This material is for the use of members of the MGH DACCPM only

Perioperative Electrophysiology:

Perioperative Management of Pacemakers

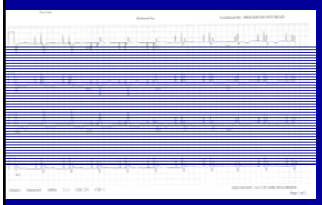
Lecture #5

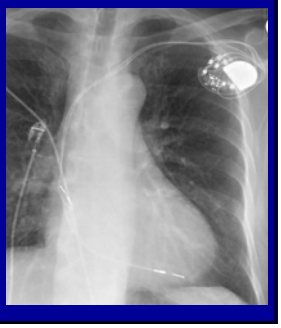
Assessment of EKGs and CXRs

Scott Streckenbach, MD
Cardiac Anesthesia Group
Director, Perioperative Electrophysiology Service
Massachusetts General Hospital
sstreckenbach@partners.org

I have no conflict of Interest

Use the EKG and CXR to understand the Pacemaker





Form a Good Habit

- Look at every patient's EKG and CXR prior to interrogating that patient's CRMD

Goals for Lecture #5

1. You should be able to use the EKG to:
   - Determine patient's underlying rhythm
   - Determine degree of pacemaker dependence
   - Determine likely pacing mode
   - Search for pacemaker malfunction
2. You should be able to use the CXR to:
   - Determine lead locations
   - Determine pacemaker manufacturer
   - Determine likely pacing mode
   - Search for pacemaker malfunction

EKG Discussion Topics

- Two EKG-Abbreviation Systems
- 5 EKG patterns you will see
- Review of fusion and pseudofusion beats
- A trick to evaluate complex EKG rhythms
- How to increase the amplitude of pacing artifacts on an EKG

EKG Abbreviations—System 1

- AP = A pace
- VP = V pace
- AS = Native P-wave
- VS = Native R-wave

EKG Abbreviations-System 2

- A = A pace
- V = V pace
- P = Native P-wave
- R = Native R-wave

What are the 5 EKG Patterns?

Normal Sinus Rhythm
A-V sequential pacing (pacer dep)
Atrial pacing (SSS)
Atrial tracking (AV Block)
Ventricular pacing (A Fib)

Interpret this EKG

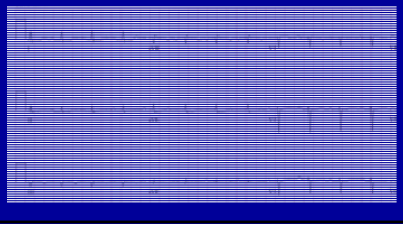
Normal Sinus Rhythm

How would you describe NSR?

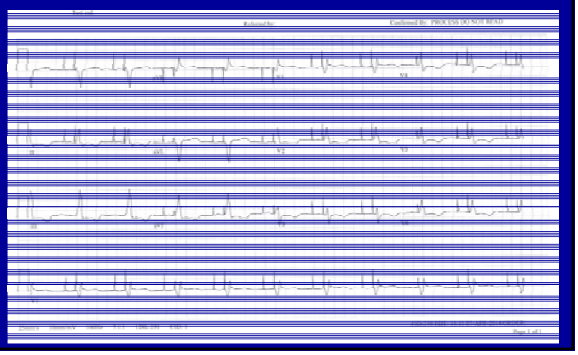
- AS-VS
- P-R

What is the Likely Pacer Setting?

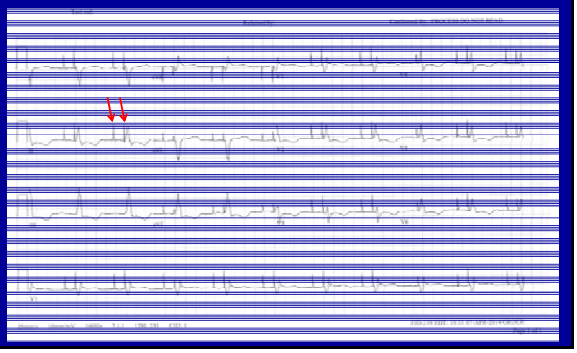
- DDD
- AAI (Sick Sinus Syndrome)
- VVI (ICD backup pacing)



Interpret this EKG

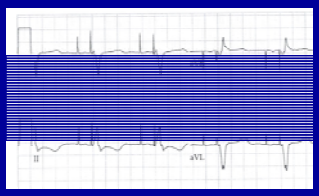


A-V Sequential Pacing



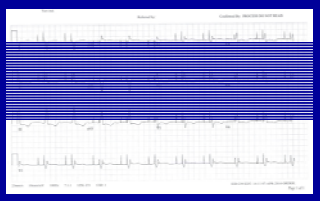
How would you describe A-V Sequential Pacing?

- AP-VP
- A-V

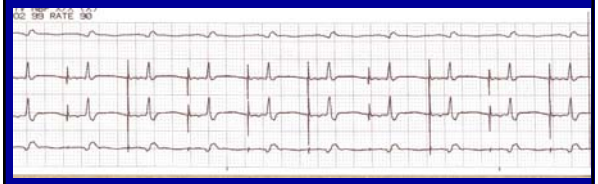


What is the Likely Pacer Setting?

- Most likely DDD
- Could be DOO (magnet applied)



Interpret this EKG



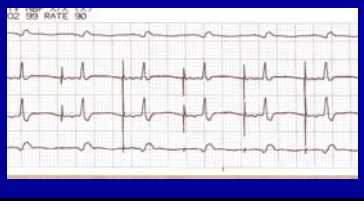
Atrial Pacing

How would you Describe Atrial Pacing?

- AP-VS
- A-R

What is the Likely Pacer Setting?

- DDD with long programmed AV interval
- AAI



Interpret this EKG

Atrial Tracking (AS-VP)

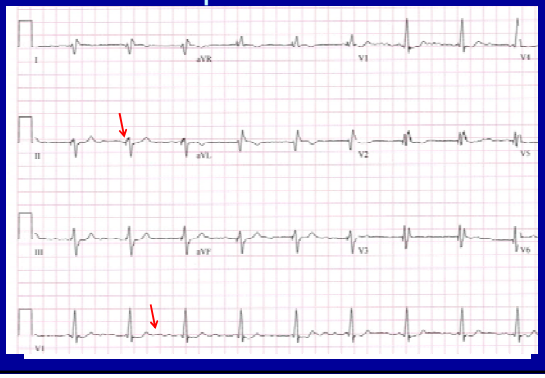
How would you Describe Atrial Tracking?

- AS-VP
- P-V

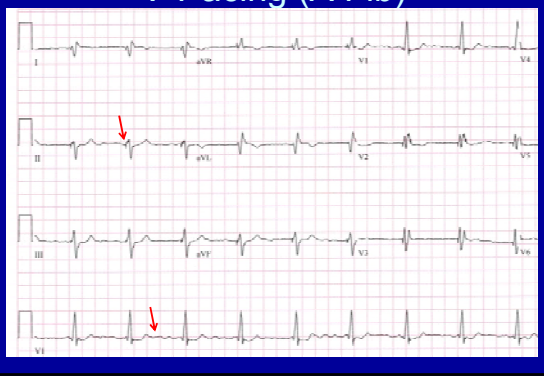
What is the Likely Pacer Setting?

- DDD
- Could be VAT

Interpret this EKG

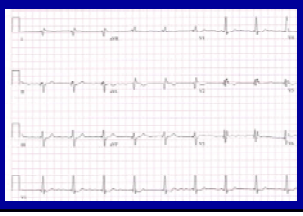


V-Pacing (A Fib)



What is the Likely Pacer Setting?

- Most likely VVI or VVIR
- Could be DDD with VVIR mode switch
- Could be DDI or DDIR (least likely)



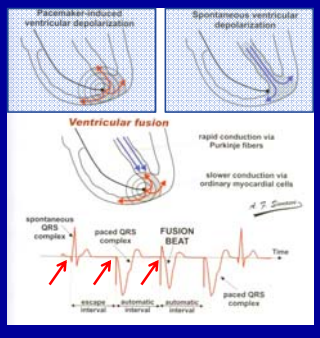
Abbreviations and Patterns Summary

System 1	Description	System 2
AS-VS	Normal Sinus Rhythm	P-R
AP-VP	A-V sequential pacing (pacer dep)	A-V
AP-VS	Atrial pacing (SSS)	A-R
AS-VP	Atrial tracking (AV Block)	P-V
VP	Ventricular pacing (A Fib)	V

Fusion vs Pseudofusion Beats

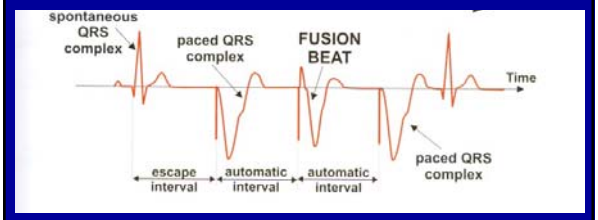
- We see these often in the OR
- Can also see them when analyzing pacers on the floor
- Recognition of these pacing patterns is important in troubleshooting
- So let's review

Ventricular Fusion Beat



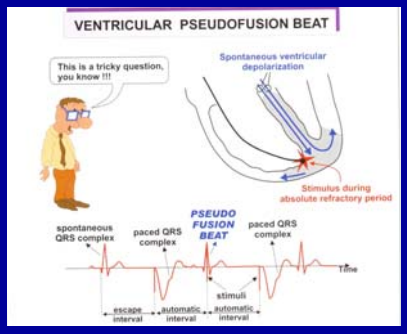
Barold SS, Cardiac Pacemakers and Resynch., p. 77

Ventricular Fusion Beat



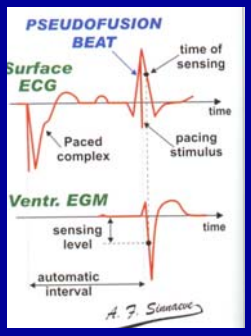
Barold SS, Cardiac Pacemakers and Resynch., p. 77

Pseudofusion Beat



Barold SS, Cardiac Pacemakers and Resynch., p. 78

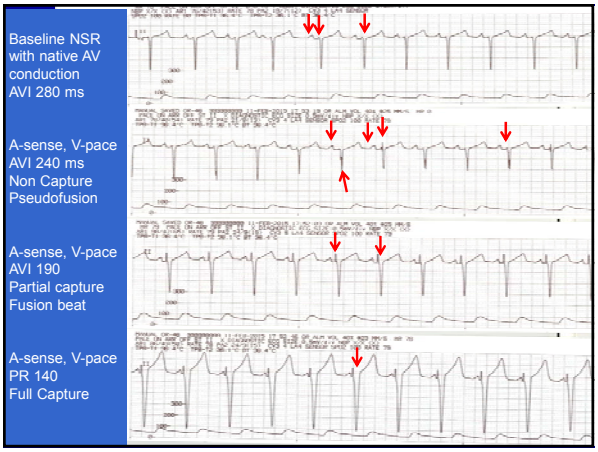
Pseudofusion Beat



Barold SS, Cardiac Pacemakers and Resynch., p. 78

Example from the OR

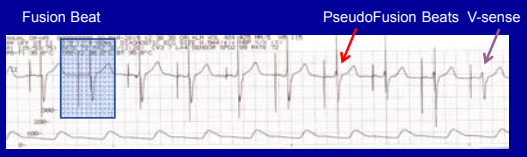
- If you have a patient with intact, but prolonged A-V conduction, you can easily create pseudofusion beats, fusion beats and finally fully paced beats
- Start A-V pacing (DDD mode) with a long A-V interval and progressively SHORTEN the pacemaker's A-V interval



Fusion Beats vs V-Paced Beats

Initial assessment reveals narrow paced beats, apparent fusion beats. As the PR interval is shortened, the ventricular pacing stimulus captures the entire ventricle and gives rise to a standard V-paced beat. Note the wider QRS.

Pseudofusion vs Fusion Beats



We start again with what appears to be a Fusion Beat during A-V pacing
This time we progressively lengthen the AV interval
Notice how the fusion beat becomes a pseudofusion beat (r' appears, QRS narrows), and then becomes a V-sense beat with pacing inhibition.

AV interval started at 180 msec and was increased to 220 msec

Key Concept to Remember

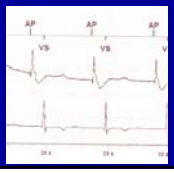
- It is nearly impossible to define with certainty a Fusion or Pseudofusion beat without the presence of a fully paced beat and a natively conducted ventricular beat
- Manipulation of the A-V interval allows one to diagnose one beat or the other

EKG Discussion Points

- Two EKG-Abbreviation Systems
- 5 EKG patterns you will see
- Review of fusion and pseudofusion beats
- A trick to evaluate complex EKG rhythms
- How to increase the amplitude of pacing artifacts on an EKG

What can you do if your patient with a Pacer has an uncertain EKG rhythm?

- Interrogate the patient's pacer with a programmer
  - The atrial and ventricular electrograms will be easier to interpret using the marker channel



How can you use the programmer to enlarge pacing artifacts on the surface EKG?

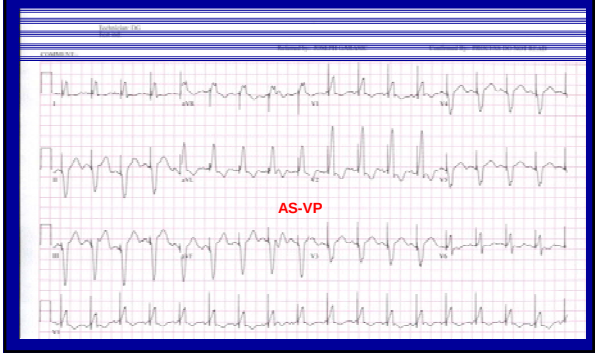
- Increase the pacing amplitude
- Switch the pacing to a unipolar configuration

Important Message

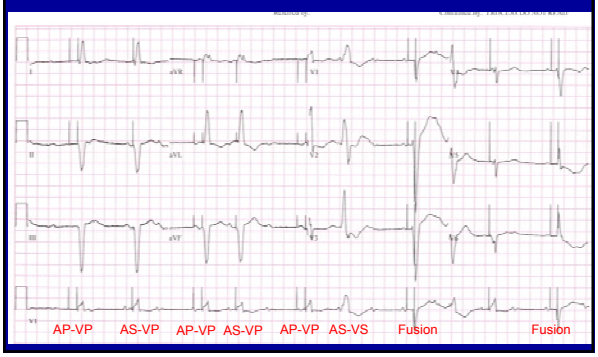
- Always look at the patient's baseline EKG and the patient's present rhythm to get at least 2 time points in your evaluation of underlying rhythm

You need a Sharp Eye to get all the possible information from the EKG

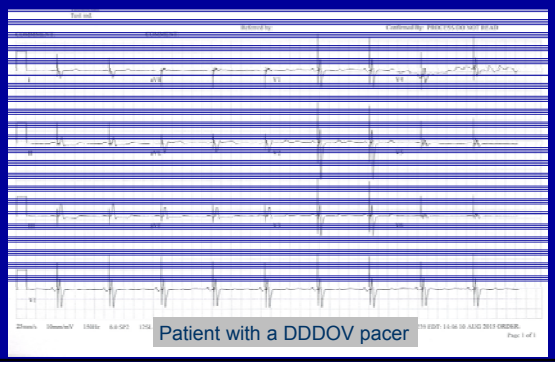
Analyze this EKG



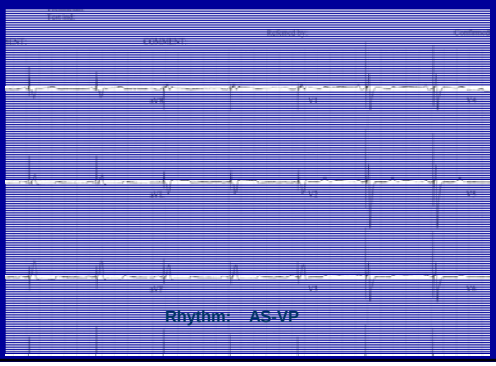
Analyze this EKG



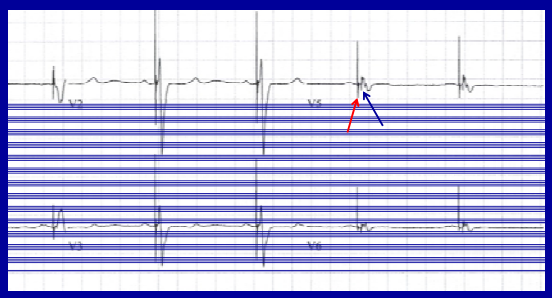
Analyze this EKG



Analyze this EKG



What do you notice in V5



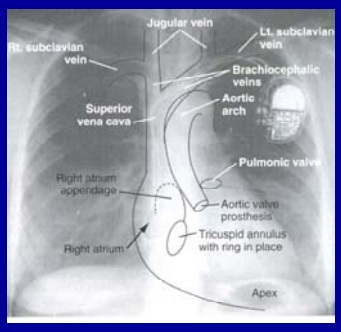
LV-RV 35 msec: LV fires 35 msec before the RV

CXR Assessment

CXR Assessment

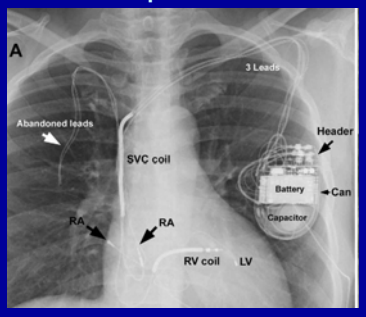
- The CXR is very useful in patients with a pacemaker
  - How many leads
  - Pacemaker vs ICD
  - Manufacturer
  - Likely pacing mode

CXR Basic Anatomy



Ellenbogen, Clin Cardiac Pacing 4th ed., p.772

The CXR Assessment can be Complicated



Jacob et al, Heart Rhythm Vol 8 No 6 June 2011, p.917

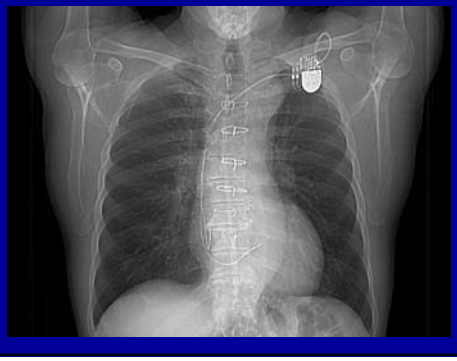
Step by Step CXR Assessment

- Pulse generator
  - Define the pulse generator location
  - Confirm the device is a pacemaker
  - Determine the device manufacturer
- Leads
  - Define lead locations
  - Are the leads endocardial or epicardial
  - Are the leads pacing leads or ICD leads
  - Are the leads connected and positioned correctly?
  - Are the leads active or passive fixation?

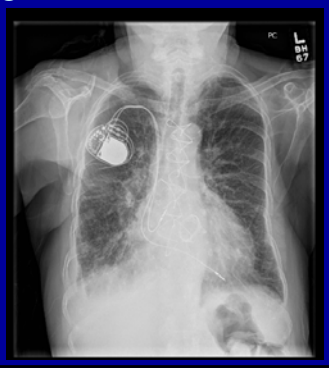
Define Pulse Generator Location

- More common implantation sites:
  - Left infraclavicular
  - Right infraclavicular
  - Abdomen

Left Infraclavicular Site



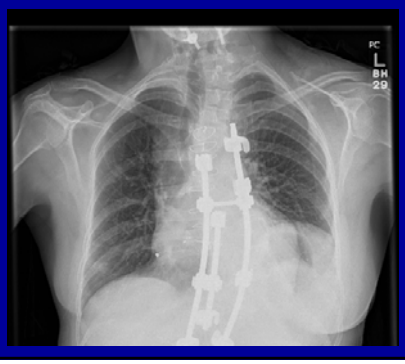
Right Infraclavicular Site



Abdominal Site

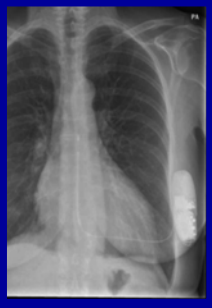
Ellenbogen, Clin Cardiac Pacing 4th ed., p.773

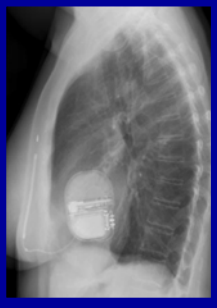
Where is the Pulse Generator?



Where is the Pulse Generator?

Where is the Pulse Generator?





S-ICD System Highlights

- Single electrode connection
- 80 joule (delivered) biphasic shock
- Charge time to 80J ≤ 10 seconds
- 30 seconds post-shock pacing

Boston Scientific

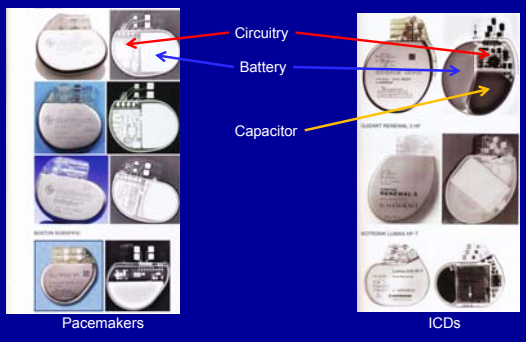
CXR Assessment

- Define the pulse generator location
- Confirm the device is a pacemaker
- Determine the device manufacturer

Confirm the Device is a Pacemaker

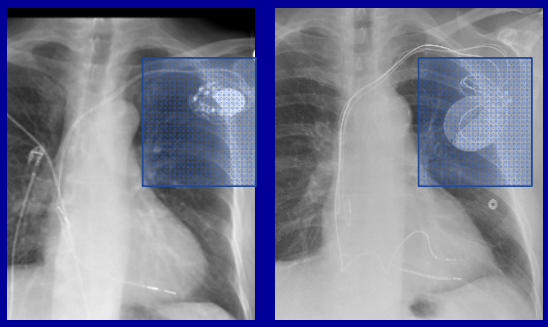
- Pacers have a radiopaque battery
- ICDs have a radiopaque battery and capacitor
- Implantable Loop Recorders are small and usually rectangular
- Vagal nerve stimulators typically have a lead going to the IJ vein

Pacemaker vs ICD



Ellenbogen, Clin Cardiac Pacing 4th ed., p.776, 9

Pacemaker ICD



Implantable Loop Recorders

Jacob et al, Heart Rhythm Vol 8 No 6 June 2011

CXR Assessment

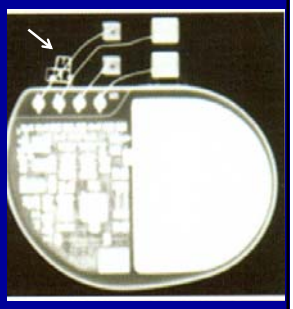
- Define the pulse generator location
- Confirm the device is a pacemaker
- Determine the device manufacturer

Two Ways to Determine the Device Manufacturer

1. Alphanumeric code
2. Characteristics of the pulse generator
   - Can shape
   - Battery shape
   - "Birth Marks"

Alpha-numeric Code

- Medtronic M
- St Jude SJM
- Bost Sci BOS GDT
- Biotronik ET/NT
- Sorin ELA



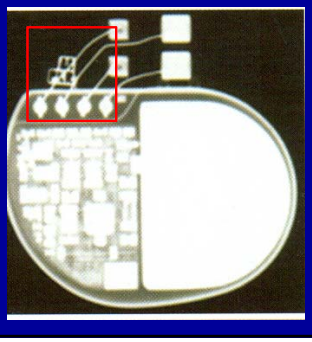
Alphanumeric Code

Biotronik and Medtronic have characteristic symbols

Jacob et al, Heart Rhythm Vol 8 No 6 June 2011, p.918

What type of Pacer is this?

Medtronic



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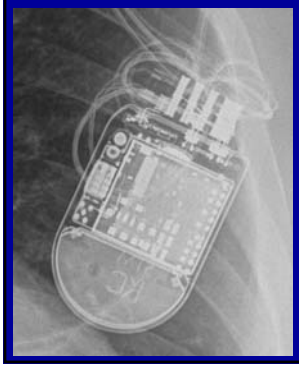
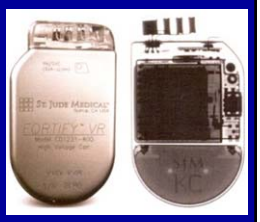
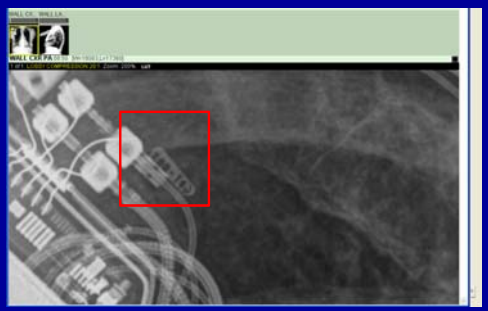




Ellenbogen, Clin Cardiac Pacing 4th ed., p.778

Which type of Pacer is this?



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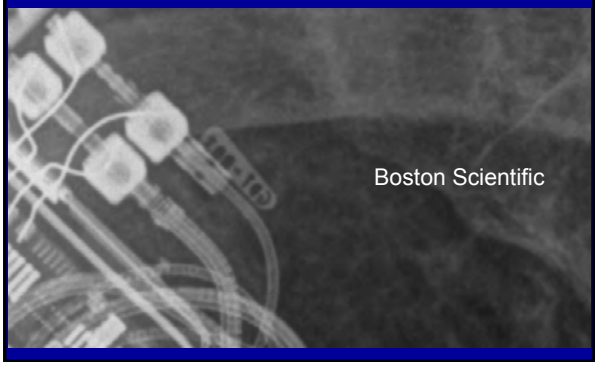
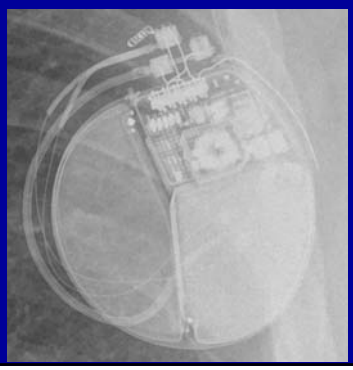


Boston Scientific Incepta ICD



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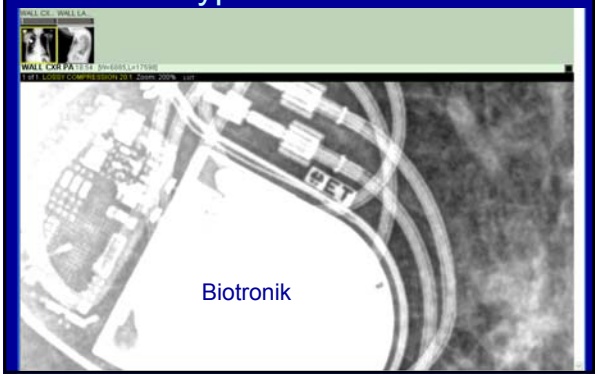

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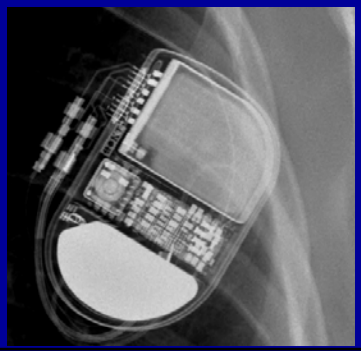

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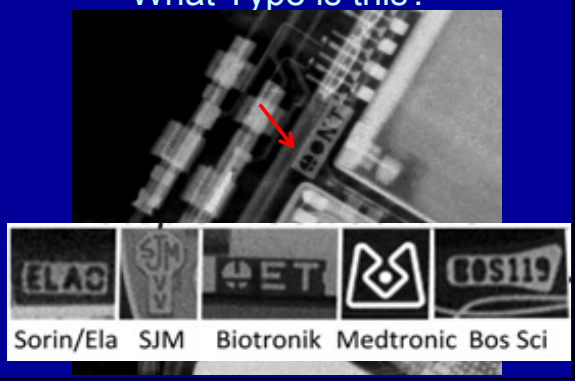


What is the manufacturer?

- Alphanumeric code
- **Characteristics of the pulse generator**
  - **Can shape**
  - **Battery shape**
  - **"Birth Marks"**

CXR Algorithm

CREATIVE CONCEPTS

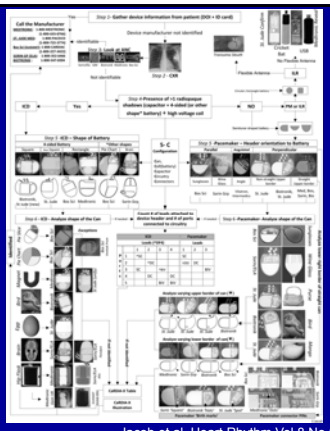
Cardiac Rhythm Device Identification Algorithm using X-Rays: CaRDIA-X

Sony Jacob, MD, Muhammad A. Shahzad, MD, Rahul Maheshwari, BS, Sidakpal S. Panaich, MD, Rajeev Aravindhakshan, MD

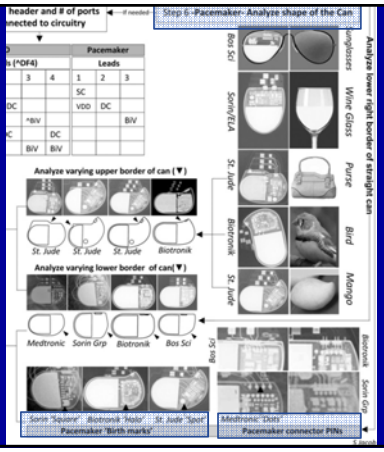
From the Division of Cardiology/Electrophysiology, Department of Internal Medicine, Harper University Hospital, Wayne State University, Detroit, Michigan.

Less than 20% of 1000 pacemakers identified with A-N codes
97% of 2200 pacemakers identified with CaRDIA-X algorithm

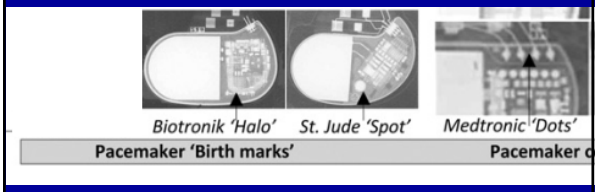
Heart Rhythm, Vol 8, No 6, June 2011



Jacob et al, Heart Rhythm Vol 8 No 6 June 2011, p.918

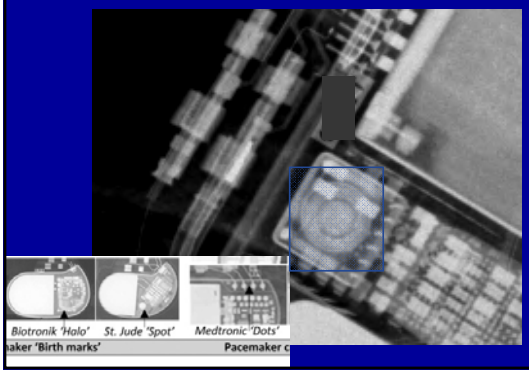


My Three Favorite

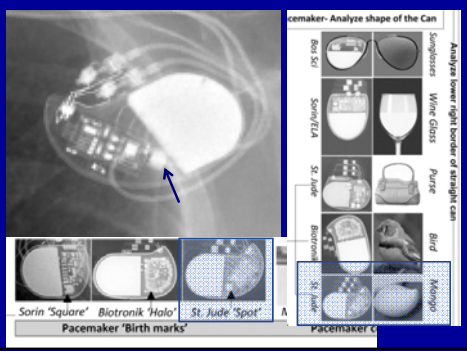


Jacob et al, Heart Rhythm Vol 8 No 6 June 2011, p.918

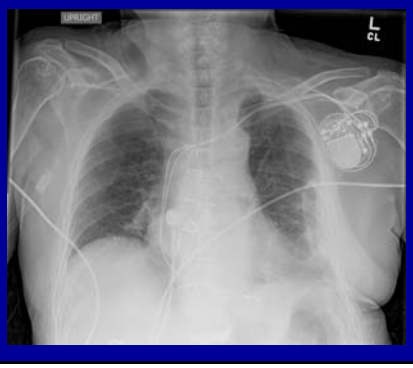
What Manufacturer?



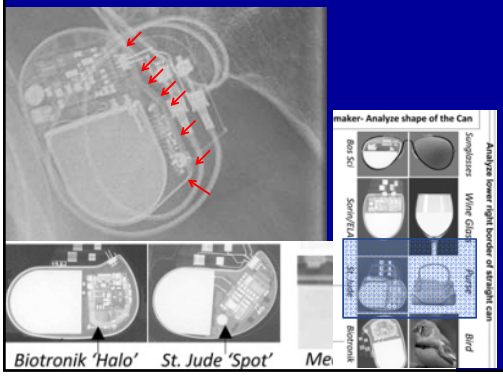
What Manufacturer?



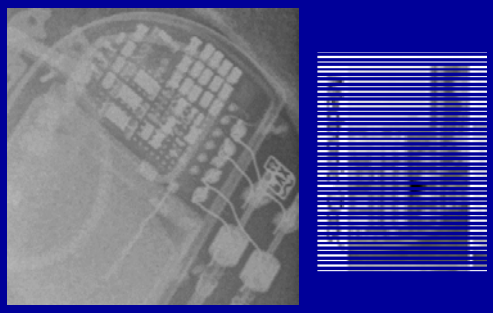
What is the Manufacturer?



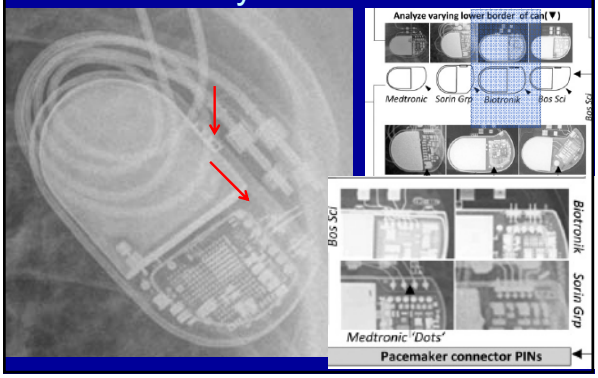
What is the Manufacturer



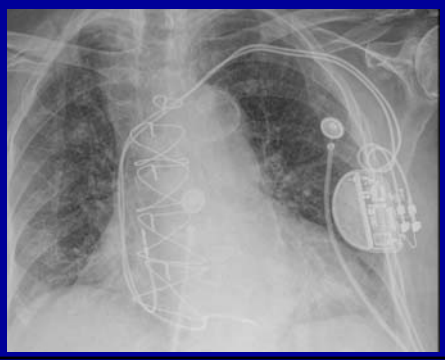
Which Manufacturer?



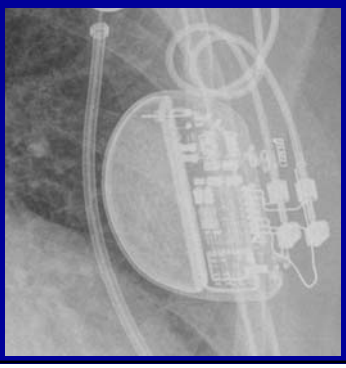
Identify this Device?



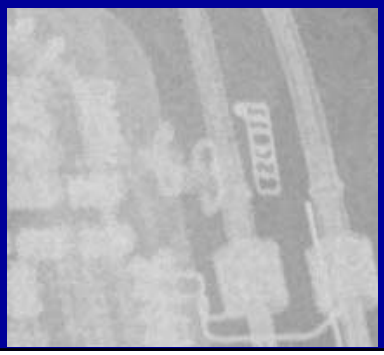
What Type of Pacer is this?

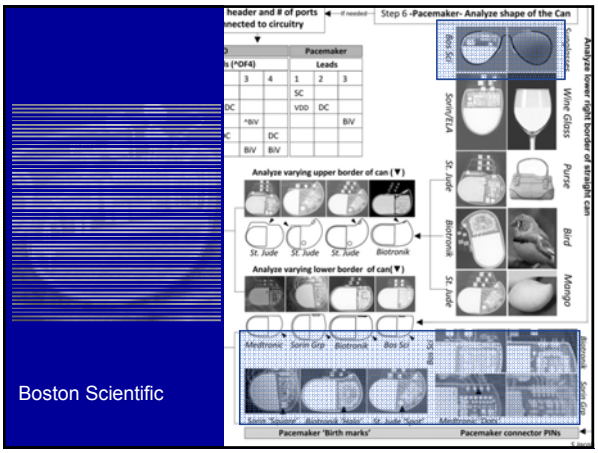


What Type of Pacer is this?



BSCO=Boston Scientific





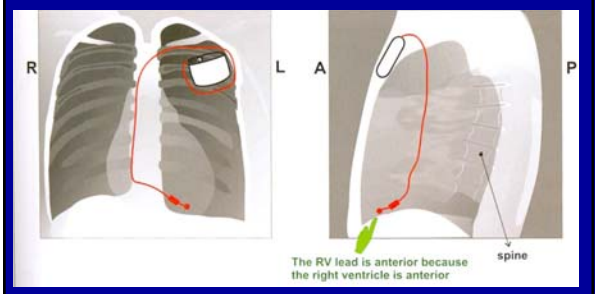
Step by Step CXR Assessment

- Pulse generator
  - Define the pulse generator location
  - Confirm the device is a pacemaker
  - Determine the device manufacturer
- Leads
  - Define lead locations
  - Are the leads endocardial or epicardial
  - Are the leads pacing leads or ICD leads
  - Are the leads connected and positioned correctly?
  - Are the leads active or passive fixation?

Define the Lead Location

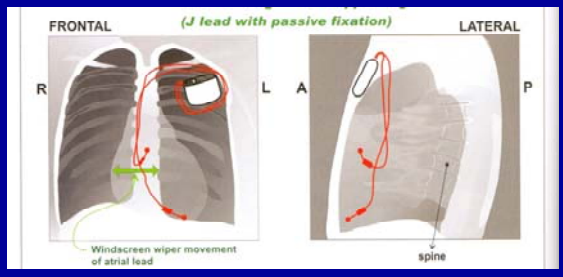
- Right Ventricle
- Right Atrium
- Coronary Sinus
- *Left Ventricle*

RV Lead



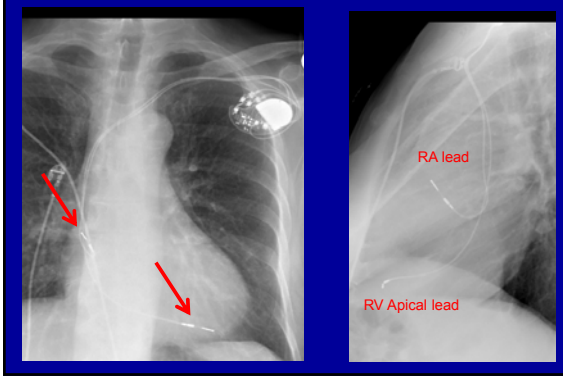
Barold SS et al, Cardiac Pacemakers and Resynch. p.193

RA Lead

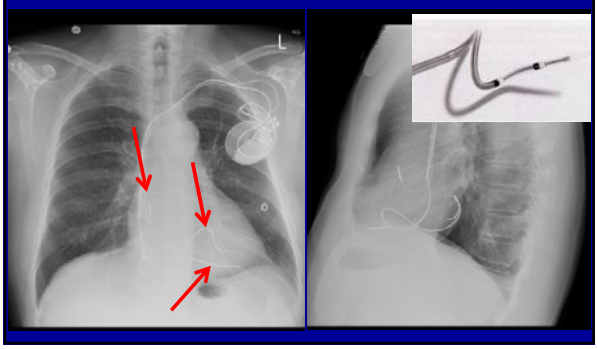


Barold SS et al, Cardiac Pacemakers and Resynch. p.194

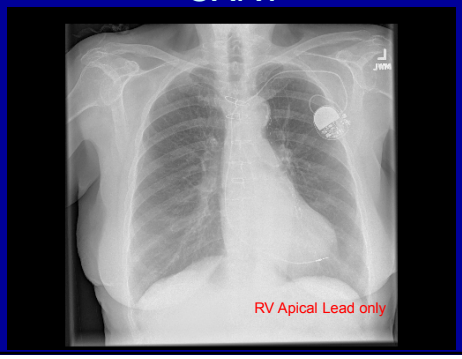
Pacemaker CXR



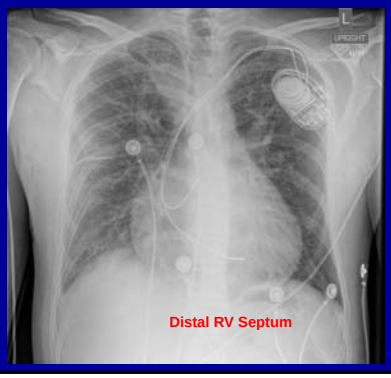
How would you interpret this CXR?



How would you Interpret this CXR?



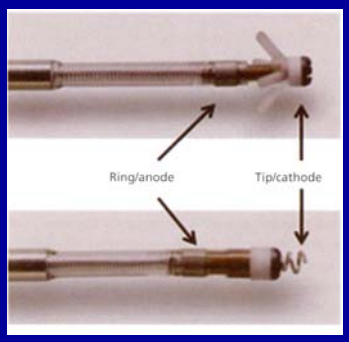
Where is the RV lead?



CXR Lead Evaluation

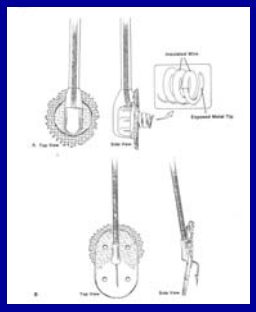
- Define the lead locations
- Are the leads endocardial or epicardial
- Are the leads pacing leads or ICD leads
- Are the leads connected correctly?
- Are the leads active or passive fixation?

Endocardial Leads



Ellenbogen K, Cardiac Pacing and ICDs 6th ed, p.51

Epicardial Active Fixation Electrodes

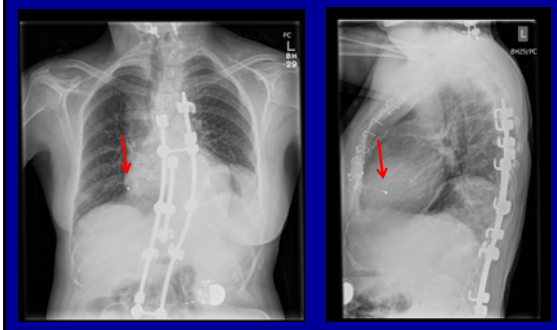


Ventricle

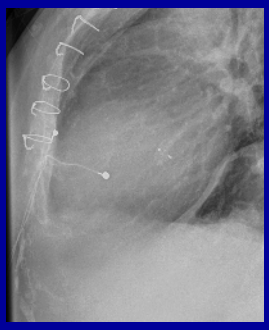
Atrial

Moses, WH: Practical Guide to Cardiac Pacing p. 32

Describe these Leads



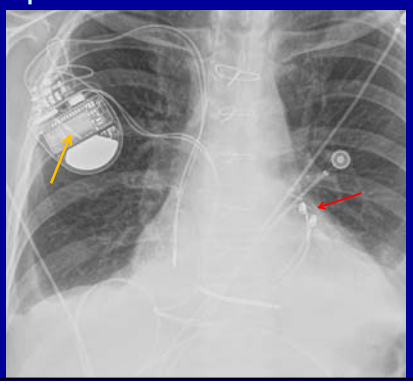
Epicardial Lead



Bipolar Epicardial Leads

Ellenbogen, Clin Cardiac Pacing 4th ed., p.773

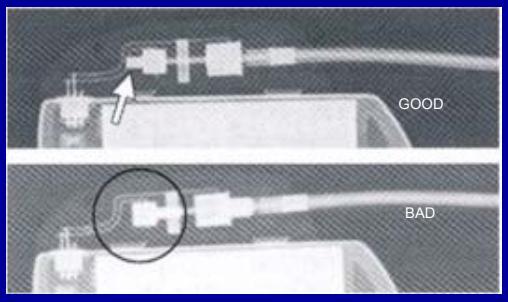
LV Epicardial Leads in a CRT-D



CXR Lead Evaluation

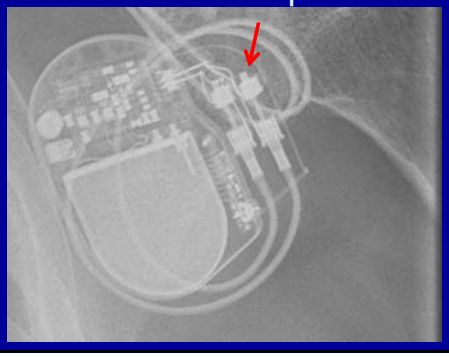
- Define the lead locations
- Are the leads endocardial or epicardial
- Are the leads connected correctly?
- Are the leads pacing leads or ICD leads
- Are the leads active or passive fixation?

Connector Pins

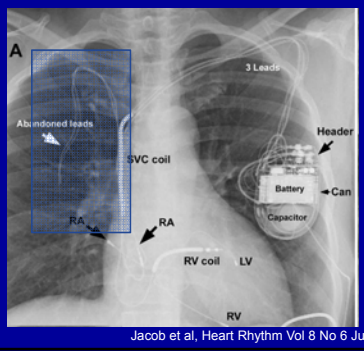


Ellenbogen K, Cardiac Pacing and ICDs 6th ed, p.60

The lead should extend beyond the connector port

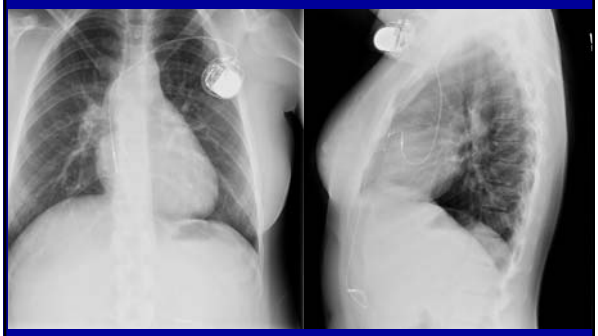


Abandoned Leads



Jacob et al, Heart Rhythm Vol 8 No 6 June 2011, p.917

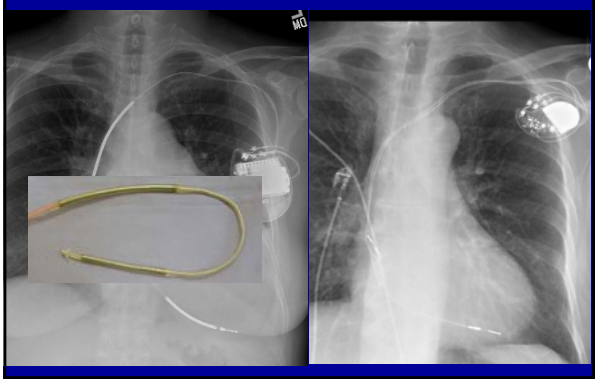
Abandoned Lead



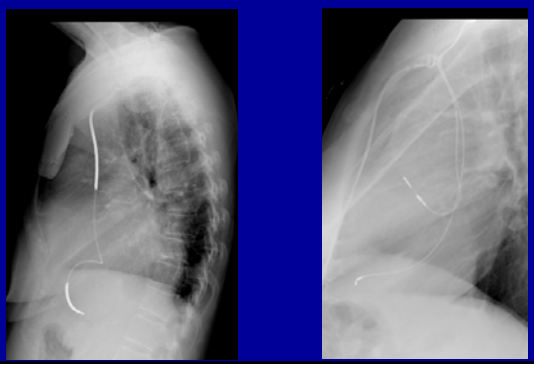
CXR Lead Evaluation

- Define lead locations
- Are the leads endocardial or epicardial
- Are the leads connected correctly?
- Are the leads pacing leads or ICD leads
- Are the leads active or passive fixation?

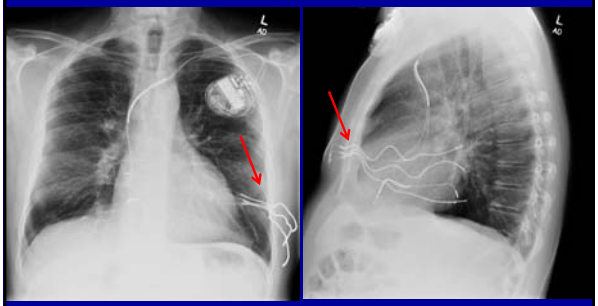
Which Device is the ICD?



Pacemaker or ICD?



What Kind of Lead is This?

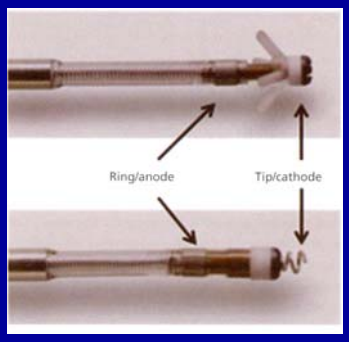


Sub-Q array Lead

CXR Lead Evaluation

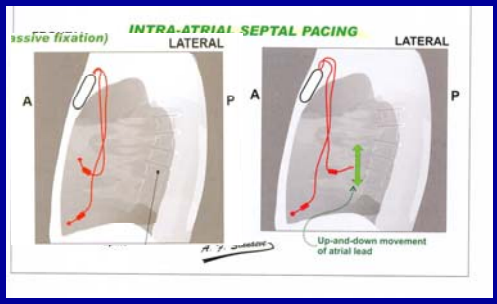
- Define lead locations
- Are the leads endocardial or epicardial
- Are the leads connected correctly?
- Are the leads pacing leads or ICD leads
- Are the leads active or passive fixation?

Passive vs Active Fixation Leads



Ellenbogen K, Cardiac Pacing and ICDs 6th ed, p.51

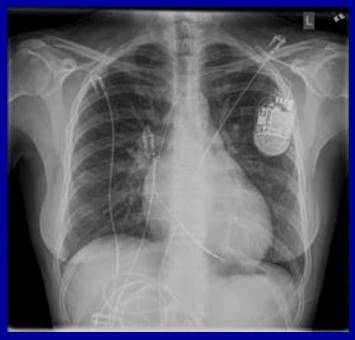
Intra-Atrial Septal Pacing



Barold SS, et al, Cardiac Pacemakers and Resynch. p. 195

Passive Fixation Leads

Active Fixation Lead



Zoomed View Active Fixation Lead

When does this matter?

- If a pacer was recently implanted and you need to place a PA line
- If the patient is about to have cardiac surgery

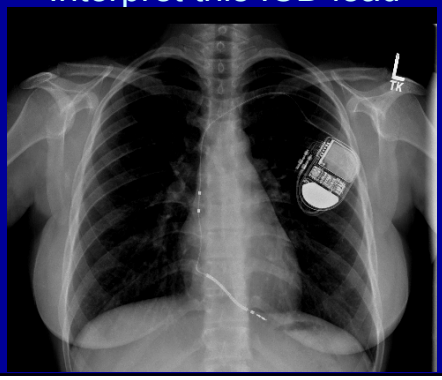
Step by Step CXR Assessment Review

- Pulse generator
  - Define the pulse generator location
  - Confirm the device is a pacemaker
  - Determine the device manufacturer
- Leads
  - Define lead locations
  - Are the leads endocardial or epicardial
  - Are the leads pacing leads or ICD leads
  - Are the leads connected and positioned correctly?
  - Are the leads active or passive fixation?

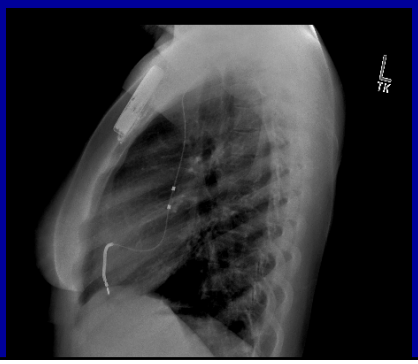
Miscellaneous

- Special Lead
- Tough Diagnosis
- Inverted CXR?
- Lead migrations
- MRI safe?
- Overconfidence?
- Future Pacemakers?

Interpret this ICD lead



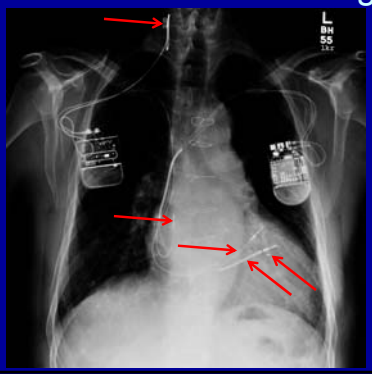
Biotronik Solox VDD Lead



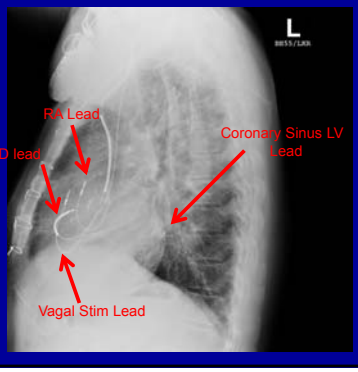
Pacer or ICD or Both?

Over-Penetrate the Image

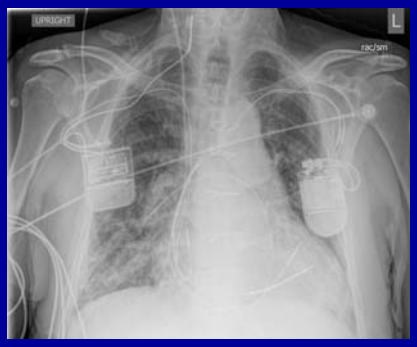
Find:
1. RIJ lead
2. RA lead
3. Vagal RV
4. RV ICD
5. LV lead



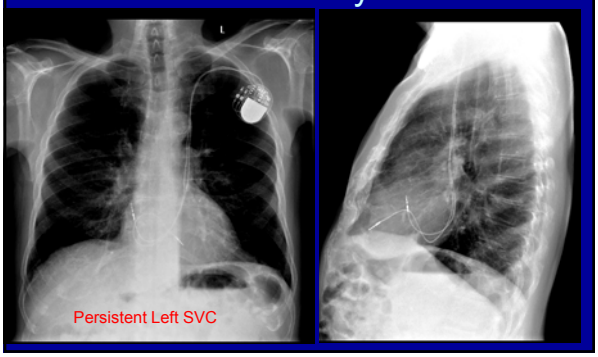
Same Patient Lateral Image



Even Harder after PA Line



Describe this Pacemaker Anatomy



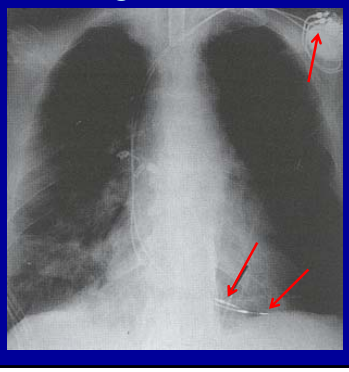
Atrial Lead Migration?

First lead is clearly in the RV.

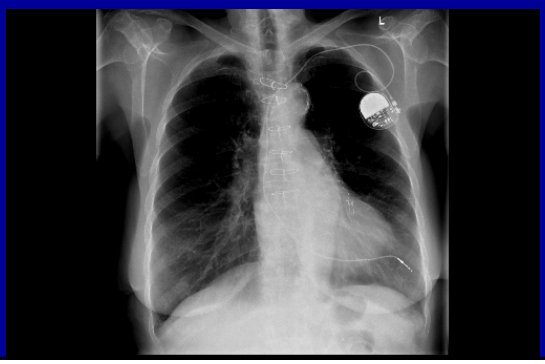
Second lead could be an abandoned RV lead or a migrated RA lead.

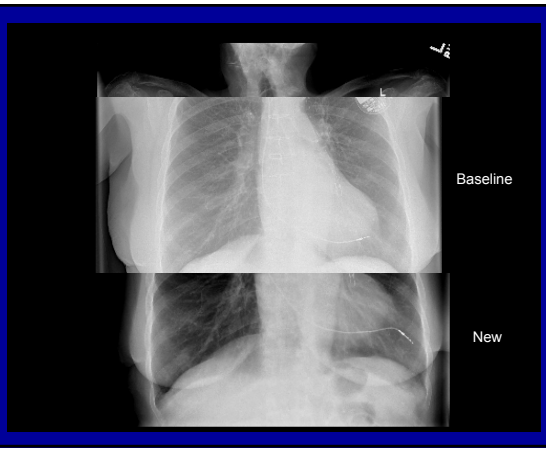
Looking at header, it appears that both leads are in the header.

Second lead must be a migrated atrial lead.

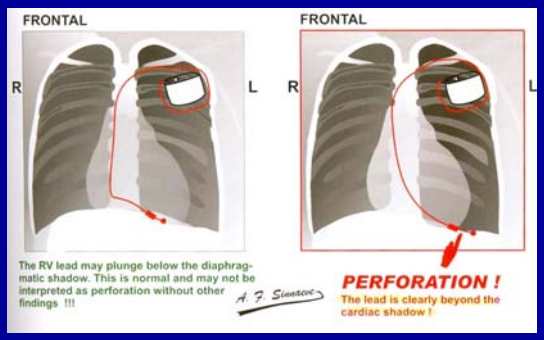


Ventricular Lead Migration?



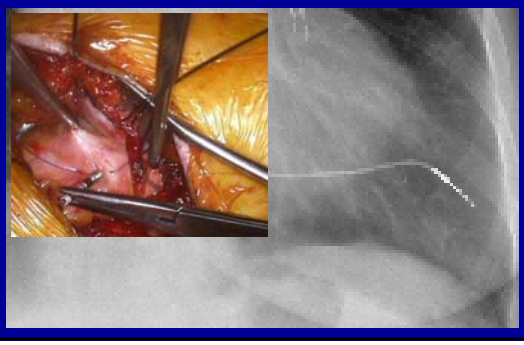


RV Lead Perforation



Barold SS, et al, Cardiac Pacemakers and Resynch. p. 193

RV Lead Perforation



Is the Pulse Generator MRI safe?

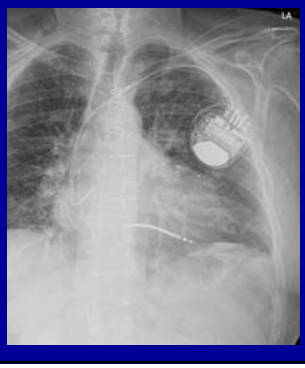
Is the Device MRI safe?

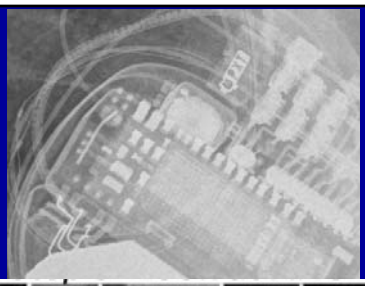
- Medtronic and Biotronik now make MRI safe pacemakers (FDA Approved)
  - Medtronic Revo and Advisa
    - Capsure Fix MRI leads
  - Biotronik Entovis and Eluna Systems
    - Setrox leads

MRI Safe Pacemakers Which have CXR Markers?

- Only the Medtronic devices have definitive markers seen on the CXR indicating MRI safety
- The Biotronik devices do not have any specific CXR indicator of MRI safety

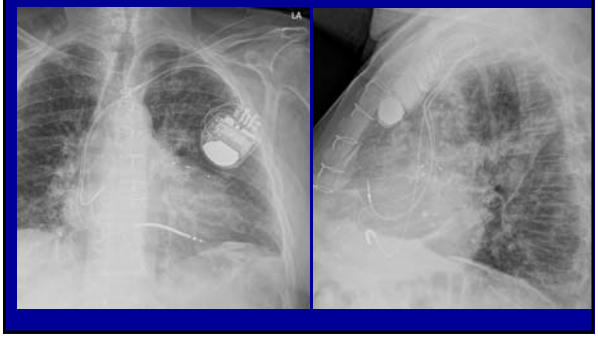
Interpret this CXR

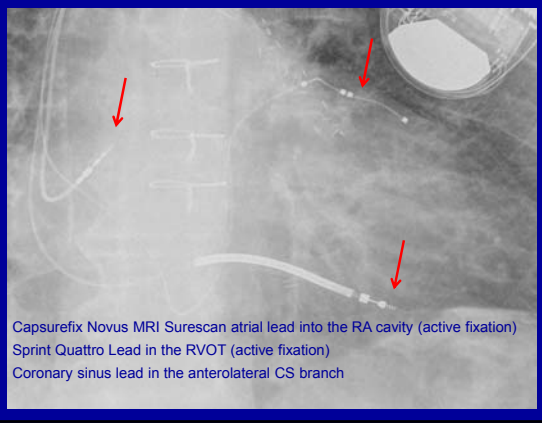




Medtronic Viva Quad XT CRT-D

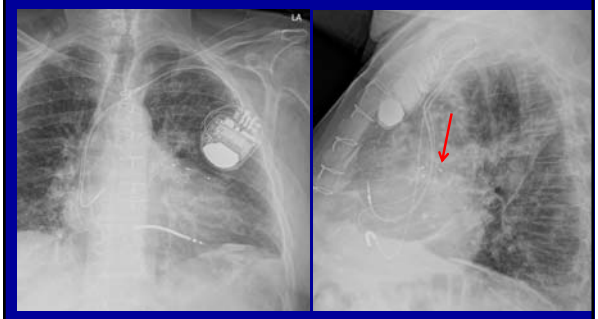
Interpret this CXR—What about the Leads?





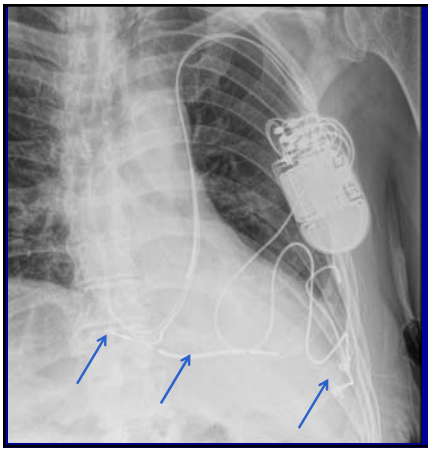
Capsurefix Novus MRI Surescan atrial lead into the RA cavity (active fixation)
Sprint Quattro Lead in the RVOT (active fixation)
Coronary sinus lead in the anterolateral CS branch

Interpret this CXR

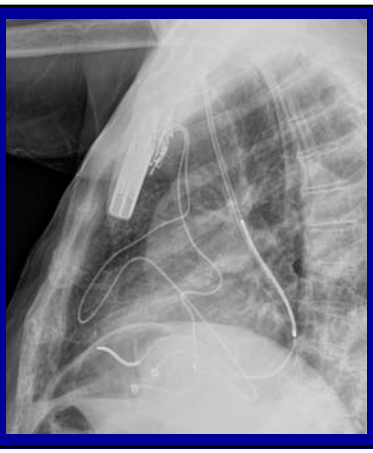


Interpret this CXR

What is the patient's anatomic anomaly?

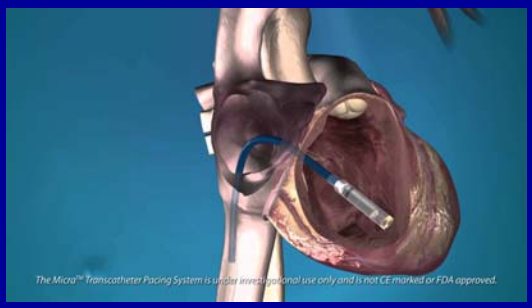


- Describe the leads:
- RA lead
- ICD with 2 shock coils
- 2 Epicardial LV leads



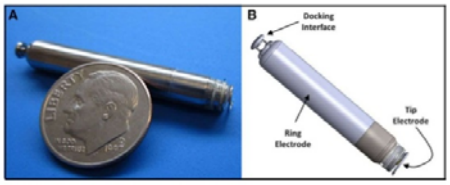
The Future Pacemaker?

Micra Implantation



The Future Pacemaker

St. Jude Nanostim

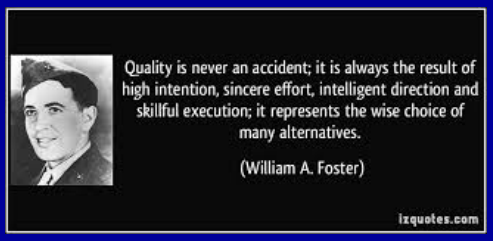


Reddy V Y et al. Circulation. 2014;129:1466-1471

Summary

- The EKG Assessment will help you determine:
  - The presenting rhythm (5 possible)
    - Remember to use the programmer if necessary
  - The degree of pacer dependence
  - The likely pacing mode
  - If there is pacer malfunction

Thank You for Coming



Summary

- The CXR will help you determine:
  - The manufacturer of the pulse generator
  - If the device is a pacer or an ICD
  - The number and location of the leads
  - The likely pacing mode
  - The likelihood that the pacer will function normally
  - Whether the pacer is MRI safe