Diagnosis and Management of Central Line Associated Bloodstream Infections (CLI) v9.0

Citation & Approval | Summary of Version Changes | Explanation of Evidence Ratings

Initial Blood Culture PHASE

Inclusion Criteria
- Inpatients and ED patients with suspected CLI
- Includes PICCs, Broviacs, hemodialysis lines, etc.

Exclusion Criteria
- Amb. Clinic patients
- Heme/Onc except Sickle Cell, BMT patients and those on ECMO

! **Do NOT perform blood cultures if CLI not suspected**

! **Remove/exchange non-tunneled catheters promptly in unstable patients: remove all catheters if tunnel infection suspected**

Obtain cultures:
- Initial fever: blood cultures peripherally and from all catheter lumens
- Ongoing fever: cultures may not be necessary in all circumstance
- Catheter site cultures if indicated
- Review clinical status

Immunocompetent Patient

Immunocompromised Patient

High suspicion of CLI, hemodynamically unstable, toxic, or at risk for complications

Low suspicion of CLI, Hemodynamically stable, non-toxic, and low risk for complications (minority of patients)

Hemodynamically stable, and non-toxic

Hemodynamically unstable, toxic, or at risk for complications

Empiric Antibiotics:
- Cefepime

PLUS
- Linezolid AND gentamicin if severely ill; OR linezolid if line site infection suspected
- AND antifungal if severely ill and with risk factors for fungal disease

Defer antibiotics

! **Allergies? Call ID!**

Empiric Antibiotics:
- Cefepime

PLUS
- Antifungal if risk factors for fungal disease

Empiric Antibiotics:
- Meropenem PLUS
- Linezolid PLUS
- Gentamicin PLUS
- Antifungal if risk factors for fungal disease

- **Infuse antimicrobials through central line(s)**
- **Re-evaluate clinical status:**
  - After first antibiotic doses and fluid resuscitation
  - Daily
- **Follow culture results**

Negative cultures at 48 hours and asymptomatic

Discontinue Antibiotics

Positive Cultures

Definition for non-tunneled or tunneled CLs

To Preliminary Cultures: Non-Tunneled CVCs

To Preliminary Cultures: Tunneled CVCs

Last Updated: May 2024
Next Expected Review: January 2018

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Preliminary Culture PHASE, Non-Tunneled CVCs

Inclusion Criteria
- Inpatients and ED patients with suspected CLI
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Exclusion Criteria
- Amb. Clinic patients
- Heme/Onc except Sickle Cell, BMT patients and those on ECMO

! **Do NOT perform blood cultures if CLI not suspected**

! **Remove/exchange non-tunneled catheters promptly in unstable patients; remove all catheters if tunnel infection suspected**

Preliminary culture results

Gram-positive organisms

Gram-Positive Organisms
- Consider removing/exchanging the catheter and culturing the catheter tip
- Evaluate for other sources of infection
- Repeat blood cultures (from CL only is acceptable)
- Then add linezolid if not currently on
- Add vancomycin lock therapy if not removing/exchanging immediately

Yeast

Yeast
- Remove/exchange the catheter and culture the catheter tip
- Evaluate for other sources of infection
- Repeat blood cultures (from CL only is acceptable)
- Then begin antifungal

Gram-negative organisms

Gram-Negative Organisms
- If CLI, remove/exchange the catheter and culture the catheter tip
- If not a documented CLI, evaluate for other sources of infection and consider remove/exchange of catheter
- Repeat blood cultures (from CL only is acceptable)
- Ensure appropriate gram-negative coverage (e.g., cefepime)
- Add second gram-negative agent if patient unstable

Polymicrobial infections
- CLIs can involve more than one organism
- Do not narrow antimicrobials until all organisms are identified and their susceptibilities known
- Call ID with questions

Documenting clearance of CLI
- Repeat blood cultures daily:
  - From CL if retained / possible, otherwise peripherally / arterially
  - Until cultures remain negative for at least 48 hours
- Assure clearance of infection prior to replacing the catheter, if needed

Final culture results available → **To Definitive Treatment: Non-Tunneled CVCs**

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Preliminary Culture PHASE, Tunneled CVCs

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- Includes PICCs, Broviacs, hemodialysis lines, etc.

Exclusion Criteria
- Amb. Clinic patients
- Heme/Onc except Sickle Cell, BMT patients and those on ECMO

! **Do NOT perform blood cultures if CLI not suspected**

! **Remove/exchange non-tunneled catheters promptly in unstable patients; remove all catheters if tunnel infection suspected**

Preliminary culture results

Gram-positive organisms

Gram-Positive Organisms

- If CLI, consider catheter salvage if patient stable
- If CLI, remove/exchange the catheter if patient unstable
- If not a documented CLI, evaluate for other sources of infection and consider remove/exchange of catheter
- Repeat blood cultures (from CL only is acceptable)
- Then add linezolid if not currently on
- Add vancomycin lock therapy if catheter retained

Yeast

Yeast

- Remove/exchange the catheter
- Repeat blood cultures (from CL only is acceptable)
- Then begin antifungal

Gram-negative organisms

Gram-Negative Organisms

- If CLI, consider catheter salvage if patient stable
- If CLI, remove/exchange the catheter if patient unstable
- If not a documented CLI, evaluate for other sources of infection and consider remove/exchange of catheter
- Repeat blood cultures (from CL only is acceptable)
- Ensure appropriate gram-negative coverage (e.g., cefepime)
- Add second gram-negative agent if patient unstable
- Add lock therapy if catheter retained

Polymicrobial infections

- CLIs can involve more than one organism
- Do not narrow antimicrobials until all organisms are identified and their susceptibilities known
- Call ID with questions

Documenting clearance of CLI

- Repeat blood cultures daily:
  - From CL if retained / possible, otherwise peripherally / arterially
  - Until cultures remain negative for at least 48 hours
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Final culture results available → **To Definitive Treatment: Tunneled CVCs**

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Definitive Results PHASE, Non-Tunneled CVCs

Inclusion Criteria
- Inpatients and ED patients with suspected CLI
- Includes PICCs, Broviacs, hemodialysis lines, etc.

Exclusion Criteria
- Amb. Clinic patients
- Heme/Onc except Sickle Cell, BMT patients and those on ECMO

!
If >3 days of positive cultures on appropriate antibiotics, obtain ECHO, remove catheter and further evaluate for metastatic infection

- Infuse antimicrobials through central line(s)
- Repeat blood cultures daily:
  - From CL if retained / possible, otherwise peripherally / arterially
  - Until cultures remain negative for at least 48 hours
- Assure clearance of infection prior to replacing the catheter, if needed

Definitive culture results (identification and susceptibilities of all organisms finalized)

Coagulase-negative *Staphylococcus* (other than *S. lugdunensis*)

All other organisms

Coagulase-Negative Staphylococcus (other than S. lugdunensis)

- If CLI, can consider catheter salvage if patient stable
- Add vancomycin lock therapy if not currently on
- Treat for 5-7 days if CL salvaged, or 3 days from line removal (*for SCH only*)
- Manage CLI due to *S. lugdunensis* similarly to recommendations for *S. aureus* CLI

Day 1 of treatment is the first day of negative cultures without subsequent positives

All Other Organisms

1. Remove/exchange the catheter whenever possible

2. *Staphylococcus aureus*:
   - ID Consult recommended for all patients, strongly recommended for patients with high illness severity or multiple comorbidities
   - S. aureus antibiotic selection
   - Treat uncomplicated CLI for 7 days, or treat for 7 days from line removal (*for SCH only*)
   - Perform echocardiography if >1 positive culture

3. Enterococci:
   - Use vancomycin lock therapy in addition to systemic therapy if the catheter is retained
   - Enterococcal antibiotic selection
   - Treat for 7-14 days, or treat for 7 days from line removal (*for SCH only*)

4. Gram-negative bacilli:
   - Gram-negative antibiotic selection
   - Treat for 7-14 days, or treat for 7 days from line removal for uncomplicated CLI (*for SCH only*)

5. *Candida* species:
   - Candida antifungal selection
   - Treat for 10 days from line removal for uncomplicated CLI (*for SCH only*)

!
Other situations, such as complicated infections. Call ID!

Last Updated: May 2024
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Definitive Results PHASE, Tunneled CVCs

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- Amb. Clinic patients
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! If >3 days of positive cultures on appropriate antibiotics, obtain ECHO, remove catheter and further evaluate for metastatic infection

- Infuse antimicrobials through central line(s)
- Repeat blood cultures daily:
  - From CL if retained / possible, otherwise peripherally / arterially
  - Until cultures remain negative for at least 48 hours
- Assure clearance of infection prior to replacing the catheter, if needed

Definitive culture results (identification and susceptibilities of all organisms finalized)

Coagulase-negative *Staphylococcus* (other than *S. lugdunensis*)

S. aureus, P. aeruginosa, Yeast, AFB, other difficult to eradicate pathogens

All other organisms

Coagulase-Negative Staphylococcus (other than S. lugdunensis)

- If CLI, consider catheter salvage if patient stable
- Add vancomycin lock therapy if not currently on
- Treat for 5-7 days if CL salvaged, or 3 days from line removal (*for SCH only*)
- Manage CLI due to *S. lugdunensis* similarly to recommendations for *S. aureus* CLI

S. aureus, P. aeruginosa, Yeast, AFB, other difficult to eradicate pathogens

- Remove / exchange the catheter
- Recommended durations of therapy based on pathogens and number of positive cultures (*for SCH only*)
- Employ the narrowest possible antibiotic therapy
- *Staphylococcus aureus* recommendations
- *Pseudomonas aeruginosa* recommendations
- Candida recommendations
- AFB recommendations
- If unable to discontinue CL, consult Infectious Diseases

All Other Organisms

- Attempt catheter salvage in stable patients
- Recommended durations of therapy based on pathogens and number of positive cultures (*for SCH only*)
- Employ the narrowest possible antibiotic therapy
- Employ lock therapy
- Enterococcus
- Gram Negative Bacilli

! Other situations, such as complicated infections. Call ID!

How to define treatment duration

Last Updated: May 2024
Next Expected Review: January 2018

Background

Millions of indwelling vascular devices are placed annually for administering medications, fluids, and nutrition. These catheters can become infected, which can cause significant morbidity and mortality. Furthermore, the variety both of vascular devices available and organisms that can cause catheter-related infections makes providing simple and easy-to-follow recommendations for the management of such infections difficult.

This pathway's intent is to standardize – to the extent possible – the diagnosis and management of such central venous catheter infections at Seattle Children's.

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To Initial Culture Phase

To Preliminary cultures, non-tunneled CVC

To Preliminary cultures, tunneled CVC

To Definitive treatment, non-tunneled CVC

To Definitive treatment, tunneled CVC

Introduction – Central Line Infections

This clinical standard work pathway is meant to entail the diagnosis and management of patients with Central Line Infections (CLI). The inclusion and exclusion criteria as are follows:

- Inclusion criteria:
  - Presence of a central venous catheter
    - This includes PICC lines, Broviacs, Hickmans, hemodialysis lines, etc.
  - Suspected CLI among inpatients and Emergency Department patients
- Exclusion criteria:
  - Patients without central venous catheters
  - Ambulatory clinic patients
  - Patients on ECMO
  - Hematology / Oncology patients

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Definition: Suspected CLI

CLI should be suspected in those with a central catheter in place for >24 hours and a new-onset fever or other systemic or local signs of infection such as hypotension or redness, tenderness, or discharge from their central catheter site.

In NICU patients, consider using this pathway for those >7 days of post-natal age and who have central catheters in place for >24 hours.

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Definition: Non-Tunneled and Tunneled Catheters

- ***Non-tunneled catheters*** include peripherally inserted central catheters (PICCs), femoral lines, IJ lines, and other central lines not tunneled under the skin.
- ***Tunneled catheters*** include those tunneled under the skin and placed surgically, such as Hickman catheters, Broviacs, and ports.

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To Initial Culture Phase

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Definition: Risk of Complications

- Low risk:
  - Patients who are immunocompetent, with a single fever or sustained low-grade fever, and without hemodynamic instability, toxic appearance, mental status changes, or indwelling hardware other than their central line (e.g., prosthetic heart valves).
- Higher risk:
  - Patients who are immunocompromised* (receiving immunosuppressive medications, transplant recipients, primary immunodeficiency, HIV), with indwelling hardware other than the central line (e.g., prosthetic heart valves), a right-to-left cardiac shunt of any kind, or otherwise of tenuous clinical status / critically ill.

    * If in doubt, assume a patient to be immunocompromised and / or call Infectious Diseases.

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Definition: Risk Factors for Fungal Disease

- No clear guidelines for when to begin empiric antifungal therapy exist, but typically empiric antifungal therapy should be begun only in the presence of known risk factors.
- *Known risk factors for fungemia include extreme prematurity, prolonged broad-spectrum antibiotics, bone marrow or solid organ transplantation or other abdominal surgery entering a viscus, central venous catheter, corticosteroids, dialysis, necrotizing pancreatitis or ongoing use of parenteral nutrition (Mermel, ✪✪✪○).*

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To Initial Culture Phase
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To Preliminary cultures, tunneled CVC
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To Definitive treatment, tunneled CVC

Blood Culture Recommendations: Initial Fever

- *Do NOT routinely obtain catheter cultures in the absence of suspected CLI. (Mermel, ✪✪✪✪)*
- *Obtain blood cultures prior to initiation of antibiotic therapy. (Mermel, ✪✪✪✪)*
- *Prepare skin and the catheter hub for peripheral culture using either alcohol or tincture of iodine or alcoholic chlorhexidine (10.5%), rather than povidone-iodine, and allow adequate skin contact and drying time. (Mermel, ✪✪✪✪)*

Blood Culture Recommendations: Ongoing Fever

- *Do NOT obtain further blood cultures for patients who are not immunocompromised, do not show signs of sepsis, and are not changing their antibiotic therapy, if initial cultures remain negative thus far. (Bright Star Collaborative)*
- *If obtaining further blood cultures, only culture one peripheral site (preferred option) or one single lumen of the central line. (Bright Star Collaborative)*

Culture All Lumens and Peripherally

- *Catheter-drawn cultures alone are significantly less specific than when peripheral cultures are also performed (Falagas, ✪✪✪○) and result in higher rates of false-positive CLI diagnoses.*
- *Similarly, culturing all lumens and obtaining peripheral cultures add sensitivity to making the diagnosis of CLI. Studies estimate that between 15.8% and 37.3% of all CLI would be missed if not all lumens are sampled (Guembe, ✪✪✪○) and that 12.3% of CLI would be missed had peripheral cultures not been drawn (Scheinemann et al., ✪○○○).*
- Arterial samples are an acceptable alternative to peripheral samples. Some central catheters (e.g., in neonates) cannot be sampled directly.
- Culture the catheter skin exit site if signs of local infection (i.e., redness) and discharge are present.

To Initial Culture Phase

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To Preliminary cultures, tunneled CVC

To Definitive treatment, tunneled CVC

Diagnosis of CLI

Definitive diagnosis of CLI includes any of the following:

- *The same organism growing peripherally and from the catheter tip. (Mermel, ✪✪✪✪)*
- *Growth of microbes from blood drawn through a catheter hub at least 2 hours before microbial growth is detected in blood samples obtained peripherally, with the same volume of blood obtained in each bottle. (Mermel, ✪✪✪✪*
- A quantitative blood culture obtained through the catheter with a colony count of microbes at least 3-fold greater than that from peripheral culture. However, SCH does not currently employ the quantitative blood culture technique.

Diagnosis of CLI (cont'd)

Diagnosis of possible CLI includes the following:

- *2 quantitative blood cultures obtained through 2 catheter lumens in which the colony count for the sample drawn through one lumen is at least 3-fold greater than that from the second lumen. Again, SCH does not currently employ the quantitative blood culture technique. The SCH laboratory does report time to positivity for blood cultures. (Mermel, ✪✪✪○)*

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To Definitive treatment, tunneled CVC

Empiric Therapy for CLI

Use the first day on which negative blood culture results are obtained as day 1 of therapy. (Mermel, ✪○○○)

Use empirical antibiotics as follows:

- Instill antibiotics through the infected catheter when possible.
- *Use piperacillin/tazobactam for empirical CLI therapy in stable immunocompetent and immunocompromised hosts (Mermel, ✪✪✪✪).*
- *Alternatively, for selected immunocompetent patients who are stable and at low risk for complications, antibiotics may be withheld pending culture results (Local consensus, ✪○○○).*
- Use cefepime and linezolid with or without gentamicin for empirical CLI therapy in unstable immunocompetent and immunocompromised hosts.
- *For empirical CLI therapy in patients with hemodialysis catheters, use vancomycin and gentamicin (Mermel, ✪✪✪✪).*
- *Use fluconazole in addition to antibiotics above for patients with any fungal infection risk factors (see risk factors definition slide; Mermel, ✪✪✪○).* Likewise use fluconazole if initial culture results suggest candidal infection (e.g., yeast identified on culture). Use micafungin instead for empiric treatment of patients who were on prior or ongoing fluconazole prophylaxis at the time of developing their invasive fungal infection or are critically ill. Amphotericin B rather than fluconazole is typically used for empiric antifungal treatment of neonates.
- *Some services (e.g., SCCA, ICU) have specific protocols for empiric antimicrobial therapy that may supersede these recommendations.*
- *Administer antibiotics through the colonized catheter (Mermel, ✪○○○).*
  - Alternate lumens if possible.
- *Do NOT routinely use urokinase and other thrombolytic agents as adjunctive therapy for patients with CLI (Mermel, ✪✪✪✪).*

When an organism has been identified and susceptibilities are available, tailor the antibiotics to the narrowest effective agent (see subsequent slides).

To Initial Culture Phase
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Empiric Antibiotic Selection by Clinical Scenario

Immunocompetent patients	Antibiotic selection	Alternatives
Stable, non-toxic, low risk for complications, ongoing monitoring assured	Can defer antibiotics	
Stable, non-toxic, low risk for complications (most patients)	Cefepime	Use meropenem if documented IgE-mediated allergy to cefepime Discuss with Infectious Diseases
Unstable, toxic, severely ill	Cefepime AND linezolid AND gentamicin AND micafungin	Use meropenem if documented IgE-mediated allergy to cefepime Discuss with Infectious Diseases
Concern for fungal infection**	Fluconazole (v)	In patients with ongoing therapy or prophylaxis with fluconazole and + blood culture for yeast, use micafungin; consider Infectious Diseases consult

Immunocompromised* patients	Antibiotic selection	Alternatives
Stable, non-toxic, low risk for complications	Cefepime [AND micafungin if risks for fungal disease]	Use meropenem if documented IgE-mediated allergy to cefepime Discuss with Infectious Diseases
Unstable, toxic, severely ill	Meropenem AND linezolid AND gentamicin AND micafungin if risk for fungal disease	Discuss with Infectious Diseases
Concern for fungal infection**	Fluconazole or discuss with (v) Infection Diseases	In patients with ongoing therapy or prior prophylaxis with fluconazole and + blood culture for yeast, use micafungin; consider Infectious Diseases consult

*See HemOnc suspected infection pathway for management of those patients

***Known risk factors for fungemia include extreme prematurity, prolonged broad-spectrum antibiotics, bone marrow or solid organ transplantation or other abdominal surgery entering a viscus, central venous catheter, corticosteroids, necrotizing pancreatitis, dialysis or ongoing use of parenteral nutrition (Mermel, ✪✪✪○).*

To Initial Culture Phase

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To Definitive treatment, tunneled CVC

Lock Therapy with Catheter Salvage

- *Use lock therapy for all patients with CLI of a long-term catheter without signs of exit site or tunnel infection and for whom catheter salvage is the goal (Mermel, ✪✪✪○).*
- Do NOT routinely use antibiotic lock therapy ALONE for CLI; use antibiotic lock therapy in conjunction with systemic antimicrobial therapy. Use recommended durations based on days of positivity and catheter retention (*for SCH only*).
- *Dwell times for antibiotic locks should be 8-12 hours per day and the lock solution should be administered 1-2 times daily to each lumen (Local consensus, ✪○○○). Do NOT routinely allow antibiotic lock solution dwell times to exceed 48 hours before re-instillation of lock solution. Re-instill lock solution every 24 hours for ambulatory patients with femoral catheters (Mermel, ✪✪✪○). Re-instill lock solution with each dialysis session for patients undergoing hemodialysis (Mermel, ✪✪✪○).*
- *Do NOT routinely use antibiotic lock therapy for CLI due to S. aureus or Candida species and instead remove the catheter, unless there are significant extenuating circumstances (Mermel, ✪✪✪✪).*
- *When vancomycin lock therapy is used, the vancomycin concentration should be at least 1000 times higher than the minimum inhibitory concentration of the microorganism involved (Mermel, ✪✪✪○).*

To Initial Culture Phase

To Preliminary cultures, non-tunneled CVC

To Preliminary cultures, tunneled CVC

To Definitive treatment, non-tunneled CVC

To Definitive treatment, tunneled CVC

Additional Gram-Negative Agent Selection

- Patients who are critically ill with suspected CLI and who have recent colonization or infection with a multi-drug resistant (MDR) gram-negative pathogen should receive gentamicin (or another agent with broad gram-negative activity from an antimicrobial class different than that of the primary antibiotic, such as ciprofloxacin) in addition to cefepime and linezolid as initial therapy; de-escalation of the initial regimen to a single appropriate antibiotic is recommended once culture and susceptibility results are available.
- Questions regarding risk or management of possible MDR infection should be directed to Infectious Diseases.

To Initial Culture Phase

To Preliminary cultures, non-tunneled CVC

To Preliminary cultures, tunneled CVC

To Definitive treatment, non-tunneled CVC

To Definitive treatment, tunneled CVC

Other Evaluation After Fungemia Identified

Additional evaluation for patients with fungemia should include an ophthalmologic exam within the first week of therapy, and if persistent/prolonged fungemia should also include abdominal ultrasound or CT scan of liver, kidneys, and spleen, and echocardiogram, to rule out other disseminated sites of infection (Mermel, ✪✪✪✪; Pappas, ✪✪✪✪).

Based on IDSA guidelines for management of Candidiasis, Pappas et al. 2015

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Catheter Removal

- Add empiric linezolid if a line site infection is suspected (e.g., red streaking or purulence at line site)
- *Remove and culture non-tunneled catheters if the patient is hemodynamically unstable or has erythema overlying the catheter insertion site or purulence at the catheter insertion site (Mermel, ✪✪✪○).*
- *Remove non-tunneled catheters from patients with CLI due to any pathogens other than coagulase-negative staphylococci (e.g., gram-negative bacilli, S. aureus, enterococci, fungi, and mycobacteria (Mermel, ✪✪✪○)).*
- *Remove tunneled catheters from patients with CLI associated with any one of the following complications (Mermel, ✪✪✪○; Freifeld, ✪✪✪○): severe sepsis; suppurative thrombophlebitis; endocarditis; tunnel infection; port abscess; exit site infections that are severe or fail to resolve with antibiotic therapy; CLI due to S. aureus, P. aeruginosa, fungi, or mycobacteria; or any bloodstream infection that continues despite 72 h of antimicrobial therapy to which the infecting microbes are susceptible.*
- *Remove catheters after blood culture contamination is ruled out on the basis of multiple positive culture results, with at least 1 blood culture sample drawn from a peripheral vein, for non-tunneled and tunneled CLI due to less virulent microbes that are difficult to eradicate (e.g., Bacillus species, Micrococcus species, or Propionibacteria), (Mermel, ✪✪✪○).*
- *In any situation when salvage of the catheter is attempted, remove the catheter if blood cultures obtained 72 hours after the initiation of appropriate therapy remain positive (Mermel, ✪✪✪○; Freifeld, ✪✪✪○).*

To Initial Culture Phase

To Preliminary cultures, non-tunneled CVC

To Definitive treatment, non-tunneled CVC

To Preliminary cultures, tunneled CVC

To Definitive treatment, tunneled CVC

Recommendations for Persistently Positive Cultures

- *Once bacteremia or fungemia has been identified, obtain blood cultures daily until cultures remain negative for at least 48 hours to document sterilization (Local consensus, ✪○○○; Shah ✪✪○○).*
- *Whenever salvage of the catheter is attempted in a patient with CLI due to any pathogen, remove the catheter if blood cultures obtained 72 hours after the initiation of appropriate therapy remain positive (Mermel, ✪✪✪○).*
- Evaluate patients with persistently positive blood cultures (bacterial or fungal) and/or ongoing fevers for >72 hours after line removal aggressively for evidence of complicated or metastatic disease, such as endocarditis, suppurative thrombophlebitis, occult abscess or osteomyelitis. Consider Infectious Diseases consultation, echocardiogram, extremity Doppler ultrasound, bone scan, ophthalmologic exam and CT scan of chest/abdomen/pelvis.

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Recommendations for Persistently Positive Cultures (Cont'd)

- Suppurative thrombophlebitis should be considered in the setting of a new, large clot and if blood cultures remain positive after line removal or in the setting of appropriate therapy for >72 hours.
- *Administer antibiotics for 4 to 6 weeks to patients with persistent fungemia or bacteremia occurring >72 hours after catheter removal (Mermel, ✪✪✪✪ for S. aureus infection; ✪○○○ for infection due to other pathogens), to patients with infective endocarditis or suppurative thrombophlebitis, and to pediatric patients with osteomyelitis (Mermel, ✪✪✪✪).*

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To Initial Culture Phase

To Preliminary cultures, non-tunneled CVC

To Preliminary cultures, tunneled CVC

To Definitive treatment, non-tunneled CVC

To Definitive treatment, tunneled CVC

S. aureus Recommendations

- *Remove short-term catheters immediately for patients with S. aureus CLI (Mermel, ✪✪✪✪).*
- *For S. aureus CLI involving long-term catheters, remove the catheter unless there are major contraindications (e.g., there is no alternative venous access, the patient has significant bleeding diathesis, or quality of life issues take priority over the need for reinsertion of a new catheter at another site; Mermel, ✪✪✪✪).*
- For methicillin-susceptible S. aureus, treat with oxacillin (cefazolin is an acceptable alternative).
- For methicillin-resistant S. aureus (MRSA), use linezolid.
- Treat patients with uncomplicated CLI due to S. aureus for 7 days.
- *Consider Infectious Diseases consultation for all patients with S. aureus bacteremia and a high illness severity of multiple comorbidities (Honda, ✪✪○○).*
- *Treat patients for 4-6 weeks if S. aureus CLI is complicated by persistent bacteremia; endocarditis; septic thrombophlebitis; OR metastatic infection (Mermel, ✪✪✪✪).*
- Perform echocardiography in all patients with >1 positive blood culture with S. aureus and any one of the following criteria: underlying structural heart disease; murmur; peripheral stigmata of endocarditis; or persistently positive cultures.
- *If an echocardiogram is performed, perform it at least 5-7 days following onset of bacteremia to minimize the likelihood of a false-negative result (Mermel, ✪✪✪○).*

To Initial Culture Phase

To Preliminary cultures, non-tunneled CVC

To Preliminary cultures, tunneled CVC

To Definitive treatment, non-tunneled CVC

To Definitive treatment, tunneled CVC

Enterococcus Species Recommendations

- *Remove short-term intravascular catheters infected with enterococci (Mermel, ✪✪✪○).*
- *Remove long-term catheters infected with enterococci in cases of insertion site or pocket infection, suppurative thrombophlebitis, sepsis, endocarditis, persistent bacteremia, or metastatic infection (Mermel, ✪✪✪○).*
- *Use lock therapy in addition to systemic therapy if the catheter is retained (Mermel, ✪✪○○).*
- For treatment of uncomplicated CLI due to Enterococcus species in stable patients:
  - *Treat with ampicillin if the isolate is susceptible (Mermel, ✪✪✪○).*
    - *Gentamicin may be added if the isolate is susceptible to gentamicin or shows gentamicin synergy and if the catheter is retained (Mermel, ✪○○○).*
  - Use linezolid if the isolate is resistant to ampicillin.
    - *Gentamicin may be added if the isolate is susceptible to gentamicin or shows gentamicin synergy and if catheter is retained (Mermel, ✪○○○).*
  - Treat for 7 days from first negative culture in cases of uncomplicated enterococcal CLI (*for SCH only*).
- For severe or complicated CLI due to Enterococcus species:
  - Add gentamicin to ampicillin or linezolid if the isolate is susceptible to gentamicin or shows gentamicin synergy.
  - Consult Infectious Diseases if there is high-level gentamicin resistance or for VRE.

To Initial Culture Phase

To Preliminary cultures, non-tunneled CVC

To Definitive treatment, non-tunneled CVC

To Preliminary cultures, tunneled CVC

To Definitive treatment, tunneled CVC

Coagulase-Negative Staphylococci Recommendations

- *If only one culture was positive and the repeat culture drawn prior to the initiation of empirical antibiotics is negative at 48 hours, discontinue antibiotics (Mermel, ✪OOO).*
- If the isolate is methicillin-susceptible, use oxacillin.
  - Cefazolin is an acceptable alternative.
  - Use linezolid for patients with anaphylactic allergies to cefazolin or oxacillin.
- If the isolate is methicillin-resistant, use linezolid.
- For uncomplicated CLI, treat with antibiotics for 3 days if the catheter is removed or for 5-7 days, in combination with lock therapy, if the catheter is retained.
- *Manage CLI due to S. lugdunensis similarly to recommendations above for S. aureus CLI (Mermel, ✪✪✪O).*

To Initial Culture Phase
To Preliminary cultures, non-tunneled CVC
To Definitive treatment, non-tunneled CVC
To Preliminary cultures, tunneled CVC
To Definitive treatment, tunneled CVC

Gram-Negative Bacilli Recommendations

- *For patients who received combination empiric therapy (e.g., piperacillin/tazobactam and gentamicin), de-escalate the initial regimen to a single appropriate antibiotic once culture and susceptibility results are available (Mermel, ✪✪✪✪).*
- Treat for 7 days from first negative blood culture for uncomplicated gram-negative CLI (*for SCH only*).
- Consult ID for complicated infections.

To Initial Culture Phase

To Preliminary cultures, non-tunneled CVC

To Preliminary cultures, tunneled CVC

To Definitive treatment, non-tunneled CVC

To Definitive treatment, tunneled CVC

Candida Species Recommendations

- *Remove catheters in cases of CLI due to Candida species (Mermel, ✪✪✪✪).*
- Depending on the candida species, use fluconazole or micafungin for treatment. The final culture result from microbiology laboratory will help guide antifungal selection, but please page Infectious Disease service for recommendations.
- Treat for 10 days from first negative blood culture for uncomplicated *Candida* CLI (*for SCH only*).
- Consult ID for complicated infections.

To Initial Culture Phase

To Preliminary cultures, non-tunneled CVC

To Preliminary cultures, tunneled CVC

To Definitive treatment, non-tunneled CVC

To Definitive treatment, tunneled CVC

Other Gram-Positive Organism Recommendations

- *Diagnosis of CLI due to Corynebacterium, Bacillus and Micrococcus species requires at least 2 positive results of blood cultures performed on samples obtained from different sites (Mermel, ✪✪✪✪). These organisms can be difficult to eradicate with antimicrobial therapy alone.*
- *For the management of these infections, remove the catheter for patients with a short-term CVC, and for patients with an infected long-term catheter or implanted port, unless there are no alternative intravascular access sites (Mermel, ✪✪OO).*

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To Initial Culture Phase

To Preliminary cultures, non-tunneled CVC

To Preliminary cultures, tunneled CVC

To Definitive treatment, non-tunneled CVC

To Definitive treatment, tunneled CVC

Replacing the Catheter (if needed)

- *The preferred method when a catheter must be replaced is to place the new catheter in a different location. If other vascular sites are unavailable and/or the patient is at increased risk for bleeding diathesis in the setting of CLI not complicated by an exit site or tunnel infection, then attempt exchange of the infected catheter over a guidewire (Mermel, ✪✪○○). In such situations, consider an antimicrobial-impregnated catheter with an anti-infective intraluminal surface for catheter exchange (Mermel, ✪✪○○).*
- Ideally, clearance of the CLI should be documented before replacing the catheter. Documenting clearance typically requires a minimum of 48 hours of negative cultures, but some slow growing organisms may require longer. Questions regarding the risks of replacing the catheter during treatment of a CLI may best be addressed by an Infectious Diseases consultation.

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To Initial Culture Phase

To Preliminary cultures, non-tunneled CVC

To Preliminary cultures, tunneled CVC

To Definitive treatment, non-tunneled CVC

To Definitive treatment, tunneled CVC

Value Tool: IV Fluconazole

DIMENSION	CARE OPTION A	CARE OPTION B	PREFERRED OPTION	ASSUMPTIONS MADE
DESCRIPTION OF CARE TREATMENT OPTION	IV Micafungin for empiric therapy when central line infection due to yeast suspected	IV Fluconazole for empiric therapy when central line infection due to yeast suspected		
OPERATIONAL FACTORS				
Percent adherence to care (goal 80%)	80%	80%	**NEUTRAL**	With both recommendations, some providers may use alternate agent
Care delivery team effects	N/A, both drugs are dosed once daily	N/A	**NEUTRAL**	
BENEFITS / HARMS (QUALITY/OUTCOME)				
Degree of recovery at discharge	Local data indicates that fluconazole	Local data indicates that fluconazole	NEUTRAL	
Effects on natural history of the disease over equivalent time	May cover fluconazole-resistant candida species		OPTION A	
Potential to cause harm	Few adverse effects	May cause elevation of liver enzymes, however very	NEUTRAL	
Palatability to patient/family	Generally not unpalatable	Generally not unpalatable	NEUTRAL	
Population-related benefits	none	May help to decrease spread of resistant candida	OPTION B	
Threshold for population-related benefits reached	n/a	unlikely due to small numbers		
COST (Arising from Options A or B) - express as cost per day				
"ROOM RATE" ($ or time to recovery)				[estimate annual patient volume]
"Dx/Rx" costs ($)	$193/day x 3 days empiric therapy = $579/patient	$106 x 3 days = $318	OPTION B	Unclear- up to 40-60 patients/year
COST (Complications/adverse effects arising from Options A or B)- express as cost per day				
"ROOM RATE" ($ or time to recovery)				[estimate probability of complication]
"Dx/Rx" costs ($)	N/A	N/A		

STEP 3: APPLY VALUE ANALYSIS GRID

	BENEFIT (QUALITY & OUTCOMES)			
COST	**A > B**	**A = B**	**A < B**	**Unclear**
A costs more than B	Make value judgement	B	B	Do B and PDSA in 1 year
A and B costs are the same	A	A or B, operational factors may influence choice	B	A or B, operational factors may influence choice, PDSA in 1 year
B costs more than A	A	A	Make value judgement	Do A and PDSA in 1 year

STEP 4: CREATE VALUE STATEMENT

FINAL CSW VALUE STATEMENT	*IV Fluconazole is preferred as empiric therapy for possible fungal central line infection because rates of fluconazole resistant candida at our institution are low, adverse effects are few and it is less costly than micafungin therapy . This approach will also minimize exposure to echinocandins and thereby decrease development of resistance. Key assumptions include the idea that candida albicans and parapsilosis will remain the most frequent species of candida identified at our hospital. This recommendation is based on microbiology data from Seattle Childrens Hospital and University of Washington and the cost dashboard. A cost-minization approach was applied.*

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Central Line Infection Approval & Citation

Approved by the CSW Central Line Infection for July 1, 2015

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Surgeon-in-Chief	Bob Sawin, MD

Retrieval Website: https://www.seattlechildrens.org/pdf/central-line-infection-pathway.pdf

Please cite as:
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Evidence Ratings

This pathway was developed through local consensus based on published evidence and expert opinion as part of Clinical Standard Work at Seattle Children's. Pathway teams include representatives from Medical, Subspecialty, and/or Surgical Services, Nursing, Pharmacy, Clinical Effectiveness, and other services as appropriate.

When possible, we used the GRADE method of rating evidence quality. Evidence is first assessed as to whether it is from randomized trial or cohort studies. The rating is then adjusted in the following manner (from: Guyatt G et al. J Clin Epidemiol. 2011;4:383-94.):

Quality ratings are *downgraded* if studies:

- Have serious limitations
- Have inconsistent results
- If evidence does not directly address clinical questions
- If estimates are imprecise OR
- If it is felt that there is substantial publication bias

Quality ratings are *upgraded* if it is felt that:

- The effect size is large
- If studies are designed in a way that confounding would likely underreport the magnitude of the effect OR
- If a dose-response gradient is evident

Guideline – Recommendation is from a published guideline that used methodology deemed acceptable by the team.

Expert Opinion – Our expert opinion is based on available evidence that does not meet GRADE criteria (for example, case-control studies).

Quality of Evidence:

✪✪✪✪ High quality
✪✪✪○ Moderate quality
✪✪○○ Low quality
✪○○○ Very low quality
Guideline
Expert Opinion

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Summary of Version Changes

- **Version 1.0 (1/23/2013):** Go live.
- **Version 1.1 (12/17/2013):** Updated “stop sign” inclusion criteria to clarify that hemodialysis catheters are included.
- **Version 2.0 (7/1/2015):** Updated recommendations for empiric and targeted antifungal therapy to recommend fluconazole as empiric therapy for most patients.
- **Version 3.0 (2/23/2016):** CSW value analysis completed including review of the fluconazole recommendation; updated to reflect 2016 IDSA guidelines for treatment of Candidiasis.
- **Version 4.0 (2/1/2018):** Updated the recommendations for treatment of enterococcus. Added more guidance around the issue of suppurative thrombophlebitis.
- **Version 5.0 (3/30/2018):** Updated the recommendations for empiric therapy from pip/tazo to cefepime.
- **Version 6.0 (9/29/2020):** Updated exclusion criteria to include Sickle Cell patients. Corrected email address.
- **Version 7.0 (8/5/2021):** Updated the Initial Blood Culture phase of the algorithm to include blood culture stewardship guidance to reduce unnecessary blood cultures.
- **Version 8.0 (12/23/2022):** Updated Initial Culture, Definitive Treatment Non-tunneled CVCs, and Definitive Treatment Tunneled CVCs phases with a reminder to infuse antimicrobials through central lines. Updated safety alerts in Definitive Treatment Non-tunneled CVCs and Definitive Treatment Tunneled CVCs phases to be more explicit about obtaining ECHOs.
- **Version 8.1 (6/30/2023):** Updated Lock Therapy information page training slides per P&T request - removed mention of ethanol locks and SCH policy. Ethanol has been restricted to cardiac ablations and the policy was retired.
- **Version 9.0 (5/30/2024):** Changed vancomycin to linezolid, nafcillin to oxacillin, and treatment durations. Medication dosages reviewed and approved by Pharmacy and Therapeutics Committee on 5/21/2024.

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Medical Disclaimer

Medicine is an ever-changing science. As new research and clinical experience broaden our knowledge, changes in treatment and drug therapy are required.

The authors have checked with sources believed to be reliable in their efforts to provide information that is complete and generally in accord with the standards accepted at the time of publication.

However, in view of the possibility of human error or changes in medical sciences, neither the authors nor Seattle Children’s Healthcare System nor any other party who has been involved in the preparation or publication of this work warrants that the information contained herein is in every respect accurate or complete, and they are not responsible for any errors or omissions or for the results obtained from the use of such information.

Readers should confirm the information contained herein with other sources and are encouraged to consult with their health care provider before making any health care decision.

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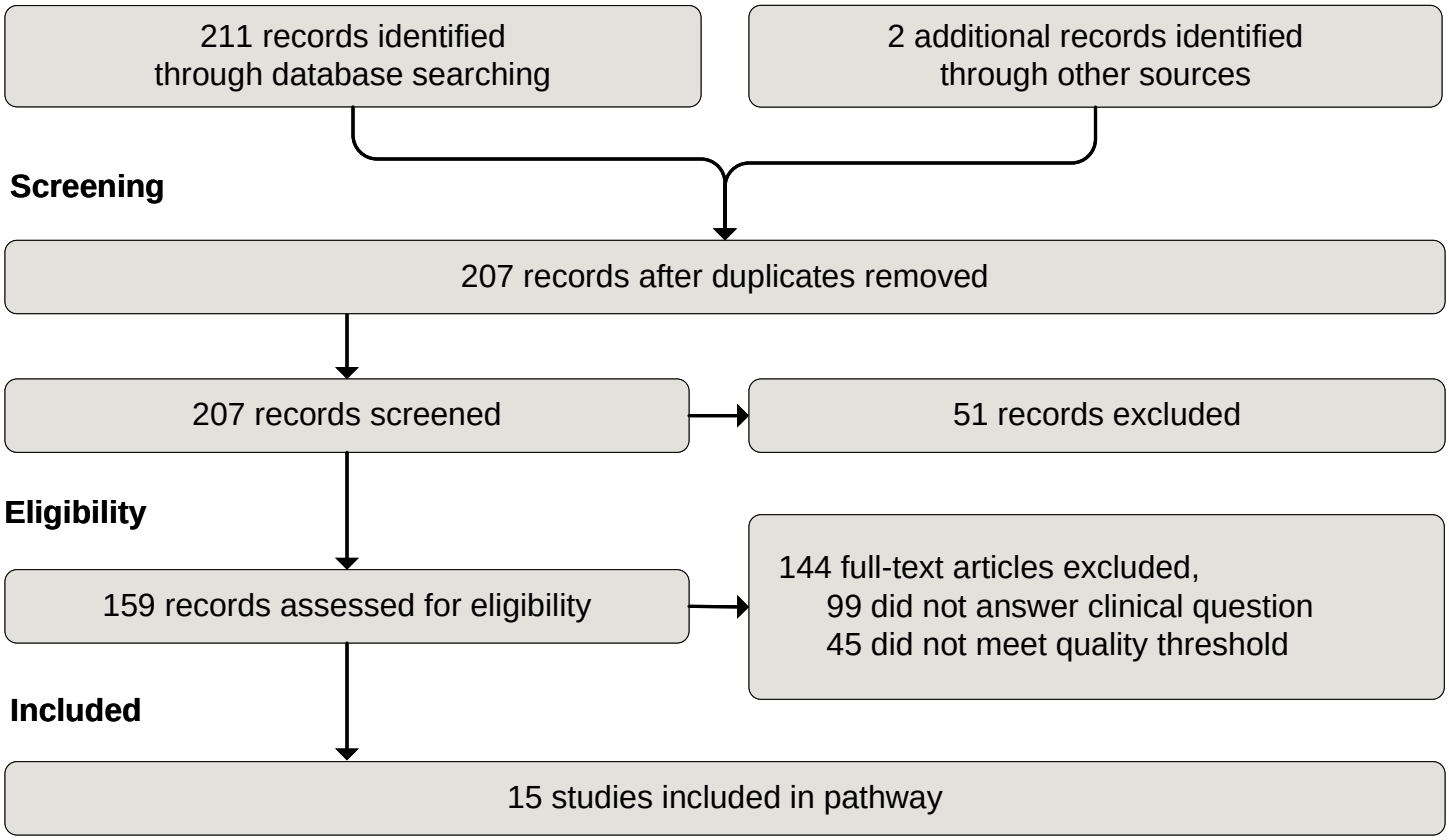
Bibliography

Search Methods, Central Line Infection, Clinical Standard Work

Studies were identified by searching electronic databases using search strategies developed and executed by a medical librarian, Susan Klawansky. Searches were performed in July 2012, from 2008 (the year prior to a major IDSA guideline on the topic) to date. The following databases were searched – on the Ovid platform: Medline, Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials; elsewhere – Embase, Clinical Evidence, National Guideline Clearinghouse and TRIP. Retrieval was limited to humans and English language. In Medline and Embase, appropriate Medical Subject Headings (MeSH) and Emtree headings were used respectively, along with text words, and the search strategy was adapted for other databases using their controlled vocabularies, where available, along with text words. Concepts searched were central venous catheters, including dozens of alternative phrases; catheter-related infections, including specific bacterial infections; and terms for diagnosis and management, such as anti-infective agents, including specific agents, microbial sensitivity tests, ethanol, device removal, diagnostic techniques and procedures, and subheadings for diagnosis, therapy and drug therapy. All retrieval was further limited to certain evidence categories, such as relevant publication types, Clinical Queries, index terms for study types and other similar limits.

Susan Klawansky, MLS, AHIP
January 3, 2013

Identification



Flow diagram adapted from Moher D et al. BMJ 2009;339:bmj.b2535

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To Bibliography, Pg 2

Bibliography

- Acuña M, O'Ryan M, Cofré J, Alvarez I, Benadof D, Rodríguez P, Torres MT, Aguilera L, Santolaya ME. Differential time to positivity and quantitative cultures for noninvasive diagnosis of catheter-related blood stream infection in children. *Pediatr Infect Dis J. 2008 Aug;27(8):681-5.*

- Al Wohoush I, Cairo J, Rangaraj G, Granwehr B, Hachem R, Raad I. Comparing Quantitative Culture of a Blood Sample Obtained through the Catheter with Differential Time to Positivity in Establishing a Diagnosis of Catheter-Related Bloodstream Infection. *Infect Control Hosp Epidemiol 2010;31(10):1089-1091.*

- Anoop P, Anjay MA. Role of Antibiotic Line Locks in the Treatment of Infected Central Venous Access Devices. *Arch Dis Child 2009;94:556-559. Mermel LA, Allon M, Bouza E, et al. Clinical Practice Guidelines for the Diagnosis and Management of Intravascular Catheter-Related Infection: 2009 Update by the Infectious Diseases Society of America. Clin Infect Dis 2009:49:1-45*

- Broom J, Woods M, Allworth A, McCarthy J, Faoagali J, Macdonald S, Pithie A. Ethanol lock therapy to treat tunnelled central line-associated blood stream infections: results from a prospective trial. *Scand J Infect Dis. 2008;40(5):399-406.*

- Bookstaver PB, Gerrald KR, Moran RR. Clinical outcomes of antimicrobial lock solutions used in a treatment modality: a retrospective case series analysis. *Clin Pharmacol. 2010;2:123-30.*

- Del Pozo JL, Rodil R, Aguinaga A, Yuste JR, Bustos C, Montero A, Espinosa G, García-Fernández N. Daptomycin lock therapy for grampositive long-term catheter-related bloodstream infections. *Int J Clin Pract. 2012 Mar;66(3):305-8.*

- Falagas ME, Kazantzi MS, Bliziotis IA. Comparison of utility of blood cultures from intravascular catheters and peripheral veins: a systematic review and decision analysis. *J Med Microbiol. 2008 Jan;57(Pt 1):1-8.*

- Freifeld AG, Bow EJ, Sepkowitz KA, Boeckh MJ, Ito JI, Mullen CA, Raad II, Rolston KV, Young JA, Wingard JR, Infectious Diseases Society of America. Clinical practice guideline for the use of antimicrobial agents in neutropenic patients with cancer: 2010 update by the infectious diseases society of america. *Clin Infect Dis. 2011 Feb 15;52(4):e56-93.*

- *Funalleras G, Fernández-Hidalgo N, Borrego A, Almirante B, Planes AM, Rodríguez D, Ruiz I, Pahissa A. Effectiveness of antibiotic-lock therapy for long-term catheter-related bacteremia due to Gram-negative bacilli: a prospective observational study. Clin Infect Dis. 2011 Nov;53(9):e129-32.*

- *Greenberg RG, Moran C, Ulshen M, Smith PB, Benjamin Jr. DK, Cohen-Wolkowiez M. Outcomes of Catheter-associated Infections in Pediatric Patients With Short Bowel Syndrome. JPGN 2010;50:460-462.*

- *Guembe M, Rodriguez-Creixems M, Sanchez-Carrillo C, Perez-Parra A, Martin-Rabadan P, Bouza E. How Many Lumens Should be Cultured in the Conservative Diagnosis of Catheter-Related Bloodstream Infections? Clin Infect Dis 2010;50(12):1575-1579.*

- *Guembe M, Martin-Rabadan P, Echenagusia A, Camunez F, Rodriguez-Rosales G, Simo G, Echenagusia M, Bouza E. J Clin Microiol 2012;50(3):1003-1007.*

- *Guttmann DM, Trerotola SO, Clark TW, Dagli M, Shlansky-Goldberg RD, Itkin M, Soulen MC, Mondschein JI, Stavropoulos SW. Malfunctioning and Infected Tunneled Infusion Catheters: Over-the-Wire Catheter Exchange versus Catheter Removal and Replacement. J Vasc Interv Radiol 2011;22:642-646.*

- *Haag GM, Berger AK, Jager D. Treatment of long-term catheter-related bloodstream infections with a taurolidine block: a single cancer center experience. J Vasc Access 2011;12(3):244-247.*

- *Halm M, Hickson T, Stein D, Tanner M, VandeGraaf S. Blood Cultures and Central Catheters: Is the "Easiest Way" Best Practice? Am J Crit Care 2011;20:335-338.*

- *Hemels MAC, van den Hoogen A, Verboon-Maciolek MA, Fleer A, Krediet TG. Shortening the Antibiotic course for the Treatment of Neonatal Coagulase-Negative Staphylococcal Sepsis: Fine with Three Days? Neonatology 2012;101:101-105*

- *Honda H, Krauss MJ, Jones JC, Olsen MA, Warren DK. The Value of Infectious Diseases Consultation in Staphylococcus aureus Bacteremia. Am J Medicine 2010;123:631-637.*

Return to Home

To Bibliography, Pg 3

Bibliography

- Liu CY, Huang LJ, Wang WS, Chen TL, Yen CC, Yang MH, Hsiao LT, Liu CY, Chen PM, Chiou TJ. Candidemia in cancer patients: impact of early removal of non-tunneled central lines on outcome. *J Infect*. 2009 Feb;58(2):154-60.

- Labelle AJ, Micek ST, Roubinian N, Kollef MH. Treatment-related risk factors for hospital mortality in Candida bloodstream infections. *Crit Care Med*. 2008 Nov;36(11):2967-72.

- McGrath EJ, Salloum R, Chen X, Jiang Y, Boldt-MacDonald K, Becker C, Chu R, Ang JY. Short-dwell Ethanol Lock Therapy in Children Is Associated With Increased Clearance of Central Line-Associated Bloodstream Infections. *Clin Pediatr* 2011;50:943-951.

- Megged O, Shalit I, Yaniv I, Fisher S, Livni G, Levy I. Outcome of antibiotic lock technique for persistent central line-associated coagulase-negative *Staphylococcus* bacteremia in children. *Eur J Clin Microbiol Infect Dis* 2010;29:157-161.

- Mermel LA, Allon M, Bouza E, et al. Clinical Practice Guidelines for the Diagnosis and Management of Intravascular Catheter-Related Infection: 2009 Update by the Infectious Diseases Society of America. *Clin Infect Dis* 2009:49:1-45

- Nucci M, Anaissie E, Betts RF, Dupont BF, Wu C, Buell DN, Kovanda L, Lortholary O. Early Removal of Central line in Patients with Candidemia Does Not Improve Outcome: Analysis of 842 Patients from 2 Randomized Clinical Trials. *Clin Infect Dis* 2010;51(3):295-303.

- O'Horo JC, Silva GLM, Safdar N. Anti-Infective Locks for Treatment of Central Line-Associated Bloodstream Infection: A Systematic Review and Meta-Analysis. *Am J Nephrol* 2011;34:415-422.

- Onder AM, Chandar J, Simon N, Diaz R, Nwobi O, Abitbol CL, Zilleruelo G. Comparison of tissue plasminogen activator-antibiotic locks with heparin-antibiotic locks in children with catheter-related bacteraemia. *Nephrol Dial Transplant*. 2008 Aug;23(8):2604-10.

- Onder AM, Billings A, Chandar J, Francoeur D, Simon N, Abitbol C, Zilleruelo G. PREFABL: predictors of failure of antibiotic locks for the treatment of catheter-related bacteraemia. *Nephrol Dial Transplant*. 2010 Nov;25(11):3686-93.

- Pappas PG, Kauffman CA, Andes D, et al. Clinical Practice Guidelines for the Management of Candidiasis: 2016 Update by the Infectious Diseases Society of America. *Clin Infect Dis* 2015:62(4):e1-e50.

- Park KH, Cho OH, Lee SO, Choi SH, Kim YS, Woo JH, Kim MN, Lee DH, Suh C, Kim DY, Lee JH, Lee JH, Lee KH, Kim SH. Outcome of attempted Hickman catheter salvage in febrile neutropenic cancer patients with *Staphylococcus aureus* bacteremia. *Ann Hematol* 2010;89:1163-1169.

- Raad I, Kassar R, Ghannam D, Chaftari AM, Hachem R, Jiang Y. Management of the Catheter in Documented Catheter-Related Coagulase-Negative Staphylococcal Bacteremia: Remove or Retain? *Clin Infect Dis*. 2009;49:1187-1194.

- Scheinemann K, Ethier MC, Dupuis LL, Richardson SE, Doyle J, Allen U, Sung L. Utility of peripheral blood cultures in bacteremic pediatric cancer patients with a central line. *Support Care Cancer* 2010;18:913-919.

- Shah SS, Downes KJ, Elliott MR, Bell LM, McGowan KL, Metlay JP. How long does it take to "rule out" bacteremia in children with central lines? *Pediatrics*. 2008 Jan;121(1):135-41.

- Slobbe L, El Barzouhi A, Boersma E, Rijnders BJ. *J Clin Microbiol*. 2009 Apr;47(4):885-8.

- Tsai MH, Hsu JF, Lien R, Huang HR, Chiang CC, Chu SM, Liang HF, Huang YC. Catheter management in neonates with bloodstream infection and a percutaneously inserted central line in situ: Removal or not? *Am J Infect Control* 2012;40:59-64.

- Valentine KM. Ethanol lock therapy for catheter-associated blood stream infections in a pediatric intensive care unit. *Pediatr Crit Care Med* 2011;12(6):e292-e296.

- Wintenberger C, Epaulard O, Hincky-Vitrat V, Brion LP, Recule C, Francois P, Stahl JP, Pavese P. Outcome of central line-related bacteraemia according to compliance with guidelines: experience with 91 episodes. *J Hosp Infect* 2012;80:245-251.

- Wong T, Clifford V, McCallum Z, Shalley H, Peterkin M, Paxton G, Bines JE. Central line thrombosis associated with 70% ethanol locks in pediatric intestinal failure patients on home parenteral nutrition: a case series. *J Parenter Enteral Nutr*. 2012 May;36(3):358-60.

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Bibliography

Additional References

- Woods-Hill, Z., Koontz, D.W., Voskertchian, A., Anping, X., Shea, J., Miller, M.R., Fackler, J.C., Milstones, A.M. The Bright Star Consensus Authorship Group. Pediatric Critical Care Medicine Journal. 2021.

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