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Temporary hemodialysis catheters: recent advances

Edward G. Clark[1,2] and Jeffrey H. Barsuk[3]

[1]Kidney Research Centre, Ottawa Hospital Research Institute, Ottawa, Ontario, Canada; [2]Division of Nephrology, The Ottawa Hospital, Ottawa, Ontario, Canada and [3]Department of Medicine, Northwestern University Feinberg School of Medicine, Chicago, Illinois, USA

The insertion of non-tunneled temporary hemodialysis catheters (NTHCs) is a core procedure of nephrology practice. While urgent dialysis may be life-saving, mechanical and infectious complications related to the insertion of NTHCs can be fatal. In recent years, various techniques that reduce mechanical and infectious complications related to NTHCs have been described. Evidence now suggests that ultrasound guidance should be used for internal jugular and femoral vein NTHC insertions. The implementation of evidence-based infection-control 'bundles' for central venous catheter insertions has significantly reduced the incidence of bloodstream infections in the intensive care unit setting with important implications for how nephrologists should insert NTHCs. In addition, the Cathedia Study has provided the first high-level evidence about the optimal site of NTHC insertion, as it relates to the risk of infection and catheter dysfunction. Incorporating these evidence-based techniques into a simulation-based program for training nephrologists in NTHC insertion has been shown to be an effective way to improve the procedural skills of nephrology trainees. Nonetheless, there are some data suggesting nephrologists have been slow to adopt evidence-based practices surrounding NTHC insertion. This mini review focuses on techniques that reduce the complications of NTHCs and are relevant to the practice and training of nephrologists.

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Correspondence: *Edward G. Clark, Division of Nephrology, The Ottawa Hospital Riverside Campus, 1967 Riverside Drive, Ottawa, Ontario, Canada K1H 7W9. E-mail: edward.clark@uottawa.ca*

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Non-tunneled temporary hemodialysis catheter (NTHC) insertion is a required procedural skill for most nephrologists and nephrology trainees. For all central venous catheters (CVCs), including NTHCs, significant morbidity, mortality and expense can be attributed to their insertion and use.[1,2] Figure 1 details the more frequent and serious complications of NTHC insertion, according to insertion site. In the past decade, various techniques implemented at the time of NTHC insertion have reduced the risk of mechanical and infectious complications. However, these advances have largely been reported in the critical care, infection control and general internal medicine literature.

There is some evidence that the nephrology community has not fully adopted techniques shown to reduce complications related to NTHC insertion.[3] Previous work evaluating trainees' skills inserting NTHCs incorporated an assessment of techniques shown to reduce complications[4] and found that procedural competency at the end of nephrology training was poor. This is concerning because, while insertion of a NTHC may be essential for provision of life-saving renal replacement therapy, mechanical and infectious complications of catheter placement can themselves be fatal and are avoidable. This mini review of practices surrounding the use of NTHCs focuses on recent advances that are relevant to the practice and training of nephrologists.

USE OF ULTRASOUND GUIDANCE TO PREVENT MECHANICAL COMPLICATIONS

Acute mechanical complications related to hemodialysis catheter insertion, such as vascular injury or hematoma, are common, occurring in up to 5% of catheter insertions.[2] Other mechanical complications such as pneumothorax, pneumopericardium, air and guidewire embolism, and arrhythmia are less frequent but can be fatal.[2]

It has been well established that the use of real-time ultrasound guidance reduces the mechanical complications associated with CVC insertion at the internal jugular (IJ) and femoral sites. The benefits of ultrasound are likely largely due to anatomic variations in IJ (Figure 2) and femoral (Figure 3) vein locations relative to the artery.[5,6] Although most data are from studies of non-dialysis catheters, a recent systematic review by Rabindranath *et al.*[7] specifically focused on the use of real-time ultrasound guidance for insertion of dialysis catheters. Seven randomized controlled trials (RCTs) involving 767 patients and 830 IJ catheter insertions (including

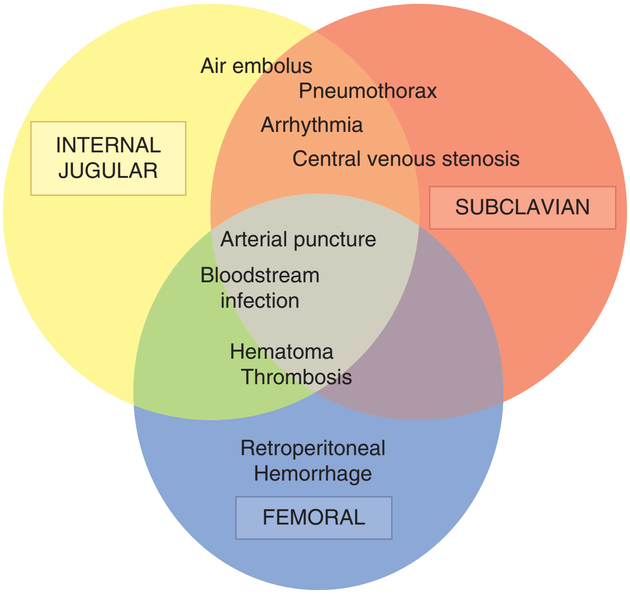

Figure 1 | Frequent and serious complications of temporary (non-tunneled) hemodialysis catheter insertion.

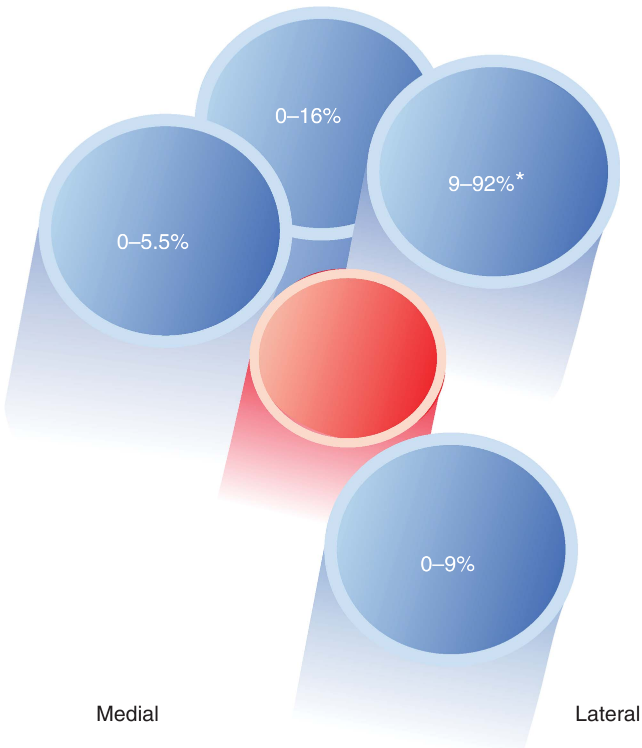

Figure 2 | Anatomic variation of the internal jugular vein relative to the common carotid artery. Right-sided, axial section (viewed from above). *54% of those with internal jugular veins anterolateral to the common carotid artery overlap the artery by ⩾75% of its diameter. Variations not shown: lateral (0–84%) and far lateral (0–4%), both with no overlap; up to 18% of internal jugular veins are not visible or are thrombosed. Adapted from: Maecken T *et al. Crit Care Med* 2007; 35(S5):S178.

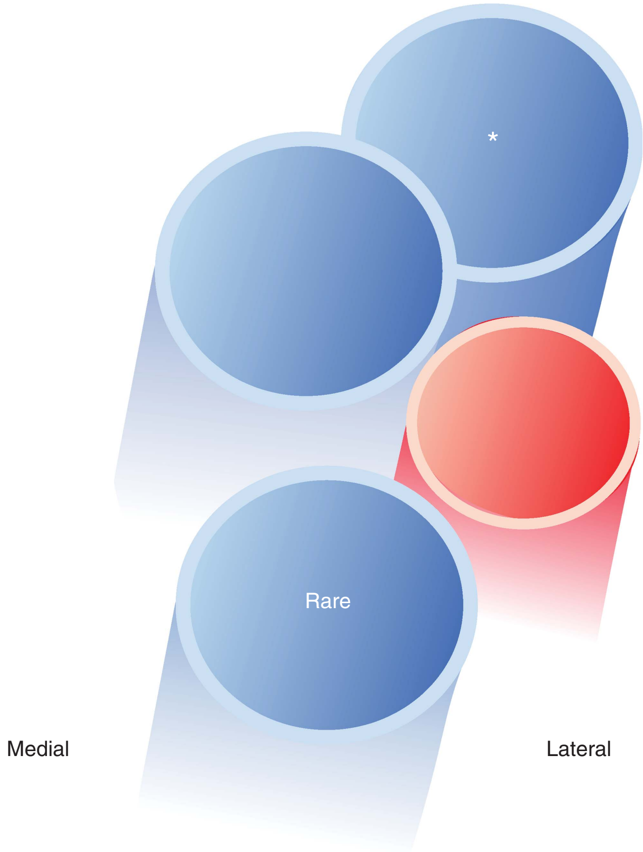

Figure 3 | Anatomic variation of the common femoral vein relative to the common femoral artery. Right-sided, axial section (viewed from above). *Over 25% overlap between the common femoral vein and common femoral artery occurs in 8% of patients. 65% of patients have some degree of overlap. Adapted from: Baum PA *et al. Radiology* 1989; 173:775-777.

both tunneled and non-tunneled catheters inserted at the femoral or IJ site) were included. The authors concluded that the use of real-time ultrasound at the time of catheter insertion resulted in a significant reduction in arterial punctures and hematomas, improved the rate of successful insertion on the first attempt and reduced the time taken for successful venous puncture compared with the anatomic landmark-guided technique with no ultrasound.[7] This accords with current recommendations regarding the use of ultrasound for NTHC insertion by renal organizations internationally.[8,9] However, it is unclear the extent to which these guidelines have been adopted. Ultrasound is used less commonly for NTHC insertions at the femoral site[3] which might be expected given that there is no risk of pneumothorax. Nonetheless, serious and even fatal complications related to femoral hemodialysis catheter insertion have been reported with the incidence of severe hemorrhage (usually retroperitoneal) estimated at 0.5%.[10] One study by Prabhu *et al.*[11] randomized 110 patients to real-time ultrasound-guided anatomic landmark-guided insertion of a femoral NTHC. The use of real-time ultrasound resulted in significantly better 'first attempt' and overall success rates compared with the use of anatomic landmarks alone: 85.5% vs. 54.5% ($P < 0.001$) and 98.2% vs. 80% ($P = 0.002$), respectively. In addition, the complication rate was 18.2% for the landmark-based technique vs. 5.5% with ultrasound guidance ($P = 0.039$). Subgroup analyses conducted according to operator experience of more or less than 6 years did not show any significant differences from what was observed overall. The current level of evidence suggests that all operators use real-time ultrasound guidance for insertion of NTHCs at the femoral site.

EVIDENCE-BASED TECHNIQUES TO REDUCE INFECTIOUS COMPLICATIONS

Infection-control techniques at the time of catheter insertion

Central line-associated bloodstream infections (CLABSIs) and exit-site infections cause significant morbidity and mortality.[1] Fortunately, the overall incidence of CLABSIs in the United States has markedly declined in recent years likely as a result of infection-control interventions targeted to the intensive care unit (ICU) setting.[1] With respect to NTHCs in particular, a systematic review reported that the rate of CLABSIs for NTHCs is higher than for other types of CVCs (4.8 vs. 2.7 per 1000 catheter days).[12]

In the ICU setting, multiple interventions at the time of CVC insertion have reduced the rate of associated infections[13] and include:

- adequate hand hygiene.
- maximal barrier precautions at the time of CVC insertion (sterile gown, mask, gloves and cap) plus full head-to-toe sterile covering of the patient using a specialized sterile drape as opposed to a 'standard-sized' sterile field.
- 2% chlorhexidine skin antisepsis applied using a 'back-and-forth' scrubbing motion for times indicated by the manufacturer on dry areas (IJ site) and moist areas (femoral site).
- avoidance of the femoral site (to be discussed in more detail below).
- systematic, daily review of the need for a catheter and removal if no longer required.

An infection-control 'bundle' consists of interventions such as these, applied together, in conjunction with staff education, facilitation of access to the required equipment in the form of a standardized kit and a program of nurse-led monitoring and real-time feedback that uses a detailed checklist to ensure compliance. Infection-control 'bundles' have been shown to dramatically reduce the rate of CLABSIs[14] and subsequently maintain this reduced rate[15] in the ICU setting. While 'bundled-interventions' have primarily been studied in ICUs, it is likely that this approach could be similarly effective in the various settings that nephrologists and trainees may insert hemodialysis catheters. This is particularly relevant given that the reduction in CLABSIs observed in recent years in ICUs has not been observed in other settings[1] and may reflect an opportunity for more widespread application of these types of interventions. As such, the various aspects of an infection-control 'bundle', as described, should be integrated into the practice and training of nephrologists.

Catheter-locking solutions

The properties of different catheter-locking solutions may influence both thrombus and biofilm formation and associated complications of catheter malfunction and infection. Multiple smaller-scale RCTs have shown that the use of various antibacterial catheter locks (ACLs) for tunneled hemodialysis catheters (and some studies including NTHCs in addition to tunneled hemodialysis (HD) catheters) can reduce the likelihood of infectious outcomes compared with conventional locking solutions such as heparin alone.[16] An RCT by Maki *et al.*[17] included 407 hemodialysis outpatients with tunneled HD catheters and compared heparin locks with ones containing a mixture of sodium citrate, methylene blue, methylparaben and propylparaben (C–MB–P). The authors demonstrated that C–MB–P locks were associated with significantly fewer CLABSIs and were significantly less likely to be discontinued due to poor flows.[17] While this study presents an exciting avenue for further research, it also highlights one of the difficulties in assessing the evidence with respect to ACLs for NTHCs: studies involving the use of ACLs for tunneled HD catheters[18,19] may not be directly applicable to NTHCs given the different settings and clinical circumstances in which they are typically used. One study to focus exclusively on the use of ACLs for NTHCs was an RCT by Kim *et al.*[20], which included 120 new hemodialysis patients using NTHCs while awaiting placement or maturation of a fistula or graft. This study compared ACLs containing gentamicin (5 mg/ml), cefazolin (10 mg/ml) and heparin (1000 IU/ml) with locks containing heparin alone.[20] The ACL group had significantly fewer CLABSIs (0.44 per 1000 catheter days vs. 3.12 per 1000 catheter days, $P = 0.031$) and no adverse events were reported.[20] Although this study did not detect any methicillin-resistant *Staphyloccocus aureus* resulting from the ACLs, it was underpowered to do so.

Overall, in addition to the lack of large scale, RCT-based evidence favoring the use of any particular ACL, there are additional concerns that have limited their broad usage: higher costs, practical issues related to the compounding of ACL solutions at individual dialysis centers and, most importantly, the possibility of promoting antibiotic resistance.[16]

Given the possibility of antibiotic resistance, it is an appealing concept to utilize antimicrobial locking solutions containing different antibiotics than those routinely used to treat CLABSIs. A recent RCT that utilized such an approach compared EDTA (30 mg/ml) + minocycline (3 mg/ml) to heparin (5000 U/ml) as the catheter lock solution in 187 catheters (144 were NTHCs).[21] This study concluded that there were no significant differences in the rate of catheter removal for dysfunction. However, there was a significant improvement in catheter-related bacteremia-free survival (hazard ratio 0.32; 95% CI 0.14–0.71) and 90 day catheter-related bacteremia-free survival (91.3% vs. 69.3%) with EDTA + minocycline.[21]

Another consideration is whether catheter locks should contain trisodium citrate (hereafter referred to as citrate) or heparin as the primary anticoagulant to maintain catheter patency. A recent systematic review and meta-analysis compared the use of citrate (with or without antimicrobials) to heparin locks in hemodialysis catheters. This review included 13 studies, two of which considered only NTHCs and two that included both NTHCs and tunneled HD catheters.[22] The authors concluded that antimicrobial-containing citrate solutions with a low to moderate concentration of citrate (i.e., $\leqslant$4%) reduced the incidence of CLABSIs compared with heparin-containing locks. There was no significant difference in exit-site infections or catheter patency.[22] Locks using higher concentrations of citrate ($\geqslant$30%) have been associated with additional safety concerns such as hypocalcemia and arrhythmia related to accidental systemic administration[22] and were subjected to a manufacturer's recall in the United States for this reason.[18] While variable outcome measures used across the included studies prevented a subgroup analysis on the basis of catheter type (NTHCs or tunneled HD catheters, specifically), the overall conclusions accord generally with what was observed for studies that involved NTHCs.

A 2011 study of exclusively NTHCs ($n = 177$) compared three types of locks: 4% citrate + 1.35% taurolidine, 5000 U/ml heparin + gentamicin and 5000 U/ml heparin alone.[23] In this study, citrate + taurolidine significantly reduced CLABSI rates more than heparin alone (RR: 0.37; 95% CI, 0.16–0.84).[23]

Overall, the evidence supports a recommendation that citrate ($\leqslant$4%) locks be favored over heparin locks for NTHCs. Currently, 4% citrate is used in most HD units in Canada in the form of prefilled 5 ml syringes (Citralok, MED-XL, Montreal, QC, Canada)[24] for patients with tunneled HD catheters. The extent to which it is used for NTHCs is unknown particularly given that NTHCs are often used in ICUs or other critical care areas. It should be noted that, in the United States, none of the most commonly used catheter-locking solutions, including heparin at the 1000 U/ml concentration, are approved by the Food and Drug Administration for use in HD catheters.[25] This also includes 4% citrate which is only available in 250- or 500-ml bags and requires further preparation before being used as a catheter lock.[24]

While citrate catheter locks should be favored over heparin ones, the efficacy and safety of specific ACLs that contain antibiotics or other antimicrobials, including those that also utilize $\leqslant$4% citrate, have yet to be established by large scale RCTs. Nonetheless, some experts have advocated for the more widespread use of ACLs with hemodialysis catheters (tunneled and NTHCs) in view of the significant burden of morbidity and mortality associated with CLABSIs amongst HD patients.[21] While we agree that the findings of recent studies are encouraging, in view of the potential risks and costs, we feel that large scale, multicenter RCTs of specific ACLs are required before recommending their routine use.

Specialized antimicrobial catheters

Reduction of thrombus and biofilm formation is another potential method to reduce CLABSIs because they are often sources for infection. As such, specialized CVCs with antithrombotic and/or antimicrobial properties (e.g., surface coatings, antimicrobial- or antithrombotic-impregnated materials) have been developed. For CVCs in general, there is insufficient evidence for routine use, although they may be indicated in circumstances where high rates of CLABSIs persist despite successful implementation of a 'bundled' program to reduce them.[13] While there is experimental evidence for silver having antimicrobial properties,[26] studies that have assessed the use of silver-coated tunneled HD catheters have not demonstrated a benefit[27,28] and silver-coated NTHCs have not been studied prospectively. A recent RCT that included 77 patients requiring acute dialysis showed significantly less bacterial colonization with a bismuth-coated NTHC, but no significant difference in the primary endpoint of time-to-catheter-removal compared with a conventional NTHC.[29] At the present time, the efficacy and safety of specialized NTHCs for reducing CLABSIs have not been evaluated in large scale RCTs and there are potential barriers to their routine use in the future such as the likelihood of higher costs and, for specialized NTHCs that might be impregnated with antibiotics, the possibility of promoting antibiotic resistance.

Catheter dressings

The Centers for Disease Control and Prevention guidelines[13] provide some guidance about the types of dressings to be used on dialysis catheters, but often do not distinguish between other CVCs and tunneled HD catheters or NTHCs. Sterile transparent semipermeable dressing or sterile gauze can be used as line dressings. Gauze dressing are recommended for patients with bleeding or diaphoresis, but must be changed every 48 h.[13] Transparent dressings afford the benefit of visualizing the line-entry site for evidence of infection and don't need to be changed for 7 days.[13] During dressing changes, 2% chlorhexidine should be used to clean the skin.[13] If there is a contraindication to chlorhexidine, povidodine–iodine or 70% alcohol can be used as alternatives.[13] Topical antibacterial ointment or creams (povidone–iodine or bacitracin/gramicidin/polymixin B) on insertion sites are not recommended except for consideration on tunneled dialysis catheters at the time of insertion and at the end of each dialysis session.[13] Chlorhexidine-impregnated sponge dressing for NTHC cannot be recommended, because studies showing its efficacy in reducing CLABSIs excluded all types of HD catheter.

S. aureus decolonization strategies

Bacterial decolonization with intranasal mupirocin has been shown to significantly reduce the incidence of *S. aureus* bacteremia for chronic hemodialysis patients with tunneled HD catheters.[18] We are unaware of any studies that have assessed decolonization strategies specifically for patients with NTHCs.

Given that NTHCs are often used for AKI in the context of critical illness, studies of decolonization strategies for unselected ICU patients are relevant to patients who have NTHCs in that setting. A recent, large, cluster-randomized trial ($n = 74,256$ patients in 73 ICUs) utilized a 5-day decolonization protocol consisting of twice daily intranasal mupirocin and daily bathing with chlorhexidine-impregnated cloths.[30] This protocol, when applied to all ICU patients, significantly reduced the rate of bloodstream infections (from any pathogen) as compared with a strategy of applying the same decolonization protocol only to methicillin-resistant *S. aureus* carriers or using a strategy that only involved isolation of methicillin-resistant *S. aureus* carriers (i.e., no decolonization).[30] It should be noted that this study did not report any analysis on the basis of whether or not patients had a NTHC in place and its applicability to non-ICU patients with NTHCs is tenuous.

INITIATION OF DIALYSIS WITH TEMPORARY CATHETERS AND OPTIMAL TIMING OF PERMANENT HEMODIALYSIS ACCESS FOR PATIENTS WITH ACUTE KIDNEY INJURY

Due to the increased risk of infection associated with NTHCs as compared with tunneled HD catheters, Centers for Disease Control and Prevention guidelines[13] suggest that tunneled catheters be considered if dialysis access is expected to be required for more than 3 weeks. For the same reason, Kidney Disease Outcomes Quality Initiative guidelines (2006 update) for vascular access suggest that NTHCs should not be used for more than 1 week at the IJ or SC sites and a maximum of 5 days at the femoral site.[8] This recommendation was based on a study that showed significantly higher infection rates for patients initiating hemodialysis with NTHCs compared with tunneled HD catheters and an exponential increase in the risk of infection after 1 week for NTHCs.[31] These recommendations are applicable to patients who are not anticipated to recover renal function and when dialysis is not urgently indicated. In such circumstances, initial placement of a tunneled HD catheter or other access is clearly preferable. However, NTHCs are often required to initiate urgent dialysis treatment in the setting of AKI and critical illness when the duration of dialysis that will be required cannot be readily predicted.[32] In addition, the requirement for specialized procedural expertise and equipment to place a tunneled HD catheter may present a barrier to timely initiation of dialysis treatment and may not be safe or feasible if it requires transferring a critically ill patient out of the ICU setting. Finally, while tunneled HD catheters can often be removed as easily as NTHCs within the first weeks after being inserted, their removal typically becomes more invasive and time consuming over time.

As highlighted by the commentary accompanying the Kidney Disease–Improving Global Outcomes (KDIGO) Clinical Practice Guidelines for AKI (2012),[9] recent large RCTs that assessed the optimal dose of RRT for AKI (the ATN and RENAL studies) indicated that RRT was required for a mean duration of 12–13 days.[33,34] It is unclear at this time if the increased infectious risks associated with a NTHC outweigh the relative burdens of placing tunneled catheters in unselected patients with dialysis-requiring AKI. An RCT that included 34 patients with AKI who required incident dialysis randomized them to receive femoral NTHCs versus tunneled femoral HD catheters.[35] This study found fewer infections and better catheter function but more hematomas and longer insertion times for those assigned to receive a tunneled catheter.[35] While this study suggests an interesting avenue for future research, its small sample size and other methodologic limitations prevent it from providing any guidance with respect to the question of whether the optimal first choice of dialysis access for AKI is a tunneled HD catheter or a NTHC. This is especially the case given that the femoral site is not an ideal first choice of site of catheter insertion in many situations (for either tunneled or NTHCs) and that tunneled femoral HD catheters are rarely used in clinical practice. In the absence of other prospective evidence, the KDIGO guidelines suggest that NTHCs be used to initiate RRT for AKI while acknowledging that this suggestion is made without high-level evidence.[9]

A related issue is that of the optimal timing for switching from a NTHC to a tunneled HD catheter when ongoing dialysis is required following AKI. To our knowledge, and echoing the commentary accompanying the KDIGO guidelines,[9] at this time there is no prospective data to guide this decision and it seems reasonable that a NTHC be replaced with a tunneled HD catheter once it becomes clear that renal recovery is unlikely in the near-term.

CHOOSING THE OPTIMAL SITE FOR TEMPORARY HEMODIALYSIS CATHETER INSERTION

A variety of factors should be taken into consideration to assess the optimal site for NTHC insertion for a particular patient. One aspect of this assessment that is unique to NTHC site selection compared with site selection for other types of CVCs relates to preservation of the vasculature should longer term hemodialysis access be required in the future. As summarized in the KDIGO Guidelines for AKI (2012),[9] whenever possible, the subclavian site should be avoided for NTHC insertion to reduce the likelihood of central venous stenosis.[9] Use of left-sided IJ and subclavian veins may also be associated with a greater risk of central venous stenosis than right-sided veins, possibly as a result of more contact between the catheter and the vessel wall throughout the more tortuous anatomic course.[9] Taking this into account, as well as past recommendations and observational data regarding the likelihood of increased risk of infection at the femoral site, the KDIGO guidelines provided an ungraded recommendation regarding site selection: ‘first choice: right jugular vein; second choice: femoral vein; third choice: left jugular vein; last choice: subclavian vein with preference for the dominant side’.[9] This recommendation was made in accordance with prospective, observational studies that indicated a higher rate of infection at the femoral site.[36,37] However, there is more recent evidence that a patient's body mass index (BMI) should be an additional factor to be considered in selected circumstances. The risk of CLABSI may be lower in patients with femoral NTHCs if BMI is <24.2 and for IJ NTHCs if the BMI >28.4[38] according to a pre-specified analysis from the Cathedia Study based on the lowest and highest BMI tertiles of included patients.[38] This RCT of femoral versus IJ NTHC insertion for patients requiring acute dialysis in the ICU included 750 bed-bound patients who required acute renal replacement therapy.[38] Overall, based on catheter colonization rates, this study demonstrated that the use of the femoral site was not associated with a higher infectious risk.[38] An extension of the Cathedia Study which analyzed data from those patients who subsequently required a second NTHC insertion at the alternative site included 134 patients and demonstrated consistent results: time to catheter-tip colonization at removal did not differ significantly between femoral and IJ sites.[39] Despite some limitations, such as the infrequent use of ultrasound for catheter insertions, the Cathedia Study provided the first high-quality RCT-based evidence regarding selection of the optimal site for NTHC insertion. Given the findings of the Cathedia Study, we suggest that for critically ill, bed-bound patients, in the absence of overriding considerations, the first choice of site for NTHC insertion should consider a patient's ambulatory status and BMI if below 24 (femoral) or above 28 (IJ). Table 1 details some of the considerations that might favor a particular site for NTHC insertion.

Another consideration regarding the optimal choice of insertion site for NTHCs pertains to the risk of catheter dysfunction and consequent 'under-dialysis'. Notably, the Cathedia Study showed no significant differences between femoral and IJ groups in terms of mean urea reduction ratio or time to catheter dysfunction.[39,40] In addition, no significant difference in the risk of deep vein thrombosis (detected using ultrasound screening) was observed.[38]

Table 1 | Selected factors favoring different temporary (non-tunneled) hemodialysis catheter insertion sites

Right internal jugular site
Critically ill and bed-bound with body mass index >28
Postoperative aortic aneurysm repair
Ambulatory patient/mobility required for rehabilitation
Femoral sites
Critically ill and bed-bound with body mass index <24
Tracheostomy present or planned in near-term
Need for long-term hemodialysis access present, highly likely or planned
Emergency dialysis required plus inexperienced operator and/or no access to ultrasound
Left internal jugular site
Contraindications to right internal jugular and femoral sites
Subclavian sites
Contraindications to internal jugular and femoral sites
Right side to be used preferentially

SIMULATION-BASED MASTERY TRAINING FOR TEMPORARY HEMODIALYSIS CATHETER INSERTION

Many medical licensing authorities require candidates seeking certification in nephrology to be competent in NTHC insertion. However, traditional nephrology fellowships may not provide the necessary skills to perform this procedure safely. Two recent surveys showed that up to 1/3 of nephrology fellows received little-to-no training and did not feel confident in inserting NTHCs.[3,41] In addition, during a simulated NTHC insertion assessment of graduating nephrology fellows from three fellowship programs in the United States, the mean score on a skills checklist was 53% items correct (only one fellow met the minimum passing score on the assessment).[2] A 2008 publication called for evidence-based guidelines to establish standards in procedural competency for nephrology fellows.[42]

To ensure today's medical trainees are proficient and competent in the procedures they are expected to perform, simulation-based mastery learning (SBML) has been promoted as an ideal training method.[43] Simulation-based training has been used in medical education to increase knowledge, provide opportunities for deliberate and safe practice and shape the development of clinical skills. Mastery learning is a rigorous form of competency-based learning where knowledge and skills are measured against a precise achievement standard.[43] All learners must reach this preset standard so that educational results are equivalent. This is accomplished by allowing varying practice times for individual learners, as necessary, to achieve these results.

First-year nephrology fellows who were trained with SBML for NTHC insertion skills demonstrated 67% higher scores on a simulated skills exam than graduating fellows ($P<0.001$).[2] Other medical trainees who participated in an SBML curriculum for CVC insertion had lower mechanical complications (including arterial punctures, number of needle passes, need for line readjustment and failed insertions) during actual line insertions on patients.[44] In addition, SBML training in central line insertion reduced CLABSI rates by 85%[45] and lowered healthcare costs with a 7:1 return on investment.[46] Based on this evidence, we believe that using SBML for NTHC insertion should be considered at all nephrology fellowship programs.

CONCLUSIONS

Given that the complications of NTHC insertion are frequent and can be fatal,[2] it is important that nephrologists and trainees practice techniques that limit these risks and are evidence based. Recent data suggest, in addition to using real-time US guidance for all NTHC insertions at the IJ site, US guidance should also be used for NTHC insertions at the femoral site.[11] Infection-control 'bundles' of specific evidence-based practices to reduce the risk of CLABSIs and exit-site infections should be implemented in all settings in which NTHCs are inserted and used. This should include the use of detailed checklists for the insertion of catheters, as well as for a daily assessment of whether or not a NTHC is still required or should be removed. Citrate ($\leqslant$4%) catheter locks should be used for NTHCs rather than heparin.[22] There is currently insufficient evidence to support the routine use of ACLs or specialized catheters with antimicrobial properties.[13] A variety of factors must be taken into consideration when determining the optimal site for NTHC insertion. If possible, the subclavian site should be avoided due to the long-term risk of central venous stenosis.[9] RCT evidence now suggests that the femoral site may not be associated with a higher risk of infection and is possibly even preferable in patients who are critically ill and bed-bound with a BMI less than 24.[38] Last, the use of SBML to teach NTHC insertion to nephrology fellows has been shown to significantly improve their procedural competency.[4] This type of educational program can reduce the risk of CLABSIs,[45] result in significant cost savings[46] and should be considered for implementation by all nephrology training programs.

DISCLOSURE

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