## Ambulatory Cardiac Monitoring

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Justin T. Mao, MD

October 13, 2021



### **Historical Perspective**

- 1962 1st commercial production of the Holter monitor
  - Inventor: Norman "Jeff" Holter -American biophysicist
  - 85 lbs of equipment
  - Cathode Ray Tube





## Indication - Diagnosis

- Symptom/Rhythm correlation is key
- Unexplained pre-syncope/syncope
  - Bradyarrhythmias (e.g. pauses, AV block)
  - Tachycarrhythmias (e.g. VT)
- Palpitations
  - H&P/EKG may suggest diagnosis
  - ✤ SHD

### FH of SCD or inherited channelopathy

- Reassurance
- Ablation or anti-arrhythmic therapy
- Cryptogenic CVA
- Chest Pain
  - Eval for CAD or Prinzmetal's Angina



# Indication - Diagnostic Yield

		Deliste (free day)	C	C	
Duration of recording	Type of recorder	Palpitations (%)	Syncope (%)	Cryptogenic stroke (%) (Sile	
<60 s	Event recorder	50-60	Not applicable	Not applicable	
24-48 hr	Standard Holter	10-15	1-5	1-5	
3–7 days	Patch/Vest/Belt Recorder/MCT/ELR	50-70	5-10	5-10 (?)	
1–4 weeks	ELR/Patch/Vest/Belt Recorder/MCT	70-85	15-25	10–15 (?)	
≤36 months	ILR	80-90	30-50	15–20 (?)	

Heart Rhythm 2017;14:e55-e96



## Indication - Prognosis

- Ischemic Heart Disease/PostInfarction
  - MUSTT Criteria Post-MI, LVEF =35-40%, NSVT --> EPS guided ICD implantation
- HCM syncope or palpitations common symptoms
  - Conduction abnormalities
  - Rapid Afib can lead to syncope or worsening CHF
  - NSVT high NPV but low PPV for SCD
- \* ARVD
  - Major or minor criteria involve NSVT, sustained VT, or frequent PVCs.



### Indication - Prognosis

- PVCs risk of PVC induced cardiomyopathy
- ✤ WPW
  - Intermittent preexcitation "low risk"
  - ✤ SVT
  - \* Afib
- Long QT syndrome
  - Transient QT prolongation or inappropriate QT adaptation to HR
  - R on T phenomenon, T wave alternans (ominous), "Long-short" coupling intervals



### Indication - Response to Therapy

### Atrial Fibrillation

- Adequacy of Rate control
- Response to antiarrhythmics or after ablation
- ✤ PVC
  - Assess overall PVC burden



### Holter Monitor

- ✤ 24-48 hours
- Not Wireless Offline Analysis and Review
- Continuous ECG recording
- Patient Diary to record symptoms
- Overall Low Diagnostic Yield
- Main Indications:
  - Afib assess rate control
  - PVC burden
  - Frequent symptoms



### **Event Monitor**

- Up to 30 days
- Not continuous don't do beat to beat analysis
- Wireless After hour calls
- ✤ 3 Types:
  - Postevent monitoring placed on chest at time of symptoms
  - Event/External Loop Recorder constantly recording but only saved during event when triggered (ECG will be saved both before and after event)
  - Auto-triggered Event Recorder Built in arrhythmia detection algorithms in addition to symptom/event triggered





# Mobile Cardiac Outpatient Telemetry (MCOT)

- Combine all of the functions of the above monitors
- Up to 30 days
- Continuous/Beat to Beat analysis
- Wireless After hour calls



### Disadvantages

### ✤ Bulky

Patient satisfaction/Patient compliance

Allergic Reaction



### Patch Monitors - ZioPatch

- Single Lead
- Up to 14 days
- No lead, wires, battery packs needed
- Water-resistant







# Patch Monitors - Zio Patch



**Telemetry**<sup>4</sup>



# Patch Monitors - Zio Patch









Aided in definitive diagnosis:

Patient preference:



American Journal of Medicine 2014;127:95.e11-95.e17



# Implantable Loop Recorders

- Subcutaneous Insertion/Simple Procedure
- ✤ ~ 3 years battery life
- Capable of Remote Monitoring
- MRI conditional
- Common Indications: Unexplained syncope & Cryptogenic CVA
- LUX --> HeartLogic









# Implantable Loop Recorders

### A Detection of Atrial Fibrillation by 6 Months



Months since Randomization

Median Time to detection of Afib = 84 days



Months since Randomization

CrystalAFStudy NEJM 2014;370:2478-86



### Wearable Tech

48% population in the world own a smartphone ✤ Up from 33% in 2016 PPG (photoplethysmography) versus electrode based Wrist worn vs App vs Portable



### Wearable Tech

- FDA cleared
  - Apple Watch ECG app
  - FitBit ECG app
  - AliveCor KardiaMobile only 6 lead ECG
  - \* prescribed

LIVMOR Halo AF Detection System - Samsung Wearable, physician





## Apple Heart Study





AF Yield (%)

> 400,000 participants Irregular Pulse Notification - 0.52% ECG Patch shipped Diagnostic Yield ~ 34% PPV - 84% (when simultaneous ECG) patch worn)



## AliveCor KardiaMobile

### **Community setting**

		95% CI		
Study	Sensitivity	Lower	Uppe	r
Orchard_J_AliveCor_2016_Comm	0.94	0.82	0.98	<b>⊢</b> -
Chan_PH_AliveCor_2016_Comm	0.71	0.53	0.85	<b>⊢</b>
Chan_PH_AliveCor_2017_Comm	0.67	0.47	0.82	← ■ 1
Lown_M_AliveCor_2018_Comm	0.88	0.79	0.93	⊢−■⊣
summary <u>Hospital setting</u>	0.82	0.65	0.91	0.5 0.6 0.7 0.8 0.9 1 Sensitivity
Lau_J_AliveCor_2013_Cardio	0.9	8 0.81	9 1.00	<b>⊢</b> _■
Haberman_Z_AliveCor_2015_Cardie	o 0.9	4 0.7	4 0.99	F
Desteghe_L_AliveCor_2017_Cardic	0.5	5 0.3	5 0.73	⊲∎
William_A_AliveCor_2018_AF_Cent	re 0.9	7 0.84	6 0.99	<b>⊢</b> _
Summary	0.9	1 0.60	6 0.98	0.5 0.6 0.7 0.8 0.9 1 Sensitivity

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### 95% CI



0.85

0.9

Specificity

0.95

1



### Heart 2020;106:1211-17.





## LIVMORE

- First Prescription Only FDA cleared October 2020
- Samsung Gear S2 Smartwatch
- Provides continuous monitoring
- 269 enrolled patients (concurrently recorded EKG)
  - 100% sensitivity
  - 93% specificity



### Advantages

### Direct to Consumer

Reduces direct contact to clinical staff

> Better control over personal health

**Better Patient Compliance** 

Promote Health Behavioral Changes

May Improve time to diagnosis

### Wearable Tech

### Disadvantages

May provide suboptimal ECG tracings

Significant additional burden on clinicians

Low diagnostic yield

Certain clinicians with lack of experience interpreting



### Conclusion

- compliance
- New Patch based monitors (ie ZioPatch) likely will supplant current monitors
- Wearable Tech wave of the future.

Current state of Holter/Event monitors are bulky with low rate of patient

