LINET

ADDRESSING SAFE PRONING IN INTENSIVE CARE ENABLED BY THE VIRTUOSO PRO MATTRESS

BACKGROUND

Intensive Care Units (ICUs) provide specialized and continuous care to critically ill patients who require close monitoring, advanced medical support, and life-saving interventions. Breathing difficulties are a common challenge among ICU patients. In some cases, simply adjusting the patient's position is sufficient. However, when this approach is ineffective, more interventional methods become necessary.

The year 2020 marked a significant turning point in the adoption of various procedures to support patient breathing, largely due to the COVID-19 pandemic. During this time, the use of the prone position for patients in respiratory distress significantly increased. Adoption rates for the prone position among COVID-19 patients rose to approximately 70%, compared to an estimated 20% in pre-pandemic times (Gattinoni L, 2023). The prone position, while effective in improving respiratory function in patients with acute respiratory distress syndrome (ARDS), requires considerable resources, including clear guidelines, sufficient medical staff, and physical strength to perform it properly.

Despite its benefits, proning presents additional challenges, particularly the risk of pressure injuries. These injuries can occur due to prolonged contact with medical devices or inadequate pressure redistribution on vulnerable areas such as the knees, genitals, feet, chest, and face. During the COVID-19 pandemic, the incidence of pressure injuries among proned patients reached as high as 57% (Ruhland J, 2023), a stark contrast to the overall ICU-acquired pressure injury rate of approximately 16.2% (Gunther S, et. al, 2021).

Pressure injuries in the ICU are not always easily preventable, as the primary focus is on saving the patient's life. With this white paper, we aim to address safety during proning through the innovative solutions offered by LINET products.

CONCLUSION

The prone position is an effective maneuver for patients with moderate to severe ARDS. The use of the prone position and its effects on the physiological function of the lungs are well described and explained in numerous studies. However, patients in the prone position still face challenges such as an increased development of pressure injuries.

Specifically for this situation, LINET has developed a model of the Virtuoso mattress called PRO. The Virtuoso PRO mattress is ideal for preventing pressure injuries in prone patients, thanks to its ability to deflate cells individually, effectively offloading pressure on high-risk areas and reducing pressure peaks by 30 % on average, as proven by pressure mapping measurements concluded in this white paper.

Pressure maps have also demonstrated that the Virtuoso PRO mattress supports patients in the prone position by reducing pressure and contact areas in sensitive regions prone to pressure injury development, for both male and female physiologies.

ARDS Management – from early insights to COVID-19 impact

The idea of proning for improving the dorsal lung regions was already considered in 1974 by Charles Bryan (Bryan, 1974). The use of proning increased during the COVID-19 pandemic, when patients experienced acute respiratory distress syndrome (ARDS). Between May 2020 and March 2022 there were an estimated 270,000 hospitalizations in ICUs in Europe, and nearly 80% of these patients needed tracheal intubation and invasive mechanical ventilation. While there are still discussions about ARDS physiopathology in COVID-19 and non-COVID-19 patients, there is consensus on the benefits of the prone position for these patients (Walter T, 2022).

The prone position has become a recommended intervention in clinical practice. For example, UK guidelines strongly endorse this technique for adult patients with moderate to severe ARDS (P:F ratio ≤ 20 kPa) (Griffiths M, 2019).

The prone position is highly recommended for patients with moderate to severe ARDS.

(Griffiths M, 2019)

PRONE TECHNIQUES TO OPTIMIZE PATIENT CARE AND OUTCOMES

Prone positioning, in which a patient is placed face-down, can be modified into several variations to improve comfort, safety, and therapeutic effectiveness.

IMAGE 1 | Swimmer's prone position in combination with reverse Trendelenburg

Swimmer's prone position, in which one arm is extended overhead while the other rests alongside the body (IMAGE 1). This technique mitigates prolonged pressure on one shoulder, reduces the risk of nerve compression, and provides greater flexibility during extended proning sessions.

The reverse Trendelenburg position can be incorporated into any variation of prone positioning. By elevating the patient's head above their feet, this approach helps relieve abdominal pressure on the diaphragm, facilitating improved respiratory mechanics, and reducing the work of breathing (IMAGE 1).

Lateral tilt is feature in specialized beds like Multicare X from LINET. Lateral tilt facilitates airway toileting and promotes redistribution of ventilation in the affected lung, even if the patient cannot be maintained in the reverse Trendelenburg position.

These variations of prone positions are designed to address individual patient needs, offering targeted benefits such as reduced joint strain, enhanced respiratory function, or minimized risk of complications like pressure injuries. Healthcare providers frequently alternate between these positions to ensure patient comfort, maintain safety, and optimize therapeutic outcomes, particularly during extended proning sessions.

BENEFITS OF THE PRONE POSITION

Prone positioning is effective in addressing several key aspects of ARDS, including gas exchange, lung mechanics, and hemodynamics.

For **gas exchange**, prone positioning enhances both oxygenation and CO_2 clearance. It improves oxygenation by redistributing lung densities (IMAGE 2), resulting in better aeration of the dorsal lung regions, while reducing ventral collapse. This redistribution promotes the recruitment of previously collapsed lung units, provided perfusion remains stable.

In terms of **CO_2 clearance**, the effects of prone positioning can vary. While it often improves clearance by enhancing alveolar recruitment and ventilation-perfusion matching, it may also impair CO_2 elimination if the balance between newly recruited and collapsed alveoli shifts unfavorably.

These physiological benefits underscore the importance of careful patient monitoring and individualized application of prone positioning in ARDS management. (Gattinoni L, 2023)

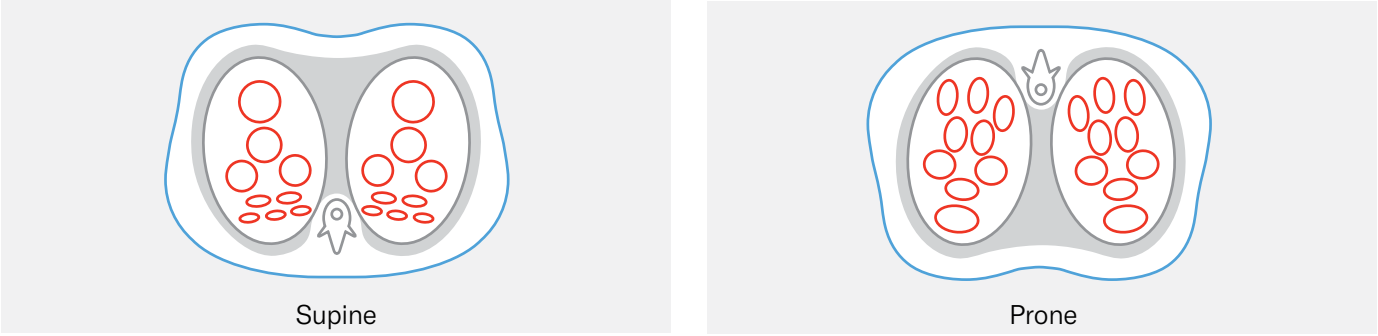


IMAGE 2 | Shape of alveoli in supine position and prone position

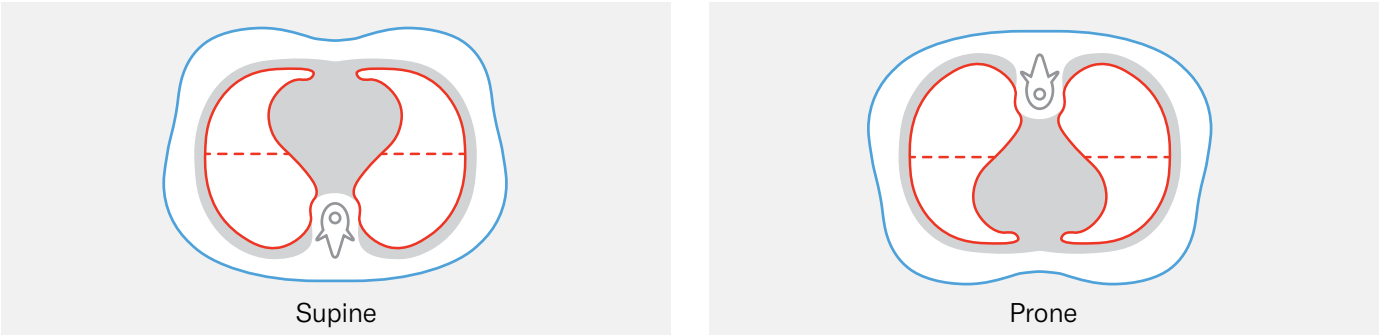


IMAGE 3 | Lung mass distribution for supine and prone positions

Another benefit of the prone position is improved lung mechanics. Due to its anatomical conformation, most lung parenchyma is located in the dorsal part of the thorax. At 50% of the sternum-vertebra distance, the nondependent lung mass in the supine position is less than 40%, while it rises to almost 60% in the prone position (IMAGE 3) (Gattinoni L, 2023). The prone position reduces the gradient of pleural pressure leading to more homogeneous distribution of lung inflation. This decreases mechanical stress and strain, which helps prevent ventilator induced lung injury. Also, chest wall compliance decreases in the prone position, altering the distribution of ventilation favorably compared to the supine position (Gattinoni L, 2023).

Regarding the patient's hemodynamic state, the regional distribution of pulmonary blood flow remains mostly unchanged, but prone positioning improves right ventricular function by reducing pulmonary vascular resistance. This is due to a decrease in hypoxic vasoconstriction and more uniform ventilation (Gattinoni L, 2023).

THE CHALLENGES CONNECTED WITH THE PRONING PROCEDURE

The proning procedure offers significant benefits for patients with acute respiratory distress syndrome (ARDS). During the COVID-19 pandemic, the adoption rate of prone positioning increased to approximately 70%, compared to an estimated 20% pre-pandemic (Gattinoni L, 2023). However, this raises the question: why did it take a global pandemic to see a higher application of this practice? The answer lies in the potential complications associated with proning, which can affect both patients and caregivers.

The adoption rate of prone positioning increased to approximately 70%, compared to an estimated 20% pre-pandemic.

(Gattinoni L, 2023)

The most severe complications related to proning involve airway management, including accidental extubation, selective bronchial intubation, and endotracheal tube obstruction. Other risks include the displacement of medical devices such as thoracic tubes, vascular catheters, or extracorporeal cannulas. Adverse effects reported include transient hypotension, desaturation (especially during the proning maneuver), vomiting, arrhythmias, and in extreme cases, cardiac arrest.

Prone positioning is associated with an increased risk of pressure injuries (PIs), which are more prevalent in this position due to prolonged pressure on specific anatomical sites. Additional complications commonly observed include facial and ocular edema resulting from vascular stasis, as well as more severe issues such as retinal damage and brachial plexus neuropathy (Gattinoni L, 2023). These risks highlight the importance of meticulous patient monitoring, strategic positioning adjustments, and protective measures to mitigate complications during prone therapy.

PRESSURE INJURIES IN PRONED PATIENTS: RISK FACTORS AND PREVENTATIVE STRATEGIES

During the COVID-19 pandemic, the incidence of pressure injuries among proned patients reached as high as 57% (Ruhland J, 2023). A study by Nadeem further revealed that patients in the prone position had a significantly higher incidence of PIs (51.5%) compared to non-proned patients (24.2%) (Nadeem R, 2023).

The incidence of pressure injuries among proned patients reached as high as 57 % during the COVID-19 pandemic.

(Ruhland J, 2023)

Proned patients have an increased risk of developing medical device-related PIs caused by thoracic tubes, vascular catheters, etc. Also, for breathing function improvements, patients need to stay in one position without the possibility to turn their body and offload sensitive areas. According to UK guidelines from 2019, it is recommended that patients should be proned for 12 hours per day (Griffiths M, 2019)). However, during the COVID-19 pandemic, this duration was often prolonged. Walter's study found that the median time that patients were kept continuously in the prone position was 39 hours. In this study, patients experienced a 25% incidence of category II pressure injuries (PIs) and 2.5% for category III PIs (Walter T, 2022). Additionally, many patients are classified as high or very high risk for PIs, meaning that even short durations of pressure on the skin and tissues can be harmful if the exposure is prolonged. While it is challenging to completely reduce the duration of pressure, the risk can be minimized through effective offloading and pressure redistribution strategies.

To mitigate these risks, pressure redistribution and offloading are critical. Both clinical practice and guidelines recommend the use of various pressure-relieving devices, including pillows, cushioning, and dynamic mattresses (ICS, 2019). Low air-loss or immersion mattresses assist in pressure redistribution, while alternating mattresses provide pressure offloading. Alternating pressure support surfaces are particularly beneficial for patients at risk of pressure injuries (PIs) or those with existing PIs (EPUAP/NPIAP/PPPIA, 2019). Some alternating pressure systems also feature individual cell deflation, allowing cells to remain deflated over sensitive areas when patients are in the prone position, further reducing pressure on vulnerable sites. (IMAGE 4)

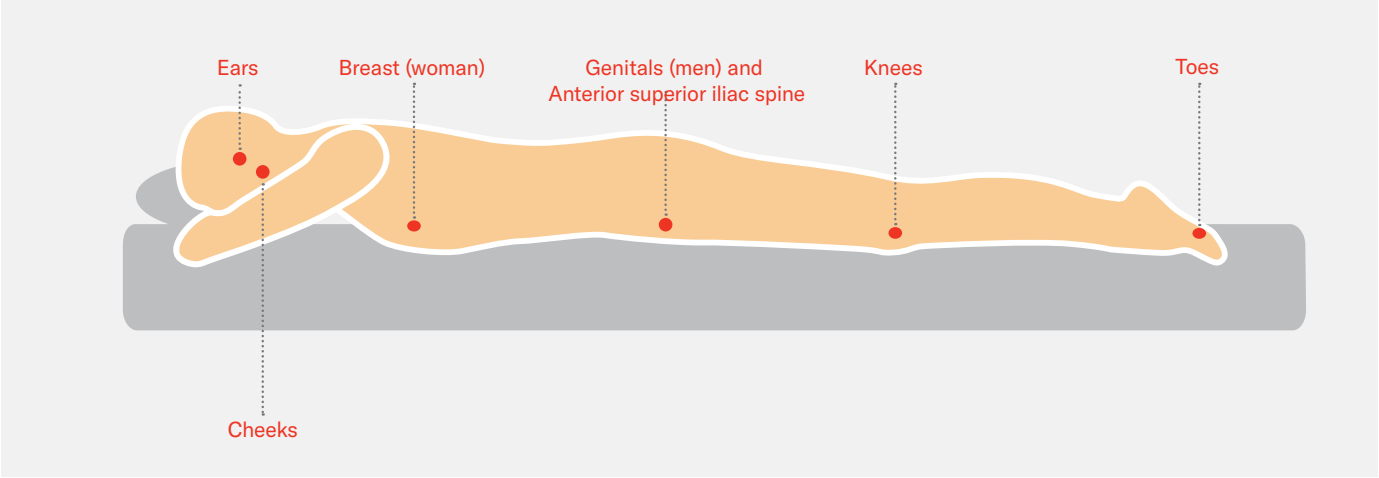


IMAGE 4 | Areas at increased risk for pressure injury development

LINET Virtuoso PRO solution for easier and safer proning

As previously discussed, prone positioning presents various challenges for both patients and caregivers. At LINET, we design equipment that not only addresses the needs of patients, but also supports caregivers in delivering optimal care. In the following section, we will provide a guide on how to effectively use the LINET Virtuoso PRO mattress to make prone positioning safer and more manageable for both patients and caregivers.

Disclaimer: This guide focuses specifically on setting up the mattress to maximize efficiency. The full proning procedure involves additional steps not covered here.

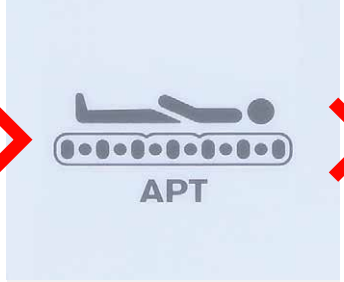
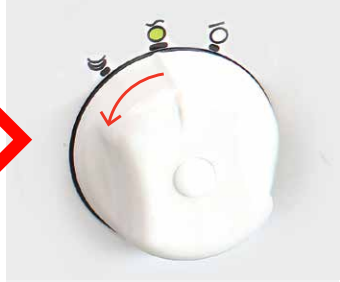
MAX MODE	APT MODE	SET THE PRESSURE	DEFLATE NEEDED CELLS
			
Set mattress to maximum pressure to create a firm surface, which reduces friction and shear forces while turning the patient to the prone position.	When the patient is in the prone position, set the mattress for Alternating Pressure Therapy (APT).	Then set the pressure inside the mattress according to the patient's weight.	And deflate the cell(s) by turning the valve to the left under the areas at high risk of PI development, such as feet, knees, genitalia/ hips, breasts and head.

IMAGE 5 | Example of individual deflated cells for the swimmer prone position for toes, knees, genitalia, breast and head

PRESSURE MAPPING WITH THE VIRTUOSO PRO MATTRESS

To evaluate the effectiveness of individually deflated cells on the Virtuoso PRO, pressure mapping was performed using a high-resolution Xsensor Pro pad. The measurements were conducted on two volunteers: one female (56 kg, 175 cm) and one male (98 kg, 180 cm). Both participants were positioned prone on the Virtuoso PRO mattress. Pressure measurements were first taken without deflating any cells, followed by measurements taken with individual cells deflated in high-risk areas, such as the breast, hips, knees, and feet, which are particularly susceptible to pressure injuries. Measurements were continuously recorded for two alternating cycles for each participant during each test.

To assess the effect of reduced pressure caused by manually deflated cells, average pressure values were used and represented by a single image. These values were obtained by merging all the measurements taken during both cycles, which are displayed as pressure map images on following pages. This approach helps identify areas subjected to higher pressures, regardless of the alternating cycle phase.

In the data analysis of the pressure maps, information about average pressure is used to show overall pressure redistribution. Maximum pressure represents potential pressure peaks, indicating areas of increased risk for pressure injuries. Lastly, the contact area is analyzed to understand how much of the body is offloaded when cells are deflated, illustrating the extent of pressure relief on the body.

RESULTS OF PRESSURE MAPPING OF 56 KG PRONED FEMALE

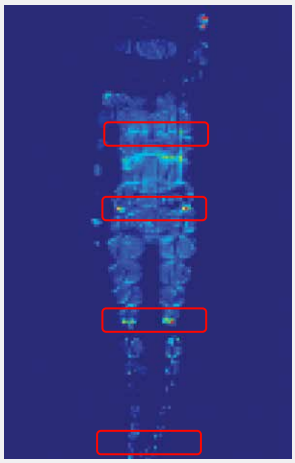


IMAGE 6 | Standard Virtuoso PRO with all cells alternating

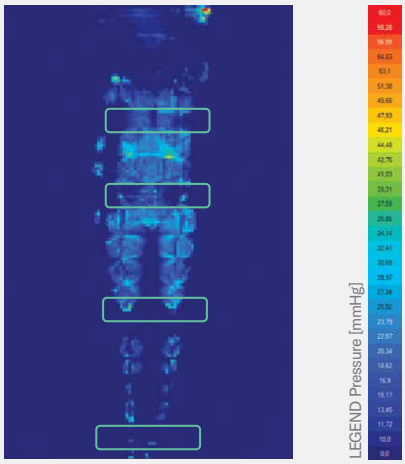


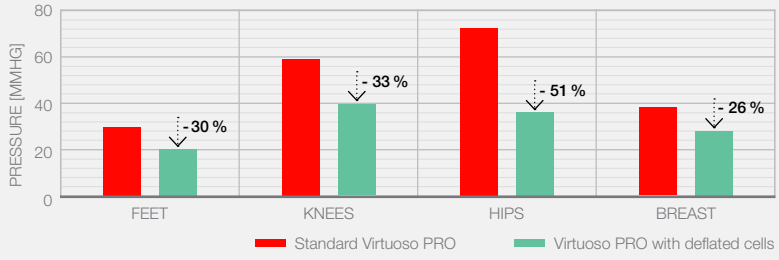
IMAGE 7 | Virtuoso PRO with deflated (not-alternating) cells at feet, knees, hips and breast

Summary

The female was petite, because of which there are visible pressure peaks, mainly at the hips and knees in IMAGE 6. When individual cells were deflated, the pressure was reduced at the hips and knees, which is visible in IMAGE 7. This was also demonstrated by a comparison of maximum pressure (pressure peaks), average pressure, and contact area in GRAPHS 1,2 and 3.

All graphs demonstrate a reduction of pressure and contact area in the feet, knees, and hips, where cells were deflated. The overall average reduction in deflated cell locations were 32% for maximum pressure, 9% for average pressure, and 47% for the contact area.

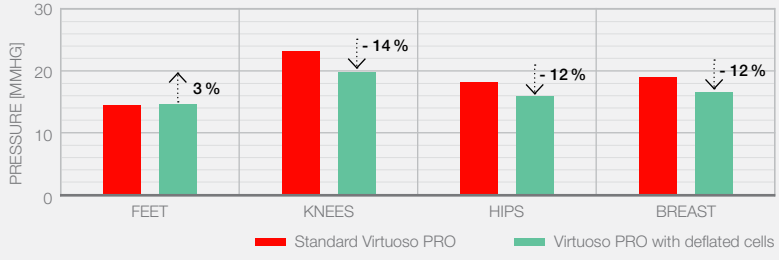
GRAPH 1 | Overview of MAX pressure changes for highlighted areas on pressure maps of the female



MAXIMUM PRESSURE

The reduction in pressure peaks was notable in all areas, where biggest reduction was in hips and knees shown in GRAPH 1.

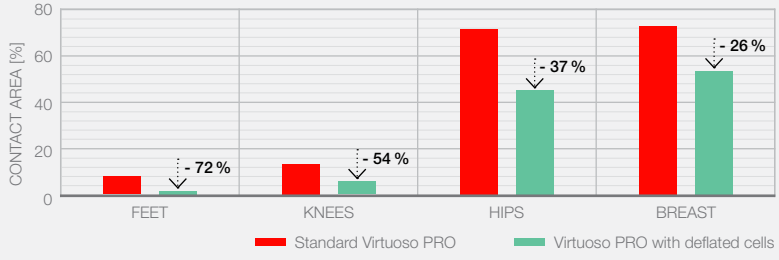
GRAPH 2 | Overview of average pressure changes for highlighted areas on pressure maps of the female



AVERAGE PRESSURE

In GRAPH 2 is visible that pressure was lower in the deflated cell areas, including the knees, hips and breast. The average pressure remains almost same for feet.

GRAPH 3 | Overview of contact area changes for highlighted areas on pressure maps of the female



CONTACT AREA

GRAPH 3 demonstrates that deflated cells provided pressure relief by offloading, evidenced by a reduction in the contact area in all four analysed regions.

RESULTS OF PRESSURE MAPPING OF 98 KG PRONED MALE

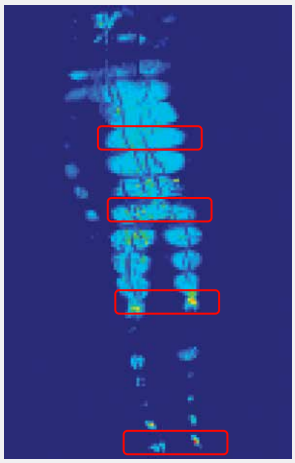


IMAGE 8 | Standard Virtuoso PRO with all cells alternating

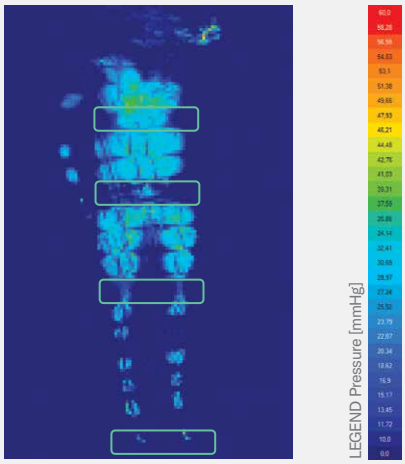


IMAGE 9 Virtuoso PRO with deflated (not-alternating) cells at feet, knees, hips and chest

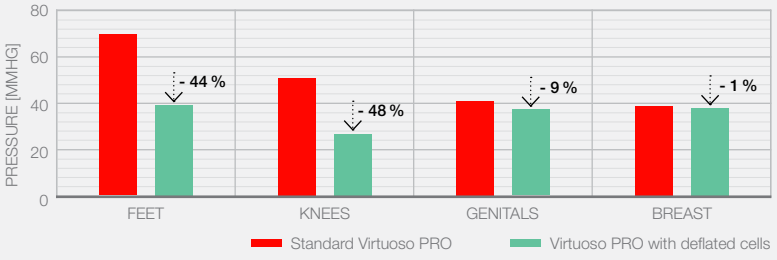
Summary

The male had a bigger constitution compared to the female. But bony prominent areas where still visible, in this case mainly the knees and feet (IMAGE 8). Unlike the female volunteer, there were no significant pressure peaks visible at the hips or in the genital area, because there is no urinal catheter, as the measurements were not perform on patients.

The pressure reduction is also supported by GRAPHS 4, 5 and 6, which demonstrate measurements of MAX pressure (pressure peaks), average pressure, and contact area for the highlighted areas.

All graphs demonstrate a reduction in pressure and contact area where cells were deflated. The overall average reductions in deflated cell locations were 25% for maximum pressure, 28% for average pressure, and 31% for contact area.

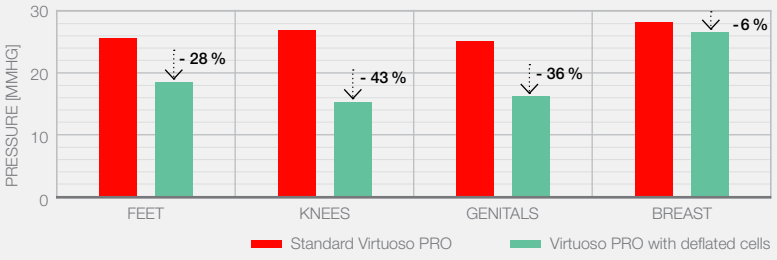
GRAPH 4 | Overview of MAX pressure peaks changes for highlighted areas on pressure maps of the male



MAXIMUM PRESSURE

In GRAPH 4, the pressure peaks were reduced by more than 40 % at the knees and feet, whereas reductions at the hips and chest were less pronounced due to the absence of significant pressure peaks in these areas.

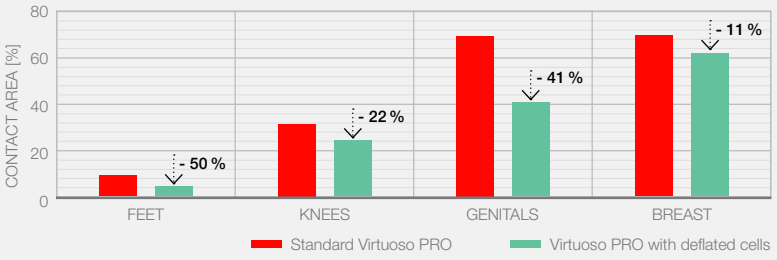
GRAPH 5 | Overview of average pressure changes for highlighted areas on pressure maps of the male



AVERAGE PRESSURE

In GRAPH 5, the average pressure was higher with the standard Virtuoso PRO, when the cells were deflated the pressure was significantly reduced. The highest reduction was at the knees by 43%.

GRAPH 6 | Overview of contact area changes for highlighted areas on pressure maps of the male



CONTACT AREA

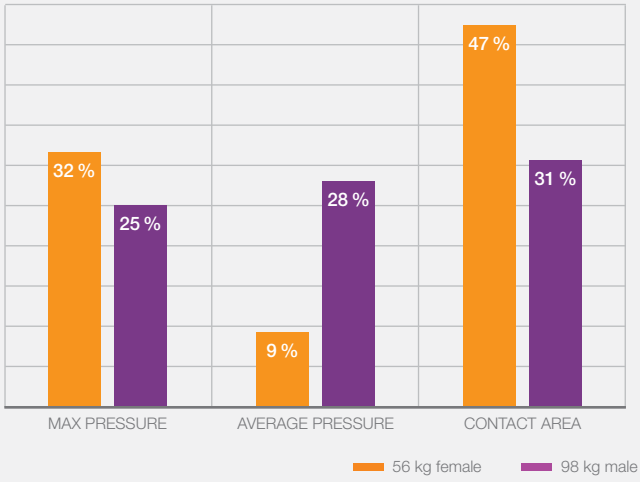
In GRAPH 6, a reduction can be seen in all focused areas. The deflated cells enabled offloading effectively at the feet, knees, genitals, and chest.

DISCUSSION OF PRESSURE MAPPING RESULTS FOR THE VIRTUOSO PRO

The pressure maps effectively demonstrated pressure relief in areas with deflated cells, as shown in GRAPH 7. Both volunteers showed the highest reduction in the contact area, which demonstrates effective pressure relief at the location of deflated cells. Additionally, a decrease in maximum pressure was observed in both cases, highlighting the role of deflated cells in reducing pressure on bone prominent areas.

The average pressure in the observed areas was reduced in both volunteers. A greater reduction was observed in the male volunteer compared to the female. This difference could be attributed to the average pressures measured: 26.7 mmHg for the male and 19.5 mmHg for the female. The lower baseline pressure for the female volunteer may have limited the potential for significant reductions compared to the male.

GRAPH 7 | Overall reduction in average pressure, maximum pressure, and contact area on the Virtuoso PRO with deflated cells, compared to the standard setup, for both volunteers.



The Virtuoso PRO mattress is ideal for preventing pressure injuries in proned patients, thanks to its ability to deflate cells individually, effectively offloading pressure on high-risk areas with a reduction in pressure peaks of 30 % on average.

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wissner-bosserhoff LINET

Members of LINET Group

L I N E T spol. s r.o.
Želevčice 5 | 274 01 Slaný | Czech Republic
tel.: +420 312 576 400 | fax: +420 312 522 668 | e-mail: info@linet.com | www.linet.com

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