Pressure Ulcers Following Spinal Cord Injury

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Key Points

The early detection of suspected pressure ulcers in individuals with SCI may be improved through the use of a handheld dermal phase meter and ultrasonography.

Magnetic resonance imaging may be helpful to anticipate the development of osteomyelitis secondary to non-healing SCI-related pressure ulcers.

Circulatory biomarkers in people with SCI have not yet proven to be useful or feasible to enhance early detection of suspected pressure ulcers.

Electrical stimulation likely decreases ischial pressures.

Electrical stimulation may increase blood flow to tissues.

Electrical stimulation likely increases tissue oxygenation.

Electrical stimulation likely helps to prevent pressure ulcer formation or progression by reducing ischial pressures and increasing tissue oxygenation.

Pressure mapping studies using able-bodied subjects should not be generalized to the SCI population because pressure differences exist between the two groups.

Typical areas of high pressure for the SCI population include sacrum, coccyx and/or ischial tuberosities.

Data generated from pressure mapping studies on seniors should not be generalized to the SCI population.

Early attendance at specialized seating assessment clinics should be part of a comprehensive rehabilitation program.

More research is needed to determine if early attendance at a specialized seating assessment clinic results in pressure ulcer prevention over time.

Structured pressure ulcer prevention education, helps individuals post SCI gain and retain knowledge of pressure ulcer prevention practices.

Research is needed to determine the specific educational needs of individuals with SCI required to reduce the risk of pressure ulcer formation.

More research is needed to determine the best approaches of pressure ulcer prevention education to reduce pressure ulcers post SCI.

Research is needed to determine the role of behavioural contingencies and other behavioural strategies in pressure ulcer prevention post SCI.

Research is needed to determine why some individuals adhere to pressure ulcer prevention strategies and others do not.
The role of telerehabilitation in delivering prevention education and treatment to those individuals with SCI living in the community is not yet proven; more research is needed.

Electrical stimulation added to standard wound management promotes healing of Stage III and IV pressure ulcers post SCI.

More research is needed to determine optimum electric current and application protocols to improve healing of pressure ulcers post SCI.

Laser treatment does not improve pressure ulcer healing post SCI.

Ultrasound/ultraviolet C should be considered as an adjunct treatment when pressure ulcers are not healing with standard wound care post SCI.

Pulsed electromagnetic energy improves wound healing in Stage II and Stage III pressure ulcers post SCI.

Pressure ulcer healing after a SCI is improved when topical negative pressure therapy is administered as compared to traditional sodium hypochlorite dressing changes.

Normothermic dressings may improve healing of pressure ulcers post SCI.

Recombinant human erythropoietin shows promise in assisting with the healing of stage IV chronic non-healing pressure ulcers post SCI.

Additional study is required to validate platelet-rich plasma therapy as a possible treatment for severe, non-healing pressure ulcers in people with SCI.

The anabolic steroid agent Oxandrolone does not promote healing of serious pressure ulcers post SCI.

Occlusive hydrocolloid dressings are useful for healing of stage I and II pressure ulcers post SCI.

Platelet gel dressings used within the first two weeks of treatment will trigger pressure ulcer healing post SCI.

Pulsatile lavage therapy is an effective, and likely safe, non-surgical management and debridement method for the treatment of grade III and IV pressure ulcers secondary to SCI.

Maggot therapy is also likely useful in this patient group. Silicone moulding may also be considered as a radical en bloc debridement method for grade IV pressure ulcers in people with SCI.
Use of topical oxygen therapy may have a positive association with healing of pressure ulcers post SCI but more research is needed.

People with spinal cord injury with persistent grade III and IV pressure ulcers in the thigh and buttock region may benefit from surgical reconstruction.

Medihoney® may be useful to treat persistent stage III and IV pressure ulcers in individuals with SCI.

Cured rot and flat sore ointment may be superior to arnebia root oil to promote accelerated healing of pressure ulcers in people with SCI.

Arginine supplementation in individuals with SCI may be helpful in accelerating pressure ulcer healing.

Pressure point localized cooling is not an effective pressure ulcer prevention strategy for people with SCI.
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## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ARO</td>
<td>Arnebia Root Oil</td>
</tr>
<tr>
<td>CRFSO</td>
<td>Cured Rot and Flat Sore Ointment</td>
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<td>ES</td>
<td>Electrical Stimulation</td>
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<td>FES</td>
<td>Functional Electrical Stimulation</td>
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<td>HVES</td>
<td>High Voltage Electrical Stimulation</td>
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<tr>
<td>HVPC</td>
<td>High Voltage Pulsed Current</td>
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<tr>
<td>IT</td>
<td>Ischial Tuberosities</td>
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<td>MRI</td>
<td>Magnetic Resonance Imaging</td>
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<tr>
<td>NMES</td>
<td>Neuromuscular Electrical Stimulation</td>
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<td>NPUAP</td>
<td>National Pressure Ulcer Advisory Panel</td>
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<td>PRP</td>
<td>Platelet-Rich Plasma</td>
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<tr>
<td>PUSH</td>
<td>Pressure Ulcer Scale for Healing</td>
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<tr>
<td>rHuEPO</td>
<td>Recombinant Human Erythropoietin</td>
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<td>SCI</td>
<td>Spinal Cord Injury</td>
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<td>SSA</td>
<td>Specialized Seating Assessment</td>
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<td>TNP</td>
<td>Topical Negative Pressure</td>
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<td>US</td>
<td>Ultrasound</td>
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<td>UTI</td>
<td>Urinary Tract Infection</td>
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<tr>
<td>UVC</td>
<td>Ultraviolet C</td>
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<tr>
<td>WSA</td>
<td>Wound Surface Area</td>
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</table>
Pressure Ulcers Following Spinal Cord Injury

1.0 Introduction

1.1 Impact of Pressure Ulcers

Pressure ulcers are a serious, lifelong secondary complication of spinal cord injury (SCI) that have the potential to “interfere with physical, psychological and social well-being and to impact overall quality of life” (Consortium for Spinal Cord Medicine 2000, p. 9). Although preventable in most situations, when they occur, pressure ulcers may “disrupt rehabilitation, prevent individuals with SCI from attending work or school, and interfere with community reintegration” (Houghton et al. 2013, p. 6). As well, the occurrence of a pressure ulcer can lead to rehospitalization often with an extended length of stay (Fuhrer et al. 1993; Krause 1998; Consortium for Spinal Cord Medicine 2000). In fact, pressure ulcers are reported to account for a disproportionate number of rehospitalization days (Dejong et al. 2013; Middleton et al. 2004) that are also typically much longer than length of stays for other conditions such as urinary tract infections (UTI; Dejong et al. 2013; Middleton et al. 2004; New et al. 2004). Rehospitalization secondary to pressure ulcers increase in frequency over time since discharge from initial rehabilitation but peaks at year five as seen in the United States SCI Model Systems 20-year database review (Cardenas et al. 2004).

It has been estimated that pressure ulcers can account for approximately one-fourth of the cost of care for individuals with SCI. In the United States alone, it has been estimated that the cost of care for pressure ulcers is about 1.2 to 1.3 billion dollars annually while prevention could cost about one-tenth of this amount (Bogie et al. 2000; Byrne et al. 1996). Because of the costs associated with treating pressure ulcers, Krause et al. (2001) state, “they [pressure ulcers] have received more attention among rehabilitation and public health professionals than any other type of secondary condition associated with SCI” (p107). Despite the attention given to prevention strategies, pressure ulcers are common among individuals with SCI (Krause et al. 2001). The most recent econometric analysis of pressure ulcer resource utilization for community dwelling people with SCI identified that 62% of the cost of pressure ulcer treatment was attributable to hospital admission costs (Chan et al. 2013). Nursing costs accounted for the greatest cost amongst non-physician health care providers (Chan et al. 2013).

The 2013 Canadian Best Practice Guidelines for the Prevention and Management of Pressure Ulcers in People with SCI (Houghton et al. 2013) not only provide an updated resource for healthcare professions but also consider the unique challenges of pressure ulcer management within publicly funded, universally available healthcare. In particular, a comprehensive approach to pressure management as well as self-management and telehealth approaches have been incorporated into these 2013 guidelines, which also serve as a thorough resource handbook for clinicians.

1.2 Incidence and Prevalence

Pressure ulcers (the term used in the current document), also known as decubitus ulcers, ischemic ulcers, pressure sores, bed sores or skin sores, have been defined as a “localized injury to the skin and/or underlying tissue usually over a bony prominence as a result of pressure or pressure in combination with shear and/or friction” (National Pressure Ulcer Advisory Panel 2007). The primary cause of pressure ulcers is felt to be externally applied pressure for a prolonged period of time over bony prominences such as the sacrum and ischial tuberosities (IT). Because pressure can be exerted while the body is in different positions, the term “decubitus” is no longer commonly used to describe pressure ulcers as it refers only to
pressure ulcers acquired while “lying down.” Applied pressure leads to decreased blood supply to the overlying soft tissues (i.e., tissue ischemia) and can ultimately cause tissue necrosis (Lamid & Ghatit 1983; Crenshaw & Vistnes 1989; Bogie et al. 1995). DeLisa and Mikulic (1985) have noted that “the visible ulcer represents only the tip of the iceberg or the apex of the lesion” (p. 210). Erba et al. (2010), using 3 dimensional analyses of silicone moulds, confirmed the pyramidal shape off stage IV ischial ulcers in all 10 paraplegic patients included in their study. Deeper tissues, such as muscle, are more sensitive than skin to ischemia caused by pressure (Daniel et al. 1981; Nolan and Vistnes 1980). Deep tissue injuries have been added as a distinct pressure ulcer in the National Pressure Ulcer Advisory Panel’s 2007 updated pressure ulcer staging system (Black et al. 2007).

Table 1 reflects that various ways that pressure ulcer incidence and prevalence is reported: by grade, by location, in paraplegia versus tetraplegia, in people with SCI from traumatic or non-traumatic origin, by time since injury and by jurisdiction (e.g., health-care setting vs. living in community or by geographic region).

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Country</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
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<tbody>
<tr>
<td>Onigbinde et al. 2012</td>
<td>Nigeria</td>
<td>Observational</td>
<td>N=318</td>
<td><strong>Population:</strong> Mean age: 42.7 yr; Gender: males=204, females=114; Injury etiology: SCI=159, orthopaedic=123, head injury=36. <strong>Data Collection:</strong> A structured questionnaire was used by hospital staff to gather information on socio-demographic and health data including age, diagnosis, date of admission, the date of skin breakdown (if any) and site of any ulcer.</td>
<td>1. Mean age of participants was 42.7±15.1 yr. 2. 44 inpatients developed nosocomial pressure ulcers within the three mo study period. 3. The mean age of those who developed pressure ulcers was 41.18±13.98 yr. The incidence rate was 13.84%. 4. Among those who developed pressure ulcers, 22 (50%) had spinal cord injuries. Therefore, of 48 people with a SCI, 45.8% developed a pressure ulcer. 5. Of the 44 inpatients with pressure ulcers, 32 (72.7%) were men and 12 (27.3%) women. 6. The period between time of admission and first appearance of pressure ulcer ranged from 3-90 days, with a median of 25 days. 7. At onset, only four (9.1%) ulcers were classified as stage 2 ulcers, after 90 days, 23 (52.3%) ulcers were at stage 2. 8. Of the 44 patients who developed pressure ulcers, 38 developed them at the sacrum, 20 on the heels and two at the occiput.</td>
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<td>Taghipoor et al. 2009</td>
<td>Iran</td>
<td>Observational</td>
<td>N=5995</td>
<td><strong>Population:</strong> Median age ranges: 21-30 and 30-40 yr; Gender: males=71.8%, females=28.2%; Injury etiology: traumatic=63.2%, non-traumatic=35.2%. <strong>Data Collection:</strong> Patients who received financial, medico-social, and rehabilitative support provided by the State Welfare Organization of Iran.</td>
<td>1. Overall incidence of pressure ulcer was 39.2% (71.8% traumatic, 28.2% nontraumatic) 2. Age was a factor associated with pressure ulcer in patients with nontraumatic SCI, but not level of injury, education, and occupational status.</td>
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| Nogueria et al. 2006 | Brazil  | Observational   | N=47              | **Population:** Age ranges: <20 yr=8, 21-30=17, 31-40=5, 41-50 yr=7, 51-60=3, >60=3; Gender: males=45, females=2; Level of injury: C=19, T=21, L=7.  
**Data Collection:** Database on patients who received care at Ribeirão Preto Medical School Hospital das Clínicas. | 3. Only occupation and education were factors associated with pressure ulcer in traumatic SCI (p<0.01), but not age.  
1. Overall incidence of pressure ulcer was 42.5% (mean=2.3 pressure ulcer per patient).  
2. Incidence by number pressure ulcer: 0=27 (57.4%), 1=7 (15.0%), 2=5 (10.6%), 3=4 (8.5%), 4=3 (6.4%), 5=1 (2.1%).  
3. Incidence of pressure ulcer by grade: Grade 1=10.9%, Grade 2=17.4%, Grade 3=6.5%, Grade 4=13.0%, Unknown=52.2%.  
4. Most common regions of pressure ulcer: sacrum=36.9%, heel=17.4%, gluteal=10.8%, ischium=10.8%, coccyx=6.5%. |
| Raghaven et al. 2003 | UK      | Observational   | N=427             | **Population:** Mean age: 47±14.7 yr; Gender: males=76.0%, females=24.0%; Mean time since SCI: 13.0±10.6 yr; Etiology of injury: traumatic SCI=425, spina bifida=2.  
**Data Collection:** Postal survey assessing pressure ulcer among individuals with SCI in the community who were being followed by the medical centre. | 1. Point prevalence was 23%.  
2. *Incidence of Grade 1=12.4%, Grade 2=10.3%, and Grade 1 and 2=0.5%.  
3. Most common pressure ulcer sites: heel=10.8%, sacrum=14%, and gluteal=23.7%.  
4. 55% had a Grade 2+ pressure ulcer at any point since their SCI.  
5. Current smoking and regular inspection of skin was associated with the occurrence of pressure ulcer.  
*N=45 patients not included in these results.* |
| Walters et al. 2002 | USA     | Observational   | N=99              | **Population:** Most patients were >50 yr and had their SCI >10 yr ago.  
**Data Collection:** A database was created to track patients’ self-reported long-term SCI complications following rehabilitation. | 1. Overall prevalence was 38%.  
2. Pressure ulcer occurred primarily in sacral, ischial, and trochanteric areas (71%). |
| Klotz et al. 2002  | France  | Observational   | N=1668            | **Population:** Mean age: 43.6 yr; Gender: males=80%, females=20%; Level of injury: C1-C2=10.5%, C3=13.1%, C4=15.4%, C5=13.9%, C6=13.4%, C7-C8=10.4%; Mean time since injury: 12.9 yr  
**Data Collection:** Tetrapigap survey – a self-reported questionnaire given to individuals in rehabilitation. | 1. 19.7% of re-hospitalization cases were due to pressure ulcers. |
| Chen et al. 1999   | USA     | Cross Sectional | N=1649            | **Population:** Mean age: 36.5 yr; Gender: males=79%, females=21%; Level of injury: incomplete tetraplegia (31%), complete paraplegia (29%), complete tetraplegia (20%), and incomplete paraplegia (19%); Time since SCI: 3 yr=702, 2 yr=716, 1 yr=231.  
**Data Collection:** Information was collected from the National SCI Statistical Center (NSCISC) database of patients admitted 1996-1998. | 1. Incidence of pressure ulcer by grade: Grade 1=27.3%, Grade 2=54.5%, Grade 3=11.9%, Grade 4=3.2%, Unknown=2.8%.  
2. Participants in rehabilitation; 63.9 had one ulcer, 21.2% had two ulcers, 10.5% had three ulcers, and 4.3% had four or more ulcers.  
3. Pressure ulcers were found most in the sacrum (39%), heels (13%) and ischium (8%).  
4. Higher percentage of pressure ulcers for participants with complete injuries; 23.1% of complete paraplegia, and |
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<th>Author</th>
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<tr>
<td>Mckinely et al.</td>
<td>1999</td>
<td>USA</td>
<td>Observational</td>
<td>N=20354</td>
<td>Population: Time since injury: 1 yr=6,776, 2 yr=5,744, 5 yr=4,100, 10 yr=2,399, 15 yr=1,285, 20 yr=500. Data Collection: Information was collected from the National SCI Statistical Center (NSCISC) database of all patients admitted from 1973 and had a follow-up phone evaluation in 1986-1998.</td>
<td>Prevalence of pressure ulcer by time since SCI: 1. 1 yr (n=4,978), 2 yr (n=3,421), 5 yr (n=2,079), 10 yr (n=1,073), 15 yr (n=450), 20 yr (n=102). Prevalence of pressure ulcer by time since SCI and level of injury: 2. Incomplete Paraplegia - 1 yr=5.6%, 2 yr=8.3%, 5 yr=10.9%, 10 yr=14.5%, 15 yr=18.4%, 20 yr=12.5%. 3. Complete Paraplegia - 1 yr=22.3%, 2 yr=24.5%, 5 yr=25.5%, 10 yr=28.2%, 15 yr=26.7%, 20 yr=29.8%. 4. Incomplete Tetraplegia - 1 yr=9.3%, 2 yr=10.2%, 5 yr=11.5%, 10 yr=18.4%, 15 yr=20.8%, 20 yr=13.3%. 5. Complete Tetraplegia - 1 yr=25.2%, 2 yr=26.4%, 5 yr=27.2%, 10 yr=25.1%, 15 yr=27.6%, 20 yr=40.6%. 6. Individuals who sustained SCI from acts of violence were the most common etiology for pressure ulcers. 7. Individuals with paraplegia had the highest prevalence of grade 3 and 4 ulcers (9.1%)</td>
</tr>
<tr>
<td>Anson &amp; Shepherd</td>
<td>1996</td>
<td>USA</td>
<td>Observational</td>
<td>N=348</td>
<td>Population: Mean age: 37 yr; Gender: males=81.9%, females=18.1%; Level of injury: C0-C4=67, C5-C8=123; T1-T11=100, T12-S5=50; Time since SCI: 1-2 yr=90, 3-5 yr=88, 6-10 yr=10, 11-15 yr=41, &gt;15 yr=27. Data Collection: Information was collected when patients returned to outpatient clinics for routine follow-up examinations.</td>
<td>Incidence of all grades of pressure ulcer by time since SCI: Grade 1 or 2=83.3%, Grade 3 or 4=16.6%. Incidence of Grade 1 or 2 pressure ulcer by time since SCI: 1. 1-2 yr=92.3%; 3-5 yr=82.4%, 6-10 yr=96.5%, 11-15 yr=94%, &gt;15 yr=68.4%. Incidence of Grade 3 or 4 pressure ulcer by time since SCI: 2. 1-2 yr=7.7%, 3-5 yr=17.6%, 6-10 yr=13.5%, 11-15 yr=16%, &gt;15 yr=31.6%. 3. The most common locations were foot/heel (27%), sacrum (18.3%), and ischium (18.2%). 4. The most common identified etiology for pressure ulcers were lack of weight shifts, postural problems, hot water burns, and improper turning in bed.</td>
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**Discussion**
Annual prevalence rate reports range from 10.2% to 38% (DeLisa & Mikulic 1985; Byrne & Salzberg 1996; Walters et al. 2002). Chen et al. (2005) reported an increasing pressure ulcer prevalence in recent years not explained by aging, years since injury or varying demographics. Risk of pressure ulcers was steady for the first 10 years and increased 15 years post injury. Fuhrer et al. (1993) noted that less severe pressure ulcers (stages I and II) comprised about 75% of the total number of ulcers observed, with the 25% as more severe (stage III and IV).

When reported overall (no breakdown by grade, location), incidence rates as high as 71.8% have been published (Taghipoor et al. 2009), although these reflect biases in the study population associated with participants limited to having low income, and motor- and sensory-complete injuries. In an Iranian study, overall incidence rates of pressure ulcers were reported as 28.2% in patients with non-traumatic SCI and 71.8% in those with SCI secondary to traumatic etiology (Taghipoor et al. 2009). The highest incidence by grade of severity is grade II (Raghaven et al. 2003) and the most common pressure ulcer site is the sacrum (Nogueria et al. 2006; Raghaven et al. 2003; Chen et al. 1999). Anson and Shepherd (1996) inferred that continuous prevention diligence (e.g., patient education, follow-up and extended medical care) may decline after 15 years post-injury as reflected by the simultaneous increase in grade III and IV ulcers (11-15 yr=16%; >15 yr=31.6%) and decrease in grade I and II ulcers (11-15 yr=94%; >15 yr=68.4%).

Although the United States Model Systems report a peak in rehospitalization as a result of pressure ulcers at five years post-discharge from initial rehabilitation (Cardenas et al. 2004), pressure ulcers were still one of the most common secondary complications at annual follow-ups (McKinley et al. 1999). Prevalence continued to increase up to 20 years post-injury for individuals with a complete injury. Prevalence for those with an incomplete injury peaked at 15 years post-injury and decreased from there when seen at 20 year follow-up. Not surprisingly, pressure ulcer prevalence was highest in individuals with a complete versus incomplete injury (McKinley et al. 1999). Prevalence continued to increase in both groups over time until 15 years post-injury. Fortunately, people with incomplete injuries saw a slight decrease in prevalence on 20 year follow-up. The difference in prevalence rates was further amplified between those with paraplegia versus tetraplegia, with the latter being more heavily plagued with pressure ulcers in general. However, those with either complete paraplegia or tetraplegia continued to reflect increasing pressure ulcer prevalence at the 20-year follow-up.

When a pressure ulcer is severe and not treated aggressively it can lead to further disability (e.g., reduced mobility, dependence, surgical intervention, amputation, fatal infection; Krause 1998). It has been estimated that 7-8% of those who develop pressure ulcers will die from related complications (Richards et al. 2004). Due to the increasing life expectancy for those who sustain an SCI, the risk of developing pressure ulcers is even greater; thus, recognition of risk factors and pressure ulcer prevention is a priority and daily concern for both individuals with SCI and health care providers.

1.3 Risk Factors

Pressure ulcer formation is a complex process that is still not clearly understood despite years of research. While the amount, duration and frequency of the applied pressure, the soft tissue’s response to loading, and the role of shear and/or friction are crucial, individual patient characteristics need to be assessed as well. Intrinsic factors such as diagnosis, history of previous tissue breakdown or surgical repair, body build, posture, muscle atrophy, nutritional status as well as magnitude and distribution of interface pressures must be considered. Extrinsic factors are also important including number of hours sitting or lying in wheelchair or
bed, types of activities performed while sitting, level of functional independence, type of wheelchair, cushion and bed surface used and the support surface microenvironment, environment (climate, continence, temperature), finances; family/caregiver support; living arrangements and ease of follow up (Krouskop et al. 1983; Garber et al. 2007; Fleck & Sprigle 2007; Reger et al. 2007).

Observational study is the typical method of identifying risk factors. The analytical methodology used for each study is highly variable and makes for difficult comparisons between studies. Typically risk factors are categorized into demographic (e.g., sex, age, education, occupation, marriage), physical/medical (e.g., SCI factors, nutritional status, co-morbidities, mobility, pressure ulcer history, bowel/bladder incontinence/moisture, sensory perception, body build), and psychosocial factors such as mental status, social support, living conditions and financial status. Marin et al. (2013) conducted a systematic review and identified that clinical (e.g., spinal lesion characteristics, pre-existing history of pressure ulcers) and functional (e.g., independence in pressure ulcer management) aspects serve as risk factors specific to the SCI population compared the general population.

Table 2 Systematic Review of Risk Factors for Pressure Ulcer Post SCI

<table>
<thead>
<tr>
<th>Authors</th>
<th>Country</th>
<th>Date included in the review</th>
<th>AMSTAR Number of articles</th>
<th>Method</th>
<th>Conclusions</th>
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<tbody>
<tr>
<td>Marin et al. 2013</td>
<td>UK</td>
<td>Review of published articles between 1980-2011</td>
<td>AMSTAR=8 N=5</td>
<td>Method: A systematic review including prospective cohort, retrospective record reviews and clinical trials that identified risk factors associated with pressure ulcer development and recurrence in SCI populations using multivariate analytical techniques. Databases: MEDLINE, EMBase and Cochrane. Level of evidence: Level 2 (prospective cohort study); level 4 (retrospective cohort study and retrospective record review); level 5 (observational study and longitudinal panel cohort) Questions/measures/hypothesis: To identify risk factors predictive of pressure ulcer development in adults with SCI.</td>
<td>1. 18 risk factors were identified and classified into six themes: sociodemographic, neurological, functional clinical, biological and medical care management. 2. Risk factors for both the general and SCI-specific populations were similar but functional and hospital management emerged as specific risk factor domains for the SCI population. 3. Findings were based on a small number of studies highlighting the need for further confirmatory work to reduce pressure ulcer development and recurrence and to provide a foundation for SCI risk assessment development.</td>
</tr>
<tr>
<td>Gelis 2009</td>
<td>France</td>
<td>Review of published articles between 1966 and 2008</td>
<td>AMSTAR=8 N=6 Studies</td>
<td>Method: Systematic Review of Literature. Databases: Medline (1966), EMBase (1980), Pascal (1990), Reedoc (1977). Level of evidence: Moderate Level of Evidence Questions/measures/hypothesis: Determine pressure ulcer risk factors correlated to the patients with SCI, medical care management during the acute as well as in the rehabilitation and chronic stages. This first part focuses on identifying the risk factors during the acute and rehabilitation stages.</td>
<td>1. Risk factors during the acute stage of an SCI are essentially linked to care management and treatment modalities. 2. There is insufficient evidence to make a recommendation on medical risk factors, however, low blood pressure on admission to the Emergency Room, with a moderate level of evidence.</td>
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<td>Author Year</td>
<td>Country</td>
<td>PEDro Score</td>
<td>Research Design</td>
<td>Total Sample Size</td>
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| Eslami et al. 2012 | Iran    |             | Observational   | N=7489            | Population: Median age range: 21-30 yr; Gender: males=4996, females=2493; Level of injury: paraplegia=66.8%, quadriplegia=9.6%, paraparesia=11.1%, quadriparesia=3.7%. Intervention: A retrospective chart review of patients included in the study, to determine risk factors for pressure ulcer development. Outcome measures: Age, gender, time passed since SCI, education, type of injury, lack of intimate partner. | 1. Patients <10 yr: female, time since SCI.  
2. Patients >11 yr: male, time since SCI, lower education level, lack of an intimate partner, quadriplegia and older age.  
3. Patients <1 yr post injury: male, quadriplegia, older age.  
4. Patients >1 yr post injury: male, quadriplegia, older age, lower level of education and lack of an intimate partner. |
| Wilczweski et al. 2012 | USA     |             | Case Series     | N=94              | Population: Median age range: 51-65 yr; Gender: males=72, females=21; Level of injury: C1-C4 incomplete injuries=32, unknown=62. Intervention: Retrospective chart review of patients included in study, to identify potential risk factors for pressure ulcer development. Outcome measures: Primary outcome was the development of a pressure ulcer. If pressure ulcer was present, the documented stage was recorded (i.e., stage I, II, III, and IV). | 1. Risk factors significantly correlated with development of new pressure ulcers:  
   - Fecal management system  
   - Incontinence of urine  
   - Acidosis  
   - Type of bed surface  
   - Use of steroids  
   - Additional equipment  
   - Prolonged hypotension  
2. Prolonged periods of hypotension were the greatest predictor of pressure ulcers. |
| Rabadi et al. 2011 | USA     |             | Case Series     | N=87              | Population: Mean age: 60 yr; Gender: males=85; females=2; Level of injury: cervical=44, thoracic=44, lumbosacral=10; Severity of injury: AIS type A=32, B=12, C=21, D=19 and E=3. Intervention: Retrospective chart review of patients included in study, to identify potential risk factors for pressure ulcer development. Outcome Measures: Basic demographics, presence of modifiable risk factors including: Hypertension, diabetes mellitus, hyperlipidemia, current smoking; presence of depression, incontinence and results from blood drawn from hemoglobin level, blood urea nitrogen, creatinine and albumin levels and lipid profile on initial enrolment. | 1. Comparisons between those with and without pressure ulcers found no significant differences for the demographic variables of age, gender, age of SCI onset, or SCI duration, but there was a trend for the groups to differ in ethnicity (p=0.05).  
2. The presence of modifiable vascular risk factors including hypertension, diabetes mellitus, hyperlipidemia, and current smoking did not differ between those with and without pressure ulcer. |
| Idowu et al. 2011 | Nigeria |             | Observational   | N=67              | Population: Mean age=38 yr; Gender: males=51, females=16; Level of injury: paraplegia=14, tetraplegia=53. | 1. No significant difference in the development of pressure ulcer in paraplegia vs tetraplegia.  
2. No significant difference in the development of pressure ulcer in complete vs incomplete SCI.  
3. Age did not demonstrate a relationship with number and seriousness of pressure ulcers. |
<p>| Jan et al. 2011   | USA     |             |                |                  | Population: Mean age: 31.3 yr; Gender: males=11, females=12; Level of injury: | 1. Maximal vasodilation was significantly smaller in people with |</p>
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<tr>
<th>Author Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
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<tr>
<td>Prospective Controlled Trial</td>
<td>N=23</td>
<td>paraplegia=4, tetraplegia=7, healthy controls=12.</td>
<td>Intervention: Patients underwent thermally induced maximal sacral skin blood flow oscillations (BFO), which were measured by laser Doppler flowmetry.</td>
<td>1.</td>
<td>SCI than in nondisabled controls.</td>
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<td></td>
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<td>Outcomes measures: Multifractal detrended fluctuation analysis (MDFA) was used to characterize nonlinear complexity of metabolic (0.0095 to 0.02 Hz), neurogenic (0.02 to 0.05 Hz), and myogenic (0.05 to 0.15 Hz) BFO.</td>
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<td>2.</td>
<td>Metabolic BFO exhibited less complexity in people with SCI.</td>
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<td>3.</td>
<td>Neurogenic BFO exhibited less complexity in people with complete SCI.</td>
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<td>4.</td>
<td>Myogenic BFO did not show significant differences between people with SCI and nondisabled controls.</td>
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<tr>
<td>Sopher et al. 2011</td>
<td>Israel</td>
<td>Observational</td>
<td>N= 21</td>
<td>Population: Study in 12 non-exercise-trained SCI patients and 9 controls matched.</td>
<td>Intervention: Cross-sectional assessment of study participants exposed to elevated strains/stresses using magnetic resonance imaging.</td>
<td>Outcome Measure: Peak strains and stresses in glutei and percentage volumes of muscle tissue exposed to above-critical strains/stresses (compression strain 50%, compression/von Mises stress 2 kPa, and strain energy density 0.5 kPa).</td>
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<td></td>
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<td>2.</td>
<td>Risk factors can be listed according to the following order of importance: fat infiltration, scars contained in both muscle and fat tissues, and spasms.</td>
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<tr>
<td>Li et al. 2011</td>
<td>China</td>
<td>Prospective Controlled Trial</td>
<td>N=20</td>
<td>Population: Mean age=36.5 yr; Gender: males=14, females=6; Level of injury: patients with SCI=10, health subjects=10.</td>
<td>Intervention: External pressure of 26.6 kPa (200 mmHg) was applied to the sacrum via a specifically designed indentor. The subjects were examined lying face-down. Ultrasound equipment was used to analyze the structure and depth of the tissue on the sacrum area.</td>
<td>Outcome measures: Tissue oxygenation signal was monitored for 20 min prior to and after the loading period from the tissue over the sacrum area using near-infrared spectroscopy (NIRS). With spectral analysis based on wavelet transform, five frequency intervals were identified (I, 0.005-0.02 Hz, II, 0.02-0.06 Hz, III, 0.06-0.15 Hz, IV, 0.15-0.40 Hz and V, 0.40-2.0 Hz) corresponding to endothelial related metabolic, neurogenic, myogenic, respiratory and cardiac activities, respectively. Waterlow Scale was used for the pressure ulcer risk assessment.</td>
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<td>2.</td>
<td>During the post-loading period, the response of [HbO2] and [Hb] oscillatory activities were significantly lower in the tissue over the sacrum for persons with SCI than that for normal subjects.</td>
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<td>3.</td>
<td>Significant negative correlation between oscillatory activities and Waterlow scale in persons with SCI.</td>
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<tr>
<td>Verschueren et al. 2011</td>
<td>Netherlands</td>
<td>Observational</td>
<td>N=193</td>
<td>Population: Mean age: 40.4 yr; Gender: males=143, females=50; Level of injury: paraplegia=121, tetraplegia=72. Severity of injury: AIS A=93, B=43, C=40, D=16, unknown=1.</td>
<td>Intervention: Retrospective analysis of patients included in the study, for the occurrence, location, and stage of pressure ulcers; and potential risk factors for pressure ulcer development.</td>
<td>Outcome Measures: Presence of pressure ulcers, including stage 1, was 36.5% during acute rehabilitation phase and 39.4% during functional rehabilitation.</td>
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<td>2.</td>
<td>Significant risk factors for pressure ulcers during functional rehabilitation are motor completeness of the lesion, tetraplegia, pressure ulcer during acute rehabilitation phase, pneumonia and/or pulmonary disease, low score on the Functional...</td>
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<tr>
<td>Saunders et al. 2010</td>
<td>USA</td>
<td>Observational</td>
<td>N=1466</td>
<td></td>
<td>ulcers during the previous, average number of pressure ulcers, demographics (e.g., age, race, employment status and indicators of chronic illness), and participants benefit status.</td>
<td>Independence Measure (FIM) self-care, continence, transfers, locomotion and total FIM motor score.</td>
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<tr>
<td>Noreau et al. 2009</td>
<td>Canada</td>
<td>Observational</td>
<td>N=482</td>
<td></td>
<td>Population: Mean age at injury: 32.5 yr; mean age since injury: 12.6 yr; Gender: males=1069, females=397; Injury severity: C1-C4 nonambulatory=167, C5-C8 nonambulatory=386, noncervical nonambulatory=504, ambulatory=409. Intervention: Retrospective analysis of patients included in the study, to identify potential risk factors for pressure ulcer development. Outcome measures: Pressure ulcers in the past yr, current pressure ulcers, surgery to repair a pressure ulcer since injury.</td>
<td>1. Significant risk factors with having a current pressure ulcer and having surgery to repair a pressure ulcer since injury: Race, Lower income, Lower education.</td>
</tr>
<tr>
<td>Smith et al. 2008</td>
<td>USA</td>
<td>Observational</td>
<td>N=2574</td>
<td></td>
<td>Population: Mean age: 59.3 yr; Gender: males=2514; females=60; Level of injury: paraplegia=1611, tetraplegia=963. Intervention: A survey questionnaire regarding pressure ulcer presence and development was mailed to participants. Outcome Measures: Presence of pressure ulcers during the previous, average number of pressure ulcers, demographics (e.g., age, race, employment status and indicators of chronic illness), and participants benefit status.</td>
<td>1. Relationships between the prevalence of secondary impairments and the duration of injury, as well as perceived health status, were observed. 2. Pressure sores have a variable prevalence rate (23%-32%), depending on the severity of the lesion.</td>
</tr>
<tr>
<td>Guihan et al. 2008</td>
<td>USA</td>
<td>Observational</td>
<td>N=64</td>
<td></td>
<td>Population: Mean age: 56.4 yr; Gender: males=64; Level of injury: paraplegia=43, tetraplegia=18, unknown=3; Severity of injury: AIS A=48, unknown=16. Intervention: Retrospective analysis of a previous randomized controlled trial to determine risk factors associated with pressure ulcer development. Outcome Measures: Pelvic pressure ulcer recurrence and time to recurrence.</td>
<td>1. 36% of respondents reported having pressure ulcers during the previous yr. 2. Characteristics significantly associated with report of one or more pressure ulcers included diabetes (p&lt;0.001), smoking (p=0.030), injury duration &gt; 30 yr (p=0.000), and depressive symptoms (p&lt;0.001).</td>
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<tr>
<th>Author Year Country</th>
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<th>Research Design</th>
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<tr>
<td>Garber et al. 2000</td>
<td></td>
<td>Observational</td>
<td>N=118</td>
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<td>USA</td>
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<td>Population: Mean age: 40.5 yr; Gender: males=118; Level of injury: paraplegia=52, tetraplegia=49, paraplegia or tetraplegia=17; Severity of injury: AIS A, B or C=101, D=17. Intervention: A questionnaire was administered to all patients regarding their SCI and pressure ulcer history. Outcome Measures: Demographic information, SCI characteristics, ulcer history, health beliefs and practices, measures of impairment, disability and handicap and skin integrity.</td>
<td>essential rehabilitation goals.</td>
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<td>1. Individuals with the identified predictive characteristics are at greater risk for developing pressure ulcers. 2. 59% presented with an ulcer 3. 31 % of the participants reported having a pressure ulcer in the first 12 mo prior to phase two.</td>
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<td>Levi et al. 1995b</td>
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<td>Observational</td>
<td>N=535</td>
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<td>Sweden</td>
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<td>Population: Mean age: 43.6 yr; Gender: males=268; females=67. Intervention: Semi-structured interviews with patients and a review of their medical chart. Outcome Measures: Patient characteristics (e.g., gender, age at injury, duration of injury and extent of neurological compromise and the occurrence of these problems).</td>
<td>Results indicate an increased risk in subjects with extensive neurological deficits, and an accumulation of complications with the increasing duration of injury.</td>
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<tr>
<td>1. Results indicate an increased risk in subjects with extensive neurological deficits, and an accumulation of complications with the increasing duration of injury.</td>
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Discussion

Many studies have found that those most likely to develop pressure ulcers fall into a typical demographic population: males who have lower levels of education and are unemployed (Byrne & Salzberg 1996; Schryvers et al. 2000; Ash 2002; Richards et al. 2004). Eslami et al. (2012) identified that lack of an intimate partner predisposed males with lower education and longer post-SCI periods to pressure ulcers.

Physical and medical factors include the biggest range of identified factors. Verschueren et al. (2011) found that the strongest risk factor for pressure ulcer occurrence was having had a pressure ulcer during acute rehabilitation; further, they noted that this is not addressed in any of the seven pressure ulcer assessment scales reviewed, including those widely adopted such as the Braden, Norton and Waterlow. Garber et al. (2000) suggested that having a pressure ulcer in the previous three years raises the risk of a subsequent ulcer, especially if the patient is younger at the age of SCI onset and self-reports as being at higher risk. Other physical/medical risk factors that have been identified most often include limitation in activity and mobility, injury completeness, moisture from bowel and bladder incontinence, lack of sensation, muscle atrophy, poor nutritional status and being underweight (DeLisa & Mikulic 1985; Salzberg et al. 1996; Krause et al. 2001). Body build, as reflected by fat infiltration, scar tissue within muscle and fat, and spasticity were considered by Sopher et al. (2011) to be risk factors for pressure ulcer development in individuals with SCI. Rabadi et al. (2011) found that only ethnicity (p=0.05) was significantly different between those with and without pressure ulcers, other than differences due to severity of the lesion. Guihan et al. (2008) suggested that difficulties for visual inspection on darkly pigmented skin may be a proxy for race, in general, as a risk factor. Gells et al. (2009) also revealed an important difference to risk factors in the acute versus chronic care stages of SCI in that risk factors are mostly care-related in the acute SCI stage. Idowu et al. (2011) similarly found that lower nurse-patient ratios was a risk factor for pressure ulcer
development and suggested an optimum ratio of one nurse to three patients. This is in contrast to the ratio of one nurse to seven patients that resulted in 50% of patients developing pressure ulcers after admission into a neurosurgical trauma unit.

Other physical/medical risk factors include smoking (Lamid & Ghatit 1993; Salzberg et al. 1996; Niazi et al. 1997; Krause et al. 2001; Smith et al. 2008), number of comorbidities especially renal, cardiovascular, pulmonary disease and diabetes (Salzberg et al. 1996; Niazi et al. 1997; Ash 2002; Smith et al. 2008; Levi et al. 1995), residing in a nursing home/hospital (Byrne & Salzberg et al. 1996), autonomic dysreflexia (Salzberg et al. 1996), anemia and hypoalbuminemia (DeLisa & Mikuli 1985; Scivoletto et al. 2004), spasticity, a history of previous ulcers (Vidal & Sarrias 1991; Byrne & Salzberg 1996; Guihan et al. 2008), an increase in tissue temperature (Fisher et al. 1978), and race and ethnicity (Guihan et al. 2008; Saladin & Krause 2009). However, Rabadi et al. (2011) did not find that modifiable vascular risk factors such as hypertension, diabetes mellitus, hyperlipidemia and current smoking, were related to the prevalence of pressure ulcer presence in a group of 87 veterans with SCI. They further showed that the groups were similar for age, gender, age of SCI onset, or SCI duration. Although some aspects of cardiovascular disease are considered modifiable, the absence of neurogenic control of vascular activity renders blood flow occlusion secondary to unrelieved pressure unmodifiable. This reduced vascular response has been shown to have a negative correlation to the Waterlow scale resulting in early tissue damage (Li 2011). Jan et al. (2011) confirmed this unmodifiable vascular characteristic in people with SCI compared to nondisabled controls. Thomas (2010) further stated that despite pressure relief diligence, tissue perfusion dysfunction in SCI is an unmodifiable intrinsic risk factor that needs special attention for more effective interventions. Wilczweski et al. (2012) identified hypotension as the strongest predictor of pressure ulcers.

Psychosocial factors are likely the most difficult to monitor but are similarly important to consider for the prevention of pressure ulcers. For example, Gelis et al. (2009) point out that behavioural factors have a bigger impact on pressure ulcer incidence and prevalence in the chronic stage (especially post-discharge) from both the care-giver and patient perspective. This is a concept that follows on the findings from a structured educational initiative to improve pressure ulcer prevention in veterans with SCI (Garber et al. 2002).

Although Saunders et al. (2010) support the notion of race as a risk factor (Guihan 2008), Saunders et al. (2010) found that African Americans with SCI are at higher risk for pressure ulcer development when they fall in a lower income level. Similar populations in Canada are not subject to this risk factor likely as a result of universal healthcare (Noreau et al. 2009). Gelis et al. (2009) also reported a similar finding and attributed the primary risk factor to the differing social-medical characteristics (e.g., level of education, access to healthcare) as proxy for the race risk factor (e.g., being African American).

Even with the numerous risk factors associated with pressure ulcers post SCI, there is limited evidence that, with more understanding of these risk factors, a decrease in pressure ulcer incidence will occur (Salzberg et al. 1996).

1.4 Assessment and Diagnosis

Identifying the significant risk factors associated with pressure ulcer development and being able to predict which individuals most at risk are considered key elements of prevention. A formal assessment is required as research has shown that clinicians tend to intervene only at
the highest levels of risk when an informal risk assessment is completed (Ayello & Braden 2002; AHCPR Executive Summary #3 1992; Keast et al. 2006). Many existing risk assessment tools were designed for the general population and for this reason their predictive value is imprecise in the SCI population (Consortium for Spinal Cord Medicine 2000; Houghton et al. 2013). In fact, the 2013 Canadian Pressure Ulcer Best Practice Guidelines go as far as to say that many existing tools have not been validated for use in the SCI population and “may [in fact] not perform better than clinical judgement” (Houghton et al. 2013).

A review of pressure ulcer risk assessment scales used with the SCI population was conducted by Mortensen and Miller (2008). Findings indicated that the SCIPUS (Salzberg et al. 1996) and SCIPUS-A (Salzberg et al. 1999), while developed specifically for the SCI population, are not yet recommendable for use without further psychometric testing. The Braden scale (Bergstrom et al. 1987) seems to be the best tool available thus far, without being well validated for the SCI population. There is adequate correlation of both the Braden and the SCIPUS scales with determining the stage of the first ulcer and of the number of ulcers (Salzberg et al. 1996; Salzberg et al. 1999; Wellard et al. 2000; Ash et al. 2002). There is no evidence supporting responsiveness for the Braden (Wellard et al. 2000) or SCIPUS over multiple assessments in the SCI population. Furthermore, Braden exhibits a ceiling effect when used in the SCI population (Wellard et al. 2000); ceiling effects have not yet been reported on for SCIPUS. Scovil et al. (2014) reported that perceived non-specificity to the SCI population led to low Braden completion rates (29%) and subsequent piloting of SCIPUS implementation. Psychometric properties of SCIPUS compared to Braden are anticipated from this group.

Another review of pressure ulcer healing assessment instruments was completed by van Lis et al. (2010). Of the eleven instruments reviewed, only two instruments had enough psychometric data to be considered useful and promising for use in the SCI population. The “ruler length and width” method was found to have good intra-rater and inter-rater reliability and concurrent validity. The Sessing scale was found to have moderate concurrent validity (van Lis et al. 2010).

Detailed analyses of SCI-specific psychometric properties for a variety of skin health assessment tools is available in SCIRE Outcome Measures (e.g., search alphabetically or by clinical area) at http://www.scireproject.com/outcome-measures. Below we will discuss the potential of new tools for diagnosis and assessment of pressure ulcers for the SCI population. Simple, reliable tools to regularly and consistently assess a person’s disposition for pressure ulcer development are much needed.

Table 4 Assessment and Diagnosis of Pressure Ulcers

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<th>Author Year Country PEDro Score Research Design Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
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<tr>
<td><strong>Handheld Dermal Phase Meter</strong></td>
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<tr>
<td>Guihan et al. 2012 USA Observational N=32</td>
<td>Population: Mean age=65.19 yr; Gender: males=32; Level of injury: Cervical=22, lumbar=1, thoracic=7, unknown=2; ASIA Classification: A=3, B=1, C=2, D=4, ASIA not available=22. Treatment: Feasibility study of using a handheld dermal phase meter. Outcome Measures: Sub-epidermal moisture (SEM), visual skin assessment and stage I pressure ulcers.</td>
<td>1. SEM was lowest for normal skin and higher for erythema/stage I pressure ulcers across all anatomic sites. 2. Ischial and buttocks SEM differentiated between normal skin and erythema/stage I pressure ulcers. 3. SEM taken at heels was lower across all skin conditions.</td>
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<td><strong>Ultrasonography</strong></td>
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<td>Author Year Country</td>
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<td>PEDro Score</td>
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<td>Kanno et al. 2009</td>
<td>Japan</td>
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<tr>
<td>De Heredia et al. 2012</td>
<td>UK</td>
<td>5</td>
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<tr>
<td>Loerakker et al. 2012</td>
<td>Netherlands</td>
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**Discussion**

A new non-invasive and practical handheld dermal phase meter is reported to detect increased sub-epidermal moisture and therefore predict the appearance of stage one pressure ulcers in the following week as was shown with a small group of predominantly female nursing home residents prevalent with urinary incontinence issues (Bates-Jensen et al. 2007). An
observational feasibility study to pilot this device was conducted on a group of 34 United States veterans with SCI. The device was found to be feasible but requiring a larger scale study to determine optimal frequency of use and threshold differences for various high risk locations on the body of those with SCI (Guihan et al. 2012).

Another method that can be used to detect early deep tissue dermal edema is high frequency ultrasonography. Using this technology in a non-randomized study with a blinded assessor, Kanno et al. (2009) demonstrated that ultrasonography was a useful tool for the early detection of deep tissue injuries or pressure ulcers. While the presence of low-echoic lesions were detected under both wounded (e.g., red or free floating) and normal skin detected by inspection and palpation, the absence of low-echoic lesions in the presence of inspection and/or palpation findings never occurred.

Magnetic resonance imaging (MRI) has become more common as a tool to visualize soft tissue pathology and therefore more important in the diagnosis and management of pressure ulcers in individuals with SCI. When 37 SCI patients with an indication of pressure ulcer underwent MRI scans (de Heredia et al. 2012), acute cortical bone erosion and abnormal marrow edema accurately predicted osteomyelitis, with strong intra-observer agreement (Hauptfleish et al. 2013). Given that osteomyelitis often follows non-healing pressure ulcers, MRIs can be a useful tool to expedite the treatment considerations for pressure ulcers and avoid devastating sequelae such as osteomyelitis.

Circulatory biomarkers for muscle damage have been proposed as an indicator of deep tissue injury in pressure ulcer development after SCI. Loerakker et al. (2012), in a small study (N=8) comparing muscle damage biomarkers, did not find differences between groups of able-bodied and SCI subjects. The expertise and time required for analysis to make use of this method may impose feasibility issues depending on laboratory capabilities at various health care facilities.

Conclusion

There is level 4 evidence (from one observational study; Guihan et al. 2004) that supports the use of a handheld dermal phase meter for the early detection of pressure ulcers secondary to SCI.

There is level 2 evidence (from one prospective controlled trial; Kanno et al. 2009) that supports the use of ultrasonography to extend the yield of routine inspection and palpation of suspected or early stage pressure ulcers in people with SCI.

There is level 3 evidence (from one case control study; de Heredia et al. 2012) that magnetic resonance imaging can predict the development of osteomyelitis in non-healing pelvic pressure ulcers in patients.

There is level 4 evidence (from one case series study; Loerakker et al. 2012) that reliance on circulatory biomarkers as an indication of muscle damage secondary to deep tissue injury in the SCI population cannot be recommended at this time.
The early detection of suspected pressure ulcers in individuals with SCI may be improved through the use of a handheld dermal phase meter and ultrasonography.

Magnetic resonance imaging may be helpful to anticipate the development of osteomyelitis secondary to non-healing SCI-related pressure ulcers.

Circulatory biomarkers in people with SCI have not yet proven to be useful or feasible to enhance early detection of suspected pressure ulcers.

1.5 Staging

“The assessment of an individual with a pressure ulcer is the basis for planning treatments, evaluating treatment effects and communicating with other caregivers” (AHCPR, Executive Summary #15 p 3). One key piece of this assessment is the staging of the pressure ulcer to classify the degree of tissue damage observed by the clinician (AHCPR, Executive summary #15 1992). In 1989, a staging system based on the original work of Shea in 1975, was refined and recommended by the National Pressure Ulcer Advisory Panel (NPUAP 1989). In 2007 as knowledge of the many factors associated with pressure ulcer formation emerged, two additional stages (Deep Tissue Injury [Suspected] Stage and Unstageable) were added to the original four to form the current six descriptive stages (NPUAP 2007).

Since 1989, this staging system has been used consistently in the literature and is widely supported (AHCPR 1992; Consortium of Spinal Cord Medicine 2000; Registered Nurses Associated of Ontario 2002; Houghton et al. 2013). However, authors of earlier studies have used numerous ways of documenting the severity of pressure ulcers making it challenging to draw parallels between older and newer studies.

Table 5 National Pressure Ulcer Advisory Panel’s (NPUAP) updated pressure ulcer staging system (NPUAP 2007)

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<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep Tissue Injury (Suspected) Stage</td>
<td>Purple or maroon localized area of discolored intact skin or blood-filled blister due to damage of underlying soft tissue from pressure and/or shear. The area may be preceded by tissue that is painful, firm, mushy, boggy, warmer or cooler as compared to adjacent tissue.</td>
</tr>
<tr>
<td>Stage I</td>
<td>Intact skin with non-blancheable redness of a localized area usually over a bony prominence. Darkly pigmented skin may not have visible blanching; its color may differ from the surrounding area.</td>
</tr>
<tr>
<td>Stage II</td>
<td>Partial-thickness loss of dermis presenting as a shallow open ulcer with a red pink wound bed, without slough. May also present as an intact or open/ruptured serum-filled blister.</td>
</tr>
<tr>
<td>Stage III</td>
<td>Full-thickness tissue loss. Subcutaneous fat may be visible but bone, tendon, or muscles are not exposed. Slough may be present but does not obscure the depth of tissue loss. May include undermining and tunneling.</td>
</tr>
<tr>
<td>Stage IV</td>
<td>Full-thickness tissue loss with exposed bone, tendon, or muscle. Slough or eschar may be present on some parts of the wound bed. Often includes undermining and tunneling.</td>
</tr>
<tr>
<td>Unstageable</td>
<td>Full-thickness tissue loss in which the base of the ulcer is covered by slough (yellow, tan, gray, green, or brown) and/or eschar (tan, brown, or black) in the wound bed.</td>
</tr>
</tbody>
</table>
1.6 Prevention

Preventing pressure ulcers is ultimately the best approach and begins at the time of injury. Lifelong prevention recommendations include examining skin daily to allow for early detection of a pressure ulcer, shifting body weight in bed and wheelchair on a regular basis independently or with assistance, keeping moisture accumulation to a minimum and cleaning and drying skin promptly after soiling, having an individually prescribed wheelchair, pressure redistribution cushion and power tilt mechanism if manual pressure relief is not possible, ensuring all equipment is maintained and functioning properly, decreasing or stopping smoking and limiting alcohol intake (Consortium for Spinal Cord Medicine 2000; Houghton et al. 2013). Krause et al. (2001) note that effective prevention strategies require individuals with SCI to take responsibility for their skin care. Prevention strategies must be individualized to promote sustainable outcomes. Individuals with SCI need assistance from health care professionals to integrate realistic prevention strategies into daily schedules (Clark et al. 2006). King et al. (2008) indicated that the value of preventative behavior needed to be emphasized. While in hospital, individuals with SCI need to practice skin care skills daily, learn to solve potential barriers while getting regular feedback on their performance. Support from both family and the health care team is essential. As well, patients need to understand how quickly and quietly a pressure ulcer may appear and how it must be treated promptly. Other strategies suggested for education include training by peers, presenting information in a variety of methods including group learning, simulation exercises and case studies (Dunn et al. 2009).

It should be noted that outcome assessment for pressure ulcer prevention can be measured via either direct or indirect means. That is, the effectiveness of preventative interventions can be determined by direct indicators, such as pressure ulcer incidence, or by indirect indicators, such as IT pressure mapping or transcutaneous oxygen tension (P\textsubscript{TCO}2) levels. The former are preferred as they reflect definitive indications of the success (or failure) of preventative interventions. Sheppard et al. (2006) indicated that knowing one’s skin tolerance was related to intention to do pressure relief. Attendance at a seating clinic would be helpful as skin tolerance can be measured.

Whenever possible, individuals who are at risk for pressure ulcer development or who are being treated for a pressure ulcer should be referred to a registered dietitian for assessment and intervention as necessary (Keast et al. 2006). In a study by Houghton and Fraser (2008), individuals with either paraplegia or tetraplegia living in the community with pressure ulcers (stage II to unstageable) underwent assessment that included medical and wound characteristics and screening of blood values for the presence of anemia, hydration status, glycemic control and hypoproteinemia. Study subjects with two or fewer abnormal blood values at the time of screening achieved complete wound closure following standard wound care and treatment with adjunctive therapy. Individuals who presented with greater than two abnormal blood values related to nutrition and hydration status did not achieve wound closure. The authors recommended that all individuals with pressure ulcers be screened for underlying inadequacies in nutrition and hydration and receive intervention to address these issues to promote optimal wound healing. Alexander et al. (1995) found that patients with paraplegia and a pressure ulcer had a resting energy expenditure that was hypermetabolic underscoring the need for thorough assessment and adequate nutritional support.

Recommendations for prevention or treatment of a pressure ulcer would include eating a well-balanced, nutritionally complete diet with appropriate calories, proteins, micronutrients (vitamins and minerals) and fluids. The nutrition plan must be individualized based on the assessed...
needs (Consortium for Spinal Cord Medicine 2000; Keast et al. 2006; Houghton et al. 2013). If a pressure ulcer is present, the plan would need to be optimized using foods, supplements and/or enteral nutrition, if warranted. The individual’s weight would need to be monitored as an undesirable weight trend has been identified as an early indicator of risk (Keast et al. 2006).

There have been numerous recommendations for the prevention of pressure ulcers post SCI but it is important to consider the evidence that informs those recommendations. Potential preventative techniques found in the SCI literature that have been reviewed include effect of electrical stimulation on ischial pressures and blood flow, pressure relief practices, wheelchair cushion selection, effect of lumbar support thickness on ischial pressures, specialized seating clinics, pressure ulcer prevention education, behavioural contingencies, and telerehabilitation.

1.7 Treatment

Once a pressure ulcer has begun it is important to prevent it from worsening and ultimately to have it heal quickly but this is challenging. Rappl (2008) examined the metabolic and physiological changes that happen in tissue below the level of a SCI in relation to the events which take place during wound healing. The author examined that every step of wound healing is affected by the physiological changes that occur post SCI explaining why pressure ulcers may heal more slowly in individuals with a SCI. As previously stated, severe pressure ulcers can lead to further disability, surgery, amputation and death (Krause 1998). According to Chen et al. (2005) pressure ulcers are among the leading cause of unplanned rehospitalization post SCI and can contribute to longer lengths of stay and more costly treatment than other medical conditions. Once an individual has had an ulcer they are at increased risk for recurrence (Krause & Broderick 2004; Verschuuren et al. 2011). Pressure ulcer treatment is more costly than prevention (Bogie et al. 2000; Jones et al. 2003). In addition to standard wound care, many adjunctive therapies are used to accelerate closure of wounds that are hard to heal. It is important to identify appropriate clients, through appropriate and regular assessment, who are likely to benefit for these treatments as they are often time consuming and expensive (Houghton & Fraser 2008; Allen & Houghton 2003).

Research has examined the effect of a variety of therapies on pressure ulcer healing including electrical stimulation, laser, ultrasound, non-thermal pulsed electromagnetic energy, topical negative pressure, normothermia, recombinant human erythropoietin, anabolic steroid therapy, dressings, maggot therapy, topical oxygen, surgery, and herbal remedies; each of these treatments will be discussed in subsequent sections.

2.0 Prevention

2.1 Electrical Stimulation

Electrical stimulation (ES) has been used since the 1960s to enhance healing of various chronic wounds including pressure ulcers in both able-bodied and SCI individuals (Kloth & Feeder 1988; Baker et al. 1996; Bogie et al. 2000). More recently, ES has been studied to assess its potential for pressure ulcer prevention post SCI.

Given that the primary cause of pressure ulcers is postulated as externally applied pressure over bony prominences such as the IT (Bogie et al. 1995), researchers have studied the role of ES in reducing ischial pressures and redistributing seating interface pressures towards prevention (Bogie et al. 2006). ES-related prevention of pressure ulcers in individuals with SCI
are directed at skin versus muscle stimulation, dynamic versus long-term effects and surface versus implanted devices (Levine et al. 1990; Bogie et al. 2000; Bogie et al. 2006).

ES also has the ability to change blood flow to skin and muscle. Bogie et al. (2006) state that with increasing interface pressures over bony prominences, regional blood flow is adversely affected. By reducing IT pressure, regional blood flow could be improved and in turn, tissue health could be useful in pressure ulcer prevention (Levine et al. 1990; Bogie et al. 1995; 2000; 2006).

Table 6 Effects of Electrical Stimulation on Pressure Ulcer Prevention

<table>
<thead>
<tr>
<th>Author Year Country PEDro Score Research Design Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
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<tbody>
<tr>
<td><strong>Smit et al. 2013a Netherlands Pre-post N=10</strong></td>
<td>Population: Mean age=40.6 yr; Gender: males=7, females=3; ASIA Classification: A=6, B=3, C=1. Intervention: Electrical stimulation (ES) using cushion made electrode garment (shorts) with built-in electrodes. Participants took part in two different protocols with differing stimulation-rest intervals (1:1s and 1:4s). <strong>Outcome Measures:</strong> Usability of shorts and IT pressure.</td>
<td>1. Both protocols resulted in an acute significant decrease of pressure during ES compared to no ES. 2. IT pressure at least 32% in both protocols. 3. IT pressure and pressure gradient during ES compared with rest were not significantly different between the time within protocol. 4. Overtime, protocol 1:4 had significantly more of an effect than protocol 1:1. 5. Fatigue occurred more in the 1:1 protocol than the 1:4 protocol. 6. Three participants needed help to put on the ES shorts. 7. No participants found the ES shorts to interfere with daily activities but the stimulator did hinder 5 of the participants in daily activities (e.g., hinder the working of a catheter). 8. All participants reported they experienced protocol 1:4 as more comfortable than 1:1.</td>
</tr>
<tr>
<td><strong>Smit et al. 2013b Netherlands Pre-post N=12</strong></td>
<td>Population: Mean age=38.1 yr; Gender: male=12; ASIA Classification: A=6, B=3, C=1. Intervention: Electrical stimulation (ES) induced gluteal and hamstring activation and pressure relief movements (PMRS) – push-ups, bending forward and leaning sideways. <strong>Outcome Measures:</strong> IT pressure, ischial oxygenation and blood flow (BF) were measured.</td>
<td>1. Compared with rest, IT pressure was significantly lower during all PMRs. 2. ES-induced gluteal and hamstring muscle activation reduced IT pressure. 3. No significant differences between PRM and ES conditions. 4. Nine of the 12 participant’s oxygenation data was collected. PMRs significantly increased mean oxygenation compared to rest but ES did not. 5. PMRs increased BF significantly but ES did not cause a significant change.</td>
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<tr>
<td>Author Year</td>
<td>Country</td>
<td>PEDro Score</td>
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</table>
| Smit et al. 2012 | Netherlands | Pre-post | N=10                      | Population: Mean age=33.7 yr; ASIA Classification: A=8, B=1, C=1. | Intervention: Electrical stimulation (ES) using cushion made electrode garment (shorts) with built-in electrodes. Just gluteal (g) or gluteal and hamstring (g+h) muscles were activated. | 1. In all participants, both protocols of g and g+h ES-induced activation resulted in a significant decrease of IT pressure.  
2. IT pressure after g+h muscles activation was reduced significantly by 34.5% compared with rest pressure.  
3. Significant reduction of 10.2% after activation of g muscles only.  
4. Pressure gradient reduced significantly only after stimulation of g+h muscles (49.3%).  
5. G+h muscle activation showed a decrease in pressure relief over time compared with g muscles. |
| Gyawali et al. 2011 | Canada | Pre-post | N=17                      | Population: Mean age=37.2 yr; Gender: males=10, females=7; Level of injury: cervical=13, thoracic=4. | Intervention: Intermittent electrical stimulation (IES; 40 Hz) on the gluteus maximus muscles. Two paradigms of IES were used: continuous (7 or 13s) and bursting (3s on, 3s off). | 1. Both IES paradigms significantly reduced pressure over the IT (p<0.05), with the mean range of pressure reductions being 10-26%.  
2. Both IES paradigms significantly increased signal intensity compared to baseline (p<0.05) showing an increase in tissue oxygenation. |
| Van London et al. 2008 | Netherlands | Case Series | N=13                      | Population: Age range: 20-74 yr; Gender: 12 males, 1 female; Cause of injury: SCI; Level of injury: C4-C7 (n=5), T5-T11 (n=8), tetraplegia and paraplegia; Type of injury: 8 complete, 5 incomplete. | Intervention: Participants received 2 surface electric stimulation protocols with 15 minutes rest between: 1) left and right gluteal muscles stimulated alternately; 2) left and right gluteal muscles stimulated simultaneously. | 1. No significant difference between left and right for any measure used.  
2. Change in pressure under IT (interface pressure) significantly decreased (p<0.001) between rest periods and alternating stimulation (106 +/- 30 mmHg to 88 +/- 30 mmHg); and a significant decrease (p<0.001) between rest period and simultaneous stimulation (100 +/- 30 mmHg to 81 +/- 33 mmHg).  
3. Maximum pressure decreased in both alternating (by 21 +/- 16 mmHg, p=0.001) and simultaneous (by 25 +/- 19 mmHg, p=0.001).  
4. Pressure spread did not differ significantly for either protocol between stimulation and rest (p=0.123, alternating; p=0.197, simultaneous).  
5. Pressure gradient decreased (p=0.002) between rest period and alternating stimulation (65 +/- 46 mmHg to 53 +/- 41 mmHg) and decreased (p=0.001) between rest period and simultaneous stimulation (67 +/- 52 mmHg to 53 +/- 46 mmHg).  
6. No significant change during either alternating or simultaneous protocols between beginning and end of the protocol for interface pressure at IT, pressure distribution, pressure gradient. |
<table>
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<tr>
<th>Author Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
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<tbody>
<tr>
<td>Liu et al. 2006a</td>
<td>United Kingdom</td>
<td>Case Series</td>
<td>N=10</td>
<td>Population: Sacral Anterior Root Stimulation (SCI group) (n=5): Gender: 4 males and 1 female; Level of injury: T3-T11 (complete paraplegia); Time since injury: 9-24 yr. Functional Magnetic Stimulation (non-disabled group) (n=5): Age range: 29-60 yr; Gender: 5 males. <strong>Intervention:</strong> Non-disabled group received Functional Magnetic Stimulation; SCI group received Sacral Anterior Root stimulation; Seat pressures recorded before, during and after stimulations seated in a standard w/c with foam cushion. <strong>Outcome Measures:</strong> Peak pressure and associated gradient compared before, during and after stimulation.</td>
<td></td>
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</tr>
<tr>
<td>Liu et al. 2006b</td>
<td>UK</td>
<td>Prospective Controlled Trial</td>
<td>N=5</td>
<td>Population: SCI: Mean age=45 yr; Gender: males=4, females=1; Level of injury: paraplegia=5; Severity of injury: complete=5. <strong>Intervention:</strong> Sacral anterior root stimulator (SARS) implant applied bilateral electrical stimulation for 10 seconds (frequency=20 pps; pulse width range=8-800 secs; amplitude of “1”). Second sacral nerve root was stimulated (S2). <strong>Outcome Measures:</strong> Peak Pressure (PP) &amp; Gradient Peak Pressure (GPP); before and during electrical stimulation using pressure mapping.</td>
<td></td>
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<td>Bogie &amp; Triolo 2003</td>
<td>USA</td>
<td>Pre-post</td>
<td>N=8</td>
<td>Population: SCI: Age=27-47 yr; Gender: males=7, females=1; Severity of injury: AIS: A=6, B=2. <strong>Intervention:</strong> The exercise regimen included 3 different stimulation patterns. Duration of exercise was varied over the or maximum pressure for the alternating protocol. 7. A significant decrease (p=0.04) in maximum pressure by 2+/-.4 mmHg from beginning to end of simultaneous protocol 8. There were no significant differences between stimulation protocols in the effect between beginning and end.</td>
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1. There was an average 33% decrease in PP during stimulation (at rest=148.6 mmHg; during functional electrical stimulation (FES) =99.8 mmHg; p<0.01). 2. There was also a mean 38% decrease in GPP during stimulation (at rest=54.6 mmHg; during FES=33.8 mmHg; p<0.05). 3. An increase in pulse width resulted in lower PP. Lowest PP was attained at a stimulation pulse width range from 64-600 secs. 4. No complications were reported. 1. Overall, with chronic neuromuscular electrical stimulation (NMES), mean interface pressure showed no significant differences between baseline and post exercise levels. 2. Mean ischial region interface pressure
<table>
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<tr>
<th>Author Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferguson et al. 1992</td>
<td>Scotland</td>
<td>Cohort</td>
<td>N=9</td>
<td></td>
</tr>
<tr>
<td>Liu et al. 2006a</td>
<td>UK</td>
<td>Prospective Controlled Trial</td>
<td>N=6</td>
<td></td>
</tr>
<tr>
<td>Bogie &amp; Triolo 2003</td>
<td>USA</td>
<td>Pre-Post Test</td>
<td>N=8</td>
<td></td>
</tr>
<tr>
<td>Mawson et al. 1993</td>
<td>USA</td>
<td>Prospective Controlled Trial</td>
<td>N=32</td>
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<tr>
<th>Methods</th>
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<td>Content</td>
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8 wk training period as the muscles became conditioned. **Outcome Measures**: Mean interface pressure, mean ischial region interface pressure.

1. Difference between resting and stimulated pressures at the ischia were statistically significant except for in one participant.
2. Pressure reduction occurred at the right ischia of all subjects.
3. Pressure reduction occurred for the left ischia in 7 subjects.
4. Heavier subjects showed relatively small pressure drops.
5. Average pressure drop at the right buttocks was 44 mmHg and 27 mmHg for the left.

**Electrical Stimulation to Increase Tissue Blood**

Population: Mean age=35-62 yr; Gender: males=5, females=1; Level of injury: T3-T1; Severity of injury: complete=6; Time since injury=9-24 yr.

**Intervention**: Sacral anterior root stimulator implant applied bilateral electrical stimulation to S2 nerve root for 10 seconds (frequency=20 pps; pulse width range 8-800 seconds; amplitude of “1”).

**Outcome Measures**: Cutaneous Hemaglobin (IHB); Oxygenation (IOX) before and during electrical stimulation.

1. IHB significantly increased during stimulation (before stimulation, M=0.8; during stimulation, M=0.9; p=0.005).
2. IOX also increased (before stimulation, M=1.1; during stimulation, M=3.0; p=0.02).

Population: Mean age=27-47 yr; Gender: males=7, females=1; Level of injury: C5/6 to T9; Severity of injury: AIS: A=6, B=2.

**Intervention**: Electrical stimulation delivered via an implanted neuroprosthesis, which included gluteal electrodes, 8 wk of conditioning exercises followed.

**Outcome Measures**: Transcutaneous Oxygen Levels.

1. Baseline mean unloaded tissue oxygen levels increased by 1-36% at post exercise assessment for 5/8 subjects.
2. Differences between baseline and post exercise tissue oxygen levels did not show any statistical significance.

Population: Mean age=18-57 yr; Site of ulcer: sacral=7, heel=2, other=1; Ulcer grade: 1-4.

**Intervention**: Study was carried out on SCI patients lying on egg crate mattresses. Sensor was applied to the skin at approximately the second sacral segment along the midline using a two-sided airtight seal. Two electrodes and conductive sponges, measuring 4 cm in diameter were used for administering electrical stimulation.

1. Experiment 1: Subsequent experiments were performed using 75 volts as no additional effect on $P_{tcO_2}$ was seen when 100 volts was used.
2. Experiment 2: Compared to final baseline $P_{tcO_2}$ reading (mean ± SD) of 49±21mmHg, the level reached at the 30min period of high voltage pulsed galvanic stimulation (HVPGS) was 66±18 mmHg -- 35% higher (p<0.00001).
3. The level fell slightly following the first
Discussion

Several articles were found that examined the effects of ES on ischial pressure. Ferguson et al. (1992) used functional electrical stimulation (FES) on the quadriceps of restrained lower legs in seated SCI subjects and found a significant change in ischial pressure reduction. However, the authors were not able to provide recommendations for stimulation frequency and duration parameters based just on this small (N=9) preliminary study. Bogie and Triolo (2003) studied changes in interface pressure distribution at the support/surface interface following eight weeks of gluteal neuromuscular electrical stimulation (NMES) delivered via an implanted neuroprosthesis. With NMES, mean ischial regional interface pressure tended towards a uniform decrease in post-exercise pressures (p<0.01).

Liu et al. (2006b) studied the effects of ES delivered via an implanted sacral anterior root stimulator on seat interface pressure distribution. With ES functional magnetic stimulation of the S2 nerve root, sufficient to result in gluteal muscle contraction, there was an average decrease of 33% in peak pressure (p<0.01) and a 38% decrease in gradient peak pressure (p<0.05) at the IT of the seated participants.

Smit et al. (2013a) sought to understand the effect of varying ES parameters applied for three hours to the gluteal and hamstring muscles via a custom-made electrode garment (i.e., shorts) with built-in electrodes to achieve IT pressure relief. They found that an on-off ES ratio of 1:4 seconds (versus 1:1 seconds) provided better IT pressure relief (32% reduction; p=0.04) without marked muscle fatigue. Study subjects also provided feedback that the ES shorts were satisfactory for daily use. An earlier study revealed that ES of the gluteal muscles alone and in combination with the hamstring muscles both provided pressure relief around the IT (Smit et al. 2012); the latter was more effective (p=0.01). When stimulating the gluteal muscles alone, there was no reported difference between two different stimulation protocols on decreased interface pressure in seated people with SCI (van Londen et al. 2008).

It is encouraging that study subjects scored the usability of the ES shorts as satisfactory (Smit et al. 2013a) as this represents progress for the feasibility of ES in clinical and daily living situations. Despite the usability of the ES shorts reported by Smit et al. (2013a), Smit et al. (2013b) found that ES-induced muscle activation was not as effective as pressure relief movements on IT pressure, and on blood flow and oxygenation of the gluteal and hamstring muscles. However, the frequency of ES is much higher and more reliable than the performance of pressure relieving movements making ES potentially more effective for pressure relief in the long term. Gyawali et al. (2011) did present evidence to show that intermittent ES resulted in some improved tissue oxygenation in addition to significant pressure redistribution in loaded muscles of individuals with SCI. Mawson et al. (1993; N=29) also found that sacral tissue
oxygen levels were 35% higher (p<0.001) after 30 minutes of high voltage pulsed galvanic stimulation.

Conclusion

There is level 2 evidence (from one prospective controlled trial and one cohort study; Lui et al. 2006b; Ferguson et al. 1992) supported by level 4 evidence (from five pre-post studies, and two case series studies; Smit et al. 2012, 2013a, 2013b; Gyawali et al. 2011; Bogie & Triolo 2003; Van London et al. 2008; Liu et al. 2006a) that electrical stimulation decreases ischial pressures post SCI.

There is level 4 evidence (from one pre-post study; Bogie & Triolo 2003) that electrical stimulation may increase blood flow at sacral and gluteal areas post SCI.

There is level 2 evidence (from two prospective controlled trials and one pre-post study; Lui et al. 2006a; Mawson et al. 1993; Bogie & Triolo 2003) that electrical stimulation may increase tissue oxygenation post SCI.

<table>
<thead>
<tr>
<th>Electrical stimulation likely decreases ischial pressures.</th>
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<tbody>
<tr>
<td>Electrical stimulation may increase blood flow to tissues.</td>
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<tr>
<td>Electrical stimulation likely increases tissue oxygenation.</td>
</tr>
<tr>
<td>Electrical stimulation likely helps to prevent pressure ulcer formation or progression by reducing ischial pressures and increasing tissue oxygenation.</td>
</tr>
</tbody>
</table>

2.2 Pressure Mapping

2.2.1 SCI vs. Able-Bodied Participants

Concern has been raised regarding the use of data from studies where able-bodied subjects are used and results are generalized to a disabled population, particularly in relation to the use of pressure mapping (fully discussed in the SCIRE Wheeled Mobility chapter). The use of able-bodied subjects is often seen in the pressure mapping data provided by support surface manufacturers. Several studies have looked at pressure mapping comparisons between disabled and non-disabled subjects to determine if there is a difference in pressure data. Drummond (1985) compared pressure mapping values of 16 subjects with paraplegia (14 with spina bifida cystica; 2 traumatic) with 15 normal subjects. The paraplegia group was divided further into those who developed ulcers (n=10) and those who did not (n=6). In subjects with ulcerations, the posterior distribution of high pressure under the IT and coccyx areas were an average of 60% of the body weight compared to 40% in the normal group. The majority of subjects (8/10) with ulcers showed asymmetrical IT loading with greater than 30% of body weight on one IT, in contrast to 0 subjects in both the non-ulcerated and normal subjects. Further, the majority of subjects (8/10) with ulcers had greater than 11% of the weight distributed to sacral and coccyx regions compared to 2/6 non-ulcerated and 0 normal subjects (Drummond 1985).

Results of a study by Stinson et al. (2003), in which the relationship between interface pressure and body mass index, gender and seating positions were evaluated in 63 volunteer students, indicated that there was no significant relationship between average pressures and height,
weight or gender. This was confirmed by a study by Karatas et al. (2008) where these same parameters were compared between 16 subjects with SCI and 18 healthy volunteer subjects. Comparing average pressure and body mass index, Stinson et al. (2003) showed significance (p<0.01) whereas the study by Karatas did not (p>0.05). Karatas et al. (2008) also used pressure mapping to examine centre of pressure displacement. Centre of pressure displacement in patients with SCI was significantly smaller in all directions than in healthy volunteers (p<0.05).

Table 7 SCI vs. Able-Bodied Participants

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
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<tbody>
<tr>
<td>Hobson 1992</td>
<td>USA</td>
<td></td>
<td>Prospective Controlled Trial</td>
<td>N=22</td>
<td>Population: SCI group (n=12); Mean Age=40.9 yr; Gender: males=10, females=2; Level of injury: paraplegia=7, tetraplegia=5; Severity of injury: complete; Mean time since injury=19.5 yr. Able-Bodied group (n=10); Mean age=39.3 yr; Gender: males=6, females=4. Intervention: Comparison of Pressure mapping and shear measurements from midline neutral posture to eight typical wheelchair-sitting postures (trunk bending left and right, forward trunk flexion 30 and 50 degrees, back recline 110 and 120 degrees and tilt 10 and 20 degrees). Outcome Measures: Tangentially induced shear (TIS) measuring shear forces; Pressure distribution – Oxford Pressure Monitor Device measuring average and maximum pressure and peak pressures gradient.</td>
<td>1. Mean maximum pressure was on average 26% higher in the SCI group versus the able-bodied group. 2. Forward trunk flexion reduced the average pressure for both groups; however, SCI group encountered a 10% increase in pressure at the initial 30° of forward flex before a reduction occurred. 3. SCI subjects had a mean peak pressure gradient that was 1.5-2.5 greater than able-bodied subjects. Maximum decrease of pressure gradient from a neutral position happened after the backrest reclined to 120°. 4. When a sitting position change occurred, a similar shift to the anterior/posterior midline location of maximum pressure was experienced in both groups. From neutral, a forward trunk flexion at 30° and 50° produced a 2.4 and 2.7 cm posterior shift. When the backrest reclined to 120°, the greatest posterior shift occurred at 6 cm.</td>
</tr>
<tr>
<td>Gutierrez et al. 2004</td>
<td>Sweden</td>
<td></td>
<td>Case Control</td>
<td>N=33</td>
<td>Population: SCI group: Gender: males=25; Level of injury: paraplegia=25; Severity of injury: AIS A=25. Able-bodied group: Gender: males=8. Intervention: Posture changes as related to pressure, contact area and symmetry of loading, on a standardized hard surface and for SCI, in their wheelchair as well. Outcome Measures: Pressure distribution via Tekscan Pressure Mat.</td>
<td>1. Significant differences were found between the groups. SCI group had increased pressure (p&lt;0.01), decreased contact area (p&lt;0.01) and increased asymmetry (p&lt;0.05). 2. The wheelchair improved pressure distribution, as compared to the hard surface. Although total seating area force increased (p&lt;0.01), the pressure reduced and the contact area increased (p&lt;0.01). 3. No improvements occurred when comparing relaxed and upright position in the wheelchair.</td>
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</tbody>
</table>
Discussion

Hobson (1992) evaluated the pressure distribution differences between able-bodied and SCI populations. The results indicated that the SCI population had, on average, 26% higher maximum pressure in all nine postures evaluated. Hamanami et al. (2004) identified the highest pressures were at the IT. Gutierrez et al. (2004) found a significant difference between their SCI group and control group, with the SCI group having increased pressure, decreased contact area and increased asymmetry. Gutierrez et al. (2004) indicated that subjects with SCI were supporting the same weight as the able-bodied subjects, but on a smaller area of surface contact with asymmetries, resulting in a higher maximum pressure; therefore, it is important to assess loading asymmetries for the SCI population. Gutierrez et al. (2004) found no significant differences in sitting configurations for high versus low thoracic SCI.

Conclusions

There is level 2 evidence (from one prospective controlled trial; Hobson 1992) to support not generalizing pressure mapping data from able-bodied subject to SCI subjects.

There is level 4 evidence (from one case control study; Gutierrez et al. 2004) to support the typical locations for high pressure in the SCI population being the ischial tuberosities and the coccyx.

Pressure mapping studies using able-bodied subjects should not be generalized to the SCI population because pressure differences exist between the two groups.

Typical areas of high pressure for the SCI population include sacrum, coccyx and/or ischial tuberosities.

2.2.2 SCI vs. Elderly Participants

The elderly have been identified as an at-risk group for skin integrity issues due to the normal changes in skin as it ages. This, in combination with decreased ambulation and more time spent in sitting, results in increased pressure related skin integrity issues. There are many similarities in potential contributing factors in pressure related skin issues of the elderly population and the SCI population. Brienza and Karg (1998) compared sitting pressures between these two groups.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
</thead>
</table>
| Brienza & Karg | 1998 | USA     | Prospective Controlled Trial | N=12 | Population: Age=21-52 yr; BMI range: 17-32.3 kg/m². Treatment: Assessed forces for 3 different surfaces (flat foam, the initial contour and final optimized contour) with the force sensing array pad between the cushion and buttocks. Compared SCI to seniors group. | 1. There was no difference in tissue stiffness between SCI and senior group on any of the surfaces.  
2. There was a significant difference in pressure for the initial contour condition between SCI and seniors (p=0.027, p=0.017, respectively), but not within other conditions. |
Outcome Measures: Electronic Shape Sensor; Computer Automated Seating System.

3. The mean maximum depth was significantly deeper for the final contour as opposed to the initial contour (p<0.0001). Also, the mean maximum depth was deeper in the SCI group than the senior group within the final contour condition (p=0.016, p=0.052, respectively).

4. Significant differences in interface pressure were found between flat and initial contour (p=0.023) and flat and final contour (p=0.006). No difference was found between the initial and final contour condition.

Discussion

Brienza and Karg (1998) found differences in interface pressure mapping between participants with SCI and elderly adults. Elderly adults are also often at risk of skin integrity issues due to pressure but not across as many parameters as people with SCI. This study identified significant differences between these two groups across most parameters measured, suggesting that data from pressure mapping should not be generalized between groups.

Conclusion

*There is level 4 evidence (from one prospective controlled trial; Brienza & Karg 1998) to support not generalizing pressure mapping data from the elderly population to the SCI population.*

Data generated from pressure mapping studies on seniors should not be generalized to the SCI population.

2.3 Specialized Seating Clinics

Developing the ability to maintain skin integrity and prevent pressure ulcer formation is an important component of any SCI rehabilitation program. Prevention education includes an emphasis on taking personal responsibility for maintaining healthy skin through personal care, inspection of skin, pressure relief and correct use of prescribed equipment. The incorporation of seating clinics into both the inpatient and outpatient rehabilitation program has been shown to reduce the incidence of pressure ulcers and readmission rates due to pressure ulcers (Dover et al. 1992). Seating clinics not only provide education but also make recommendations for appropriate seating systems based on interface pressures, thermography and assessment of tissue viability. Verbal and visual feedback is provided to the individual with SCI and active participation is encouraged (Dover et al. 1992; Coggrave & Rose 2003; Kennedy et al. 2003).

Table 9 Effect of Specialized Clinics on Pressure Ulcer Prevention
Kennedy et al. (2003) studied 50 individuals with SCI participating in a comprehensive rehabilitation program. The individuals were divided into 3 groups to determine if attendance at a specialized seating assessment clinic (SSA) would improve skin management ability as evidenced by lower “to be achieved” scores on the skin subscale of the Needs Assessment Checklist (NAC); optimal timing of attendance at the SSA was also studied. Results indicated significant differences between group 1 (attendance at SSA prior to NAC 1 (within one month of mobilization)) and group 3 (no attendance at SSA) at both NAC 1 (p<0.05) and NAC 2 (on admission to pre-discharge ward) (p<0.01). Skin management “to be achieved” scores were significantly lower for individuals who attended SSA before their first NAC at both time points. Significant differences were also observed between “to be achieved” scores at first and second NAC within all groups: Group 1 (p<0.0001), Group 2 (p<0.01) and Group 3 (p<0.01). Results indicate that attendance at a SSA did improve individual’s skin management abilities and that early attendance was optimal. The results also indicate that attendance at SSA is an adjunct to the skin management abilities taught during a comprehensive rehabilitation program. More research is needed to determine if early attendance at a SSA translates into prevention of pressure ulcers over time.

For study reviews related wheelchairs and seating as well as the effects of position/postural changes in relation to pressure management, as measure by interface pressure mapping and blood flow measurements, please refer to the SCIRE Wheeled Mobility chapter.

**Conclusion**

*There is level 2 evidence (from one cohort study; Kennedy et al. 2003) showing that early attendance at specialized seating assessment clinics increases the skin management abilities of individuals post SCI.*
2.4 Pressure Ulcer Prevention Education

Pressure ulcer prevention education programs for individuals with SCI provide knowledge and emphasize behaviours intended to reduce the risk of pressure ulcer occurrence (Bogie 1995; Rodriguez & Garber 1994; Schubart et al. 2008). Although there is much diversity about specific educational programming conducted across various settings, typical approaches in inpatient rehabilitation include structured programs, often delivered in group lecture formats (question and answer), augmented by unstructured, informal “just-in-time” education delivery and content driven educational materials such as pamphlets, information sheets, websites or binders (Lawes et al. 1985; Wolfe et al. 2012). Typically this education is delivered while the individual is an inpatient at a time when they and their family are adjusting to a diagnosis of SCI and are likely suffering from information overload. Under these circumstances, an individual's ability to appreciate the knowledge and behaviours necessary to prevent pressure ulcers over their lifetime is likely compromised (Garber et al. 1996; Potter et al. 2004; Schubart et al. 2008). With shorter lengths of stay, there is less time to deliver prevention education and fewer opportunities for reinforcement of acquired knowledge. This means that individuals with SCI are being discharged with potentially less information on pressure ulcer prevention (Garber et al. 1996). As well, there is little data on the specific education needs required by individuals with SCI at risk for pressure ulcer formation (May et al. 2006; Schubart et al. 2008).

Table 10 Pressure Ulcer Prevention Education

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rintala et al. 2008</td>
<td>USA</td>
<td>PEDro=6</td>
<td>RCT</td>
<td>N=41</td>
<td>Population: Mean age=29-78 yr; Gender: males; Injury etiology: SCI=39, multiple sclerosis=2; Level of injury: cervical=39%, thoracic=56%; Severity of injury: complete=68%. Intervention: SCI and multiple sclerosis patients receiving surgical repair of a stage III or IV pressure ulcer were randomized into 3 groups: Group 1: received an enhanced education and monthly structured follow-up intervention (via telephone) for 2 yr after discharge; Group 2: received monthly contacts (via mail) for up to 2 yr after discharge to assess skin status, but no education; Group 3: received minimal contact by mail every 3 mo for up to 2 yr after discharge to assess skin status but no education. Outcome Measures: Recurrence of pressure ulcers or 2 yr after discharge.</td>
</tr>
</tbody>
</table>

1. Group 1 had a significantly longer time before recurrence of pressure ulcers than other groups, p=0.002; while no significant difference was seen between Group 2 and 3.
2. Individuals were ulcer free longer if many yr had passed since their last surgery.
3. Health status had no significant effect on staying ulcer free.
4. For those with no previous ulcer surgery, persons in Group 1 were ulcer free longer than those in Group 2 or 3 (19.6 vs. 10.1 or 10.3 mo).
5. Ulcer recurrence occurred in 1/3 of Group 1 (33.3%) compared to Group 2 (60%) and Group 3 (90%).
<table>
<thead>
<tr>
<th>Author Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garber et al. 2002</td>
<td>USA</td>
<td>PEDro=5</td>
<td>RCT</td>
<td>N=41</td>
<td>Population: Mean age=53 yr; Gender: males=41; Injury etiology: SCI=39, multiple sclerosis (MS)=2; AIS: A=28, B=10, D=1. MS=2; Time since injury=17 yr. Intervention: Intervention group (n=20): four 1-hr enhanced education sessions dealing with management and prevention of pressure ulcers and structured follow-up (monthly telephone contact regarding skin status and use of prevention behaviours). Control group (n=21): Standard educational information given with no structured follow-up (periodic telephone contact to address skin status only). All subjects followed for 2 yr after discharge or until recurrence of pelvic pressure ulcer. Outcome Measures: Demographic and health information questionnaire; Pressure ulcer knowledge test; Health beliefs questionnaire; Multidimensional health locus of control scale.</td>
<td>1. At discharge, both groups had an improvement on the pressure ulcer knowledge test, but more pressure ulcer knowledge was acquired within the intervention group (p&lt;0.03). 2. At discharge, no notable differences were found on the health beliefs questionnaire and the multidimensional health locus of control scale. 3. Even though both groups remembered pressure ulcer knowledge obtained 2 yr prior, the intervention group maintained a higher level of pressure ulcer knowledge (68%) than did the control group (60.8%) at 2 yr post-discharge.</td>
</tr>
<tr>
<td>Schubart 2012</td>
<td>USA</td>
<td>Pre-post</td>
<td>NInitail=15; Nfinal=14</td>
<td>Population: Median age=37 yr; Gender: males=10, females=5; Level of injury: cervical=8, thoracic=5, lumbar=2. Intervention: Interactive e-learning program about pressure ulcer prevention and management completed over a two wk timeframe. Follow-up questionnaire. Outcome Measures: (1) Internet evaluation and utility questionnaire; (2) Internet impact and effectiveness questionnaire; (3) Internet adherence questionnaire; (4) Knowledge acquisition using a questionnaire (based on the Needs Assessment Checklist) assessing skin and posture management, mobility and transfers, and wheelchair/equipment.</td>
<td>1. Program rated “mostly” or “very” easy to use, with the information being understandable and useful. 2. The impact of increasing confidence in prevention/detection of pressure ulcers was rated “mostly” (n=4) and “very” (n=10). 3. Adherence was rated as “slightly” (n=2), “somewhat” (n=10), and “very” (n=2), with the mean sitting lasting 45 minutes. 4. Mean total knowledge scores increased from 92 to 106. Means by subsection: skin and posture, 39 to 49; mobility, 32 to 34; and equipment, 20 to 23. Greatest improvement was shown for skin checks and prevention of skin problems (p&lt;0.005).</td>
<td></td>
</tr>
<tr>
<td>Thietje et al. 2011</td>
<td>Germany</td>
<td>Pre-post</td>
<td>N=214</td>
<td>Population: Level of injury: paraplegia=122, tetraplegia=92. Intervention: Neurological examinations of patients admitted between January 2005 and May 2008. Outcome Measures: (1) Performance of everyday tasks using the Spinal Cord Injury Measurement (SCIM) II; (2) Knowledge of pressure ulcers and bladder management pre and post discharge using the Knowledge Boberg Score; (3) Patients asked source of knowledge. Measures were taken at admission, 1 and 3 mo post-admission, and 6, 18 and 30 mo post discharge.</td>
<td>1. Total SCIM II was higher at discharge compared to admission (p&lt;0.001). Scores increased until 18 mo post-discharge. 2. Mean knowledge scores increased from admission to discharge (5.4 to 11.2, p&lt;0.001). At discharge knowledge was rated as poor, average or good for 22.4%, 30.4% and 47.2%, respectively. Poor knowledge was more common in older adults (65+, p&lt;0.001). 3. Clinical staff and special hospital courses were knowledge resources. Post-discharge, they were general</td>
<td></td>
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</table>
Table 11 Systematic Review on Pressure Ulcer Prevention Education

<table>
<thead>
<tr>
<th>Authors; Country</th>
<th>Date included in the review</th>
<th>AMSTAR Score</th>
<th>Number of articles</th>
<th>Method: Systematic literature review of clinical trials written in English or French, with a human population. Article must pertain to pressure ulcers.</th>
<th>Level of evidence: Level 2 evidence (4 RCTs), level 4 (2 pre-post).</th>
<th>Questions/measures/hypothesis: 1. Determine the place of therapeutic patient education (TPE) in persons at risk of and/or those who have pressure ulcers and make recommendations for clinical practice.</th>
<th>Conclusions</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>Questions/measures/hypothesis: 1. Determine the place of therapeutic patient education (TPE) in persons at risk of and/or those who have pressure ulcers and make recommendations for clinical practice.</td>
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<tr>
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<td>2. No studies focused on specifically an elderly population.</td>
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<td>3. TPE had a positive impact on the occurrence and severity of pressure ulcers.</td>
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<td>4. Two yr post-intervention showed to have an impact on recurrence rate compared to controls (33% vs. 90%, p=0.007).</td>
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<td>5. The impact of TPE on depression and quality of life were conflicting.</td>
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</tbody>
</table>

Discussion
Overall, most investigations have demonstrated that specific educational programming can be beneficial for pressure ulcer prevention in persons with SCI, although there are a relatively small number of studies in this area. This aligns with results reported by Gelis et al. (2012) in a systematic review of therapeutic patient education directed toward persons at chronic risk of pressure ulcer formation, with 5 of 6 studies in this review involving persons with SCI. These authors noted a low level of evidence (Level 2 resulting in Grade B recommendations), acknowledging the relative immaturity of the literature in this area. Additionally, Gelis et al. (2012) noted limitations associated with biomedical thinking resulting in clinicians focusing on “educating” their patients (i.e., dissemination strategies) rather than adopting more behavioural approaches (Jones et al. 2003) or those that are grounded in adult learning principles as noted by May et al. (2006).

Although the various and specific educational experiences imparted over an inpatient rehabilitation stay are difficult to characterize, two studies have reported knowledge gains in pressure ulcer prevention methods associated with general inpatient rehabilitation programming as assessed at admission versus discharge, as well as at a later follow-up (May et al. 2006; Thietje et al. 2011). Thietje et al. (2011) did not specify particular aspects of the educational programming provided, however, they noted that significant knowledge gains were achieved by discharge and maintained at 30 months with patients identifying rehabilitation physicians, physiotherapists and nurses as the most important knowledge resources as well as in-hospital special courses.

Following discharge, general practitioners and physiotherapists were identified as the most important SCI knowledge resources. May et al. (2006) reported similar findings in knowledge gain at discharge and retention at 6 months post discharge as assessed by a customized multiple choice questionnaire developed by a clinical nurse educators and former patients. Notably, May et al. (2006) did characterize a main component of the educational experience provided to patients as involving an 8 week lecture series with classes held twice a week with content including pressure sore prevention techniques along with many other topics relevant to persons with SCI. Skin care, along with bladder and bowel care, was consistently reported by patients as the most important issue in relation to a variety of topics usually deemed relevant within SCI rehabilitation (May et al. 2006). Perhaps the most significant finding associated with this study was that problem-solving ability, as assessed using a qualitative Life Situation Scenario approach, was only marginally improved from admission to discharge and many patients continued to demonstrate poor problem-solving ability (i.e., applying knowledge to behavioural actions) at discharge. May et al. (2006) noted that the lecture series approach was likely not effective in this regard as it did not incorporate adult learning strategies (e.g., focus on perceived learning needs, readiness to learn, active learning).

Other studies have tested the effectiveness of more specific educational programming. For example, Brace and Schubart (2010) and Schubart (2012) have conducted pre-post, pilot studies examining the effectiveness of an interactive eLearning program designed to prevent pressure ulcers in persons with SCI as applied during inpatient rehabilitation (n=18) or following discharge to home (n=14), respectively. In each case, knowledge as assessed by performance on a customized test about this topic was significantly improved immediately after completing the online module. In addition, Schubart (2012) reported that participants rated aspects of the program’s ease of use and utility very high as well as providing positive self-reports on perceived knowledge gain and improved self-efficacy about pressure ulcer prevention.
In an RCT conducted by Garber et al. (2002), inpatients awaiting pressure ulcer surgery were randomly assigned to an intervention group (n=20) that received four 1-hour sessions of enhanced education on the prevention and management of pressure ulcers. Information presented at the sessions included education regarding preventative strategies such as skin inspection, weight shifts/turns, nutrition and pressure redistribution surfaces for the bed and wheelchair, as well as pressure ulcer etiology. The control group (n=21) received standard education regarding preventative practices. After discharge, the groups were followed for two years or until recurrence of pelvic pressure ulcer. Improvement on the pressure ulcer knowledge test was noted in both groups upon discharge from hospital; however, it was significantly different between the groups (p<0.03), with those in the intervention group gaining more knowledge about preventing pressure ulcers. No significant differences were noted on the multidimensional Health Locus of Control Scale and the Health Beliefs Questionnaire between the two groups at discharge. Two years post treatment, it was noted that both groups had retained most of the knowledge they had gained during their hospitalization, but the level of knowledge retained by the control group was below that of the treatment group: 60.8% versus 68% on the pressure ulcer knowledge test.

In a parallel study, Rintala et al. (2008) randomized similar subjects into three groups: Group 1 (N=20) had received enhanced education sessions. Group 1 was followed through structured monthly telephone contact where they were questioned regarding skin status, pressure ulcer preventative behaviors and reminded of behaviors they were not using. Group 2 (N=11) were contacted monthly by mail to assess skin status only and group 3 (n=10) were contacted every three months by mail to assess skin status. If those in groups 2 and 3 had not responded in two weeks, they were contacted by telephone. Group 1 had a significantly longer time before recurrence of pressure ulcers (19.6 months, p=0.002) while no significant difference was reported between group 2 or 3. For persons who had not had previous pressure ulcer surgery, the enhanced education and structured follow-ups extended their ulcer free time. As well, less people in group 1 had a recurrence of a pressure ulcer (33.3%) versus group 2 (60%) and group 3 (90%).

In summary, those individuals who received an enhanced education and structured follow-up, showed more improvement on the pressure ulcer knowledge test at discharge, retained more of this knowledge 2 years post intervention and had fewer recurrences of pressure ulcers. For those individuals who went on to have a recurrence, time to recurrence was much longer. Of note, this latter study is the only investigation described in this section to include an assessment of health status as well as to include behavioural aspects to their intervention. In general, this research could be strengthened considerably by adopting more fulsome outcome measurement approaches to evaluate the effectiveness of interventions (i.e., assessing behavior change directly in addition to its impact on health) as well as by incorporating theory-based behavior change strategies as parts of an intervention.

The 2013 Canadian Best Practice Guideline for Prevention and Management of Pressure Ulcers in People with SCI provided a Level IV recommendation (based on studies of self-management approaches used within various chronic diseases) to promote self-management for people with SCI by helping them to learn, consistently apply, and incorporate into their daily lives the effective and appropriate pressure ulcer prevention strategies.

**Conclusion**

*There is level 1b evidence (from two randomized controlled trials and three pre-post studies; Rintala et al. 2008; Garber et al. 2002; May et al. 2006; Brace & Schubart 2010;*
Providing enhanced pressure ulcer prevention education is effective at helping individuals with SCI gain and retain this knowledge. There is level 4 evidence (from two pre-post studies; Schubart et al. 2012; Brace & Schubart 2010) that online eLearning modules may improve knowledge on prevention of pressure ulcers among persons with SCI.

There is level 1b evidence (from one randomized controlled trial; Rintala et al. 2008) that providing enhanced pressure ulcer education and structured follow-up is effective in reducing recurrence of pressure ulcers especially in those individuals with no previous history of pressure ulcer surgery.

Structured pressure ulcer prevention education, helps individuals post SCI gain and retain knowledge of pressure ulcer prevention practices. Research is needed to determine the specific educational needs of individuals with SCI required to reduce the risk of pressure ulcer formation. More research is needed to determine the best approaches of pressure ulcer prevention education to reduce pressure ulcers post SCI.

2.5 Effect of Behavioural Contingencies on Pressure Ulcer Prevention

Despite the attention given to the prevention of pressure ulcers, they continue to be a common occurrence among individuals with SCI. For many patients admitted to hospital with a pressure ulcer it is often their first time although there is a group of patients who have recurring pressure ulcers. For some of these individuals the recurrence is due to noncompliance with prevention strategies, possibly related to lack of incentives to maintain healthy behaviours (Jones et al. 2003). What is not known is whether rewarding positive prevention strategies, a proven behaviour change approach, would reduce the severity of pressure ulcers or prevent them entirely, and if the results would be sustainable once the rewards are withdrawn.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jones et al. 2003</td>
<td>USA</td>
<td>Pre-post</td>
<td></td>
<td></td>
<td>N&lt;sub&gt;Initial&lt;/sub&gt;=8; N&lt;sub&gt;Final&lt;/sub&gt;=6</td>
</tr>
<tr>
<td>Study 1:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Study 2: N&lt;sub&gt;Initial&lt;/sub&gt;=4; N&lt;sub&gt;Final&lt;/sub&gt;=3</td>
</tr>
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</table>

Population: Mean age=25-40 yr; Gender: males=6, females=2; Level of injury paraplegia; Time since injury=12-20 yr.

**Intervention:** Study 1 - Behavioural Intervention: 3 primary components: health plan, clinic visits and financial rewards. Study 2 - Behavioural intervention: 2 treatments components were implemented (Health plan and visits) during the initial phase. Phase 2 - which began after the patient began to experience skin problems (Included visits plus payment).

**Outcome Measures:** Severity of pressure sores were recorded at each phase. Study 1:
1. PUSH decreased from baseline by an average of 10.5 points per participant.
2. Six participants were hospitalized (not during the intervention) a total of 16 times due
3. Fewer hospitalizations were also noted during the post-intervention phase compared to the baseline phase. Average monthly cost of care decreased from $6262.00/participant to $235.00 (US)
### Discussion

Jones et al. (2003) examined the effectiveness of several behavioural strategies (i.e., rewards, counselling and creation of an action plan) in four small pilot studies that examined pressure sore status and health care utilization. Results from the first study showed average Pressure Ulcer Scale for Healing (PUSH) scores were lower by 10.5 points from baseline; no hospitalizations were required and costs declined from $6,263.00 (US) to $235.00 (US). In the post-intervention phase, three subjects were able to maintain the lower PUSH scores and three were not. In the second study the results were highly variable. Mean PUSH scores decreased from baseline by 8.3 points (visits only) and a further 3.1 points when payments were added. For two or three participants PUSH scores rose again during the post-intervention phase. The mean number of hospitalizations dropped from 1.67 (baseline) to 0.33 (intervention and post-intervention).

Although this was a very small study, data from the first study indicated that when behavioural contingencies were introduced, positive behaviours resulted. As well, this is one of the few prevention studies that did not use indirect outcome measures. For some participants results were sustainable once behavioural contingencies were withdrawn. More research is needed to determine the role of behavioural contingencies (i.e., rewards) and other behavioural strategies in pressure ulcer prevention post SCI.

### Conclusion

*There is level 4 evidence (from one pre-post study; Jones et al. 2003) to suggest that the introduction of behavioural contingencies and other behavioural strategies is associated with a reduction in pressure ulcer severity and decreased health care costs.*

Research is needed to determine why some individuals adhere to pressure ulcer prevention strategies and others do not.

### 2.6 Telerehabilitation and Pressure Ulcer Management

Telerehabilitation has been defined as “the use of telecommunication technology to deliver rehabilitation services at a distance” (Vesmarovich et al. 1999: p 264). Telerehabilitation allows for visual and verbal interaction between an individual with SCI and a health care provider.
Impaired mobility and great distances to specialized SCI centers often make follow-up care difficult for individuals with SCI (Mathewson et al. 2000; Galea et al. 2006). Telerehabilitation has the potential to deliver medical rehabilitation including education, nutritional and psychosocial elements of health care at a distance thereby facilitating continuity of care (Galea et al. 2006). Shorter lengths of stay have potentially increased the need for education post-discharge and technology can be used to continue education begun during inpatient rehabilitation including education on pressure ulcer prevention and care of ulcers if they occur. Continuation of pressure ulcer prevention education and early detection and intervention via technology may reduce the need for hospitalization related to pressure ulcers (Phillips et al. 2001). The use of a videophone capable of transmitting high resolution images, and verbal interactions between nurse, patient and caregiver could mean accurate and timely assessment and treatment of wounds and improved healing (Mathewson et al. 1999). In a study conducted at a mock home setting, Hill et al. (2009) found “video conferencing was better overall than the use of the telephone when assessing the detailed clinical characteristics of a pressure ulcer (p 200).” Both were found to be useful when assessing for the presence of a pressure ulcer.

The 2013 Canadian Best Practice Guideline for Prevention and Management of Pressure Ulcers in People with SCI provided a Level IV recommendation (based on studies of telerehabilitation for wounds of various etiologies including SCI) telerehabilitation as a promising approach for delivering pressure ulcer prevention ad management to people with SCI. A Canadian multisite pressure ulcer internet clinic feasibility study will assist to elucidate the specific utility of telerehabilitation for pressure ulcer management in people with SCI (Rick Hansen Institute, 2009).

**Table 13 Telerehabilitation and Pressure Ulcer Management**

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Country</th>
<th>Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Houlihan et al. 2013</td>
<td>USA</td>
<td>PEDro=6</td>
<td>RCT</td>
<td>N=142</td>
<td>Population: Mean age=48.2 yr; Gender: males=51, females=55; Injury etiology: SCI=106, Multiple Sclerosis=36, Level of injury (SCI): paraplegia=54, tetraplegia=46. Medical history: depression=55, pressure ulcer=66.</td>
<td>Outcome Measures: Pressure Ulcer Scale for Healing (PUSH) tool v.3.0, Patient Health Questionnaire -9 (PHQ-9), Cornell Services Index (CSI) and Craig Hospital Inventory of Environmental Factors – Short Form.</td>
</tr>
<tr>
<td>Phillips et al. 1999</td>
<td>USA</td>
<td></td>
<td>Case Control</td>
<td>N annot=37; N final=35</td>
<td>Population: Mean age=35 yr.</td>
<td>Outcome Measures: Number of pressure ulcers, emergency room (ER) visits, hospitalizations, doctor’s visits.</td>
</tr>
</tbody>
</table>
### Author Year Country Score Research Design Total Sample Size

<table>
<thead>
<tr>
<th>Author Year Country Score Research Design Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vesmarovich et al. 1999 USA Case Series N=8</td>
<td>annually and employment rate.</td>
<td>the other two groups.</td>
</tr>
<tr>
<td></td>
<td>4. Over half the members of each group had no hospitalizations during the study period. It was also noted that 26% of the subjects had returned to work 6 mths after injury.</td>
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<tr>
<td></td>
<td></td>
<td>No statistical results reported</td>
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<tr>
<td></td>
<td></td>
<td>1. Subjects were seen approximately seven times (range 1-18 visits).</td>
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<td>2. Seven wound sites healed completely and two needed surgery.</td>
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<tr>
<td></td>
<td></td>
<td>3. Subjects and family were highly satisfied.</td>
</tr>
</tbody>
</table>

### Discussion

Vesmarovich et al. (1999) described the use of telerehabilitation delivered via a videophone system that transmitted still images and audio to treat stage III and IV ulcers. While no statistical results were reported, 7 out of 12 ulcer sites healed. Using the same videophone system, Philips et al. (1999) divided SCI participants into 3 groups. The videophone group had the highest number of identified and/or reported ulcers. The annualized data for emergency room (ER) visits, hospitalizations and health care visits were similar for the video and telephone groups while hospitalizations and visits were less in the standard care group. No differences were significant at p<0.05. However a small non-randomized sample size and several other limitations were identified to inform future investigations.

Results of these two small studies fail to support the use of this form of telerehabilitation in delivery of cost effective prevention strategies and early pressure ulcer identification and treatment. However, Houlihan et al. (2013) did achieve some positive results by employing interactive voice response (IVR) telephony called “CareCall” to enable virtual health care to monitor and assess patients’ health with respect to pressure ulcers and depression and to increase appropriate use of health resources such as preventative outpatient clinics and to reduce ER visits. Participants (N=142) were randomized into either a control (i.e., usual care) or intervention (i.e., “CareCall”) group and received service over a 6 month period. Those receiving “CareCall” received weekly automated calls and could call into the service at any time to receive algorithm-based, branched-logic modules (scripts of content deemed relevant to their health concerns). The scripts were delivered by both clinicians and persons with spinal cord disease and were developed through consideration of health behavior change theory (i.e., Social Cognitive Theory and Transtheoretical Model) to promote healthy behaviours. Using this approach, women were found to have reduced pressure ulcer incidence over the study period (p<0.0001) for the “CareCall” group versus control, whereas men did not. There was no difference in healthcare utilization between the two groups although the intervention group did self-report perceived increases in health-care availability.
Despite these promising results, more research is needed to determine how and what telerehabilitation strategies can be used to deliver and monitor compliance with pressure ulcer prevention strategies as well as their use in identification and treatment of pressure ulcers post SCI.

**Conclusion**

*There is level 1b evidence (from a randomized controlled trial; Houlihan et al. 2013) that telerehabilitation using an automated call-in system with built-in theory-based behavior change strategies may make a significant difference for women but not men in preventing pressure ulcers post SCI.*

*There is level 4 evidence (from one case series; Vesmarovich et al. 1999) that telerehabilitation via videophone to support clinical interactions and digital photography does not make a significant difference in the prevention and treatment of pressure ulcers post SCI.*

*More research is needed to determine what telerehabilitation strategies are effective in preventing pressure ulcers, improving healing and reducing costs.*

---

**3.0 Treatment**

Once a pressure ulcer has begun it is important to prevent it from worsening and is challenging to have it heal quickly. Rappl et al. (2008) examined the metabolic and physiological changes that occur in tissue below the level of a SCI in relation to the events which take place during wound healing to explain why pressure ulcers may heal more slowly in individuals with a SCI. It is widely known that severe pressure ulcers can lead to further disability, surgery, amputation and death (Krause 1998); further, pressure ulcers are among the leading cause of unplanned rehospitalization post SCI that can also contribute to longer lengths of stay with more costly treatment than other medical conditions (Chen et al. 2005). Pressure ulcer treatment is more costly than prevention (Bogie et al. 2000; Jones et al. 2003) and once an individual has had an ulcer they are at increased risk for recurrence (Krause & Broderick 2004; Verschueren et al. 2011). Furthermore, in addition to standard wound care, many adjunctive therapies are required to accelerate closure of hard to heal wounds. As such, it is important to identify appropriate clients, through appropriate and regular assessment, who are likely to benefit from these often time consuming and expensive treatments (Houghton & Fraser 2008; Allen & Houghton 2003). Research in this field covers examines electrical stimulation, laser, ultrasonography, non-thermal pulsed electromagnetic energy, topical negative pressure, normothermia, recombinant human erythropoietin, anabolic steroid therapy, effectiveness of various dressings, maggot therapy, topical oxygen, surgery and other herbal remedies for healing of pressure ulcers post SCI. Each of these treatments will be discussed in subsequent sections.

**3.1 Electrical Stimulation**

The use of various forms of electrical current in augmenting tissue repair was reported as early as the 1600s when charged gold leaf was used to prevent scarring in smallpox survivors (Kloth
& Feedar 1988). The therapeutic effects of electrical stimulation for wound healing have been well documented since the 1960s, especially for wounds not responding to standard forms of treatment (Kloth & Feeder 1988; Bogie et al. 2000).

Galvanotaxis is the process by which electrical stimulation directs cell movement and it is thought to be a process that can impact wound healing through the migration of cells such as epithelium, macrophages, neutrophils and fibroblasts (Feedar et al. 1991; Bogie et al. 2000). Under normal circumstances there is a flow of charged particles from an uninjured area to an injured area triggering a biological repair system. The belief is that application of exogenous electrical current should be able to enhance healing in non-healing wounds by mimicking the body's own healing system (Carley & Wainapel 1985). A second theory purports that the application of electric current activates cutaneous nerves and creates a centrally mediated increase in circulation to the wound to indirectly promote healing (Kaada 1982). Despite the increasing use of electrical stimulation to promote wound healing, there remains a lack of clear understanding as to how it works to repair tissue (Bogie et al. 2000).

Some of the documented effects of electrical stimulation on wound healing include decreased healing time, increased collagen synthesis, increased wound tensile strength, increased rate of wound epithelialization and increased bactericidal and bacteriostatic effects (as cited in Kloth & Feedar 1988). Electrical stimulation has also been shown to indirectly improve healing by improving tissue perfusion and reducing edema formation (Houghton & Campbell 2007). The studies on electrical stimulation for wound healing have examined low-intensity direct current, high voltage pulsed direct current, and alternating current. The literature shows a high variability as to which protocols are the most effective for a specific patient or ulcer (Bogie et al. 2000).

The use of electrical stimulation to promote closure of pressure ulcers, when combined with standard wound interventions, has been recommended in both the able bodied and individuals with SCI. Most studies discuss the adjunctive role of electrical stimulation in pressure ulcers which have failed to respond to standard treatments (Houghton et al. 2013; Consortium of Spinal Cord Medicine 2000; Keast et al. 2006; AHCPR, Executive Summary # 15 1992).

<table>
<thead>
<tr>
<th>Author Year Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Results</th>
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<tbody>
<tr>
<td>Houghton et al. 2010 Canada</td>
<td>PEDro=9</td>
<td>RCT</td>
<td>N=34</td>
<td>Population: Mean age=23-74 yr; Gender: male=20, female=14; Time since injury=1-51 yr; Severity of injury: complete and incomplete; Ulcer location: IT, sacrum, coccyx, hip, leg; Duration of ulcer=0.3-20 yr. <strong>Intervention:</strong> Stimulation with monophasic high voltage pulsed current (HVPC) 19,200 min/day 7 days/wk with standard wound care (interdisciplinary team assessment) or standard wound care alone (SWC). <strong>Outcome Measure:</strong> Percent decrease in wound surface area.</td>
<td>1. Percent decrease in wound surface area was significantly greater (p=0.048) in those treated with HVPC+SWC (70 ± 25%); versus those with only SWC (36 ± 61%). 2. Proportion of Stage III, IV, X pressure ulcers improving by at least 50% was significantly greater in the HVPC+SWC than in the SWC (p=0.20)</td>
</tr>
<tr>
<td>Cukjati et al. 2001 Slovenia</td>
<td>PEDro=5</td>
<td></td>
<td></td>
<td>Population: Mean age: 28-59 yr; Injury etiology: 71.7% SCI; Time since injury: 2-38 mo; Wound area &gt;1cm² and at least 4</td>
<td>1. AC group healed significantly faster than the sham group (p=0.018) and at the same rate as the DC group</td>
</tr>
<tr>
<td>Author Year Country</td>
<td>PEDro Score</td>
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<tr>
<td>RCT N=217</td>
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<td>wk duration; Ulcer location: trochanter, sacrum, gluteus, other; Ulcer duration: 3-18 wk. <strong>Intervention:</strong> Biphasic-current stimulation (AC group) (N=136) received biphasic current by placing electrodes on intact skin across the wound. Direct-current stimulation (DC group) (N=35) received direct current (0.6mA) through positive electrode placed over wound and 4 negative electrodes placed on intact skin around the wound. Stimulation was applied 0.5hrs, 1hr, or 2 hours/day 7 days/wk. Comparisons were made to the Conservative treatment group (N=54) and sham group (N=23). <strong>Outcome Measure:</strong> Wound healing rate.</td>
<td>(p=0.170) with the 2-hour wound treatment. 2. AC group healed significantly faster than DC group with 1-hour treatment (p=0.001). 3. Wound healing rate depend upon wound area, grade, shape, patient's age, elapsed time from SCI to wound appearance, and elapsed time from wound appearance to beginning of treatment.</td>
</tr>
<tr>
<td>Adegoke &amp; Badmos 2001 Nigeria PEDro=6 RCT N=7</td>
<td>Population: Mean age=21-60 yr; Mean ulcer surface area=15.8 mm; Ulcer location: greater trochanter and sacrum. <strong>Intervention:</strong> Stimulation with interrupted direct current (IDC) and nursing care or placebo IDC and nursing care; 3-45 minute treatments 1x/wk for 4 wk. <strong>Outcome Measures:</strong> Percent decrease in wound surface area.</td>
<td>1. Surface area of pressure ulcers of IDC group decreased by 22.2% versus 2.6% in placebo IDC group. 2. Most of the decrease in surface area occurred during the first two wk of the study (IDC group 15.4 to 13.3 mm², % change 15.8%; placebo IDC group 15.4 to 15.1 mm², % change 1.9%).</td>
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<tr>
<td>Karba et al. 1997 Slovenia PEDro=6 RCT N=50</td>
<td>Population: Pressure ulcer ≥ 500 mm²; Pressure ulcer stage: III or IV. <strong>Intervention:</strong> DC+ group receiving positive stimulation electrode overlaid on ulcer; DC+/- group received the same stimulation but two electrodes were placed on healthy skin across the wound; SHAM group had electrodes placed on the wound but no current. <strong>Outcome Measures:</strong> Relative rate of healing.</td>
<td>1. The DC+ group reported significantly (p=0.028) greater relative healing rate (7.4%/day) compared to SHAM group (4.2%/day), while the DC+/- group (4.8%/day) had similar relative healing rates as the SHAM group.</td>
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<tr>
<td>Baker et al. 1996 USA PEDro=4 RCT N=80</td>
<td>Population: Mean age=17-76 yr; Gender: males=66, females=14; Time since injury: 1-420 mo; Severity of injury: complete and incomplete; Total number of wounds=192; Ulcer location: foot, thigh, ischial and sacral. <strong>Intervention:</strong> Stimulation of A (asymmetric biphasic), vs. B (symmetric biphasic) vs. microcurrent (MC) group originally thought to incorporate stimulation below effective level became the 3rd treatment group when some early therapeutic effect was noted. All remained on their stimulation protocols until their ulcers healed, the MD intervened or subject withdrew from study. Control group received sham for 4 wk duration.</td>
<td>1. No statistical differences were noted between the initial or discharge ulcer areas or in the mean healing rates among the four treatment groups. 2. Comparing the descriptive data by classifying them as good or poor healing responses failed to identify any statistically significant differences between the 2 groups. 3. When looking at the good response group, the group A protocol was most effective as compared to the MC and C protocols (p&lt;0.05). No significant differences were found between B protocol and other treatments.</td>
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<td>Author Year</td>
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<tr>
<td>Jerčinović et al. 1994</td>
<td>Slovenia</td>
<td>PEDro=5</td>
<td>RCT</td>
<td>N=73</td>
<td>wk then were entered into either A or B groups. Electrical stimulation treatment for all subjects consisted of 1.5 hr of stimulation 5 days/wk. <strong>Outcome Measures:</strong> Mean rate of healing.</td>
</tr>
<tr>
<td>Griffin et al. 1991</td>
<td>USA</td>
<td>PEDro=7</td>
<td>RCT</td>
<td>N=17</td>
<td><strong>Population:</strong> Mean age: 18-68 yr; Severity of injury: &gt;1 mo; Ulcer location: sacrum, legs, trochanter, gluteal, other. <strong>Intervention:</strong> Stimulation with biphasic current (n=61) 2 hrs/day 5 days/wk for 4 wk in addition to conventional therapy was compared to the control group receiving conventional therapy alone (n=48). <strong>Outcome Measures:</strong> Mean rate of healing.</td>
</tr>
<tr>
<td>Recio et al. 2012</td>
<td>USA</td>
<td>Case Series</td>
<td>N=3</td>
<td></td>
<td><strong>Population:</strong> Adults with SCI and recalcitrant pressure ulcers; Ulcer location: heel, ischium, IT. <strong>Intervention:</strong> High voltage electrical stimulation (HVES) was applied directly into the wound bed for 60 minutes 3-5 times/wk until completely healed. <strong>Outcome Measures:</strong> Healing recalcitrant pressure ulcers.</td>
</tr>
<tr>
<td>Stefanovska et al. 1993</td>
<td>Slovenia</td>
<td>Prospective Controlled Trial</td>
<td>N=150</td>
<td></td>
<td><strong>Population:</strong> SCI with one or more pressure ulcers (otherwise, not specified). <strong>Intervention:</strong> Currents were applied across the wounds by a pair of self-adhesive skin electrodes. DC group (n=18) treated with direct currents (600µA) for two hours daily. AC group (n=82) were treated with low frequency pulsed currents for two hours daily. CO group (n=50) received “conventional” treatment (not described) for the first mo. <strong>Outcome Measures:</strong> Mean rate of healing.</td>
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</table>
Discussion

Recio et al. (2012) conducted a retrospective case series examining the effects of high voltage electrical stimulation (HVES) one hour per day, 3-5 times per week on healing recalcitrant pressure ulcers in subjects with SCI. HVES was shown to enhance healing of Stage III and IV pressure ulcers that were unresponsive to standard wound care. Recalcitrant pressure ulcers (11-14 months) were completely closed within 7-22 weeks of treatment with HVES.

Houghton et al. (2010) conducted a randomized single blind study evaluating the effects of high voltage pulsed current (HVPC) with standard wound care for healing pressure ulcers in community dwelling patients with SCI. Subjects who received HVPC showed a significant decrease in percent wound surface area (WSA) after three months compared with those who received standard wound care alone (p=0.048). The proportion of Stage III, IV, and unstageable ulcers in which WSA improved ≥50% was significantly higher in the HVPC group than the standard wound care group (p=0.02).

Adegoke and Badmos (2001) randomly treated six stage IV pelvic pressure ulcers with standard nursing care augmented with interrupted direct current or with placebo IDC. Subjects treated with IDC and nursing care showed a decrease in WSA by 22.2% versus 2.6% in the placebo group.

Cukjati et al. (2001) randomly divided participants into four treatment groups: biphasic current, direct current, sham treatment, and conservative treatment. Wounds treated for two hours with biphasic current healed significantly faster than sham-treated wounds (p=0.018) and conservative therapy, but healed at similar rates as direct current (p=0.170). Although wounds treated with direct current healed faster than sham treated wounds, the difference was not statistically significant. (p=0.085).

Karba et al. (1997) demonstrated that when using direct current, placement of the positive stimulation electrode covering the pressure ulcer and the negative electrodes on intact skin resulted in a greater relative healing rate per day (7.4%, p=0.028) compared to when the positive and negative electrodes were both placed on intact skin on opposite sides across the wound (4.8%).

Baker et al. (1996) showed that for ulcers that responded to any form of electrical simulation (“good responses”), asymmetric biphasic stimulation (group A) was most effective for enhanced wound healing. Wounds that were already showing healing in the control group, with the addition of either protocol A or B (symmetrical Biphasic) showed that healing rate was greater (43.3% Δ/week) when compared to control period (9.7% Δ/week).

Jerčinović et al. (1994) demonstrated that pressure ulcers in patients with SCI treated with low frequency pulsed current and conventional therapy for four weeks had a significantly (p=0.006) higher healing rate than those treated with conventional therapy alone. Subjects in the conventional group who crossed over to the electrical stimulation group after four s had improved healing rates in 19 out of the 20 subjects.

Stefanovska et al. (1993) treated 150 pressure ulcers in individuals with SCI with conventional therapy alone, or in combination with direct or alternating current. Wounds treated with low frequency pulsed current (alternating current) showed significantly better healing rates than
those treated with direct current or conventional treatment alone after the exclusion of deep, superficial and long-term wounds.

Griffin et al. (1991) also performed a randomized controlled trial showing the efficacy of HVPC for healing pelvic pressure ulcers in subjects with SCI. When compared to the placebo group, subjects treated with HVPC showed a greater percentage decrease in WSA at day 5 (p=0.03), day 15 (p=0.05) and day 20 (p=0.05).

While there were differences in the type and duration of electric current applied in the nine studies, and in some cases electrode placement, all of the studies demonstrated that when used in conjunction with standard wound management electrical stimulation accelerates the healing rate of pressure ulcers in patients with SCI. More study is needed to determine optimum electric current and application protocols to enhance healing of pressure ulcers post SCI. Mittman et al. (2011) reported that in additional to standard wound care, electrical stimulation results in a cost savings of $224 over a one-year time frame for treating stage III and IV pressure ulcers in individuals with SCI. The cost-savings associated with improved healing rates offset the cost of adding electrical stimulation to standard practice.

Conclusion

_There is level 1 evidence (from six randomized controlled trials; Houghton et al. 2010; Cukjati et al. 2001; Adegoke & Badmos 2001; Karba 1997; Jercinovic 1994; Griffin 1991) that electrical stimulation accelerates the healing rate of stage III and IV pressure ulcers when combined with standard wound management._

Electrical stimulation added to standard wound management promotes healing of Stage III and IV pressure ulcers post SCI.

More research is needed to determine optimum electric current and application protocols to improve healing of pressure ulcers post SCI.

### 3.2 Laser Treatment

Lasers have been used in the treatment of wounds since the 1970s because of the belief that fibroblast activity and tissue granulation in the proliferative phase of non-healing, chronic wounds is enhanced. Currently the use of laser to promote wound closure in chronic wounds is not supported by evidence (Houghton et al. 2013; Houghton & Campbell 2007; Consortium of Spinal Cord Medicine 2000) and the two relevant studies are presented and discussed below.

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<tr>
<th>Author</th>
<th>Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
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<tbody>
<tr>
<td>Taly et al. 2004</td>
<td>India</td>
<td>PEDro=10</td>
<td>RCT</td>
<td>N=35</td>
<td></td>
<td>Population: Mean age=8-65 yr; Gender: males=27, females=8; Stage of ulcers: Stage 2=55, Stage 3=8, Stage 4=3. Intervention: Treatment for the experimental group consisted of multi-wavelength light therapy (gallium</td>
<td>1. Overall no significant differences were found between the control and treatment groups. 14 ulcers healed completely in the control group compared to 18 in the treatment group (p&lt;0.802).</td>
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<td>Author Year</td>
<td>Country</td>
<td>PEDro Score</td>
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<tr>
<td>Nussbaum et al. 1994</td>
<td>Canada</td>
<td>PEDro=6</td>
<td>RCT</td>
<td>aluminum arsenide laser source) in addition to conventional treatment. For the control group, the light therapy source was held over the ulcer after switching off the beam. 14 treatments were given, 1 every other day, three times per wk. Treatments ended when the ulcer healed or after the 14 treatment exposures. <strong>Outcome Measures</strong>: Number of ulcers that healed.</td>
<td>2. The mean time taken to heal was 2.45 wk in the treatment group and 1.78 in the control group (p&lt;0.330). 3. Multi-wavelength light therapy reduced the time taken by a small subgroup of stage three and four ulcers to reach stage two, treatment group (n=4) 2.25 wk; control group (n=5) 4.33 wk (p=0.047).</td>
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**Discussion**

Taly et al. (2004) studied 35 subjects (64 ulcers) using multi-wavelength light therapy compared to “standard” wound care alone. Overall, no significant differences were found between the two groups with regard to the number of ulcers healed and time taken to heal. Nussbaum et al. (1994) studied 16 patients and compared standard wound care alone or combined with either laser or Ultrasound/Ultraviolet C (US/UVC). Results showed that laser treatment combined with standard wound care had the least effect on wound healing compared to the control group and US/UVC group. A significant difference was found between the groups with the US/UVC treatment demonstrating a greater effect on wound healing. Both of these studies demonstrated that laser treatment was no more effective in promoting wound healing than standard wound care alone, post SCI.

**Conclusion**

*There is level 1 evidence (from two randomized controlled trials; Taly et al. 2004; Nussbaum et al. 1994) that laser treatment has no added benefit in pressure ulcer healing post SCI than standard wound care alone.*

Laser treatment does not improve pressure ulcer healing post SCI.
3.3 Ultrasound/Ultraviolet C

Houghton and Campbell (2007) note that both ultrasound (US) and ultraviolet light C (UVC) have been used in the treatment of chronic wounds. Ultrasound acts mainly at the “inflammatory stage of the wound healing cascade to stimulate the release of chemical mediators of cells which in turn produces changes in the amount and strength or integrity of the scar tissue” (Houghton et al. 2001; p 464). The bactericidal effects of UVC suggest that it is indicated for the treatment of chronic infected wounds where there is much surface bacteria or where bacteria have become resistant to antibiotic therapy. As well, research supports the use of UVC in the treatment of chronic infected wounds, while therapeutic US was not shown to have added benefit when used to treat pressure ulcers. The Consortium of Spinal Cord Medicine (2000) and Houghton et al. (2013) found minimal data specific to the use of US or UVC to treat pressure ulcers in SCI. Schmuckler (2008) in a case series of 5 SCI patients with sacral pressure ulcers used low frequency, noncontact, nonthermal ultrasound (Acoustic Pressure Wound Therapy, MIST Therapy Systems) to prepare the wound bed for subsequent treatments. The author demonstrated that in 80% of wounds the therapy was effective in reducing slough and eschar (e.g., shedding dead tissue), promoting granulation tissue and reducing wound area and volume. One small RCT will be discussed that combined US/UVC and compared its effects to laser and standard wound care.

Table 16 Ultrasound/Ultraviolet C for Pressure Ulcer Healing

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<th>Author Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
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<tbody>
<tr>
<td>Nussbaum et al. 1994</td>
<td>Canada</td>
<td>PEDro=6</td>
<td>RCT</td>
<td>N=16</td>
<td>Population: Mean age=15-61 yr Intervention: Subjects were assigned into one of three groups: control group received “standard” wound care consisting of twice daily cleansing with Hygeol (1:20) and Jelonet dressing, and avoidance of pressure on existing ulcers; Laser group received standard wound care plus laser treatment 3x/wk; Ultrasound/Ultraviolet C (US/UVC) group received standard wound care with US and UVC treatments alternating over a 5 day period.</td>
<td>1. Healing rate was not equal under all treatment conditions. 2. Paired comparisons showed the significant difference was between US/UVC and laser treatment with US/UVC showing greater effect on wound healing. 3. Mean percentage of change per wk in ulcer size from day 0 to complete healing for control (32.4%), US/UVC (53.5%), and laser (23.7%) 4. Several subjects showed deterioration over the study. Ulcers increased in size; (laser=3, 62-167% change; control=1, 58% change; US/UVC=1, 1% change). All ulcers healed by end of study with last ulcer healed in laser group by wk 20 as opposed to US/UVC group at wk 6.</td>
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</table>

Discussion

In one small RCT (n=16) Nussbaum et al. (1994) demonstrated that between standard wound care with or without US/UVC, the combined treatment showed a greater effect on wound healing in a shorter period of time. Since US and UVC alternated over 5 days was considered a single treatment, efficacy conclusions do not cover the individual effects of US or UVC. Understanding the effects of US or UVC individually or in different combinations would require further study.
Conclusion

There is level 1b evidence (from one randomized controlled trial; Nussbaum et al. 1994) that the combination of US/UVC with standard wound care decreases wound healing time of pressure ulcers post SCI; there is no evidence to support the benefit of UVC or US, used individually.

US/UVC should be considered as an adjunct treatment when pressure ulcers are not healing with standard wound care post SCI.

3.4 Non-Thermal Pulsed Electromagnetic Energy

Keast et al. (2006), in updating best practices recommendations for the prevention and treatment of pressure ulcers, recommends considering electromagnetic fields as one adjunctive modality for stimulating closure of chronic non-healing pressure ulcers even though results from more than one RCT are not consistent. Electromagnetic energy is believed to act at the proliferative stage of wound healing to promote production of granulation tissue formation (Houghton & Campbell 2007).

Table 17 Non-Thermal Pulsed Electromagnetic Energy for Healing of Pressure Ulcers

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<tr>
<th>Author Year Country PEDro Score Research Design Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
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<tr>
<td>Salzberg et al. 1995 USA PEDro=8 RCT N=30</td>
<td><strong>Population:</strong> Stage II group: Age=24-69 yr. No data for Stage III group. <strong>Intervention:</strong> A non-thermal pulsed high frequency, high peak power, electromagnetic energy (PEE), was delivered through a treatment head placed in light contact with the wound site and tuned to resonance in the area of the wound. Treatment was non-invasive and delivered through wound dressings for 30 minutes, twice daily for 12 wk or until healed. The control group received 12 wk of sham treatment. <strong>Outcome Measures:</strong> Pressure Ulcer Status.</td>
<td>1. Stage II group: Treatment (n=10), control (n=10). After 1 wk, the treatment group had a greater percentage of ulcer healed (84%) compared to the control group (40%), p=0.01 and the median size of ulcer was also smaller at one wk (2.7 versus 16.5 cm², p=0.015). 2. For complete healing, the treatment group healed in a median of 13 days versus 31.5 days for the controls (p&lt;0.001). 3. Given that there were more large ulcers (&gt;60 cm²) in the sham group, data was reanalyzed for 15 subjects with ulcers &lt;60 cm² with similar results as found initially. 4. Stage III group: Treatment n=5, control n=5. 3/5 healed with an average of 43 days of treatment. 0/5 healed in control group. Ulcer area decreased by average 70.6% versus 20.7% in control group.</td>
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Discussion

An RCT studying the effects of electromagnetic energy on pressure ulcer healing in patients with SCI (Salzberg et al. 1995) evaluated the effects of non-thermal pulsed electromagnetic energy for healing of stage II and III ulcers in patients with SCI. In the stage II ulcer group
(n=10), a greater proportion of ulcers healed (84%) after one week of treatment compared to the control group (40%; p=0.01). For complete healing, the treatment group healed in a median 13 days versus 31.5 days for controls (p<0.001). In the stage III ulcer group, healing was also associated with non-thermal pulsed electromagnetic energy treatment where three of five ulcers healed, on average, within 43 days. In the control group none of the ulcers healed. Ulcer area decreased 70.6% in the treatment group versus 20.7% in the control group.

In a Cochrane systematic review, Ravaghi et al. (2006) examined two articles and found no statistically significant difference in the healing rates of people treated with electromagnetic therapy compared to controls. More research is needed to further our understanding of the mechanism of action of non-thermal pulsed electromagnetic energy and its role in pressure ulcer healing in individuals post SCI.

**Conclusion**

*There is level 1b evidence (from one randomized controlled trial; Salzberg et al. 1995) that pulsed electromagnetic energy accelerates healing of stage II and III pressure ulcers post SCI.*

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<tr>
<th>Author Year Country</th>
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<tbody>
<tr>
<td>De Laat et al. 2011 Netherlands</td>
<td>PEDro=7</td>
<td>RCT</td>
<td>N=24</td>
<td>Population: Patients 18 yr who were admitted to the study hospital with difficult-to-heal surgical wounds, or paraplegic and tetraplegia patients with pressure ulcers grade IV according to the European Pressure Ulcer Advisory Panel grading system 19. <strong>Intervention:</strong> Topical negative pressure therapy or treatment with conventional dressing therapy with sodium hypochlorite. <strong>Outcome Measures:</strong> 50% wound volume</td>
<td>1. Topical negative pressure resulted in almost 2 times faster wound healing than treatment with sodium hypochlorite, and is safe to use in patients with difficult-to-heal wounds.</td>
</tr>
</tbody>
</table>

3.5 Topical Negative Pressure

Topical negative pressure therapy (TNP) distributes negative pressure (i.e., sub-atmospheric pressure) across an ulcer WSA via continuous or intermittent application of vacuum through a sealed dressing. This therapy to promote wound healing has been used to treat a variety of acute and chronic wounds including pressure ulcers (Smith et al. 2007; Argenta & Morykwas 1997). An airtight system is created using special foam, sterile tubing and canister, and an adhesive film drape (Houghton & Campbell 2007). Vacuum is applied via a suction bottle or pump (Müllner et al.1997). The negative pressure in the wound bed removes local edema, increases blood flow, decreases local tissue edema, decreases bacterial colonization and increases granulation tissue formation and mechanical wound closure (Smith et al.2007; Houghton & Campbell 2007; Argenta & Morykwas 1997).

**Table 18 Topical Negative Pressure Therapy for Pressure Ulcer Healing**
<table>
<thead>
<tr>
<th>Ho et al. 2010</th>
<th>USA</th>
<th>Observational</th>
<th>N=86</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population:</strong> SCI inpatients with Stage III/IV pelvic pressure ulcer.  <strong>Intervention:</strong> Standard wound care with NPWT versus standard wound care alone (NoNPWT).  <strong>Outcome Measures:</strong> Change in wound surface area (WSA) using the Verg Videometer Measurement Documentation software.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Coggrave et al. 2002</th>
<th>UK</th>
<th>Pre-post</th>
<th>N=7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population:</strong> Mean age=44.4 yr; Gender: males=5, females=2; Level of injury: paraplegia=4, tetraplegia=3; Location of pressure ulcer: trochanter=3, sacrum=4; Stage of ulcer: IV=6.  <strong>Intervention:</strong> Topical negative pressure (TNP) applied continuously (125 mmHg), dressing changed every 4-7 days. All patients seen and assessed by dietitian; nursed on a pressure redistribution surface; turned frequently; wound debrided as necessary pre-treatment.  <strong>Outcome Measures:</strong> Picture and wound swabs (every dressing change); Pressure ulcer volume (beginning and end of treatment).</td>
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</table>

1. In SCI patients with Stage III/IV pelvic pressure ulcers, NPWT did not significantly influence the rate of healing.  2. Healing outcomes in the NPWT group were significantly influenced by albumin status.  3. Nutritional status appears to be important in the effectiveness of NPWT.  

**Discussion**

De Laat et al. (2011) randomized 12 inpatients with SCI to TNP or conventional sodium hypochlorite dressing (control) and yielded an almost two-times faster TNP healing time to 50% wound volume reduction (p<0.001) with minimal adverse events. Similar results were achieved for a parallel group of 12 inpatients of mixed disease etiology who also suffered with difficult-to-heal wounds. Combined results including both groups of patients did not alter the efficacy or safety conclusions. Another advantage of TNP is the reduced workload required of caregivers. The TNP sealed sponges are changed every 48 hours in contrast to the thrice daily sodium hypochlorite-soaked dressing changes.

Ho et al. (2010) conducted a retrospective analysis of negative pressure wound therapy versus traditional best practice standard care on stage III or IV pelvic pressure ulcers in patients with SCI. No significant difference in WSA was found between groups. Despite the use of WSA software (versus manual measurement) for more objective WSA measurements, a key problem with the data is that depth measures were not included. This is particularly problematic given that lack of depth measurements may ignore the importance of healing of undermining and tunnelling in more severe wounds. Another key finding by Ho et al. (2010) was that treated patients registered has having significantly poor nutritional status as measured by lowered serum albumin concentrations (p<0.05) during the 4 week study. This was not apparent in the control group and therefore suggests that the treatment may have partially contributed to the lower serum albumin concentrations in malnourished participants who are less able to compensate for wound-related protein loss. The significance of this finding is likely reduced with the absence of prealbumin measurements that better reflect recent and common nutritional factors such as dehydration.
Coggrave et al. (2002) applied TNP continuously to pressure ulcers of seven individuals with SCI to prepare the wound for surgical closure. Treatment time varied from 11 to 73 days with percent decrease in wound volume varying from 33% to 96%. Granulation tissue was seen to develop and bacterial colonization decreased in five cases. Given the small sample size and variable responses, this study provides limited evidence.

A case study (N=1) described increased TNP performance when used in combination with super-oxidised solution (SOS-Dermacyn) for infection control (Angelis et al. 2012). Another potential contraindication for TNP is described in Mhatre et al. (2013) where a case study of two individuals with SCI described TNP triggered episodes of autonomic dysreflexia. Since only three TNP studies for people with SCI were found, these two case studies are included only as additional information but they do not impact the evidentiary conclusions.

**Conclusion**

*There is level 1a evidence (from one randomized controlled trial and one pre-post study; De Laat et al. 2011; Coggrove et al. 2012) that topical negative pressure facilitates wound healing for pressure ulcers in people with SCI and other patient etiologies. This conclusion is contradicted by level 5 evidence (from one observational study; Ho et al. 2010) but there are significant limitations in the latter study.*

**3.6 Normothermic Dressings**

Heat has been used for centuries because of its positive effects on wound healing (Kloth et al. 2000). Heat when applied to healthy skin causes vasodilation resulting in an increase in blood flow and oxygen delivery to tissues (Rund & Sussman 2007). This has led to a belief by some, that these effects may be beneficial for wounds such as pressure ulcers where perfusion is compromised by pressure (Kloth et al. 2000). Normothermia is the application of controlled levels of radiant-heat energy to a wound (Consortium of Spinal Cord Medicine 2000; Kloth et al. 2000).

**Table 19 Effects of Normothermic Dressing in Pressure Ulcer Healing**

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
</thead>
</table>

Pressure ulcer healing after a SCI is improved when topical negative pressure (TNP) therapy is administered as compared to traditional sodium hypochlorite dressing changes.
Population:  
Treatment group: Mean age=65.4 yr; Pressure ulcer stage: III=9, IV=7; Number of pressure ulcers: SCI=7, Geriatrics=8.  
Control group: Mean age=59 yr; Pressure ulcer stage: III=3, IV=3; Number of pressure ulcers: SCI=3, Geriatrics=3.  

Intervention: A semiocclusive heated dressing applied (38°C) to treatment groups’ ulcers 4.5 hrs/day, Monday to Friday, for 4 wks. Heating element delivered two 60 minute periods of warmth with 1 hr of no heat between and at the end of treatment session. Standard wound care was received by both groups.  

Outcome Measures: Peak daily skin temperature; change in wound surface area.

1. Treatment group’s skin temperature increased 1.88°C inside and 1.86°C outside the pressure ulcer on average, between baseline and end of a session (p<0.05).  
2. Treatment group’s pressure ulcer surface area improved significantly, when compared to the control group (60.73% and 19.24% respectively, p<0.05).

Discussion

In a four week controlled trial of fifteen stage III and IV pressure ulcers where almost 50% of the wounds were post SCI, Kloth et al. (2000) reported a 61% reduction in WSA for wounds treated with a normothermic dressing. In the six control wounds treated with standard wound care, there was a 19% reduction in WSA.

Conclusion

There is level 2 evidence (from one prospective controlled trial; Kloth et al. 2001) that normothermic dressings may improve healing of pressure ulcers post SCI.

3.7 Alternative Pharmacological Treatments

There are many common treatment options for pressure ulcer healing (e.g., topical antimicrobials) and other less common pharmacological treatments including exudate and odour absorbents, protective barriers, healing stimulants, dressings with varying characteristics, non-traditional, holistic and/or naturopathic remedies, physical treatment modalities, etc. It is not uncommon for those with SCI to have multiple co-morbidities that contribute to non-healing pressure ulcers and therefore some adjunctive alternative pharmacological treatments have specifically been trialed for individuals with SCI suffering with pressure ulcers. Recombinant Human Erythropoietin (rHuEPO), Platelet-Rich Plasma (PRP) and anabolic steroids are three such specialized treatments that show promise for pressure ulcer healing in people with SCI.

3.7.1 Recombinant Human Erythropoietin

Chronic ulcers experienced by individuals, such as those with SCI, with hemoglobin values less than 100 g/L may be difficult to heal because of impaired tissue oxygenation. It is important to distinguish between iron deficiency anemia and anemia of chronic disease. This condition occurs in individuals with chronic inflammatory and/or infectious processes; a chronic non-healing pressure ulcer is a chronic inflammatory condition. Anemia of chronic disease is thought to be the result of impaired red blood cell production because of persistent elevated levels of
circulating inflammatory cytokines (Spivak 2002). The endogenous hormone erythropoietin and recombinant human erythropoietin (rHuEPO) play crucial roles in the regulation of hematopoiesis and induce red blood cell production. It has direct hemodynamic and vasoactive effects and modulates the inflammatory process, thereby potentially reversing the conditions believed to underlie chronic pressure ulcers. Treatment with rHuEPO has been shown to be effective in increasing hemoglobin values in five individuals with stage IV pressure ulcers related to anemia of chronic disease (Turba et al. 1992) and in the complete healing of a chronic leg ulcer in a single case report (Al-Momen 1991). One study has been performed that investigated the value of rHuEPO in the healing of chronic wounds among those with SCI.

Table 20 Recombinant Human Erythropoietin for Healing of Pressure Ulcers

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keast &amp; Fraser 2004</td>
<td>Canada</td>
<td></td>
<td>Pre Post N=4</td>
<td></td>
<td>Population: Mean age: 59 yr; Gender: males=4, females=0. Intervention: Six wk of recombinant human erythropoietin (75 IU/kg, three times per wk), in addition to regular rehabilitation practice (inpatient and outpatient). Outcome Measures: Hemoglobin count; Pressure ulcer quantity, area and depth.</td>
<td>1. Day 1: Mean hemoglobin=88g/L; Mean ulcer surface area=42.3cm²; Mean ulcer depth=2.3cm. 2. End of wk 6: Mean hemoglobin=110g/L. Mean ulcer surface=38.4cm²; Mean ulcer depth=1.2cm.</td>
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</table>

Discussion

A retrospective chart review of four individuals with SCI and stage IV chronic pressure ulcers was performed by Keast and Fraser (2004). Following treatment with 75 IU/kg of rHuEPO subcutaneously thrice weekly for six weeks, the mean baseline hemoglobin for the subjects increased from 88±7.4 g/L to 110±3.7 g/L. Mean ulcer surface area decreased from 42.3±40.2 cm² to 38.4±44.3 cm² over six weeks of treatment despite the fact that one of the subjects showed a significant increase in WSA as a result of surgical de-roofing performed to eliminate all undermining. All subjects showed a decrease in the depth of the target ulcer from 2.3±1.2 cm to 1.2±1.0 cm. Observations suggested that some of the subjects demonstrated increased ability to fight recurrent infections; all subjects reported that they felt more energetic and better able to participate in their rehabilitation activities. No adverse effects were observed. rHuEPO shows promise not only in resolving the anemia of chronic disease associated with stage IV pressure ulcers but also in the healing of these wounds in persons with SCI although further study is warranted.

Conclusion

*There is level 4 evidence (from one case series; Keast & Fraser 2004) that recombinant human erythropoietin aids in the healing of stage IV chronic non-healing pressure ulcers post SCI.*

Recombinant human erythropoietin shows promise in assisting with the healing of stage IV chronic non-healing pressure ulcers post SCI.
3.7.2 Sustained-Release Platelet-Rich Plasma Therapy in Grade IV Pressure Ulcers

Platelet-rich plasma is an enriched source of growth factors and cytokines that are critical to tissue regeneration and resolution of inflammation. PRP therapy has been used successfully in orthopedic medicine for the repair of cartilaginous and ligamentous damage (Alsousou et al. 2009). People with SCI often have multiple co-morbidities that contribute to chronic inflammation and non-healing ulcers. PRP therapy has also been used for the treatment of chronic skin ulcers (Anitua et al. 2008).

### Table 21 Platelet-Rich Plasma for Treatment of Pressure Ulcers

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sell et al. 2011</td>
<td>USA</td>
<td>Case Series</td>
<td>N=3</td>
<td>Population: Mean age: 50 yr; Gender: male=3, female=0; Level of injury: paraplegic=1, tetraplegic=2; Wound status: grade IV ulcer=3. Intervention: Treated with a sustained release platelet-rich plasma (PRP) therapy to stimulate wound healing. Outcome Measures: Formation of tissue, vascularity, ulcer area and volume.</td>
<td>1. Treatment resulted in the formation of granulation tissue. 2. Improved vascularity for each patient treated. 3. Overall ulcer area and volume decreased.</td>
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</tr>
<tr>
<td>De Angelis et al. 2012</td>
<td>Italy</td>
<td>Case Report</td>
<td>N=1</td>
<td>Population: 61-yr-old patient was affected by flaccid paraplegia for 20 yr because of posttraumatic medullar injury caused by an accidental fall, with stage IV sacral pressure Ulcer for 3 yr. patient later developed stage IV sacral pressure ulcer. Intervention: Patients received platelet rich plasma (PRP) intra-lesion and peri-lesional injections, combination Dermacyn® and NPWT. Outcome Measures: Reduction in diameter and the depth, reduction of exudates with a change in colour and reduction of odour, infection and the size of pressure ulcer.</td>
<td>1. Exudate &lt; post 48 hours, disappearance in five applications. 2. Odour &lt; post 1 applications. 3. Infection &lt; post 3 applications. 4. Ulcer diameter &lt;1 cm² for every applications. 5. Ulcer depth &lt;post 3 applications. 6. Granulation tissue growth was good. 7. Healing time &lt;30% compared to others protocols. 8. Colour changed from green to yellow.</td>
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</table>

### Discussion

Sell et al. (2011) sought to use immediate and sustained-release CaCl₂-activated PRP therapy for the purpose of improving stage IV (sacral or greater trochanter) pressure ulcer healing in three veterans with SCI. Each patient underwent a different course of treatment (e.g., one patient underwent vacuum therapy and skin allograft) before healing rates stalled or plateaued. PRP therapy accelerated pressure ulcer healing in all three patients but more so in the patient whose pressure ulcer was not undermined. The two patients with severely undermined pressure ulcers did improve with respect to increased granulation and vascularity of tissue in-growth. These latter two patients’ pressure ulcers were also in more pressure sensitive locations which may have additionally contributed to slower improvement. This small case study of reactivated pressure ulcer healing in three patients is a promising indicator for a larger scale study to investigate the invigoration of healing in severe, non-healing pressure ulcers.

Although SCIRE criteria do not allow for single case studies, the single case study by De
Angelis et al. (2012) increases the total sample size of patients by 33% and therefore is added here until future studies involving a larger sample size is available. In total, all four severe, non-healing ulcers reflected in these two studies showed improvement in healing as a result of PRP therapy.

**Conclusion**

*There is level 5 evidence (from one case series and one case study; Sell et al. 2011; De Angelis et al. 2012) that supports the possibility of platelet-rich plasma therapy facilitation of reactivated healing in severe, non-healing pressure ulcers, post SCI.*

Additional study is required to validate platelet-rich plasma therapy as a possible treatment for severe, non-healing pressure ulcers in people with SCI.

### 3.7.3 Anabolic Steroid Agents

Impaired nutritional status and decreased nutritional intake are common in those with SCI and significantly associated with development and timely healing of pressure ulcers (Consortium for Spinal Cord Medicine 2000; Houghton et al. 2013). Spungen et al. (2001) stated that use of anabolic steroids and increased protein intake have been associated with promoting anabolism, weight gain and in turn wound closure in burn patients. The United Stated Food and Drug Administration approved oxandrolone for the treatment of involuntary weight loss and for chronic infections. Since a "hypermetabolic, potentially catabolic state also is associated with pressure ulcers" (Spungen et al. 2001, p. 140), the use of an anabolic steroid agent may also promote closure of nonhealing, pressure ulcers in the SCI population.

#### Table 22 Anabolic Steroid Agents for Healing of Pressure Ulcers

<table>
<thead>
<tr>
<th>Author Year Country</th>
<th>PEDro Score Research Design Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bauman et al. 2013</td>
<td>USA PEDro=5 RCT N=212</td>
<td>Population: Inpatients with SCI and stage III or IV target pressure ulcers (TPUs). <strong>Intervention:</strong> Oxandrolone, 20 mg/d (n=108), or placebo (n=104) until the TPU healed or 24 wk. <strong>Outcome Measures:</strong> The primary outcome was healed TPUs. The secondary outcome was the percentage of TPUs that remained healed at 8-wk follow-up.</td>
<td>1. Oxandrolone showed no benefit over placebo for improving healing or the percentage of TPUs that remained closed after 8 wk of treatment.</td>
</tr>
<tr>
<td>Spungen et al. 2001</td>
<td>USA Case Series N=9</td>
<td>Population: Mean age=24-73 yr; Gender: males=9; Total number of pressure ulcers since SCI=1 to 7. <strong>Intervention:</strong> Subjects with stage III and IV pressure ulcers were treated with 20 mg of oxandrolone daily with 20 g of glutamine dissolved in orange juice. Pressure ulcer care and support surfaces remained consistent. <strong>Outcome Measures:</strong> Number of pressure ulcers healed.</td>
<td>1. After oxandrolone and glutamine treatment, 8/9 subjects were completely healed, the majority within 3-6 mo. Two subjects required 12 mo of treatment for complete healing.</td>
</tr>
</tbody>
</table>
Discussion

In a case series of nine subjects with stage III and IV pressure ulcers, Spungen et al. (2001) demonstrated complete healing in the majority of subjects (8/9), 3-12 months after daily administration of 20mg of oxandrolone. Bauman et al. (2013; N=212) initiated a RCT in a similar patient group suffering from stage III and IV pressure ulcers. Unfortunately, this ambitious study was terminated early due to feasibility issues. The most significant of these issues included the heterogeneity of confounding co-morbidities across the study cohort, non-uniformity of clinical care across contributing sites, and high withdrawal rates in both groups likely due to the propensity of people with SCI to develop complications independent of the study. Available results did not show improvement in wound healing or closure between the active and control groups. The results did, however, reveal markedly increased serum pre-albumin levels that reflected improved better nutritional status in general. Ultimately, this RCT did not produce results to support that oxandrolone was more useful than placebo to improve chronic pressure ulcer healing.

Conclusion

There is level 2 evidence (from one flawed randomized controlled trial; Bauman et al. 2013) that does not support the use of oxandrolone (anabolic steroid) to facilitate healing of serious pressure ulcers post SCI. However, very limited, earlier level 4 evidence (from one case series; Spungeon et al. 2001) did lend some support for the use of oxandrolone to promote healing of stage III and IV pressure ulcers post SCI.

The anabolic steroid agent Oxandrolone does not promote healing of serious pressure ulcers post SCI.

3.8 Dressings

Dressings are one of several interventions required to treat a wound. The appropriate choice of a dressing aids the body’s ability to heal a wound. Dressings are intended to keep the wound bed moist, remove excess exudate, provide a barrier against contamination, and to promote gas exchange. An appropriate dressing increases healing rate, reduces pain, and decreases infection rates while being cost effective and affordable (Broussard 2007). Due to the estimated costs associated with pressure ulcers and their treatment, various dressings used with the SCI population have been investigated. There is little evidence that dressing protocols in pressure ulcers in people with SCI are different than the general population (Houghton et al. 2013). The Registered Nurses Association of Ontario (2007), as cited by Houghton et al. (2013), recommends that the dressing selected:

- Keeps the ulcer bed continuously moist and the surrounding skin dry
- Controls exudate but does not dry out the wound bed or macerate the peri-wound
- Provides thermal insulation and wound temperature stability
- Protects the wound from microbial contamination
- Maintains its integrity and does not leave fibres or foreign substances in the wound
- Does not cause wound bed trauma on removal
- Meets the following criteria: simple handling, economical in cost and time, promotes (or does not slow) wound healing, acceptable to the person with the pressure ulcer
Although many dressing products are available, only three specific dressing materials (i.e., hydrocolloid, hydrogel, platelet gel and phenytoin) have some evidence for use in the SCI population.

When hydrocolloid dressings are placed over a wound, the dressing absorbs the exudate and changes into a gel. The outside of the dressing allows for gas exchange and protects against outside contamination. Hydrocolloid dressings maintain a moist wound environment and support autolytic debridement. Dressings can be left in place for 3-7 days, decreasing time and costs (Heynemen et al. 2008; Consortium for Spinal Cord Medicine 2000; Houghton & Campbell 2007; Houghton et al. 2013). Hydrocolloid dressings are typically used for stage II and III pressure ulcers (Heynemen et al. 2008).

Hydrogel dressings act to retain moisture and rehydrate wounds, provide autolytic debridement and fill dead space. They provide minimal absorption of exudates. Hydrogel is available as a sheet or in an amorphous viscous form which requires a secondary dressing (Broussard 2007; Consortium for Spinal Cord Medicine 2000). Hydrogel dressings can be left in place for 48-72 hours depending on the type of hydrogel in use (Broussard 2007).

Platelet gels are rich in growth factors that are thought to aid wound healing and are stored in the frozen state until ready for use. It is commonly used in conjunction with a polyurethane sponge/semi-permeable film dressing system (Biatain Coloplast®).

Phenytoin is most commonly known as an oral anti-epileptic medication but the healing properties of topical phenytoin were first reported over 50 years ago. Over the years, various topical preparations of phenytoin have been studied and, while its exact mechanism of action is unknown, it is thought to enhance healing by stimulation of fibroblast proliferation, promotion of collagen deposition, antibacterial activity and decreased collagenase activity (Anstead et al. 1996; Kelin & Gorling 1961; Subbanna et al. 2007). It has not been widely used because its efficacy has not been sufficiently established through controlled clinical trials (Ovington 1999; Subbanna et al. 2007).

Table 23 Effectiveness of Dressings for Treatment of Pressure Ulcers

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scevola et al. 2010</td>
<td>Italy</td>
<td>PEDro=4</td>
<td>RCT</td>
<td>N=13</td>
<td>Population: Patients affected by SCI with 16 pressure sores over a period of 20 mo. Intervention: Allogenic platelet gel or with current best practice approach to chronic wounds dressing protocol. Outcome Measures: Volume reduction of pressure ulcers, reduction in amount of ulcers.</td>
<td>1. No statistically significant difference was demonstrated in volume reduction between the two groups, although a statistically significant difference could be demonstrated in the onset time of granulation tissue proliferation as in the wounds treated with platelet gel the healing process was triggered earlier. 2. Platelet gel is mostly effective within the first 2 wk of treatment while a prolonged treatment does not provide any significant advantage.</td>
</tr>
<tr>
<td>Subbanna et al. 2007</td>
<td>Population: Patients with stage II ulcers.</td>
<td>1. Improvement in PUSH 3.0 and</td>
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<tr>
<td>Author Year</td>
<td>Country</td>
<td>PEDro Score</td>
<td>Research Design</td>
<td>Total Sample Size</td>
<td>Methods</td>
<td>Outcome</td>
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<tr>
<td>India</td>
<td>PEDro=9</td>
<td>RCT</td>
<td>N=28</td>
<td>Treatment group (n=14): Mean age=34.25 yr; Gender: males=13, females=1; Control group (n=14): Mean age=31.64 yr; Gender: males=12, females=2. All subjects had stage II ulcers. <strong>Intervention</strong>: Patients were randomly placed (double blind manner) in the treatment group which received 5mg/ml phenytoin solution soaked sterile gauge for their pressure ulcer dressing once daily for 15 days and the control group received saline soaked gauge. <strong>Outcome Measures</strong>: Pressure ulcer scale for healing (PUSH) 3.0, ulcer size, ulcer volume</td>
<td>ulcer size was seen in the topical phenytoin group however this difference did not reach statistical significance, p=0.261 and 0.132 respectively. 2. Reduction in ulcer volume was seen in the control group however it was not significant, p=0.777</td>
<td></td>
</tr>
<tr>
<td>Hollisaz et al. 2004</td>
<td>Iran</td>
<td>PEDro=7</td>
<td>RCT</td>
<td>Population: Gender: males=83; Level of injury: paraplegia; Stage of pressure ulcers: I=33, II=58. <strong>Intervention</strong>: 1 of 3 dressing groups: 1) Simple dressing (SD) – changed twice daily; 2) Hydrocolloid dressing (HD) – changed 2x/wk; 3) Adhesive plus phenytoin cream (PC) – changed once daily. <strong>Outcome Measures</strong>: Healing status of pressure ulcer.</td>
<td>1. HD group had the most healing (74%) as compared to the PC group (40%, p&lt;0.01) and the SD group (27%, p&lt;0.005). 2. Of all the groups, the HD group also had higher rating of healing of stage I ulcers (p&lt;0.05). 3. For stage II ulcers, HD treated ulcers healed better than SD treated ulcers (67% vs. 16%) p&lt;0.005 but no better than PC (48%, p&gt;0.05) treated ulcers. 4. HD also healed gluteal ulcers more completely than other groups (p&lt;0.001); however, groups did not differ on healing of sacral ulcers.</td>
<td></td>
</tr>
<tr>
<td>Kaya et al. 2005</td>
<td>Turkey</td>
<td>PEDro=4</td>
<td>RCT</td>
<td>Population: Mean age=16-56 yr; Gender: males=24, females=3; Ulcer stage: I=12, II=34, III=3. <strong>Intervention</strong>: Treatment group (n=15, 25 PU): an occlusive hydrogel dressing, changed every 4 days (unless contaminated). Control group (n=12, 24 PU): povidone-iodine soaked gauze changed daily. <strong>Outcome Measures</strong>: Healing rate (cm²/day).</td>
<td>1. Healing rates did not differ between groups. 2. More wounds healed in the treatment group (n=21) than in the control group (n=13), p&lt;0.04.</td>
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<tr>
<td>Whittle et al. 1996</td>
<td>Canada</td>
<td>Case study</td>
<td>N=4</td>
<td>Population: Mean age=55.75 yr; Gender: males=3, females=1; Level of injury: paraplegia=2, tetraplegia=2; Pressure ulcer (5 ulcers) stage: II=1, III=3, IV=1. <strong>Intervention</strong>: Hydrogel dressings, for different time periods depending on the case. <strong>Outcome Measures</strong>: Pressure ulcer improvement, measured 1x/wk.</td>
<td>1. Hydrogel dressing application varied from 4 to 6 wks. 2. In all cases, pressure ulcers improved drastically, with 3 cases being completely healed.</td>
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</table>

**Discussion**
In a RCT involving 83 subjects, Hollisaz et al. (2004) found that those in the hydrocolloid dressing group (n=28) had the greatest completion of healing regardless of ulcer location and stage (74%; p<0.005), compared to those in the phenytoin cream group (40%; n=28) or simple dressing group (27%; n=27). For stage I ulcers, those in the hydrocolloid group healed faster than those in the other two groups; however, for stage II ulcers, there was no difference in healing between the hydrocolloid and phenytoin cream groups (67% vs 48%; p>0.05). In examining the area of injury, gluteal ulcers also healed more completely in the hydrocolloid group than in the other two, whereas the healing of sacral ulcers did not differ between the three groups.

Using a phenytoin solution (5mg/ml), Subbanna et al. (2007) found improvements in PUSH 3.0 and ulcer size when compared to normal saline but the differences did not reach statistical significance (p=0.261 and p=0.132, respectively).

Whittle et al. (1996) treated five pressure ulcers (stage II-IV) with hydrogel dressings. After approximately 4-6 weeks of treatment, three ulcers healed completely while the two others showed a large improvement. Kaya et al. (2005) compared the effectiveness of applying an occlusive hydrogel type dressing to a povidone-iodine soaked gauge dressing. There were no statistically significant differences in rate of healing but significantly more ulcers healed with the hydrogel dressing.

In a RCT, Scevola et al. (2010) found healing was triggered earlier as indicated through onset time of granulation tissue proliferation when platelet gels were used to treat pressure ulcers in individuals with SCI. Platelet gel use did not make a difference in wound volume reduction and was only effective within the first two weeks of treatment.

**Conclusion**

*There is Level 1 evidence (from one randomized controlled trial; Hollisaz et al. 2004) that completion of healing for stage I and II pressure ulcers is greater with an occlusive hydrocolloid dressing compared to phenytoin cream or simple dressing post SCI.*

*There is Level 2 evidence (from one randomized controlled trial; Kaya et al. 2005) that occlusive hydrogel-type dressings heal more pressure ulcers than conservative treatment post SCI.*

*There is level 1 evidence (from one randomized controlled trial; Subbanna et al. 2007) that topical phenytoin shows a trend towards healing of stage I and II pressure ulcers post SCI.*

*There is level 2 evidence (from one randomized controlled trial; Scevola et al. 2010) that platelet gel dressings, when used within the first 2 weeks of treatment can trigger earlier granulation tissue proliferation towards pressure ulcer healing, post SCI.*

<table>
<thead>
<tr>
<th>Occlusive hydrocolloid dressings are useful for healing of stage I and II pressure ulcers post SCI.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platelet gel dressings used within the first two weeks of treatment will trigger pressure ulcer healing post SCI</td>
</tr>
</tbody>
</table>
3.9 Non-Surgical Management and Debridement

A long-standing pressure ulcer management procedure is to excise diseased tissue in and around the wound to reduce the risk of wound progression and infection (Conway & Griffith 1956). Although the most common method of debridement is surgical, non-surgical debridement methods are also beneficial to the healing of pressure sores in people with SCI. For people with SCI, three types of non-surgical debridement methods have been studied that are also useful in regular pressure ulcer management: pulsatile lavage, maggot therapy and silicone moulding. Autolytic debridement using occlusive dressings is discussed in section 3.8 (Effectiveness of Dressings for Treatment of Pressure Ulcers Post SCI) above since dressings are used predominantly for routine care of pressure ulcers and contraindicated in the presence of infection where debridement is often required.

Table 24 Maggot Therapy for Healing of Pressure Ulcers Post SCI

<table>
<thead>
<tr>
<th>Author Year Country PEDro Score Research Design Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pulsed Lavage</strong></td>
<td><strong>Population:</strong> People with SCI and stage III and IV pelvic pressure ulcers. <strong>Intervention:</strong> Daily low-pressure pulsatile lavage treatment with 1 L of normal saline at 11 psi of pressure was applied to the treatment group along with standard dressing changes. The control group received only sham treatment and standard dressing changes. <strong>Outcome Measures:</strong> Linear and volume measurements of pressure ulcer dimensions were obtained 1x/wk for 3 wk.</td>
<td>1. Pulsatile lavage enhanced stage III and IV pelvic pressure ulcer healing rates in people with SCI relative to standard pressure ulcer treatment alone.</td>
</tr>
<tr>
<td>Ho et al. 2012 USA PEDro=5 RCT N=28</td>
<td><strong>Population:</strong> Mean age = 55 yr; Gender: males=28, females=0; Level of Injury: paraplegic=12, tetraplegic=12; Wound status: grade III ulcers=8, grade IV ulcers=IV. <strong>Intervention:</strong> Chart reviews of patients who were treated by pulsatile lavage therapy. <strong>Outcome Measures:</strong> Adverse effects, treatment discontinuation and injuries to clinical care providers.</td>
<td>1. No adverse events for patients or care providers (mean therapy duration 46 days). 2. Treatment was temporarily discontinued in one patient due to mild bleeding from wound and resumed six days later. 3. Treatment discontinued for two patients due to a fever in one patient and rapid improvement in wound size in another.</td>
</tr>
<tr>
<td>Bogie et al. 2013 USA Observational N=28</td>
<td><strong>Population:</strong> Patients with diabetic foot ulcers and 18 patients with pressure ulcers after SCI. <strong>Intervention:</strong> Maggot therapy or traditional dressing. <strong>Outcome Measures:</strong> Changes in the lesions were observed and bacterial cultures tested.</td>
<td>1. Maggot therapy is a safe and effective method for treating chronically infected lesions 2. All ulcers healed completely. The times taken to achieve bacterial negativity, granulation and healing of lesions were all significantly shorter in the maggot therapy group than in the control group, both for diabetic foot ulcers (p&lt; 0.05) and pressure ulcers (p&lt; 0.05).</td>
</tr>
</tbody>
</table>

Wang et al. 2010 China Observational N=25
Discussion

Hydrotherapy is considered a form of mechanical debridement that is gentle and almost free of pain (Krasner D 1990). However, hydrotherapy via daily whirlpool (Burke et al. 1998) can be costly in terms of personnel and facility resources and potentially can be a source of cross-contamination, especially when wounds are draining heavily (Maragakis et al. 2004). Conversely, Ho et al. (2012) found that pressurized saline hydrotherapy directed on the wound at the bedside is an effective form of hydrotherapy that is less resource intensive and reduces the potential for cross-contamination. This form of pulsatile lavage therapy has been successfully used in intra-operative joint cleansing during orthopaedic surgery. As such, pulsatile lavage therapy can also be used for non-debridement related cleansing of wounds at the bedside. The findings by Bogie et al. (2013) on cleansing and debridement for grade III and IV align with those by Ho et al. (2012) in that it is beneficial. In both studies, the wound dimensions decreased significantly in the pulsatile lavage group with a significantly faster rate of healing.

In the retrospective chart review undertaken by Bogie et al. (2013), adverse events were reported as a result of pulsatile lavage therapy used to promote pressure ulcer healing. One adverse event was reported Bogie (2013) but none by Ho et al. (2012). However, an outbreak of multidrug-resistant Acinetobacter baumannii associated with pulsatile lavage wound treatment was reported at Johns Hopkins Hospital as a result of extensive environmental contamination during pulsatile lavage (Maragakis et al. 2004). In addition to multidrug-resistant Acinetobacter baumannii transmission between patients, and caregiver splash injuries, the authors postulated additional potential adverse events such as pain, bleeding, and autonomic dysreflexia with subsequent hypertensive crisis, myocardial infarction and cerebrovascular accident. The one adverse event reported for one of 28 patients in Bogie et al. (2013) was described as minor wound bleeding leading to interruption of treatment. Although environmental contamination could not be evaluated in the 2013 retrospective chart review, after examination of the circumstances of the Johns Hopkins outbreak, Bogie et al. (2013) suggested that standard infection control practices would eliminate the potential for clinical safety concerns. These standard infection control practices include low-pressure pulsatile lavage, avoidance of common wound care treatment areas (e.g., bedside lavage is preferred), and wound area draping.
The beneficial effects of fly larvae have been known for centuries but the intentional use of fly larvae (maggot therapy) for the treatment of wounds was used extensively the 1930s and 1940s. It then fell out of favour when antimicrobials and other forms of debridement (including surgical) were introduced. Maggot therapy, using sterilized larvae of *Phaenicia sericata* species, was reintroduced to treat intractable wounds in the 1990s (Mumcuoglu et al. 1999; Sherman 1995, 2002). Maggot therapy is believed to work through three processes: debridement of necrotic tissue, disinfection of the wound and promotion of tissue growth (as cited by Sherman 2002). In a non-RCT, Sherman et al. (1995) reported that 8 of 20 patients diagnosed with stage III and IV pressure ulcers were treated with maggot therapy. All eight patients underwent three weeks of conventional treatment, followed by maggot therapy. All necrotic wounds were debrided within one week of maggot treatment and wound healing was faster among those who had received maggot therapy than those who had not. Another maggot study that included only 42% SCI patients (Wang et al.2010, SCI N/N=18/43) was included in this discussion given the dearth of studies on this intervention. Wang et al. (2010) examined maggot bio-debridement and reported that all SCI related pressure ulcers healed more quickly as evidenced by bacterial negativity, granulation (p<0.05) and no recurrence after an average follow-up of 3.5 months.

Effective mechanical and sharp debridement requires clear visualization of the necrotic tissue in order to be thorough and also to not cause additional damage by perforating healthy and/or regenerating tissue. Methylene blue diluted with hydrogen peroxide instilled in the wound can leave a visual guide for tissue excision. However, the wound cavity shape itself can be a barrier to effective visualization even if the necrotic tissue deeper in the cavity has been stained. To overcome this barrier, Erba et al. (2010), with a convenience sample of 10 paraplegic patients presenting with grade IV ischial ulcers, injected silicone to fill the ulcer cavity. Within six minutes, the silicone vulcanized into a tumor-like mass that was an imprint of the ulcer cavity. Under palpatory control, the imprint was then expelled and examined for completeness of excised necrotic tissue. Wheelchair mobilization at six weeks after the procedure, discharge after ten weeks and four consecutive 6-month follow-up assessments (including clinical assessment for potential adverse events (e.g., hematoma, infection, seroma) and photographic documentation), revealed no observation of early or late postoperative consequences including recurrence.

Conclusion

*Level 1 evidence (from one randomized controlled trial; Ho et al. 2012) underpins the use of pulsatile lavage hydrotherapy debridement for Stage III and IV pressure ulcers secondary to SCI.*

*There is level 5 evidence (from one observational study; Bogie et al. 2013) that pulsatile lavage therapy, used in conjunction with standard infection control standards, is likely a safe debridement method for Stage III and IV pressure ulcers in people with SCI.*

*There is level 2 evidence (from one prospective controlled trial and one observational study; Wang et al. 2010; Sherman et al. 1995) that supports the use of maggot therapy as an adjunctive therapy for pressure ulcer debridement post SCI.*

*There is level 4 evidence (from one post-test study; Erba et al. 2010) that supports the use of silicone moulding as a radical en bloc debridement method for pyramidal shaped grade IV pressure ulcer cavities in people with SCI.*
Pulsatile lavage therapy is an effective, and likely safe, non-surgical management and debridement method for the treatment of grade III and IV pressure ulcers secondary to SCI. Maggot therapy is also likely useful in this patient group. Silicone moulding may also be considered as a radical en bloc debridement method for grade IV pressure ulcers in people with SCI.

### 3.10 Topical Oxygen

Chronic hypoxia of a wound and periwound tissues is known to impede wound healing by impairing collagen formation, angiogenesis and epithelialization. Hypoxia also lowers a wound's resistance to infection (Stotts et al. 2007). Oxygen supply to chronic wounds has been augmented by treatment with systemic (hyperbaric) oxygen therapy or through a less studied modality, topical oxygen therapy (Stotts et al. 2007; Kalliainen et al. 2003). No controlled studies have examined the efficacy of hyperbaric oxygen on the healing of pressure ulcers (Houghton & Campbell 2007; Consortium of Spinal Cord Medicine 2000; Houghton et al. 2013). Kalliainen et al. (2003) studied topical oxygen and its effects on the healing of chronic wounds, some of which were noted to be pressure ulcers but the exact number was not reported. Among 58 wounds, 38 (65.5%) healed during treatment with topical oxygen alone but pressure ulcers were included in wounds found to be least responsive to topical oxygen.

#### Table 25 Topical Oxygen for Treatment of Pressure Ulcers

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banks &amp; Ho 2008</td>
<td>USA</td>
<td>Pre-post</td>
<td>N=3</td>
<td></td>
<td>Population: Mean age=61 yr; Gender: males; Level of injury: C7, T12, T10; Severity of injury: AIS A. Treatment: SCI patients with stage IV pressure ulcers in their pelvic region were treated with EpiFLO device (extracts oxygen from air, concentrates to near 100% and delivers oxygen via cannula to saturate wound) daily during rehabilitation. Outcome Measures: Wounds linear measure and volume.</td>
<td>1. First patient linearly had 49% improvement 9 wk post treatment; pre-treatment the patient's wound measured 20.5cm linearly and volume was 252cm³, while 9 wk later, the linear measure reduced to 10.2cm linearly with a volume of 24 cm³. 2. The second patient's wound reduced from 10.5 cm linearly to 5.5cm after 5 wk treatment and volume decreased from 30cm³ to 4 cm³, linearly this was a 48% improvement from baseline. 3. The last patient's wound decreased by 31% from baseline after 5 wk treatment.</td>
</tr>
</tbody>
</table>

#### Discussion

In one very small, pre-post study of three patients, Banks and Ho (2008) demonstrated that when topical oxygen (EpiFLO device) was applied to stage IV pelvic pressure ulcers, comparison of pre- and post-treatment linear measurements showed 49%, 48% and 31% improvement, respectively, for each patient. While a positive effect was shown, more research is needed to determine the role of topical oxygen therapy as an adjunctive therapy for the healing of pressure ulcers post SCI.
Conclusion

There is level 4 evidence (from one pre-post study; Banks & Ho 2008) that topical oxygen therapy may improve healing of pressure ulcers post SCI.

Use of topical oxygen therapy may have a positive association with healing of pressure ulcers post SCI but more research is needed.

3.11 Surgical and Other Miscellaneous Topical and Physical Treatments

The introductory information on incidence, prevalence and impact of pressure ulcers solidify the importance of understanding the spectrum of prevention and management of pressure ulcers, especially in people with SCI given their neurologically compromised sensation, mobility and cardiovascular functions. Previous sections of this chapter have discussed assessment of risk factors and assessment. The most important factor in the management of all stages of ulcers (i.e. SDTI, stage I, II, III, IV) is a comprehensive assessment of risk factors and co-morbidities to choose the most effective treatment methods. Regular reassessment is also necessary, especially in more severe ulcers (i.e. stage III and IV) that are often persistent and/or recur. There are many non-surgical methods of management that facilitate healing of all pressure ulcers but stage IV ulcers almost always require surgery. Before surgery is elected, removal of unhealthy tissue using surgical (and non-surgical) methods is a standard procedure that can also expedite the healing of persistent stage III and IV ulcers. The studies reviewed in this section provide evidence that surgery can reduce rehabilitation costs and time by preventing protein loss from the wound, development of sepsis or osteomyelitis and development of additional skin conditions, such as Fournier’s gangrene (Backhaus et al. 2011) and necrotizing fasciitis (Citak et al. 2011), secondary to the pressure ulcer. Some studies also provide data to support surgical choices that improve quality of life of people with severe ulcers by decreasing limitations of daily functioning and improving the hygiene and appearance of the skin. With the many surgical reconstruction options available for wound repair, this section attempts to summarize the potential benefits of surgical repair for pressure ulcers in people with SCI.

### Table 26 Surgical and Other Miscellaneous Topical and Physical Treatments

<p>| Author Year | Country | PEDro Score | Research Design | Total Sample Size | Population: Gender: males=285, females=67; Level of injury: paraplegic=268, tetraplegic=84; Wound status: grade I ulcers=84, grade II ulcers=152, grade III ulcers=254, grade IV ulcers=167. | Intervention: None. Patient charts were reviewed if they received surgery for pressure ulcers. | Outcome Measures: Rate and type of complications after pressure ulcer surgery. | Outcome |
|-------------|---------|-------------|-----------------|------------------|-------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|----------------------------------|
| Biglari et al. 2013 | Germany | Observational | N=352 | | 1. 87 complications in 421 flaps. 2. Suture line dehiscence was the most common complication (27 cases), followed by 22 cases of infection, 17 cases of hematoma, 12 cases of necrosis and 9 cases of flap necrosis. 3. Rotation flaps had the lowest rate of complications (11.5%). |
| Grassetti et al. 2013 | Italy | Observational | N=143 | | Population: Mean age=51 yr; Gender: male=87, female=56; Level of injury: paraplegic=79, tetraplegic=63; Wound status: grade IV ulcer=143. | 1. 8 patients had major complications requiring reoperation. 2. 6 patients developed a new occurrence. 3. Overall complication percentage was 22.4% (included dehiscence and flap necrosis). |</p>
<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Country</th>
<th>Study Design</th>
<th>Sample Size</th>
<th>Population</th>
<th>Intervention</th>
<th>Outcome Measures</th>
<th>Additional Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bertheuil et al. 2013</td>
<td>France</td>
<td>Observational</td>
<td>N=23</td>
<td>Mean age=40.4 yr; Gender: males=20, females=3; Level of injury: paraplegic=19, tetraplegic=4; Wound status: stage IV ulcers=23 patients.</td>
<td>None. Patient charts were reviewed if they underwent reconstruction for persistent decubitus ulcers.</td>
<td>Surgery rates of complication, reoccurrence or failed procedures.</td>
<td>Complication resulted in an average of 5.8 additional days of bed rest.</td>
<td></td>
</tr>
<tr>
<td>Mehta et al. 2012</td>
<td>USA</td>
<td>Observational</td>
<td>N=90</td>
<td>Mean age: 60 yr; Gender: male=2, female=88; Level of injury: paraplegic=61, quadriplegic=27, spina bifida=2; Wound status; grade III or IV ulcer=90.</td>
<td>None. Patient charts were reviewed if they underwent reconstruction for persistent decubitus ulcers.</td>
<td>Incidence of recurrence for biplanar flaps and fasciocutaneous flaps.</td>
<td>The incidence of recurrence for the fasciocutaneous group was 53% (mean follow-up, 38.5 mo). The incidence of recurrence for the biplanar flap was 25% (mean, follow-up 41 mo). No significant difference in the frequency of wound dehiscence, wound infection, seroma or hematoma formation between groups.</td>
<td></td>
</tr>
<tr>
<td>He et al. 2012</td>
<td>China</td>
<td>Post-test</td>
<td>N=11</td>
<td>Mean age=47 yr; Gender: males=9, females=2; Level of injury: paraplegic=11; Wound status: grade III or IV ischial ulcer=11.</td>
<td>Surgery using free partial lateral latissimus dorsi musculocutaneous flap.</td>
<td>Recurrence and success rates of surgery.</td>
<td>All surgeries were successful. No recurrence occurred during follow-up (mean 60 mo). All patients experienced various degrees of back tightness, shoulder weakness and limited shoulder motion since surgery. Within 9 mo adverse side effects had stopped in all but 3 patients.</td>
<td></td>
</tr>
<tr>
<td>Unal et al. 2012</td>
<td>Japan</td>
<td>Post-test</td>
<td>N=11</td>
<td>Mean age: 37.8 yr; Gender: males=9, females=2; Level of injury: paraplegic=11; Wound status: recurrent lesions or multiple ischial sores=11.</td>
<td>Use of inferior gluteal artery (IGA) and posterior thigh perforators in ischial pressure sore management.</td>
<td>Perforator of flap, recurrences, complications and postoperative follow-up.</td>
<td>Nine IGA and five posterior thigh perforator flaps were used and in two patients a combination of both was done. Six patients presented with recurrent lesions and five were operated for sacral and contralateral ischial pressure sores previously. Two patients had suture detachments and their wounds were resutured (mean, follow-up 34.3 mo). During follow-up, two patients had recurrences.</td>
<td></td>
</tr>
<tr>
<td>Chen et al. 2011</td>
<td>China</td>
<td>Observational</td>
<td>N=160</td>
<td>Mean age=47.4 yr; Gender: males=119, females=41; Level of injury: SCI=141, brain trauma and lesion=15, other=4. Wound status: grade IV ulcer=160.</td>
<td>Skin traction for surgical treatment and until wound heals.</td>
<td>Healing and complication rates from surgery.</td>
<td>All sores but 10 healed primarily (mean follow-up 35.5 mo). Two of the ten patients had sacral and coccygeal sores where wound cavity and tissue loss was too extensive to complete closure during the first operation. The remaining eight cases had sores of IT in which collection of blood in the wound cavity required a second extended debridement and closure.</td>
<td></td>
</tr>
</tbody>
</table>
### Ahluwalia et al. 2010
**Canada**
**Observational**
**N=78**

**Population:** Mean age=43 yr; Gender: males=57, females=21; Level of injury: spinal cord=73; Wound status: Stage III or IV pressure wound.

**Intervention:** None. Viewed charts of those who had surgical re-construction of an ischial pressure sore.

**Outcome Measures:** Success rates and complication rates by sore location and reconstruction method.

1. Flap complications at follow-up were observed in 17 patients.
2. There was a 7% recurrence rate.
3. 15% of patients required a second reconstruction.

### Kim et al. 2010
**Korea**
**Post-test**
**N=75**

**Population:** Mean age=54 yr; Gender: males=43, females=32; Level of injury: paraplegia=34, tetraplegia=5, ambulatory=36.

**Intervention:** Gluteus maximus perforator-based island flap for coverage of buttocks defects.

**Outcome Measures:** Recurrence and complication rates of gluteus maximus perforator-based island flap surgery.

1. No recurrence at follow-up (mean, 15 mo).
2. 3 complications (distal flap necrosis, wound dehiscence, infected sacral sore).

### Singh et al. 2010
**India**
**Pre-post**
**N=30**

**Population:** Mean age: 33.2 yr; Gender: male=23, female=7; Level of injury (ASIA): grade A=21, grade B=6, grade C=2, grade D=1, grade E=0; Wound Status: grade III or IV ulcer=30.

**Intervention:** Various types of flap surgery were performed.

**Outcome Measures:** Improvement in health (hemoglobin, serum proteins, and general well-being), patient satisfaction and global quality of life scores according to the visual analog scale.

1. There was a statistically significant increase in mean values of quality of life, hemoglobin and total serum proteins at 6-mo follow-up.
2. Improvements in subjective well-being were reported in 76.7% of patients.
3. Satisfaction was reported in 83.3% of patients with the ultimate outcome of the surgery.

### Borgognone et al. 2010
**Italy**
**Post-test**
**N=12**

**Population:** Mean age=52 yr; Gender: male=10, female=2; Level of injury: paraplegic=12; Wound status: grade III ulcers or grade IV ulcers=12.

**Intervention:** ‘Criss-cross’ surgical treatment of ischial pressure sores.

**Outcome Measures:** Recurrence of ulcer.

1. Recurrence of ulcer occurred in one patient (mean follow-up 45 mo).
2. All flaps survived however two distal cutaneous partial necroses of the flaps occurred.
3. Suture dehiscence at the wound edge occurred in one patient.
4. A second procedure was necessary for one patient with a hematoma under the flap.

### Lin et al. 2010
**China**
**Post-test**
**N=12**

**Population:** Mean age=40 yr; Gender: males=9, females=3; Level of injury: paraplegic=10, tetraplegic=2; Wound status: grade IV ulcer=12.

**Intervention:** Surgical reconstruction with a laterally based posterior-thigh fasciocutaneous flap.

**Outcome Measures:** Flap survival, recurrence of pressure sore and primary wound healing.

1. In two patients pressure sores recurred (mean follow-up, 62 mo).
2. All the flaps survived.
3. Primary wound healing occurred in all patients.

### Srivastava et al. 2009
**India**
**Post-test**
**N=25**

**Population:** Mean age=27.6 yr; Gender: female=6, male=19; Level of injury: paraplegic=22, tetraplegic=3; Level of ulcer: stage III=13, stage IV=23, unknown=3.

**Intervention:** Surgery (debridement, split skin grafting, flap mobilization and closure).

**Outcome Measures:** Ulcer healing rate,

1. Four participants had initial complications: wound dehiscence and delayed graft healing (mean follow-up, 15.4 mo).
2. Four participants had ulcer recurrence.
3. The majority of participants (56.5%) significantly improved neurologically on ASIA grade and functional evaluation.
postoperative complications, ulcer recurrence rate and neurologic (ASIA grade) and functional recovery (Barthel index).

<table>
<thead>
<tr>
<th>Study</th>
<th>Methodology</th>
<th>N</th>
<th>Population: Mean age=</th>
<th>Gender:</th>
<th>Level of injury:</th>
<th>Intervention:</th>
<th>Outcome Measures:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tavakoli et al. 1999</td>
<td>Observational</td>
<td>23</td>
<td>43.7 yr</td>
<td>female=6, male=19</td>
<td>paraplegic=14, tetraplegic=9</td>
<td>None.</td>
<td>Recurrence rate of pressure ulcers.</td>
</tr>
<tr>
<td>Kierney et al. 1998</td>
<td>Observational</td>
<td>158</td>
<td>34.5 yr</td>
<td>female=35, male=123</td>
<td>quadriplegic=27, paraplegia=54, congenital spina bifia=11, multiple sclerosis=7, other (e.g stroke)=19</td>
<td>Retrospective chart review of patients who underwent surgical closure of pressure sores.</td>
<td>Pressure sore recurrence, patient recurrence (previous patient who developed new sore), rates at sites and for specific flap location.</td>
</tr>
</tbody>
</table>

1. Four participants died at follow-up (mean, 62 mo).
2. Overall ulcer recurrence rate was 41.4% and patient recurrence was 47.8%.
3. No evidence of ulceration was observed in 79.5% of patients in the region of their flaps.
4. Seven flaps had to undergo at least one re-advancement due to pressure sore recurrence.
5. One patient required a second re-advancement.
6. Males recurrence rate was 53.8% compared to 40% for females.
7. Tetraplegic versus paraplegic patients recurrence rates were 33.3% and 57.1% respectively.

<table>
<thead>
<tr>
<th>Study</th>
<th>Methodology</th>
<th>N</th>
<th>Population: Mean age=</th>
<th>Gender:</th>
<th>Localization of primary pressure sores:</th>
<th>Intervention:</th>
<th>Outcome Measures:</th>
</tr>
</thead>
</table>

1. Overall pressure sore recurrence rate of 19% (mean follow-up, 3.7 yr).
2. Patient recurrence rate of 25%.
3. Recidivism was similar between institutions (22% at Harborview Medical Centre, 16% at the University of Washington Medical Center).
4. Consistency also among anatomic sites.
5. Least recurrences occurred for fasciocutaneous (15%) and myocutaneous flaps (13%).

Discussion

Consistent across the studies (all uncontrolled and observational; level 5 evidence) included in this review, was the confirmation of the most severe pressure ulcers occurring in the buttock.
and hip areas in individuals with SCI due to being primary wheelchair users. The most common types of severe pressure ulcers in people with SCI were confirmed, in descending order: ischial, sacral and trochanteric (Grassetti et al. 2013, Biglari et al. 2013, Mehta 2012, Chen et al. 2011, Kierney et al. 1998, Relander & Palmer 1988).

Before surgical reconstruction is elected as a treatment option, a long-standing preparatory procedure is to excise diseased tissue in and around the wound to reduce the risk of wound progression and infection (Conway & Griffith, 1956). Although the most common method of debridement is also surgical, non-surgical debridement methods have also been used to treat pressure sores in people with SCI and are discussed in section 3.9 (Non-Surgical Management and Debridement for Healing of Pressure Ulcers Post SCI).

Erba et al. (2010) confirmed the pyramidal shape of severe pressure ulcers (i.e. grade III and IV) by analyzing silicone imprints of the ulcer cavity and provided evidence of more pronounced deep muscle tissue pressure sensitivity relative to resilience to pressure in the superficial layers of ectodermal tissue. Therefore, the surface opening of the wound is quite small relative to base of the pyramidal cavity. Even with active pressure relief strategies counteracted by the almost sole reliance on the wheelchair for mobility, grade IV ulcers are at constant risk for persistence and progression. It is not uncommon that grade IV ulcers in the buttock and hip regions are large and require careful considerations of surgical flaps to provide enough coverage and vascularization for effective closure. Diaz et al. (2013) provide a listing of the types of flaps best suited for different types of pressure ulcers and although the authors providing evidence in this current review, echo the matching of flap type to defect type, some flaps appear to be more commonly chosen for defect correction in people with SCI. Specifically, the subset of flaps reported in this current review include thigh (posterior, lateral, medial) and buttocks (gluteus maximus, tensor fascia latae), fascio-cutaneous, myofascio-cutaneous, bi-planer, and flaps perforated with inferior and superior gluteal artery and profunda femoris artery. An informed comparison of all the types of flaps used to close the various types of pressure ulcers (e.g., severity grade and location) is beyond the scope of this chapter. Instead, a table detailing the flap type and pressure ulcer characteristics is provided for those who wish to look into further comparisons.

### Table 27 Studies Assessing Pressure Ulcer Surgical Flaps

<table>
<thead>
<tr>
<th>Study Population</th>
<th>Grade Location</th>
<th>Flap type</th>
<th>Compl† (%)</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kim et al. 2010</td>
<td>“varying”</td>
<td>GMP</td>
<td>4</td>
<td>R=N/A</td>
</tr>
<tr>
<td>Srivastava et al. 2009</td>
<td>III, IV Is, S, T, gluteal, LE</td>
<td>Split skin grafts, local flaps</td>
<td>10.2</td>
<td>R=17.3</td>
</tr>
<tr>
<td>Singh et al. 2010</td>
<td>III, IV Not specified</td>
<td>“various types”</td>
<td>13</td>
<td>R=10</td>
</tr>
<tr>
<td>Ahluwalia et al. 2010</td>
<td>III, IV Is</td>
<td>PMTFc + BF</td>
<td>15</td>
<td>R=7</td>
</tr>
<tr>
<td>Borgognone et al. 2010</td>
<td>III, IV Is</td>
<td>PTCCGM</td>
<td>16</td>
<td>R=8</td>
</tr>
<tr>
<td>Lin et al. 2010</td>
<td>IV Ischial</td>
<td>PTFc</td>
<td>17</td>
<td>R=17</td>
</tr>
<tr>
<td>Biglan et al. 2013</td>
<td>III (254/657) IV (98/657) Is, S, T, LE, pelvic</td>
<td>9 types listed including BF, gluteal</td>
<td>21</td>
<td>R= N/A</td>
</tr>
<tr>
<td>Unal 2012</td>
<td>N/A Is</td>
<td>IGAP</td>
<td>36.4</td>
<td>R=18</td>
</tr>
</tbody>
</table>

65
<table>
<thead>
<tr>
<th>Ref.</th>
<th>Type</th>
<th>Flap Type</th>
<th>Recurrence Rate</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bertheuil et al. 2013</td>
<td>IV, Is</td>
<td>BF</td>
<td>38.4</td>
<td>N/A</td>
</tr>
<tr>
<td>He et al. 2012</td>
<td>III, IV, Is</td>
<td>FPLLDM</td>
<td>N/A</td>
<td>R=0</td>
</tr>
<tr>
<td>Chen et al. 2011</td>
<td>IV, Is, S, T</td>
<td>Not specified</td>
<td>N/A</td>
<td>R=6</td>
</tr>
<tr>
<td>Grassetti et al. 2013</td>
<td>IV, Is, S, T</td>
<td>I-GAP, S-GAP, PFAP-1, PFAP-am</td>
<td>N/A</td>
<td>R=22.4, N=4.2</td>
</tr>
<tr>
<td>Kierney et al. 1998</td>
<td>III, IV, Is, S, T</td>
<td>Cutaneous, Limberg, Fc, Mc</td>
<td>N/A</td>
<td>R=23 (SCI)</td>
</tr>
<tr>
<td>Mehta et al. 2012</td>
<td>III, IV, Is, S, T</td>
<td>Biplanar, Fc</td>
<td>N/A</td>
<td>R=25, Rf=53</td>
</tr>
<tr>
<td>Tavakoli et al. 1999</td>
<td>N/A</td>
<td>Hamstring Mc Island flap (V-Y advancement)</td>
<td>N/A</td>
<td>R=41.4 (by ulcer), R=47.8 (by pt)</td>
</tr>
<tr>
<td>Relander &amp; Palmer 1988</td>
<td>Persistent and requiring surgery Is, S, T</td>
<td>Cutaneous, Mc</td>
<td>R=48, R=43, Rm=33</td>
<td>LoS=48 days, LoS=37 days, LoSr=79 days</td>
</tr>
</tbody>
</table>

Note. Complications: dehiscence, infection, flap necrosis (partial or total), hematoma, R=recurrence, N=new occurrence, Is=ischial; S=Sacral; T=Trochanteric; LE=lower extremity; PTFc=posterior medial thigh fasciocutaneous; Mc=Musculocutaneous; BF=biceps femoris; PTCCGM=partial thickness criss cross gluteus maximum; I- and S-GAP=inferior and superior gluteal artery perforator flap; PFAP-1=first perforator of the profunda femoris artery flap; PFAP-am=profunda femoris artery adductor magnus flap; FPLLDM=free partial lateral latissimus dorsi musculocutaneous flap, GMP=gluteus maximum perforator-based island; N/A=not reported.

This table is intended to help identify the flap types used for the most common severe pressure ulcers (i.e., grade III and IV, ischial, sacral and trochanteric) in people with SCI and echos a subset of a much longer list of flap types presented by Diaz et al. (2013). Specifically, the subset of flaps reported in this current review include thigh (posterior, lateral, medial), buttocks (gluteus maximum, tensor fascia latae), fascio-cutaneous, myofascio-cutaneous, bi-planer, and flaps perforated with inferior and superior gluteal artery and profunda femoris artery.

In all studies considered here, reported recurrence rates continue to decline as surgical reconstruction methods evolved over the last 75 years (Davies 1938). The use of flaps with varying degrees of vascularization and tissue layers chosen to match the type of wound requiring repair has been of benefit to recurrence rates. Relander and Palmer (1988) reported no difference in recurrence rate between pressure ulcers treated with cutaneous and musculo-cutaneous flaps despite better initial healing response to musculo-cutaneous flaps (e.g., muscle tissue eventually undergoes atrophy). However the high recurrence rate for these flap types reported 25 years ago (48%; Relander & Palmer 1988) has fortunately continued to decrease (22%, Kierney et al.1998; 17%, Lin et al. 2010), likely due to the improvement in collaboration between caregivers and also in patient education (Kierney et al.1998). Use of combination flaps (Ahluwalia et al. 2010) or flaps novel in design (Borgognone et al. 2010) have reported even further decreases in recurrence rates (e.g., 7% and 8%, respectively). However, use of the biceps femoris flap on its own may be prone to a high complication rate (38.4% for grade IV ischial sores; Bertheuil et al. 2013) which may be reduced if used in conjunction with a posterior medial thigh fascio-cutaneous flap (15% for grade III and IV Ischial sores; Ahluwalia et al. 2010). The reported recurrence rates differed significantly and were likely impacted by the follow-up period at the time of reporting. For example, Tavakoli et al. (1999) reported that 33% and 47.8% of patients had recurrence of ulcers at an average follow-up period of 20 and 62 months, respectively. Patients lost to follow-up (including for reason of death) over the longer time period.
also impacted the related rates of patients with recurring ulcers (e.g., N=27 at 20 month follow-up versus N=19 at 62 months follow-up).

Two level 5 studies (Chen et al. 2011; NSCI/N=141/160 and Grassetti et al. 2013; NSCI/N=107/143) similar in study size, and pressure ulcer grade and location (IV; ischael, sacral, trochanteric) suggest an average length of hospitalization of approximately 45 and 16 days, respectively. The study by Chen et al. (2011) was primarily a description and observation of a novel traction closure method that should not be compared with traditional surgical closure. However, the study by Grassetti et al. (2013) can be favourably compared to length of stay data for general pressure ulcer reconstruction surgery patients reported at 20 days (Larson et al. 2012; Foster et al. 1997) and even up to 79 days (Marriott & Rubayi 2008; Isik et al. 1997; Srivastava et al. 2009; Relander & Palmer 1988). Considering the significant costs associated with pressure ulcer healing in the hospital (Zoutman et al.1998) and in the community (Chan et al. 2013) a reduction in healing time is also of benefit to health care systems. Surgical reconstruction of pressure ulcers in people with SCI can also improve Barthel Index scores (Srivastava et al. 2009), feelings of well-being (76.6%) and satisfaction with rehabilitation (83.3%) as reported after patients underwent surgical repair of severe pressure ulcers (Singh et al. 2010).

Based on level 5 evidence, caregiver collaboration (Kierney et al. 1998) and flap type selection (Ahluwalia et al. 2010; Borgognone et al. 2010; Bertheuil et al. 2013) when considering surgical reconstruction of severe pressure ulcers, facilitates healing (Grassetti et al. 2013) without undue risk of complications (Ahluwalia et al. 2010; Borgognone et al. 2010) and improves the well-being and satisfaction with the rehabilitation experience (Singh et al. 2010) of people with SCI. However, a sufficiently powered, controlled study is needed to investigate the degree of benefit of severe pressure ulcer reconstruction for individuals living with SCI.

Conclusion

There is level 5 evidence (multiple studies; Table 27) that supports various surgical repair methods for persistent, severe thigh and buttock pressure ulcers secondary to SCI, as a beneficial treatment option.

People with spinal cord injury with persistent grade III and IV pressure ulcers in the thigh and buttock region may benefit from surgical reconstruction.

3.12 Alternative Organic or Herbal Treatments

For a variety of reasons, including the critical concern of antibiotic resistance, availability of alternative organic or herbal treatments will be a welcome addition to the toolkit to manage pressure ulcers. As with other disease populations that are susceptible to pressure ulcers, individuals with SCI need to keep their wounds dry, and bacteria free in a simple and cost-effective way without negative side effects. This section reviews three alternative treatments including Medihoney®, a Chinese herbal ointment (CFSRO), and a powdered arginine supplement.

3.12.1 Medihoney®
Medical grade honey is derived from a single plant species from New Zealand and is processed consistently for effectiveness (e.g., high osmotic potential and low pH), sterilized by gamma irradiation to destroy inadvertent bacterial agents. It is of relatively low cost.

**Table 28 Medihoney®**

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biglari et al. 2012</td>
<td>Germany</td>
<td>Pre-post</td>
<td>N=20</td>
<td>Population: Mean age=48.7 yr; Gender: males=13, females=7; Level of injury: paraplegic=14, tetraplegic=6; Wound status: stage III ulcers=5, stage IV ulcers=15.</td>
<td></td>
<td>1. After one wk of Medihoney treatment, all swabs were void of bacterial growth. 2. 18 patients showed complete wound healing after 4 wk. 3. No negative side effects were noted.</td>
<td></td>
</tr>
</tbody>
</table>

Biglari et al. (2012) included Medihoney® as a component of a comprehensive, conservative and surgical wound-care program within a German SCI trauma and rehabilitation centre. In total, 20 individuals with SCI with chronic pressure ulcers produced bacteria free wound swabs after one week of once daily Medihoney® treatment. Before the Medihoney® treatment, the wound was cleaned with sterile Ringer’s solution and the surrounding skin was disinfected with Octenisept® or Octeniderm®. Ninety percent of these patients’ wounds completely healed with soft and elastic scars after four weeks of treatment as documented by photography, measurement and cultures. No adverse events, allergies, or blood sugar impact in diabetic patients resulted from Medihoney® treatment. This observational cohort study, suggests that Medihoney® is highly effective in persistent, severe, pressure ulcer management in individuals with SCI. Additional study is required to elucidate optimal treatment parameters and long-term effects of Medihoney® treatment for the full spectrum of pressure ulcers.

**Conclusion**

*There is level 4 evidence (from one pre-post study; Biglari et al. 2012) that supports the use of Medihoney® for improved healing rate as well as residual soft, elastic scars in persistent stage III and IV pressure ulcers in individuals with SCI.*

Medihoney® may be useful to treat persistent stage III and IV pressure ulcers in individuals with SCI

**3.12.2 Cured Rot and Flat Sore Ointment**

Eastern cultures often use other naturally occurring herbal remedies for various disease conditions. Arnebia root oil (ARO) is an ancient herbal remedy thought to be useful as an antipyretic, antiseptic and analgesic. It is postulated to promote basic fibroblast growth factor in healing wound tissue in a Chinese study (Pei et al. 2005) but has not been replicated in the SCI population. However, practitioners of traditional Chinese medicine in a Chinese Military Hospital called upon their years of experience with various traditional Chinese medicine remedies when they were not satisfied with the analgesic and curative effect of ARO. They produced a traditional Chinese medicine ointment called cured rot and flat sore ointment (CRFSO)
comprised of hydrargyum oxydatum crudum, red orpiment, borneol and gypsum fibrosum as a diluant and treatment of “heat syndrome” according to “Yin-yang” theory. Anecdotal observations of superior effects led to a randomized, parallel-group, retrospective trial comparing ARO and CRFSO to treat stage IV pressure ulcers in paraplegic patients (Liu et al. 2013).

Table 29 Cured Rot and Flat Sore Ointment CRFSO

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liu et al. 2013</td>
<td>China</td>
<td>Case Control</td>
<td>N=35</td>
<td></td>
<td>Population: Median age: 59.1 yr; Gender: male=19, female=16; Level of injury: paraplegic=10; Wound status: grade IV ulcer=35. Intervention: Patients underwent 28 days of arnebia root oil (ARO) or Chinese herbal formula (CRFSO) treatment after undergoing surgery. Outcome Measures: Therapeutic effect (healing, effective, improved, no response) and therapeutic duration of treatment.</td>
<td>1. Statistically significant difference (p&lt;0.005) between the two groups (follow-up occurred after 28 days of treatment). 2. No patients had adverse reaction during treatment. 3. Healed: 17 out of 20 patients in the CRFSO group. 4. Effective: 2/20 patients in CRFSO group. 5. Effective: 2/11 patients in ARO group. 6. Improved: 1/11 ulcers in ARO group. 7. Therapeutic duration of treatment with CRFSO averaged 19.47 days. 8. Therapeutic duration of treatment with ARO averaged 29.18 days.</td>
</tr>
</tbody>
</table>

Discussion

Liu et al. (2013) reported that there was a significantly shorter treatment time recorded for CRFSO (19.5±5.0 days) compared to those receiving ARO (29.2±3.2 days; p<0.05). Other aspects of improved outcome included presence of a scab, contractibility, granulation tissue, reduced secretions and alleviation of pain upon day 28 evaluation. ARO or CRFSO treatments were used in conjunction with sodium chloride cleansing, hydrogen peroxide and saline removal of vesicular, ulcerated and necrotic tissue, 30 minute infrared irradiation of disinfected pressure ulcers and surrounding 2-3 cm area, and routine care (e.g., aseptic dressing/bandage changes every 1-2 days) and pain treatment until the ulcers had healed. The ARO group also received 240,000 units of gentamicin gauze wetted with 100ml 9% sodium chloride. CRFSO responses were reported to be better in all categories of outcome assessment versus ARO responses with time to healing as the primary outcome. However, no mention of NPUAP pressure ulcer documentation guidelines use was mentioned (e.g., drainage amount-scant, moderate, copious), colour/consistency (e.g., serous, serosanguineous, purulent), odor). As well, no stratification for comparison of pressure ulcer healing by location was provided.

Conclusion

There is level 3 evidence (from one case control study; Liu et al. 2013) that supports the use of CRFSO over ARO to accelerate pressure ulcer healing but it needs to be noted that objective outcome assessment was not clearly outlined.
CRFSO may be superior to ARO to promote accelerated healing of pressure ulcers in people with SCI.

3.12.3 Powdered Arginine Supplement

Alternative medicine often relies on nutritional supplements to augment deficiencies in disease states. Because the exudate of pressure ulcers are a source of bodily protein loss, daily intake of up to 2.0 g/kg of protein for individuals at risk of pressure ulcer development is advocated by Van Anholt et al. (2010). Similarly, supplementation with amino acids that act as substrates for protein synthesis and subsequent nitrogen balancing may also promote pressure ulcer healing. Brewer et al. (2010) undertook to test the effectiveness in supplementing individuals with SCI with the semi-essential amino acid, arginine, for improvement in pressure ulcer healing.

Table 30 Powdered Arginine Supplement

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brewer et al. 2010</td>
<td>Australia</td>
<td>Pre-post N=35</td>
<td></td>
<td></td>
<td>Population: Mean age= 50.5 yr; Gender: males=34, females=1; Level of injury: paraplegic=25, quadriplegic= 10; Wound status: grade II ulcer= 10, grade III ulcer=14, grade IV ulcer= 6. Intervention: 9 g commercial powdered arginine supplement per day. Outcome Measures: Healing rates.</td>
<td>1. Time to healing took an average of 21.1 wk in the historical control group. 2. Time to healing took an average of 10.5 wk in the intervention (powdered arginine supplement) group.</td>
</tr>
</tbody>
</table>

Discussion

Brewer et al. (2010) compared a cohort of 18 community dwelling individuals with SCI and pressure ulcers, who were supplemented with 9 g/day powdered arginine, against audits of a matched historical control group. Arginine treatment continued until pressure ulcers were healed but it should be noted that the supplemental powder also contained carbohydrates and vitamins C and E, the latter vitamins of which are controversial in their effects over pressure ulcer healing in other patient populations (Ehrlich et al.1972; Vilter 1980; Albina 1994; Dorner et al. 2012). However, the authors did take care to exclude participants who presented with other healing comorbidities such as renal insufficiency, metabolic diseases and other co-morbidities. The resulting healing time was significantly improved by half the number of weeks required for healing by the historical controls across all categories of pressure ulcers (p<0.006).

Conclusion

There is level 4 evidence (from one pre-post study; Brewer et al. 2010) for arginine supplementation for pressure ulcer healing.

Arginine supplementation in individuals with SCI may be helpful in accelerating pressure ulcer healing.

3.13 Miscellaneous Physical Treatments
Although pressure redistribution to reduce ischemia is the primary method for pressure ulcer prevention and management, it is also understood that decreased skin temperature leads to reduced tissue metabolic demand that might translate to reduced reactive hyperemia post ischemia. To test this theory, Tzen et al. (2013) compared the effects of controlled local cooling on reactive hyperemia resulting from pressure induced ischemia for people with and without SCI.

Table 31 Localized Cooling for Treatment of Pressure Ulcers

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Country</th>
<th>PEDro Score</th>
<th>Research Design</th>
<th>Total Sample Size</th>
<th>Methods</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tzen et al. 2013</td>
<td>USA</td>
<td></td>
<td>Prospective Controlled Trial</td>
<td>N=28</td>
<td>Population: Mean age: 35.79 yr; Gender: males=20, females= 8; Level of injury (ASIA): grade A or B=14, control group=14. Intervention: All subjects were tested under three conditions: pressure with fast cooling (-4 degrees Celsius/min), pressure with slow cooling (-33 degrees Celsius) and pressure with no cooling. Outcome Measures: Reactive hyperemia and its spectral densities in the metabolic, neurogenic and myogenic frequency ranges.</td>
<td>1. Reactive hyperemia was greater in pressure only when compared to the cooling conditions in the control group. 2. No change in spectral densities for both cooling conditions in SCI or control group. 3. Neurogenic spectral density increased without cooling for control group. 4. In SCI patients, no difference noted in reactive hyperemia in any conditions. 5. Metabolic and myogenic spectral densities increased without cooling and all spectral densities increased with slow cooling for the SCI group. 6. No change in all spectral densities with fast cooling.</td>
</tr>
</tbody>
</table>

Discussion

Tzen et al. (2013) were able to confirm that microclimate control was an effective pressure ulcer prevention strategy in at-risk individuals without SCI; unfortunately, this was not the case for individuals with neurologically compromised vasoconstriction and capillary smooth muscle contraction as in people with SCI.

Conclusion

*There is level 2 evidence (from one prospective controlled trial; Tzen et al. 2013) that localized cooling is not a viable pressure ulcer prevention strategy that is effective for individuals with SCI. Conversely, with neurological control of vasoconstriction and capillary smooth muscle contraction, those without SCI may benefit from microclimate controlled surfaces as a pressure ulcer prevention strategy.*

Pressure point localized cooling is not an effective pressure ulcer prevention strategy for people with SCI.
4.0 Summary

There is level 4 evidence (from one observational study; Guihan et al. 2004) that supports the use of a handheld dermal phase meter for the early detection of pressure ulcers secondary to SCI.

There is level 2 evidence (from one prospective controlled trial; Kanno et al. 2009) that supports the use of ultrasonography to extend the yield of routine inspection and palpation of suspected or early stage pressure ulcers in people with SCI.

There is level 3 evidence (from one case control study; de Heredia et al. 2012) that magnetic resonance imaging can predict the development of osteomyelitis in non-healing pelvic pressure ulcers in patients.

There is level 4 evidence (from one case series study; Loerakker et al. 2012) that reliance on circulatory biomarkers as an indication of muscle damage secondary to deep tissue injury in the SCI population cannot be recommended at this time.

There is level 2 evidence (from one prospective controlled trial and one cohort study; Lui et al. 2006b; Ferguson et al. 1992) supported by level 4 evidence (from five pre-post studies, and two case series studies; Smit et al. 2012, 2013a, 2013b; Gyawali et a. 2011; Bogie & Triolo 2003; Van London et al. 2008; Liu et al. 2006a) that electrical stimulation decreases ischial pressures post SCI.

There is level 4 evidence (from one pre-post study; Bogie & Triolo 2003) that electrical stimulation may increase blood flow at sacral and gluteal areas post SCI.

There is level 2 evidence (from two prospective controlled trials and one pre-post study; Lui et al. 2006a; Mawson et a 1993; Bogie & Triolo 2003) that electrical stimulation may increase tissue oxygenation post SCI.

There is level 2 evidence (from one prospective controlled trial; Hobson 1992) to support not generalizing pressure mapping data from able-bodied subject to SCI subjects.

There is level 4 evidence (from one case control study; Gutierrez et al. 2004) to support the typical locations for high pressure in the SCI population being the ischial tuberosities and the coccyx.

There is level 4 evidence (from one prospective controlled trial; Brienza & Karg 1998) to support not generalizing pressure mapping data from the elderly population to the SCI population.

There is level 2 evidence (from one cohort study; Kennedy et al. 2003) showing that early attendance at specialized seating assessment clinics increases the skin management abilities of individuals post SCI.

There is level 1b evidence (from two randomized controlled trials and three pre-post studies; Rintala et al. 2008; Garber et al. 2002; May et al. 2006; Brace & Schubart 2010; Schubart et al. 2012) that providing enhanced pressure ulcer prevention education is effective at helping individuals with SCI gain and retain this knowledge.
There is level 4 evidence (from two pre-post studies; Schubart et al. 2012; Brace & Schubart 2010) that online eLearning modules may improve knowledge on prevention of pressure ulcers among persons with SCI.

There is level 1b evidence (from one randomized controlled trial; Rintala et al. 2008) that providing enhanced pressure ulcer education and structured follow-up is effective in reducing recurrence of pressure ulcers especially in those individuals with no previous history of pressure ulcer surgery.

There is level 4 evidence (from one pre-post study; Jones et al. 2003) to suggest that the introduction of behavioural contingencies and other behavioural strategies is associated with a reduction in pressure ulcer severity and decreased health care costs.

There is level 1b evidence (from a randomized controlled trial; Houlihan et al. 2013) that telerehabilitation using an automated call-in system with built-in theory-based behavior change strategies may make a significant difference for women but not men in preventing pressure ulcers post SCI.

There is level 4 evidence (from one case series; Vesmarovich et al. 1999) that telerehabilitation via videophone to support clinical interactions and digital photography does not make a significant difference in the prevention and treatment of pressure ulcers post SCI.

More research is needed to determine what telerehabilitation strategies are effective in preventing pressure ulcers, improving healing and reducing costs.

There is level 1 evidence (from six randomized controlled trials; Houghton et al. 2010; Cukjati et al. 2001; Adegoke & Badmos 2001; Karba 1997; Jercinovic 1994; Griffin 1991) that electrical stimulation accelerates the healing rate of stage III and IV pressure ulcers when combined with standard wound management.

There is level 1 evidence (from two randomized controlled trials; Taly et al. 2004; Nussbaum et al. 1994) that laser treatment has no added benefit in pressure ulcer healing post SCI than standard wound care alone.

There is level 1b evidence (from one randomized controlled trial; Nussbaum et al. 1994) that the combination of ultrasound/ultraviolet C with standard wound care decreases wound healing time of pressure ulcers post SCI; there is no evidence to support the benefit of either therapy used individually.

There is level 1b evidence (from one randomized controlled trial; Salzberg et al. 1995) that pulsed electromagnetic energy accelerates healing of stage II and III pressure ulcers post SCI.

There is level 1a evidence (from one randomized controlled trial and one pre-post study; De Laat et al. 2011; Coggrove et al. 2012) that topical negative pressure facilitates wound healing for pressure ulcers in people with SCI and other patient etiologies. This conclusion is contradicted by level 5 evidence (from one observational study; Ho et al. 2010) but there are significant limitations in the latter study.
There is level 2 evidence (from one prospective controlled trial; Kloth et al. 2001) that normothermic dressings may improve healing of pressure ulcers post SCI.

There is level 4 evidence (from one case series; Keast & Fraser 2004) that recombinant human erythropoietin aids in the healing of stage IV chronic non-healing pressure ulcers post SCI.

There is level 5 evidence (from one case series and one case study; Sell et al. 2011; De Angelis et al. 2012) that supports the possibility of platelet-rich plasma therapy facilitation of reactivated healing in severe, non-healing pressure ulcers, post SCI.

There is level 2 evidence (from one flawed randomized controlled trial; Bauman et al. 2013) that does not support the use of oxandrolone (anabolic steroid) to facilitate healing of serious pressure ulcers post SCI. However, very limited, earlier level 4 evidence (from one case series; Spungeon et al. 2001) did lend some support for the use of oxandrolone to promote healing of stage III and IV pressure ulcers post SCI.

There is Level 1 evidence (from one randomized controlled trial; Hollisaz et al. 2004) that completion of healing for stage I and II pressure ulcers is greater with an occlusive hydrocolloid dressing compared to phenytoin cream or simple dressing post SCI.

There is Level 2 evidence (from one randomized controlled trial; Kaya et al. 2005) that occlusive hydrogel-type dressings heal more pressure ulcers than conservative treatment post SCI.

There is level 1 evidence (from one randomized controlled trial; Subbanna et al. 2007) that topical phenytoin shows a trend towards healing of stage I and II pressure ulcers post SCI.

There is level 2 evidence (from one randomized controlled trial; Scevola et al. 2010) that platelet gel dressings, when used within the first 2 weeks of treatment can trigger earlier granulation tissue proliferation towards pressure ulcer healing, post SCI.

Level 1 evidence (from one randomized controlled trial; Ho et al. 2012) underpins the use of pulsatile lavage hydrotherapy debridement for Stage III and IV pressure ulcers secondary to SCI.

There is level 5 evidence (from one observational study; Bogie et al. 2013) that pulsatile lavage therapy, used in conjunction with standard infection control standards, is likely a safe debridement method for Stage III and IV pressure ulcers in people with SCI.

There is level 2 evidence (from one prospective controlled trial and one observational study; Wang et al. 2010; Sherman et al. 1995) that supports the use of maggot therapy as an adjunctive therapy for pressure ulcer debridement post SCI.

There is level 4 evidence (from one post-test study; Erba et al. 2010) that supports the use of silicone moulding as a radical en bloc debridement method for pyramidal shaped grade IV pressure ulcer cavities in people with SCI.
There is level 4 evidence (from one pre-post study; Banks & Ho 2008) that topical oxygen therapy may improve healing of pressure ulcers post SCI.

There is level 5 evidence (multiple studies; Table 27) that supports various surgical repair methods for persistent, severe thigh and buttock pressure ulcers secondary to SCI, as a beneficial treatment option.

There is level 4 evidence (from one pre-post study; Biglari et al. 2012) that supports the use of Medihoney® for improved healing rate as well as residual soft, elastic scars in persistent stage III and IV pressure ulcers in individuals with SCI.

There is level 3 evidence (from one case control study; Liu et al. 2013) that supports the use of CRFSO over ARO to accelerate pressure ulcer healing but it needs to be noted that objective outcome assessment was not clearly outlined.

There is level 4 evidence (from one pre-post study; Brewer et al. 2010) for arginine supplementation for pressure ulcer healing.

There is level 2 evidence (from one prospective controlled trial; Tzen et al. 2013) that localized cooling is not a viable pressure ulcer prevention strategy that is effective for individuals with SCI. Conversely, with neurological control of vasoconstriction and capillary smooth muscle contraction, those without SCI may benefit from microclimate controlled surfaces as a pressure ulcer prevention strategy.
References


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