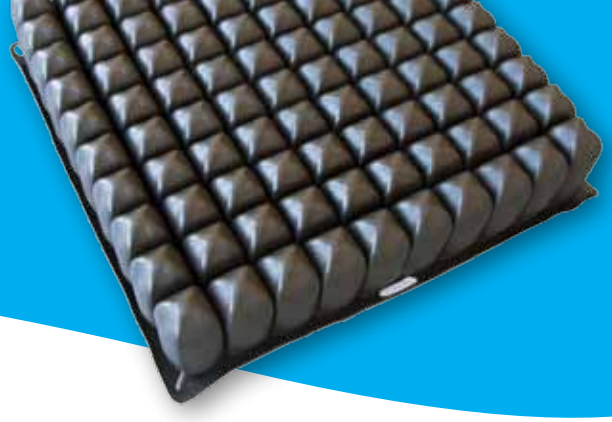
BEDS AND MATTRESSES



INTRODUCTION

Speciality beds, bed frames and mattresses can serve many purposes in the spinal cord disorders (SCI/D) population. They can be used to prevent and treat pressure injuries, enhance mobility and facilitate sphincter management,.[1-3] The addition of power/adjustable components may facilitate positioning for individuals requiring total assistance for mobility, thus enhancing comfort, reducing spasticity and contractures, optimizing respiratory function, and facilitating the management of autonomic dysautonomia (autonomic dysreflexia and orthostatic hypotension).[3] Finally, specialty beds, bed frames and mattresses may help optimize sleep quality, which is a significant health issue in SCI/D individuals dealing with pain, depression and/or poor quality of life.[4] Regardless of the pressure-distribution capabilities of a bed or support surfaces, repositioning is still necessary to manage pressure. [5,6]

In this chapter, specialty beds, bedframes and support surfaces indications for use will be described. Indications for use and specific considerations will also be discussed. Criteria for selection and a summary of current clinical recommendations based on literature will be presented..

BED AND SUPPORT SURFACES: EFFECT ON PRESSURE AND SHEAR STRESSES

The force opposing gravity's pulling force of an individual's body resting on a support surface can be divided into two distinctive components: 1) a perpendicular force resulting in pressure, and 2) a tangential component resulting in shear stresses. [7] Accordingly, soft tissues placed over a bony prominence are being compressed (by pressure) and deformed (by stretching and distorting stresses in the tangential plane) when resting on a support surface (Figure 1). Shear stresses and pressure act in conjunction to produce capillary damage and ischemia of the skin and deeper tissues leading to pressure injury development. Distinction should be made with friction, which refers to the force occurring when two surfaces are rubbed together (for instance, between the skin and support surface). While the latter is not recognized to be a direct cause of pressure injuries, friction is involved in the development of shear stresses in skin and deeper tissue layers.[7]

By offering different pressure distribution properties and position adjustments, bed and mattress devices can influence the impact of pressure and shear forces on the skin and deeper tissues. Support surfaces generally aim to reduce the interface pressure by increasing contact area, thereby decreasing compression and tensile forces. Specific types of support surfaces may also decrease or remove pressure from vulnerable areas (see Section 3.2). Bed frame, providing different adjustments for positioning the individual on the bed, may also influence shearing stresses and friction.

Accordingly, specific positions (such as 90 degrees side-lying or the semi-recumbent position at an angle of 45 degrees from the erect position) should be avoided as they are shown to increase pressure and/or shearing over the trochanteric and sacral bony

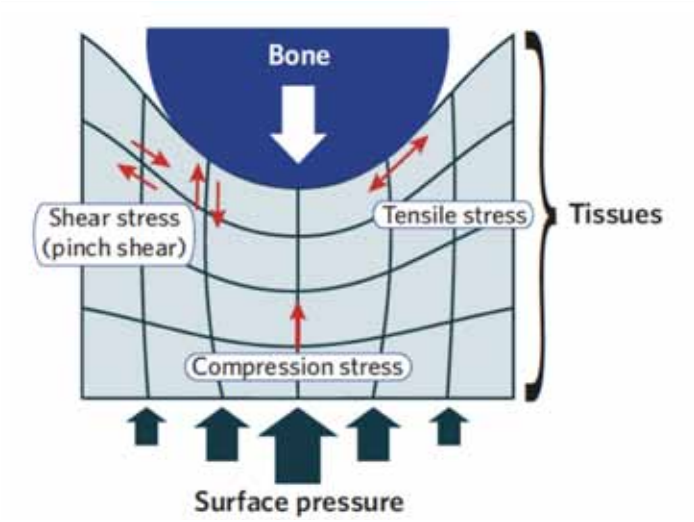


Figure 1: Shear stresses resulting from an even pressure distribution. Retrieved from *Pressure ulcer prevention: pressure, shear, friction and microclimate in control. A consensus document. London: Wounds International, 2010*[7]

prominences respectively. When these positions are required for medical purposes (e.g. dyspnea, prevent aspiration), repositioning should be done more frequently.[6,7]

DESCRIPTION OF BED, BED FRAMES AND SUPPORT SURFACES

The term "bed" refers to the bed frame and operating mechanism, while the term "mattress" refers to the support surface upon which the person lies.

Bed and Bed Frames

Individuals with SCI/D with limited mobility may benefit from specialized beds and bedframes which allow adjustment of height as well as head and foot elevation (Table 1). These adjustments may promote functional independence, enhance sleep quality, and manage different medical conditions following SCI/D.

Mattresses (Support Surfaces)

Support surfaces are specialized devices designed to reduce tissue loads, optimize the microclimate and promote other therapeutic functions, as important strategies for pressure injury prevention and treatmentPressure redistributing support surfaces are available in three main forms[5]:

- **Mattress Overlay:** A support surface device placed over an existing mattress. Mattress overlays elevate the sleeping surface and may put users at risk of falling off the bed if too thick. It is therefore

Table 1: Description of hospital and bed frames

Hospital Bed Frames	**Manual**	**Pros:** Require manual cranking for head and foot adjustments Less expensive than electric beds. Can be dissembled and reassembled for home settings. **Cons:** Cannot be used independently by SCI/D individuals while in bed; adjustments need to be operated by a caregiver. Generally only available in twin or standard sizes.
	Semi-electric	**Pros:** Power may be used for some adjustments of the bed (high-low position or head of the bed). Less expensive than a full electric bed. **Cons:** Some positions can only be adjusted manually.
	Full Electric	**Pros:** All adjustments of the bed are power-generated-enhancing functional independence. Bed adjustments can be made quickly for medical purposes and facilitating transfers. Does not require manual cranking from caregivers. Available in many sizes (twin, double, queen and bariatric). **Cons:** More expensive than manual and semi-electric beds. Can also be noisy and bulky in home settings.
Non-medical Beds	**Adjustable**	**Pros:** Provide head and foot adjustments. Bedroom amenities (such as night light and charging ports) may be available. Controllable through remote control and/or smart phone Aesthetically appealing Available in many sizes (twin, double, queen, king) **Cons:** No medical benefit other than head and foot adjustments. May not allow the use of mobile floor lift. Absence of rails that may support mobility and safety in bed Limited selection of support surfaces that often do not meet the needs for persons with SCI. Generally not FDA-approved medical devices.

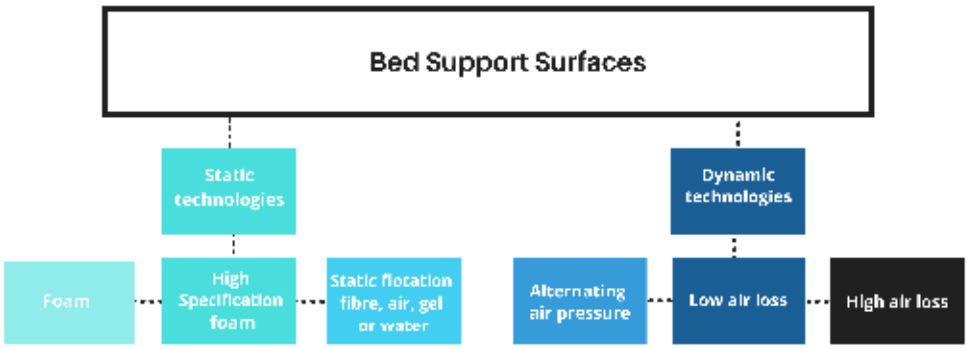


Figure 2: Classification of bed support surfaces based on the Canadian Best Practice Guidelines for the Prevention and Management of Pressure Ulcers in Spinal Cord Injury. A resource handbook for Clinicians (2013)[3]

recommended that bedrails be at least 10cm higher than the surface of the mattress overlay.[6]

- **Pressure Redistributing Mattress:** A device intended to replace standard mattresses while allowing continued use of the existing bed frame.
- **Integrated Bed System:** System combining a bed frame and a support surface (usually an alternating pressure mattress). These are most often used by SCI/D individuals for pressure injury prevention and treatment, or following surgical treatment of pressure injuries.

Gel mattress overlays may be used in the early acute phase following traumatic SCI prior to spinal surgical intervention, as other technologies using air or water may not provide necessary spinal stability. Current recommendations for "pressure-reduction mattresses or overlays" during acute SCI remain unclear.; however,[8] gel/silicone mattress overlays are currently used in specialized SCI trauma centers.[9] Based on this knowledge, it is the author's expert opinion that gel mattresses be used in the early acute phase following traumatic SCI.

Mattresses and support surfaces can be classified based on their capability to change the load distribution. For static technologies, the load distribution will change only when the individual's position changes. For dynamic technologies, periodic changes in load distribution result from the active movement of the mattress and/or support surface.

Static Support Surfaces

Static surfaces are commonly used for prevention and treating pressure injuries. Static technologies can be integrated into mattress replacements or overlays. Static support surfaces involve two modes of pressure redistribution-the envelopment mode and the immersion mode. The "envelopment" mode refers to the ability of the support surface to conform, to fit or mold around irregularities of the individual's body. The "immersion" mode refers to the effect of the body sinking (penetrating) into the support surface. (Figure 3).[6]

Patient needs must be considered when selecting a support surface as immersion and envelopment may impact a person's mobility and independence. For example a softer support surface may limit the individual's postural control, positioning and transferring ability. (Section 4). Moreover, attention should be given to ensure that the support surface's material is not too soft (causing the person to end up sitting on the underlying surface), or that it's cover is not too tight, creating a "hammock effect" (preventing the support surface to properly mould on the body). Both may lead to the development of high pressure over a small area resulting in pressure injury development particularly in the sacral area.[6] The different types of static support surfaces technologies, their specific characteristics and considerations for clinical selection are described in Table 2.

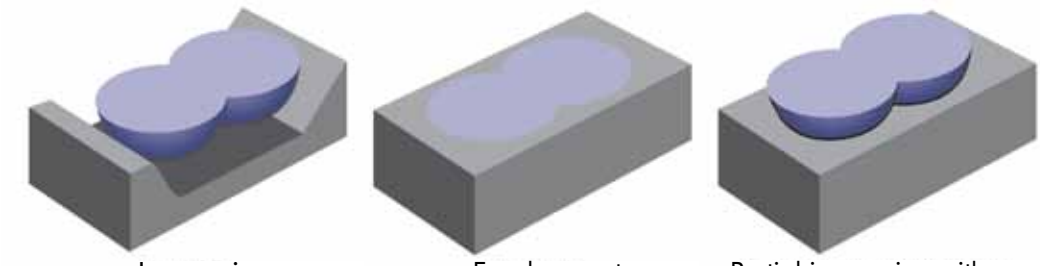


Figure 3: Immersion and envelopment (Retrieved from International review. Pressure ulcer prevention: pressure, shear, friction and microclimate in control. A consensus document. London: Wounds International, 2010)[7]

Table 2: Description of static support surface technologies[3,5]

Type of Redistribution Support Surface	Description and Performance Characteristics	Clinical Considerations PR	SR	MC	T
Monobloc Foam	Single piece of foam covered by a plastic or r nylon cove	+	–	–	–
High-specification Foam	Multiple foam layers of different densities, with specific foam sections that can be removed temporarily to remove pressure on corresponding specific areas. Gel or air-filled cells may be used in addition to foam.	++	–	–	+/–
Static Flotation, Air, Gel or Water	Constant low pressure surface consisting of: • Synthetic fibres coated with silicone arranged in a series of connected cells, • Fluid/water system conforming to body contours, • Air- or gel-filled compartments providing envelopment and immersion depending on the pressure of the air or gel in the compartments.	++	+	–	+

PR, Pressure redistribution; SR, Shear reduction; MC, Microclimate management; T, Impact on self-transferring ability

Static support surfaces do not require power and are considered cost-effective when properly matched to individuals. Despite this, it is important to remember that they can lead to a significant increase in shear loads, heat and moisture.[6]

While monobloc foam mattresses are generally used as standard mattresses for non-SCI patients in hospitals and long-term care facilities, other technologies involving high-specification foam, static flotation, air, gel or water are generally preferred for pressure injury prevention or treatment of uncomplicated pressure injury.[3,7] However, gel and water mattresses can be heavy to move.

Dynamic Support Surfaces

As showed in Figure 2, dynamic support surfaces comprise three different types of technologies and are generally indicated for individuals who are at higher risk of pressure injuries or are being treated for pressure injuries.[3,6,7,10,11] Dynamic support surface technologies are described in Table 3. These systems offer greater pressure reduction than static systems.[3,6]

Low air loss systems are generally used when pressure injuries fail to heal on an alternating air system and when pressure injuries occur on multiple (>1) turning positions of the body.[3,8]

High air loss (air fluidized) surfaces require a completely integrated bed system and may be used for individuals who cannot tolerate other support systems. Several randomized controlled studies have shown the benefit of this system for individuals with stage III and IV pressure injuries in comparison with standard beds, foam and other non-fluidized support surfaces.[7] Air fluidized support surface may also be used for post-operative myocutaneous flaps or skin grafts.[3,12] While this system provides the greatest immersion and envelopment some drawbacks of use have been reported. First, repositioning and transfers may be very difficult to perform independently and thus using this system may result in further functional limitation and may also interfere with patient handling.[3] Also, patients may not tolerate the sensation of floating or the warmth of the surface. Finally, this system may cause dehydration due to increased heat in the room and on the patient. It also requires occlusive dressing on wounds in order to avoid dryness and is very costly.[12]

Additional Features and Emerging Technologies

Fully integrated bed systems may include powered and computerized lateral rotation (tilting) of the support surface for assisting patients requiring total assistance for mobility, in order to allow periodical repositioning

BEDS AND MATTRESSES

Full eElectric

Low Air-loss

Air Cell Filled

High Air-loss or Air-fluidized Therapy

Figure 4
Freedom Bed™ by ProBed Medical: Automated Lateral Rotation Bed available in 3 sizes, Standard, Extended and Bariatric (https://www.pro-bed.com/overview)

Figure 5
Adjustable Rotational Bed (https://theraposture.co.uk/adjustable-beds/rotoflex)

in bed. In addition to potentially promoting functional independence, these systems also facilitate caregiver interventions for turning and transferring the individuals, examining the skin, assisting in bedding equipment changes, and providing physical/respiratory therapies. **Figure 4** below shows a bed which automatically rotates the individual to the right and left sides throughout the night or as programmed. This type of bed can be used in individuals who are unable to reposition themselves while in bed. **Figure 5** below shows an example of a bed which rotates completely to allow the individual to stand up from a seated position though this can only be used for individuals with good trunk control and more minimal mobility deficits. Electronic systems such as these are more expensive than conventional electric bed frames. The efficacy of self-rotating beds versus manual rotation has not been extensively studied in the SCI population.

Table 3: Description of dynamic support surface technologies[3,5]

Type of Redistribution Support Surface	Description and Performance Characteristics	Clinical Considerations			
		PR	SR	MC	T
Alternating Air Pressure	Small or large air-filled cells redistributing pressure through cyclic inflation/deflation	+++	++	–	–
Low Air-loss	Made of air holes in top surface, this technology provides a continual blow out of air causing the patient to float, reducing the skin interface pressure with the mattress surface and reducing moisture.	+++	++	++	++
High Air-loss or Air-fluidized Therapy	Using a continuous circulation of filtered air through silicone or glass-coated beads that have pressurized air forced between them creating a fluid-like medium. This support surface provides the greatest immersion and envelopment of any support surfaces.	++++	++	++	+++

PR, Pressure redistribution; SR, Shear reduction; MC, Microclimate management; T, Impact on self-transferring ability

Features	Reasons
Level of mobility within the bed	Degree of envelopment and immersion may significantly affect transfer and postural control. Patients requiring total assistance for mobility may require electric/ adjustable bedframes to mobilize themselves in bed and help caregivers.
Patient Comfort	Some systems may be uncomfortable for patients.
Need for Microclimate Management	Low and high air loss systems may assist with managing heat and moisture.
Care Setting	Some integrating bed systems may be unavailable or inconvenient for home settings due to weight, noise or power source.
Lifestyle	Total and consecutive number of hours spent on the bed in a day, tasks to be accomplished from the bed surface, and the environmental context (partners who sleep in the same bed and help from caregivers) should be considered
Safety Issues	Beware of entrapment of individuals with reduced mobility between the edge of the mattress and side rails. The height of the bed frame may place the patient at risk of falls during transfers. Falls may also occur when bed rails are not used or are too low compared to the support surface
Financial Resources	Financial capacity and primary payer should also be considered as costs may significantly differs for the different technologies

Bariatric patients require special consideration as they may be too heavy for some active support surfaces, and require extra width or adapted versions of bed and mattresses specifically designed for their weight and size.

KEY SELECTION CRITERIA FOR SUPPORT SURFACE SELECTION

Selection of the bed, mattress, and support surface should not only be based on the risk of pressure injury, but should incorporate a multidisciplinary coordinated approach engaging patients and considering important key features described below.[3,6]

Re-assessment of Bed and Mattresses Devices in SCI Population

Once the bed and mattress are put into place, regular skin assessments should be provided to ensure that the load redistribution strategy is still effective and adapted to the person's condition. Presence of pressure injury, change in the condition of the patient should particularly target systematic re-assessment of the risk levels for pressure injury and of the support surfaces, including bed and mattress devices.[3,5,6]

When a specialized support surface is used, these features should be checked and monitored regularly to ensure that pressure redistribution and other important features are still effective[6]:

- Foam mattress may lose their "spring/memory" effect and thus fail to recover their initial geometry when compression is released
- Air filling devices should be properly inflated and checked for potential air leaks
- Gel should be evenly distributed throughout the surface when a gel mattress is used
- Air alternating systems should inflated and deflated properly
- Power devices should be checked and must be properly plugged into a power supply.

CURRENT EVIDENCE RELATED TO THE USE OF BED PRESSURE-RELIEVING DEVICES IN THE SCI POPULATION

These recommendations are issued from the current Canadian, American and International guidelines for prevention and management of pressure injuries for people with SCI[3,7,8,13]

Prevention and Education

Provide individuals with SCI, their family, significant others, and health-care professionals with specific information on effective strategies for the prevention and treatment of pressure injuries. This should include the following: (Recommendation Level II/III/IV/V)[8]

- Etiology of pressure injury
- Measures for reducing risk of pressure injuries
- Skin cleansing, drying and care techniques
- Management of incontinence
- Frequency and techniques of skin inspection
- Frequency, duration, and techniques of recommended position changes
- Frequency, duration, and techniques of recommended pressure redistribution
- Nutrition as it relates to maintaining skin integrity
- Use and maintenance of support surfaces (mattresses and cushions)
- Skin changes to be reported to the health-care team

Evaluate the individual and his/her environment for optimal maintenance of skin integrity (Recommendation of Level II/III/IV)[8]

- Apply pressure-reducing support surfaces preventively to protect soft tissues from bruise and injury.
- Prevent moisture accumulation and temperature elevation at the support surface-skin interface
- Apply pillows and cushions to bridge contacting tissues and unload bony prominences, do not use donut-type devices
- Establish a mechanism to follow up on equipment performance specific to pressure injury prevention and determine if changes in medical or health status have altered the effectiveness of the support surface

The principles involved in minimising the effect of shear stresses and friction with regards to bed and mattresses, include:[7]

- Decreasing tangential forces by minimising head of bed elevation, and during sitting in bed, avoid sliding downwards and forwards. Accordingly, limit head-of-bed elevation to 30 degrees for an individual on bedrest, unless contraindicated by

medical condition. If sitting in bed is necessary, avoid head of bed elevation or a slouch position that places pressure and shear on the sacrum and coccyx.

- Encourage individuals to sleep in a 30 to 40 degrees side lying position or flat in bed if not contraindicated
- Avoiding actions that induce tissue distortion such as: avoiding sliding or dragging, by ensuring that patients are positioned in a way that does not allow them to slip easily and by ensuring that body tissues are not dragged upon repositioning or left distorted following repositioning, use transfer aids to restrict friction and shear, lift –don't drag- the individuals when repositioning.
- Increasing contact area with support surface: this spreads the perpendicular and tangential loads and friction force over a larger area, reducing the localised pressure and shear stresses.

Selection of Support Surface

Use a support surface with advanced pressure-redistributing properties, compared with a standard hospital foam mattress, to minimize peak pressure areas around bony prominences and protect soft tissue from bruising and injury (Level 4 Recommendation)[3]

Use pressure-redistribution bed support surfaces for individuals who are at risk for or who have pressure injuries (Recommendation Level I,II,IV,V)[8,13]

- Select a static support surface for individuals who are able to reposition themselves enough to avoid weight bearing on all areas at risk for pressure injuries and who have a stable spine.[13]
- Select a dynamic support surface for individuals who are unable to reposition themselves, who cannot be positioned without pressure on a current pressure injury, when a static support surface bottoms out, if there is no evidence of healing or if new injuries develop using this surface[13]
- Select low air-loss or high air-loss (air-fluidized) beds in the treatment of pressure injuries if one or more of the following conditions exist:
    - Presence of pressure injuries on multiple turning surfaces
    - Compromise skin temperature and moisture control in the presence of large stage III or IV pressure injuries
    - For individuals who are status post flap/skin graft within the past 60 days.[8]
- Replace the existing mattress with a support surface that provides better pressure distribution, shear reduction and microclimate control in the following situation (Level 4 Recommendation)[3]
    - Pressure injuries on multiple turning surfaces
    - Compromised control of microclimate in the presence of deep tissue injury
    - Person cannot be positioned off the pressure injury
    - They are a high risk of developing additional pressure injuries
    - Failure to heal or wound deterioration
    - Bottoms out on the existing support surface"
- Select smooth, low-friction, breathable fabrics for bedding and clothing to optimize microclimate control and minimize friction (Level 4 Recommendation)[3]

Positioning

Use bed-positioning devices and techniques that are compatible with the bed type and the individual's health status (Recommendation Level II/V)[8]

- Avoid positioning individuals directly on pressure injuries regardless of the pressure injury anatomical location unless such position is necessary for performance of ADLs, such as eating or hygiene
- Use pillows, cushions, and positioning aids to reduce pressure on existing pressure injuries or vulnerable skin areas by elevating them away from the support surface
- Avoid closed cut-outs or donut-type cushions
- Prevent contact between bony prominences
- Elevate the head of the bed no higher than 30 degrees unless medically necessary

The use of a pressure redistributing support surface does not eliminate the need for repositioning. While a systematic review of pressure injury prevention

strategies found insufficient evidence to support a specific repositioning regimen. However, the traditional 2-hourly repositioning regimen may provide a useful point from which frequency can be adjusted, based on the patient's tissue tolerance, level of mobility, general medical condition and the support surface in use.[7]

Follow-up and Re-assessment

Regular observation is essential in evaluating the efficacy of pressure redistribution strategies: any sign of pressure damage should prompt re-evaluation of the strategies in place.[7]

Re-evaluate the suitability of the support surface for pressure injury prevention and treatment at least every 4 years, and sooner if the person's medical condition changes (Level 4 Recommendation)[3]

CONCLUSION

Individuals with SCI are highly vulnerable to pressure injuries throughout the continuum of care. Selection of bed and mattress and recommendations when using bed devices should be individualized based on many factors, such as the level of mobility, medical status and previous or current pressure injuries. A multidisciplinary evaluation by a team who has expertise in SCI care is thus recommended using a holistic approach.

References

1. National Collaborating Centre for Nursing and Supportive Care (UK). The use of Pressure-Relieving devices (Beds, Mattresses and Overlays) for the Prevention of Pressure Ulcers in Primary and Secondary care. London: Royal College of Nursing (UK); 2003 Oct.
2. Kruger EA, Pires M, Ngann Y, Sterling M, Rubayi S. Comprehensive management of pressure ulcers in spinal cord injury: Current concepts and future trends. J Spinal Cord Med 2013;36(6):572-85.
3. Hougton PE, Campbell KE and CPG Panel. Canadian Best Practice Guidelines for the Prevention and Management of Pressure Ulcers in Spinal Cord Injury. A resource handbook for Clinicians (2013). Accessed at: http://www.onf.org
4. Fogelberg DJ, Leland NE, Blanchard J, Rich TJ, Clark FA. Experience of sleep in individuals with spinal cord injury. OTJR (Thorofare NJ) 2017;37(2):89-97.
5. Consortium for Spinal Cord Medicine Clinical Practice Guidelines. Pressure ulcer prevention and treatment following spinal cord injury: a clinical practice guideline for health-care professionals. J Spinal Cord Med 2001;24(Suppl 1):S40–101
6. National Pressure Ulcer Advisory Panel (NPUAP). Support Surface Standards initiative: Explore What's new & Discover What's in it for you! NPUAP Webinar. Retrieved at: www.npuap.org (May 2018).
7. International review. Pressure ulcer prevention: pressure, shear, friction and microclimate in control. A consensus document. London: Wounds International, 2010.
8. Consortium for Spinal Cord Medicine Clinical Practice Guidelines. Early acute management in adults with spinal cord injury: a clinical practice guideline for health-care professionals. J Spinal Cord Med. (2008) J Spinal Cord Med. 2008;31(4):403-79.
9. Richard-Denis A, Thompson C, Mac-Thiong JM. Effectiveness of a multi-layer foam dressing in preventing sacral pressure ulcers for the early acute care of patients with a traumatic spinal cord injury: comparison with the use of a gel mattress. Int Wound J 2017;14(5) :874-81.
10. Edsberg L, Geyer MJ, Zulkowski K. The NPUAP Support Surface Initiative. Advances in skin and wound care 2005;18(3): 164-66.
11. Cullum NA, Deeks J, Sheldon TA, Song F, Fletcher AW. Beds, mattresses and cushions for pressure sore prevention and treatment (Review). Cochrane Database of Systematic Reviews 2000, Issue 2. Art. No.:CD001735.
12. Fleck CA, Rappl LM, Simman R, Titterington V, Conwill J, Koerner C et al. Use of alternatives to air-fluidized support surfaces in the care of complex wounds in postflap and postgraft patients. J Am Col Certif Wound Spec. 2010;2(1):4-8.
13. Consortium for Spinal Cord Medicine Clinical Practice Guidelines, et al. Pressure ulcer prevention and treatment following spinal cord injury: a clinical practice guideline for health-care professionals. J Spinal Cord Med. Second Edition (2014) Retrived from: http://pdfs.semanticscholar.org/38f6/d7ba153cc2d837f81ff60337cbf4bbc2592.pdf