Ullman AJ, Cooke M, Rickard CM. Examining the role of securement and dressing products to prevent central venous access device failure: a narrative review. Journal for the Association of Vascular Access on line May 2015. JIF=N/A.

Title: Examining the role of securement and dressing products to prevent central venous access device failure: a narrative review

Abstract

Objective To describe the underpinning principles involved in central venous access device (CVAD) securement and dressing products to prevent CVAD failure and complications through a synthesis of research studies.

Background Functional, dependable CVAD are a necessary part of patient care. Dressing and securement products are used to prevent CVAD failure and complication, but there are a large variety of products available for clinicians to access, with variable effectiveness.

Methods A narrative review of studies describing the mechanisms for CVAD securement and dressing products to prevent failure and complication was undertaken. After a systematic search, 20 clinical and laboratory studies were included in the review.

Discussion The major mechanisms by which CVAD dressing and securement products prevent failure are providing a barrier to microbial contamination and motion reduction. CVAD securement and dressing products provide these functions using coating, adhesion, antimicrobial properties, absorbency and moisture vapor transmission; without causing irritation to the skin and maintaining visibility of the insertion site. The complexity of patients requiring CVAD securement and dressing means that universal recommendations across CVAD populations and broad generalization of studies' from single populations (e.g. intensive care) or devices (e.g. peripherally inserted central catheters) are ill-advised.

Conclusion CVAD securement and dressing products provide important, multi-faceted functions to prevent CVAD failure and complication.

Keywords

Central venous catheterization; healthcare-associated infection; evidence-based practice; wound care.

Introduction

Central venous access devices (CVADs) are a necessary part of contemporary healthcare. They provide a consistent method to access the vascular system and infuse vital, vessel-irritant medications and fluids over extended periods of time.[1] Multi-disciplinary healthcare practitioners and patients rely on these devices, assuming they will be functional throughout treatment.

However literature has reported high incidences of CVAD failure prior to the completion of treatment. [2-4] The predominant mechanisms resulting in failure are CVAD-associated bloodstream infection (BSI), thrombosis, occlusion, dislodgement, breakage and local skin irritation or infection.[5, 6] Each of these complications results in an interruption to necessary treatment, the insertion of a replacement vascular access device and the attributable morbidity and mortality of the complication.

Many of these complications are considered preventable with the consistent application of evidence-based strategies,[7, 8] and should not be viewed as an unavoidable consequence to technical medicine.[9] In recent years international healthcare agencies have prioritised the prevention of CVAD-associated BSI related to insertion practices within the intensive care setting.[10, 11] Celebration over the success of CVAD insertion bundles should be metered by the continuing rate of CVAD failure and complication due to other mechanisms which occur later in the catheter life. Healthcare practitioners are continuing to search for novel and innovative ways to improve CVAD management for their patients.

Dressing and securement products have always been used as a means to prevent CVAD failure and complication. The first CVAD dressing product utilised in the clinical setting was gauze and tape, with clear polyurethane dressings becoming prominent in the 1980s.[6] Additional CVAD securement has traditionally been achieved via the use of silk or synthetic

sutures. There is now a large variety of CVAD securement and dressing products available in the clinical setting, and even more in development.

Securement and dressing products are a practicality of healthcare provision for all vascular access specialists who insert and manage CVADs. Their importance and relative effectiveness should also not be taken for granted by the wider healthcare community (e.g. oncologists, general surgeons) benefiting from their effectiveness to prevent CVAD failure. But the mechanisms by which these products act to prevent CVAD failure may be poorly understood. By reviewing the available evidence surrounding the role of CVAD securement and dressing products, clinicians, researchers and product manufacturers can work collaboratively to develop practical, effective and efficient strategies for all patients requiring CVAD. Previous systematic reviews and meta-analysis have focussed on the relative effectiveness of specific dressing and securement products. [6, 12-14] This review focusses on studies that explore the fundamental principles of CVAD securement and dressing products to prevent failure and complication.

Aims

The aim of this review is to synthesize the available literature to describe the underpinning principles involved in CVAD securement and dressing products and how they prevent CVAD failure and complications.

Methods

A narrative review was undertaken to synthesize the accumulated state of knowledge and trends within CVAD securement and dressing research. This includes *a priori* inclusion

criteria for study selection, following the recommendations for narrative review methodology by Green and colleagues. [15]

Eligibility criteria

All studies that focused on the underpinning principles involved in CVAD securement and dressing products for the prevention of CVAD failure and complications are included in the review. All randomized controlled trials (RCTs) that had previously been included within an included meta-analysis were excluded, to ensure a lack of study result repetition. Studies were excluded if they were not written in English.

Literature search strategy

Ovid MEDLINE (1950 to December 2014), Ovid EMBASE (1980 to December 2014); EBSCOhost CINAHL (1982 to December 2014) and Cochrane Central Register of Controlled Trials (December 2014 issue) were systematically and independently searched. Medical Subject Headings (MeSH) were developed in collaboration with a healthcare librarian and were "dressing", "intravenous device" and "central venous catheters". Additional studies were identified through searches of bibliographies. Searches were performed without year restrictions and not limited to human studies.

Results

Systematic search results

As demonstrated in the PRISMA flow chart (Figure 1), from the database searches, 213 titles were identified, 66 were removed as duplicates with 147 abstracts reviewed. Seventeen

studies were excluded as the authors reported the results of cross-sectional surveys or descriptions of the variety of CVAD dressing and securement practices. Forty-five were RCTs included within the three meta-analyses.

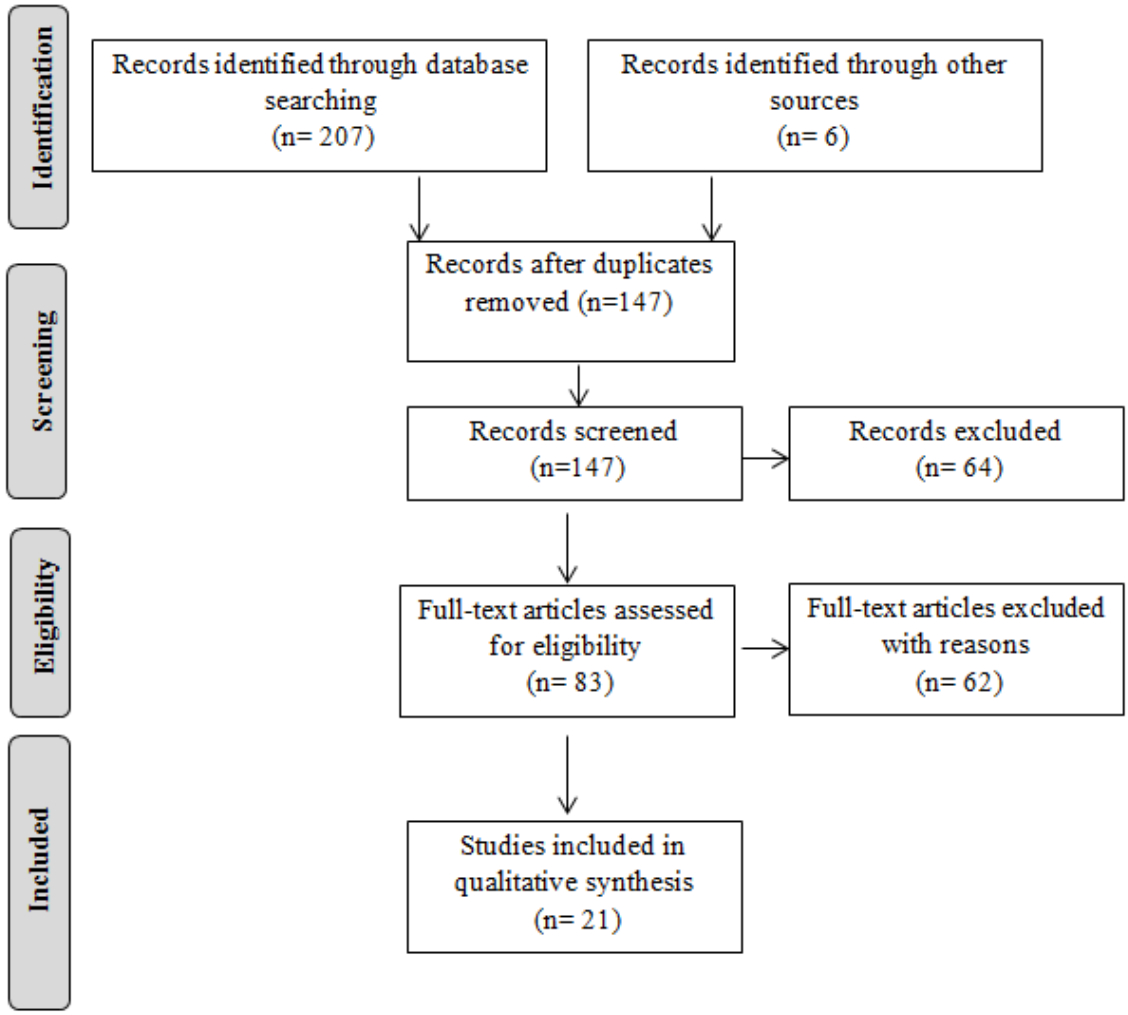

Figure 1: PRISMA flow chart of study selection

Characteristics of included studies

Tables 1 and 2 describe the population, interventions, aims, and major findings of the 21 included studies: three meta-analysis[12-14],; six RCTs [16-21]; three quazi-experimental[22-24]; three observational cohort[25-27] studies; and six laboratory studies.[28-33]

See Table 1 & 2

The overarching principles of CVAD securement and dressing to prevent CVAD failure and complication described within the included studies centred around: providing a barrier to microbial colonization and contamination; reducing internal and external motion; and the impact of dressing disruption. CVAD securement and dressing products provide these functions using coating, adhesion, antimicrobial properties, absorbency and moisture vapor transmission; without causing irritation to the skin and maintaining visibility of the insertion site.

Barrier to microbial colonization and contamination

The puncture of the skin by the CVAD provides a potential entrance point for pathogenic bacteria and fungi to enter the surrounding tissue and bloodstream, resulting in local or systemic infections. One of the primary functions of CVAD dressings is to provide a physical barrier from external contaminants onto the CVAD exit site. However the shielding mechanism is only effective if contaminants are not present under the dressing, and that the dressing environment does not provide a setting for microbes to proliferate.[20] An industry sponsored laboratory study, carried out by Bashir and colleagues,[28] found that with site antisepsis using 2% Chlorhexidine Gluconate (CHG) in 70% alcohol on healthy volunteers in accordance with product manufacturers recommendations and international clinical practice guidelines, skin flora was still not completely eradicated. The skin underlying the CVAD is never completely sterilized.

Because of normal human body temperature and environmental humidity, the skin surface underneath a CVAD dressing may be conducive to bacterial or fungal growth. This

favourable environment is further exacerbated by the presence of wound-based exudate and sweating underneath the CVAD dressing, both of which are common occurrences throughout acute and chronic illness. In order to combat the issue of microbial growth underneath CVAD dressing products, the initial occlusive polyurethane dressings were developed in the 1990s to become semi-permeable to oxygen, carbon dioxide and water vapor.[6]

In 2009 an independent laboratory based- study [31] compared the moisture vapor transmission of CVAD dressings to estimate effectiveness of these products across simulated humidity, fluid presence and temperature settings. Of the gauze and polyurethane dressings tested, IV3000 (Smith & Nephew®; London) had the highest moisture vapor transmission when encountering humid, moist, human-body temperature simulated environments. Whether these high moisture vapor transmission rates equate to reduced CVAD site microbial colonization, and thereby catheter-related infection, was not established by the study. But these findings contrast with the Cochrane Systematic Review by Webster and colleagues,[12] which found the use of a polyurethane dressing, in comparison to gauze and tape, resulted in a higher frequency of catheter-related BSI (odds ratio 4.19; 95% CI 1.02-17.23; P=0.047).

Medication-impregnated CVAD dressing products are now available, aiming to further prevent the growth of microbes underneath the CVAD dressing product via release of antiseptic solution. Most prevalent are the CHG-impregnated products, which have become widely adopted as a means to reduce the risk for CVAD-associated local and systemic infections. CHG is a cationic biguanide with broad spectrum antimicrobial and antifungal activity. The rapid electrostatic attraction of the cationic chlorhexidine molecule and the negatively charged bacterial cells contribute to the rapid kill rate associated with chlorhexidine.[32] The optimal antimicrobial activity of CHG is achieved with a pH ranging from 5.5-7, similar to the human skin.[32, 33] An early manufacturer funded laboratory study [33] first demonstrated the effectiveness of CHG-impregnated polyurethane foam patches in

inhibiting the growth of CR-BSI causing pathogens including methicillin resistant *Staphylococcus aureus* (MRSA), methicillin resistant *Staphylococcus epidermis* (MRSE), and vancomycin resistant *Enterococcus faecium* (VRE). The effectiveness of CHG impregnated products to reduce the incidence of CVAD-associated BSI and catheter colonization for intravascular devices has now been demonstrated in several large RCTs and meta-analyses.[13, 34-36]

A laboratory based, Tegaderm® CHG manufacturer funded study [28] described the comparative effectiveness of the different CHG products, CHG disc (Biopatch®; Johnson & Johnson NJ) and CHG dressing (Tegaderm® CHG IV Securement; 3M St Paul), against standard dressings to reduce mean log counts of skin flora after antisepsis over seven days in on the back of healthy volunteers (n=32). This study found that while both CHG products reduced the mean log counts of skin flora in comparison to standard dressings, the CHG dressing maintained lower mean log counts, than the CHG disc, at seven days (P=0.01).

In addition to CHG-based products, silver compounds are used widely as effective antimicrobial agents.[32] Silver ions can inhibit replication of bacterial through binding to the microbial DNA, and/or switch off important enzymes, leading to microbial death.[37] Another laboratory-based Biopatch® manufacturer funded study[32] compared the effectiveness of silver and CHG-based dressing products for the inhibition the growth of CVAD-associated BSI pathogens over a seven day period. This study demonstrated that the silver-treated dressing products had good efficacy against *Pseudomonas aeruginosa* compared to CHG, but concluded that CHG showed greater sustained efficacy in the majority of tested bacteria and yeasts. Highest ranked of the silver dressing products were the silver alginate dressing (Silversite®; Centurion Healthcare products; Williamston) and the polyurethane foam patch with ionic silver alginate (Algidex® Ag I.V; DeRoyal TN). Whether the reduction of skin flora seen in the CHG dressings within Bashir and colleagues'[28] study or the sustained

efficacy of the CHG discs in Bhende and Rothenburgers' [32] study are associated with a clinically significant reduction of CVAD-associated infections has not been established, as no RCTs have been undertaken to directly compare these products.

Motion reduction

The other primary function of CVAD securement devices is the reduction of internal and external movement of the CVAD. The external portion needs to be secured so the CVAD does not dislodge from the correct position in the central vein, ensuring device patency. Figure 2 illustrates the typical stressors evident in the clinical environment which impact upon CVAD security. CVAD security also needs to be maintained to prevent micromotion or 'pistoning' in and out of the vein which irritates the vein wall, causing thrombosis, occlusion and vessel erosion.[38, 39] This has traditionally been accomplished by the use of synthetic or silk sutures; attaching the CVAD internal or external segment to the patients subcutaneous tissue.[38] Bordered polyurethane dressing products are also available, aiming to provide additional strength in securement compared to simple polyurethane dressings, via a tough fabric adhesive border around the central polyurethane. In addition to this option, clinicians frequently reinforce device security using non-commercial options including sterile strips or non-sterile tape, with varying effectiveness and sterility.

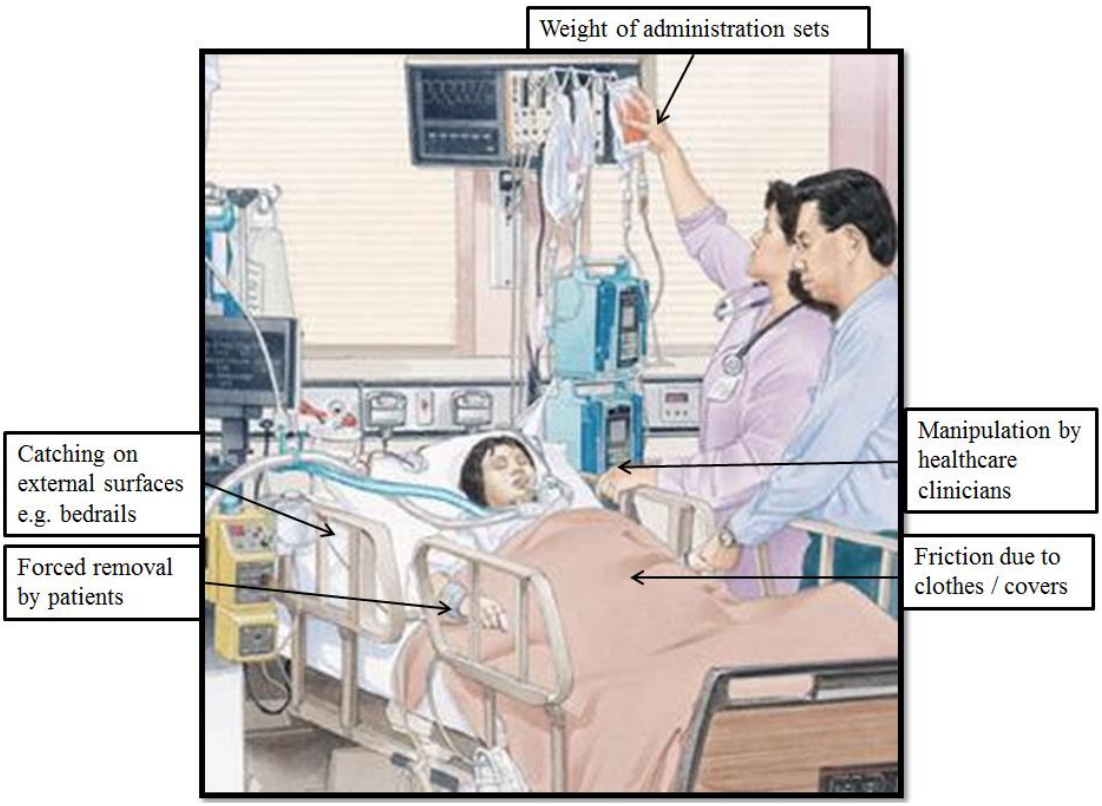

Figure 2

International clinical practice guidelines generally recommend suturing of the CVAD to the surrounding tissue however there is some concern regarding the association between suturing and increased risk for CVAD dislodgement and CVAD-associated infection. [40-43] Building on the retrospective study by Wood and colleagues,[44] Yamamoto and colleagues[17] undertook a landmark RCT in the US, comparing prolene sutures to a sutureless securement device (StatLock®; Bard; Georgia) for 130 peripherally inserted central catheters (PICCs) in adult patients for the prevention of all-cause PICC failure and CVAD-associated BSI. While the reduction of PICC failure was not significantly different between the two groups, CVAD-associated BSI was significantly reduced in the StatLock® group (StatLock 2/85, 2.3%; suture 10/85, 11.8%; P=0.032). While replication of this work has not been undertaken, clinicians have embraced this technology and device, with wide application in the clinical setting for PICCs.[7] Further research needs to be undertaken to establish the effectiveness of

sutureless securement devices to reduce non-PICC CVAD failure caused by internal and external motion.

The securement strength of some CVAD dressing products has been tested under laboratory conditions by Keene and colleagues[30]. This study established that dressing adherence varied significantly on the basis of application technique and on the basis of "sandwich" versus "loop-line" technique. Many studies have documented the challenges associated with achieving consistent implementation of standardised evidence-based CVAD practice into the clinical setting.[7, 45, 46] CVAD securement products need to have clear, easy-to-follow, simple instructions to ensure their correct application, and maximise their effectiveness in reducing internal and external movement.

New advancements in CVAD securement continue. Simonova and colleagues[29] described the potential role of tissue adhesive as an intravascular device securement product using laboratory conditions. Tissue adhesive is a medical grade 'superglue' cyanoacrylate, used commonly in surgical settings as an alternative to sutures in both internal and external wounds. [47] During their laboratory-based study[29] using a porcine skin model, simple polyurethane did not significantly increase pull-out force compared to no dressing at all (No dressing: 1.5; simple polyurethane: 9.2; $P>0.05$). However, both tissue adhesives and sutureless securement devices significantly increased required pull-out force (Tissue adhesive 1: Dermabond® (Johnson & Johnson, London): 15.5 and StatLock® (Bard, Georgia): 22.1 $P<0.01$; Tissue adhesive 2: Histoacryl® (B.Braun, Germany): 36.7 $P<0.001$). There was no visible damage to skin on removal.

Dressing disruption

Each CVAD dressing disruption has the potential for contamination during the dressing change and for skin irritation associated with dressing removal to occur. Current international clinical practice guidelines recommend that CVAD polyurethane dressings be changed every seven days and gauze dressings every three days, in order to minimise the risk of contamination.[1, 40, 41, 43] In 2012, a secondary analysis of a large RCT by Timsit and colleagues, found the disruption of catheter dressings was common and an important risk factor for catheter-related infections.[25] Likewise, previous studies found that a prolonged time interval between dressing changes did not lead to an increased number of CVAD- associated infections and even contributed to reduced occurrence of insertion-site inflammation occurrence.[16, 18, 21, 24] Each of the new dressing and securement devices under development and used in the clinical setting need to be assessed for dressing change requirements independently. It is important that old recommendations, established prior to the use of higher-grade adhesives, different materials and medication-impregnation, do not roll forward to be recommended for new generation products without being evaluated.

Discussion

Patients requiring a CVAD are a vulnerable and heterogeneous population. A 'one size fits all' approach is inappropriate when considering CVAD securement and dressing products to prevent CVAD failure. An example of this is the broad application of CHG-impregnated dressing products. The meta-analyses and RCTs evaluating their effectiveness to prevent CVAD-associated infections are heavily dominated by ICU patients with short-term percutaneously inserted CVAD, and other short-term vascular access devices.[13, 34-36, 48, 49] The generalizability of this evidence outside of these populations and devices should be cautioned. Several case reports and RCTs have been published documenting the genuine risk

of contact dermatitis, especially for neonates and patients with impaired skin (e.g. radiation-induced injuries).[49, 50]

Different CVADs, in different sized populations, inserted in different positions require a distinct securement and dressing approach. For example, the limited space available to secure and dress neonatal or infant jugular CVAD result in some securement devices being unfeasible. Different CVAD types may also have dissimilar tensile strength requirements due to their length, insertion site and the weight of the attached administration sets. Non-tunneled PICCs, in comparison to tunneled subclavian CVADs, may have higher strength requirements due to limb movement, insertion technique and the tunneling providing increased securement due to tissue engraftment. Cuffed CVADs include a short Dacron cuff that is designed to inhibit ascending migration of organisms from the skin, and to stimulate tissue growth around the cuff so as to anchor the device. [51] This cuff provides an internal security, which is maximally effective from four weeks after insertion.

Clinical trials have questioned the need for a dressing or securement device after this initial stabilization period finding equivalence in CVAD-associated BSI incidence between dressing and no-dressing groups. Lawrence and colleagues[22] described a CVAD-associated BSI rate of 0.08 per 1,000 catheter days for those with no dressing and 0.15 per 1,000 catheter days for those with a dressing and Olson and colleagues [52] described 50% incidence of CVAD-associated BSI in each group. Comparatively, Chambers and colleagues[53] reported a reduction in exit site and tunneled CVAD infections when using CHG-impregnated dressings (9%) in comparison to no dressing (43%; OR 0.13; 95%CI 0.04-0.37; P<0.001) and a reduction in premature removal of CVADs in the CHG dressing group (37%) than in the no dressing group (10%; OR=0.20; 95%CI 0.53-0.07; P<0.05). But there was no statistical difference in all-cause CVAD failure or CVAD-associated BSI. CVAD structure (e.g.the

presence of cuffs and tunneling) needs to be considered when deciding between CVAD securement and dressing requirements.

Patients with impaired skin integrity also provide great challenges when choosing the appropriate CVAD securement and dressing products. This includes patients with inflamed skin, adhesive-related skin stripping, weeping or purulent drainage. These conditions are prevalent throughout patients requiring CVADs; especially the elderly, premature infants and patients undergoing allogenic bone marrow transplant.[54, 55] Patient and clinical characteristics including facial or body hair, sweating, use of heating or cooling treatments also complicate CVAD securement and dressing strategy suitability. These complexities demand the tailoring of CVAD securement and dressing products, for greatest effectiveness at preventing CVAD failure. There are currently no formal guidelines, algorithms or research studies to guide clinicians when making these multifaceted decisions. Clinicians, family members and patients require evidence and education to ensure these complex choices in CVAD securement and dressing are made appropriately, to prevent CVAD failure throughout the care continuum.

Estimation of costs associated with CVAD securement and dressing is complex. Simple comparisons are often evident in the literature, where direct comparisons are made between simple products and advanced products. It is reasonable that advanced products may cost more in the short term, including immediate purchasing of the product and the education requirements associated with their proper application. However, long-term costs associated with reductions in CVAD failure need to be considered.

Crawford and colleagues[56], Schwebel and colleagues[57] and Ye and colleagues[58] described the cost-benefit to hospitals and the international community when using CHG-impregnated products, in terms of the reduction of catheter-associated infections and their sequelae

countered with increased contact dermatitis. Cost-benefit analysis considering other types of CVAD failure using the myriad of other products available has not been established. To truly estimate the cost burden associated with premature CVAD failure, future appraisals need to consider the financial burden of increased length of stay, the materials, staff and staff-time associated with insertion of replacement CVADs and the consequences to delayed treatments (e.g. antibiotic blood levels falling below therapeutic requirements). The product and associated failure financial costs may also differ between world regions, so estimates may be unstable.

In comparison to the traditional separation of the securement and dressing domains of CVAD products (e.g. sutures, polyurethane dressings), recent years have seen the advent of combined securement and dressing products (e.g. SorbaView SHIELD®, Centurion Medical Products, Williamston; PICC/CVC Securement systems, 3M^{TM}, St Paul). The unification of these previously separate domains has implications for the associated costs of the products. This may be in a reduction in the overall requirement for individual and/or supplementary products, and the cost associated with skilled labor used during their application (e.g. medical time with suturing). Further research is required to test the effectiveness of these products to reduce CVAD failure, and their related cost-effectiveness.

Conclusion

Patients requiring CVADs are complex, heterogenous and vulnerable to complications. A requirement for a single CVAD only until the completion of treatment should be a goal for each patient requiring their insertion. CVAD securement and dressing products provide an important contribution to the prevention of CVAD failure. However the individual efficacy of each dressing and securement type needs to be ensured for each of the populations requiring

them. A blanket approach to CVAD securement and dressing is not functional, economic or appropriate. Further research within this field is required, to ensure optimal health outcomes for patients worldwide and the efficient use of scant healthcare resources.

Relevance to clinical practice

The majority of clinicians utilise CVADs to administer treatment, but the securement and dressing of CVAD is frequently undervalued or low in priority. Some laboratory and clinical research is available to inform practice in this area, but gaps between the bench and the bedside are apparent and bidirectional. Laboratory-based studies need to be actively informed by current clinical questions, and the application of available evidence to the bedside needs to be further encouraged. Clinicians need to consider the individual risk factors and priorities for patients, in order to make an informed decision for an appropriate CVAD securement and dressing product. Healthcare institutions need to consider the long-term costs associated with the use of CVAD dressing and securement devices, rather than the simple short-term purchasing costs. Innovative solutions to reduce CVAD failure are becoming available, and clinicians need to be supported and informed to implement them to improve patient outcomes.

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Legend for tables and figures

Table 1: Clinical studies examining CVAD dressing and securement products to prevent failure

Table 2: Laboratory-based studies examining the mechanisms of CVAD dressing and securement products to prevent failure

Figure 1: PRISMA flow chart of study selection

Figure 2: Illustration of potential stressors in the healthcare environment which impact CVAD securement

Table 1: Clinical studies examining CVAD dressing and securement products to prevent failure

Authors (year)	Population	Products evaluated; outcome measures	Findings	Industry sponsored
Meta-analysis				
Safdar (2014)	All intravascular devices	CHG-impregnated dressings compared with conventional dressings. Outcomes: CR BSI; catheter colonization	Use of a CHG-impregnated dressing resulted in a reduced prevalence of CR BSI (RR 0.60; 95% CI 0.41-0.88; P=0.009) and catheter colonization (RR 0.52; 95% CI 0.43-0.64; P<0.001). Skin irritation noted in neonates.	No
Webster (2011)	CVADs	Gauze and tape compared with polyurethane dressings Outcomes: CR BSI; catheter cultures; skin / site colonization; exit-site infection; tunnel infection; catheter security; skin irritation; dressing condition / durability	Use of a polyurethane dressing resulted in a higher frequency of CR BSI (OR 4.19; 95% CI 1.02-17.23; P=0.047). No other significant differences found.	No
Ho (2006)	All intravascular devices and epidural catheters	CHG-impregnated dressings compared with placebo or povidine-iodine dressing Outcomes: Epidural, intravascular device or exit-site colonization; CR BSI; central nervous system infection; local skin reactions	Use of a CHG-impregnated dressing reduced the risk of epidural (OR 0.07; 95% CI 0.02-0.31; P=0.0005); intravascular or exit-site colonization (OR 0.47; 95% CI 0.34-0.65; P<0.00001). No significant differences for CR BSI. Use of a CHG-impregnated dressing resulted in an increased risk for local skin reactions (OR 8.17; 95% CI 1.19-56.14; P=0.04).	No
Randomized controlled trials				
Vokurka (2008)	81 patients with acute myeloid leukaemia with non-tunneled CVADs.	Once weekly compared to twice-weekly polyurethane CVAD dressing change Outcomes: Local cutaneous damage, catheter-associated infections	No statistically significant difference in local cutaneous damage or catheter-associated infections between groups.	No
Yamamoto (2002)	170 patients with peripherally inserted central	Securement of PICCs with suture or sutureless securement device (StatLock®; Bard, Georgia)	No statistically significant difference in all-cause complication or dislodgement. Significant reduction in PICC-related BSI for StatLock® group (2/85; 2.3%) vs suture group (10/85; 11.8%;	Yes

	catheters (PICCs)	Outcomes: Total complications; dislodgement; PICC-related BSI; occlusion; Leakage and CVAD-thrombosis	P=0.032).	
Laura (2000)	399 patients undergoing bone marrow transplantation with tunneled CVAD	CVAD dressing changes every five or ten days, in comparison to two or five days. Outcomes: Site infection and local skin irritation.	Participants that had the dressing changed every two days had a significantly increased risk of local skin irritation.	No
Madeo (1998)	31 arterial catheters and CVADs	Silver-impregnated dressing compared to polyurethane dressing Outcomes: Site colonization; catheter tip colonization	No statistically significant difference in site and catheter tip colonization between groups.	No
Reynolds (1997)	100 patients with CVAD	Tegaderm® (3M, St Paul) compared to IV 3000® (Smith & Nephew, London) polyurethane dressings Outcomes: Site colonization; catheter tip colonization; BSI	No statistically significant difference between groups.	No
Engervall (1995)	32 patients with haematological conditions with tunneled CVAD	Once weekly compared to twice-weekly polyurethane CVAD dressing change Outcomes: CVAD failure; catheter tip colonization; exit site infection; CR-BSI.	No statistically significant difference in all cause CVAD failure between groups. Participants that had the dressing changed weekly had statistically significantly increased catheter tip colonization (79% vs 22%; P<0.05).	No
Quazi-experimental studies				
Lawrence (2014)	119 patients with long-term haemodialysis CVADs	Polyurethane dressing compared to no dressing for showering and long term care Outcomes: Rate of CVAD failure; BSI; local infections	No statistically significant difference between groups	No
Pfaff (2012)	Adult ICU	Polyurethane dressing compared with	No statistically significant difference between groups.	No

	patients	CHG-impregnated dressing Outcome: CR-BSI		
Young (1988)	Adult patients receiving total parenteral nutrition via CVAD	Gauze and tape dressings changed three times per week compared with polyurethane dressing changed weekly; changed every 10 days and changed twice-weekly. Outcome: CR-BSI	No statistically significant difference between groups.	Yes
Observational cohort studies				
Timsit (2012)	1,419 adult ICU patients	Association between frequency of dressing disruption and CR-BSI	The rate of catheter-related bloodstream infection increased after the second dressing disruption from 0.5 to 1.5 per 1,000 catheter days.	No
Silveria (2010)	Ten patients with tunneled CVAD undergoing bone marrow transplant	Frequency of CVAD-associated infection and local skin irritation when using polyurethane and gauze and tape dressings	Three patients with polyurethane dressings in comparison to one with gauze and tape experienced local skin reaction. CVAD-associated infections were prevalent in four cases.	No
Treston-Aurand (1997)	Adult patients with 3,931 CVADs	Comparison of polyurethane, gauze and tape and a highly permeable transparent dressing in terms of catheter-related infection.	There was a statistically significant difference in catheter-related infection rates: highly permeable transparent 3.3%; polyurethane 5.5% and gauze and tape 8.5% (P<0.05 all comparisons).	No

BSI = Bloodstream infection; CHG = Chlorhexidine Gluconate; CI= Confidence interval; CR-BSI = Catheter-Related Bloodstream Infection; CVAD=Central Venous Access Device; ICU = Intensive Care Unit; RR=Relative risk

Table 2: Laboratory-based studies examining the mechanisms of CVAD dressing and securement products to prevent failure

Laboratory-based studies	Study aim	Results	Industry Sponsored
Bashir (2012)	Compare the effectiveness of chlorhexidine-impregnated dressing types to standard dressings to prevent skin colonization after antisepsis using 2% Chlorhexidine Gluconate in 70% Alcohol. Products: • Polyurethane dressing (Tegaderm®; 3M, St Paul); • Chlorhexidine-impregnated dressing (Tegaderm® CHG IV Securement; 3M, St Paul); • Chlorhexidine-impregnated disc (Biopatch®; Johnson & Johnson, NJ). Outcome: Quantitative cultures of skin samples from baseline to 7 days after dressing application.	Mean log counts were 3.2 log^{10} CFU/cm^2 before antisepsis and 0.4 after antisepsis. Mean log counts obtained on days 1, 4, and 7 were 0.4, 0.3, and 0.5 log^{10} CFU/cm^2 for the chlorhexidine-impregnated dressing; 0.4, 0.4, and 0.9 log^{10} CFU/cm^2 for the chlorhexidine impregnated disc; and 0.9, 1.2, and 1.5 log^{10} CFU/cm^2 for the standard polyurethane dressing. The CHG-impregnated dressing maintained lower mean log counts to a greater extent than the disc at 7 days (P=0.01).	Yes
Simonova (2012)	Compare chemical compatibility, pull out forces and bacterial migration between new and conventional IVD securement technology Products: • Tissue adhesive (Dermabond®; Johnson & Johnson, NJ; Histoacryl® B. Braun, Germany); • Polyurethane dressing (Tegaderm® 1624, 3M, St Paul); • Bordered polyurethane dressing (Tegaderm® 1633, 3M, St Paul); • Sutureless securement device (Statlock®; Bard Medical, Georgia); • No securement	Neither tissue adhesive weakened the catheters. Both tissue adhesives and sutureless securement devices significantly increased the pull-out force compared to no dressing (No dressing: 1.49; Dermabond®: 15.53; Histoacryl®: 36.67; StatLock®: 22.11; P<0.01). Microbial growth was observed in the polyurethane dressing models at 72 hours, while no growth was visible in the tissue adhesive group.	No

	Outcomes: Assessment of chemical compatibility with catheters and removal products; pull-out forces; microbiological skin contaminants.		
Keene (2009)	Identify the adherence properties of tunneled, cuffed CVAD dressings Products: • Two polyurethane dressings (IV 3000® Smith & Nephew, London; Tegaderm®3M, St Paul), • Leukoplast ® Sleek® (Smith & Nephew, London) • Mefix® (Molyncke, Sweden) Using "loop line", "sandwich" and "bridge" application models. Outcome: Dressing to skin adherence was tested by applying increasing weights to the line.	Dressing to skin adherence was poorest for polyurethane dressings (mean weight 1.74-2.68kg), followed by Mefix and Sleek (mean weight 4.24-4.30 kg) and greatest for the combination of Tegaderm and Mefix (mean weight >5.2 kg). Sandwich technique was superior to loop-line technique (P<0.001).	No
Lin (2009)	Comparison of moisture vapour transmission rates (MVTRs) of transparent and gauze dressings Products: • Gauze; • Polyurethane dressings: IV 3000® (Smith & Nephew, London); OPSITE FLEXIGUARD® (Smith & Nephew, London); Tegaderm® HP (3M, St Paul) and Tegaderm® (3M, St Paul).	During simulation at normal skin humidity and temperature, gauze had the highest MVTRs, followed by IV 3000; Tegaderm HP; OPSITE FLEXIGRIP and Tegaderm (P<0.01). During simulation of dressings in contact with sweating or exudate skin at normal skin temperature IV3000 had the highest MVTRs, followed by Tegaderm HP, OPSITE FLEXIGRID, and Tegaderm (P<0.01).	No
Bhende (2007)	Comparison of inhibition essay by five silver and CHG dressing products against CR-BSI causing bacteria and yeast over seven days. Products: • Polyurethane foam patch with ionic silver	Silver-treated dressings showed good efficacy against *Psedomonas aeruginosa* compared to CHG. The CHG foam showed sustained efficacy for a period of 7 days for 5/7 organism; including the only dressing to prevent *Candida albicans* growth. The silver	Yes;

	alginate (Algidex ® Ag I.V; DeRoyal, TN); • Hydrogel silver dressing (SilvaSorba®; AcryMed, Inc, OR); • Silver barrier dressing (Silverlon® Lifesaver (Argentum Medical LLC, IL); • Silver alginate dressing with polyurethane foam backing (Silversite®; Centurion Healthcare products, MI). • Polyurethane foam with CHG: BIOPATCH® (Johnson & Johnson; NJ) • Polyurethane foam; no impregnation Outcomes: Zone of inhibition tests against MRSE, MRSA, VRE, *C.albicans, P.aeruginosa, A.baumanii, K.pneumoniae* over 7 days.	alginate dressing and foam patch were the best performers of the silver dressings.	
Bhende (2004)	Comparison of inhibition essays of CHG foam dressing against plain foam samples against antibiotic-resistant clinical isolates. Products: • Polyurethane foam with CHG: BIOPATCH® (Johnson & Johnson; NJ) • Polyurethane foam; no impregnation Outcomes: Zone of inhibition tests against MRSE, MRSA, VRE, *C.albicans, P.aeruginosa,* over 24 hours.	Polyurethane foam with CHG had an antimicrobial effect against all tested bacteria and yeast.	Yes

CHG = Chlorhexidine Gluconate; CFU=Colony forming units