Reaching New Heights in Understanding CVC Complications

Heighten Your DVT Awareness

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Clinical Specialist

Objectives

1. Identify 3 central venous catheter (CVC) related complications
2. Recognize the prevalence and clinical relevance of 3 CVC-related complications
3. Examine in-depth details of CVC-related thrombosis
4. Distinguish varying methods of managing catheter-related thrombosis
Complications of Central Venous Catheters (CVCs)

Catheter-Related Infections

There are three types of CVC-Related-Infections:

- Bloodstream infection (BSI)
  - Sepsis or bacteremia
- Catheter colonization
- Exit-site infection

Catheter-Related Bloodstream Infections

- 5,000,000 Patients each year in U.S. with a central venous catheter
- ~250,000 Bloodstream infections each year
- ~30,000-60,000 Attributable mortality annually
How Often Do PICCs Cause CR-BSIs?\textsuperscript{6,31}

Prevalence and Relevance

Approximately 0.5 – 2.2% of PICCs have CR-BSIs\textsuperscript{12}

| Devices                  | No. of devices studied | No. of CR-BSIs | % CR-BSIs
|--------------------------|------------------------|----------------|-----------
| Peripheral venous catheter| 13                    | 3.7            | 2.0       |
| Arterial catheter        | 6                      | 2.9            | 2.0       |
| Short-term central catheter | 4                    | 3.3            | 2.0       |
| Permanent catheter       | 12                     | 3.4            | 3.0       |
| Hemodialysis catheter    | 15                     | 3.5            | 3.0       |
| Proximally inserted catheter | 1                   | 2.5            | 2.0       |
| Long-term catheter       | 16                     | 1.9            | 2.0       |
| Subcutaneous venous port | 13                     | 3.5            | 2.0       |

Catheter-Related Thrombotic Occlusions

Prevalence

- Most common non-infectious complication in the long-term use of CVCs, and in particular, PICCs\textsuperscript{5,7}
- Approximately 1 in 4 CVCs may become occluded\textsuperscript{8}
- Occlusions may present as:
  - Partial or complete
  - Thrombotic or non-thrombotic
  - Intraluminal or extraluminal
How Do YOU Determine Occlusion?7

Potential indicators of catheter occlusion7

- Inability to infuse fluids
- Lack of free-flowing blood return
- Increased resistance when flushing
- Sluggish flow
- Frequent infusion pump alarms

CVC-Related Occlusions7,8

Prevalence by occlusion type
- Non-Thrombotic Occlusions
  - Mechanical
  - Lipid or chemical aggregation
  - Precipitate
- Thrombotic Occlusions
  - Intraluminal
  - Extraluminal
    - Mural thrombosis
    - Fibrin sheath

Intraluminal Occlusions4,7,13

- Fibrin accumulation can also initiate inside the catheter tip
  and is often the result of blood reflux into the catheter4,13
What Role do Fibrin Sheaths Play in Thrombosis?^{4,9,12}

- All catheters develop a fibrin sheath upon insertion
- Development of sheath begins with endothelial injury from CVC insertion
- Next, localized organization of the sheath occurs
  - Plasma proteins deposit along the outside of the catheter
  - Inflammatory response follows, with proliferation of smooth muscle, fibroblasts, and endothelial cells
- Presence of a fibrin sheath alone may not be sufficient to cause either thrombosis or bloodstream infection, however it may serve as the foundation for thrombus development^{12}
Fibrin Sheath formation may lead to a fibrin tail or flap. 

Extraluminal Occlusions

- Fibrin sheath formation may lead to a fibrin tail or flap.

Catheter-Related Deep Vein Thrombosis (CR-DVT)
Deep Vein Thrombosis Awareness\textsuperscript{10,11}

Prevalence and Relevance

- Each year 200,000–600,000 Americans suffer from Venous Thromboembolism (VTE), which includes Deep Vein Thrombosis (DVT) and Pulmonary Embolism (PE)\textsuperscript{11}
- At least 100,000 deaths per year are directly related to VTE\textsuperscript{10}
- VTE is responsible for more deaths annually than highway fatalities, breast cancer and AIDS combined\textsuperscript{12}
- 74\% of people surveyed have little or no awareness of DVT symptoms\textsuperscript{12}

Correlation Between Infection, Occlusion and DVTs\textsuperscript{4,20,32}

Infection is linked to occlusion and DVTs\textsuperscript{4,32}

- CVC placement provides a rich culture for bacterial growth because of foreign body response upon insertion of CVC
  - Biofilm layer develops that encloses and protects bacteria, which can lead to infection
- Post-mortem evaluation of 72 cancer patients with CVCs showed a strong correlation between CR-sepsis and CVC thrombosis
  - Fibrin layer present on ALL catheters
  - CR-Thrombosis present in 38\% of cases
  - 23\% of these had sepsis
  - No patients without CR-thrombosis had sepsis

Venous Thrombosis Risks\textsuperscript{15}

<table>
<thead>
<tr>
<th>Clinical</th>
<th>Technical</th>
<th>Treatment-Related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malignancy</td>
<td>Larger catheter diameter\textsuperscript{-1}</td>
<td>Estrogen or progestosterone agents</td>
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<tr>
<td>Extensive vascular compression</td>
<td>Multi-lumen catheters</td>
<td>Recombinant human Interleukin-2</td>
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<td>Age extreme (ex: geriatric, pediatric)</td>
<td>Catheter tip malposition</td>
<td>Granulocyte-macrophage CSF</td>
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<td>Pregnancy</td>
<td>Two or more insertion attempts</td>
<td>Thalidomide</td>
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<tr>
<td>Smoking</td>
<td>Left-sided placement</td>
<td>Vesicants (ex: Vanco)</td>
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<tr>
<td></td>
<td>Subclavian vein insertion</td>
<td>Hypersomolar medications (ex: TPN)</td>
</tr>
</tbody>
</table>
Venous Thrombosis - Collaterals

Venogram – Subclavian Venous Thrombosis

Catheter Tip

Venous thoracic outlet syndrome
Effort-related thrombosis (Paget-Schroetter syndrome)
Idiopathic

Catheter-related thrombosis
Cancer-associated thrombosis
Surgery or trauma of the arm or shoulder
Hormone-induced coagulation abnormalities (i.e., pregnancy, oral contraceptives)

Upper Extremity DVT
Approximately 10% of all DVT involve upper extremities

Primary (20%)

Secondary (80%)
PICC-Related DVT Incidence Rates

38% Rate of combined Symptomatic and Asymptomatic PICC Related DVTs

- Only 1-4% of PICC Related DVTs are symptomatic
- Median time to thrombus: 8 to 12 days
- Asymptomatic thrombi pose significant risks for patients

Known Sequelae of UEDVT

- Pulmonary embolism - Occurs in approximately 6% of patients
- Post-thrombotic syndrome
  - Pain on standing
  - Limb edema
  - Lipodermatosclerosis
  - Skin changes (ulcers, eczema)
  - Secondary, superficial varicose veins
- SVC Syndrome

Risk Factors for CR-UEDVT

- Prior DVT
- Catheter Diameter
  - Increased incidence of thrombosis with larger diameter catheters and smaller vessels (e.g. cephalic)
- Hypercoagulability
- Surgery Duration > 1 hour
- PICC Duration/Length of Stay
- Male Gender

Symptomatic DVT Rates

- 0%
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Inherent CVC-Related Risk Factors for DVT\textsuperscript{14,16}

- Virchow’s Triad illustrates the inherent risk factors that present with CVC placement, predisposing a patient to DVT\textsuperscript{14,16}
  1. Vessel wall injury
  2. Stasis
  3. Hypercoagulable state

Why is Vessel Wall Injury a Risk for VT?

- The endothelium is a thin layer of cells that provides a non-thrombogenic surface.
- Disruptions in the endothelium may cause the thrombin cascade to become activated.
- PICC placement may cause a disruption to the endothelium.
  - 21 G needle puncture (sometimes double wall)
  - Irritation caused by indwelling PICC
  - Wire, sheath, and dilator trauma

Wire, Sheath, And Dilator Trauma\textsuperscript{18,19}

The tools used for PICC insertions can be a part of the issue
Vessel Damage
Damage to cephalic vein

Stenosis in Vessel
Stenosis and thrombosis of cephalic vein due to PICC

Why is Stasis a Risk for VT?
Understanding Stasis and Poiseuille’s Law - Mathematical equation related to fluid flow and hemodynamics (blood flow)

- Fluid movement within a tube – movement near the edge moves slowly due to friction
- Fluid movement near center of the tube (vessel) moves more quickly
- A CVC displaces some of the faster-moving blood and creates turbulence
- A CVC also provides additional friction due to its own surface area
- Overall flow is reduced and a level of stasis results
How are Devices Related to Venous Stasis?20

- PICC French size may contribute to venous stasis
- Smaller devices in larger vessels are less likely to cause venous stasis

<table>
<thead>
<tr>
<th>Ven</th>
<th>Initial Flow</th>
<th>2 hr</th>
<th>6 hr</th>
<th>24 hr</th>
<th>6 hr</th>
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<tbody>
<tr>
<td>Groin</td>
<td>5</td>
<td>2.5%</td>
<td>10%</td>
<td>2.1</td>
<td>21%</td>
</tr>
<tr>
<td>Brach</td>
<td>5</td>
<td>5.8%</td>
<td>6%</td>
<td>5.4%</td>
<td>6%</td>
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<tr>
<td>Axillary</td>
<td>19</td>
<td>9.2%</td>
<td>6%</td>
<td>7.2</td>
<td>86%</td>
</tr>
<tr>
<td>Subclav</td>
<td>500</td>
<td>7.5%</td>
<td>1%</td>
<td>6%</td>
<td>3%</td>
</tr>
</tbody>
</table>

What are the Causes of Hypercoagulability?21

Defects Responsible for Hypercoagulability21

- Activated protein C resistance
- Protein S deficiency
- Protein C deficiency
- Hyperhomocysteinemia
- Prothrombin 20210A allele
- Dysproteinemia
- High plasminogen activator inhibitor
- Dyshomocysteinemia
- Elevated factor VIII

Inherited | Acquired | Non-Coagulant Factors
---|---|---
- Antiphospholipid syndrome
- Hyperhomocysteinemia
- Thrombocytopenia
- Dysproteinemia
- HIT
- Estrogens

Maladaptive
- Pregnancy
- Bed rest
- Surgery
- Trauma

PICC-Related Thrombosis20

<table>
<thead>
<tr>
<th>Study</th>
<th>Type</th>
<th>Detection</th>
<th>Thrombosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ng</td>
<td>Prospective</td>
<td>Symptomatic</td>
<td>Clinical with US Confirmation 1.6%</td>
</tr>
<tr>
<td>Grove</td>
<td>Retrospective</td>
<td>Presumed</td>
<td>Ultrasound 3.9%</td>
</tr>
<tr>
<td>Cheml</td>
<td>Retrospective</td>
<td>Symptomatic</td>
<td>US or Venogram 2.5%</td>
</tr>
<tr>
<td>King</td>
<td>Retrospective</td>
<td>Symptomatic</td>
<td>Clinical with US Confirmation 2.5%</td>
</tr>
<tr>
<td>Coste</td>
<td>Prospective</td>
<td>Symptomatic</td>
<td>Clinical with US Confirmation 7.8%</td>
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<tr>
<td>Gondin</td>
<td>Retrospective</td>
<td>Asymptomatic</td>
<td>US Central Vein Only 7.5%</td>
</tr>
<tr>
<td>Abdallah</td>
<td>Prospective</td>
<td>Asymptomatic</td>
<td>Venogram 8.5%</td>
</tr>
<tr>
<td>Allen</td>
<td>Retrospective</td>
<td>Asymptomatic</td>
<td>Venogram 13.3%</td>
</tr>
</tbody>
</table>

Average asymptomatic rate: 48.9%
For patients with acute upper-extremity DVT we recommend initial treatment with therapeutic doses of low molecular weight heparin, unfractionated heparin, or fondaparinux, as described for leg DVT.
1.1.3. For patients with acute DVT, we recommend initial treatment with low molecular weight heparin, unfractionated heparin, or fondaparinux for at least 5 days and until the INR is > 2.0 for 24 h.

1.1.4. In patients with acute DVT, we recommend initiation of Coumadin together with LMWH, UFH, or fondaparinux on the first treatment day.

8.4.1. For patients with acute UEDVT, we recommend treatment with Coumadin for > 3 months.

8.4.3. For patients who have UEDVT in association with a central venous catheter that is removed, we do not recommend that the duration of long-term anticoagulant treatment be shortened to < 3 months.

8.6.1. In patients with UEDVT who have persistent edema and pain, we suggest elastic bandages or elastic compression sleeves to reduce symptoms of post-thrombotic syndrome of the upper extremity.
8.4.2. For most patients with UEDVT in association with a central venous catheter we suggest that the catheter not be removed if it is functional and there is an ongoing need for the catheter.

Summary of VT and DVT Management

Guidelines and recommendations for VT and DVT management are available, but it is critical to consider each patient’s specific situation and treatment needs when determining management requirements.

- Anticoagulant therapy
- Thrombolytic therapy
- Device management
  - Catheter maintenance, removal or replacement

Recent Data on Catheter-Related Deep Vein Thrombosis (CR-DVT)
PICC-Related Venous Thrombosis


- Study aims to determine thrombosis rate in relation to PICC placement in patients discharged from the ICU
- 239 patients / 114 PICCs / 125 CVC
  - In post critically ill patient population PICC related DVT incidence rate significantly higher than CVCs
    - 27.2% versus 9.6%
    - 7.7 per 1000 catheter days vs 4.4 per 1000 catheter days
    - Higher incidence rates in females and with placement in left basilic vein
- Recommended routine ultrasound surveillance, especially during the first 2 weeks after placement

Clinical Significance of PICC-Related DVT

Fletcher, J., et al., Neurocritical Care, 2011

- Study aims to determine the clinical significance of PICC-related DVT in critically ill patients
- Retrospective study
  - 479 had PICCs placed over course of 2-year review period
  - 39 patients developed symptomatic PICC-related DVT (8.1%)
    - Size and location of device was not associated with thrombosis development; male gender was associated
    - Pulmonary embolus attributed to PICC-related DVT (1.3%)
- Authors recommend prospective studies comparing PICCs and CVCs in critically ill patients

Catheter / Vein Size Ratio

Nifong, T., et al., CHEST, 2011

- Recent mathematical study on catheter/vein size ratio
  - Decrease in fluid rate with each successive catheter size increase is statistically significant
  - Results demonstrate that fluid flow is dramatically decreased by the insertion of a centrally located obstruction
  - Assuming that blood flow in veins behaves in a similar manner to the models used in this test, PICCs in particular may substantially decrease venous flow rates by as much as 93%
Improving Clinical Practice

- Measure vein with calipers & compare to French size
- Measure smallest part of vein without a tourniquet
- Consider the outer diameter and the size of the taper (variances in manufacturing)
- Consider percent occupancy: 50% rule for normal coags...33% for increased DVT risk

Guidance on Vessel Size

<table>
<thead>
<tr>
<th>Catheter Size</th>
<th>Catheter Size*</th>
<th>Minimum Vein Size**</th>
<th>Optimal Vein Size**</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 French</td>
<td>1.0 mm</td>
<td>2.0 mm</td>
<td>3.0 mm</td>
</tr>
<tr>
<td>4 French</td>
<td>1.3 mm</td>
<td>2.6 mm</td>
<td>3.9 mm</td>
</tr>
<tr>
<td>5 French</td>
<td>1.7 mm</td>
<td>3.4 mm</td>
<td>5.0 mm</td>
</tr>
<tr>
<td>6 French</td>
<td>2.0 mm</td>
<td>4.0 mm</td>
<td>6.0 mm</td>
</tr>
<tr>
<td>7 French</td>
<td>2.3 mm</td>
<td>4.6 mm</td>
<td>6.9 mm</td>
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*Sizes based on convention 0.53 mm = 1 French mm values are rounded to the nearest 0.1 mm
Exact measurements of catheters are calculated in 0.001 mm – this is only a reference tool! Catheter sizes do vary and the individual catheter manufacturer applies the ISO Standard scale to determine labeling. For exact measurement refer to the catheter labeling in mm. (EN ISO 80369-1 1996)

**Scale based on minimum vein size 2 x catheter size, optimal vein size 3 x catheter size

A Parting Question......

*Do You Know YOUR Institution’s Rate of Catheter related UEDVT?*
Summary

- Let this program be your stepping stone in heightening your awareness of DVTs and the relationship to PICCs
- Don’t stop here....continue your quest.
- Teach others!
- Make this awareness your new mission in doing the right thing!

Citations