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Management of Central Venous Access Device–Associated Skin Impairment

An Evidence-Based Algorithm

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ABSTRACT

Patients relying on central venous access devices (CVADs) for treatment are frequently complex. Many have multiple comorbid conditions, including renal impairment, nutritional deficiencies, hematologic disorders, or cancer. These conditions can impair the skin surrounding the CVAD insertion site, resulting in an increased likelihood of skin damage when standard CVAD management practices are employed. Supported by the World Congress of Vascular Access (WoCoVA), developed an evidence- and consensus-based algorithm to improve CVAD-associated skin impairment (CASI) identification and diagnosis, guide clinical decision-making, and improve clinician confidence in managing CASI. A scoping review of relevant literature surrounding CASI management was undertaken March 2014, and results were distributed to an international advisory panel. A CASI algorithm was developed by an international advisory panel of clinicians with expertise in wounds, vascular access, pediatrics, geriatric care, home care, intensive care, infection control and acute care, using a 2-phase, modified Delphi technique. The algorithm focuses on identification and treatment of skin injury, exit site infection, noninfectious exudate, and skin irritation/contact dermatitis. It comprised 3 domains: assessment, skin protection, and patient comfort. External validation of the algorithm was achieved by prospective pre- and posttest design, using clinical scenarios and self-reported clinician confidence (Likert scale), and incorporating algorithm feasibility and face validity endpoints. The CASI algorithm was found to significantly increase participants' confidence in the assessment and management of skin injury ($P = .002$), skin irritation/contact dermatitis ($P = .001$), and noninfectious exudate ($P < .01$). A majority of participants reported the algorithm as easy to understand (24/25; 96%), containing all necessary information (24/25; 96%). Twenty-four of 25 (96%) stated that they would recommend the tool to guide management of CASI.

KEY WORDS: Algorithm, Central venous access device (CVAD), Central venous catheterization, CVAD-associated skin impairment (CASI), Medical adhesive–related skin injury, Moisture-associated skin damage.

INTRODUCTION

Central venous access devices (CVADs) are used to deliver a wide range of therapies from lifelong administration of parenteral nutrition to the acute infusion of vesicant inotropic support for the

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DOI: 10.1097/WON.0000000000000322

critically ill, and the prolonged delivery of anticancer therapies.¹ Patients requiring these treatments are frequently very old, very young or have chronic health conditions.²

The insertion of a CVAD requires the passage of a catheter through the epidermis and stratum corneum, creating a surgical wound that persists for as long as the CVAD is in situ. A CVAD is typically inserted in a sterile percutaneous manner through the skin of the upper chest or upper arm by a specially trained physician or nurse. Once in the vein, the catheter is advanced to the superior vena cava or right atrium.³ The catheter is secured to the skin via suture, or manufactured securement device, with a transparent dressing.⁴ The break in the skin caused by a CVAD provides an entry route for bacteria, increasing the patient's risk for local, systemic, and bloodstream infection.² To minimize CVAD-associated infections, evidence-based management strategies have been developed by international organizations such as the Centers for Disease Control and Prevention.⁵ Strategies include the continued application and removal of medical-grade adhesives (eg, dressing products) and decontamination with solvents and detergents (eg, alcohol and chlorhexidine gluconate [CHG]), using a friction-based technique.² While these strategies reduce the risk of infections, following these recommendations exposes the CVAD site to ongoing irritation and trauma.

Potential risk factors for CVAD skin damage include the patient's age, number and type of comorbid conditions, and irritation of the CVAD site during maintenance procedures.² Local site infections, moisture-associated skin damage, contact dermatitis, and medical adhesive-related skin injuries (MARSIs) related to CVAD sites are frequently reported in the literature^{2,4,6-9}; however, evidence concerning prevalence rates is sparse. Farris and colleagues¹⁰ reported findings from a single site prospective study. They found that the prevalence of all-cause MARSIs was 3.4% to 25.0% of acute care (nonintensive) patients; the highest occurrence rates were patients aged 65 to 74 years who had a mean prevalence of 20.9%. Medical adhesive-related skin injuries are a significant, and potentially avoidable, burden on the healthcare system.

Broadhurst and colleagues¹¹ completed a cross-sectional descriptive study survey of vascular access clinicians to explore current practice patterns associated with CVAD site care across 34 countries. Findings revealed inconsistencies in CVAD site care practices across the domains of skin antisepsis, dressing selection, frequency of dressing change, and device securement practices. Respondents indicated that these inconsistencies were most common in CVAD sites with impaired skin integrity, such as inflamed or infected skin.¹¹ Almost 90% of respondents reported having no policy or algorithm to guide care of compromised CVAD sites within their organizations.

To rectify the obvious gap in literature regarding the management of CVAD-associated skin impairment (CASI), an international team of researchers and clinicians initiated a multiphase project, sponsored by the World Congress of Vascular Access (WoCoVA). The aims of this phase of the project were to develop an evidence- and consensus-based algorithm designed to (1) improve identification and diagnosis of impaired skin around CVAD sites; (2) guide decision making to best management of these sites; and (3) improve clinician confidence in when caring for patients with skin damage at a CVAD site.

METHODS

Development and validation of the algorithm were divided into several stages. A scoping review of the literature was undertaken to map the existing research and highlight gaps.¹² The search was carried out using the MEDLINE, EMBASE, and CINAHL electronic databases. A search strategy was developed with the assistance of a health librarian and included the following MeSH and other key words: "central venous catheters," "central venous access devices," "skin injury," "contact dermatitis," "exit site infection," "skin tears," "skin blisters," "skin injury," and "skin impairment." Articles that described (1) care of CVAD and (2) diagnosis or management of skin impairment were eligible for inclusion. The management of infiltration, extravasation, thrombophlebitis, CVAD-associated bloodstream infections, and skin conditions such as eczema and impetigo were excluded from the review. Additionally, studies carried out on nonhuman subjects and those published in a language other than English were excluded. Priority was given to clinical practice guidelines that had previously summarized and critiqued the level of evidence to support clinical decision making in the areas of CVAD and skin impairment management. Eligible articles were then retrieved and provided to each of the panel members prior to the consensus group meeting.

The advisory group comprised 16 clinicians and academicians from North America, Europe, and Australia with special-

ties in wounds, vascular access, pediatrics, geriatric care, home care, intensive care, infection control, and acute care. Criterion sampling was used to select experts based upon: publication history, professional, policy and program leadership in the field; actively working in the field of vascular access therapy; certification in relevant professional organizations; and international geographic representation. Three wound care and vascular access experts (employees of 3M; St Paul, Minnesota) were invited to provide technical advice but were not given voting rights on the panel.

The group met in May 2014 in St Paul to review and critique the current literature supporting CVAD wound care practices and made recommendations regarding the algorithm scope (ie, skin conditions to be addressed), diagnostic criteria, and wound management strategies. After discussion and critique of the available literature were completed, the algorithm components were developed using a 2-phase, modified Delphi technique.^{13,14} During Phase 1, panel members completed open text surveys of specific algorithm components (scope, diagnostic criteria, wound management strategies). The results of these surveys were then debated by the panel; this discussion was facilitated by independent study authors (D.B., N.M.). Decisions regarding entry points, assessment tasks, and decision nodes concerning CASI management were constructed collaboratively, and at completion of the discussion, a draft algorithm was completed. After the panel meeting, the study authors (D.B., N.M.) transferred the draft algorithm to electronic template, and distributed it to the panel electronically for phase 2 consensus and feedback. Within phase 2 feedback, panel members were asked to indicate their opinion whether the CASI algorithm adequately fulfills the required scope, diagnostic criteria, and wound management necessary to guide CASI clinical practice, as discussed in the panel meeting, and if not, what further changes were necessary to meet these conditions.

Establishing External Validity

External validity of the algorithm was evaluated using a pre- and posttest design that incorporated feasibility and face validity endpoints.¹⁵ Four fictitious, but realistic case studies of patients with impaired skin at CVAD sites were developed by the authors using criteria evident in previous research that place patients at high risk for CASI.^{2,7,10} The case studies involved the description of CVAD sites with an exit site infection, skin injury, skin irritation/contact dermatitis, or noninfectious exudate; clinical information and photographs were provided for each fictitious case.^{2,4,7} All 4 of these scenarios were then provided to clinicians across the United States, Canada, Australia, and New Zealand, within vascular access conferences (Canadian Vascular Access Association, Association for Vascular Access, WoCoVA) and local clinical networks, to provide a balanced geographic diversity. Clinicians targeted for participation possessed variable levels of experience in maintaining vascular access across home, acute and critical care, and pediatric and adult settings. Clinicians were asked to diagnose and describe their planned management for each case study, with open-ended questions in a written survey format. The clinicians' confidence in making a diagnosis and formulating recommendations for management of each case was measured using a 5-point Likert scale (very confident/confident/somewhat confident/somewhat not confident/not at all confident).

Clinicians were then provided the CASI algorithm, along with a standardized education session. Face-to-face educational sessions between the study authors and clinicians lasted

around 5 to 7 minutes. It comprised a step-by-step explanation of components of the CASI algorithm, including its general design and overall content. The clinicians then repeated the clinical scenarios and, including the written surveys regarding diagnosis and management, provided additional written feedback regarding the algorithm’s usefulness, clarity, and overall impressions.

Data Analysis

Panel consensus for the CASI algorithm was established in the second step of the Delphi process; agreement among more than 85% of surveyed panel members indicated approval of the algorithm. Data related to external validation evaluation were entered and analyzed using Predictive Analytics Software Statistics Version 22.0 (SPSS Inc, Chicago, Illinois). Descriptive statistics were used to describe the validation results, including frequency, percentages, means, and standard deviations. A 2-tailed, paired-samples, *t* test was used to compare mean clinician confidence pre- and postalgorithm.¹⁶ A *p* value <.05 was deemed statistically significant. All missing data are presented within the relevant results tables.

OUTCOMES

Results of the scoping literature review are presented in a PRISMA flow chart (Figure 1). Of the 1122 articles originally identified during searches, 17 were provided to the advisory

group prior to the meeting; these publications included 10 clinical practice guidelines,^{5,7,9,17-23} 2 randomized controlled trials,^{24,25} 2 prospective cohort studies,^{26,27} and 3 peer-reviewed expert opinion articles^{2,8,28} (Table 1). After prolonged discussion and debate facilitated by the modified Delphi technique, including phase 2 draft algorithm review, the final algorithm received 93.7% approval and overall endorsement by the panel.

Building upon the MARS definition,⁷ the researchers developed the following definition for CASI: “CVAD-associated skin impairment (CASI) is an occurrence of drainage, erythema, and/or other manifestation of cutaneous abnormality, including but not limited to vesicle, bulla, erosion or tear, at a CVAD site in the underlying area of a dressing, which persists 30 minutes or more after removal of the dressing.”

CASI Algorithm

To support the assessment, management, and prevention of CASI, the advisory group developed the CASI Algorithm, displayed in Figure 2. Consensus determined the 4 most commonly seen skin impairment conditions associated with CVADs to be addressed in the algorithm: (1) exit-site infection; (2) skin injury (including skin stripping, skin tears, and tension blisters); (3) skin irritation (irritant or allergic contact dermatitis); and (4) weeping/oozing (noninfectious drainage). The algorithm is not intended to address cutaneous conditions such as eczema and impetigo that are not directly related

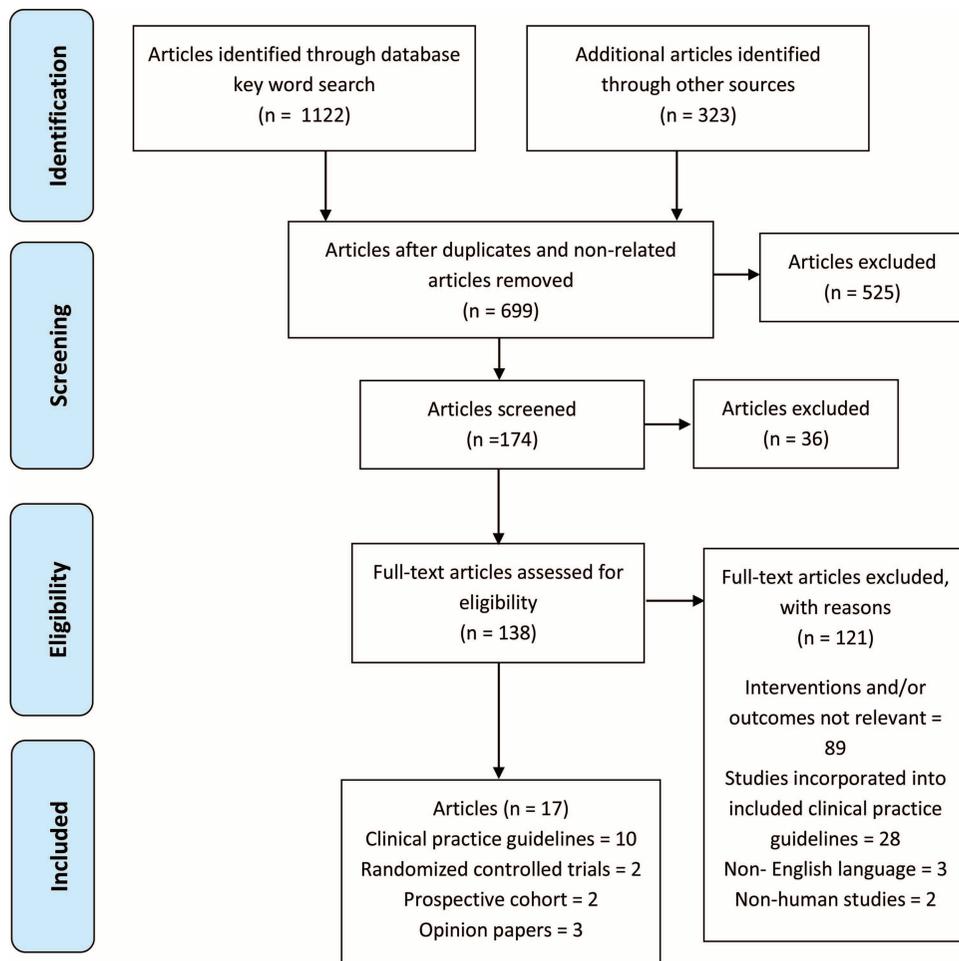


Figure 1. PRISMA flow diagram.

TABLE 1.
Summary of Literature Review Articles

Author (Year)	Country, Organization	Design	Scope of Article
Bourke et al (2009) ¹⁷	United Kingdom, British Association of Dermatologists	Clinical practice guideline	Identification and management of contact dermatitis
Brandt et al (1996) ²⁵	United States, NA	Randomized controlled trial	Comparison of dressing types for hematology, oncology patients requiring bone marrow transplantation
Haffejee et al (1991) ²⁶	Durban, NA	Prospective cohort	Comparison of hydrocolloid dressings for CVADs used for parenteral nutrition
Infusion Nurses Society (2011) ¹⁹	United States, Infusion Nurses Society	Clinical practice guideline	Standards of practice for infusion nurses
Kramer et al (2011) ²⁰	United States, NA	Clinical practice guideline	Management of CVADs for patients in the home care setting
Kutzscher (2012) ⁸	United States, NA	Expert opinion	Management of irritant dermatitis for patients with peripherally inserted central catheters
LeBlanc and Baranoski (2011) ⁹	United States, NA	Clinical practice guideline	Identification and management of patients at risk for skin tears
McNichol et al (2013) ⁷	United States, NA	Clinical practice guideline	Assessment, prevention, and management of adhesive-related skin injuries
Mermel et al (2009) ¹⁸	United States, Infectious Diseases Society of America	Clinical practice guideline	Diagnosis and management of intravascular catheter-related infections
Nikoletti et al (1999) ²⁴	Australia, NA	Randomized controlled trial	Comparison of dressing types for patients in intensive care settings with multilumen, percutaneous CVAD
O'Grady et al (2011) ⁵	United States, Centers for Disease Control and Prevention (CDC)	Clinical practice guideline	Prevention of intravascular catheter-related infections
Pittiruti et al (2009) ²²	Europe, European Society for Clinical Nutrition and Metabolism (ESPEN)	Clinical practice guideline	Insertion, management, and diagnosis of complications associated with CVADs used for parenteral nutrition
Royal College of Nursing (2010) ²¹	United Kingdom, Royal College of Nursing	Clinical practice guideline	Standards of practice for infusion therapy
Thayer (2012) ²	United States, NA	Expert opinion	Skin damage associated with vascular access devices
Waterhouse and Winterbottom (2010) ²⁷	United Kingdom, NA	Prospective cohort	Identification of CVAD site infections across ethnic groups
Wittich (2001) ²⁸	United Kingdom, NA	Expert opinion	Management of exit sites for patients with hemocatheters undergoing dialysis
World Union of Wound Healing Societies (2008) ²³	International, World Union of Wound Healing Societies	Clinical practice guideline	Identification and management of wound infections

Abbreviations: CVAD, central venous access device; NA, not applicable.

to CVADs. It is not intended to address conditions that require more complex interventions such as tunnel and port infections, extravasation, or thrombophlebitis. The algorithm was designed to provide guidance to healthcare professionals who provide either direct CVAD care (ie, generalist and vascular access nurses) or those consulted to manage CASI (ie, wound care specialists, physicians, and physician assistants).

To guide the clinician in determining the appropriate management of CASI, the interventions are described in 3 sequential domains: assessment, skin protection, comfort. Upon entering the algorithm, the clinician first performs an assessment of the patient to identify the type of skin impairment, moving then to the selection of the appropriate skin protection interventions (including skin antisepsis, barrier film and dressing) from both a management and preventative perspective, and employing comfort measures.

ASSESSMENT DOMAIN

The algorithm first guides the clinician to assess the patient and CVAD site to identify the type and cause of skin damage. Table 2 describes the signs and symptoms of CASI skin conditions included within the CASI algorithm.

Recommendations

In order to determine skin health at the CVAD site, the clinician should inspect the skin for color, texture, uniformity of appearance, and integrity.⁷ The clinician must also assess the severity of any skin damage. Lesions should be described based on: (1) color (eg, pink, red, purple, tan, white) and shape; (2) type (papule, vesicle, pustule); (3) arrangement (eg, linear, ring-like); (4) size and depth (eg, superficial, partial thickness, or full thickness); and (5) distribution or extent of skin disruption (eg, confined to dressing surface area or found on other body sites).^{2,7} In patients with deeply pigmented

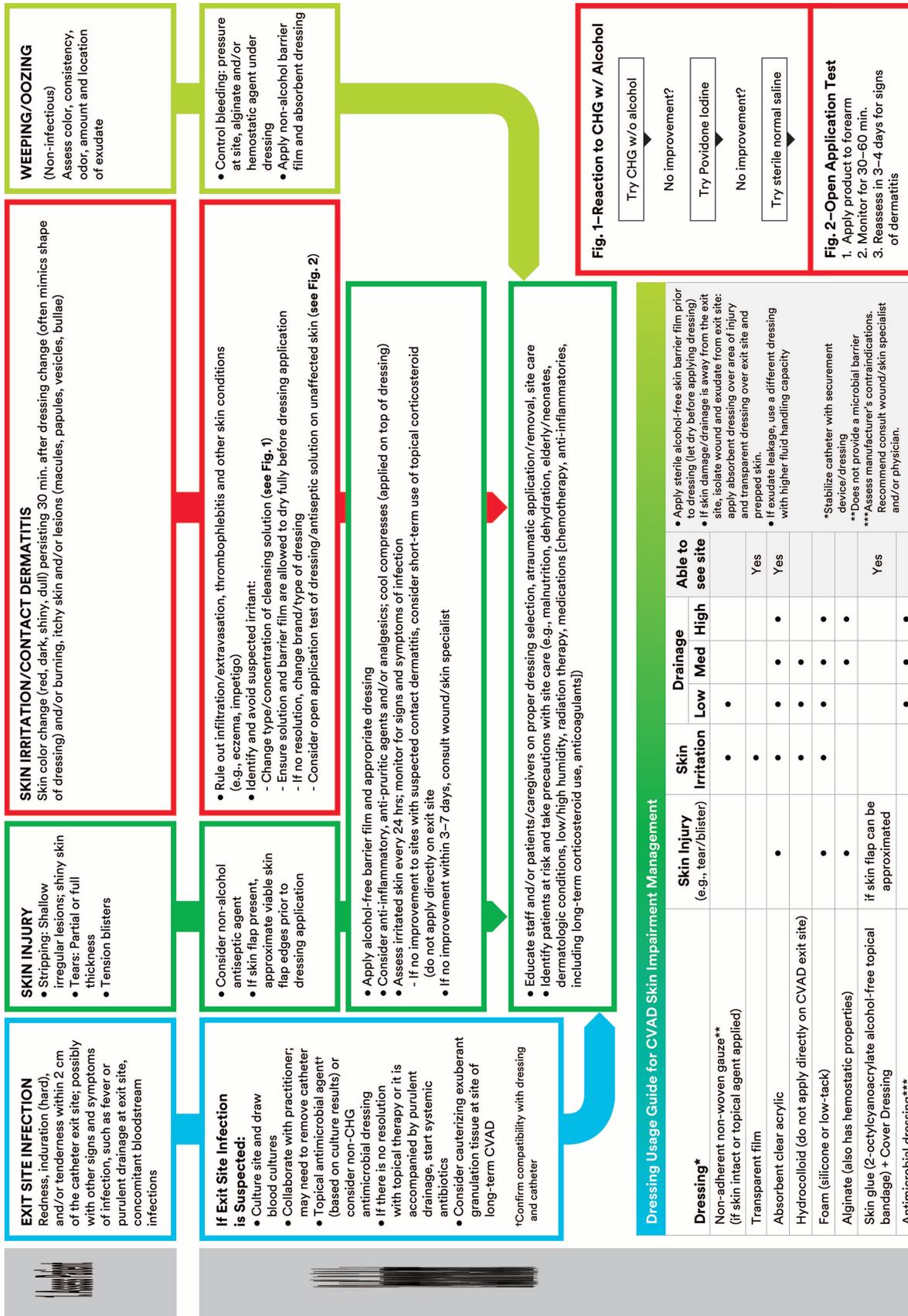


Figure 2. CVAD-associated skin impairment (CASI) algorithm.

TABLE 2.**Types of CVAD-Associated Skin Impairment^a**

Complication Definition	Clinical Example
<p>Exit-site infection Characterized by redness, hardness, and/or tenderness within 2 cm of catheter exit site; possible with other signs and symptoms of infection, such as fever or purulent drainage at exit site. Concomitant bloodstream infections may be present. Diagnosis should be confirmed via swab culture.</p>	 <p data-bbox="1104 464 1277 493">Early exit site infection</p>
<p>Skin injury <i>Skin stripping:</i> Removal of 1 or more layers of the skin occurring following traumatic removal of adhesive tape or dressing. Lesions are frequently shallow and irregular in shape; skin may appear shiny or moist dark pin or red with significant discomfort if exposure to nerve endings. May have open lesions with erythema and blisters. <i>Skin tear:</i> Wound caused by shear, friction, and/or blunt force resulting in separation of skin layers (often related to traumatic dressing removal); can be partial or full thickness. <i>Tension blister:</i> Wound (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.</p>	 <p data-bbox="1000 729 1311 754">Skin tear © 3M 2016. All rights reserved.</p>
<p>Skin Irritation <i>Irritant contact dermatitis:</i> Nonallergic reaction to chemical irritant; well-defined affected area correlates with the area of exposure; may be reddened and swollen and vesicles present; typically of shorter duration. <i>Allergic contact dermatitis:</i> Cell-mediated immunologic response to a component of a product; typically area of erythematous, vesicular, pruritic dermatitis corresponding to area of exposure and/or beyond, which may persist for up to a week. Irritant/allergen may be a component of the antiseptic solution, skin barrier solution, or dressing.</p>	 <p data-bbox="1118 1040 1259 1069">Allergic dermatitis</p>
<p>Weeping/oozing (noninfectious) Drainage at the CVAD exit site. <i>Clear amber:</i> Often considered normal (but may be associated with infection or lymph node nicked during insertion). <i>Pink or red:</i> Due to the presence of red blood cells; often related to trauma of CVAD insertion, particularly in neutropenic patients. <i>Cloudy, milky:</i> May indicate fibrin strands (a response to inflammation) or infection (purulent exudates containing white blood cells and bacteria).</p>	 <p data-bbox="1069 1292 1311 1319">Hemerosus ooze postoperative</p>

Abbreviation: CVAD, central venous access device.

^aData adapted from Thayer,² McNichol et al,⁷ Mermel et al,¹⁸ and World Union of Wound Healing Societies.²³

skin, mild erythema may not be apparent and lesion color may vary from that seen in persons with lighter skin tones.⁷

When assessing any exudate at the site, the clinician should note (1) color (eg, clear, amber, cloudy, pink or red, green, yellow or brown); (2) consistency (eg, high viscosity—thick sometimes sticky or low thin, “runny”); (3) odor of the exudate (eg, unpleasant); (4) dressing leakage/strikethrough²³; and (5) noninfectious exudate. Noninfectious exudate is a common problem in the immediate post-CVAD insertion period due to bleeding related to the venipuncture; it may persist over prolonged period in patients with coagulopathies.²⁹ Panelists supported the Infectious Diseases Society of America’s recommendation to swab sites and process microscopy culture sensitivities (MCSs) when catheter infection is suspected. Indications of a potential catheter infection are fever, chills, and/or hypotension with no other apparent source of infection and exudate at the site.¹⁸ The clinician should also assess the skin for the presence of a fungal infection, such as *Candida*, which may be

differentiated from dermatitis within the MCS,¹⁸ and for presence of whitish or raised red areas on the skin that are unresponsive to other treatment. Finally, the clinician should assess the patient’s history of known or suspected allergies or episodes of irritant contact dermatitis, the type of skin antiseptic agent, skin barrier, and previously used dressing products.⁷

PROTECTION DOMAIN

Upon identification of the skin condition to be treated, the reader enters the “Protect” domain of the algorithm. This domain comprises interventions to protect skin health through the promotion of skin regeneration and protection from further skin damage. Promotion of skin health is achieved through both treatment of the skin at the CVAD site and protecting the skin from further or repeated skin damage by avoiding subsequent exposure to identified or suspected factors contributing to the impaired skin integrity.

Recommendations

Chlorhexidine gluconate is the preferred antiseptic solution for CAVD sites.^{5,30} If contact dermatitis is suspected, the clinician should consider whether the reaction was caused by improper application of the antiseptic solution versus sensitivity to the product. It is crucial to allow an antiseptic solution to dry completely before covering the skin to prevent a reaction due to the interaction of the wet solution and the barrier film or adhesive agent.² If inappropriate antiseptic application is not suspected, consider changing the concentration (ie, replace CHG 2% in 70% alcohol, with 0.5% CHG in 70% alcohol or nonalcoholic CHG). When sensitivity to CHG is deemed likely (no resolution occurs despite a change in concentration of the CHG solution), consider an alternative antiseptic solution (eg, povidone-iodine). In extreme circumstances (ie, no improvement occurs despite a change of type of antiseptic solution), consideration may be given to the use of sterile normal saline, although this solution is not antiseptic.⁵ If this recommendation is followed, clinicians must recognize higher risk of infection and closely assess for signs of infection.

Adhesives in the CVAD dressing may sometimes be the cause of skin damage,^{7,10} and consideration should be given in changing the brand of dressing product. Alternatively, a nonadherent nonwoven gauze may reduce further skin damage caused by adhesives.^{4,5,31} The application of skin barrier solutions prior to applying a dressing was unanimously recommended by the advisory group and is supported by the 2016 Infusion Nurses Society *Infusion Therapy Standards of Practice*, to reduce the risk of CASI.³ Skin barrier products provide a protective interface between the skin and adhesives and have demonstrated the ability to reduce erythema and skin stripping following medical adhesive removal.^{2,3,7} However, further evidence is required to support their more generalized use.

Irritant or allergic CVAD management products may be identified by a modified open application patch test,³² particularly if the patient is unable to access dermatologic or allergist services.³³ The suspected product (eg, antiseptic agent or dressing) is applied to the forearm (contralateral arm to the vascular access device) or thigh and monitored for signs of reaction for 30 to 60 minutes and reassessed in 3 to 4 days for signs of contact dermatitis.

Uncomplicated exit site infections involve no signs of systemic infection, purulent drainage, or positive blood cultures. For long-term CVADs, in which the goal is catheter salvage, the Infectious Diseases Society of America recommends the use of topical antimicrobial agents specific to the MCS results such as mupirocin ointment for *Staphylococcus aureus* infection and ketoconazole or lotrimin ointment for *Candida* infection.¹⁸

Appropriate CVAD dressing selection is required to manage exudate, promote wound healing, and ensure catheter stabilization.³⁴ This is especially relevant for patients with CASI, with previous research reporting wide variance in the selection of CVAD dressings for patients with CASI.¹¹ For patients with skin tears around their CVAD site, previous guidelines have cautioned against the use of adhesive strips, traditional transparent film, and hydrocolloid dressings owing to the risk of epidermal stripping if not removed properly.⁹ Education is a key strategy in the avoidance and management of CASI. Many skin injuries are preventable with the use of proper dressing application and removal techniques and application of antiseptics; nurses and patients performing the dressing changes must be informed how to safely perform these procedures to prevent CASI.^{7,9}

COMFORT DOMAIN

While administering interventions to protect the skin, the clinician must concurrently address patient comfort. Skin damage can often present as painful acute wounds that impair health-related quality of life and well-being.⁹ CASI may also involve other distressing and uncomfortable symptoms including stinging or itch. Providing pain and discomfort symptom relief is an important element in the holistic, patient-focused management of CASI.

Recommendations

Clinicians should regularly assess and document pain, using a standardized, validated assessment tool such as the Visual Analogue Scale or Numeric Rating Scale.³⁵ Local and systemic pain relief should be administered, including the use of analgesics. Pain relief needs to be prescribed and administered in accordance with the overall treatment team, to ensure that they are not contraindicated with other therapies or underlying conditions. The management of pruritic, irritated skin should also involve regular, standardized assessment³⁶ and involve the administration of cool compresses, and systemic antihistamines, where appropriate.³⁷

The algorithm also provides guidance for referrals. If CASI does not respond to the conservative management outlined in the CASI algorithm, or the wound further deteriorates, a skin or wound care specialist should be consulted.⁷

EXTERNAL VALIDITY

As described in Table 3, 25 nurses and nurse practitioners, with a range of experience and educational preparations from Canada (n = 13; 52%), Australia (n = 8; 32%), the United States (n = 2; 8%), and New Zealand (n = 2; 8%), contributed to the external validation of the algorithm. Participants were based in dedicated adult (n = 15; 60%), pediatric (n = 8; 32%), or mixed population (n = 2; 8%) settings. Participants had a variety of years of nursing experience including 1 to 5 years (n = 6; 24%), 6 to 10 years (n = 8; 32%), and greater than 10 years (n = 11; 44%), with a minority completing a specialist vascular access certification (n = 7; 28%).

When compared with decision making using the standardized case scenarios described earlier, the use of the CASI algorithm significantly improved mean clinician confidence for the management of skin injury (2.81 ± 1.18 vs 1.65 ± 0.70 ; $P = .002$), skin irritation/contact dermatitis (2.81 ± 1.22 vs 1.75 ± 0.68 ; $P = .001$), and noninfectious exudates (2.45 ± 1.19 vs 1.50 ± 0.61 ; $P < .001$) (Table 4). The overall feedback for the algorithm was positive. Clinician evaluators indicated that it was easy to understand, contained appropriate information to guide interventions, and would help them save time. They also indicated that they would recommend algorithm use to other clinicians (Table 5).

DISCUSSION

This article describes systematic development and validation of an algorithm to promote the identification and management of impaired skin surrounding CVAD sites. Development began with a scoping review of relevant literature. This literature was then evaluated by an international group of clinical experts in the field. The advisory panel used a 2-step modified Delphi approach to design an evidence- and consensus-based CASI algorithm.

TABLE 3.
Demographics of External Validation Participants (N = 25)

Profession	
Nurse	23 (92%)
Nurse practitioner	2 (8%)
Country currently practicing	
New Zealand	2 (8%)
United States	2 (8%)
Australia	8 (32%)
Canada	13 (52%)
Patient population	
Neonates	0
Pediatrics	8 (32%)
Adults	15 (60%)
All	2 (8%)
Years' experience managing CVADs	
<1	0
1-5	6 (24%)
6-10	8 (32%)
>10	11 (44%)
Formal certification in vascular access	
Yes	7 (28%)
No	18 (72%)

Abbreviation: CVAD, central venous access devices.

External validity was demonstrated using a pre- and posttest design that incorporated feasibility and face validity endpoints.¹⁵

This is the first published algorithm to comprehensively guide clinical practice surrounding CASI. Some aspects of CASI identification and management were previously provided by the MARS1⁷ and skin tear⁹ consensus statements. Expanding on this work, the CASI algorithm provides additional guidance for recognizing and treating other types of CASI (eg, exit site infection)

TABLE 4.
Clinician Confidence^a Pre- and Postalgorithm Across Clinical Scenarios (N = 25)

Scenario	Time Point	Clinician Confidence, ^a	Significance (P) ^b
		Mean (SD)	
Exit site infection	Pre	2.53 (1.17)	.083
	Post	1.75 (0.83)	
Skin injury	Pre	2.82 (1.18)	.002
	Post	1.65 (0.70)	
Skin irritation/contact dermatitis	Pre	2.81 (1.22)	.001
	Post	1.75 (0.68)	
Noninfectious exudate	Pre	2.45 (1.19)	<.001
	Post	1.50 (0.61)	

^aFive-point Likert responses: 1 = very confident; 2 = confident; 3 = somewhat confident; 4 = somewhat not confident; 5 = not at all confident.

^bTwo-tailed, paired-samples t test.

TABLE 5.
Overall Feedback Surrounding "CVAD-Associated Skin Impairment Algorithm"

	5-Point Likert Scale ^a	Number (%)
"It is easy to for me to understand"	Strongly agree	17 (68%)
	Agree ^b	7 (28%)
"It contains all the necessary information I need to determine the appropriate information for interventions"	Strongly agree	14 (56%)
	Agree ^b	10 (40%)
"Using this tool will help save me time in making decisions about skin impairment management"	Strongly agree	13 (52%)
	Agree	9 (36%)
	Uncertain ^b	2 (8%)
"This tool will reduce my uncertainty about the course of action to take"	Strongly agree	11 (44%)
	Agree	9 (36%)
	Uncertain	2 (8%)
	Disagree ^b	2 (8%)
"This tool is compatible with the way I think things should be done"	Strongly agree	13 (52%)
	Agree	8 (32%)
	Uncertain ^b	3 (12%)
"Would you recommend this tool to other clinicians to guide management of CVAD sites with skin impairment?"	Strongly agree	14 (56%)
	Agree ^b	10 (40%)

Abbreviation: CVAD, central venous access device.

^aFive-point Likert responses: strongly agree; agree; uncertain; disagree; strongly disagree.

^bMissing data = 1 (4%).

and provides evidence- and consensus-based recommendations across the scope of the Assess, Protect, and Comfort domains.

Evidence supporting the assessment and management of CASI remains limited and multiple recommendations in the algorithm are based upon expert opinion. Nevertheless, expert opinion was incorporated into the algorithm only when no other evidence was available. This method is in accordance with guideline development recommendations.^{38,39} External validation has been achieved only within a simulated setting and we recommend that in the future, validation of the algorithm is within prospective trials in the clinical setting.

The development of the CASI algorithm has identified the urgent need for research across many areas of general CVAD and CASI management. Currently the burden of CASI on the healthcare environment is estimated by small single population studies,^{10,40} or as a secondary endpoint of interventional studies.^{30,41} Research is urgently needed to define the prevalence of CASI within the wider healthcare environment. It is also necessary to describe the risk factors for CASI development, in order to judiciously, and effectively, focus CASI prevention procedures. We also advocate additional research into the effectiveness of individual elements of CASI management, including strategies for securement, skin antisepsis, and application of skin protectants such as barrier films.

CONCLUSIONS

The CASI is an important and valid tool to promote the identification and management of impaired skin surrounding CVAD sites. We believe that the use of the CASI algorithm will support identification, management, and decision making of clinicians when caring for individuals with a CVAD. Further validation of the CASI algorithm should be enhanced through prospective trials in the clinical setting.

ACKNOWLEDGMENTS

We thank the WoCoVA Skin Impairment Management Advisory Panel, which includes D.B., N.M., A.J.U., and (in alphabetical order) Dianna Denton (Indianapolis, Indiana), Darcy Doellman (Edgewood, Kentucky), Bridget Dowd (Stamford, Connecticut), Peter Hobday (Culver City, California), Jan Hitchcock (London, United Kingdom), Jim Lacy (Draper, Utah), Melissa Leone (West Barnstable, Massachusetts), Ruth Nicole (Vancouver, British Columbia, Canada), Claire Rickard (Brisbane, Australia), Mark Rowe (Little Rock, Arkansas), Pamela Savage (Toronto, Ontario, Canada), Deborah Thurman (Cleveland, Ohio), Melissa Whitehead (Dallas, Texas), and Kelly Ann Zazyczny (Bryn Mawr, Pennsylvania). Technical advice was provided by Nancy Melloy Harper, Elaine Tardif, and Deborah Thayer from 3M (St Paul, Minnesota). We extend special thanks to Elaine Tardif and Nancy Melloy Harper for their assistance with logistics and their sensitivity to maintaining an unbiased work product. We thank the advisory board group and all clinicians who contributed to the validation of the algorithm for their insights and encouragement.

This project was partially supported via an unrestricted project grant from the World Congress of Vascular Access, provided by 3M. Daphne Broadhurst reports personal fees (ie, consultancy, travel, and honoraria) and nonfinancial support from 3M, Carefusion, Angiodynamics, Fresenius, and Excelsior Medical. As an employee of PICC Excellence, Nancy Moureau has received speaker honorarium from 3M, Teleflex, Excelsior, Access Scientific and Entrotech; educational consultant for Angiodynamics, Teleflex, Nexus, Chiesi, Analogic, B Braun, Fresenius, Parker Labs, Medcomp, Cook, Trinity Sterile, and Vascular Pathways; and research grants from Entrotech, 3M, and Cook. Amanda Ullman has received funding through Griffith University for her research and travel support from 3M, Carefusion (Becton Dickinson), Centurion Medical Products, Adhesion, B Braun, and Angiodynamics.

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