FEATURE ARTICLE

Medical Adhesives and Patient Safety: State of the Science

Consensus Statements for the Assessment, Prevention, and Treatment of Adhesive-Related Skin Injuries

Laurie McNichol, Carolyn Lund, Ted Rosen, Mikel Gray

ABSTRACT: Skin injury related to medical adhesive usage is a prevalent but underrecognized complication that occurs across all care settings and among all age groups. If proper technique for application and/or removal of adhesive products is not used, tissue trauma can occur, impacting patient safety and quality of life and increasing healthcare costs. Little guidance exists in the literature regarding appropriate selection and proper use of adhesive products to minimize medical adhesive–related skin injury, as well as best practices for skin care preventive strategies, application and removal techniques, and assessment and treatment of such injuries. In an effort to define best practices for prevention of such injury, a consensus panel of 23 recognized key opinion leaders convened to establish consensus statements on the assessment, prevention, and treatment of medical adhesive–related skin injury. The consensus summit was held in December 2012 and was made possible by an unrestricted educational grant from 3M. This document details the consensus definitions and statements and identifies research priorities for development of new adhesive technologies and protocols for skin protection.

Key words: Bandages, Dressings, Medical adhesive, Skin integrity, Skin stripping, Skin tear, Surgical tape

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INTRODUCTION

Medical adhesives comprise an integral part of healthcare delivery and are used by virtually every medical specialty in all care settings. Medical adhesives are a component of a variety of products, including tapes, dressings, electrodes, ostomy supplies, and patches; they provide securement for both critical and noncritical devices and products, facilitate skin protection and healing, and allow noninvasive monitoring.

Skin injury related to medical adhesive usage is a prevalent but underrecognized complication that occurs across all care settings, from healthy patients in the ambulatory environment to acute and critically ill patients. Although often described as being limited to the extremes of age, such skin injury occurs across all age groups. If proper technique is not used, superficial layers of the skin are removed along with the adhesive product, which not only affects skin integrity but can cause pain and the risk of infection, increase wound size, and delay healing, all of

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which reduce patients' quality of life.[1] However, under certain circumstances, adhesive products can also cause deeper tissue injuries beyond loss of superficial skin layers. Medical adhesive-related skin injury (MARSI) has a significant negative impact on patient safety. In addition, treating skin damage is costly in terms of service provision, time, and additional treatments and supplies.[2] The average cost of treating a skin tear in an extended convalescent center was recently reported to be $21.96 per patient per incident.[3]

Healthcare providers play an important role in medical adhesive safety, but literature review reveals little guidance regarding appropriate selection and proper use of adhesive products in order to minimize MARSI. In addition, outside of clinical textbooks on wound and ostomy care,[4–6] there is a paucity of information regarding best practices for skin care preventive strategies and application and removal techniques, as well as assessment and treatment of MARSI. For example, only 2 relevant guidelines were identified in the literature: the Association of Women's Health, Obstetric and Neonatal Nurses Neonatal Skin Care Guideline[7] and evidence-based recommendations/national guidelines in Portuguese resulting from the 1st InterPele: Symposium on Skin Integrity Prevention Strategies, held in Angra dos Reis, Brazil, in March 2011.[8]

In an effort to increase awareness of MARSI and define best practices for its prevention, a consensus panel of 23 key opinion leaders convened to establish consensus statements on the assessment, prevention, and treatment of MARSI. Additional goals included defining knowledge gaps regarding medical adhesives and skin safety, documenting the spectrum of care settings and medical applications where MARSI occurs, and identifying research priorities for development of new adhesive technologies and protocols for skin protection. The interdisciplinary Medical Adhesives & Patient Safety Consensus Summit was held December 10 to 11, 2012, in St. Paul, Minnesota. An industry partner, 3M provided an unrestricted grant for the consensus summit, and a third party (Magellan Medical Technology Consultants) was contracted to manage the project.

METHODS

Three standing members of the 3M Skin Integrity Advisory Board were invited and agreed to serve an advisory role (Task Force). Medical specialties and/or practice settings where medical adhesives are used were identified and used as a guide to extend invitations to potential panel members. Specialty practice areas represented by the panel members were critical care; dermatology; electrophysiology; geriatrics; infection prevention; infusion therapy; neonatology; oncology; orthopedics; pediatrics; perioperative; physical therapy; plastic surgery; and wound, ostomy and continence. Researchers in the area of skin and wound care, including pressure ulcers, were also among the invited participants.

Literature reviews were conducted during September and October 2012. An initial search was conducted in the Scopus database using terms identified by the Task Force, which included adhesive(s), adhesive surgical tape, allergic contact dermatitis, bandages, barrier film, dressing, epidermal injury, epidermal stripping, fragile skin, irritant contact dermatitis, maceration, medical adhesive, medical adhesive tape, medical bandage, skin abrasion, skin injury, tape blister, and tape burn. As many of these key terms are broad, search limiters such as adhesive(s), adverse effects, skin injury, skin protection, and/or trauma were incorporated using the Boolean function "AND." After initial review of records, results were limited to articles published in English since 1990. An additional review was completed for studies investigating medical adhesive stripping published in English since 1990. This review included the following five electronic databases: MEDLINE, EMBASE, BIOSIS Previews, CHEMICAL ABSTRACTS, and EMcare. Search terms included keywords for bandage or dressing or tape combined with key words for skin stripping. A separate search was conducted for relevant practice guidelines or procedures. Textbooks were not included in these searches.

In addition to randomized clinical trials and comparison cohort studies, individual case studies, multiple cases series, clinical practice guidelines, consensus documents, practice surveys, laboratory studies, preclinical research studies, technical articles, letters to the editor, and product related articles were retrieved. Publications outside the scope of the topic were excluded and all remaining articles (n = 167) were reviewed on a case-by-case basis by the Task Force; of these, 88 (52.6%) were considered relevant. In order to obtain a manageable cross section of key publications for consensus statement development and background information for invited panel members, each relevant article was categorized according to medical specialty and practice setting. Task Force members then ranked each article on a scale of 1 to 3 (where 1defined the lowest level of information and 3 the highest), while also including as many representative specialties/practice settings as feasible. The 31 top-scoring articles (articles totaling 10 points or more) were identified as key publications.

The 2-day Summit began with a presentation summarizing pre-Summit activities and state of the science, which was followed by a review of draft consensus statements. An interactive PowerPoint software program and wireless response system pads (IML ViewPoint Express and IML Click, IML, Minneapolis, Minnesota) were used to allow anonymous interactive voting by the panel members and Task Force and to capture responses. Consensus on each statement was obtained based on general principles outlined in Murphy and colleagues,[9] using 80% agreement as the criterion for consensus. If consensus was not achieved on the first vote, the statement was edited based on participant input and a second, and sometimes third, vote was taken. In cases where consensus could not be

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reached, or if a statement was considered not relevant, consensus regarding deletion of the statement was obtained. Additional background on the establishment of the Medical Adhesives and Patient Safety Consensus Summit and its methodology can be found in Supplemental Digital Content 1, http://links.lww.com/JWOCN/A18.

BACKGROUND

Medical Adhesives and Medical Adhesive Products

Literature review identified several definitions for medical adhesives and medical adhesive tapes/bandages (Supplemental digital content 2, http://links.lww.com/JWOCN/A20). A medical adhesive can be defined as a product used to affix an external component (ie, tape, dressing, catheter, electrode, ostomy pouch, or patch) to the skin. However, selected tapes, dressings, and devices can also function as medical adhesives. According to Widman and colleagues,[10] medical adhesive tape can be simply defined as a pressure-sensitive adhesive and a backing that acts as a carrier for the adhesive. The US Food and Drug Administration more specifically defines a medical adhesive tape or adhesive bandage as "a device intended for medical purposes that consists of a strip of fabric material or plastic, coated on one side with an adhesive, and may include a pad of surgical dressing without a disinfectant. The device is used to cover and protect wounds, to hold together the skin edges of a wound, to support an injured part of the body, or to secure objects to the skin."[11]

Medical adhesive tapes/dressings/devices are composed of several layers (Figure 1). The type of backing and adhesive incorporated into the design determines the properties and performance of the adhesive product. For example, tape backings may consist of paper or a paper blend, plastic, silk (woven polyester), soft (nonwoven) cloth, traditional cloth, or foam and/or elastic. Examples of types of adhesives used in tapes and dressings include acrylates, silicones, hydrogels, hydrocolloids, and polyurethanes, as well as those that are natural-rubber latex based or contain zinc oxide.[1,12] Technical considerations demand that some adhesives are only paired with certain backings. Examples of adhesive dressings and dressing adhesive combinations include hydrocolloids, hydrogel sheets, foams (silicone, acrylate, polyurethane, or hydrocolloid), semipermeable transparent films (silicone or acrylate), and hydrofiber dressings (Table 1).

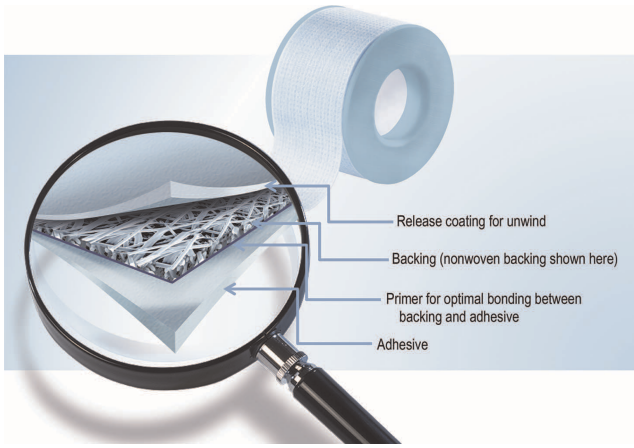


FIGURE 1. Anatomy of medical adhesive tape.

Medical adhesives are pressure sensitive; firm pressure applied to the surface of the medical tape/dressing/device will activate the adhesive by increasing the surface area contact.[12] Over time, the adhesive will warm and flow to fill in gaps between the adhesive and the irregularities in the skin surface, increasing the strength of the bond. The length of time for this process differs among the various types of adhesive products. Some softer adhesives, such as silicone, have a lower surface tension and fill in these gaps quickly and maintain the same level of adherence over time. Others adhesives, such as the acrylates, act more slowly, and adherence increases over time.

Medical Adhesive–Related Skin Injury

The pathophysiology of MARSI is only partially understood. Skin injury results when the skin to adhesive attachment is stronger than skin cell to skin cell attachment. Cohesive failure occurs when adhesive strength exceeds the strength of skin cell to skin cell interactions. As a result, the epidermal layers separate or the epidermis separates completely from the dermis. Even when there is no visible trauma, adhesive removal commonly results in detachment of varying amounts of superficial epidermal cell layers; repeated application and removal result in compromised skin barrier function and initiate inflammation and the wound healing response. The association of a specific product with skin stripping or injury arises from a combination of factors, including energy required to remove the adhesive (often measured in Newtons), the rheology of the adhesive, its occlusiveness, and the rigidity of the material used as tape backing.[13] For example, rigid tape backing can lead to injury if there is skin movement due to edema or joint movement.[14,15] Trapping of moisture beneath an occlusive tape may result in maceration and irritation, which renders the skin more vulnerable to mechanical trauma. Types of MARSI are described in Figure 2.

Various intrinsic and extrinsic factors also influence the risk of skin injury (Table 2). For example, age-related physiologic factors exert a major impact on a patient's susceptibility to MARSI.[1,12,23] Neonatal skin is 40% to 60% thinner than adult skin, largely due to the presence of fewer epidermal cell layers in the stratum corneum.[12] This underdeveloped stratum corneum provides a less-efficient barrier, particularly in premature infants, resulting in increased transepidermal water loss, evaporative heat loss, and permeability.[24] Removal of any layers of the neonatal stratum corneum during the process of adhesive removal can further reduce the skin's barrier function, which significantly compromises fluid

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TABLE 1. Common Adhesives/Backings Used in Medical Tapes[a]

Adhesive	Backing	Advantages	Disadvantages	Clinical Implications
Natural rubber latex based	elastic traditional cloth	Oldest class of adhesives, used for 100 + y Very strong tape when paired with woven cloth backing Generally tolerates moisture better than acrylate or silicone adhesive	Adhesive can be very aggressive on skin Can cause damage if applied and/or removed incorrectly Natural rubber latex is known to cause sensitization and allergic reactions	Good backing strength for securement of heavy tubes, dressings and appliances Can be used for selected applications where contact with moisture and secretions are a consideration (eg, endotracheal tubes)
Acrylate	Elastic foam paper plastic silk soft cloth traditional cloth	This class of adhesives has been used for 50 + y This type of is low sensitizing and usually termed hypoallergenic Can be formulated to be gentler or more aggressive depending on adhesive formulation	Widely and safely used; however, incorrect selection, application, or removal of this tape can lead to skin damage and pain upon removal	Select the tape with the appropriate adhesion level. Higher adhesion than needed may increase risk of skin damage Considerations for tape selection include gentleness, stretch, backing strength, and moisture tolerance
Silicone	paper plastic	Newest class of adhesive available Very gentle to skin Very low sensitizing	Not recommended for primary securement of critical tubing and appliances Less tolerant to moist conditions compared to acrylate or rubber-based adhesives	Good choice for securement of lightweight dressings and tubing on at-risk skin or where frequent retaping is required Better securement can be achieved by increasing surface area covered by tape Tape removes easily and painlessly over hairy areas
Hydrocolloids	film	Initially adheres to dried surfaces, and nature of adhesion varies over time according to water content of the hydrocolloid mass, eventually weakening Molds well to skin surfaces	Has been shown to cause skin trauma equal to acrylate tape when removed at 24 h	Used in wound dressings and over skin as taping platforms
Hydrogels and polyurethanes	These types of adhesives are not frequently used. Consult manufacturer instructions for information.			

[a]This is general information only. Attributes and performance characteristics may vary by brand.

balance and homeostasis and increases skin permeability; this leads to potential toxicity and irritation from topically applied substances, as well as an increased risk of infection. In addition, the cohesion between the dermis and epidermis is lower in neonatal skin than in adult skin, increasing the risk for select skin injuries.[12]

A number of skin changes inherent to the aging process increase the risk of skin injury in older adults. These include loss of dermal matrix and subcutaneous tissue; epidermal thinning; reduced cohesion between the dermal and epidermal layers; reduced vascularity, elasticity, tensile strength; and loss of moisture.[1,23,24]

Emerging evidence suggests that differences in skin structure and function among various ethnic groups may affect their risk of skin injury. These include racial differences in percutaneous absorption rates of various substances as well as stratum corneum lipid (ceramide) content, which is highest in African Americans.[25] More recently, ethnic differences in tensile mechanical properties of the dermis have been demonstrated, suggesting that African

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Mechanical

Skin (Epidermal) stripping—Removal of one or more layers of the stratum corneum occurring following removal of adhesive tape or dressing; lesions are frequently shallow and irregular in shape and the skin may appear shiny; open lesions may be accompanied by erythema and blister formation[1,16,17]

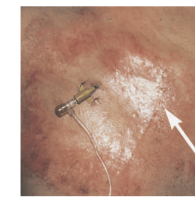


Photo courtesy of 3M

Tension injury or blister—Injury (separation of the epidermis from the dermis) caused by shear force as a result of distension of skin under an unyielding adhesive tape or dressing, inappropriate strapping of tape or dressing during application, or when a joint or other area of movement is covered with an unyielding tape[16,18,19]

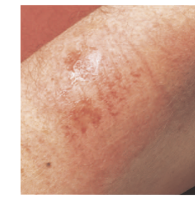


Photo courtesy of 3M

Skin tear—Wound caused by shear, friction and/or blunt force resulting in separation of skin layers; can be partial- or full-thickness[20]

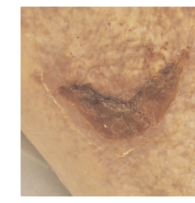


Photo courtesy of 3M

Dermatitis

Irritant contact dermatitis—Non-allergic contact dermatitis occurring as a result of a chemical irritant; a well-defined affected area correlates with the area of exposure; may appear reddened and swollen and vesicles may be present; typically of shorter duration[10,21]

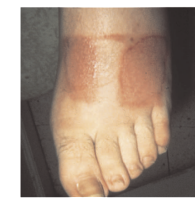


Photo courtesy of 3M

Allergic dermatitis—Cell-mediated immunologic response to a component of tape adhesive or backing; typically appears as an area of erythematous, vesicular, pruritic dermatitis corresponding to the area of exposure and/or beyond; persists for up to a week[10,21,22]

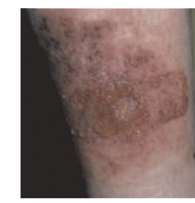


Photo courtesy of Ted Rosen

Other

Maceration—Changes in the skin resulting from moisture being trapped against the skin for a prolonged period; skin appears wrinkled and white/gray in color; softening of the skin results in increased permeability and susceptibility to damage from friction and irritants



Photo courtesy of 3M

Folliculitis—Inflammatory reaction in hair follicle caused by shaving or entrapment of bacteria; appears as small inflamed elevations of skin surrounding the hair follicle; may be nonsuppurative (papules) or contain pus (pustules)



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FIGURE 2. Types of adhesive-related skin injury.

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TABLE 2. Factors That Can Increase the Risk of Medical Adhesive–Related Skin Injury[1,4,12,20,23]

Intrinsic Factors	Extrinsic Factors
Extremes of age (neonate/premature infant and the elderly)	Drying of the skin due to harsh skin cleansers, excessive bathing, low humidity, etc
Race/ethnicity	Prolonged exposure to moisture
Dermatologic conditions (ie, eczema, dermatitis, chronic exudative ulcers, epidermolysis bullosa)	Certain medications (ie, antiinflammatory agents, anticoagulants, chemotherapeutic agents, long-term corticosteroid use)
Underlying medical conditions (ie, diabetes, infection, renal insufficiency, immunosuppression, venous insufficiency, venous hypertension, peristomal varices)	Radiation therapy
Malnutrition	Photodamage
Dehydration	Tape/dressing/device removal
	Repeated taping

American skin is more rigid than non-Hispanic white skin, which may affect risk of injury.[26]

Additional intrinsic factors that can increase the risk of MARSI include a number of dermatologic and underlying medical conditions, malnutrition, and dehydration; extrinsic factors such as drying of the skin, prolonged exposure to moisture, certain medications, radiation therapy, photodamage, and previous use of adhesive products also play an important role in enhanced susceptibility to skin injury (Table 3).[21,22]

Epidemiology

The prevalence of skin injury due to adhesives is largely unknown. In one prospective cohort study of older individuals admitted to a long-term care facility, the cumulative incidence of skin injury caused by adhesive tape was reported to be 15.5% (incident density 38 per 1000 person days).[27] Clinical manifestations of MARSI observed in this study included contact dermatitis (71%), trauma (21%), and infection (9%). The use of adhesives was also identified as the primary cause of skin breakdown among neonatal intensive care unit patients in a nursing research utilization project involving 2820 newborns.[28]

Tape-related skin (epidermal) stripping can occur at any age and in any clinical setting, but it is especially prevalent at the extremes of life (in the elderly and neonates).[1,16,29,30] In a 1-day prevalence audit, 8% of hospitalized infants and children were found to have tape-related skin stripping.[29] In the 2003 National Pediatric Pressure Ulcer and Skin Breakdown Prevalence

TABLE 3. Preventable Causes of Medical Adhesive–Related Skin Injury[4,45]

- Improper choice of tape
  - Using tape with excessive adhesion for the purpose
  - Wrong choice of tape (ie, not using a tape with stretch for an area where swelling or movement is anticipated)
- Improper application technique
  - Tension on application (ie, strapping)
  - Applying in wrong direction (ie, not allowing stretch in direction of expected swelling/movement)
  - Applying to wet/moist skin
  - Use of alcohol-based skin preps, which are drying to the skin
  - Not allowing skin preps/barriers to dry (a common cause of irritant contact dermatitis)
  - Not clipping/trimming hair prior to application
  - Excessive use of substances that increase the stickiness of adhesives (ie, tackifiers, bonding agents)
- Leaving occlusive tapes or dressings on too long
- Improper removal technique
  - Quick removal
  - Removal at a high angle
  - Insufficient support of the skin at the peel line when removing the adhesive product
- Repeated taping or dressing changes

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Survey, the prevalence of skin stripping related to adhesive tape was reported as 17%.[30]

One clinical setting where the incidence of MARSI has been fairly well documented is orthopedic surgery. Tension injuries or blisters are more prominent in this setting as a result of multiple factors, including the use of large amounts of tape to hold large compression bandages securely. In this setting, the risk of tape damage is compounded by joint movement, skin friction, and the presence of tissue edema, which creates a strapping effect. The incidence of tension blisters has been reported to be in the range of 6% to 41% following knee or hip surgery[18,19,31–33] and 0% to 6% following knee arthroscopy.[34]

Medical adhesives are a common contributor to skin tears[20,35] and are a critical concern in caring for the elderly and for patients with compromised skin. In the International 2010 Skin Tear survey, dressing removal was cited as one of the top causes of skin tears.[20] During a 12-month period, the Pennsylvania Patient Safety Authority reported tape as the third most common cited cause of skin tears, following hospital beds and patient transfers.[35] The units where skin injury occurred most often included medical/surgical, intermediate care, rehabilitation, and specialty units.

CONSENSUS DEFINITIONS

Medical Adhesive

Panel members established the following definition for a medical adhesive:

> ***A medical adhesive is a product used to approximate wound edges or to affix an external device (ie, tape, dressing, catheter, electrode, pouch, or patch) to the skin.***

Medical Adhesive–Related Skin Injury

Konya and associates define skin injury due to adhesive tape as "a condition in which persistent erythema or other skin injury is evident even 60 minutes after removal of the tape."[27(p1237)] Building upon this terminology, and based on the use of a 30-minute timeframe to defi ne erythema persistence in the definition of stage 1 pressure ulcers in guidelines developed by the Wound, Ostomy and Continence Nurses Society in 198836 and in measurement of alterations in skin barrier function following adhesive removal in some research trials (eg, Lund and colleagues[37]), as well as clinical practice, panel members established the following definition for MARSI:

> ***A medical adhesive–related skin injury is an occurrence in which erythema and/or other manifestation of cutaneous abnormality (including, but not limited to, vesicle, bulla, erosion, or tear) persists 30 minutes or more after removal of the adhesive.***

CONSENSUS STATEMENTS

Assessment—General

1. During use of adhesive-containing products, the skin should be assessed for evidence of damage on a daily basis or with adhesive device changes; this is especially important for those patients deemed to be at high risk for adhesive-related injury.

It is a widely accepted standard of care that skin be assessed on all patients on admission to a healthcare facility and then at regular intervals, with more frequent assessment of patients at higher risk for skin breakdown or damage.[7,38,39] Assessment of the skin is particularly important during the use of adhesive-containing products, particularly in patients at high risk for adhesive-related injury. Skin inspection requires thorough observation and data collection, followed by interpretation.[40] Good lighting is essential for this process. The skin should be assessed for color, texture, uniformity of appearance, and integrity. Any lesions should be described accurately with regard to type, color, arrangement, size, and distribution.

Accurate description of the skin and any lesions can help distinguish adhesive-related skin damage from other nontraumatic dermatologic disorders or conditions and may help identify an infectious process if present. In patients with deeply pigmented skin, mild erythema may not be apparent and lesion color may vary from that seen in persons with lighter skin tones.

2. For all medical adhesive–related skin injuries, a comprehensive assessment should be performed to determine severity and guide management.

If an MARSI is noted during a skin assessment or device change, the injury should be assessed and the severity determined in order to guide management. As a whole, mechanical injuries (skin stripping, tension injuries, and skin tears) may be assessed as general wounds and classifi ed according to depth (ie, superficial, partial thickness, or full thickness).[41] The Neonatal Skin Condition Scale,[42] a validated assessment tool that incorporates evaluation of dryness, erythema, and skin breakdown, provides an objective measurement of skin condition and may be used in clinical practice to assess MARSI in this patient population. Existing skin tear assessment and classification systems, such as the Payne-Martin or Skin Tear Audit Research instruments, are not widely accepted,[20] and there currently are no such systems for other adhesive-related injuries in clinical practice. Although it may be difficult to clinically distinguish between irritant and allergic dermatitis, a thorough assessment may identify distinguishing features and enable determination of severity, thus guiding appropriate management.[43] Identification of allergic dermatitis is important, since the patient should be advised regarding future avoidance of the same or

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similar materials (see the following section). Assessment for evidence of infection should be performed in all cases of MARSI.

Assessment—Allergy/Sensitivity

3. Obtain a history of patients' known or suspected allergies and sensitivities to minimize the risk of medical adhesive–related skin injury.

Medical adhesive products are a common cause of nonallergic irritant contact dermatitis,[10,27,44] and such reactions are more likely to occur with extended exposure.[10] Allergic contact dermatitis related to adhesive products occurs much less frequently than irritant contact dermatitis, although numerous case reports of allergic reactions to components of adhesive products can be found in the literature.[10,44] Because avoidance of the causative substance is key to the prevention and management of dermatitis,[43] it is prudent to obtain a history of a patient's known or suspected allergies, as well as any previous episodes of irritant contact dermatitis, before using an adhesive product.

4. The incidence of true allergic contact dermatitis related to adhesives is not known; suspected allergic contact dermatitis should prompt consideration for referral and/or appropriate investigation (such as patch or scratch tests).

If there is a high suspicion of allergic contact dermatitis and/or irritant contact dermatitis cannot be ruled out, one should consider referring the patient for further evaluation. If avoidance and empiric treatment do not resolve a suspected case of allergic contact dermatitis, patch testing may be indicated.[43] The clinician can contact the manufacturer of the adhesive product in question for further assistance in identifying potential allergens. However, while the components of the adhesive may contribute in some way to the adverse reaction, it is neither logical nor possible in many cases to separate out these components for testing; it is the final combination that is the product, not necessarily its constituent parts.

Prevention—General

5. Identification of patients at high risk for medical adhesive–related skin injury is a key component of prevention.

As noted previously, a number of physiologic and pathologic conditions and extrinsic factors have an adverse effect on skin structure and function and thus can increase the risk of skin injury (refer to Table 2). Therefore, identification of patients who may be at increased risk for MARSI is a key component of prevention, as extra precautions can often be taken to help protect the skin from injury. These include the use of gentler adhesives, barrier products, and medical adhesive removers.

6. Care of the skin, including prevention of adhesive-related injury, should be a standard of care for all healthcare providers.

Skin care is an important aspect of patient care. Because medical adhesives play such an integral part of healthcare delivery and affect nearly every patient, prevention of MARSI is paramount to good patient care. A number of preventable causes of MARSI were found in the literature or identified by the consensus panel members (Table 4). By addressing these issues, the risk of skin injury can be reduced.

7. Prevention of medical adhesive–related skin injuries is facilitated by good nutrition and hydration.

Proper nutrition and hydration are important aspects of good skin care and overall patient health. Overall nutrition should include adequate calories, amino acids, carbohydrates, and fats, as well as trace minerals and vitamins that are essential components for maintaining intact and healthy skin.

Prevention—Selection, Application, and Removal

Selection

8. Select the most appropriate adhesive product based on its intended purpose, the anatomic location, the adhesive will be applied to, and the ambient conditions present at the application site.
9. Appropriate product selection entails consideration of properties of adhesive-containing products such as adhesive gentleness, breathability, stretch, conformability, and flexibility.

When selecting an adhesive product, one must consider both patient- and product-related factors. Perhaps the foremost patient consideration is the intended use or purpose of the product (ie, securement of a critical device, noncritical device, or dressing; wound closure; etc). The intended use of the product, in turn, influences anticipated wear time. The clinician should then consider anatomic location and skin thickness, as well as the ambient conditions present at the site. Key considerations include whether the area is smooth or contoured, subject to movement or friction, or exposed to moisture, perspiration, humidity, irritants, exudate, and/or body fluids.

The intrinsic characteristics of all components of an adhesive product must then be taken into account to address these patient factors. Properties of the adhesive to be considered include cohesiveness over time and gentleness; properties of the tape/backing/dressing to be considered include breathability, stretch, conformability, flexibility, and strength. The goal is to select a product that will fulfill the intended purpose for the anticipated wear time, at the specific anatomic location, and under the conditions present.

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TABLE 4. Recommended Procedures for Applying and Removing Adhesive-Containing Products[4,5,45,58]

Application	Removal
Ensure that the area is clean and dry.	Loosen the edges of the adhesive product. If there is no folded edge/tab already in place, a small piece of tape may be affixed to an edge of the product to form a tab to facilitate removal.
Clip hair if necessary.	With the fingers of the opposite hand, push the skin down and away from the adhesive.
Apply an alcohol-free skin barrier film to protect at-risk skin.	Remove the adhesive product low and slow back over itself in the direction of hair growth, keeping it horizontal and close to the skin surface.
Allow all preps to dry thoroughly before applying the adhesive product.	As the product is removed, continue moving fingers of the opposite hand as necessary to support newly exposed skin.
Apply the adhesive product without tension, pulling, or stretching. If desired, an edge could be folded over to form a tab to facilitate removal.	Nonbordered transparent film dressings may also be removed by loosening a corner of the dressing and stretching it horizontally in the opposite direction of the wound (stretch and relax technique). Walk fingers under dressing to continue stretching it. One hand continuously supports the skin adhered to the film dressing. The process can be repeated around the dressing.
Smooth the adhesive product into place with firm gentle pressure, avoiding gaps and wrinkles.	Tape strips may be removed by slowly removing each side toward the wound. When both sides are completely loosened, lift the strip up from the center of the wound.
Use gentle, stretchable adhesive products if edema/movement is anticipated, considering the direction of the stretch when securing the product.	Use medical adhesive remover if needed to loosen the adhesive bond. Consider using lotion, petrolatum, or mineral oil if not reapplying an adhesive product to the same area.
If compression is needed, stretch the adhesive over the dressing only and press remaining tape onto skin without tension.	

The clinician must remember that it is the combination of the adhesive and the backing that give the adhesive product its overall characteristics.

Silicone adhesives represent a newer type of medical adhesive, and limited evidence suggests that these products are gentler than other types of adhesives and associated with lower risk of skin injury due to their physical properties.[1,15,46,47,49] Silicone adhesives have lower surface tension than traditional adhesives, which allows them to conform to the skin's natural contours and to rapidly create a secure bond.[48] In contrast to conventional adhesives, which gradually increase contact with the skin surface and therefore increase adhesion over time, silicone adhesives contact the entire skin surface quickly and the adhesion then remains constant over time. These properties result in less peel force (defined as the average amount of force required to remove an adhesive product from the skin), less propensity for epidermal cell stripping, and less discomfort upon removal. In addition, some silicone adhesive products can be repositioned if needed.

10. Consider the potential adverse consequences of insufficient adhesion and/or adhesive failure, when selecting medical adhesive products for use in securing a critical device.

Critical devices include those for which there is a risk of significant clinical impact to a patient if the device is dislodged or does not perform as expected. Examples include vascular access devices, endotracheal tubes, nasogastric feeding tubes, and indwelling urinary catheters. Proper securement of critical devices is paramount to patient safety. For example, inadequately secured vascular access devices increase the risk of phlebitis, infection, and catheter migration or displacement.[49] Displacement of a small-bore nasogastric feeding tube can have dire consequences; for example, aspiration of a substance because a tube has moved out of position.[50] As such, the more critical the device, the greater the need for use of a higheradhesion product and/or a stronger backing. Higheradhesion products and/or stronger backings are usually necessary for securing items such as heavy tubing and immobilization splinting.

11. Exercise caution when using silicone adhesives to secure some devices as this may result in suboptimal adherence or adhesion failure.

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Silicone adhesives adhere poorly to other silicone products, and research into medical silicone technology has not produced a silicone adhesive formulation that adheres well to plastics.[51] While silicone adhesives are commonly used for wound dressings and in securement of lightweight tubes and devices, products such as silicone adhesive tapes have not been evaluated for use as primary securement of critical tubing. For this reason, caution should be exercised when using silicone adhesives to secure critical tubes and devices and frequent monitoring is essential to ensure that proper securement is maintained.

Selection and Application

12. Anticipate changes in skin and/or joint movement following injury and operative or other procedures when selecting and applying medical adhesive products.

Tension injuries or blisters represent a separation of the epidermis from the dermis, which is more likely to occur when the skin is stretched underneath an unyielding tape or when a joint or other area of movement is covered with an unyielding tape.[31] As noted earlier, the incidence of tension injuries in the orthopedic surgery setting can be high. For example, in the case of hip surgery, tension forces can develop beneath the posterior dressing when the skin moves as a result of flexion of the hip.[33] However, skin movement can normally be expected in any area of the body affected by joint articulation or tissue expansion or movement. In addition, skin movement may occur in other areas of the body due to edema resulting from inflammation, injury, or operative and other procedures. To minimize the risk of tension injuries in these situations, an adhesive product that stretches should be applied so that the direction of stretch corresponds with the direction of movement.

13. Anticipate skin movement with edema when selecting and applying medical adhesive products.

Potential skin movement should also be considered in cases of edema that occur unrelated to inflammation, injury, or operative and other procedures. Edema can occur in a wide range of medical conditions, including allergic reactions, cirrhosis, congestive heart failure, deep vein thrombosis, hypoalbuminemia, chronic kidney disease, burns, sepsis, and fluid overload, such as might be seen in critical care settings.

Application

14. Consider the role of skin tension (Langer's lines) and the effects of medical adhesive products when applied with the lines or against/across these lines.

Langer's lines, also known as tension or cleavage lines, correspond to the alignment of collagen fibers within the dermis and the direction in which the skin is under the highest tension and has the least extensibility.[52] Surgical incisions, and especially cosmetic procedures, are made parallel to the direction of Langer's lines because this approach is associated with better healing and less scarring. Skin movement is more likely across Langer's lines, where the skin tension is lower; if it is necessary to apply adhesive products across these lines, it would be beneficial to use products that stretch. In contrast, reduced skin movement and potentially fewer tension injuries are anticipated if a rigid adhesive product is applied parallel to Langer's lines. Nevertheless, evidence supporting clinical applications of these principles is lacking and additional research is needed to more clearly define application of adhesive devices along or in parallel to the direction of Langer's lines.

15. Consider application of a skin barrier prior to applying an adhesive product.

Skin barrier products provide a protective interface between the skin and adhesives and are recommended to reduce the risk of MARSI and to protect the skin from body fluids, exudates, urine, and stool.[4,5] Most commonly available as liquid barrier films (foams, wipes, or sprays), they may be composed of silicones, acrylates, organic polymers, or inorganic compounds dispersed in a solvent. Following application of a liquid barrier film, the solvent evaporates, forming a transparent, breathable, protective coating. Some barrier films also include an added component (plasticizer) that allows flexibility in the applied product. Pectin-based products are also available.

Clinical studies have demonstrated the ability of barrier films to reduce erythema and skin stripping following medical adhesive removal in various patient populations, including neonates,[53–55] as well as their ability to protect periwound skin.[56] For these reasons, the use of barrier products prior to adhesive product application should be considered, particularly in patients at high risk for skin injury. Use of barrier products in neonates and in the periwound and ostomy setting is particularly important, given the propensity for compromised skin integrity.

However, current neonatal skin care guidelines recommend avoidance of alcohol because of its drying effects.[7,12] Due to the neonate's high body surface-toweight ratio, deficient stratum corneum, and certain skin immaturity factors, the guidelines also recommend avoidance of solvents containing hydrocarbon derivatives or petroleum distillates due to risk of toxicity. These guidelines also recommend that barrier products be limited to use of pectin or hydrocolloid barriers, or barrier films, such as an alcohol-free skin protectant, which is recommended for use in infants over 30 days of age. In clinical practice, pectin and hydrocolloid

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barriers are used more often in neonates as a platform for adhesives because they allow better molding and attachment. However, limited evidence suggests that skin injury can occur with the use of these products.[37] As a result, silicone based skin barrier films are often used off label in neonates regardless of age. Use of these barrier films has been described in neonates[54] and premature infants,[57] but further research is needed.

16. Limit or avoid substances, such as compound tincture of benzoin, which increase the stickiness of adhesives.

Substances that increase the stickiness of adhesives, sometimes referred to as tackifiers or bonding agents, may be used to increase the cohesive strength of an adhesive, particularly when it is subject to stress. They increase the flow and spread of an adhesive on the surface of the skin, thus increasing immediate adhesion. Such agents are usually low-molecular-weight materials that are derived from natural products, such as rosin (eg, tincture of benzoin) or citrus peels, or from petroleum-based compounds. However, the enhanced adherence provided by such substances may lead to skin injury with adhesive removal and should be avoided, particularly in neonates.[7,12] Panel members concurred that the use of these agents should be limited to selected adult patients when enhanced adhesive adherence is needed.

Application and Removal

17. Use proper application and removal techniques for adhesive-containing products.

Proper application and removal of adhesive-containing products are critical to minimizing skin damage. Recommended procedures for applying and removing adhesive-containing products are summarized in Table 3. It is important that adhesive-containing products not be applied under tension (strapping), as this can lead to tension injuries.[45,58] In addition, rapid, vertical pulling has been shown to generate a higher peel force than slow removal while keeping the adhesive product horizontal and folded onto itself.[59]

18. Consider use of medical adhesive removers to minimize discomfort and skin damage associated with removal of adhesive products.

Removing medical adhesive products can strip layers of the stratum corneum, causing skin injury and pain to the patient. Medical adhesive removers are used in clinical practice to aid in removal of adhesive products and to remove adhesive and barrier film residues. The 3 main types of medical adhesive removers are alcohol or organic solvent-based, oil-based, or silicone-based. They may be formulated as wipes, pads, or sprays. Of these, the silicone-based removers are the newest, often being promoted as being "no-sting" because they do not contain alcohol.

Medical adhesive removers have not been studied in neonates. Current neonatal skin care guidelines recommend avoidance of alcohol and organic solvent-based medical adhesive removers and recommend slow and careful removal using water-soaked cotton balls to continuously wet the adhesive-skin interface.[7] Alternatively, mineral oil or petrolatum can be used to loosen tape in cases where retaping is not necessary.

Prevention–Electrodes

19. To prevent electrochemical burns under adhesive electrodes, powered (battery and line voltage) equipment should be maintained and monitored for dangerous leakage currents.

Electrical components and devices are encased in nonconducting insulation to ensure that the electric current is contained within the unit and follows the intended pathway through the device's electrical circuit. If this insulation deteriorates or is damaged, current will leak through the insulation and flow to the ground. These leakage currents can cause electrochemical burns under adhesive electrodes, as the electrode connection and/or the adhesive itself are electrically conductive. Direct current leakage currents, such as from batteries, are particularly dangerous.

Normally, leakage currents are felt by the patient as a shocking or tingling sensation near an applied electrode. However, electrochemical injuries have been reported in anesthetized patients connected to battery-operated medical devices as a result of leakage currents.[60] Typically, these injuries can be differentiated from other electrical injuries such as burns due to allergic or chemical reactions or thermal burns, due to the fact that they appear different on the anode, where the reaction is acidic versus the cathode, where the reaction is alkaline.[60,61]

All types of powered equipment should be properly maintained and monitored to measure leakage currents to verify that they are electrically safe.[61] Each piece of equipment should be examined prior to use to ensure that it has been recently inspected and tested, that insulation and connectors are clean and intact, and if battery operated, that any batteries are secure and covered.

Infection Prevention

20. Adhesives may promote overgrowth of microorganisms. Monitor sites exposed to adhesive materials for manifestations of infection.

Several researchers have documented increased bacterial growth beneath occlusive tapes.[62,63] Adhesives may also promote overgrowth of yeasts and saprophytic fungi.[64,65] Therefore, any site exposed to adhesive materials should

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be monitored for evidence of localized or systemic infection. Signs and symptoms of localized bacterial infection include increased pain, edema, erythema, warmth, or suppuration (eg, presence of pustules, folliculitis, or furunculosis). Signs and symptoms of localized fungal infection include, but are not limited to, an erythematous maculopapular rash with satellite papular or pustular lesions.

As with any skin injury, those that result from the use of adhesive-containing products may lead to localized or systemic infections, particularly in vulnerable populations.[1,12,18] These include patients with factors or comorbid conditions that compromise immune function, such as diabetes, renal failure, malignancy, solid organ transplantation, or a history of or current use of immunosuppressive drugs; surgical patients; as well as the elderly, neonates, and premature infants.

21. Store and use adhesive-containing products in a manner that prevents contamination.

Medical adhesive products have been documented in the literature as potential reservoirs of pathogenic microorganisms as early as 1974.[66–70] For example, one study demonstrated that 59 of 80 tape specimens (74%) collected at various clinical areas in one hospital were found to be colonized by pathogenic bacteria.[65] More recently, Harris and colleagues[70] documented that 11 of 21 samples (52%) of partially used surgical adhesive tapes collected from several clinical areas of three hospitals in Australia were contaminated with multiresistant organisms (methicillin-resistant *Staphylococcus aureus* and/or vancomycin-resistant enterococci).[70]

These reports represent case studies or investigations with small sample sizes where only rates of colonization were determined. However, as medical adhesive products are used to affix items that come into contact with blood, normally sterile tissue, or mucous membranes, there is the potential for infection with use of products that are not packaged as single use, particularly many tape products, as well as certain barrier products, ostomy supplies, and other medical adhesive devices. For example, pectin-based adhesive skin barrier sheets were implicated in a 5-year outbreak of *S aureus* in a neonatal unit in the United Kingdom.[71] In addition, outbreaks of cutaneous *Rhizopus* infection have been reported with the use of adhesive products such as polyethylene tape,[72] ostomy pouches,[73] and elasticized adhesive dressings used over surgical wounds.[67,68] Cases of cutaneous mucormycosis associated with the use of temperature probes and monitoring electrodes in neonates have also been reported.[74,75]

As such, any medical adhesive product that is not packaged as single use should be stored and used in a manner that prevents contamination. Boxes containing multiple items should remain closed and ideally, individual items brought to the patient's bedside as needed. Clean items should be separated from those that are frequently touched and/or have already been used (eg, adhesive tape rolls). Items such as adhesive tape rolls should not be left on contaminated surfaces or carried around in pockets or on stethoscopes, and strips of tape should not be placed on bedrails, tables, or other potentially contaminated surfaces prior to application on the patient.

22. Single-patient-use adhesive products are preferred.

Federal and Centers for Disease Control guidelines suggest that, to help prevent cross-contamination, nondisposable patient items that cannot be cleaned and disinfected between patients, such as adhesive tape, should be dedicated for use only on a single patient.[76,77] Because adhesive tape has the potential to act as a significant fomite, Harris and colleagues[70] recommend that short rolls of medical adhesive tape be supplied in sealed packets for individual patient use. Many adhesive products, such as dressings, are already packaged as single-use items and manufacturers now offer adhesive tape in single-patient-use rolls for the reasons cited previously.[78] Therefore, single-patient-use adhesive products should be used whenever possible.

Treatment

23. Apply evidence-based wound care principles when treating medical adhesive–related skin injuries.
24. Consult an appropriate skin or wound care specialist if a medical adhesive–related skin injury does not respond to conservative management within 7 days or if the wound deteriorates despite conservative care.

The same general principles used to manage other acute wounds should be employed when treating adhesive related skin injuries (refer to the National Guidelines Clearinghouse, http://www.guidelines.gov, for examples of wound care guidelines). Specific guidance regarding the management of skin tears has recently been published.[20]

After an initial assessment to determine the severity of the adhesive-related injury, the wound should be cleansed with a noncytotoxic solution to remove adhesive residue, bacteria, and cellular debris. Afterward, a therapy that supports moist wound healing should be applied. Irritant contact dermatitis can be managed with use of lipid-rich moisturizers to improve the damaged skin barrier and use of cool compresses for acute inflammation. Although topical steroids are often used initially to control inflammation in this form of dermatitis, there is some evidence that they may compromise barrier function and some recommend steroids be avoided.[43] Cool compresses and low- to mid-potency topical steroids (eg, hydrocortisone butyrate, desonide, or triamcinolone) can be used to reduce the inflammation seen with allergic contact dermatitis. Folliculitis should be treated with proper skin hygiene

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and topical and/or oral antibiotics as needed. If an MARSI does not respond to conservative management within 7 days or if the wound deteriorates despite conservative care, an appropriate skin or wound care specialist should be consulted.

Future Research

25. Further research is needed to expand the scientific knowledge of adhesive performance and use, including mechanisms of medical adhesive–related skin injury, prediction, prevention, assessment and documentation, and treatment.

Consensus panel members identified a number of areas where further research is needed to expand the scientific knowledge of adhesive performance and use (Table 5).

CONCLUSIONS AND RECOMMENDATIONS FOR PRACTICE

Panel members were in agreement that MARSI is far reaching and affects patients of all ages across all settings of care. The care of the skin, including its protection against MARSI, is a basic requirement for patient care. Healthcare providers should strive to prevent and reduce the incidence of MARSI but first must be made aware of the problem and its causes. They, as well as patients and caregivers, need to be provided with the knowledge and tools necessary for preventing and managing adhesive-related injury. Best practice guidelines are needed to assist those who use medical adhesives in using them appropriately, identifying patients at risk for skin injury, and implementing prevention and management strategies. A glossary of terms used in this document can be found in Supplemental Digital Content 2, http://links.lww.com/JWOCN/A19.

KEY POINTS

- **Expert opinion suggests that appropriate selection of adhesive products and the use of proper application and removal techniques can help minimize MARSI.**
- **Expert opinion recommends considering the role of skin tension and anticipating skin and/or joint movement when selecting and applying medical adhesive products.**
- **Expert opinion recommends that adhesive-containing products be stored and used in a manner that prevents contamination, and that single-patient-use products be used whenever possible.**

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TABLE 5. Recommended Areas for Further Research

Mechanisms of MARSI	Although much physiologic data regarding wounds and wound healing exists in the literature, there is less adhesive-specific research in this area, particularly how the various components of adhesive products interact to cause injury, as well as specific adhesive measurements, such as surface energy, viscosity, and skin adherence.
Prediction	Further clarification of adhesive-specific risk factors for skin injury is needed.
Prevention	There is a need to study potentially beneficial products (eg, skin protectants and silicone adhesive removers) in neonates and premature infants, as there are limited data of use of these products in this patient population.
Assessment and documentation	Tools for clinical assessment and documentation of MARSI are lacking. Currently, the relative degree of MARSI can be estimated only by in vivo, side-by-side comparisons of objective and subjective measurements under identical experimental conditions. Objective measurements include TEWL, the number of cells or amount of protein removed, cutaneous confocal microscopy, and colorimetric measurement of erythema.[13,37] Subjective measurements, which are typically used in the clinical setting, include overall skin appearance (ie, presence of vesicles or bullae) and degree of erythema or dryness following repeated adhesive applications.
Treatment	Identification of best practices to facilitate healing of MARSI is needed.

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