Techniques in vascular access

JVA The Journal of Vascular Access

The Journal of Vascular Access
1–7

DOI: 10.1177/11297298211034306
journals.sagepub.com/home/jva
SAGE

Rapid Assessment of Vascular Exit Site and Tunneling Options (RAVESTO): A new decision tool in the management of the complex vascular access patients

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Abstract
In the last decade, different standardized protocols have been developed for a systematic ultrasound venous assessment before central venous catheterization: RaCeVA (Rapid Central Vein Assessment), RaPeVA (Rapid Peripheral Vein Assessment), and RaFeVA (Rapid Femoral Vein Assessment). Such protocols were designed to locate the ideal puncture site to minimize insertion-related complications. Recently, subcutaneous tunneling of non-cuffed central venous access devices at bedside has also grown in acceptance. The main rationale for tunneling is to relocate the exit site based on patient factors and concerns for dislodgement. The tool we describe (RAVESTO—Rapid Assessment of Vascular Exit Site and Tunneling Options) defines the different options of subcutaneous tunneling and their indications in different clinical situations in patients with complex vascular access.

Keywords
Assessment, central venous access, tunneling, infection prevention, catheter dislodgement, exit site

Date received: 27 April 2021; accepted: 4 July 2021

Introduction

The most critical phase in medicine is assessment, and central venous catheterization is no exception. Whether the patient is candidate for a peripherally inserted central catheter (PICC), or centrally inserted central catheter (CICC) or a femorally inserted central catheter (FICC), pre-procedural venous assessment is of paramount importance. The recent diffusion of venous access assessment protocols such as RaPeVA (before PICC insertion),[1] RaCeVA (before CICC insertion),[2] and RaFeVA (before FICC insertion)[3] has provided the ability to safely choose the appropriate puncture site based on vascular anatomy, type and duration of therapy, required dwell time of the device, previous device history, and underlying comorbidities. Yet at times these insertion sites are associated with the risk of potential infection and/or catheter dislodgment. With an overall reduction in morbidity and mortality, patients are now living longer than before, so that complex clinical conditions occur, resulting in repeated hospitalizations and progressively depleted vascular access options; also, these patients may also have varying levels of cognition. The exit site of the catheter should be chosen based on distribution of skin contaminants in the area or determined according to the risk for dislodgement, particularly in the cognitively impaired patient. An example of attention to the appropriate choice of the exit site is Dawson's[4] Zone Insertion Method (ZIM) for peripherally inserted central catheters, that considers three regions of risk for PICC insertion, defined as yellow, green, and red zone. Tunneling the catheter allows for a puncture site in the yellow zone with an exit in the green zone.[5] Indeed, the ZIM approach as well as this strategy of tunneling to achieve the safest exit site can be applied to all central insertion sites.

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Figure 1. Tunneled PICC.

For decades, tunneling has been considered only for cuffed catheters and for catheters to be connected to a subcutaneously implanted port. Recently, subcutaneous tunneling of non-cuffed central venous access devices at bedside has also grown in acceptance.[6,7] Today, tunneling any catheter, including non-cuffed catheters, should be regarded as a new and promising strategy which may reduce complications and optimize vascular access device choice. If we define "puncture site" as the location where the needle hits the skin and "exit site" as the location where the catheter comes out of the skin, the goal of tunneling is to obtain an exit site that does not coincide with the puncture site. The main rationale for tunneling is to relocate the exit site considering all patient-related factors which may affect the risk for bacterial contamination and/or dislodgement. As the vascular access specialist's scope of practice expands into tunneling, the need for alternate exit sites can now be met. This paper will present RAVESTO (Rapid Assessment of Vascular Exit Site and Tunneling Options), an assessment tool for suggesting the different options of tunneling and their proper indication in different clinical situations.

Tunneling PICCs

The indication for tunneling a PICC is mainly based on Dawson's ZIM. The ZIM suggests the best exit site for a PICC is the mid-third of the arm (the "green" zone); nonetheless, it may occur that the ideal vein for puncture and cannulation (in terms of catheter/vein ratio and/or safety of venipuncture) is in the proximal third (the "yellow" zone). This is the obvious indication for tunneling the PICC (Figure 1). Interestingly, the ZIM is as useful tool both for defining when tunneling is indicated (see above) but also for establishing how long the tunnel should be: that is long enough to locate the exit site inside the green area.

Another potential indication of tunneling a PICC, regardless of the site of venipuncture, is the need for long standing protection from bacterial contamination. In fact, tunneling is recognized as an effective method for protecting any venous access device from bacterial invasion by the extraluminal route. Moving the exit site far from the entrance of the catheter into the vessel is an easy and effective strategy for reducing the risk of infection, for example in the case of PICCs to be used in patients at high risk for infection (e.g. bone marrow transplant recipients) and/or in patients with long term intravenous treatment (e.g. home parenteral nutrition or cycles of chemotherapy) (Table 1).

Tunneling CICCs

When the CICC is inserted by ultrasound-guided approach to the supraclavicular veins (internal jugular, external jugular, brachio-cephalic, subclavian),[8] the exit site may be in the neck or in the supraclavicular fossa. The latter is obviously to be preferred, in terms of stability and possibility of easy management of the dressing. Still, both options may be inappropriate in obese patients, or in presence of secretions from an endotracheal tube or a tracheostomy, as both situations will increase the risk of bacterial contamination of the exit site; also, a tracheostomy collar may be obstructing the dressing change. In clinical conditions as the above mentioned, supraclavicular CICCs can be tunneled in different directions, so to obtain an exit site in the infraclavicular area (Figure 2), or on the back (Figure 3), or at the arm (Figure 4 and Table 1).

The ultrasound-guided approach to the infraclavicular veins (axillary, cephalic)[8] is usually characterized by an exit site below the clavicle, quite appropriate in terms of stability and low risk of bacterial contamination. Though, in some clinical situations, this exit site can be contaminated by secretions from a tracheostomy, or it may be difficult to manage because too close to a surgical site (pacemaker, sternotomy, etc.); also, it may be located in a region where the confused/non-collaborative patient can easily pull off the catheter. In clinical conditions as the above mentioned, infraclavicular CICCs can be tunneled to the chest (Figure 5), or to the arm (Figure 6), so to obtain a safer location of the exit site (Table 1).

Tunneling FICCs

FICCs are commonly inserted by ultrasound-guided puncture of the common femoral vein at the groin. This is usually the preferred site in emergency situations. Though, catheters with the exit site at the groin—according to the current guidelines—should be removed within 24–48 h, considering the high risk of infection. In fact, this insertion site is subject to exposure to urine and feces as well as hindering ambulation.

In non-emergency situations, FICCs may be needed in patients with contraindications to PICC/CICC insertion,

Table 1. RAVESTO—Rapid Assessment of Vascular Exit Site and Tunneling Options.

Central venous access device	Type and path of tunnel	Indications for tunneling
PICC	Tunnel to Dawson's green area	Puncture site in Dawson's yellow area; non-hospitalized patients with expected long intravenous treatment
CICC (supraclavicular puncture)	Tunnel to infraclavicular area	Long term intravenous treatment in non-hospitalized patients (antibiotics, parenteral nutrition, chemotherapy); expected difficulties in management of the exit site in hospitalized patients (beard, humidity, tracheostomy, instability, etc.)
	Tunnel to arm	Compromised skin integrity of the chest area; oral or endotracheal secretions over chest; implanted device on ipsilateral chest; chest surgery; contracted shoulder; etc.
	Tunnel to back	Cognitive disorder resulting in device removal; contraindication to chest or arm exit site
CICC (infraclavicular puncture)	Tunnel to lower chest	Long term intravenous treatment in non-hospitalized patients (antibiotics, parenteral nutrition, chemotherapy); expected problems in management of the exit site in hospitalized patients (tracheostomy, etc.)
	Tunnel to arm	Compromised skin integrity of the chest area; oral or endotracheal secretions over chest; implanted device on ipsilateral chest; chest surgery; contracted shoulder; etc.
	Tunnel to back	Cognitive disorder resulting in device removal; contraindication to chest or arm exit site
FICC (puncture at the groin)	Tunnel to the abdomen	Non-emergency line in walking patients with contraindication to PICC/CICC
	Tunnel to mid-thigh	Non-emergency line in bedridden patients with contraindication to PICC/CICC
FICC (puncture at mid-thigh)	Tunnel to the abdomen	Non-emergency line in walking patients with contraindication to PICC/CICC
	Tunnel to distal thigh	Long term intravenous treatment in bedridden patients with contraindication to PICC/CICC

Figure 2. Tunneled CICC (supraclavicular puncture, exit site in the infraclavicular area).

Figure 3. Tunneled CICC (supraclavicular puncture, exit site in the scapular area).

such as obstruction of the superior vena cava and/or of both brachio-cephalic veins, impaired skin integrity of arms/chest (burns; diffuse skin disease), etc. To avoid an exit site at the groin, one option is the ultrasound-guided cannulation of the superficial femoral vein, which implies

Figure 4. Tunneled CICC (supraclavicular puncture, exit site at the arm).

Figure 5. Tunneled CICC (infraclavicular puncture, exit site in the chest).

an exit site at mid-thigh.[9] This exit site is far from the inguinal crease, but it may be nonetheless contaminated by urine and feces in the bedridden patient; also, in the ambulatory patient there may be some risk of dislodgment due

Figure 6. Tunneled CICC (infraclavicular puncture, exit site at the arm).

Figure 7. Tunneled FICC (common femoral venipuncture, exit site at mid-thigh).

to leg movements. To overcome such problems, FICCs inserted in the common or superficial femoral vein can be tunneled so to obtain an exit site at the distal third of the thigh (Figures 7 and 8) or on the abdomen (Figure 9 and Table 1).

Figure 8. Tunneled FICC (superficial femoral venipuncture, exit site at mid-thigh).

Figure 9. Tunneled FICC (common femoral venipuncture, exit site on the abdomen).

The rationale of tunneling

In situations where an extended dwell time of the venous access is expected (long-term antibiotic treatment, home parenteral nutrition, antiblastic chemotherapy, long-term inotrope support), tunneling of the exit site should be considered. The recognized benefits of tunneling include reduced risk of infection (protection from extraluminal bacterial contamination), improved catheter stabilization (if the catheter is cuffed or secured by subcutaneous anchorage), patient comfort, and a reduced risk of accidental catheter removal in the cognitively impaired patient.

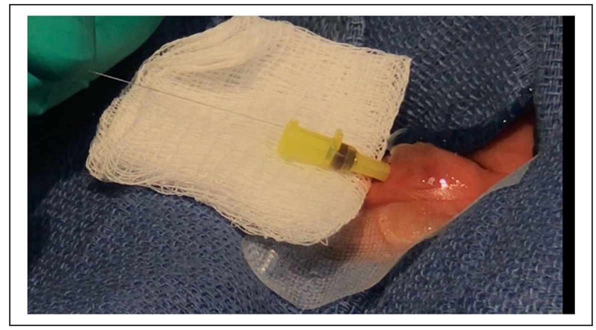

Figure 10. Pseudo Tunneling: extended subcutaneous route with peripheral cannula.

The ideal exit site would be characterized by several features: a clean flat surface, far from humid or hairy areas, far from sources of contamination, and far enough from other devices (pacemaker, defibrillator, tunneled dialysis catheter, etc.) which may interfere with dressing change. In patients with impaired cognitive status, a location in an area that cannot be reached by the patient is also desirable.

Tunneling has been originally described as a technique mainly related to cuffed-tunneled catheters, either for outpatient dialysis or for long term home intravenous treatments. As this practice has expanded also to non-cuffed catheters, more and more hospitalized patients are able to benefit from tunneling. Recent case reports have demonstrated the importance of providing the most appropriate exit site in patients with complicated breast cancer[10] or in premature newborns.[11,12] The exit site in the scapular region has been adopted in both pediatric and adult patients with cognitive challenges, so to prevent self-removal of the catheters.[13,14] Also, chest-to arm tunneling has been used for port placement in patients with contraindications to placement of the reservoir in the infraclavicular area.[15]

Techniques of tunneling

1. "**Pseudo-tunneling**" can be performed with all access devices and involves a single puncture (Figure 10). By this method, the venipuncture device (needle or catheter-over-needle) creates a long subcutaneous trajectory before reaching the vessel.[5] This technique has also been defined as "extended subcutaneous route."[16] Considering that tunneling is defined as that technique where the entry site of the needle into the skin (puncture site) is different from the catheter exit site, the "extended subcutaneous route" cannot be regards as a real tunneling, hence the term "pseudo-tunneling." This technique has limited indications

Figure 11. Tunneling technique: metallic tunneling device.

since the exit site can be moved only few centimeters far from the venipuncture site. It may be useful in neonates, in children and in PICCs requiring short tunneling.

2. **Tunneling** is usually performed using a dedicated tunneling device (in metal or in plastic) (Figure 11). This technique involves ultrasound guided cannulation of the vessel followed by guide wire insertion. A catheter is then brought subcutaneously from a new exit site to the insertion site (anterograde tunneling) or from the insertion site to the new exit site (retrograde tunneling). Tunneling devices of different length (5–25 cm) are commercially available. They are characterized by a "proximal" end to be connected with the catheter and a "distal" end (sharp or blunt) which creates the subcutaneous tunnel.
3. As an alternative option, tunneling can also be performed with a **peripheral intravenous cannula** (Figure 12). The needle cannula creates the tunnel: then the needle is removed, and the final catheter is threaded inside the cannula. A 14-gauge intravenous cannula can accept a 4–5 Fr catheter (or smaller); a 16-gauge cannula can accept a 3 Fr catheter (or smaller). This can be done both as anterograde, or retrograde tunneling. As most commercially available cannulas are shorter than 6 cm, the main limitation of this technique is that each tunneling cannot be longer than 4–5 cm. (Figure 10)

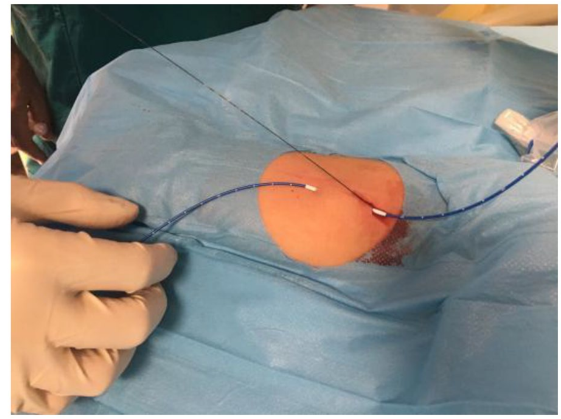

Figure 12. Tunneling techniques: short peripheral cannula.

4. **Multiple tunneling** maneuvers may be needed when the planned exit site is very far from the venipuncture site or when the trajectory between exit site and puncture site is not linear. Multiple tunneling is usually performed by dedicated tunneling devices.

Discussion

The standardized ultrasound-based protocols of venous assessment (RaCeVA, RaPeVA, and RaFeVA) assist the clinician in determining the ideal site for venipuncture of a CICC, PICC, or FICC. In hospitalized patients, non-tunneled central venous catheters should always be considered as a first choice, to provide the simplest and least invasive solution for patient access. Though, as above discussed, a non-tunneled central line may be associated with an inappropriate exit site. An exit site at the neck will be associated with difficult management of the dressing, since the proximity to oral, nasal, or tracheal secretions and the instability of the catheter will increase the risk of infection, dislodgement, and catheter-related thrombosis. An exit site too close to an existing tracheostomy may be inappropriate, too. Patients with contracted upper extremities make dressing changes to these types of catheters difficult. An exit site at the groin, after venipuncture of the common femoral vein, is located in a particularly compromised area, where instability, humidity, proximity to the perineum can all significantly increase the risk of bacterial contamination, catheter-related thrombosis, and dislodgement.

The relevance of the exit site has been discussed within international conferences, and the approaches suggesting innovative solutions of alternative exit sites, are used, as the exception, rather than incorporating these approaches into normal practice for patients, based on their clinical characteristics. RAVESTO is designed to list the exit site locations of different central VADs, to guide the clinician to recognize the proper indication to tunneling, to choose the alternative exit site and to define the type of tunneling (direction and technique). This tool is meant to allow the clinician to easily match the proper insertion site with the appropriate exit site.

Conclusion

When the exit site associated with the puncture site is anticipated to be inappropriate in terms of risk of dislodgment, infection, or thrombosis, the RAVESTO protocol, as presented in Table 1, may suggest safer and more reliable options. This protocol is intended to help the clinician to individualize the indication for tunneling and decide on the most appropriate location for the exit site. Each of these tunneling techniques can be easily carried out at bedside, with minimal resources, making the operating theater or the radiology suite arrangements unnecessary. Though these maneuvers of subcutaneous tunneling are quite easy and no major complications have been described, proper training is nonetheless mandatory, including formal education programs and simulation training.

Author contributions

All the authors have equally contributed to the manuscript and approved its content. The authors obtained the consent for the use of the images from their institutions and from the patients.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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