Assessment of dressing and securement techniques for peripheral arterial catheters: a narrative review

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ABSTRACT

Background: **Peripheral arterial catheters (AC) are widely used in critical care patients for continuous blood pressure monitoring and blood sampling, yet failure — from dislodgement, accidental removal, phlebitis, pain, occlusion or infection — is common. Effective methods of dressing and securement are needed to prevent complications that cause failure, yet few studies have been conducted that explore this problem.**

Aim: **To perform a narrative review of research literature about dressing and securement of ACs.**

Methods: **A literature search of the Cochrane Central Register of Controlled Trials, Ovid MEDLINE, Ovid EMBASE, and EBSCO CINAHL, as well as Google and Google Scholar was performed. A meta-analysis or systematic review was not possible because of scarce literature.**

Results: **Guidelines for dressing and securement of intravascular devices did not specifically address ACs. One large, non-randomised study compared "band aids" with a sutureless securement device, finding a significant reduction in catheter failure associated with the sutureless securement device. Other studies of polyurethane dressings versus sutureless securement devices only studied intravenous, not ACs. One small, pilot, randomised controlled trial (RCT) indicated feasibility of the use of tissue adhesive plus a polyurethane dressing for ACs.**

Conclusion: There is limited high-quality research literature about effective dressing and securement of ACs.

INTRODUCTION

Millions of patients worldwide need a peripheral arterial catheter (AC) as a vital component of their critical care management[1]. Peripheral ACs are routinely inserted into a peripheral artery and are used for continuous blood pressure (BP) monitoring[2] and frequent blood sampling for essential blood tests, including blood gas analysis[3]. Although necessary and beneficial, ACs are not without complications, which may be mechanical or infective[4,5]. Up to 25% of ACs fail prematurely during treatment because of accidental removal (with the associated risk of life-threatening haemorrhage), dislodgement, occlusion or infection[4,6], and these adverse events are often related to inadequate dressing and securement of the catheter to the skin. Bloodstream infections occur in these devices about as often as in central venous catheters (CVCs), with ACs an under-recognised cause of catheter-related blood stream infection (CRBSI)[7-9]. Annually, Australians need up to an estimated 200,000 ACs to provide routine, necessary care in the operating theatre (OT) and intensive care unit (ICU). International yearly usage of ACs is extensive, with up to eight million in the United States of America (USA), and 2.5 million in Europe[1,5]. Failure of an AC from complications requires the device to be removed and a new device inserted for continued treatment. Complications of ACs, as with all intravascular catheters, are associated with patient suffering, prolonged hospitalisation, more expensive health care costs and increased mortality/morbidity[10-13]. The substantial costs of catheter-related infections create an imperative for health care providers to improve patient outcomes and reduce health care expenses[14].

The failure incidence in peripheral ACs is not often reported in the literature, but in one of the few studies available, it was reported that 69% (40/58) of AC insertion-related incidents were related to inadequate securement, and 24% (60/249) of post-insertion AC use problems involved dislodgement or inadvertent removal[4]. Further, high rates of accidental removal of ACs have been described compared with CVCs in intensive care studies, with two to four times as many incidents reported[15,16]. Other literature acknowledges the serious risk of infection in peripheral ACs, and that this is commonly underestimated[7]. The incidence of AC-related infection in intensive care has been reported as 0.59 to 1.7 per 1,000 catheter days, with 0.3% to 0.8% of patients developing

a CRBSI[7,17]. A systematic review and meta-analysis confirmed that ACs have a substantial burden of CRBSI, with pooled incidence of CRBSI in ACs of 0.96 per 1,000 catheter days[8].

Two key factors in preventing AC complications are: (1) occlusive dressings — with the insertion site covered to prevent infection, and (2) effective securement — with ACs successfully secured to the skin to withstand external forces which may lead to dislodgement. For decades, the most common wound/insertion site dressing used for ACs have been simple polyurethane (SPU) — a small, transparent, rectangular film dressing with an adhesive layer. These dressings are inexpensive and popular, yet there is no evidence that they provide adequate securement rather than functioning merely as a wound dressing. They may not retain adhesion in patients who are diaphoretic or have AC insertion sites that are oozing, as seen in many ICU patients. In recent years, bordered polyurethane (BPU) dressings have emerged that are similar to SPU dressings, but with a toughened, adhesive fabric border. These dressings have not yet been rigorously and independently tested for use in ACs compared to SPUs. An independent, non-randomised study (n=407) in peripheral intravenous (IV) catheters (not ACs), reported less device failure with BPU dressings than with SPU, but this was not statistically significant (29% vs 19%, p=0.18)[18], and has limited generalisability to ACs.

AC securement has traditionally been via sutures, with an SPU dressing placed on top, paralleling a similar method of securement used for CVCs. This approach (sutures plus SPU) has been dominant since the 1980s, despite evidence of significantly increased bloodstream infections with sutures in peripherally inserted CVCs, and recommendations not to suture for CVCs by the American Centers for Disease Control (CDC)[13,19,20]. New alternatives for AC securement and dressings have become available that may be superior to sutures and SPU to prevent complications, but these have not yet been adequately tested for efficacy or cost-effectiveness. An option for ACs is to use a sutureless securement device (SSD), with strong adhesive pads that offer additional anchor points into which the AC can be "clipped" for securement, with an SPU still used as the wound covering. The CDC recommends the use of SSDs for CVCs to prevent vessel inflammation, catheter migration or dislodgement, and potentially CRBSIs, but there is no such recommendation for ACs[14]. The Infusion Nurses' Society Standards of Practice recommend SSDs for all intravascular catheters to maintain patency, minimise catheter movement at the hub, prevent dislodgement and to avoid suture-related complications of infection, pain, tissue trauma if the catheter is accidentally dislodged, as well as potential needlestick injuries[21]. In general, many intravascular catheter-related complications, either mechanical or infective, may be related to poor quality dressings and securement, with resultant catheter failure.

METHODS

The paucity of quality studies reporting efficacy of dressing and securement methods which may prevent complications and catheter failure in ACs, did not allow a meta-analysis or a systematic review. Thus, the available literature was critiqued using a narrative review. First, a literature search of the following electronic databases was made to identify reports of relevant randomised controlled trials (RCTs):

- The Cochrane Wounds Group Specialised Register; The Cochrane Central Register of Controlled Trials (CENTRAL) (2014)
- Ovid MEDLINE (1946 to present)
- Ovid EMBASE (1974 to present)
- EBSCO CINAHL (1982 to present).

The following search strategy was used in CENTRAL with MeSH descriptors: catheterisation, peripheral, peripheral arterial catheter, AC, occlusive dressings, securement device, StatLock®, tissue adhesive, skin glue, occlusive, gauze, tape, polyurethane, permeable, non-permeable, transparent, antimicrobial, anaesthesia, anesthesia, intensive care, ICU, Opsite®, Tegaderm™, Micropore™, and Hypafix®. The Ovid MEDLINE search was combined with the Cochrane Highly Sensitive Search Strategy for identifying randomised trials in MEDLINE, and the EMBASE search was combined with the Ovid EMBASE filter developed by the UK Cochrane Centre[22]. The following clinical trial registries were also searched:

- ClinicalTrials (http://www.clinicaltrials.gov/)
- WHO International Clinical Trials Registry Platform (http://apps.who.int/trialsearch/Default.aspx)
- EU Clinical Trials Register (https://www.clinicaltrialsregister.eu/).

This strategy was then adapted to search Ovid MEDLINE, Ovid EMBASE, EBSCO CINAHL, Google and Google Scholar for all studies and articles. The reference lists of all relevant publications which were retrieved were also searched for articles which had not been identified by the methods described above. Studies were not restricted with respect to language, or date of publication.

RESULTS

Guidelines for intravascular catheter dressings

Centers for Disease Control and Prevention: Guidelines for the Prevention of Intravascular Catheter-Related Infections

The CDC guidelines have no specific dressing recommendations for ACs, but advise either sterile gauze or a sterile, transparent, semi-permeable dressing to cover intravascular catheter sites, and SSDs to reduce the risk of catheter migration, colonisation and CRBSI, and needle stick injury[14]. Presumably, ACs fall under these broad recommendations, but specific guidance for these ACs would be preferable.

Australian Guidelines for the Prevention and Control of Infection in Healthcare

The National Guidelines[23] address health care-associated infections in relation to the management of intravascular catheters, as well as many other topics. They cite background information and recommendations extracted from the CDC guidelines, as well as from their own systematic review[24]. Catheter dressing regimens are specified as the use of either sterile gauze or sterile, transparent and semi-permeable dressings to cover intravascular catheter sites, with no specific protocols recommended for ACs.

Infusion Nurses' Society Standards of Practice

The Infusion Nurses' Society (INS) *Standards of Practice* Standard 44 specifies dressings for generic intravascular catheters, with advice for application of a sterile dressing that should be changed at established intervals, and immediately if integrity becomes compromised. Specified dressing choices include the transparent SPU dressing or gauze. It is recommended that the SPU dressing is changed every seven days, and gauze every 48 hours[25].

Standard 36 focuses on the importance of stabilisation for all intravascular catheters, and the latest recommendations include the routine use of stabilisation devices, and these may be interpreted as SSDs, although this is not specified[26]:

> *Standard 36.1* states that stabilisation should be used to preserve the integrity of the catheter, to minimise catheter movement at the hub, and prevent catheter dislodgement and loss of access.

Standard 36.2 states that intravascular catheters should be stabilised using a method that does not interfere with assessment and monitoring of the access site or impede vascular circulation or delivery of the prescribed therapy.

Standard 36.3 recommends that stabilisation methods be used that are established in organisational policies, procedures, and/or practice guidelines.

Standard 36.4 states that the nurse be competent in the proper use and application of stabilisation methods and devices.

Clinical practice criteria are also discussed in this Standard. The use of a stabilisation device is suggested as the preferred alternative to tape or sutures. The Standard states there is insufficient evidence to support the use of transparent SPU dressings for stabilisation at the IV catheter hub alone[26].

Primary research studies on dressing and securement of ACs

Standard polyurethane, bordered polyurethane dressings and securement-dressings

SPU and BPU dressings are also referred to as transparent, polyurethane, semi-permeable, window (BPU), and/or film dressings, as previously described, and are used to cover the catheter insertion site. BPU dressings are essentially an SPU dressing with a reinforced, opaque border with extra adhesive strips to secure the hub and tubing. Securement-dressings (S-Ds) are window-type BPUs with an extremely adhesive section and a second dressing placed over the first. Research about SPU dressings is first presented, followed by studies of BPU dressings and S-Ds. Product names of dressings are provided as named in the individual studies.

The most commonly used SPU dressings used since the 1980s have been Opsite®, Opsite® IV3000® [27] and Tegaderm™ [28]. It is notable that the manufacturers' product information states SPU dressings are not specifically designed to prevent catheter dislodgement, with their indications to cover and protect the insertion site, rather than provide catheter fixation. This does not appear to be understood clinically, with SPUs often used as the sole product both for dressing and securement. Opsite® is marketed for the management of superficial wounds such as shallow pressure sores, minor burns, cuts and abrasions, for use as a secondary dressing, and also specifically with Opsite® IV3000® to provide catheter fixation. Tegaderm™ package information describes it as indicated to protect IV sites, enhance wound healing, prevent skin breakdown, and to protect clean, closed surgical incisions[27,28].

Tegaderm™ is indicated for use to retain peripheral and central IV catheters only, but not to retain ACs, according to product testing guidelines as set out in the Surgical Materials Testing Laboratory (SMTL) Datacard for Tegaderm™ [29]. The SMTL Dressings Datacard website is part of the Welsh National Health Service, and is dedicated to providing a repository of independently authored datacards and test reports on surgical dressings and bandages[30]. Each datacard is written by an experienced author in the field, and submission requires peer-reviewed papers, technical product information and product samples. It is unclear why SPU dressings were marked as unsuitable for ACs. This statement was not referenced with clinical evidence. Details of authorship were not disclosed, so the author was not able to be contacted. Anecdotally in clinical practice, SPUs are often used for ACs.

Historically, SPU dressings have been applied to both AC and CVC insertion sites after the catheter has been sutured in place[31]. Suturing is now considered to contribute to CRBSI risk[14,32]. The literature provides evidence in peripherally inserted central

catheters (PICCs)[32], and the CDC guidelines reflect this change in perspective[14], with advice to use an SSD in preference to sutures, for intravascular catheters generically.

SPU dressings differ with respect to size, permeability and weight[33]. There may be corresponding clinical advantages in these variations, such as increased durability, improved catheter security, visibility of the wound or catheter site, and a better barrier to microorganisms. The manufacturers suggest these dressings provide infection protection by preventing the passage of liquids, bacteria and viruses through the dressing, while allowing water vapour, oxygen, and carbon dioxide to be exchanged with the surrounding air. This is measurable as the moisture vapour transmission rate to assess water vapour diffusion. However, no optimal transmission rate has been provided by clinical evidence[28]. There is better patient comfort if the dressing conforms to body contours, stretches easily, and prevents skin stress with patient movement. Tegaderm™ dressings are radiologically transparent, with a hypoallergenic, latex-free, acrylic adhesive, designed to be gentle when applied to the skin. Complete visibility of the site is provided by SPUs, allowing monitoring for signs of infection, leakage or catheter dislodgement[28]. SPUs may be worn for longer than tape and gauze[14], which enhances their affordability, with possible savings in nursing time and supply costs for dressing changes.

Large studies of SPU dressings are restricted to IV, not AC use. IV catheter data is somewhat, but not completely generalisable to ACs. Many manufacturers launched second-generation SPU dressings in the late 1980s and the 1990s, which claimed to have higher permeability to water vapour and various gases. This may increase the rate of evaporation at the catheter site, with the possibility of decreasing infection risk[34,35]. Maki and Ringer[35] found in their RCT of 2,088 peripheral IV catheters that moisture under the dressing was a significant risk factor for infection with a relative risk of 2.48 with older style SPU dressings. There have been no RCTs or other studies comparing the older and newer SPUs in ACs.

BPU dressings entered the marketplace in the 2000s with their transparent windows. With the strong, opaque adhesive described as retaining the advantage of a visible insertion site, while better securing the catheter, these dressings intended to avoid loosening and catheter movement[36]. BPU dressings meet USA industry definitions of a catheter securement device, rather than simply a wound dressing. Such BPU dressings have been developed by 3M™ [28] and Smith & Nephew[27], among others. The BPU dressing of Tegaderm™ I.V. Advanced Securement Dressing[37] and other similar dressings are increasingly used by those who believe they minimise the risks and pain of catheter movement and dislodgement. According to product information, Tegaderm™ I.V. Advanced Securement Dressings are intended to provide increased securement in short-term CVCs and ACs. The patterned film adhesives of these dressings hold strongly, and form a seal around the catheter site when applied with firm pressure. Additional sterile tape strips are precut for anchoring hubs, lumens or tubing to enhance stabilisation, and allow the dressing to withstand additional pull force. Tegaderm™ I.V. Advanced Securement Dressings plus tape strips are stated by the manufacturer to withstand twice the pull force of an SPU dressing[37]. As with SPU, this transparent film is said to allow effective oxygen-vapour exchange, while assisting in protection from external contaminants like bacteria and viruses infiltrating the catheter wound and contributing to CRBSIs.

There are only a few studies that have investigated the clinical use of BPU dressings or a related new class of S-Ds, notably the SorbaView SHIELD[18,38,39]. Callaghan *et al.*[18] performed a non-randomised trial of 407 IV catheters in paediatric patients, and

compared Tegaderm™ BPU dressings against tape used alone. The trial was independent of manufacturer sponsorship. Complications of dislodgement, insecure dressings, signs of phlebitis, and/or extravasations occurred in 41/212 (19%) catheters in the tape group, and at a significantly higher rate of 56/195 (29%) in the BPU group, p=0.018. Penney-Timmons[38] observed phlebitis and infiltration in relation to health care costs in 1,345 IV catheters, following introduction of an insertion kit[40], which contained a SorbaView® SHIELD S-D, against standard care of no kit and SPU plus tape. The study was independent of manufacturer sponsorship. Over a six-month period, phlebitis and infiltration incidence associated with the use of the insertion kit and SorbaView® dressing were zero — with cost savings of US$188,640 in a 700-bed facility. A major limitation is that no "pre-data" were provided on earlier complication incidence for comparison and understanding of cost calculations. Limitations of both studies were non-randomised designs, no sample size calculations, no blinding, and lack of reporting detail. Thus, they only provided weak evidence to support BPU use, especially as neither trial included ACs.

Flippo and Lee[39] also evaluated the SorbaView® SHIELD[41] BPU dressing in IV catheters, conducted over three phases. The catheter failure rate was 8/94 (9%) and 86% of nurses rated the overall performance of the SorbaView® SHIELD as good to excellent in 86% of cases. There were several limitations, with no control group, underpowered sample size, and no statistical comparisons. There was also a possibility of manufacturer bias, with the study materials and in-service training provided by the manufacturer. Overall, clinical studies to date have provided only limited and weak evidence regarding the effectiveness of BPU or securement dressings, but they do suggest a potential benefit that needs to be further investigated in ACs.

The properties of BPU have been compared with SPU and other securement methods in the laboratory setting, measuring the amount of force required to remove a peripheral IV catheter, which is technically the same catheter which may be used as an AC, in preference to a custom-made AC. The dressings and securements were compared in an *in vitro* comparative study. Mechanical tests compared securement options on porcine skin and showed that neither SPU nor BPU dressings significantly increased the pull-out force, compared with control catheters that had no dressing at all ($p>0.05$)[42]. This demonstrated that BPU, as well as SPU, did not significantly contribute to enhanced securement in the *in vitro* model. This may not translate to human tissue in the clinical setting, but it raises a concern, particularly in addition to the limited clinical evidence regarding the efficacy of BPU dressings.

Sutureless securement devices in peripheral ACs

SSDs came into being in the 1990s. They anchor intravascular catheter hubs to the skin to provide suture-free securement, and are used with an SPU that covers the catheter insertion site. SSDs have an adhesive anchoring pad holding the catheter in place. These devices are designed to improve patient comfort and safety and are intended to minimise complications in different catheter types, in particular ACs. There is importantly a secondary benefit in the elimination of needle stick injury risk by avoiding sutures. The StatLock® Select Arterial Stabilization Device[43] — and other SSDs that have now entered the market, such as Grip-Lok®[44], NovaCath™[45] and SecurAcath[46] — meet USA guidelines for sutureless securement as defined by the FDA. They are now recommended in both the INS and CDC guidelines[14,26,47]. However, the majority of research studies to date have been performed with the StatLock® device.

There is only one study that has tested the effectiveness of SSD use in ACs compared with other dressings and securement to prevent complications causing failure[6]. This large, non-randomised trial studied compared SSD to AC securement with two "band aids" plus

non-sterile tape (controls). Comparison of the clinical effect and cost benefit was made with 468 catheters secured with Tegaderm™ and the StatLock® Arterial Select device as the experimental group. There was an AC failure rate of 60/468 (12.8%) in the StatLock® group, compared with 253/995 (25%) failure in controls, which was statistically significant, p<0.001. This represented a 48.8% relative reduction in AC failure with the StatLock® device. The SSD cost more to purchase, but its use was cost-neutral in view of reduced complications[6]. It was an independent study powered to test the primary hypothesis, but had the limitations of a non-randomised design and inequality of group sizes. Further study using an RCT design is needed.

The landmark study by Yamamato e*t al.*[32] in PICCs, as referenced in the CDC guidelines[14,48], is often cited in peer-reviewed journals. It provides strong evidence of an RCT to support the use of the StatLock® SSD in place of sutures in intravascular catheters to prevent infection, as recommended in the CDC Guidelines, but not specifically in ACs[32].

Use of tissue adhesive for catheter securement

Limited clinical use of cyanoacrylate tissue adhesive (TA) to secure invasive catheters has been reported in the literature, with the initial uses reported with catheters other than ACs. The first use for securing any type of catheter in human participants was reported in the USA in 2004, to prevent displacement of epidural catheters during labour[49]. A drop of the TA, n-butyl-2-cyanoacrylate, was placed at the catheter insertion sites of seven patients' lumbar epidural catheters. The anaesthetists performing the study considered the "skin glue" would be beneficial to prevent displacement. They thought this would restrict catheter migration, and therefore limit the catheter failure rate. In this case series, six out of seven catheters showed no movement, and no complications were reported. The seventh catheter was dislodged. Limitations of this study were no control, small sample size, lack of randomisation, and no statistical analysis. Effective securement of CVCs and further use in epidural catheters has been achieved in a limited capacity using the TA Histoacryl® in adults. A small number of case studies and case series have shown TA to prevent accidental dislodgement of epidural catheters, as well CVCs[50-53].

A recent pilot randomised controlled trial of novel dressing and securement technologies for AC dressing and securement was performed to provide baseline estimates of effect as well as assess the feasibility of further study[54]. This four-arm, parallel, randomised, controlled, non-blinded pilot trial with 195 short-term intensive care patients investigated BPU, SSD and TA (experimental groups) compared with an SPU control group. AC failure was significantly worse with SPU dressings (10/47 [21%]) than with BPU dressings (2/43 [5%]; p = 0.03), but not significantly different to TA (6/56 [11%]); p = 0.18) or SSD (8/49 [16%]; p = 0.61). The newer technologies were all found to be feasible options, with further study of the interventions recommended. Most recently, a pilot RCT in the operating theatre and intensive care[55] tested one dressing (BPU) and two securement methods (StatLock® SSD and Histoacryl® TA) versus usual care SPU in 123 patients. The primary outcome of catheter failure was 2/32 (6.3%) for TA, 4/30 (13.3%) for BPU and 6/30 (20%) for the SSD. Cost analysis suggested that tissue adhesive was the most cost effective. Therefore, use of TA to secure ACs has been shown to be a potentially effective method, but requires further study.

CONCLUSION

Millions of patients in the operating theatre and the intensive care unit are at risk of having peripheral ACs inadvertently dislodged, or suffering other mechanical or infective complications which result in catheter failure. These complications can be critical, with

the potential for life threatening outcomes including haemorrhage following inadvertent removal, and CRBSI. There are few studies in ACs about complications leading to catheter failure in ACs which may be prevented by improved dressing and securement. Research continues to be conducted about the incidence and outcomes of CRBSI in ACs, however, these studies often make comparisons of incidence with other intravascular catheters. Only two pilot AC studies have investigated SPU/BPU dressings and SSDs, to demonstrate their feasibility for future research[54,55]. The one large non-randomised study of dressing and securement of ACs focused on SSDs, and showed a significant reduction in AC failure[6]. The use of TA to perform securement for intravascular catheters is a new concept, and has shown preliminary effectiveness in securing ACs in two pilot trials[54,55]. It is notable that this review found no reports of problems (potential of actual) with the dressing and securement methods in any of the studies. In summary, a review of the literature has shown only a few studies that have investigated the many available dressing and securement methods and their relationship with AC failure. This literature gap presents a crucial area for future large-scale randomised controlled studies to establish a strong evidence base for dressing and securement of ACs.

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