SECTION 1—CATHETER TIP LOCATION

The Relevance of Catheter Tip Location

There is overwhelming evidence that improper tip location negatively impacts clinical outcomes. A direct link has been observed between central vascular access catheter tips located outside of the optimal position and venous thrombosis, chemical and mechanical vessel erosion, fibrin sleeves, spontaneous malpositions, and catheter dysfunction including persistent withdraw occlusions.

The Guidelines Regarding Catheter Tip Location

In 1998, the National Association of Vascular Access Networks (NAVAN now AVA) issued a position statement recommending that the optimal location for the tip of peripherally inserted central catheter (PICC) is the lower one-third of the superior vena cava (SVC), close to the junction of the SVC and the right atrium. The Intravenous Nurses Society (INS) shares this recommendation in their Infusion Nursing Standards of Practice 2011 stating “central venous access devices (CVADs) shall have the tip dwelling within the superior vena cava (SVC) near its junction with the right atrium.”

Other Organizations with Recommendations on Tip Location Include:

- Oncology Nurses Society—Access Device Guidelines 2010: Distal third of the superior vena cava.

Why The Lower 1/3 Superior Vena Cava/Right Atrial Junction?

- Large vein diameter.
- High velocity blood flow.
- Improved infusate distribution and dilution.
- Position offers the least amount of interference with vein intima.

The Vascular Access Specialist Challenge

- Reduce time to therapy.
- Achieve consistent and accurate catheter placements.
- Reduce catheter malpositions. (Rates documented to be as high as 30%)
- Reduce patient radiation exposure.
- Improve patient satisfaction.
- Improve clinician workflow and efficiency.

SECTION 2—PICC PLACEMENT TECHNOLOGIES

The Intravenous Nurses Society Standards of Practice 2011; 35.8—“Tip location of CVAD shall be determined radiographically or by other approved technologies prior to initiation of infusion therapy.” The traditional practices to ensure proper tip location for peripherally inserted central catheter (PICC) placement has included pre-procedure landmark and anthropometric (surface) measurements followed by post-procedural chest radiography (X-ray). The challenge has been in the inherent inefficiency of radiography and the known inconsistency of the interpretation of the PICC tip position via radiographic image. Considering the clinical significance and the position of peer groups such as AVA and INS regarding proper tip placement, it is not only best practice, but also should be the professional standard of practice to ensure proper central tip placement is achieved. Consequently, clinicians should consider more accurate and efficient technologies to reach this goal.

Navigation vs. Tip Location Technology

Navigation refers to a technology that ascertains information regarding general directionality of a vascular access device. Tip Location refers to a technology that ascertains a precise location of the distal tip of a vascular access device within the superior vena cava (SVC).

1. Electromagnetic Catheter Navigation—Technologies that utilize electro-magnetic field detection to illustrate audibly or visually catheter direction and general position. These systems measure the relationship between the catheter stylet and its external sensor (chest plate or hand held wand). These devices require a custom stylet wire inserted within the catheter. These devices are effective in reducing catheter malpositions, however they do not provide detailed information regarding the catheter’s tip location with respect to the heart.

2. Electrocardiographic (ECG) Tip Location—Technologies that employ a saline column or stylet as an intracavitary electrode to monitor ECG waveform changes as the vascular access device approaches final tip position.
The heart is composed of four chambers: right atrium, right ventricle, left atrium, and left ventricle. These chambers are electrically stimulated to contract in specific timed and paced fashion. The heart’s primary pace maker is a bundle of cells, known as the sinoatrial node (SA node), located upper posterior wall of the right atrium. While at rest, the myocardial muscle is negatively charged or polarized. The stimulation, called depolarization, causes these muscles to become positively charged and contract. This depolarization is immediately followed by repolarization. Both depolarization and repolarization are electrical phenomena and can be detected by sensors on the skin. These signals are represented by the deflections we see on an ECG strip. Electrical signals from the brain arrive at the SA node to stimulate a heartbeat. The depolarization spreads from the SA node across the atrium causing the atrial muscle to contract while generating the P-wave. This stimulation reaches the atrioventricular node (AV node) and passes through a set of fibers out to the ventricles. This depolarization then spreads across the ventricles causing the ventricles to contract while generating the QRS wave. The repolarization of the ventricles generates the T-wave as the ventricular muscles relax.

The height or amplitude of the deflection is a measure of voltage. Positive deflections are upward on an ECG, negative deflections are downward. ECG analysis examines the shape, consistency, and the time between waveforms elements (deflections) to assess the functionality of the hearts conduction system.

**ECG Examples**

**Normal Sinus Rhythm (NSR):** Sinus rhythms are a class of rhythms which originate at the SA node. Sinus rhythms generally travel through the heart’s entire conduction system without inhibition.

NOTE: NSR is required for reliable ECG tip location.

**Atrial Fibrillation (A-Fib):** Atrial Fibrillation is most common sustained arrhythmia. It affects as many as 10% of patients over 75 yrs. A-Fib is characterized by small, rapid, erratic spikes that may appear like a wavy baseline. A-Fib is caused by an unorganized depolarization of the atrial foci.

NOTE: A-Fib will not allow accurate interpretation of the P-wave response for ECG tip location.

**Atrial Flutter (A-Flutter):** A-Flutter is recognized by the distinct “saw tooth” pattern of P-waves. It is characterized by a series of identical “flutter” waves in back to back succession.

NOTE: A-Flutter will not allow accurate interpretation of the P-wave response for ECG tip location.

**Artificial Pacemaker:** With SA node pace failure, an artificial pacemaker may be implanted as a permanent pace making source. The demand feature engages when the inherent rate of the SA node is insufficient.

NOTE: An artificially atrial paced heart will not allow accurate interpretation of the P-wave response for ECG tip location.
Assessing P-Waves:
1. Are they present?
2. Do they look alike?
3. Do they occur at a regular rate?
4. Is there one P-wave for each QRS?
5. Are they upright?

ECG Tip Location Applied:

Electrodes Defined—Electrodes are placed on the skin surface to detect the faint electrical activity of the heart. ECG tip location generally utilizes 3 electrodes. These electrodes are placed on the body in what is known as Einthoven’s Triangle; right arm (RA), left arm (LA), left leg (LL). The three electrodes are colored white (RA), black (LA), and red (LL) in accordance with the American Heart Association (AHA) standards.

NOTE: These color standards are not universal. The International Electrotechnical Commission (IEC) has different color standards, red (RA), yellow (LA), and green (LL). Place electrodes only on clean, dry skin and in areas of minimal muscle activity.

ELECTRODE PLACEMENT MNEMONICS:
“White to the right. Red to the ribs. Black on top.”
“White to the right. Smoke (black) over fire (red).”

ECG Tip Location Explained

In ECG tip location, the catheter itself becomes an intracavitary traveling electrode. As the catheter advances toward the SA node the electrical activity is monitored. This activity appears on ECG as a progressively larger P-wave. As the catheter enters the superior vena cava (SVC) the P-wave response will reflect the catheter’s proximity to the SA node within the upper right atrium. In this fashion, we can identify an anatomical landmark (the SA node), from which to base our catheter tip location.

Figure 1
No evident P-wave changes indicates a catheter is not in acceptable position.

Figure 2
A P-wave at its maximum height will indicate the catheter is in the lower 1/3 of superior vena cava/right atrial junction.

Figure 3
A downward deflection on the leading edge of the P-wave indicates the catheter entering the right atrium.

Figure 4
A biphasic P-wave indicates the catheter is within the right atrium.

Figure 5
An inverted P-wave indicates a catheter is approaching the right ventricle.
**Leads Defined**

Two electrodes form a bipolar lead. Lead I is a lateral view from the RA to LA electrodes. Lead II is an inferior view from the RA to the LL electrodes. In ECG tip location it is generally lead I or Lead II that is monitored. For the purposes of central line placement lead I or lead II is generally monitored. Lead I monitoring implies the electrical activity is measured from right arm to left arm. Lead II ECG monitoring implies that the electrical activity is measured from the right arm to the left leg.

**ECG Connection Techniques**

**Guidewire Technique**—In this method the metal guidewire or stylet within the catheter is used as our conductive material to receive the electronic signals from the heart (SA node). In this technique the wire must not advance beyond the tip of the catheter being placed.

**References**


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