Complications of dialysis central venous catheters

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Dialysis CVC related complications

Central venous catheters are essential in the management of hemodialysis patients, but they also carry unintended negative consequences, adversely affecting patient morbidity and mortality.

Early vs. late complications
- Early
  - Insertion related
- Late
  - Infection
  - Dysfunction/Thrombosis
Complications of hemodialysis catheter insertion

Ultrasound guidance reduces risks and liability


RCT, 900 ICU patients
Central venous catheters: legal issues

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Insertion-related complications

Use of insertion devices and techniques that can prevent accidents amenable of legal liability should be encouraged.

• **Aspects of legal interest:**
  • Use of maximal sterile barriers
  • Use of ECG monitoring
  • Use of ultrasound guidance for cannulation
  • Use of fluoroscopy (position of the metal guide-wire; final position of the CVC tip)
  • Air embolism (over the wire insertion and valved insertion devices)
Liability with a CVC related complication

- Was any deviation from best practice guidelines justified and documented?
- Was the CVC inserted in an appropriate room, with sterile technique?
- Was catheter management in the dialysis setting correct?
- How long has the CVC been in place (especially for ntCVC)?
- Is an access coordinator taking care of access problems in the dialysis unit? (prompt recognition and treatment)
- Was the response to adverse events adequate?
A RCT in the intensive care setting

Intravascular Complications of Central Venous Catheterization by Insertion Site


CONCLUSIONS
In this trial, subclavian-vein catheterization was associated with a lower risk of bloodstream infection and symptomatic thrombosis and a higher risk of pneumothorax than jugular-vein or femoral-vein catheterization.
Primary end point:
• composite of symptomatic deep-vein thrombosis and bloodstream infection

Principal safety secondary end point:
• mechanical complications

Primary outcome incidence: 1.5, 3.6, and 4.6 per 1000 catheter-days; P=0.02

<table>
<thead>
<tr>
<th></th>
<th>Subclavian (N=843)</th>
<th>Jugular (N=845)</th>
<th>Femoral (N=844)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical (grade ≥3)</td>
<td>18 (2.1%)</td>
<td>12 (1.4%)</td>
<td>6 (0.7%)</td>
</tr>
<tr>
<td>Symptomatic deep-vein thrombosis</td>
<td>4 (0.5%)</td>
<td>8 (0.9%)</td>
<td>12 (1.4%)</td>
</tr>
<tr>
<td>Bloodstream infection</td>
<td>4 (0.5%)</td>
<td>12 (1.4%)</td>
<td>10 (1.2%)</td>
</tr>
</tbody>
</table>

Dialysis CVC related Infections

General principles
(one slide)
Relationships between factors associated with hemodialysis CVC-related bloodstream infections

Dialysis CVC
Thrombosis / dysfunction

- CVC dysfunction is a major cause of inadequate depuration.
- This presentation will focus on the etiology, prevention, and management of CVC-related dysfunction, which is mainly associated with inadequate blood flow.
Definition of CVC dysfunction

There is not a commonly accepted definition of CVC dysfunction in the recent literature.

Failure to attain or maintain an extracorporeal blood flow higher than 300 ml/min at a pre-pump arterial pressure more negative than -250 mmHg.

This definition is considered excessively simplistic, because the required blood flow for adequate dialysis could be higher (up to 400 ml/min) or lower than 300 ml/min depending on the length of dialysis session.
Signs of CVC dysfunction: assessment

- Blood pump flow rates <300 mL/min
- Arterial pressure ↑ (< -250 mm Hg)
- Venous pressure ↑ (>250 mm Hg)
- Conductance ↓ (<1.2): the ratio of blood pump flow to the absolute value of prepump pressure
- URR progressively <65% (or Kt/V <1.2)
- Unable to aspirate blood freely (late manifestation)
- Frequent pressure alarms—not responsive to patient repositioning or catheter flushing
- Trend analysis of changes in access flow is the best predictor of access patency and risk for thrombosis.

How common is CVC dysfunction?

A CVC blood flow rate higher than 300 mL/min occurred during only 10% of dialysis sessions, but 75% of patients had adequate dialysis kinetics, thus indicating that tunneled catheter blood flow rates less than 300 mL/min may provide adequate hemodialysis treatment.

Key: adapt dialysis time to the achievable blood flow

The definition of catheter dysfunction should not be based on blood flow only, but it should include more meaningful parameters for assessing the ability to provide adequate dialysis.

Pathogenesis of early and late CVC dysfunction

Based on the time of occurrence, CVC dysfunction may be distinguished into early or late.

- Early dysfunction is usually determined by mechanical causes, such as CVC displacement, incorrect position of the CVC, kinking, CVC damage.
- Late dysfunction is usually determined by thrombosis.

However, it should be kept in mind that early complications (i.e. mechanical events) can occur late and “late complications” (i.e. thrombosis) can determine early CVC dysfunction.
Early CVC dysfunction

The cause of early dysfunction is generally technical and the CVC shows blood flow impairment immediately (in the procedure room) or at its first use:

- Incorrect tip positioning
- Catheter damage
- Kinking obstructing blood flow.
Early CVC dysfunction

Tips for avoiding early dysfunction:

• Check tip position with fluoroscopy during the CVC insertion
• Avoid sharp angles in the subcutaneous tunnel (prevents kinking)
• At the end of the procedure, check if rapid blood flow is easily obtained with a 10 or 20 ml syringe
• First use dysfunction: consider adequate dialysis anticoagulation, might disappear in the following HD sessions
• If possible, wait 24 hours before using a new tunneled CVC: then use with full anticoagulation.
Dysfunctional right internal jugular tunneled dialysis catheter with kink at entry point (arrow)

Niyyar et al.
Clin JASN 2013;8:1234-43
CVC tip position

A tunneled hemodialysis CVC tip positioned outside the right atrium (in the superior or inferior vena cava, or in case of accidental insertion in the azygos vein) will be likely associated with blood flow impairment and low quality dialysis treatment. High performance dialysis catheters should have the tip positioned within the upper right atrium. Vascular perforation or erosion can occur with the catheter tip in any location.

Use continuous ECG monitoring during the insertion procedure to detect arrhythmias from:
• Guidewire (most common cause of arrhythmias)
• Inappropriate CVC tip position
CVC tip position

Where is the upper right atrium?
Lower than it appears

SVC Length
Mean: 6.6 cm (Range 4.4 – 10)

SVC to Right Heart Border
Mean: 5.8 cm (Range 2.5 – 10)


Figure: Tom Vesely
The right tracheobronchial angle is the best radiographic landmark for identifying the boundaries of the SVC.
CVC tip position

The cavoatrial junction is located 5 cm below the tracheobronchial angle (range: 29 mm – 68 mm)
CVC tip position changes with patient’s movement

A CVC tip in the right atrium at time of insertion may retract cephalad when the patient assumes an upright position:
• Average retraction is $3.2 \pm 1.81$ cm

CVC tip also may move upwards during deep inspiration and in female patients with large breasts

Kowalski et al. JVIR 1997; 8:443-447
Late CVC dysfunction

- Late CVC dysfunction is mainly related to thrombosis.
- CVC-related thrombosis can be classified as either intrinsic or extrinsic.
- Extrinsic formation of a fibrous connective tissue sheath around the catheter (aka “fibrin sheath”) is another relevant manifestation of dysfunction.
- Right atrial or mural thrombus may also determine blood-flow impairment.
- Infection, a severe CVC related complication, may be linked to and facilitated by thrombosis, but it may occur in the absence of CVC dysfunction.
- Infection is not further addressed in this presentation.
Pathogenesis of thrombosis related CVC dysfunction

Thrombus, (intraluminal and/or extrinsic)

Fibrous connective tissue sheath
(‘Fibrin Sheath’)

CVC dysfunction
Partially adherent fresh thrombus in the superior vena cava, 2 days after the insertion of a CVC

Forauer et al. J Vasc Interv Radiol 2003
Pathophysiology of thrombus formation

Niyyar et al. Clin JASN 2013;8:1234-43
Fibrous connective tissue sheath (fibrin sheath)

Contrast injection reveals long segment fibrin sheath (arrowhead) after retracting left internal jugular tunneled CVC (tip of catheter at arrow).

Niyyar et al.
Clin JASN 2013;8:1234-43
The fibrous connective tissue sheath ('Fibrin' sheath): a significant problem

- Formation of a fibrin sheath around the CVC is inevitable
- This is not always associated with a clinical problem
- If blood flow is inadequate, often the CVC is partially displaced (retracted tip) compared to the original position
- Urokinase is not effective
- CVC repositioning or substitution is needed
- Balloon sheath disruption may be needed

Photo Courtesy: G. Beathard
Use of an angioplasty balloon may be necessary for repositioning of a CVC through an established fibrin sheet
Mural thrombosis: gross specimen from the superior vena cava with a long-term (501 days) tunneled catheter in place.

Note the thickened vein wall (arrows) and pedicle-like attachment (white arrowhead) between the catheter and vein wall. There is also a prominent fibrin sheath surrounding the catheter.

Forauer et al. J Vasc Interv Radiol 2003
Prevention of thrombosis-related CVC dysfunction

• Prevention of CVC dysfunction is important for containing costly pharmacologic and interventional treatment, which also affect patients’ quality of life.
• Prevention is based on the use of anticoagulant and/or thrombolytic CVC locks, which are only partially effective.
• Chronic oral anticoagulation with warfarin has also been proposed, but its use for this indication is controversial and its overall risk-benefit profile has not been clearly established.
Prevention of thrombosis-related CVC dysfunction

2011- PRECLOT Study: prevent thrombosis to improve malfunction and infection

The use of rt-PA once weekly (instead of heparin), compared with the use of heparin three times a week as a CVC locking solution significantly reduced the incidence of catheter malfunction and bacteremia.
Prevention of thrombosis-related CVC dysfunction: PRECLOT Study

Hazard ratio, 1.91 (95% CI, 1.13–3.22)

Treatment of thrombosis-related CVC dysfunction

**TABLE 2. Treatment of catheter thrombosis**

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<thead>
<tr>
<th>Primary</th>
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<tbody>
<tr>
<td>Forceful flush</td>
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<tr>
<td>Fibrinolytic enzyme</td>
</tr>
<tr>
<td>Instillation</td>
</tr>
<tr>
<td>Infusion</td>
</tr>
<tr>
<td>Mechanical therapy</td>
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<tr>
<td>Secondary</td>
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<tr>
<td>Catheter exchange</td>
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<tr>
<td>Fibrin sheath stripping</td>
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</tbody>
</table>

Beathard G. Semin Dialysis 2001; 14: 441-5
Treatment of thrombosis-related CVC dysfunction

• Thrombolysis with urokinase or rTPA can be undertaken in the dialysis unit, restoring adequate blood flow in most patients, preserving the existing catheter, and avoiding an interventional procedure.
• If thrombolytics fail, mainly because of the presence of fibrous connective tissue sheath, catheter exchange with fibrin sheath disruption may be successful and preserve the venous access site.
Interventional treatment
Catheter exchange or replacement for CVC dysfunction


Interventional Nephrology: Catheter Dysfunction—Prevention and Troubleshooting

Vandana Dua Niyar* and Micah R. Chan†
Algorithm for the endovascular management of dysfunctional catheters in the interventional suite.

Chest radiograph in the interventional suite

Appropriate catheter position

Catheter malposition

Reposition or exchange the catheter

Early dysfunction

Catheter kink

Remove tight sutures, dissect subcutaneous tissue

No abnormalities on exam or radiograph

Exchange catheter

Sufficient blood flow restored

Blood flow remains poor

Late dysfunction

Suspected fibrin sheath or thrombus

Angiogram

Central venous stenosis detected

Fibrin sheath detected

No abnormalities

Relocate catheter or angioplasty and exchange catheter

Balloon angioplasty followed by catheter exchange

Exchange catheter

Niyyar et al. Clin JASN 2013;8:1234-43
Conclusions

• Catheters increase the risk of death and they should be avoided but they may also be lifesaving.
• If correctly managed, they can last for years with low complication rates.
• Optimization of CVC function needs preventive care and timely interventional approaches, when needed.
• Although relocating the catheter to a new vein may be successful in the short term, vein abandonment increases the risk of future vein exhaustion.
10th Congress of the Vascular Access Society
April 5–8, 2017 | Ljubljana, Slovenia
www.vas2017.org