Briefly Legal: Pleural Effusion Secondary to a Malpositioned Peripherally Inserted Central Catheter

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An 875-gram female infant was born at 25 weeks gestation via cesarean delivery secondary to severe maternal preeclampsia. The mother, a 28-year-old, gravida 1, para 0 with a history of preexisting hypertension, had been controlled by medications until 25 weeks gestation when she developed altered mentation, generalized edema, and severely elevated systolic and diastolic BPs (>200 />100mmHg.

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After admission to the hospital, she received magnesium sulfate and one dose of antenatal steroid shortly before the undertaking cesarean section under general anesthesia, which was complicated by difficult intubation. The baby was very depressed at birth and required intubation, chest compressions, and epinephrine. Her Apgar scores were 1^{1},1^{5},1^{10}, and 2^{15}. Her initial neonatal course was complicated by respiratory distress syndrome requiring one dose of surfactant and high-frequency oscillatory ventilation on DOL 1. Early clinical findings and X-ray revealed bilateral pneumothoraces which were treated with chest tubes inserted bilaterally. The patent ductus arteriosus was treated medically. Her complete blood counts were unremarkable, and blood cultures were ultimately negative.

Umbilical catheters were placed and discontinued timely. On DOL 2, she was extubated to a high-flow nasal cannula. The baby's nutritional needs were met by trophic feeds starting on DOL 5 and by parenteral nutrition (PN) initially through an umbilical venous catheter and on DOL 3 through a central catheter (PICC) inserted in the antecubital area of her left upper extremity. The tip of the PICC was confirmed radiographically at the junction of the superior vena cava and the right atrium. However, several subsequent chest radiographs beginning on DOL 5 showed the tip of the PICC in the left subclavian vein. The baby expired on DOL 13,

In reviewing the concentrations of the intravenously delivered trophic feeds for DOL 8, with a PICC confirmed to be in a non-central position (subclavian vein) were: 16% dextrose, 3.5% protein, 10% calcium gluconate, sodium, potassium, acetate, magnesium, and 20% intralipid. This corresponded to an osmolality >900mosm/liter.

On day 13, the baby became lethargic and desaturated. A chest radiograph showed bilateral pleural effusions. Bilateral chest tubes were again placed with egress of a large volume of fluid consistent with parenteral nutrition.

Despite the chest tubes, the baby's condition deteriorated progressively, and two hours after the placement of the chest tubes, the baby required full resuscitation but could not be revived.

Postmortem examination revealed a perforation of the left subclavian vein with only small pleural effusions remaining. The PICC line was found in the subclavian vein. The pathologist and treating physicians concluded that the hyperosmotic PN had eroded through the subclavian vein and caused the pleural effusions. The hospital and neonatologist were sued for negligence.

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Allegations

When the case was deliberated, the plaintiff neonatologist was critical of:

- The failure of the staff to appreciate the malpositioned PICC line
- The failure of the staff to monitor the depth of the PICC from outside markings and from radiographs showing the position of the PICC – notwithstanding that indication for obtaining the radiographs was unrelated to the PICC location.
- Continuing to infuse constituents with high osmolarity despite the suboptimal location of the catheter tip
- The neonatologist should have decreased the concentration of the components to ensure that the osmolarity was not excessive for the subclavian vein or removed it and reinserted another PICC

The case was settled before trial.

Discussion

Parenteral nutrition (PN) has become a standard feature of managing premature and critically ill babies in the Newborn Intensive Care Unit (NICU). The choice of providing PN via peripheral or central access depends on the anticipated duration of the nutritional therapy. Since the peripheral route only permits low concentrations of the nutritional components (osmolality 300-900mOsmol/L), the peripheral route usually is restricted to babies requiring only small supplements to their nutrition for a limited duration of time, generally less than two weeks, when it is anticipated that the large bulk of their nutrition will be met enterally generally. On the other hand, Central PN allows for high concentrations of nutrients (osmolality >900 mOsmol/L) and is reserved mainly for babies who will need parenteral nutritional support beyond two weeks and when alimentation needs cannot be met enterally or by the peripheral

route. The most popular method of providing central parenteral nutrition is by a peripherally inserted central catheter (PICC) because it is a simple procedure performed at the bedside that is considered relatively safe when inserted and monitored by skilled practitioners. PICCs provide a portal for fluids, concentrated parenteral nutrition, and sometimes medication.

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Central venous access is defined as a catheter whose distal tip lies in the distal vena cava (part of the vena cavae within the pericardial reflection). PICCs are typically placed via the antecubital vein. The **location of the PICC tip is critically important**. PICCs inserted from the upper extremity should have their distal tips reside at the junction of the superior vena cava and right atrium (as was the case here early on), and if inserted from the lower extremity, the tip should be at the junction of the inferior vena cava and right atrial junction. Getting the catheter tip as close to the atrial-caval junction as possible and confirming its correct placement is of the utmost importance and can be done by radiograph or ultrasound. This tip position residing at these junctions takes advantage of the increased volume and turbulence in the vasculature, which helps to dilute the high osmolar PN solutions, thereby decreasing the risk of the PN causing osmotic endothelial damage to a vessel. The thick wall of the vena cava near the atrium makes the PICC less likely to perforate by erosion or tip puncture. The tip should never reside in the right atrium because of the risk of arrhythmia. The PICC tip that resides at or near the right atrial wall increases the risk of puncture or hyperosmolar transudation. Perforation or transudation of fluid into the pericardial sac can create a pericardial effusion and tamponade. Indeed, to emphasize the vulnerability of the tip in this location, the wall of the right atria has been compared to "wet paper."

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Given that the maximum osmolarity that can be delivered via a non-central route is 900mOms/L, it is usually impossible to supply all the required nutrients for many preterm or critically ill term newborns in this fashion. Although PICCs are intended to be placed centrally, occasionally, they cannot be advanced to an ideal position, perhaps because of venous tortuosity or valves. However, if this happens and the peripheral approach is undertaken, ensuring that the catheter tip is in the prescribed location becomes critical. If the decision is made to leave the PICC in a non-optimal position, the osmolarity must be adjusted to ≤900 mOmol/L.

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When dealing with a centrally placed PICC, it is also important to recognize the potential causes and consequences of the tip that has migrated to a non-central location, often to the brachiocephalic or subclavian vein. This development demands prompt recognition and a change in osmolarity to avoid complications of the malpositioned catheter. Understandably, the potential for adverse events is increased if the PICC migration/malposition is not appreciated and appropriately managed. In cases when the tip has migrated distally, the tip could impinge on the vessel wall, disrupting the endothelium, and triggering the coagulation cascade. As pointed out, an influx of hyperosmolar fluid might be caustic to the vessel's endothelium, eventually resulting in perforation of the vessel and damage to the surrounding tissues. In addition, the tip could perforate the vessel wall and move into the various tissues, including the pleural space. Whether by transudation or outright perforation, the extravasation of hyperosmolar fluid is caustic. Such a complication also potentiates the damage with the extravasation of caustic drugs given via the PICC line, including calcium gluconate and calcium chloride. Pharmacists determine the osmolarity of a PN solution, or one can approximate the osmolarity from Table 1 or use one of several equations:

1. mOsm/L= (grams amino acids/L x10) + (grams dextrose/L x 5) + ({mEq Na + mEqK} x2)/L + (mEq Ca x1.4)/L.

2. Another method is a) multiply grams of dextrose per liter by 5 b) multiply grams of protein per liter by 10. c) 300-400 for vitamins and mineral contribution. Then add a +b+c to give a close approximation of the osmolarity of PN.

The Osmolarity of Components in Parenteral Nutrition	
Component	**Osmolarity (mOsm/L)**
5% Dextrose	252
10% Dextrose	505
15% Dextrose	631
20% Dextrose	1010
25% Dextrose	1263
30% Dextrose	1515
10% Dextrose, 1% amino acids	800
10% Dextrose, 2% amino acids	900
12.5% Dextrose, 1% amino acids	925
12.5% Dextrose, 2 % amino acids	1025
20% Dextrose, 2% Amino Acids	1400
10% Calcium gluconate	680

In addition to the above, a malpositioned PICC may cause a **pleural effusion related to one of several** mechanisms including: 1) disruption or obstruction of lymphatic drainage around the site of PN extravasation which can cause increased hydrostatic pressure and transudation of fluid into the pleural space 2) mechanical perforation of the tip of the PICC into the pleural space 3) hyperosmotic endothelial damage and increased vascular permeability causing the PN to into the pleural space 4) proximal migration of the PICC into the a) pulmonary artery (from the right atrium to the right ventricle to the pulmonary artery, to become wedged in one of the branches) or b) into the pulmonary vein (from the right atrium, through the foramen ovale, to the left atrium and thence into a pulmonary vein) 5) extension of ascites fluid into the pleural space if the PICC was placed below the diaphragm With the appearance of pleural effusion, the infant presents signs of respiratory distress which may arise within a few hours or even several days after placement of the catheter. Tachycardia, hypotension, and hypoglycemia can be expected to occur when increasing amounts of PNare delivered outside of the intravascular space.

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Catheter-related bloodstream infection with PICC is another risk for NICU patients in addition to malpositioned PICCs. The incidence of infection is highest with prolonged use, and it is common in the most premature infants. Risks of infection with PICCs are also proportional to the degree of manipulation of the catheter and breaks in the line for administration of products (e.g., medications, blood components). The most common organism colonizing catheters is a coagulase-negative staphylococcus (CONS), followed by gram-negative bacilli and fungi. The onset of catheter-related CONS infection usually is insidious with low-grade clinical features, such as apnea, feeding intolerance, temperature instability, increased oxygen requirement, and lethargy. The prognosis for catheter-related CONS infection is good, with greater than 90% survival.

Arm movements have been shown to affect the position of the tip of PICCs. Catheters placed in the basilic or cephalic veins below the level of the elbow are likely to move toward the heart when the elbow is flexed. Catheters placed in the basilic or axillary veins migrate toward the heart with adduction of the arm, and catheters placed in the cephalic vein move away from the heart with adduction of the arm. An awareness of this is important when images are evaluated for migration. Obstruction of the PICC, characterized by an inability to infuse fluids or withdraw blood or by increased infusion pump pressures, is often caused by thrombosis, malposition, or chemical precipitates from minerals, drugs, or lipids infused. The catheter position should be evaluated. If malposition is ruled out, dissolving the clot or precipitate may be attempted if salvaging the catheter is vital. Heparin (0.5 to 1.0 mL per mL of intravenous fluid) should be added to infused fluids.

"Complications of PICCs can be minimized with proper insertion with aseptic technique, good skin fixation, proper positioning of the tip at the caval-right atrial junction, monitoring the position for possible migration issues, making osmolar changes in PN if it becomes non-central, and keeping manipulations and entries into the line minimal. Prompt recognition and timely intervention for a non-central position of the tip are critical."

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Suggested reading

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