Central Venous Catheter-Related Venous Thromboembolism Guidelines

Purpose

Central venous catheters are often necessary to provide life-sustaining treatments to hospitalized patients. Although essential for treatment, they also have associated morbidity. The principal among these is the risk of venous thromboembolism. The purpose of this guide is to assist providers in minimizing this risk by carefully considering the type, location, and size of the catheter. As with all guidelines, providers should consider these recommendations in light of individual patient's needs, which may preclude adherence to the guidance presented here.

Eligibility Criteria: Patients of any age admitted to DCMC requiring a central venous catheter, excluding umbilical venous catheters or *surgically* placed tunneled lines (e.g., Hickman and Broviac catheters, ports).

Summary of Recommendations:

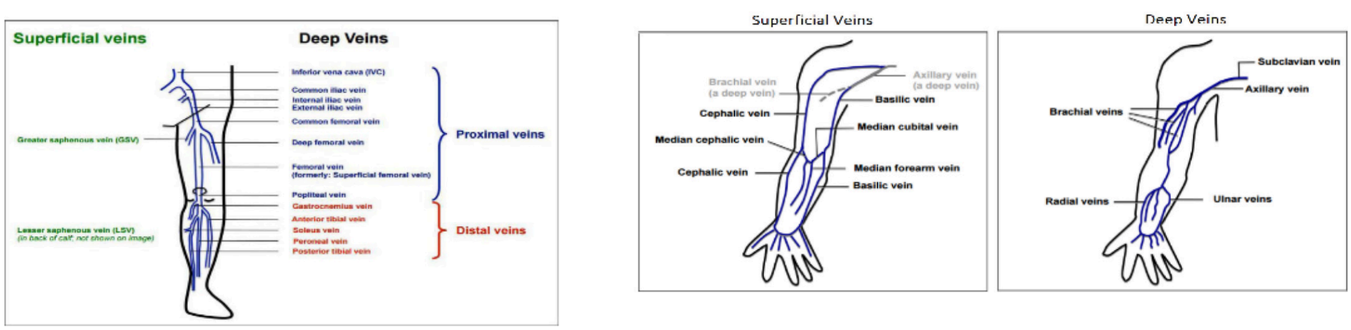
- Use the catheter-to-vessel diameter ratio to guide the choice of catheter size whenever possible.
- Use internal jugular (IJ) or subclavian sites whenever possible.
- Place IJ and subclavian on the right side whenever possible.
- Place upper extremity catheter tips in the lower third of the SVC by the right atrium unless contraindicated.
- Use as few lumens as medically necessary.
- Consult hematology early if the patient has a history of prior VTE or additional risk factors such as a family history of VTE in a 1st degree relative, cancer, systemic infection, gastrointestinal/liver disease, or renal failure requiring dialysis or nephrotic syndrome among others for consideration of preventative anticoagulation.

Definitions:

- Central venous lines (CVCs) include peripherally inserted central venous catheters (PICCs), midline catheters, and central venous lines (non-tunneled, tunneled, and ports).
- Non-tunneled central lines are inserted directly into the vein without forming a tract within the skin.
- Tunneled central lines are placed subcutaneously, forming a tunnel under the skin before entry into the vein to increase line stability and decrease the risk of infection. Please **note that** surgically placed tunneled lines have a cuff that facilitates tissue formation, anchors the catheter, and minimizes bacterial migration. PICC tunneled catheters do not have a cuff and thus are not as stable nor decrease the risk of infection to the same degree, but can be removed by non-surgical providers.
- Venous thromboembolism (VTE) includes deep vein thrombosis (DVT) and superficial vein thrombosis (SVT).
- Superficial veins drain blood from the skin and superficial fascia, whereas deep veins drain blood from the deeper fascia, muscles, and bones; anatomy has been demonstrated in **Figure 1** (Doan, 2021).

Figures

Figure 1: Deep vs Superficial Vein Anatomy Upper and Lower Extremity (Doan, 2021)



Epidemiology:

The most prevalent risk factor for venous thromboembolism (VTE) development in children is the presence of a central venous catheter (CVC) (Jaffray, 2018). The rate of CVC placement is increasing in the pediatric population (Kreuziger, 2017).

Incidence:

The incidence of CVC-related VTE varies largely on study design and patient population (Jaffray, 2017). CVC-related thrombosis has been estimated between 50-80% of all

VTEs in pediatric populations, compared to only 10% in adult populations (Sridhar, 2020).

Etiology:
CVC contributes to VTE formation via endothelial injury, which leads to inflammation, thrombus formation, and intimal hyperplasia (Forauer, 2003). In conjunction with patient factors such as hypercoagulable states and other factors contributing to stasis, this injury raises the risk of thrombosis for patients with CVC (Wall, 2016).

Primary Prevention:

Insertion - Risk Reduction for CVC-related VTE:

Catheter-to-vessel ratio

- Literature Review: Simulated models have found that successively increasing catheter size causes a statistically significant decrease in flow rate and increase in turbulent flow along the catheter length (Nifong, 2011, Shridhar, 2020). Historically, it has been accepted that 33% of the vein should be occupied by the catheter and not more. This conveniently translates into the ideal catheter size (in Fr) being equal to the diameter of the vessel and is widely known as the ‘rule of thumb.’ However, there is limited evidence in clinical practice regarding the exact catheter-to-vessel ratio that should be used. A single hospital study with pediatric patients found that a catheter-to-vein diameter ratio (CVR) greater than 33% contributes to a greater risk of thrombosis (Menedez, 2016). More recently, this ratio has been questioned. A large adult prospective multicenter study concluded that a catheter-to-vein diameter ratio of 45% predicted symptomatic catheter-related VTE with a 13-fold increased risk when this threshold was violated (Sharp, 2014). This standard is currently supported by the Infusion Therapy Standards of Practice (Gorski,2021). In 2017, Spencer and Mahoney challenged the idea that the diameter should be used to determine the catheter-to-vessel ratio. Instead, they proposed that since the vessel is a 3-dimensional object area, no diameter should be used to calculate this ratio. The resulting “ CVR tool “ has appeared in published guidelines such as the Michigan Hospital Medicine Safety Consortium. However, this approach has not been tested and may lead to a catheter selection that is too large (e.g., recommends up to 6Fr catheter in a 3mm diameter vessel).

➤➤ *Recommendation*: In consultation with the vascular access team and interventional radiology, the committee reviewed Spencer’s theoretical catheter-to-vein area ratio tool based on catheter and vessel area and determined that this recommendation was not adequately supported in the literature and clinical practice. We therefore recommend that providers use a catheter-to-vessel diameter ratio to guide the choice of the catheter.

Based on the minimal literature and expert opinion, a CVR ratio of **33% or less is preferred**, 33-45%, CVR cautionary, >45% high risk. See (Figure 2).

Location of CVC

- Literature Review: Currently, most studies support the placement of CVCs in the internal jugular and subclavian veins over the femoral vein to reduce CVC-related VTEs(Jaffray, 2017; Shah, 2015; Latham, 2014; Derderian,2018). However, it is important to remember that thrombosis of the femoral and subclavian veins is more likely to be reported given symptomatic presentations. In contrast, jugular vein thrombosis may remain silent, given collateral drainage (Latham, 2014). In addition, other risks, such as pneumothorax or chylothorax, need to be considered with subclavian vein insertion (Parienti, 2015).

  When considering the side of insertion, studies have shown a higher incidence of VTE with left-sided CVC compared to right-sided CVC due to contrasting anatomy favoring right-sided unobstructed flow and decreased endothelial disturbance (Sridhar, 2020).

  ➤➤ Recommendation: Based on the literature, the femoral vein consistently appears to have the highest risk for *clinically significant* thrombosis and should be considered a significant risk factor for catheter-related VTE in children. Additionally, when inserting central catheters into the upper body vein, they should preferentially be inserted on the right side due to the anatomy of the upper venous drainage systems.

  This recommendation may be influenced by cardiac anatomy in patients with congenital heart disease. In addition, the Kidney Disease Outcomes Quality Initiative recommends avoiding placement of CVCs in the non-dominant subclavian or upper extremity vessels in patients with stage 4 or 5 CKD who may require future placement of an AV fistula.

Location of catheter and catheter tip within the vessel:

- Literature Review: The ideal place for the catheter tip is at the RA-SVC junction. Patients are seven times more likely to develop VTE when the catheter tip ends in the proximal SVC. (Luciani). There is less risk for clotting when the tip ends in the distal SVC due to increased SVC flow. (Sridhar, 2020). Furthermore, if the catheter traverses a sharp bend, it is important to continue advancing the catheter so that the tip is along the same axis of the vessel to avoid catheter-tip-associated endothelial damage; this becomes more important with insertion from the left side (Fletcher, 2000; Sridhar, 2020). When PICC lines are inserted, efforts should be made to reduce the risk of SVTs, which are more frequent than DVTs (Menedez, 2016). This is likely because they occupy a larger proportion of the vessel's intraluminal diameter (Chopra, 2013; Geerts, 2014).

➤➤ Recommendation: Upper body catheter tips should be positioned by the right atrium in the lower third of the superior vena cava (SVC). Catheter tips should remain within the same axis as their respective venous terminus. When PICCs are placed in the upper extremities, efforts should be made to place them above the antecubital fossa and into larger vessels with optimization of catheter-to-vein ratio to decrease the risk of SVT and possible progression to DVT.

One exception to this recommendation is for patients with single ventricle anatomy in whom SVC clots would be catastrophic. In these cases, providers may elect to place the catheter tip proximal to the SVC.

Number of Lumens:

- Literature Review: A meta-analysis of four adult studies demonstrated that patients with multiple lumens are three times more likely to have catheter-related venous thrombosis than those with a single lumen (Liu, 2022). Although these studies did not control for the variations in overall catheter size (Fr) in the setting of multiple lumens, increased lumens have been associated with increased thrombosis risk in adult patients with PICC lines ((Bhargava, 2020; Zochios, 2014). This makes theoretical sense in that the smaller caliber of each individual lumen would be expected to increase turbulence and restrict flow, which might lead to thrombosis formation.
  ➤➤ Recommendation: Based on the above studies and theoretical plausibility, we recommend that catheters contain as few lumens as medically necessary (Ullman, 2020).

Type of Central Venous Catheter:

- Literature Review: Although PICC lines have been associated with a higher risk of thrombosis than surgically tunneled CVC (Jaffray, 2020), data regarding PICC and non-surgically tunneled CVCs is conflicting. A meta-analysis of 11 studies of ~3790 adult patients demonstrated that PICCs were associated with an increased risk of DVT compared with other CVCs (Chopra, 2013). This was not supported by a recent retrospective single-institution pediatric study (Clark 2022), which found no difference. The risk of DVT in midline catheters is similar, if not greater, than in other more invasive devices such as PICC (Bahl 2019). In choosing between a non-tunneled CVL and PICC line, other factors should be considered, including safety of placement, risk of CLASBI, need for hemodynamic monitoring, and duration of need for central access.

➤➤ Recommendation: There is insufficient evidence to recommend one type of line over the other (centrally placed non-surgically tunneled CVC vs. PICC) to minimize thrombosis, and other factors, as outlined above, should be considered.

Patient and Treatment Related Factors: History of Venous Thromboembolism:

- Literature Review: Children who have a prior history of DVT are more likely to develop DVT with subsequent CVC placement, regardless of previous location of DVT (Jaffray, 2020, Liu, 2022, Clark, 2022, Bauman, 2017).

  ➤➤ Recommendation: Before line placement, providers are encouraged to review the patient's medical history, including hematology notes (if available) and ultrasound vessel imaging to determine if there is a history of DVT. If there is a history of CVC-related DVT or unprovoked DVT, early consultation with Hematology regarding preventive anticoagulation is recommended (Clark, 2022). This risk is increased in children with congenital heart disease, full TPN dependence, and more than one CVC (Clark, 2022). There is currently a lack of data to support the use of preventative anticoagulation in patients with a history of superficial vein thrombosis. (Bates,2013)

Additional Patient and Treatment-Related Factors

- Literature Review: In addition to the factors outlined above, recent meta-analyses have investigated the role of underlying disease states with the risk of CVC-related DVT. Among the most commonly cited patient-related factors in adult and pediatric studies were cancer, systemic infection, and gastrointestinal and liver disease (Tian 2021, Lui 2022) . The history of VTE in a first-degree relative is associated with risk (Revel-Vilk, 2010), although the role of inherited thrombophilia is unclear (van Ommen, 2017). Treatment-related factors often cited include parental nutrition, ECMO, and hemodialysis (Tian 2021, Clark 2022). This list is not comprehensive and other risk factors associated with non-line associated VTE (see EBOC VTE Prophylaxis Guideline) should also be considered when assessing patient risk.

➤➤ Recommendation: Although there is limited and sometimes conflicting data, we recommend that providers determine whether the patient has comorbid conditions or is undergoing treatments that increase the risk of VTE. If present, consider consulting hematology to determine if additional preventative measures such as anticoagulation are warranted. (see next section)

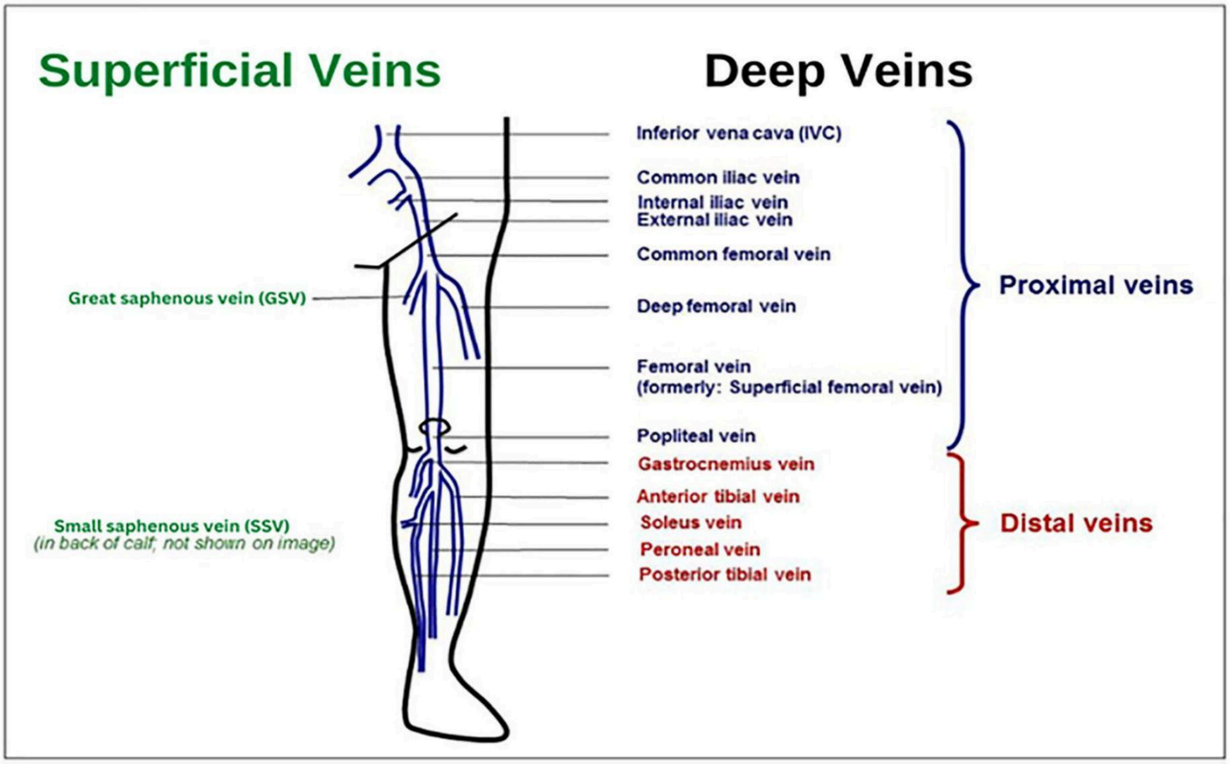
Role of anticoagulation in the prevention of CVC-related VTE

- Literature Review: There is no clear consensus regarding the role of anticoagulation in preventing CVC-VTE. Several studies using prophylactic dosing strategies for the primary prevention of CVC VTE have not demonstrated efficacy. (Pelland-Marcotte 2020) A small phase 2B trial examining the role of early prophylaxis (<24 hrs. from CVL placement) was inconclusive (Faustino, 2021). One single-center retrospective study compared treatment dose enoxaparin to prophylactic dosing demonstrated decreased odds of recurrent CVC-VTE (odds ratio [OR] 0.35; 95% CI 0.19-0.65) with full dosing but not prophylactic dosing (OR 0.61; 95% CI 0.28-1.30) with low rate of major bleeding (Clark 2022).

➤➤ Recommendations: Based on the limited nature of current evidence and the lack of large randomized clinical trials, we cannot offer global recommendations on the use, timing, or dose of enoxaparin to prevent CVC-related thrombosis. These decisions should be made in consultation with hematology based on the individual patient's associated thrombosis and bleeding risks.

Figures

Figure 1: Deep vs Superficial Vein Anatomy Upper and Lower Extremity (Doan, 2021)



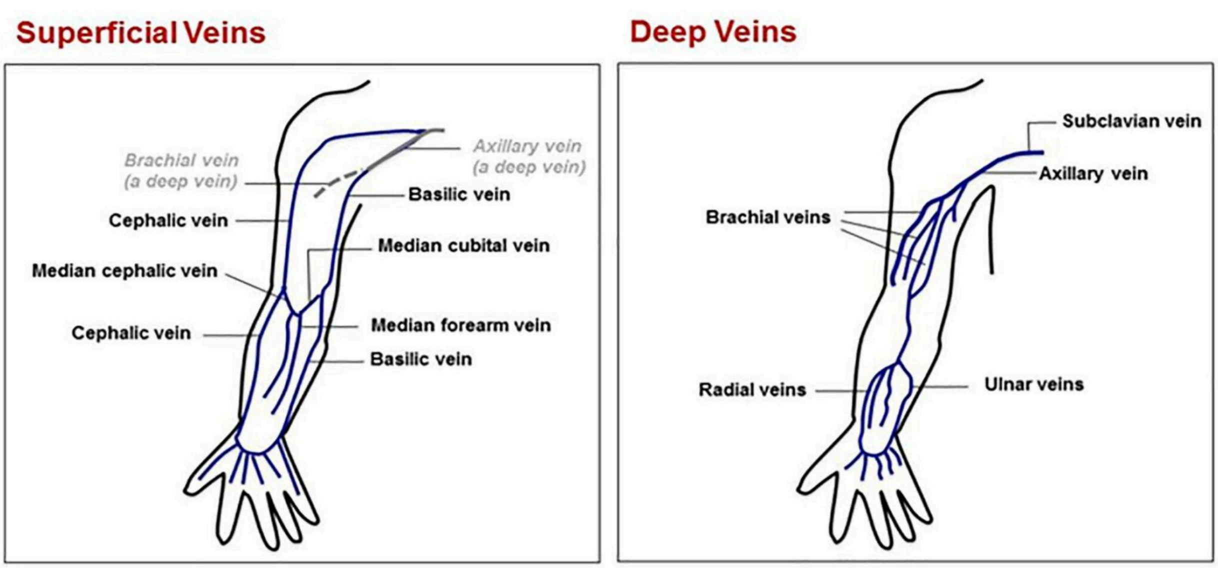


Figure 2: Ultrasound measurement of vessel diameter (Spencer, 2017)

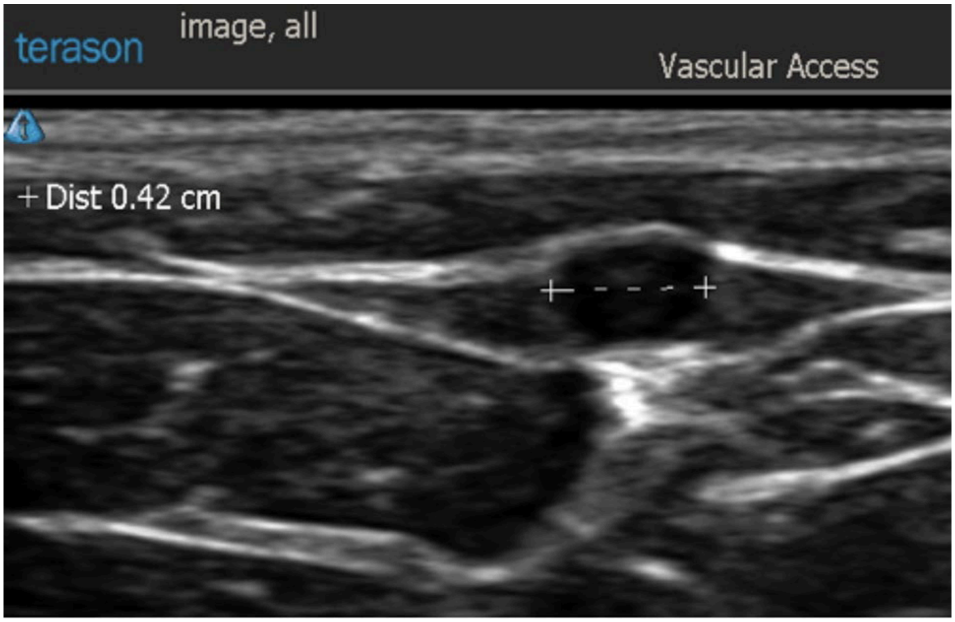


Figure 3.
Recommended catheter size based on CVR ratio (diameter).
Vessel Diameter should be measured with ultrasound without a tourniquet.

Catheter size[1]	Catheter size in mm (rounded)	Minimum Vessel size mm (33%) [2]	Minimum vessel size mm (45%)
1.4 F [3]	0.47	1.4	1.0
1.9 F [3]	0.63	1.9	1.4
2.7 F	0.90	2.7	2.0
3 F	1.00	3.0	2.2
4 F	1.33	4.0	3.0
5 F	1.67	5.1	3.7
6 F	2.00	6.1	4.4
7 F	2.33	7.1	5.2
8 F	2.67	8.1	5.9
9 F	3.00	9.1	6.7
10 F	3.33	10.1	7.4
11 F	3.67	11.1	8.2

11.5 F	3.83	11.6	8.5
12 F	4.00	12.1	8.9
12.5 F	4.17	12.6	9.3
13 F	4.33	13.1	9.6
13.5 F	4.50	13.6	10.0
14 F	4.67	14.1	10.4
14.5 F	4.83	14.7	10.7
15 F	5.00	15.2	11.1

1. The equation to convert French (F) to millimeter (mm): French/3 = catheter size in mm.
2. Often referred to as the "rule of thumb" i.e. ideal catheter size ~ vessel diameter
3. These catheters cannot be used for drawing blood samples.

References:

1. Liu, G. D., Ma, W. J., Liu, H. X., Tang, L., & Tan, Y. H. (2022). Risk factors associated with catheter-related venous thrombosis: A meta-analysis. *Public Health*, *205*, 45–54. https://doi.org/10.1016/j.puhe.2022.01.018
2. Geerts, W. (2014). Central venous catheter–related thrombosis. *Hematology*, *2014*(1), 306–311. https://doi.org/10.1182/asheducation-2014.1.306
3. Luciani, A., Clement, O., Halimi, P., Goudot, D., Portier, F., Bassot, V., Luciani, J.-A., Avan, P., Frija, G., & Bonfils, P. (2001). Catheter-related upper extremity deep venous thrombosis in cancer patients: A prospective study based on Doppler US. *Radiology*, *220*(3), 655–660. https://doi.org/10.1148/radiol.2203001181
4. Evans, R. S., Sharp, J. H., Linford, L. H., Lloyd, J. F., Woller, S. C., Stevens, S. M., Elliott, C. G., Tripp, J. S., Jones, S. S., & Weaver, L. K. (2013). Reduction of peripherally inserted central catheter-associated DVT. *Chest*, *143*(3), 627–633. https://doi.org/10.1378/chest.12-0923
5. Jaffray, J., Witmer, C., O'Brien, S. H., Diaz, R., Ji, L., Krava, E., & Young, G. (2020). Peripherally inserted central catheters lead to a high risk of venous thromboembolism in children. *Blood*, *135*(3), 220–226. https://doi.org/10.1182/blood.2019002260
6. Nifong, T. P., & McDevitt, T. J. (2011). The effect of catheter to vein ratio on blood flow rates in a simulated model of peripherally inserted central venous catheters. *Chest*, *140*(1), 48–53. https://doi.org/10.1378/chest.10-2637
7. Spencer, T. R., & Mahoney, K. J. (2017). Reducing catheter-related thrombosis using a risk reduction tool centered on catheter to vessel ratio. *Journal of Thrombosis and Thrombolysis*, *44*(4), 427–434. https://doi.org/10.1007/s11239-017-1569-y
8. Jaffray, J., Mahajerin, A., Young, G., Goldenberg, N., Ji, L., Sposto, R., Stillings, A., Krava, E., & Branchford, B. (2018). A multi-institutional registry of Pediatric Hospital-acquired thrombosis cases: The Children's Hospital-acquired thrombosis (CHAT) project. *Thrombosis Research*, *161*, 67–72. https://doi.org/10.1016/j.thromres.2017.11.019
9. Baumann Kreuziger, L., Jaffray, J., & Carrier, M. (2017). Epidemiology, diagnosis, prevention and treatment of catheter-related thrombosis in children and adults. *Thrombosis Research*, *157*, 64–71. https://doi.org/10.1016/j.thromres.2017.07.002
10. Andrew, M., David, M., Adams, M., Ali, K., Anderson, R., Barnard, D., Bernstein, M., Brisson, L., Cairney, B., & DeSai, D. (1994). Venous thromboembolic complications (VTE) in children: First Analyses of the Canadian Registry of VTE. *Blood*, *83*(5), 1251–1257. https://doi.org/10.1182/blood.v83.5.1251.1251
11. Forauer, A. R., & Theoharis, C. (2003). Histologic changes in the human vein wall adjacent to indwelling central venous catheters. *Journal of Vascular and Interventional Radiology*, *14*(9), 1163–1168. https://doi.org/10.1097/01.rvi.0000086531.86489.4c
12. Wall, C., Moore, J., & Thachil, J. (2015). Catheter-related thrombosis: A practical approach. *Journal of the Intensive Care Society*, *17*(2), 160–167. https://doi.org/10.1177/1751143715618683
13. Latham, G. J., & Thompson, D. R. (2014). Thrombotic complications in children from short-term percutaneous central venous catheters: What can we do? *Pediatric Anesthesia*, *24*(9), 902–911. https://doi.org/10.1111/pan.12410

14. Castro D, Martin Lee LAM, Bhutta BS. Femoral Vein Central Venous Access. [Updated 2023 Aug 17]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK459255/
15. Fletcher, S. J., & Bodenham, A. R. (2000). Safe placement of central venous catheters: where should the tip of the catheter lie? *British journal of anaesthesia*, *85*(2), 188–191. https://doi.org/10.1093/bja/85.2.188
16. Paterson, R. S., Chopra, V., Brown, E., Kleidon, T. M., Cooke, M., Rickard, C. M., Bernstein, S. J., & Ullman, A. J. (2020). Selection and insertion of vascular access devices in pediatrics: A systematic review. *Pediatrics*, *145*(Supplement_3). https://doi.org/10.1542/peds.2019-3474h
17. Chopra, V., Anand, S., Hickner, A., Buist, M., Rogers, M. A., Saint, S., & Flanders, S. A. (2013). Risk of venous thromboembolism associated with peripherally inserted central catheters: A systematic review and meta-analysis. *The Lancet*, *382*(9889), 311–325. https://doi.org/10.1016/s0140-6736(13)60592-9
18. Derderian, S. C., Good, R., Vuille-dit-Bille, R. N., Carpenter, T., & Bensard, D. D. (2019). Central venous lines in critically ill children: Thrombosis but not infection is site dependent. *Journal of Pediatric Surgery*, *54*(9), 1740–1743. https://doi.org/10.1016/j.jpedsurg.2018.10.109
19. Parienti, J.-J., Mongardon, N., Mégarbane, B., Mira, J.-P., Kalfon, P., Gros, A., Marqué, S., Thuong, M., Pottier, V., Ramakers, M., Savary, B., Seguin, A., Valette, X., Terzi, N., Sauneuf, B., Cattoir, V., Mermel, L. A., & du Cheyron, D. (2015). Intravascular complications of central venous catheterization by insertion site. *New England Journal of Medicine*, *373*(13), 1220–1229. https://doi.org/10.1056/nejmoa1500964
20. Jaffray, J., Bauman, M., & Massicotte, P. (2017). The impact of central venous catheters on pediatric venous thromboembolism. *Frontiers in Pediatrics*, *5*. https://doi.org/10.3389/fped.2017.00005
21. Shah, S. H., West, A. N., Sepanski, R. J., Hannah, D., May, W. N., & Anand, K. J. S. (2015, April 8). *Clinical risk factors for central line-associated venous thrombosis in children*. Frontiers. https://www.frontiersin.org/articles/10.3389/fped.2015.00035/full
22. Menéndez, J. J., Verdú, C., Calderón, B., Gómez‐Zamora, A., Schüffelmann, C., de la Cruz, J. J., & de la Oliva, P. (2016). Incidence and risk factors of superficial and deep vein thrombosis associated with peripherally inserted central catheters in children. *Journal of Thrombosis and Haemostasis*, *14*(11), 2158–2168. https://doi.org/10.1111/jth.13478
23. Citla Sridhar, D., Abou-Ismail, M. Y., & Ahuja, S. P. (2020). Central venous catheter-related thrombosis in children and adults. *Thrombosis Research*, *187*, 103–112. https://doi.org/10.1016/j.thromres.2020.01.017
24. Sharp, R., Cummings, M., Fielder, A., Mikocka-Walus, A., Grech, C., & Esterman, A. (2015). The catheter to vein ratio and rates of symptomatic venous thromboembolism in patients with a peripherally inserted central catheter (PICC): A prospective cohort study. *International Journal of Nursing Studies*, *52*(3), 677–685. https://doi.org/10.1016/j.ijnurstu.2014.12.002
25. Gorski, L. A., Hadaway, L., Hagle, M. E., Broadhurst, D., Clare, S., Kleidon, T., Meyer, B. M., Nickel, B., Rowley, S., Sharpe, E., & Alexander, M. (2021). Infusion therapy standards

of practice, 8th edition. *Journal of Infusion Nursing*, *44*(1S). https://doi.org/10.1097/nan.0000000000000396
26. Bell D, Smith D, Sharma R, French gauge. Reference article, Radiopaedia.org (Accessed on 01 May 2023) https://doi.org/10.53347/rID-59517
27. Doan, P., Cox, A., Rao, E., & Branchford, B. (2021). Temporal and anatomic relationship between superficial and deep vein thromboses in hospitalized children. *Thrombosis Research*, *200*, 30–33. https://doi.org/10.1016/j.thromres.2021.01.010
28. Bhargava, M., Broccard, S., Bai, Y., Wu, B., Dincer, E. H., & Broccard, A. (2020). Risk factors for peripherally inserted central catheter line-related deep venous thrombosis in critically ill intensive care unit patients. *SAGE open medicine*, *8*, 2050312120929238. https://doi.org/10.1177/2050312120929238
29. Ullman, A. J., Bernstein, S. J., Brown, E., Aiyagari, R., Doellman, D., Faustino, E. V., Gore, B., Jacobs, J. P., Jaffray, J., Kleidon, T., Mahajan, P. V., McBride, C. A., Morton, K., Pitts, S., Prentice, E., Rivard, D. C., Shaughnessy, E., Stranz, M., Wolf, J., … Chopra, V. (2020). The Michigan appropriateness guide for intravenous catheters in pediatrics: Minimagic. *Pediatrics*, *145*(Supplement_3). https://doi.org/10.1542/peds.2019-3474i
30. Clark, H. H., Ballester, L., Whitworth, H., Raffini, L., & Witmer, C. (2022). Prevention of recurrent thrombotic events in children with central venous catheter-associated venous thrombosis. *Blood*, *139*(3), 452–460. https://doi.org/10.1182/blood.2021013453
31. Bahl, A., Mielke, N., & Xing, Y. (2023). Risk of midline catheter-related thrombosis due to catheter diameter: An observational cohort study. *Thrombosis Research*, *228*, 172–180. https://doi.org/10.1016/j.thromres.2023.06.007
32. Bahl, A., Karabon, P., & Chu, D. (2019). Comparison of venous thrombosis complications in midlines versus peripherally inserted central catheters: Are midlines the safer option? *Clinical and Applied Thrombosis/Hemostasis*, *25*, 107602961983915. https://doi.org/10.1177/1076029619839150
33. Tian, L., Li, W., Su, Y., Gao, H., Yang, Q., Lin, P., Wang, L., Zeng, J., & Li, Y. (2020). Risk factors for central venous access device-related thrombosis in hospitalized children: A systematic review and meta-analysis. *Thrombosis and Haemostasis*, *121*(05), 625–640. https://doi.org/10.1055/s-0040-1720976
34. Liu, G. D., Ma, W. J., Liu, H. X., Tang, L., & Tan, Y. H. (2022a). Risk factors associated with catheter-related venous thrombosis: A meta-analysis. *Public Health*, *205*, 45–54. https://doi.org/10.1016/j.puhe.2022.01.018
35. van Ommen, C. H., & Nowak-Göttl, U. (2017). Inherited thrombophilia in pediatric venous thromboembolic disease: Why and who to test. *Frontiers in Pediatrics*, *5*. https://doi.org/10.3389/fped.2017.00050
36. Faustino, E. V., Shabanova, V., Raffini, L. J., Kandil, S. B., Li, S., Pinto, M. G., Cholette, J. M., Hanson, S. J., Nellis, M. E., Silva, C. T., Chima, R., Sharathkumar, A., Thomas, K. A., McPartland, T., Tala, J. A., & Spinella, P. C. (2020). Efficacy of early prophylaxis against catheter-associated thrombosis in critically ill children: A Bayesian phase 2b randomized clinical trial*. *Critical Care Medicine*, *49*(3). https://doi.org/10.1097/ccm.0000000000004784

37. Clark, H. H., Ballester, L., Whitworth, H., Raffini, L., & Witmer, C. (2022a). Prevention of recurrent thrombotic events in children with central venous catheter-associated venous thrombosis. *Blood*, *139*(3), 452–460. https://doi.org/10.1182/blood.2021013453
38. Pelland-Marcotte, M.-C., Amiri, N., Avila, M. L., & Brandão, L. R. (2020). Low molecular weight heparin for prevention of central venous catheter-related thrombosis in children. *Cochrane Database of Systematic Reviews*, *2020*(6). https://doi.org/10.1002/14651858.cd005982.pub
39. Jaffray, J., Witmer, C., O'Brien, S. H., Diaz, R., Ji, L., Krava, E., & Young, G. (2020). Peripherally inserted central catheters lead to a high risk of venous thromboembolism in children. *Blood*, *135*(3), 220–226. https://doi.org/10.1182/blood.2019002260
40. Bates, S. M. (2013). Superficial venous thrombosis: Recognizing the risk. *Blood*, *122*(26), 4159–4160. https://doi.org/10.1182/blood-2013-11-537019
41. Revel‐Vilk, S., Yacobovich, J., Tamary, H., Goldstein, G., Nemet, S., Weintraub, M., Paltiel, O., & Kenet, G. (2010). Risk factors for central venous catheter thrombotic complications in children and adolescents with cancer. *Cancer*, *116*(17), 4197–4205. https://doi.org/10.1002/cncr.25199
42. Zochios, V., Umar, I., Simpson, N., & Jones, N. (2014). Peripherally inserted central catheter (picc)-related thrombosis in critically ill patients. *The Journal of Vascular Access*, *15*(5), 329–337. https://doi.org/10.5301/jva.5000239

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