub-committee of the National Pressure Injury Advisory Panel (NPIAP). The aim of these standards is to provide clinically relevant standardised methods to objectively measure the performance of full body support surfaces[23]. The first published standards address the performance characteristics of immersion/envelopment, shear/friction and microclimate management which are important in PI prevention[23]. A brief overview of each test and its clinical relevance is provided below.

Immersion & Envelopment Testing – Hemispherical Indentor: SS1:2019 (Section 6)[34]

Immersion testing provides one measure of the pressure redistribution properties of a surface, by measuring how far a load sinks into a surface. Increased immersion can lead to an increase in envelopment.

Envelopment testing is designed to assess/measure how well a support surface conforms around irregularities of the body to redistribute pressure and immersion.

Figure 23a



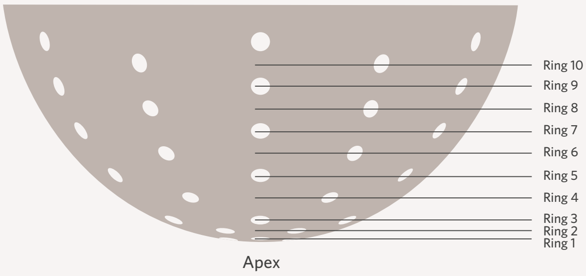


Figure 23b

The indenter (Figure 23a) is embedded with 'rings' of pressure sensors (Figure 23b), which record pressures as the indenter sinks into the support surface.

Envelopment is calculated as a percentage of how many rings have been activated. A ring is considered 'active' if the average pressure of sensors across that ring exceeds 1 mmHg. The aim is to activate as many rings as possible. For example, activation up to ring 6 out of a possible 11 rings would mean 6/11 or 55% envelopment.

Immersion is measured as the total distance the indenter travelled through the top of the mattress. This is measured using a laser distance sensor.

Figure 23: Measuring the immersion and envelopment properties of a support surface with an indentor

Methods: Immersion and envelopment testing use specific types of indentors or mannequins for each test (Figure 23). The level of immersion is measured by the distance the indentor sinks into the surface being tested, whilst envelopment is measured with sensors embedded into the indentor (arranged in "rings") to gather how well the surface conforms around it.

Clinical Relevance: Higher levels of immersion and envelopment equate to lower interface pressure and more potential for pressure redistribution[37]. Figure 24 provides an illustrative example using the Velaris adaptable alternating mattress replacement in reactive mode.

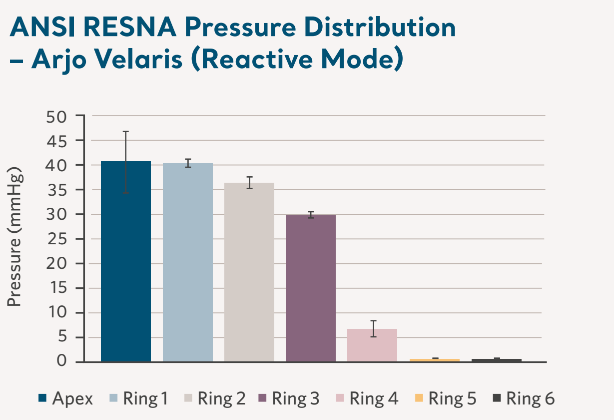


Figure 24: ANSI/RESNA Immersion & Development Testing: Velaris Adaptable Alternating Surface

Figure 24 – Key Characteristics

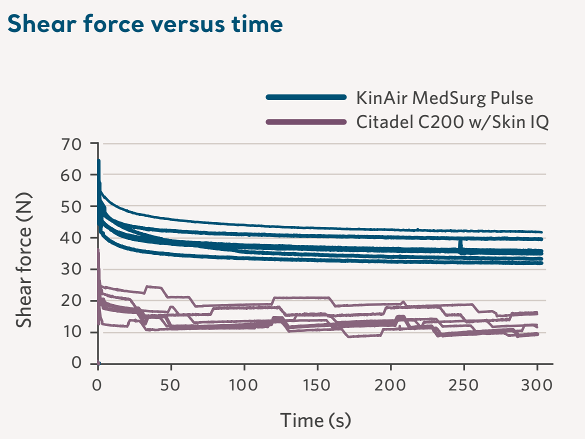
Category	Measurement	Comments
Immersion	87.3 mm	Higher immersion is usually better, as it allows the patient to sink into the mattress more. However too much immersion will cause the patient to bottom out
Envelopment	43.65%	Higher envelopment is better, as it will show the surface is redistributing pressure more effectively
Peak Pressure	40.63 mmHg	Lower peak pressures are better. This measure will also highlight if the patient could bottom out as a result of too much immersion, which will cause very high peak pressures

Horizontal Stiffness (Shear) Test: SS-1:2019 (Section 5)[34]

The purpose of this test is to simulate shear forces that occur as a result of patient movement on a support surface. The test allows for comparison of the shear forces present on different support surfaces with a simulated patient.

Method: A pelvic indenter representing the trunk and pelvic area of a 50th percentile male is pulled horizontally on a support surface toward the foot end, simulating patient movement.

Clinical Relevance: Minimising the effects of shear is an important element in pressure injury prevention and support surface design. Figure 25 shows the C200 + Skin IQ MCM has a lower horizontal stiffness and so offers less resistance to patient motion on the surface. This reduces the effects of shear, which is critical for patients with sensitive tissue areas.



- The initial point (at t=0) on the graph shows the static force that prevents the movement of the mannequin (patient) which has to be overcome in order for movement to occur.
- Once movement starts, the force is then known as dynamic force. The dynamic force shown in the graph acts on the mannequin during movement and is comparable to forces during repositioning and in-bed movement.
- The lower initial static and dynamic forces measured with the C200 + Skin IQ MCM can be expected to reduce the shear effect and tissue strain on the patient when repositioned.

Figure 25: An illustrative example of how horizontal stiffness (shear) forces can be compared between surfaces

Measuring Microclimate Parameters

Heat and water dissipation characteristics for full body support surfaces

Sweating guarded hot plate (SGHP) method: SS-1 (2019): Section 4[34]

Any surface that is in contact with the skin has the potential to affect its microclimate. The overall effect is dependent on the nature of the support surface and the cover[21]. The purpose of the sweating guarded hot plate test procedure is to identify the ability of the support surface to remove heat and moisture from the patient interface.

Method: A heated, moist indenter measures the resistance to flow of heat and humidity through a support surface simulating the skin in contact with the support surface. The evaporative capacity reported by this test details the ability of the support surface to dissipate moisture at the patient interface. An illustrative example of this is provided in Figure 26.

Clinical Relevance: Managing microclimate helps to improve tissue tolerance to pressure, friction and shear which are important considerations in support surface design.

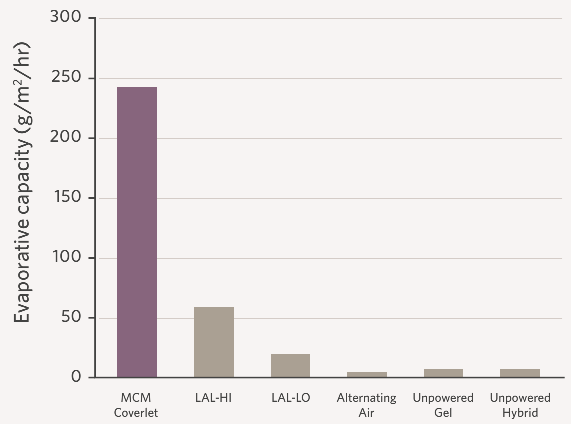


Figure 26: Illustrative example of how evaporative capacity can be compared by surface type

Body Analogue Method: SS-1 (2019): Section 3[34]

This test measures the heat and moisture dissipation properties of the support surface by creating a comparable environment to the human body lying on a mattress. This test also includes a simulated repositioning event at 180 minutes to assess the ability of a surface to return to its original state prior to loading.

Method: A Thermodynamic Rigid Cushion Loading Indenter (TRCL) is used to generate, control and measure the environmental conditions of temperature and relative humidity (%RH) at the patient interface.

Clinical Relevance: Humidity can have an adverse effect on tissue viability and often results in moisture being condensed and trapped under the patient's body. Products that provide less resistance to heat flow and more breathability will have RH closer to 50% with lower temperature[37]. Figure 27 provides a typical graphical representation of the relative humidity of a support surface using this method.

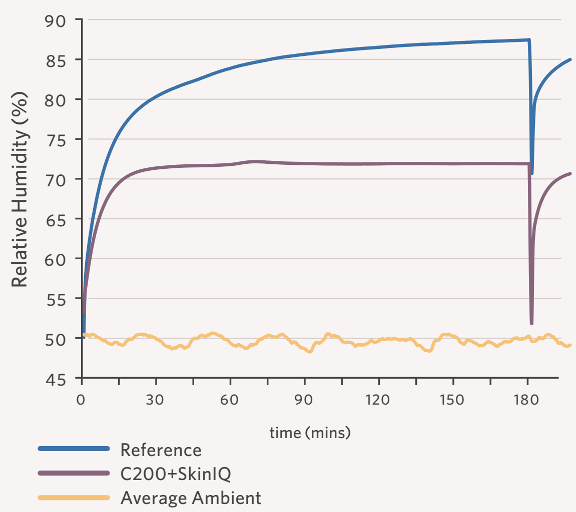


Figure 27: Typical graphical representation of the relative humidity of a support surface using the body analogue method

Considerations for Support Surface Selection

Whilst support surfaces represent an important component in pressure injury prevention and management practices, they are just one element in the overall care pathway and should therefore not be used in isolation[21]. Important factors such as early risk prediction and identification, mobility status and nutrition are also highly important and need to be considered to ensure a multifaceted approach to care[1].

The most recent pressure injury prevention and treatment guidelines[21] recommend selecting a support surface that meets the individual's need for pressure redistribution including:

- Level of immobility and inactivity
- The need to influence microclimate control and shear reduction
- Size and weight of the individual
- Number, severity and location of pressure injuries
- Risk for developing new pressure injuries

A decision chart to help guide appropriate support surface selection is provided in the Appendix. For further insight and support please contact your local Arjo representative.

To provide further support to improve outcomes and deliver value, Arjo offers the **Early and Targeted Intervention Kit (ETIK)** to equip you with the knowledge, tools and skills to act on a new standard of clinical excellence and improve outcomes in the early identification, prevention and management of pressure injuries.

For further information on Arjo ETIK solutions, please speak to your local Arjo representative.

The Arjo Early & Targeted Intervention Kit (ETIK) for pressure injury prevention

EARLY
Secure a window of opportunity of up to 5 days (median)[38] to deploy preventive intervention.

TARGETED
Targeted interventions guided by objective and anatomically-specific risk assessment.

INTERVENTION
Comprehensive portfolio ranging from support surfaces to solutions for repositioning and mobilisation.

KIT
Our multi-component intervention kit includes tailored programs, aligned with the latest best practice, to support you in achieving and sustaining improved outcomes.

Objective and early risk assessment with **Provizio® SEM Scanner**

Comprehensive **therapeutic support surfaces** portfolio

Targeted **repositioning** and enhanced **mobilisation**

Outcome programs delivering measurable and sustainable outcomes

Early & objective risk identification + Timely and targeted intervention & management = Better outcomes & true prevention

Summary

Support surface technologies represent an important component in pressure injury prevention and management strategies, and should be used as part of a multifaceted care pathway. Mechanical loading conditions can have a detrimental effect on the skin and underlying tissues at an early stage of injury development, and hence surface design principles should be geared towards optimising pressure redistribution as well as enhancing tissue tolerance.

Support surface performance depends on many complex factors, a clear understanding of the science behind the support surface, specific design principles, and the methods for assessing product performance, along with a clear understanding of how such testing can help to inform clinical practice and guide surface selection. Although many surfaces may appear to be of similar construction, their performance will differ.

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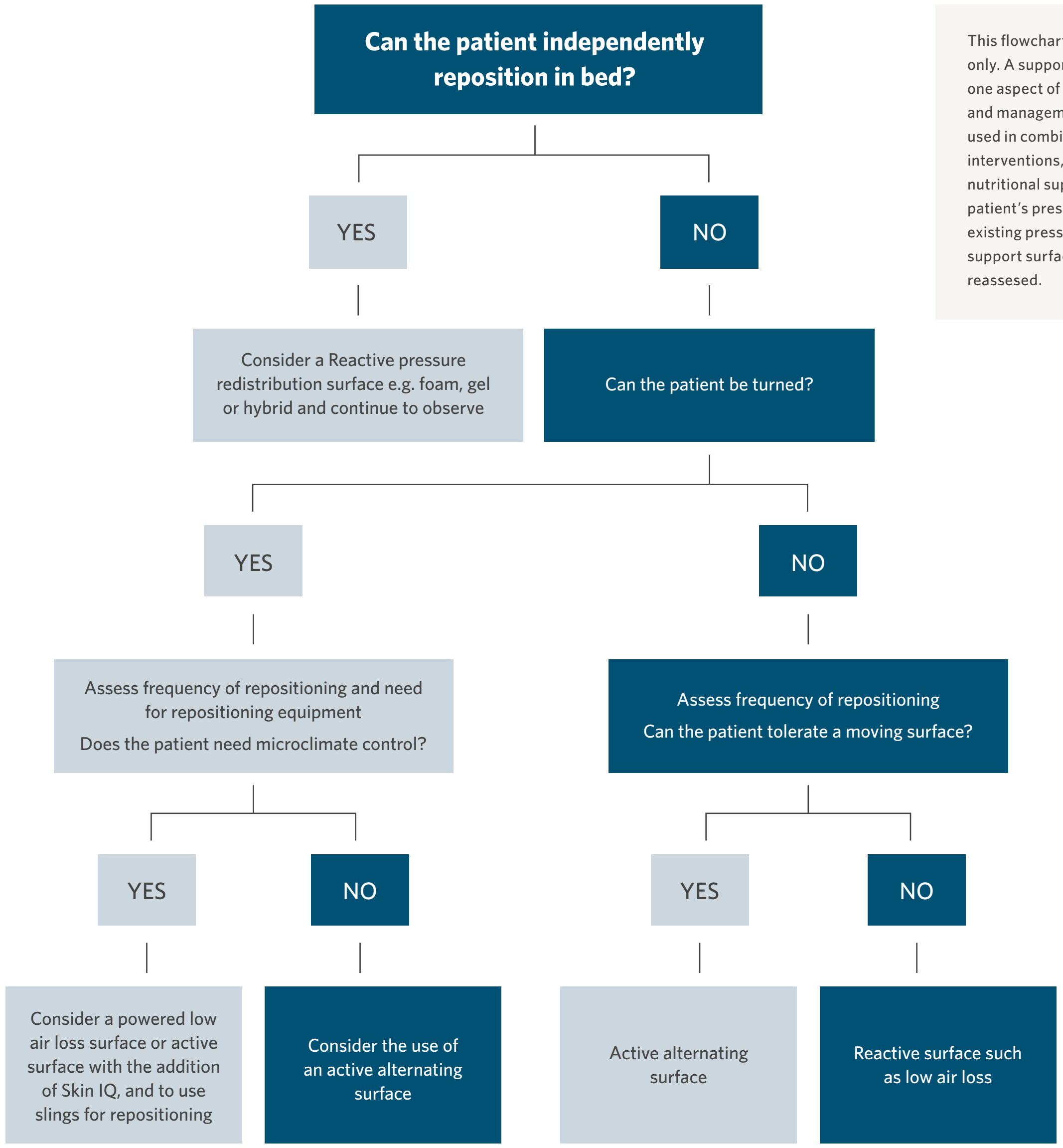
Appendix:

Support Surface Selection Flowchart



This flowchart is for example purposes only. A support surface represents only one aspect of a pressure injury prevention and management program and should be used in combination with other approriate interventions, e.g. patient repositioning, nutritional support and mobilisation. If the patient's pressure injury risk increases or existing pressure injury wounds deteriorate, support surface requirements should be reassesed.

At Arjo, we believe that empowering movement within healthcare environments is essential to quality care. Our products and solutions are designed to promote a safe and dignified experience through patient handling, medical beds, personal hygiene, disinfection, diagnostics, and the prevention of pressure injuries and venous thromboembolism. With over 6000 people worldwide and 60 years caring for patients and healthcare professionals, we are committed to driving healthier outcomes for people facing mobility challenges.

Arjo AB · Hans Michelsensgatan 10 · 211 20 Malmö · Sweden · +46 10 335 4500

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