The state of the art of tip location

Antonio LaGreca
Catholic University, Rome, Italy
Why is the position of the tip of central lines so important?

Inappropriate position

= 

increased rate of complications
Why is the position of the tip of central lines so important?

**Too short:**

- venous thrombosis
- malfunction

**Too long:**

- arrhythmias
- tricuspid damage
Zone A (low SVC/upper right atrium). This is a suitable tip site from any access point in the upper body. We believe catheter tips can be sited safely within the upper right atrium provided they do not abut the atrial wall end-on or pass through the tricuspid valve or into the coronary sinus.\

Zone B (upper SVC). This is a suitable site for tips of catheters placed via the right internal jugular route.\

Zone C (mid-point, left innominate vein). This is a suitable site for the tip when the catheter is introduced from the left internal jugular or subclavian vein, and reduces the risk of SVC perforation.
Best position(s) – F&B’s zone A

In the lower third of SVC
i.e.: where the SVC is wrapped by the pericardial reflexion
Catheter runs vertically in this tract
On x-ray: 1 -3 cm below the tracheal carina

At the cavo-atrial transition
‘oblique’, not trasversal junction…
On x-ray: approximately 3 cm below the tracheal carina

In the upper part of right atrium
‘safe’ area of right atrium
On x-ray: 3 – 5 cm below the tracheal carina
‘tip location’

- Methods to verify that the tip of the catheter is in the desired position (for most central lines, this corresponds to the CAJ)

- The method of ‘tip location’ must be precise enough to allow a safe use of the central line, considering that the tip is verified to be in the correct site.
‘tip location’ methods

**DURING THE INSERTION**
- Intracavitary ECG
- Fluoroscopy
- Ultrasound/echocardiography (TTE, TEE)

**AFTER INSERTION**
- Chest x-ray
- CT, MR, angiography
- Echocardiography (TTE)
Radiology for tip location
Control of tip position: radiology

Anatomy of the Frontal Chest X-Ray

- Pleura
- Lung markings
- C.A.J.
- C.P.A.
- Diaphragm
- Trachea
- Aortic arch
- Heart contour
Control of tip position radiology

1a. Axillary
1b. Brachiocephalic
1c. SVC, superior 1/3
2. SVC, medium-distal 1/3 and junction
3. RA (junction and superior 1/3 sup)
4. Deep atrium
5. IVC

Anatomy of the Frontal Chest X-Ray
In 38% of patients, the cranio-lateral radiological “right” cardiac silhouette is made by the left atrial shadow. As a result, the tip of well-positioned catheters may appear well within the cardiac silhouette and then seem “too long” (Aslamy, Chest 1998);
Comparison of radiographic landmarks and the echocardiographic SVC/RA junction in the positioning of long-term central venous catheters

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Printed in Singapore. All rights reserved

J.-H. Hsu¹, C.-K. Wang², K.-S. Chu³, K.-I. Cheng³, H.-Y. Chuang⁴, T.-S. Jaw⁵ and J.-R. Wu¹
Departments of ¹Pediatrics, ²Medical Imaging, ³Anesthesiology and ⁴Clinical Research, Kaohsiung Medical University Hospital, Kaohsiung, Taiwan

**Conclusion:** Both the radiographic SVC/RA junction and the thoracic vertebral bodies are not reliable landmarks for the SVC/RA junction defined by TEE. Physicians should be aware that using the radiographic SVC/RA junction to confirm proper positioning of permanent central venous catheters risks placing the catheter tip in the upper SVC, with subsequent potential long-term complications. More reliable radiographic landmarks for the SVC/RA junction should be investigated.
Accuracy of radiological landmarks

The carina as a radiological landmark for central venous catheter tip position

P. A. Stonelake and A. R. Bodenham


Schuster M
The carina as a landmark in central venous catheter placement, BJA 2000
The carina landmark

The most reliable, repeatable and objective criteria for defining the position of the CAJ

1 cm below the carina (neonates)
1-2 cm below the carina (1mo-3yr)
1.5-3 cm below the carina (4yr-11yr)
2-4 cm below the carina (> 12yr)
Accuracy of radiological landmarks

Bedside Trunk rotation Cardiothoracic surgery Pulmonary “central” oedema
The Sweet Spot™

Ken Symington, MD
Spokane, WA
DEFINITION OF SWEET SPOT™

The SWEET SPOT™ is a rectangular template superimposed on a frontal CXR, whose margins and internal area are acceptable for VAD catheter tip position. This is tailored to the individual patient's chest x-ray. As such, it has no fixed length or width but does have fixed proportions with the craniocaudal length being twice the width on a frontal chest x-ray. Depending on patient anatomy, it can exceed 8 x 4 cm. The template is simply compared in size to the CXR at hand. This template is very easy to memorize and just as easy to teach.
How to draw the Sweet Spot™
1. On a frontal CXR, identify the CAJ and the right CPA.

2. Start at a point as close as possible to the CPA that permits a vertical line to be drawn along the right edge of the cardiac silhouette.

3. Go twice the distance of the CPA to the CAJ.

4. Next, continue a horizontal line to your right equaling one-half the length of the previous vertical line.

5. Lastly, turn inferiorly and complete the rectangle.
ORIGIN OF SWEET SPOT™

The SWEET SPOT™ was created for two main reasons. The first was to improve patient safety by decreasing the complications caused by improperly positioned venous access devices (VAD) as encountered by me and other members of my IR practice. The second was to remove the always subjective and sometimes erroneous chest x-ray (CXR) interpretation of VAD tip position (as well as resultant unnecessary recommendations for repositioning) in my own large and highly sub-specialized radiology group (55 members at present).
Tip location by chest radiology

Two possible approaches which may minimize the subjectivity of judgement:

- The carina landmark
- The Sweet Spot

We compared the two approaches

Both of them, though, have limited accuracy if compared to ECG or US
‘Sweet Spot’ vs. carina: two criteria for verifying tip location by chest x-ray

Mauro Pittiruti, Andrea Bilancia, Gloria Ortiz Miluy

AVA 2015
Purpose

The position of the tip of PICCs is often verified at the end of the procedure by chest x-ray (CXR). Though, the radiological criteria for defining tip location are sometimes poorly defined, subjective and/or non-repeatable. We considered two recent methods for tip location at CXR - the Sweet Spot criteria (SSC) (developed by Ken Symington) and the Carina criteria (CC) (developed by German radiologists) – comparing them in terms of feasibility and accuracy.
Methods

Using the radiology database of three hospitals, we examined all CXR performed on patients after PICC insertion, choosing catheters whose tip location had been verified by the intracavitary ECG technique (IC-ECG). Tip location was identified by SSC and CC on all CXR.
Results

We reviewed 1116 PICCs successfully placed by IC-ECG (maximal height of P wave = tip at the cavo-atrial junction).

**CC** was not feasible in 0.45% (impossible visualization of the carina) and difficult in 1.5% (difficult visualization of the carina); in 97.7%, tip position was appropriate (1-5 cm below the carina), in 0.6% too high (< 1 cm), in 1.2% too low (6-9 cm).

On the other hand, because of unclear visualization of radiological landmarks, **SSC** was not feasible in 0.9% and difficult in 8.6%; in 99.1%, the tip was within the spot (94.2% in the middle, 2.5% close to the superior border, 2.3% close to the inferior border); no tip was visualized outside of the spot.
Conclusions

CC and SSC were similar in terms of feasibility (99.5% vs. 99.1%) and accuracy (97.7% vs. 99.1%).

Though, **CC was easier to perform (98.05%) if compared to SSC (89.5%).**
Fluoroscopy

Expensive
Logistically unsustainable
Inaccuracy of radiological landmarks
Fluoroscopy

It might be used simultaneously for tip location AND tip navigation

Though

- Expensive
- X-ray exposure
- Less accurate than US or EKG
- Not appropriate for bedside VADs (PICCs, short term CVCs)
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Fluoro and chest x-ray are almost always applicable, but they may not be feasible and/or accurate (*poor diagnostic criteria; poor imaging due to obesity, abnormal anatomy, enlarged heart, artefacts, etc.*). They are not 100% safe and they are expensive.
Ultrasound for tip location
Trans Esophageal Echocardiography
The most accurate method
Though: expensive and invasive

Tip at CAJ
Tip in lower 1/3 SVC

Tip in upper SVC
Trans Thoracic Echocardiography

TTE
Accurate and precise

May be difficult or not feasible in some adult patients (BPCO, obesity, abdominal surgery, etc.)
CEUS
Contrast-enhanced Ultrasonography
(M-Mode)

- Very accurate
- Needs very specific training
Ultrasonic Examination
An Alternative to Chest Radiography after Central Venous Catheter Insertion?

ERIC MAURY, JEAN GUGLIELMINOTTI, MARC ALZIEU, BERTRAND GUIDET, and GEORGES OFFENSTADT
Service de Réanimation Médicale, Hôpital Saint-Antoine, Assistance Publique-Hôpitaux de Paris, Paris, France

Guidewire localization by transthoracic echocardiography during central venous catheter insertion: a periprocedural method to evaluate catheter placement

Ultrasound localization of central vein catheter and detection of postprocedural pneumothorax: An alternative to chest radiography

Antonella Vezzani, MD; Claudia Brusasco, MD; Salvatore Palermo, MD; Claudio Launo, MD; Mario Mergoni, MD; Francesco Corradi, MD, PhD

Contrast enhanced ultrasound vs chest X-ray to determine correct central venous catheter position

Francesca Cortellaro, MD a,*, Luca Mellace, MD a, Stefano Paglia, MD a, Giorgio Costantino, MD c, Sara Sher, MD b, Daniele Coen, MD a

Color Doppler signals in the vena cava.

Increased colour signal due to turbulent flow during infusion of saline solution.
Central venous cannulation: are routine chest radiographs necessary after B-mode and colour Doppler sonography check?

Table 2 Malpositions and complications

<table>
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<th>Complications</th>
<th>Postprocedural chest radiograph</th>
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<td>Pneumothorax</td>
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Even better in neonates

Epub 2013 Jun 13.

A randomized controlled trial of ultrasound-guided peripherally inserted central catheters compared with standard radiograph in neonates.

Katheria AC(1), Fleming SE, Kim JH.

(1)Division of Neonatology, Department of Pediatrics, University of California, San Diego, CA, USA.
TTE = best choice in neonates
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TEE is almost always applicable, is extremely accurate and precise, but has minimal feasibility and minimal cost-effectiveness (too invasive, too expensive, etc.).
(same for CT, MR, Angio, etc.)
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TTE is very accurate (specially as CEUS); it is safe and cost-effective, but (a) requires training and (b) may not easy or feasible in all adult patients.
Intracavitary ECG for tip location
IC-EKG method

- Intracavitary ECG (lead II)
- The intracavitary electrode is the tip of the catheter
- Based on changes of P wave during the progression of the catheter into the central veins
- CAVO-ATRIAL JUNCTION: maximal peak of the P wave (Stas, Yeon, Schummer, Pittiruti/La Greca, etc.)
  (= CRISTA TERMINALIS)
P increasing

Maximal P

P decreasing and/or diphasic
A very old method…

Von Hellerstein HK
...which has come back.

The EKG method for positioning the tip of PICCs: results from two preliminary studies

Mauro Pittiruti¹ MD, Giancarlo Scoppettuolo¹ MD, Antonio La Greca¹ MD, Alessandro Emoli¹ RN, Alberto Bruttì¹ RN, Ivano Migliorini¹ RN, Laura Dolcetti² RN, Cristina Taraschi² RN, Gennaro De Pascale² MD
¹Dept. of Surgery, ²Dept. of Infectious Diseases, ³Dept. of Oncology, ⁴Intensive Care Unit
Catholic University Hospital, Rome, Italy

Abstract

Two preliminary studies were conducted to determine feasibility of using the electrocardiography (EKG) method to determine terminal tip location when inserting a peripherally inserted central catheter (PICC). This method uses the guidewire inside the catheter (or a column of saline contained in the catheter) as an intracavitary electrode. The EKG monitor is then connected to the intracavitary electrode. The reading on the EKG monitor reflects the closeness of the intracavitary electrode (the catheter tip) to the superior vena cava (SVC). The studies revealed that the EKG method was extremely precise; all tips placed using the EKG method and confirmed using x-ray were located in the superior vena cava. In conclusion, the EKG method has clear advantages in terms of accuracy, cost-effectiveness, and feasibility in conditions where x-ray control may be difficult or expensive to obtain. The method is quite simple, easy to learn and to teach, non-invasive, easy to reproduce, safe, and apt to minimize malpositions due to failure of entering the SVC.
Applicability

- The IC-EKG method is applicable to any central venous access, valved or not, peripherally inserted or not, independently from the access technique.

- Current limit of IC-EKG method: it is applicable only in patients with evident P wave in the surface ECG

This excludes 7 – 9 % of patients: atrial fibrillation, pacemaker (if constantly active), so called ‘junctional rhythm’, atrial flutter, etc.
Applicability

Applicability is not a relevant issue in pediatric patients.

In the recent GAVeCeLT Multicenter Study on IC-ECG in Children (5 hospitals, 309 patients), applicability was 99.4%:

- Only in 2 children out of 309, the P wave was not identified on the surface ECG, so that IC-ECG was not performed
  - One child 2 mo. old
  - One child 5 yr old
What about applicability of IC-EKG in neonates?

- Preliminary personal experience (47 cases, not included in the multicenter study)
  - Saline technique
  - Caths >3Fr, central insertion, US-guidance
  - Age 3hrs – 29 days; weight > 950 gr

RESULTS
- Applicability 100%
- Feasibility: 45 cases out of 47 (96%)
- Accuracy: 100% (check by x-ray and/or echocardiogram.)
Feasibility

Feasibility = in which % of cases do we get an ‘atrial P’ in the intracavitary EKG?

- **GAVeCeLT multicenter study 2012:**
  - 1440 patients, any type of VAD
  - All pts with evident P on basal ECG
  - Both saline technique and guidewire technique
  - Overall feasibility **99.3 %**
    - Feasibility with the saline technique **99.9 %**
    - Feasibility with the guidewire technique **98.6 %**
309 children (5 hospitals)
any type of VAD
only saline technique
307/309 had evident P on basal ECG
An ‘atrial P’ was detected in 305/307

Applicability was 99.4 %
Overall feasibility 99.4 %
Feasibility

0.6 – 0.7 % of failure (‘not feasibility’) depends on:

- Technical problems of the connection between monitor and catheter
- Technical problems of the ECG monitor
- Experience of the operator (ability to recognize P changes)
- Low signal (catheter < 3Fr)
Feasibility

Technical problem of the connection between monitor and catheter
- Saline technique better than guidewire technique
- Some cables may not work properly
- Air bubbles in the catheter
- Poor connection between aligator clip and stylet (or guidewire)
Feasibility

Technical problem of the ECG monitor
- AC interferences, lack of appropriate filters
Feasibility

Experience of the operator (ability to recognize P changes)
Improve feasibility?

1) Use of ‘dedicated’ ECG monitor or ECG monitors specifically designed for the IC-EKG + use of good quality cables
   • Good electrical connections
   • Proper filters
   • Protection from interferences
Improve feasibility?

2) Appropriate training of the operators
   - Short courses (2 days)
   - Short learning curve (few procedures)

Proper procedure:
   a - advance while P is increasing
   b - stop when diphasic
   c - pull back until maximal value
Education/training

We will need more ‘formal’ training courses to teach the EKG method
Accuracy

Accuracy = in which % the ‘atrial P’ corresponds to the cavo-atrial junction?

Almost 99%
IC-EKG - Is it accurate?

In the last two decades, many clinical studies have proved the accuracy of the EKG method:

- Compared with radiological methods
- Compared with trans-esophageal echocardiography (TEE)
TEE vs IC-EKG

Cavoatrial junction = maximal P wave (EKG)
Cavoatrial junction = crista terminalis (TEE)

100% accuracy - In 30 patients, EKG = TEE
Tip at the cavoatrial junction
TIP in lower 1/3 of SVC
Tip in middle 1/3 of SVC
TEE vs. IC-EKG

Transesophageal echocardiographic evaluation of ECG-guided central venous catheter placement

Yunseok Jeon MD, Ho-Geol Ryu MD, Seung-Zhoo Yoon MD, Jin-Hee Kim MD, Jae-Hyon Bahk MD†

Conclusions: During ECG-guided central venous catheterization, the tallest peaked P wave may be used to place the CVC tip at the SVC/RA junction, the normally-shaped P wave identifies the mid to upper SVC, and biphasic P waves identify RA localization.

54 patients  Cavoatrial junction = crista terminalis
IC-EKG vs. X-Ray

**The Accuracy of Electrocardiogram-Controlled Central Line Placement**

Ralf E. Gebhard, MD*
Peter Szmuk, MD†
Evan G. Pivalizza, MBChB, FFASA‡
Vladimir Melnikov, MD‡
Christianne Vogt, MD‡
Robert D. Warters, MD‡

**BACKGROUND:** Electrocardiogram (ECG) guidance to confirm accurate positioning of central venous catheters (CVC), placed before surgery in the operating room, is rarely used in the United States. We designed this randomized, controlled trial to investigate whether the use of this technique impacts the accuracy of CVC placement.

**METHODS:** Patients in group ECG (n = 147) had a CVC placed using right-atrial ECG to guide catheter tip positioning. CVCs in group NO-ECG (n = 143) were positioned without this technique.

**RESULTS:** Overall, guidewire-ECG control resulted in more correctly positioned CVCs (96% vs 76%, P ≤ 0.001) without increasing placement time. Significantly more CVCs were placed in the middle of the superior vena cava in group ECG (P ≤ 0.001), although placement into the right atrium or right ventricle and into other vessels occurred significantly more often in group NO-ECG (P ≤ 0.001). Twenty patients in group NO-ECG required repositioning of their CVC after surgery, whereas this maneuver was necessary only in three patients in group ECG (P ≤ 0.001).

**CONCLUSIONS:** ECG guidance allows for more accurate CVC placement, and should be considered to increase patient safety and reduce costs associated with repositioning procedures.


147 pts – correct tip positioning in 96 %
TEE vs. IC-EKG vs. X-Ray

200 patients - accuracy 99% for EKG, 88% for X-ray
Endovascular electrocardiography to guide placement of totally implantable central venous catheters in oncologic patients

Cecilia Pelagatti, Gianluca Villa, Andrea Casini, Cosimo Chelazzi, Angelo Raffaele De Gaudio

Department of Critical Care, Section of Anesthesiology and Intensive Care, University of Florence, Florence - Italy

ABSTRACT

Purpose: Appropriate tip position of totally implantable central venous catheters is essential in order to prevent catheter-related complications, in particular thrombosis. Endovascular electrocardiography is an economic and safe method to guide placement of catheters into the central veins. Although widely utilized, there is still lack of conclusive evidence about its efficacy. The aim of the study was to assess the efficacy and safety of endovascular electrocardiographic guided placement compared to the anthropometric method.

Methods: Endovascular ECG was employed to guide electrocardiographic placement of a central venous catheter in a cohort of oncologic patients. The rate of correct placement and the incidence of catheter-related thrombosis were considered. Patients in which central venous catheters were inserted with the anthropometric technique were considered as control group.

Results: The rate of correct placement was 91% and 50% for ECG-guided and anthropometric catheters (p<0.0001) respectively. None of the patients suffered from early insertion-related complications. The rate of catheter-related vascular thrombosis was lower for ECG-guided catheters (3.6% vs. 9.6%, n.s.), in particular for left-inserted catheters (0% vs. 33.3%, p=0.02).

Conclusion: Endovascular electrocardiography was more effective than the anthropometric technique in placement of implantable central venous catheters and was associated with a lower incidence of catheter-related thrombosis, in particular for those inserted from the left-side.
Intra-cavitary ECG is an effective method for correct positioning the tip of tunneled Groshong catheters

Giuseppe Capozzoli, Gino Accinelli, Loris Fabbro, Roberta Pedrazzoli, Franco Auricchio

Anesthesia and Intensive Care Unit, Bolzano Central Hospital - Italy

ABSTRACT

**Background:** Intra-cavitary electrocardiography (ECG) is a well-known method for correct positioning of the tip of central venous catheters (CVC). A significant increase in the P wave, as registered by the intra-cavitary electrode, signals the entrance of the catheter into the right atrium.

**Methods:** In this prospective observational study, 155 consecutive oncologic patients were enrolled for cannulation of the right or left internal jugular vein for insertion of a tunneled Groshong catheter. In 150 patients the tip was positioned by means of intracavitary ECG. Five patients with atrial fibrillation (N=4) or pacemaker in place (N=1) were excluded from the study. As the P-wave amplitude began to increase, the catheter was secured in that position and the insertion depth was registered.

**Results:** Intra-cavitary ECG was always apt to detect the increase in the P wave. On the post-operative chest x-ray all Groshong catheters except two were in the correct position.

**Conclusions:** The need for chest x-ray or fluoroscopy may be virtually eliminated by using the ECG technique.

Accuracy = 99 %
The intracavitary ECG method for positioning the tip of central venous catheters: results of an Italian multicenter study

Mauro Pittiruti¹, Daniele Bertollo², Ermanno Briglia³, Massimo Buononato⁴, Giuseppe Capozzoli⁵, Luigi De Simone⁶, Antonio La Greca¹, Cecilia Pelagatti⁷, Pier Sandro Sette⁸

¹Department of Surgery, Policlinico Universitario ‘A.Gemelli’, Roma - Italy
²Department of Anesthesia and Intensive Care, Ospedale Civile di Varese, Varese - Italy
³Department of Anesthesia and Intensive Care, Ospedale Castelnuovo Monti, Reggio Emilia - Italy
⁴Department of Surgery, Ospedali Riuniti di Cremona, Cremona - Italy
⁵Department of Anesthesia and Intensive Care, Ospedale Civile di Bolzano, Bolzano - Italy
⁶Department of Anesthesia and Intensive Care, Az. Osp. Universitaria di Pisa, Pisa - Italy
⁷Department of Anesthesia and Intensive Care, Ospedale Careggi, Firenze - Italy
⁸Department of Anesthesia and Intensive Care, Ospedale Fracastoro, San Bonifacio - Italy
GAVeCeLT Multicenter Study

8 hospitals, 1440 patients
Any type of central VAD
Intra-procedural IC- EKG vs. post-procedural X-Ray
X-ray criteria for CAJ:
  CAJ = 3 cm below the carina
  Lower 1/3 SVC = 1-3 cm below the carina
  Upper 1/3 RA = 3-5 cm below the carina
GAVeCeLT Multicenter Study

IC-EKG (intra-op.) vs. Chest X-Ray (postop.)

**Total Match (Accuracy): 95,4 %**

Mismatch EKG/Xray = 3.8 % (55 cases)

in 44/55 cases, tip was higher on X-Ray

… but in most of these patients post-op- Chest X-Ray had been performed in standing position
GAVeCeLT Multicenter Study

IC-EKG (intraop.) vs. Chest X-Ray (postop.)

...considering the confounding factor that IC-EKG had been performed in supine position and Chest X-Ray in standing position:

Match (Accuracy): 99 %
GAVeCeLT Pediatric Multicenter Study

Accuracy = 95.8% (307 children)

Age < 4yr  96.2%
Age 4-11yr 95%
Age 11-18yr 96.8%

In the 95 cases performed with a dedicated ECG monitor (Nautilus) accuracy was higher: 98.8%
The intracavitary ECG method for positioning the tip of central venous access devices in pediatric patients: results of an Italian multicenter study

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⁵ Pediatric Intensive Care Unit, Catholic University Hospital, Roma - Italy
⁶ Department of Anesthesia and Intensive Care, Ospedale Civile di Bolzano, Bolzano - Italy
False positive

Extremely rare false positive (atrial P ok, but the tip is not at the CAJ)

Arterial or pleural position of the tip
Pericardial reflection
Vascular malformations
False positive?

- Some false ‘atrial P waves’ may be associated with very rare complications such as extravascular or intra-arterial position of the CVC
  - Not described for PICCs
  - Described only for non-tunnelled CVCs positioned with the ‘blind technique’ (risk of non-intravenous position of the CVC)
- Not one case in GAVeCeLT Multicenter Study (1440 pts) where all VADs were inserted by ultrasound guidance
False negative

Extremely rare false negative (no atrial P, but the tip is at the CAJ)

*Poor interpretation of the operator (children)*

*Vascular malformations*

*Technical problems (poor conductivity)*
Yes

GAVeCeLT Multicenter Study 2012:
1440 patients, any type of VAD
No complication - directly or indirectly related to the EKG method – was reported
The overall incidence of arrhythmias was low (0.7%)

GAVeCeLT Pediatric Multicenter Study 2013:
309 children, any type of VAD
No complication - directly or indirectly related to the EKG method – was reported
EKG method means safety

- No x-ray exposure
- No risk of arrhythmias
  - The whole manoeuvre is performed under EKG monitoring
  - The operator enters the heart with the catheter, not with a guidewire (saline method!)
- The operator knows in any moment where the tip is
  - No risk of getting close to the tricuspid or to the ventricle
- Intracavitary EKG = no risk of electric hazard
- No risk of malpositions potentially missed at x-ray
- Easy-to-read documentation of the tip position
Easiness
Easiness

Easy to perform
Easy to teach
Easy to learn
Old fashioned ECG monitor: it worked well for us for a decade.....
New defibrillators/ECG monitor: terrific for the EKG method.....
Getting easier?

The guidewire technique has been abandoned and completely replaced by the saline technique, which appears to be:

- Simpler
- Safer
- Easier
- And works with all catheters

Saline technique is getting even simpler and easier by means of dedicated ECG monitor such as Nautilus and Nautilus Delta.
The method is easy... even easier with a dedicated monitor

Nautilus
Intracavitary reading (Atrial P wave)

Surface ECG
Print out for the patient’s chart
Documentation
Nautilus vs. standard EKG monitor

- Easy to use:
  - Pre-setted monitor

- Easy identification of P changes:
  - Direct comparison surface EKG vs. IC-EKG
  - Direct comparison between different positions of the tip (‘freezing’ one position on the right side of the display)

- Easy documentation
  - Print-out of the IC-EKG
Even better: Wireless IC-ECG

Delta
Delta (Romex) is a new wireless system specifically dedicated to the IC-ECG, which consists of a small box connected to the ECG cables, sending data to a smartphone or a tablet by bluetooth technology.

The phone/tablet is provided with a software application which allows to display both the surface and intracavitary ECG.

The system can be operated by command buttons placed on the box or directly by touching the screen of the phone/tablet.
The IC-ECG method is performed according to the standard procedure.

The identification of the peak of the P wave (corresponding to the cavo-atrial junction) is made easy by the freeze function, which can be operated either from the box or from the phone/tablet.

At any time, the display can be saved and/or printed for documentation.
The new device was adopted for tip location in 207 central VADs (154 PICCs, 49 ports, 2 short term CICCs and 2 cuffed-tunneled catheters) placed after cannulation of different veins (96 basilic, 41 brachial, 57 axillary-subclavian, 6 internal jugular, 7 brachio-cephalic).

The P wave was evident on basal ECG in all patients.

A peak of the P wave was easily detected in all patients.
The P wave was evident on basal ECG in all patients.

A peak of the P wave was easily detected in all patients.

In 36 patients (28 PICCs and 8 ports), the procedure was simultaneously carried out both with a standard dedicated ECG device (Nautilus, Romedex) and with the new wireless device: no differences were noted in terms of performance.
This new wireless system for IC-ECG had an optimal clinical performance in terms of applicability and feasibility.

Transmission of the data to the moveable device by bluetooth simplified the wire connections.
Some potential advantages over other ECG monitors are:

- the system is light and easy to carry - which makes it ideal for bedside insertion;

- it can be operated by the same professional inserting the VAD;

- it implies no risk of electrical hazard;

- it can be used on a personal portable device, allowing easy storage of data and easy printing for documentation.
DELTA

Presented in WoCoVA 2014 and AVA 2014

No published paper available yet
Central venous access in neonates and children: tip location using a new wireless device for intracavitary ECG

Mauro Pittiruti, Davide Celentano and Daniele Biasucci
Catholic University Hospital, Rome - Italy
Purpose

Tip location of central lines is particularly important in children and ideally it should be assessed during the procedure.

We have adopted the intracavitary ECG method (IC-ECG) since a decade. We report our recent experience with a wireless device for IC-ECG.
Methods

We reviewed all centrally (CICC) and peripherally inserted central catheters (PICC) placed in our Pediatric Intensive Care Unit (PICU) using a wireless IC-ECG device (Delta, Romedex).
All insertions were performed according to our **PICU protocol**: sedation or general anesthesia, ultrasound scan of all veins, maximal barrier precautions, skin antisepsis with 2% chlorhexidine, ultrasound guided venipuncture using a micro-introducer kit, tip location by IC-ECG (maximal height of the P wave = cavo-atrial junction), securement of the catheter by cyanoacrylate glue, sutureless device and transparent dressing.
Results

Wireless IC-ECG was used in 85 children (age range 2 hrs - 12 y.o.: 58 patients were < 2 y.o.). Lowest weight was 1100 g.
Results (2)

We inserted 81 non-cuffed catheters (power injectable, polyurethane, non-valved, open ended; 3Fr single lumen or 4Fr double lumen):

- 55 CICCs (in 95%, cannulation of the brachio-cephalic vein + tunneling to the infraclavicular area)

- 26 PICCs (cannulation of deep veins of the arm; in 75%, cannulation of the axillary vein at the axilla + tunneling to the arm or to the lateral thoracic area).

In 4 cases, we inserted tunneled, cuffed CICCs (5Fr single lumen) for long term therapy: all 4 were children > 6 years.
Results (3)

We had no insertion-related complications. IC-ECG was easily performed in all cases. Post-procedural confirmation of tip location was performed by echocardiography or (in a few cases) by chest x-ray: no malposition was detected.
Conclusions

Tip location with the new wireless IC-ECG device was applicable, feasible, safe and accurate in 100% of our pediatric patients, even in small neonates.
Please remember

IC-ECG is the preferred choice for tip location.

Hundreds of published papers (1949-2014) have validated the method in terms of accuracy.
Cost effectiveness
Cost-effectiveness

Low cost method
‘low cost’ training
Applicable even when X-Ray is contraindicated or difficult or expensive (pregnancy, morbid obesity, hospice, home care, etc.)
‘real time’ verification
i.v. treatment can start immediately after
Save money (cost of X-Ray, cost of repositioning)
Cost effectiveness

In its basic form: **IC-EKG is inexpensive** (connection cables cost few euros)

**Big saving comes from:**

- Avoiding expensive equipment (fluoroscopy, TEE)
- Avoiding x-ray expenses (direct and indirect)
- Avoiding delay due to post-procedural chest x-ray or post-procedural TEE/TTE)
- Avoiding need for reposition (it may happen with post-procedural chest x-ray or post-procedural TEE/TTE)
How much cost-effective?

It is highly cost effective for **ports**, if associated with using US guidance and performing the procedure in a dedicated ambient and NOT in a surgical or radiological theater.

UCSC data (2010): each port insertion in Day Hospital using US + EKG saves €2500 if compared to insertion in operating room with fluoroscopy.

It is highly cost effective for **PICCs**

Every 100 PICC insertions, €7000 saved (UCSC data):

- Prevention of 10% malposition - €200 x 10 = €2000
- Avoid 100 chest x-rays - €50 x 100 = €5000
Conclusions
In adult patients, IC-EKG has been proven to be

**Applicable** in 91-93%
7-9% of adults may not have visible P on surface ECG

**Feasible** in 99% of cases
Using the saline technique and a dedicated monitor, the ‘atrial’ P is visible in almost all pts

**Accurate** in 91-99% of cases (maximal P = CAJ)
‘Real’ accuracy (IC-EKG vs. TEE): 99%
‘Standard’ accuracy (IC-EKG vs. Xray): 91-98%
In children, IC-EKG has been proven to be applicable in 99.4%. Almost all children have visible P on surface ECG.

Feasible in 99.4% of cases:
- Using the saline technique and a dedicated monitor, the ‘atrial’ P is visible in almost all children.

Accurate in 95-98% of cases (maximal P = CAJ):
- Accuracy improves when using a dedicated monitor.
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Intracavitary ECG is accurate (as much as TTE/TEE), 100% safe, highly cost-effective, easy and feasible. Its only limit is that cannot be applied to all patients (in approximately 7% of patients with no evident P wave the method is not applicable).
Do we still need x-ray?

To rule out pleura-pulmonary damage? NO

To check tip position? NO

When do we need post-op. x-ray?
If IC-EKG is not applicable (no P evident on surface EKG) – 7-9 %
If atrial P is not clearly identified during the procedure (IC-EKG ‘not feasible’) - rare
Any time ‘good common sense’ suggests it (strange P patterns, resistance to progression etc.) – rare?
Practical decisional tree

Basal ECG

P. evident
EKG method
Atrial P. evident
No postop x ray.

P. not evident
Atrial P. not evident
Postop. chest x-ray

Fluoroscopy
Tracking and/or US assessment of direction
No postop x ray.
**Table 2. Patient Safety Strategies Ready for Adoption Now**

**Strongly encouraged**
- Preoperative checklists and anesthesia checklists to prevent operative and postoperative events
- Bundles that include checklists to prevent central line–associated bloodstream infections
- Interventions to reduce urinary catheter use, including catheter reminders, stop orders, or nurse-initiated removal protocols
- Bundles that include head-of-bed elevation, sedation vacations, oral care with chlorhexidine, and subglottic suctioning endotracheal tubes to prevent ventilator-associated pneumonia
- Hand hygiene
- The do-not-use list for hazardous abbreviations
- Multicomponent interventions to reduce pressure ulcers
- Barrier precautions to prevent health care–associated infections
- **Use of real-time ultrasonography for central line placement**
- Interventions to improve prophylaxis for venous thromboembolisms
**Encouraged**

- Multicomponent interventions to reduce falls
- Use of clinical pharmacists to reduce adverse drug events
- Documentation of patient preferences for life-sustaining treatment
- Obtaining informed consent to improve patients’ understanding of the potential risks of procedures
- Team training
- Medication reconciliation
  - **Practices to reduce radiation exposure from fluoroscopy and CT**
    - The use of surgical outcome measurements and report cards, such as those from ACS NSQIP
- Rapid-response systems
- Use of complementary methods for detecting adverse events or medical errors to monitor for patient safety problems
- Computerized provider order entry
- Use of simulation exercises in patient safety efforts
FIRST FACT

A proper tip location methodology – preferably carried out during the procedure – is mandatory in all placements of central lines.
SECOND FACT

In adult patients, intracavitary ECG should be the preferred method of tip location: it is accurate, safe, easy, inexpensive, highly cost-effective and it can be applied to the vast majority of patients.
THIRD FACT

Few selected adult patients might need intra-procedural fluoroscopy (when IC-ECG is not applicable or feasible) and/or post-procedural control of tip location by chest x-ray or TTE (when intra-procedural tip location has not been carried out or it has provided dubious results).
FOURTH FACT

In neonates and children, tip location of central lines can be verified with maximal safety, accuracy and cost-effectiveness by a combination of intra-cavitary ECG (during the procedure) and TTE (during or after the procedure).
Current controversies (1)

What is the best approach for tip location in the patients with no evident P wave on surface ECG (AF, etc.)?
The mean increase of the baseline electrical activity on the intracavitary ECG recorded in patients with atrial fibrillation may be used for detecting the transition of the catheter electrode from the superior vena cava to the right atrium

(Engelhardt; Pittiruti et al.)
“EKG-controlled placement of central venous catheters in patients with atrial fibrillation”
(Pittiruti, La Greca, Scoppettuolo et al. - INS 2011)
Prospective clinical study

Patients with atrial fibrillation candidate to a central line insertion

- Exclusion criteria: presence of an active pacemaker

Goal: to investigate the possibility of using the EKG technique for verifying the central position of the tip, using a dedicated device (Nautilus)
The cavo-atrial junction was detected by two criteria:
(a) abrupt appearance of high-voltage waves when entering the right atrium and their brisk disappearance when pulling the catheter back into the vena cava superior;
(b) sudden increase (2-fold, 5-fold) of the amount of energy recorded by the intracavitary electrode.
SVC pattern

Right Atrium pattern

Energy recorded
SVC pattern

Right Atrium pattern
The cavo-atrial junction was correctly identified in 25 patients out of 27, as proven by the radiological control.

In two patients, the ECG pattern was seriously deranged and no clear intra-cavitary ECG tracking could be obtained.
The intra-cavitary EKG method for verifying the position of the tip of central venous access devices can be applied in most patients with atrial fibrillation, with high accuracy (no false positives; few false negatives).
Patients affected by atrial fibrillation and candidate to cardiac surgery (aorto-coronaric bypass, valvular replacement) under emodynamic monitoring via trans-esophageal echocardiography + CVAD placement in the operating room have been consecutively enrolled.

In each patient, the TEE probe was inserted after completion of the general anesthesia procedure and adjusted to obtain the atrio-bicaval view.
CVCs were inserted under ultrasound and IC-ECG guidance according to our Institution standard policy.

The CVC tip was placed at the CAJ as defined with regard to the crista terminalis, the anatomical and US landmark of the CAJ and then threaded 2 cm below and pulled 2 cm above it always under TEE guidance.

The IC-ECG traces corresponding to the three US-based tip positions were saved for subsequent analysis and the catheter was left in situ at the site defined by TEE.
Guidewire J-tip and the crista terminalis can be clearly located by the TEE operator in all patients.
An abrupt increase in the mean intracavitary amplitude of the asynchronous atrial electrical activity (i.e. the T-Q segment on the ECG trace) as compared to the surface trace was recorded with the J-tip placed at the crista terminalis.

A clear reduction in amplitude was evident in the two alternative positions in all patients.
Another option

Analyzing the waves.....

The area under the T-Q segment = atrial energy
Another possible option

Adding a navigation system may help directing the tip towards the SVC thus obtaining the expected variations in amplitude of P wave or T-Q segment.
“TIP NAVIGATION + TIP LOCATION: AN ALGORITHM FOR MAXIMIZING SAFETY AND COST-EFFECTIVENESS OF CENTRAL VADs”

- 30 patients consecutively studied during PICC placement
- Navigator (Corpak) as tip navigation system
- Intracavitary ECG method for tip location.
The tip navigation device was successfully used in all patients, making the procedure easier and faster.

In all patients, the correct tip location as evaluated by the intracavitary ECG method corresponded to the electromagnetic detection of the tip below the third intercostal space, with the tip properly directed downward.
AF – one more option?

Vasonova VPS

Is it useful for tip location in AF?

- No published data on peer-reviewed journals
- Reported success on 5 pts with AF (JAVA, 2014)
- More studies are needed; in particular, a clinical study of doppler alone in AF is highly needed (doppler navigation technology has never been validated separately from IC-ECG)
Correct positioning of peripherally inserted central venous catheters using a new electric method

Maurits K Konings, Leonard J van Schelven, Ronald C Meijer, Albert H Westra, Roland A Snijder, Anton J van Boxtel

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MK, LS, AW, and RS are with the dept. of Medical Technology, and RM is with the dept. of Thoracic Surgery, University Medical Center Utrecht, Utrecht, the Netherlands. AB is with Infu-In, Bilthoven, the Netherlands
AF – maybe the best option..

ULTRASOUND:

TTE +/- CEUS
Avoid X-Ray in IC-ECG definitively unsuitable patients: ULTRASOUND

**Ultrasonic Examination**

An Alternative to Chest Radiography after Central Venous Catheter Insertion?

**Negative assessment:**
IJV & SCV (supraclavicular view), RA (subcostal view)

**Guidewire localization by transthoracic echocardiography during central venous catheter insertion: a periprocedural method to evaluate catheter placement**


**Negative assessment:**
RA (subcostal view) + predictive length

**Ultrasound localization of central vein catheter and detection of postprocedural pneumothorax: An alternative to chest radiography**

"Positive" assessment:
Saline + air bubbles in linear flow appearing within 2 seconds (subcostal view)
“I have used ultrasound by visualizing all 4 central vessels and RA with agitated saline injection (CEUS) to confirm placement in SVC along with pulmonary US to exclude pneumothorax. However, I do not routinely use this in all patients but in selected cases (such as AF)”

Jason T Nomura MD, RDMS, posted on April 11, 2010 in Emergency & Critical Care Ultrasound Community Discussions, www.aiumcommunities.org
Current controversies (2)

Which protocol/algorithm for tip location and tip navigation is associated with the maximal cost-effectiveness?
This cannot be determined yet.
Our current algorithm

1) P wave evident:
   - tip location by IC-ECG (peak of P wave = CAJ);
   - tip navigation by ultrasound (when using a standard ECG monitor) or by ECG-based navigation (when using Delta)
Our current algorithm

2) P wave absent:
   - in AF: tip navigation by NAV, with approximated tip location (third intercostal space on the right parasternal line) + tip location by IC-ECG (abrupt change in amplitude of TQ)
   - in APM or other arrhythmias: tip navigation by NAV, for approximated tip location (see above) + confirmation by TTE (intra-procedural) or chest X-Ray (post-procedural).
Final remarks

1) use an **intra-procedural tip location** method whenever possible (preferably based on IC-ECG)

2) When adopting a tip navigation method as an add-on to tip location, **consider its cost-effectiveness** (which is still under debate for many devices)

3) The most cost-effective method of tip location for **AF patients** is still uncertain
Our Vascular Team....