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Risky business: Preventing skin breakdown in children with spina bifida

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Abstract. The purpose of this article is to provide an overview of skin issues in children with spina bifida. Included in the discussion below is a review of the etiology of pressure ulcers and the updated 2007 pressure ulcer definition and pressure ulcer staging system as defined by the National Pressure Ulcer Advisory Panel (NPUAP). Pediatric risk factors for skin breakdown are presented including risk factors unique to children with spina bifida. Pediatric pressure ulcer risk assessment scales are described. The 5 Million Lives Kids' Campaign which has a focus on preventing hospital-acquired pressure ulcers in children is also reviewed along with evidence based prevention strategies. The key to preventing skin breakdown and pressure ulcers in children with spina bifida is early identification of the child's individual risk factors so that a prevention protocol can be implemented in all settings: hospital, home and the community. Options for wound management, dressing selection and pain management are included.

Keywords: Spina bifida, pediatric pressure ulcers, insensate skin, prevention

1. Introduction

Developing a pressure ulcer significantly impacts the child and the family related to hospital costs, loss of school or work time and interrupted social and recreational activity. Treating pressure ulcers is costly. A children's hospital in Ohio conducted a four year long longitudinal study to monitor the skin status of children with spina bifida and spinal cord injury. Out of 4,533 hospital days studied, 994 (22%) were found to be related to skin ulceration. Total cost of hospital care over the four year period exceeded $1.3 million (American) [2]. For the special population of children with spina bifida, minimal studies and case reports of skin breakdown and pressure ulcer occurrence have been described in the literature.

The current scientific literature has numerous studies documenting skin breakdown and strategies for pressure ulcer prevention and management in adults. A number of pressure ulcer clinical practice guidelines have been developed for adults by many agencies and specialty groups. These include, among others, the Agency for Healthcare Research and Quality (AHRQ [formerly the Agency for Healthcare Policy and Research]), the European Pressure Ulcer Advisory Panel, the Wound Ostomy Continence Nurses Society and Paralyzed Veterans of America. Clinical practice guidelines improve clinical practice and patient care by providing up-to-date scientific clinical scientific evidence [26]. Evidence based research studies looking at skin breakdown and wound treatment in children have started emerging but the knowledge base for prevention and management of pediatric wounds remains small.

2. Physiology of skin

The skin, the largest organ of the body, has a number of functions: protection, immunity, thermoregulation, sensation, metabolism and communication. The skin consists of two layers, the epidermis and dermis. Below the dermis, is a layer of loose connective tissue called the hypodermis [58].

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The epidermis, the outer most layer of the skin, is avascular and is constantly being renewed about every two months. The basement membrane zone (BMZ) also called the dermal-epidermal junction separates the epidermis and dermis. Major proteins found in the BMZ include glycoproteins, type IV and VII collagen and heparin sulfate proteoglycan, a glycosaminoglycan. The BMZ is affected in blister formation. During the wound healing process the BMZ is disrupted and must be re-formed [58].

The dermis is the thickest tissue layer and contains the dermal proteins: collagen and elastin. Collagen gives skin its tensile strength while elastin provides the skin's elastic recoil. Mast cells, macrophages and lymphocytes are also found in the dermis. The hypodermis connects the dermis to underlying structures. It also provides insulation to the body, energy stores and cushioning while facilitating skin mobility over the underlying structures [58].

When skin is injured, healing occurs in a cascade of events. The first response to injury is inflammation, which progresses to proliferation (rebuilding phase) when granulation tissue is formed. Wound edges contract and epithelial "resurfacing" occurs. The final phase, maturation/remodeling, can last up to two years after wound closure. During this time the scar tissue continues to reorganize but it only regains about 80% of the original tensile strength as compared to non-wounded tissue [14].

Wound healing in adults and children occurs in the same manner but children heal at a much faster rate. Children have more fibroblasts and produce more collagen and elastin resulting in faster granulation tissue formation than in adults [2].

Certain risk factors, however, place children at greater risk for skin breakdown compared to adults. These include fluid and electrolyte imbalances that develop more often and more rapidly in infants and young children as compared to older children and adults, greater body surface area, higher body water content, and increased metabolic needs that occur with fever and infection. With dehydration, skin cells can become hypoxic from decreased peripheral perfusion resulting in increased risk for skin breakdown with minimal trauma [13].

3. Development of pressure ulcers

While pressure ulcers have been thought to be mostly a problem of adults, skin ulceration also occurs in children, a concept under-recognized in the pediatric population. This lack of clinician awareness creates a risk factor for children if skin assessments are not performed and prevention strategies are not implemented [4].

Pressure ulcers develop when the skin and subcutaneous tissues are compressed causing impeded capillary blood flow and subsequent tissue necrosis. At risk patients must be identified quickly since pressure ulcers can occur within two to six hours from the time of skin injury [28].

In addition to pressure, skin can be injured by friction, shear and moisture. Friction occurs when two forces move across one another—such as the force exerted when skin is dragged across a rough surface such as bed linens (e.g., during patient repositioning while in bed). Shear injury is caused by a mechanical force that is parallel rather than perpendicular to an area. When shearing occurs, tissue layers rub against each other causing the subcutaneous blood vessels to stretch or kink resulting in interrupted blood flow [56]. Shear injuries can occur during wheelchair transfers or transferring out of a car on warm days. If insensate skin sticks to the wheelchair cushion or car seat during the transfer process, the internal tissues attached to bone are pulled in one direction while the surface tissue remains stationary and blood vessels can be injured. Shearing can also occur when the head of the bed is raised and the body slides downward.

Moisture from fecal or urinary incontinence causes skin maceration, a significant contributor to pressure ulcer development. Fecal incontinence results in greater skin damage than urinary incontinence due to the bacteria and enzymes in the stool. When fecal enzymes come in contact with skin, the skin pH becomes more alkaline making it more susceptible to other irritants [56].

4. Pressure ulcer definition and staging

Skin can be damaged from pressure or other sources of injury such as an abrasion, skin tear, tape burn, perineal dermatitis, or excoriation. Wounds caused by factors other than pressure are classified by the partial-thickness and full-thickness model. A partial-thickness wound causes damage to the epidermis and part of the dermis while a full-thickness wound extends through the epidermis and dermis and may extend into the subcutaneous tissue, fascia and muscle [14].

Table 1
Pressure ulcer assessment and documentation guidelines

Location and size	length, width, depth (measured in centimeters)
Wound color	red, pink, yellow, tan, black, purple
Exudate: amount and type	serous, sero-sanguinous, bloody, purulent
Odor	yes or no
Presence of pain	yes (episodic or continuous) or no
Color/type of tissue in wound bed	epithelial, granulation, slough, eschar
Evidence of healing	yes or no (based on type of tissue in wound bed)
Description of wound edges and surrounding tissue	rolled edges, redness, hardness/induration, maceration

Healing in partial-thickness wounds occurs by resurfacing or reepithelialization. Healing in full-thickness wounds occurs by secondary intention through the formation of granulation tissue, contraction and reepithelialization. Separate classification systems exist for neuropathic ulcers and pressure ulcers to describe tissue injury and healing [5].

When skin breakdown occurs, the wound must be assessed, described and a treatment plan initiated. Wound assessment must occur at each dressing change and the treatment plan modified as needed to facilitate wound healing. Pressure ulcers, in addition, must be staged and include certain documentation descriptors. Pressure ulcer assessment and documentation parameters are listed in Table 1 [5,7,28]. After the ulcer characteristics have been described, the ulcer can be staged.

The original pressure ulcer staging system was defined by Shea in 1975 to describe the amount of anatomical tissue loss. Those original definitions caused confusion and resulted in inaccurate staging of ulcers caused by perineal dermatitis or ulcers from deep tissue injury. In 1989, the National Pressure Ulcer Advisory Panel (NPUAP) revised Shea's definitions and this classification system is the most widely used in the United States [37].

In 1997, the Stage I definition was revised by the NPUAP to better reflect diversity and differences in skin pigmentation. The NPUAP continued to review and refine the Stage I definition as more data emerged regarding the concept of deep tissue injury which was identified in 2001. After a conference in 2005, the definitions were refined again with input from an online evaluation of face validity, accuracy, clarity, succinctness, utility and discrimination. The final definitions were reviewed by a consensus conference for approval in 2007. The 2007 revisions included the four original pressure ulcer stages with detailed "further description" in each stage and two new categories were added: deep tissue injury and unstageable (Appendix) [28,37].

According to the NPUAP [37], a pressure ulcer is 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. A number of contributing or confounding factors are also associated with pressure ulcers; the significance of these factors is yet to be elucidated". Correct assessment and staging of pressure ulcers is critical as pressure ulcer incidence rates were reported as high as 27% in a study of 322 patients in three pediatric intensive care units (PICU) [11].

Monitoring for other types of skin breakdown in children is just as important as assessing skin for pressure ulcers. In 2003 McLane and associates [32] conducted a study to document the prevalence of pressure ulcers and different types of skin breakdown in hospitalized children. The survey included 1,064 inpatient children (ranging in age from neonate to 17 years) from nine children's hospitals across the United States. The pressure ulcer prevalence rate was 4% and other skin breakdown was 14.8%. Of the pressure ulcers, 92% were partial thickness, Stages I and II (staging description used in article). Pressure ulcer locations included the head area (31%), seat area (20%) and foot area (19%). Sixty-six percent of the pressure ulcers were acquired in the facility. The three most common types of skin breakdown included excoriation/diaper dermatitis, skin tear, and IV extravasation.

5. Risk factors for skin breakdown

Risk factors for skin breakdown have been studied in the adult population and over 100 have been identified. The six most common risk factors in adults include reduced mobility, nutritional status, fecal and urinary incontinence, medications that cause a change in sensation or mobility, decreased tissue oxygenation or reduced oxygenated blood and age [27,57].

Recent studies have begun to document risk factors for pressure ulcer development in children [25]. Not surprisingly, particular risk accompanies medical equipment and devices. Willock and colleagues [55] conducted a multi-site study in 11 hospitals in England and Wales to identify the characteristics of the children

Table 2
High Risk Factors for pressure ulcers (neonatal/infant/pediatric population)

Length of hospital stay greater than 96 hours
Marked edema or anasarca
Decrease or no spontaneous activity (i.e. sedated, paralyzed, neurogically impaired)
Limited positioning options (i.e. ECMO, high-frequency ventilation, postop gastroschisis-with silo application)
Spinal cord injury (SCI)
Neurological impairment (i.e. myelomeningocele, muscular dystrophy, cerebral palsy, head injury)
Nutritional deficits
Large head circumference
Poor tissue perfusion or oxygenation (i.e. cardiac disorders)
Exposure to prolonged pressure from hospital apparatus or tubes (i.e. C-spine collars, restraints)
Lengthy operations (i.e. time in surgery greater than 4 hours)
Significant prematurity
Incontinence
Medications

most at risk for pressure ulceration. Fifty-four children were evaluated with varying conditions: orthopedic, neuromuscular/neurological and multiple diagnoses. The majority of the children had reduced mobility and almost half were completely immobile. Fifty per cent of children developed pressure ulcers related to equipment pressing or rubbing on the skin. Other studies have reported similar findings related to medical devices contributing to pressure-related skin injury in the hospitalized pediatric population [11,13,38].

Common devices that cause pressure ulcers in neonates and children include: arm boards, endotracheal tubes, head dressings and hats, improperly worn or ill-fitting orthotics, nasal prongs and continuous positive airway pressure (CPAP) mask, nasogastric or orogastric tubes, outgrown wheelchair or cushion, plaster casts, tracheal plates or ties and transcutaneous oxygen probes [3,55]. See Table 2 for additional risk factors for skin breakdown [35]. Risk factors can by affected by institutional practice. For example, postop gastroschisis is considered a risk factor related to inability to reposition, but many patients are closed without a silo and thus positioning is not a problem. Intensive care pediatric patients are at risk for wounds and pressure ulcer development. Contributing factors include: presence of edema, increasing length of stay, patients on increasing use of positive-end expiratory pressure, not turning the patient, use of a specialty bed in the turn mode, and weight loss [30].

Very few studies have looked at skin breakdown in children with myelomeningocele. Okamoto et al. [39] studied children with spina bifida over a 20 year period. They found that 227 children had 468 positive observations for skin breakdown: excessive pressure (42%); plaster casts or orthotic devices (23%); urinary and fecal soiling (23%); excessive activity (10%) burns (1%) and unknown causes (1%). They noted that skin breakdown prevalence increased with age from infancy to age 10 and then leveled off at 20–25%. Skin breakdown occurred in the perineum, gibbus and lower extremities. Table 3 [39] summarizes the common risks for skin breakdown in the child with myelomeningocele.

Table 3
Characteristics which increase risk for skin breakdown in children with myelomeningocele

High paraplegia
High sensory impairment
Intellectual disability
Large head size
Kyphoscoliosis or kyphosis
Abnormal neurological exam of upper extremities
Chronic fecal or urinary soiling

Samaniego [46] studied 69 children with myelodysplasia or cerebral palsy who were treated in an outpatient wound clinic. Risk factors included paralysis, insensate areas, high activity and immobility. The majority of the pressure ulcers occurred in the lower extremities, primarily the feet. As children got older or neurological condition deteriorated, sacral ulcers occurred frequently in wheelchair users [46]. Murphy [34] described the skin health management issues of obese children with neural tube deficits and the chronic wounds that occur in this sub-set of children with myelomeningocele. Common problems related to obesity include: frequent adjustments to the wheelchair and/or cushion with excessive or ongoing weight gain, difficulty with wheelchair transfers (i.e. dragging the body resulting in shearing of skin in the transfer process) and irritation/skin breakdown in the groin from pinching/bunching of diapers and undergarments.

Warm weather acts as a risk factor for children with spina bifida due to increased outdoor activity coupled with heat. Children with insensate skin can be burned from various sources: sand, stone/concrete patios, metal playground equipment, hot pavement at water parks, water in hot tubs, and wheelchairs being left in the sun. Other sources of burns include diarrhea, bowel cleanouts, plates/containers of hot food and bath water [15]. Surgery increases skin breakdown risk if the child experiences unexpected pain (i.e. abdominal pain related to bladder augmentation surgery) and reduces his usual movement and stays in one position [41].

6. Risk assessment tools

The key to preventing pressure ulcers in all patient groups is early identification of risk factors so that a prevention protocol can be implemented. A number of risk assessment tools have been developed for the adult population to identify patients at risk for pressure ulcer occurrence. The commonly used scales for adults are the Norton Scale, the Gosnell Scale and the Braden Scale. Using risk assessment scales are economical and non-invasive, but for evidenced based practice must have predictive validity. In summary, predictive validity encompasses sensitivity (the ability of the scale to identify those at risk of developing a pressure ulcer – true-positives) and specificity (the ability of the scale to identify those who are not at risk – true-negatives) [42]. While a number of pediatric pressure ulcer risk assessment scales have been developed, only three of the 10 published scales have been tested for sensitivity and specificity. Those include the Braden Q Scale, the Glamorgan Scale and the Neonatal Skin Risk Assessment Scale (NSRAS) [4].

6.1. The Braden Q Scale

Adapted from the Braden Scale (used in adults), the Braden Q includes the original six subscales: sensory perception, moisture, activity, mobility, nutrition and friction and shear. A seventh subscale was added: tissue perfusion and oxygenation. Predictive validity testing was evaluated in a multi-site study of 322 pediatric intensive care unit (PICU) patients. Using a cutoff of 16, the Braden Q was found to be 88% sensitive and 58% specific in children aged 21 days to 8 years [12]. Children with cardiac shunting or unrepaired congenital heart disease were not included in the sample which limits its generalizability [4]. In addition Pallija et al. [41] noted that children with spina bifida and lumbosacral deficits are at high risk for skin breakdown in the acute care setting but fell in the low risk category for skin breakdown when assessed using the Braden Q Scale.

6.2. The Glamorgan Scale

The Glamorgan Scale is based on data from the characteristics of 336 hospitalized children in pediatric acute care settings (61 children who developed pressure ulcers and 275 without ulcerations), a review of the literature and feedback of clinical experts. This scale identifies 11 statistically significant pediatric pressure ulcer risk factors (Table 4) [54]. Using a cutoff score of 15, the Glamorgan Scale is 98.4% sensitive and 67.4% specific [54]. It is currently undergoing an international, multi-center study to examine inter-rater reliability [4].

Table 4
The Glamorgan Scale Pediatric Pressure Ulcer Risk Factors

Cannot be moved without great difficulty or deterioration in condition, or having prolonged surgery
Unable to change position without assistance/cannot control body movement
Some mobility, but reduced for age
Equipment / objects / hard surface pressing or rubbing on skin
Significant anemia (hemoglobin $<$ 9 g/dL)
Persistent pyrexia (temperature $>$ 37.5C for more than 12 hours)
Poor peripheral perfusion (cold extremities / capillary refill $>$ 2 seconds / cool mottled skin)
Inadequate nutrition (unable to take / not absorbing oral or enteral feeds and not supplemented with hyperalimentation)
Low serum albumin ($<$ 3.5 g/dL)
Weight $< 10^{th}$ percentile
Incontinence (inappropriate for age)

6.3. The Neonatal Skin Risk Assessment Scale (NSRAS)

The NSRAS was also developed based on the Braden Q. It includes six subscales applicable to neonates (mental status, mobility, moisture, general physical condition, activity and nutrition) and accounts for gestational age. Testing for reliability and validity was performed with 32 neonatal intensive care unit patients from 26–40 weeks gestation. When all six subscales were used, inter-rater reliability was poor. When only the subscales of general physical condition, activity and nutrition were used, sensitivity was 83%, specificity was 81% and inter-rater reliability was 97% with a cutoff score of 5 [22]. The authors continue to recommend that all subscales be used when assessing the neonate's risk [4].

Another risk assessment tool, the *Starkid Scale*, was developed prior to the publication of the reliability and validity data of the Braden Q. It was designed to be a shorter, simpler version of the Braden Q and to be utilized as a skin breakdown risk assessment guideline in hospitals or other health care settings. The authors modified the Braden Q subscales (i.e. combining mobility and activity), subscale descriptors and categories to make a single page measurement tool. Data on skin breakdown were collected from 347 pediatric patients on four inpatient units (PICU, medical-surgical, oncology and adolescents). Skin breakdown prevalence in the acutely hospitalized child was 23% with 77.5% of

the breakdowns presenting as erythema of the skin. The most common locations of breakdown occurred on the buttocks, perineum and occiput. The Starkid Scale had high inter-rater reliability (85%) and high specificity (98.5%) but sensitivity (17.5%) was low [51].

7. Strategies for prevention of skin breakdown and pressure ulcers

Prevention strategies remain a key factor in all aspects of health care and particularly so in the prevention of pressure ulcers. Risk factors of children with myelomeningocele must be considered in developing a skin breakdown prevention protocol. Skin breakdowns occur in multiple settings: hospitals, at home, during outdoor play and while engaging in recreational activities. For optimal prevention, parent and patient education continue as a highest priority. Health care providers, school nurses, coaches, day care providers and others who work with children with myelomeningocele should be familiar with the skin risks in this special population.

The Institute for Healthcare Improvement (IHI) and its partner organizations launched the 100,000 Lives Campaign, an effort to reduce preventable deaths in US hospitals. Over 3,000 hospitals participated in this initiative and 122,000 lives were saved in 18 months. Given its success, the Campaign developed an extended focus: preventing medically-induced injuries in healthcare. The specific goal is to protect patients from 5 million incidents of medical harm during a 2 year period (December 2006 – December 2008). This initiative is known as the "5 Million Lives Campaign" and challenges American hospitals to adopt 12 changes in care to save lives and reduce patient injury (Table 5) [23]. Prevention of pressure ulcers is one of the targeted interventions of the new campaign [1,23].

Recommendations for prevention of pressure ulcers in pediatric patients were developed as part of the 5 Million Lives Campaign. A review of adult and pediatric literature related to pressure ulcers and risk factors for skin breakdown resulted in the "How-to Guide" for prevention efforts. The goal of the Guide is to "prevent hospital-acquired pressure ulcers in pediatric patients by reliably implementing the six components of care recommended in the Guide" [35]. The "Guide" lists six essential prevention elements and then expands on each element with specific implementation strategies utlizing evidenced based research. Case studies, suggested practice protocols, patient education materials and examples of risk assessment tools are included in the Guide [35,36].

Table 5
Six interventions from the 100,000 Lives Campaign

• Deploy Rapid Response Teams
• Deliver Reliable, Evidence-Based Care for Acute Myocardial Infarction
• Prevent Adverse Drug Events (ADEs)
• Prevent Central Line Infections
• Prevent Surgical Site Infections
• Prevent Ventilator-Associated Pneumonia
New interventions targeted at harm (5 Million Lives Campaign)
• Prevent Harm from High-Alert Medications
• Reduce Surgical Complications
• *Prevent Pressure Ulcers*
• Reduce Methicillin-Resistant Staphylococcus Aureus (MRSA)
• Deliver Reliable, Evidence-Based Care for Congestive Heart Failure
• Get Boards on Board

The Guide's 6 essential elements for pressure ulcer prevention in pediatric in-patient settings [35] include:

1. Conduct a Pressure Ulcer Admission Assessment for All Patients
2. Reassessing Risk for Patients
3. Inspect Skin Daily
4. Manage Moisture: Keep the Patient Dry and Moisturize Skin
5. Optimize Nutrition and Hydration
6. Minimize Pressure

These elements are applicable to children with spina bifida. Special focus on their risk factors: paralysis, insensate skin, incontinence, bony prominences, immobility and obesity is warranted. Children who have previously had a pressure ulcer are at high risk for skin breakdown reoccurrence at the same body location. Parents should be encouraged to inform health care professionals of skin or pressure ulcer issues in previous hospitalizations. Such information can facilitate care plans such as the use of pediatric pressure redistribution devices (i.e. specialty mattresses).

In the home setting, daily skin assessments are key to prevention of wounds. Review of prevention strategies to keep skin healthy should be provided during each outpatient clinic visit. The likelihood of skin breakdown changes as the child gets older related to increased mobility and participation in outdoor activities. One important prevention strategy is performing "skin checks" when the child is getting dressed and undressed each day. Teaching the child to look for reddened areas and then notifying the parent or caregiver is part of the prevention habit. Children's involvement

in "skin checks" should be incorporated when developmentally appropriate. Use of a skin inspection mirror with a flexible handle is helpful in observing "hard to see" areas (ex: plantar surfaces of feet, the back and buttocks).

Use of medical devices can contribute to skin breakdown. Most children with spina bifida use orthoses, walkers, and/or wheelchairs on a regular basis. Pressure areas on the feet/legs can occur when braces are out-grown or need adjustment. The Orthotics Department of this author's institution conducted a chart review of patients with spina bifida who used orthotic devices and had skin breakdown attributable to brace wear. Skin breakdown was noted to occur at two specific times after delivery of the new brace: 2 months and 12 months. The 12 month occurrence presumably relates to the child's normal growth. Braces should be checked regularly and skin should be monitored for red marks that remain for more than 20 minutes after brace removal. "Sitting" on the back support bar of a walker has been associated with skin breakdown on the buttocks and should be discouraged.

Wheelchairs that are outgrown or wheelchair cushions that do not provide appropriate pressure redistribution (i.e. air cushions with a "leak") contribute to skin breakdown in this population. When children gain or lose weight wheelchair equipment must be modified. Wheelchair evaluations should be performed by a mobility specialist. Use of a pressure mapping system to evaluate the cushion helps pinpoint "hot spots" of pressure at bony prominences. Pressure mapping the cushion should also be utilized if the child develops a wound on the buttocks as the cushion may need to be changed to a higher category of pressure redistribution. Children should also be taught to avoid placing any objects such as books, water bottles, or notebook binders between their skin and the side or back cushion of the wheelchair. Such hard objects as these create pressure points on insensate skin and can lead to pressure ulcer development.

Bowel and bladder continence deserves discussion and encouragement regularly during patient visits. Achievement of continence reduces the likelihood of skin breakdown by reducing exposure to moisture. Older children or overweight children who continue wearing diapers can develop skin breakdown in the groin because the tight diaper "edge" cuts into the skin. Moisture barrier creams should be utilized for bowel clean outs (i.e. in preparation for elective urologic surgery) to prevent scalding of perineal skin.

Change in mobility status or position can result in pressure ulcers in children with spina bifida. All children who are status post spinal fusion and use a wheelchair should have their wheelchair and cushion re-evaluated after instrumentation [34]. The change in spine position after surgery changes the back, buttock and feet position in the wheelchair and new pressure points may occur. If adjustments are not made, ulceration can occur. Likewise, re-evaluation of the wheelchair cushion should be performed after flap surgery. Use of a calendar to track increasing sitting times can be helpful to the child and family to mark sitting progress. For children that usually walk, use of a wheelchair may be required temporarily if a foot wound occurs. Wearing shoes when in the wheelchair protects the foot plantar surface from breakdown due to pressure from the foot plate.

Table 6
Comprehensive Patient Assessment Parameters for Wound Treatment

Allergies and skin sensitivities (especially related to previously used skin products)
Family support systems
Pain status (use of a validated pediatric pain tool required)
Nutritional history (oral motor difficulties / dysphagia history / weight loss)
History of previous wounds and wound location
Previous treatment/dressings used; and effectiveness of healing
Pressure ulcer risk assessment score (use valid and reliable pediatric tool)
Devices and equipment used including support surfaces to manage tissue load
Level of sensation
Family/patient knowledge of disease/chronic condition; document factors that affect learning needs
Family/patient perception of the cause of wound/pressure ulcer
Targeted physical exam

8. Treatment of wounds

There are numerous choices for treating skin breakdown and/or wounds. The starting point for intervention is assessment of the "total patient". For those with chronic conditions such as spina bifida, wound healing can be inhibited and prolonged. Successful skin and wound healing is enhanced by a methodological sequence: assessment, planning, implementation, evaluation and documentation [21]. Guidelines for a conducting a comprehensive patient assessment are listed in Table 6 [2,21].

Ascertaining nutritional status is critical. Up to 40% of children with special health care needs are at risk nutritionally [45]. In such high-risk populations, nutritional assessment should include anthropometric measurements (weight, length/height, head circumference,

Table 7
Characteristics of an ideal dressing

• Maintain a moist environment
• Facilitate autolytic debridement
• Be comfortable to the patient
• Come in numerous shapes and sizes
• Absorbent
• Provide thermal insulation
• Serve as a bacterial barrier
• Reduce/eliminate pain at the wound site; not cause pain when removed

body mass index and skin folds), a detailed nutrition history and laboratory values (albumin, prealbumin, iron profile, zinc, complete blood count). However, caution must be used when assessing biochemical data as they can be affected by medications, hydration, changes in metabolism, infection and inflammation [43]. A clinical assessment of oral motor function is often needed. Chewing or swallowing difficulties can preclude adequate caloric intake and protein for wound healing. Alternative feeding options (nasogastric tube or gastrostomy tube) may be needed to supplement oral intake and meet nutritional needs.

Choosing the wound treatment depends on several factors: therapy goals, practice environment, available resources, patient age, skin condition, product concentration and adherence, potential for skin sensitization, and impact of product absorption. Product safety and usage in the pediatric population must also be considered. This information can be obtained through review of the manufacturer's recommended use data [2].

Dressing selection criteria has several components. Additional key questions should be considered as part of the wound assessment prior to dressing selection including the wound's moisture content, presence of dead/open space or edema and condition of the peri-wound skin (skin surrounding the wound). Answers to these questions will guide the dressing selection [16]. Major advances in skin and wound care have resulted in a plethora of products. The ideal dressing should protect the wound, be easy to apply and remove without trauma, not require frequent changes, keep the wound moist, be the correct size or be able to be cut to fit the area (see Table 7) [6].

Commonly used wound products include: alginates, antimicrobials, collagens (derived from animal products), composites, contact layers, foams, hydrocolloids, hydrogels, transparent films, biologics and other dressings, advanced skin care products [16], liquid barrier films, soft silicone dressings (available in many types of wound products), topical enzymes and negative pressure wound therapy [2]. Generic wound dressing categories, their actions and indications are described in Table 8. A review of the literature shows anecdotal usage, case studies and/or clinical series reports using the following products with pediatric patients: silicone dressings [49], non-alcohol-based liquid barrier films [53], hydrocolloids [18,44], hydrogels [10], foams [18,52], composite dressings [2], hydrofiber dressings [52], negative pressure wound therapy [9,31] and medicinal honey [48].

Wet-to-dry dressings enjoy a lengthy history in wound care. At this time, there is increasing consensus that this modality is best left in history. The reason for that consensus includes the following: drying of the wound resulting in local tissue cooling, distribution of airborne bacteria during dressing changes, pain with dressing changes and reinjury to the tissue since gauze cannot distinguish between "good and bad" tissue [40, 50]. In 2002 Ovington [40] reviewed several studies that demonstrated the disadvantages of using wet-to-dry dressings for the patient (pain, impeded healing), the clinician (labor intensive) and the health care system (cost–supplies and labor). Despite the above, some wounds get better with wet-to-dry gauze. But at this time the consensus is best summarized by Soter [50], "Wet-to-dry dressing should be sent out to dry."

It's important to remember that as the wound changes the dressing product will require reassessment [6]. Consulting a Certified Wound Ostomy Continence Nurse (CWOCN), Certified Wound Care Nurse (CWCN) or Certified Wound Specialist (CWS) is helpful in choosing the correct product for the wound type and monitoring the wound to determine when the treatment needs to be changed.

While the majority of wounds in children with spina bifida occur in insensate areas, wounds can occur in sensate areas (i.e. the back with a dehisced spinal fusion incision). Pain management is crucial during dressing changes when sensation is present. Pain status should be determined by using a validated pediatric pain assessment tool [20]. In addition to medication management, many non-pharmacologic interventions are available to reduce pain during dressing changes. Non-pharmalogical interventions shown to decrease distress associated with painful procedures in children include interventions used "before" (e.g. distraction), "during" (e.g. distraction), and "following" the procedure (e.g. positive reinforcement) [29]. Table 9 describes non pharmacologic management strategies for pain reduction [19].

There are many causes of wound pain: infection, dried dressings or strong adhesives during dressing re-

Table 8
Wound product categories and usage*

Generic category	Description	Indications	Advantages	Disadvantages
(Calcium) Alginates	Dressings derived from seaweed; forms a moist gel when contacts wound fluid	Moderately draining wounds; partial and full-thickness wounds of various etiologies	Highly absorbent; trauma free removal	Use has not been studied in pediatric population; requires secondary dressing; can dry out wound bed if wound has only minimal drainage; not recommended for neonatal use due to calcium absorption concerns
Antimicrobials	Contain agents such as silver, iodine, or polyhexethylene biguanides; reduce bacterial load and superficial infection	Infected wounds; colonized, chronic nonhealing wounds; partial/full-thickness wounds	Available in many forms; reduces infection risk; reduces inflammation; inhibits growth of pathogens especially MRSA and VRE	Contraindicated if sensitivity to iodine or silver; secondary dressing required; **silver dressings must be removed and wound cleansed prior to MRI;** do not use silver with enzymatic debriding agents; silver may stain/discolor surrounding tissue due to oxidation
Collagens	Major body protein that stimulates cellular migration in all phases of wound healing; contributes to new tissue development and wound debridement; derived from bovine products	Partial & full-thickness wounds; pressure ulcers (check package insert); donor sites; surgical wounds	Absorbent, non-adherent; easy application & removal; conformable; can use in combination with topical agents	Contraindicated in 3^{rd} degree burns and sensitivities to collagen or bovine products; requires secondary dressing; not recommended for necrotic wounds; **be aware of cultural issues and bovine products**
Composites	Combination of 2 different types of dressings with distinct properties in 1 dressing that provides multiple functions; used a primary or secondary dressing; contains adsorptive layer, adhesive border & strike-through barrier	Partial & full-thickness wounds; pressure ulcers; minimal to heavy draining wounds; surgical incisions	Conformable; easy application & removal; waterproof; effective in areas of excessive body moisture	Adhesive borders may irritate fragile skin; check package insert for specific contraindications
Contact Layers	Comprised of woven net or mesh with low adhesion properties; apply directly to wound bed; allows exudate to pass through the layers while protecting wound bed	All wound types	Diminishes pain; protects wound bed	Contraindicated with silicone allergy
Foams	Non-adherent, absorbent dressing; made from polymers that trap moisture; provides moist wound healing; thermoregulation and protection	Partial and full-thickness wounds with minimal to heavy drainage; pressure ulcers; surgical wounds; infected and non-infected wounds; tunneling and cavity wounds; under compression wraps/stocking	Non-adherent; trauma-free removal; Absorbs minimal to heavy drainage; easy to apply and remove; available in adhesive or non-adhesive varieties and waterproof backing; reduces pain; certain types have low adherence to wound bed	Not recommended for non-draining wounds or wounds with eschar; may require secondary dressing; not all foams can be used in cavities/tunnels or infected wounds
Hydrocolloids	Advanced occlusive and semiocculsive dressings composed of carboxymethyl-cellulose, pectin or gelatin; impermeable to bacteria; prevents excretions and exudate from eroding and denuding peri-wound skin	Pressure ulcers; partial- and full-thickness wounds; under compression and wraps; necrotic wounds; prevention in high friction areas; secondary dressing or under taping procedures; under compression wraps/stocking	Facilitates autolytic debridement; self adherent; reduces wound pain; variety of shapes/sizes; absorbs minimal to moderate drainage; reduction of epidermal water loss; can be used in incubators and humidified environments; barrier for other adhesives	Not recommended for heavy drainage, sinus tracts or fragile skin; some contraindications for infected wounds; can be hard to remove; edges may “roll up”; may have odor when dressing is changed; leakage can occur

Table 8, continued

Generic category	Description	Indications	Advantages	Disadvantages
Hydrogels	Water or glycerin based, non-adherent hydrophilic, cross-linked polymers; numerous forms: gels, sheets, strips and gauze; donates moisture to wound and some may absorb drainage while moisturizing depending on wound's need	Pressure ulcers; partial- and full-thickness wounds; dermabrasion; painful wounds; radiation tissue damage; wound dehiscence; extravasation injuries; fungating lesions; burns; autolytic debridement (some types)	Trauma free removal and soothing to wound; gentle healing for skin tears; non-adherent; reduces wound pain; rehydrates wound bed; can be used with topical medications	May require secondary dressing; can macerate peri-wound skin; do not use in heavily draining wounds
Transparent film	Made of polymer membranes with adhesive layer; varying thickness; impermeable to liquid and microbes but permeable to oxygen and moisture vapor	Primary dressing for lacerations, skin tears and intravenous sites; secondary dressings for longer wear; partial-thickness wounds; pressure ulcers (Stage I and II); abrasions	Impermeable to external fluids and bacteria; allows wound inspection; prevention and reduction of friction; numerous sizes; waterproof; lower overall infection rates as compared to traditional gauze dressings	Non-absorptive; adhesive may damage fragile skin; do not use for draining wounds; may macerate peri-wound skin
Biologics and other dressings	Dressings made of polyacrylates impregnated with Ringer's solution which absorb and irrigate simultaneously; others are made of bioengineered cellulose or biosynthetics to provide a healing matrix for granulation and epithelialization	Wound debridement (polyacrylates); used in recalcitrant wounds to promote closure (biologics and biosynthetics)	Moist wound healing; pain-free debridement; matrix dressings have been shown to promote higher incidence in wound healing in recalcitrant wounds	
Advanced Skin Care Products	Ointments, protectants and barriers; may contain zinc oxide, dimethicone or silicone combination	Protect/heal partial-thickness skin loss; Stage I and II ulcers; protect closed wounds or vulnerable areas	Can be used in place of an adhesive dressing that could injure the wound	Choose barrier products that can be used on open and closed skin; must be able to "stick" to tissue if a wet environment is present
Liquid barrier films	Alcohol and non-alcohol based; prep pads and spray	Applied to skin to prevent epidermal stripping during adhesive removal; protection against skin erosion from wound exudate; *Use of non-alcohol product recommended in pediatrics related to skin absorption issues*	Easy to apply; some products have longer "wear" time	Alcohol based liquid barrier films can be painful if alcohol comes in contact with wound bed in persons with sensation
Soft silicone dressings	Dressings available as contact layers, absorbents, antimicrobials, exudate transferrants; scar management and fixation tape	Product usage based on wound characteristics; provides pain reduction during dressing changes	Adhesive free; versatile; reduces pain	Avoid in persons with silicone allergies
Topical enzymes (enzymatic debriders)	Chemical agent that is proteolytic and breaks down devitalized tissue; prescription required	Debridement of necrotic wounds and pressure ulcers	Nonsurgical debridement method; dressing changes required daily and/or twice daily	Inactivated by soaps, acidic solutions, detergents and metallic ions (silver); requires secondary dressing; have not been tested for safety/efficacy in neonatal/pediatric populations but anecdotal use in pediatrics has been reported

Table 8, continued

Generic category	Description	Indications	Advantages	Disadvantages
Negative pressure wound therapy: *mechanism of action in wound bed is product dependent*	Active, noninvasive therapy applied to wound bed using negative pressure to promote wound healing – one method utilizes specialized foams to interface with the wound bed; the other method utilizes antimicrobial gauze interfacing with wound bed	Product dependant: draining wounds; partial- and full-thickness wounds with exudate (moderate to heavy); venous, arterial and diabetic ulcers; chronic and acute wounds; dehisced wounds; burns, flaps, meshed grafts and bioengineered tissue and abdominal wounds; pressure ulcers Stages II to IV	Decreases edema and bacterial colonization; increases blood supply; promotes granulation formation; machine settings can be adjusted based on patient and type of wound; dressing changed every 48–72 hours (recommendations vary by manufacturer)	Training required for healthcare personnel to apply and operate equipment; may increase pain in some wounds; may adhere to some wounds; not indicated for patients with malignancy in wound; untreated osteomyelitis; non-enteric and unexplored fistulas; necrotic tissue with eschar present

*Note: Products described represent categories of dressing selection options and is not an all-inclusive list. Always consult manufacturer's recommendations for safe use in pediatrics. Usage based on wound characteristics, indications and contraindications. Multiple resources were used for chart construction. Refer to reference list [2,6,8,10,16,18,24,31,33,44,47,49,52,53].

Table 9
Non-Pharmacologic Management Strategies for Pain Reduction

- Education/instruction
- Relaxation strategies or breathing exercises
- Meditation or prayer
- Distraction (music)
- Imagery
- Hypnosis
- Biofeedback
- Acupuncture
- Pain reducing dressing (soft silicone)
- Self dressing changes
- Time outs during dressing changes
- Positioning, elevation, immobilization or rest
- Pressure reducing devices/positioning devices
- Heat or cold applications
- Physical therapy
- Trancutaneous electrical nerve stimulation (TENS)
- Support groups or counseling

moval, debridement and increased pressure secondary to exudate. Choosing a dressing that promotes moist wound healing facilitates healing and reduces pain. When nerve endings are kept moist, nerve receptors do not become dehydrated and pain is reduced [17]. When children experience wound pain, remember to warm irrigation/treatment solutions before use, wet the dressing before removal, allow the child to participate in the dressing removal if developmentally appropriate, use "time outs" to take a break during the dressing change and always practice gentle removal and application of wound products [19].

9. Summary and recommendations

Wound treatment is complex and costly for children, families and health care systems. Pressure ulcer prevention remains a daunting challenge for individuals with spina bifida, health care professionals supporting them and caregivers in the home and/or community. Information provision about pressure ulcer prevention and skin injury should begin at birth and continue through each developmental stage into adulthood.

Use of a pediatric pressure ulcer risk assessment tool can help pinpoint risk factors but should not be the only consideration in developing a prevention protocol. Careful consideration of the child's previous wound and/or skin breakdown issues will assist in management. Development and implementation of prevention strategies and treatment of skin breakdown is a "team sport" involving multiple specialties including the child and the family. The healthcare team includes wound care specialists, developmental pediatrics, nursing, surgery, dietary, physical therapy, occupational therapy, mobility, orthotics, child life, and therapeutic recreation.

The child and family remain the key players on "the team." Many prevention strategies and interventions will be accomplished in the local community, often at some distance from tertiary, specialty centers that have focused programs on spina bifida. Being knowledgeable regarding specific risk factors for skin breakdown will equip all team members to proactively meet the goals of minimizing costs – financial and emotional – and improving the health of each child.

Appendix

Pressure Ulcer Stages – National Pressure Ulcer Advisory Panel (NPUAP)

(**Suspected Deep Tissue Injury**): 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.

Further description: Deep tissue injury may be difficult to detect in individuals with dark skin tones. Evolution may include a thin blister over a dark wound bed. The wound may further evolve and become covered by thin eschar. Evolution may be rapid exposing additional layers of tissue even with optimal treatment.

Stage 1: Intact skin with non-blanchable 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.

Further description: The area may be painful, firm, soft, warmer or cooler as compared to adjacent tissue. Stage 1 may be difficult to detect in individuals with dark skin tones. May indicate "at risk" persons (a heralding sign of risk).

Stage II: 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.

Further description: Presents as a shiny or dry shallow ulcer without slough or bruising.* This stage should not be used to describe skin tears, tape burns, perineal dermatitis, maceration or excoriation.

*Bruising indicates suspected deep tissue injury.

Stage III: Full thickness tissue loss. Subcutaneous fat may be visible but bone, tendon or muscle is not exposed. Slough may be present but does not obscure the depth of tissue loss. May include undermining and tunneling.

Further description: The depth of a stage III pressure ulcer varies by anatomical location. The bridge of the nose, ear, occiput and malleolus do not have subcutaneous tissue and stage III ulcers can be shallow. In contrast, areas of significant adiposity can develop extremely deep stage III pressure ulcers. Bone/tendon is not visible or directly palpable.

Stage IV: Full thickness tissue loss with exposed bone, tendon or muscle. Slough or eschar may be present on some parts of the wound bed. Often include undermining and tunneling.

Further description: The depth of a stage IV pressure ulcer varies by anatomical location. The bridge of the nose, ear, occiput and malleolus do no have subcutaneous tissue and these ulcers can be shallow. Stage IV pressure ulcers can extend into muscle and/or supporting structures (e.g., fascia, tendon or joint capsule) making osteomyelitis possible. Exposed bone and tendon is visible or directly palpable.

Unstageable: 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.

Further description: Until enough slough and/or eschar is removed to expose the base of the wound, the true depth, and therefore the stage, cannot be determined. Stable (dry, adherent, intact without erythema or fluctuance) eschar on the heels serves as "the body's natural (biological) cover" and should not be removed.

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