Remote Monitoring 의 활용 :
PM, ICD, CRT

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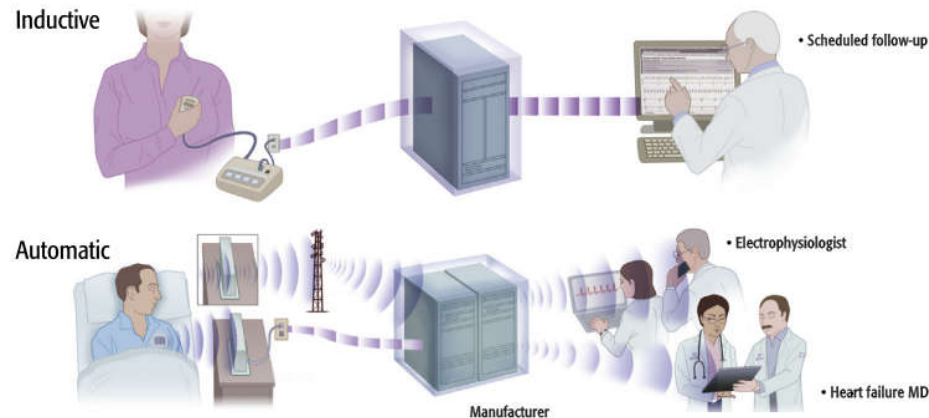**Yonsei University College of Medicine, Seoul, Korea**

Remote monitoring of CIEDs

■ **Data transmission :**

- ✓ Basic device information (lead parameters, battery status)
- ✓ Arrhythmias (types, incidence, details on therapy, intracardiac EGMs)
- ✓ Physiologic parameters (hearty rate, thoracic impedance, physical activity)
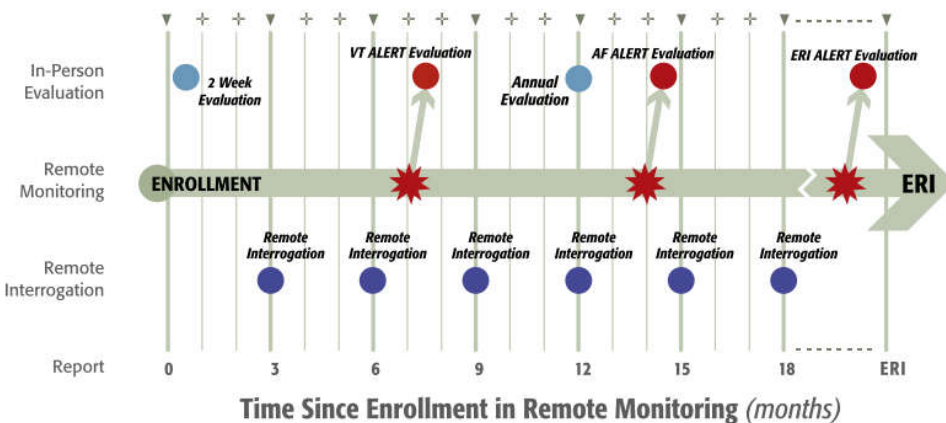
■ **Alert/Notification**

- ✓ Changes in lead impedance
- ✓ Development of atrial arrhythmias
- ✓ Episodes of VT/VF
- ✓ Delivery of shocks
- ✓ Changes in hemodynamic status

Inductive — Scheduled follow-up

Automatic — Electrophysiologist — Heart failure MD

Manufacturer

Slotwiner D et al. Heart Rhythm 2015;12:e69–e100

Definition of Remote Interrogation/Remote monitoring

In-Person Evaluation — 2 Week Evaluation — VT ALERT Evaluation — Annual Evaluation — AF ALERT Evaluation — ERI ALERT Evaluation

Remote Monitoring — ENROLLMENT — ERI

Remote Interrogation — Remote Interrogation (repeated)

Report — 0 3 6 9 12 15 18 ERI

Time Since Enrollment in Remote Monitoring *(months)*

* Any wireless PM, ICD, CRT device with auto thresholds and auto-sensing algorithms
▼ Interim report generation & communication with other health care providers, including heart failure data
✛ Interim (monthly) remote monitoring heart failure report

ABBREVIATIONS: AF + atrial fibrillation; CHF = congestive heart failure; ERI = elective replacement indicator.

- Recommended standard interrogation duration
  - ✓ Every 6-12 months for pacemakers
  - ✓ Every 3-6 months for ICD/CRTs

- Remote Interrogation (RI) : Scheduled remote interrogations that are intended to mimic in-office checkups.

- Remote monitoring (RM) : refers to data that are acquired automatically with unscheduled transmissions of any pre-specified alerts related to device function or clinical events
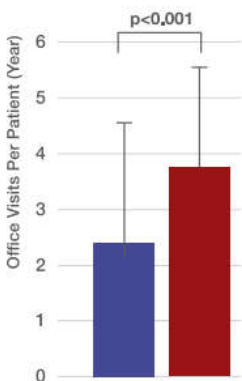
Remote Monitoring of ICDs
: partial replacement of "[in-office visit] to [RI]" and RM

TABLE 1 Enrollment Criteria for Included RCTs

| Study (Ref. #)	Number of Centers	Eligibility	Home Monitoring Group	IO
Al-Khatib et al., 2010 (15)	Single	≥18 yrs of age, have an ICD with or without CRT for an approved indication, devices followed-up at center, must have a telephone (land line)	Patient-initiated transmissions every 3 months plus IO visit at 12 months	IO visit every 3 months
TRUST, 2010 (16)	Multicenter	≥18 yrs of age, implanted within the last 45 days or being considered for implant with a Biotronik ICD for class 1 indications, not pacemaker dependent	IO visit at 3 and 15 months; RM replaced office visits at 6, 9, and 12 months	IO visit every 3 months
CONNECT, 2011 (17)	Multicenter	≥18 yrs of age, implanted with a Medtronic Conexus-enabled CRT-D or ICD	IO visit at 1, 3, and 15 months; RM replaced office visits at 6, 9, and 12 months	IO visit every 3 months
EVOLVO, 2012 (18)	Multicenter	LVEF ≤35%, implanted with a wireless-transmission-enabled Medtronic ICD or CRT-D	IO visit at 8 and 16 months; RM replaced office visits at 4 and 12 months	IO visit every 4 months
EVATEL, 2012 (14)	Multicenter	≥18 yrs of age, first implantation of single- or dual-chamber ICD in primary or secondary prevention, ICD with data-transmission features, GSM mobile phone network at patient home compatible with remote transmission	IO visit at 6 weeks and 12 months; RM replaced office visits at 3, 6, and 9 months	IO visit at 6 weeks, then every 3 months
SAVE-HM, 2013 (19)	Single	ICD indicated for primary prevention of sudden cardiac death in patients experiencing chronic systolic heart failure, geographically stable with a stable medical condition, and sufficient GSM network coverage at their place of residence	IO visit at 12 months; RM replaced office visits at 6 months	IO visit every 6 months
MORE-CARE, 2013 (20)	Multicenter	Left ventricular systolic dysfunction (LVEF ≤35%), NYHA functional class III to IV, QRS ≥120 ms, with CRT-D devices	IO visit at 1 and 8 months; RM replaced office visits at 4 and 12 months	IO visit at 1 month, then every 4 months
ECOST, 2013 (21)	Multicenter	Indication for single- or dual-chamber ICD except for NYHA functional class IV	IO visit at 1–3 months and 15 and 27 months; RM replaced office visits at 9 and 21 months	IO visit at 1–3 months, then every 6 months
IN-TIME, 2014 (7)	Multicenter	Indication ICD or CRT-D, heart failure (≥3 months), NYHA functional class II or III, LVEF ≤35%	IO visit at 12 months; RM replaced office visits at 6 months	IO visit every 6 months

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2015 HRS expert consensus Statement on Remote monitoring



Reduction in In-Clinic Evaluations*

p<0.001

*Data from TRUST are presented and show that remote monitoring reduced in-clinic evaluations by 45% per year. A similar effect was seen in the CONNECT trial in which remote management was associated with a reduction of office visits from 6.3 in conventional care to 3.9 per person year.

Early Detection*

p<0.001   p<0.001

n=172 n=145   n=271 n=114
   All**   Silent***
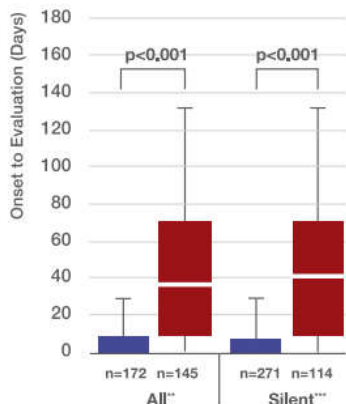
*Data from TRUST are presented. The CONNECT Trial shows similar results for early detection
**In CONNECT, median time from event to clinical decision was 4.6 days in the Remote arm vs. 22 days in conventional care.
***Time to detect clinically asymptomatic (silent) conditions was not reported in CONNECT".

Rates of failed scheduled evaluations in remote only vs. conventional care over 1 year*

p<0.001
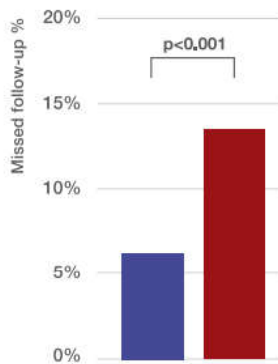
*Data from TRUST are presented. Rates of failed calendar-based evaluations in remote only vs. conventional care over 1 year data information was not available from the CONNECT Trial

■ — REMOTE MONITORING   ■ — CONVENTIONAL

HRS Remote Monitoring Consensus Statement Recommendations

Device Follow-Up Paradigm	Class of Recommendation	Level of Evidence
A strategy of remote CIED monitoring and interrogation, combined with at least annual IPE, is recommended over a calendar-based schedule of in-person CIED evaluation alone (when technically feasible).	I	A
All patients with CIEDs should be offered RM as part of the standard follow-up management strategy.	I	A

Slotwiner D et al. Heart Rhythm 2015;12:e69–e100

Early detection and Early Action

- TRUST trial (n=1,450 ICD patients, FU 15months, 2:1 randomization)
  - ✓ RM significantly reduced the time from event onset to evaluation
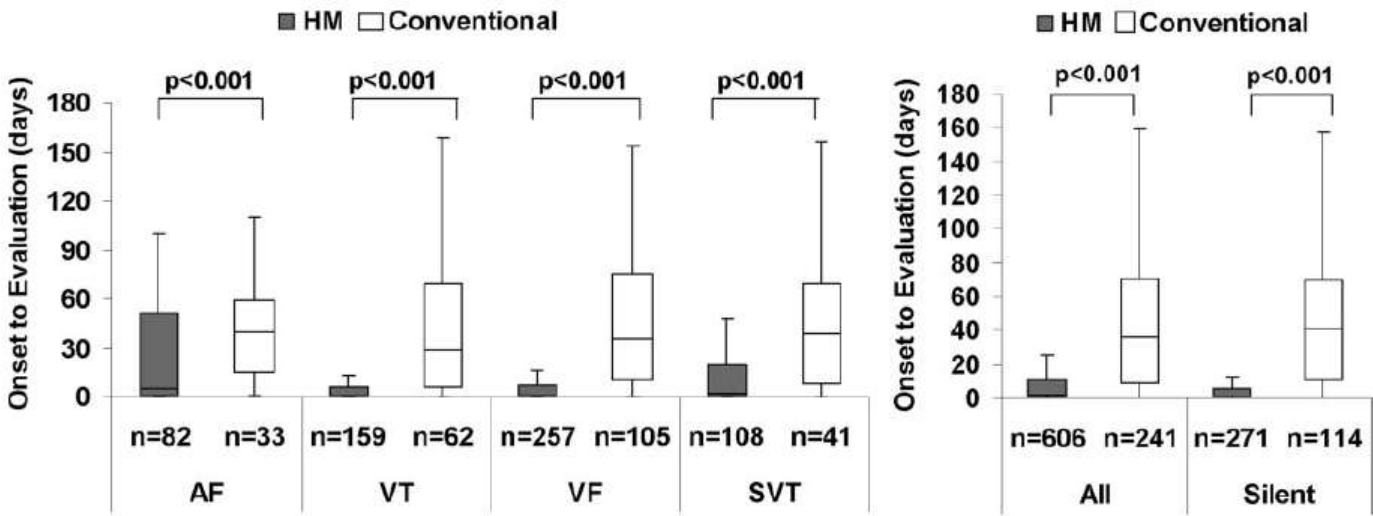 - ✓ Early diagnosis/managements for AF than conventional FU (5.5 days vs 40days)

Figure 4. Early detection. HM secured earlier physician evaluation of arrhythmias (left) and silent events (right).

Varma N et al. Circulation. 2010;122:325–332

Reduction in hospitalization for device related adverse events

	All patients, (n = 494)	Active group, (n = 248)	Control group, (n = 246)
Deaths			
Stroke	4	0	4
Heart failure	3	3	0
Pulmonary disease	3	1	2
Cancer	9	6	3
Other non-cardiac causes	12	8	4
All deaths	31	18	13
Hospitalizations for cardiovascular adverse events			
Ventricular arrhythmia	2/2	1/1	1/1
Atrial arrhythmia, stroke[a], or both	24/23	6/6	18/17*
Heart failure	24/19	18/13	6/6
Acute coronary syndrome	12/11	6/5	6/6
Others	8/8	6/6	2/2
All hospitalizations for cardiovascular adverse events	70/61	37/29	33/32
Hospitalizations for device-related adverse events			
Infection, extrusion	4/4	0	4/4
Lead dislodgment	2/2	0	2/2
Venous thrombosis	3/2	2/1	1/1
High ventricular threshold	1/1	0	1/1
All hospitalizations for device-related adverse events	10/8	2/1	8/7
All adverse events[b]	104/90	54/43	50/47

- COMPAS trial (n=538 PM patients, FU 18months, 1:1 random)
  - ✓ 75% reduction in hospitalization for device related adverse events
  - ✓ 66% reduction in hospitalization for atrial arrhythmia and related stroke

Pabo P et al. Eur Heart J. 2012 May;33(9):1105-11

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RM reduces inappropriate shock and related hospitalizations

- ECOST trial (n=473 ICD patients, FU 27months, 1:1 random)
  - ✓ 52% reduction in inappropriate shock
  - ✓ 72% reduction in inappropriate shock related hospitalization
  - ✓ 76% reduction in number of charged shocks (battery preservation)

A Intention-to-treat population

HR 0.91; 95% CI 0.68–1.23; P=0.53; log-rank

Number at risk						
Active group	221	177	164	155	143	116
Control group	212	169	153	139	127	106
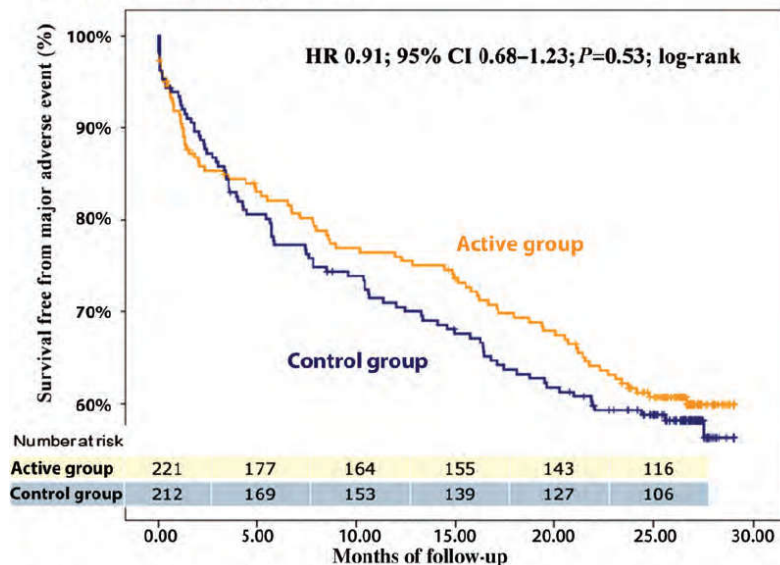
	Study groups		P
	Active (n = 221)	Control (n = 212)	
Appropriate and inappropriate shocks delivered	193 [0–33]	657 [0–116]	
Patients with ≥1 delivered shock	47 (21.3)	56 (26.4)	0.21
Mean per patient-month	0.04 ± 0.27	0.20 ± 1.13	0.02
Inappropriate shocks delivered	28 [1–8]	283 [1–82]	
Patients with ≥1 inappropriate shock	11 (5.0)	22 (10.4)	0.03
Mean per patient-month	0.13 ± 0.15	0.83 ± 1.86	0.28
Capacitor charges	499 [0–58]	2081 [0–760]	
Patients with ≥1 capacitor charge	69 (31.2)	72 (34.0)	0.54
Mean per patient-month	0.11 ± 0.38	1.65 ± 18.81	0.11

Reduction in ICD inappropriate shock
: Early detection and intervention of AF

- AF is the main cause for inappropriate ICD shock.
- RM provides early detection of AF.
- ICD-RM can prevent inappropriate ICD shock, which is partially due to early intervention of AF.

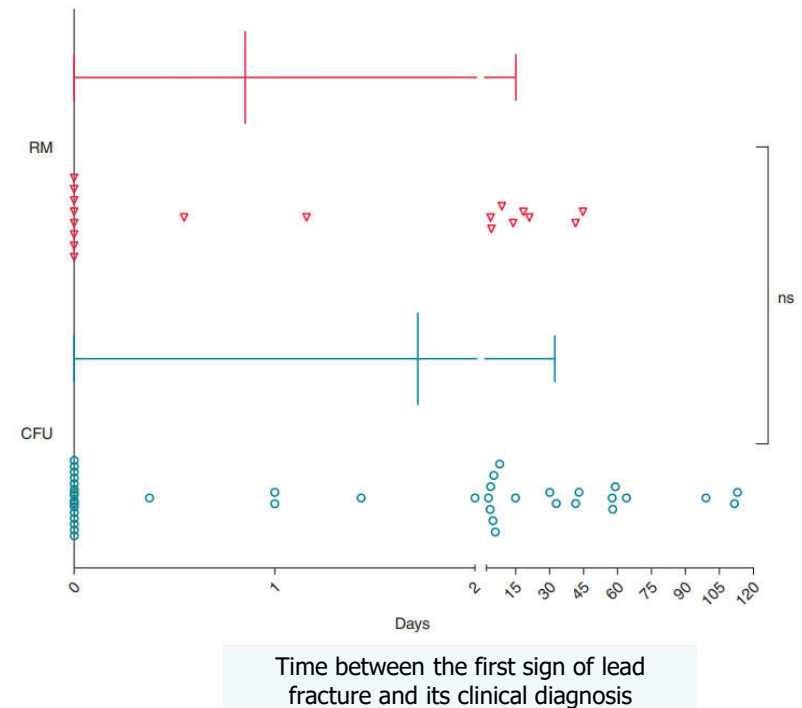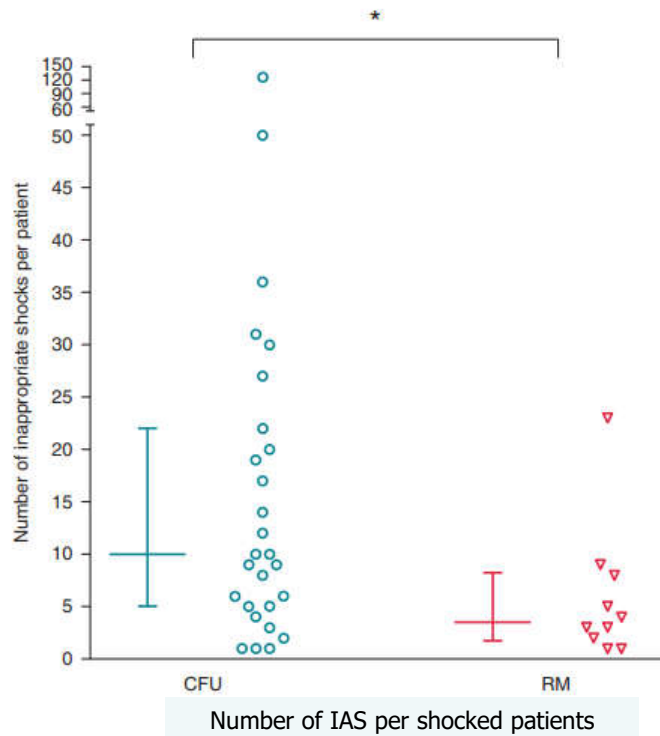|		
RM is useful to reduce the incidence of inappropriate ICD shocks.	I	B-R
RM is useful for the early detection and quantification of atrial fibrillation.	I	A

Slotwiner D et al. Heart Rhythm 2015;12:e69–e100
Parthiban N et al. J Am Coll Cardiol. 2015;65:2591-600

Reduction in ICD inappropriate shock
: Early detection of lead fracture
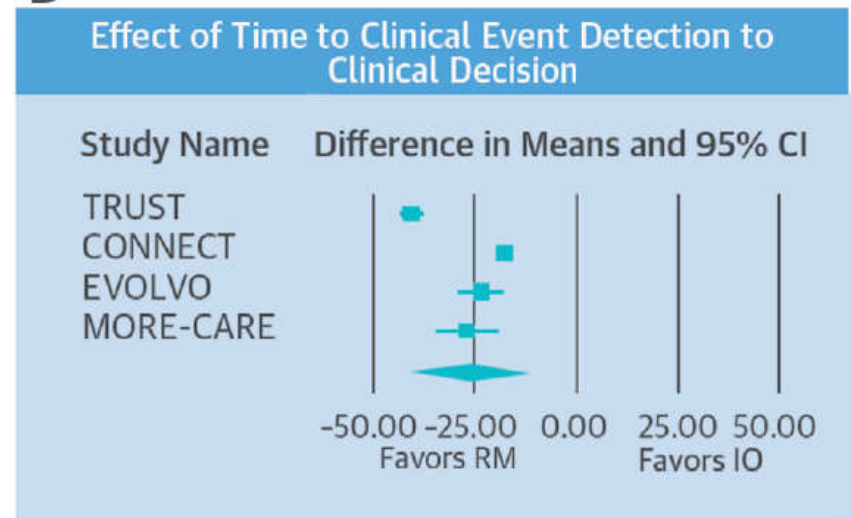
- French single-centre registry (n=115 with lead fracture)

Number of IAS per shocked patients

Time between the first sign of lead fracture and its clinical diagnosis

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Meta-Analysis for Remote Monitoring of ICDs
: Time from detection to decision ↓ Inappropriate ICD Shock ↓

B

Effect of RM on Inappropriate ICD Shocks

Study Name	Odds Ratio and 95% CI
Al-Khatib Study	
ECOST	
EVATEL	

0.01   0.1   1   10   100

Fewer Inappropriate Shocks with RM   Fewer Inappropriate Shocks with IO

D

Effect of Time to Clinical Event Detection to Clinical Decision

Study Name	Difference in Means and 95% CI
TRUST	
CONNECT	
EVOLVO	
MORE-CARE	

−50.00   −25.00   0.00   25.00   50.00

Favors RM   Favors IO

Parthiban N et al. J Am Coll Cardiol. 2015;65:2591-600

RM and Mortality in ICD patients
: Controversial

FIGURE 2 All-Cause Mortality

A

Cardiovascular Mortality

Parthiban N et al. J Am Coll Cardiol. 2015;65:2591-600
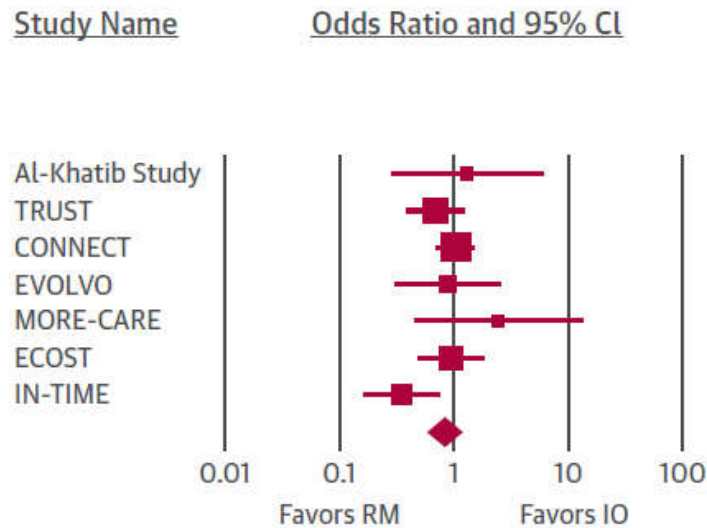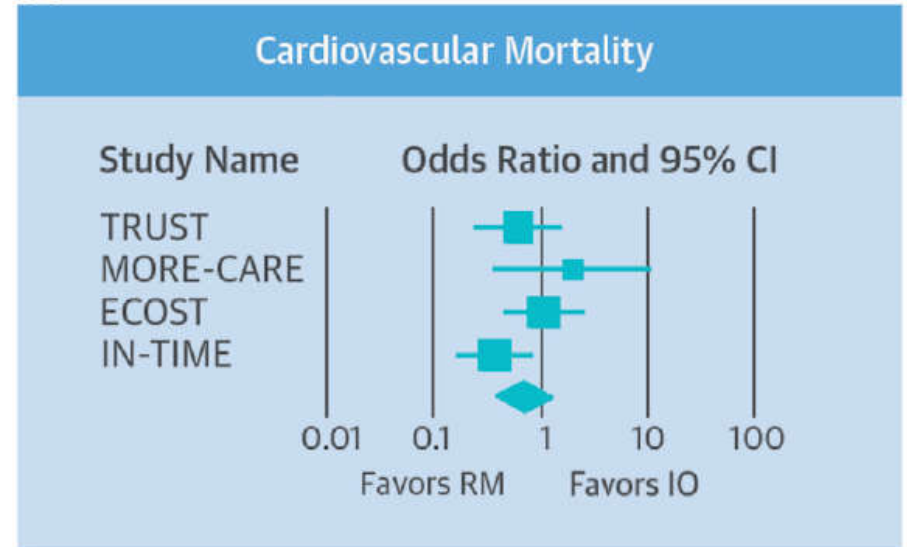
Benefit of RM (IN-TIME Trial)
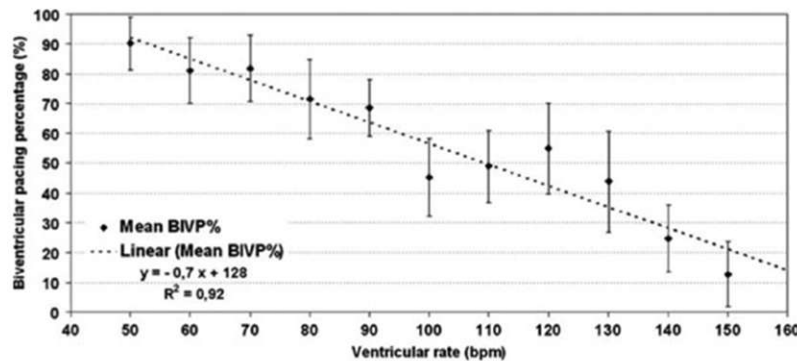## : CRT-D (n=390) vs ICD (n=274)
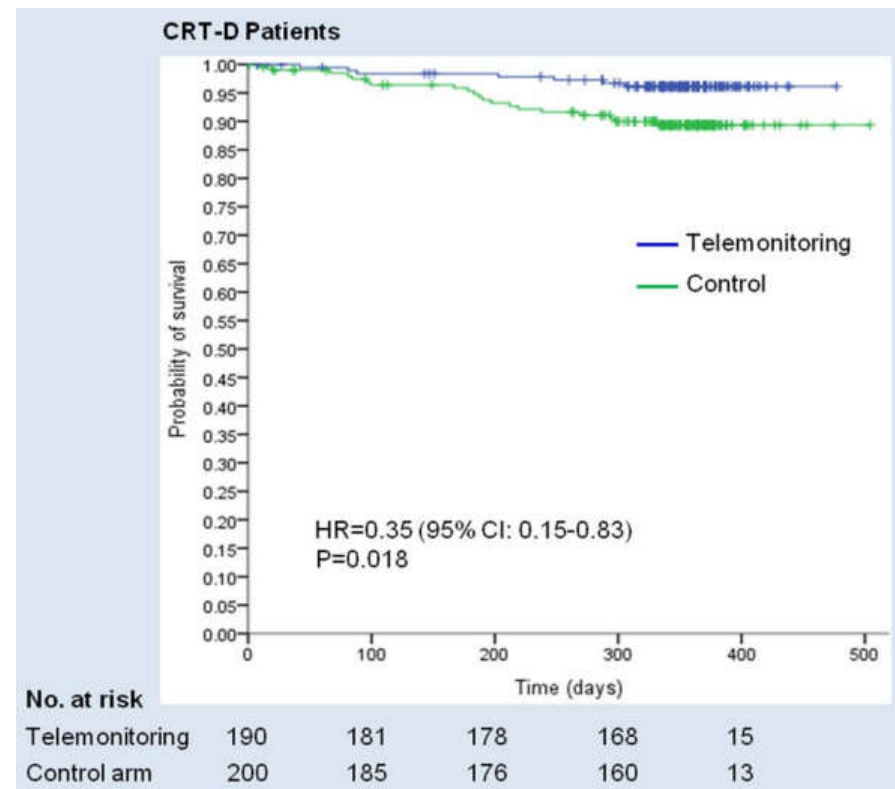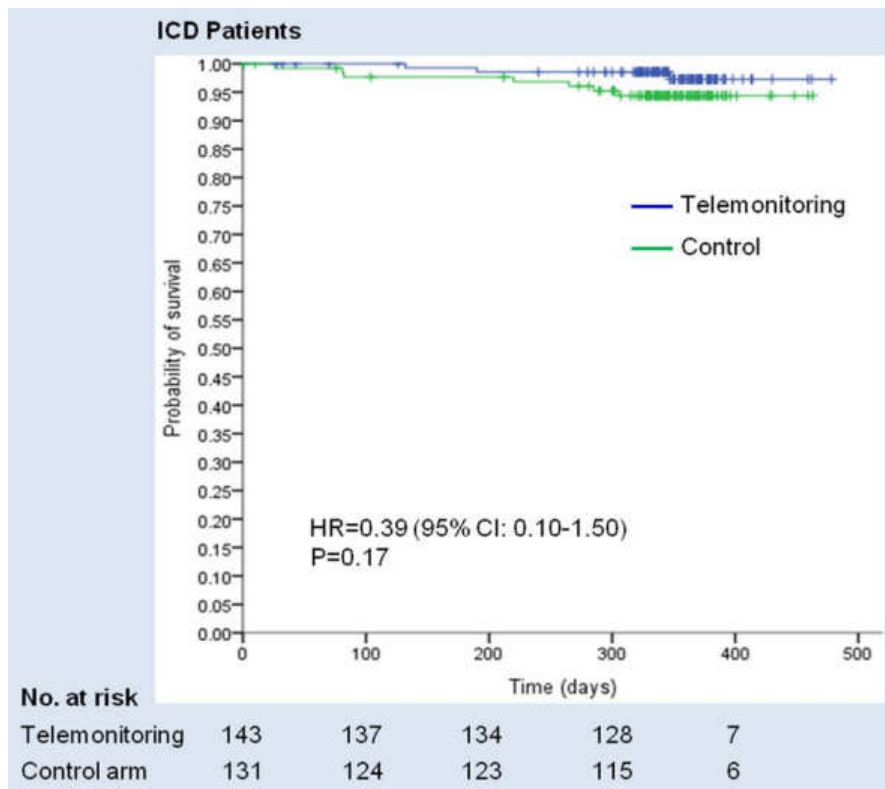
*Geller JC et al. Clin Res Cardiol. 2019 Oct;108(10):1117-1127*

CRT and responders
: The importance of BiV pacing percent

Lower ventricular rate → more BiV pacing

$y = -0.7 x + 128$
$R^2 = 0.92$

- Mean BIVP%
- Linear (Mean BIVP%)

Brenyo, Andrew, et al. *Journal of the American College of Cardiology* 58.16 (2011): 1682-1689.

BiV pacing > 98.5%

BiV pacing >98.5% – no AFib
BiV pacing <98.5% – no AFib
BiV pacing >98.5% – AFib
BiV pacing <98.5% – AFib
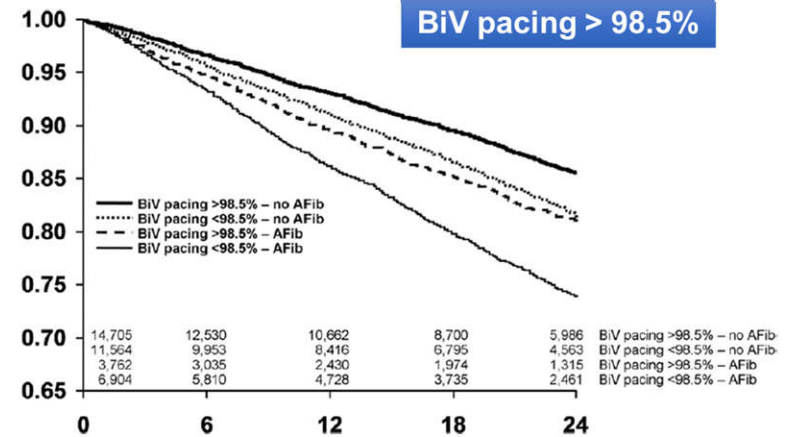
A large cohort of **36,935** patients
followed up in a remote-monitoring network
the LATITUDE Patient Management system
(Boston Scientific Corp., Natick, Massachusetts)

- The suppression of arrhythmias can increase the success of, and prevent the NR to CRT.

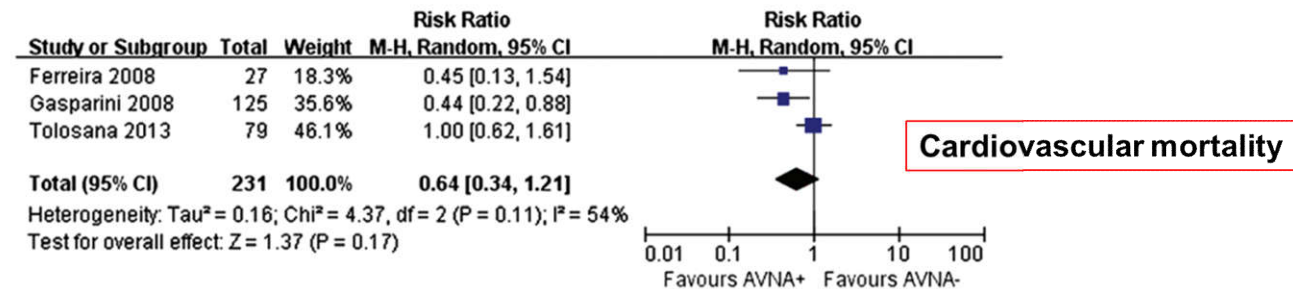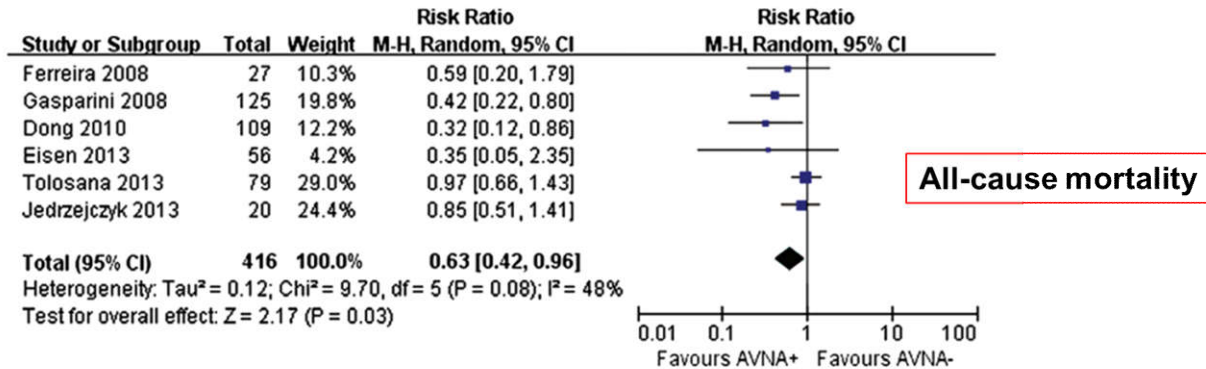*Hayes DL et al. Heart Rhythm 8.9 (2011): 1469-1475.*

What decreases BiV pacing percent?
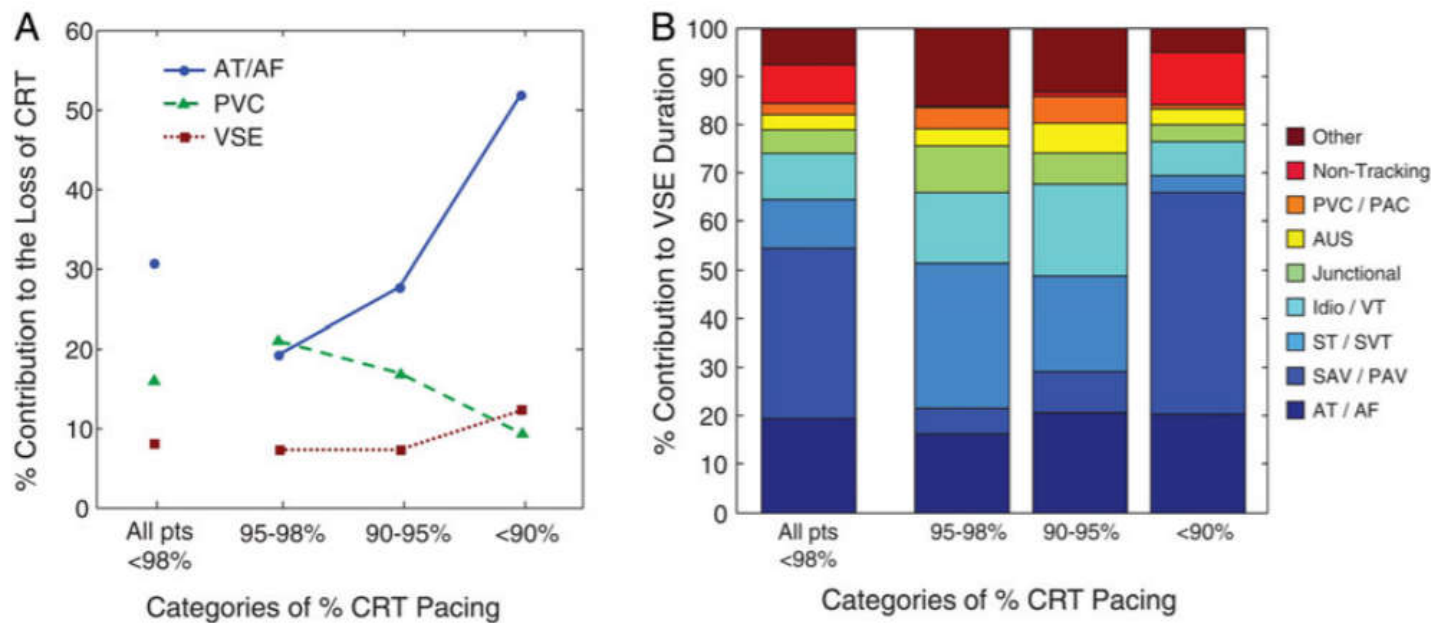
- Atrial tachyarrhythmias and frequent VES are the cause confirmed in one-third of NRs to 6 months of CRT
- 11.5% had <90% BiV stimulation, caused by ATA in over 50% and by frequent VES in nearly 10%.

Daubert C et al. Eur Heart J. 2017 May 14;38(19):1463-1472
Cheng A et al. Circ Arrhythm Electrophysiol 2012;5: 884 –888

AVN ablation in CRT and AF/AT

Study or Subgroup	Total	Weight	Risk Ratio M-H, Random, 95% CI
Ferreira 2008	27	10.3%	0.59 [0.20, 1.79]
Gasparini 2008	125	19.8%	0.42 [0.22, 0.80]
Dong 2010	109	12.2%	0.32 [0.12, 0.86]
Eisen 2013	56	4.2%	0.35 [0.05, 2.35]
Tolosana 2013	79	29.0%	0.97 [0.66, 1.43]
Jedrzejczyk 2013	20	24.4%	0.85 [0.51, 1.41]
Total (95% CI)	**416**	**100.0%**	**0.63 [0.42, 0.96]**

All-cause mortality

Heterogeneity: Tau² = 0.12; Chi² = 9.70, df = 5 (P = 0.08); I² = 48%
Test for overall effect: Z = 2.17 (P = 0.03)

Favours AVNA+   Favours AVNA-

Study or Subgroup	Total	Weight	Risk Ratio M-H, Random, 95% CI
Ferreira 2008	27	18.3%	0.45 [0.13, 1.54]
Gasparini 2008	125	35.6%	0.44 [0.22, 0.88]
Tolosana 2013	79	46.1%	1.00 [0.62, 1.61]
Total (95% CI)	**231**	**100.0%**	**0.64 [0.34, 1.21]**

Cardiovascular mortality

Heterogeneity: Tau² = 0.16; Chi² = 4.37, df = 2 (P = 0.11); I² = 54%
Test for overall effect: Z = 1.37 (P = 0.17)

Favours AVNA+   Favours AVNA-

- A high rate of BiV pacing is required to achieve maximum benefit from CRT.
- This may be difficult to achieve in patients with AF without AV block.

PVC and CRT response

Table 4	Change in Various Echo Parameters Before and [...]		
Change in Echo Parameters	Pre-Ablation	Post-Ablation
Δ EF	26.2 ± 5.5	32.7 ± 6.7
Δ LVEDD	6.83 ± 0.83	6.51 ± 0.91
Δ LVESD	5.83 ± 0.55	5.62 ± 0.32
Δ LVESV	178 ± 72	145 ± 23
Δ LVEDV	242 ± 85	212 ± 63

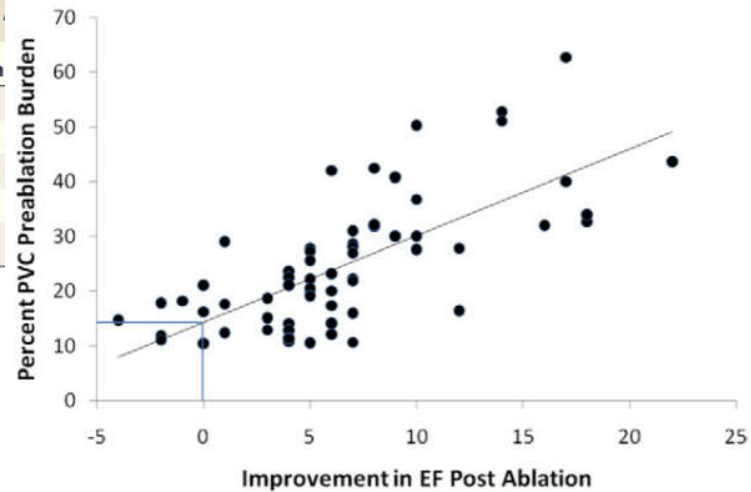Values are mean ± SD.
  Abbreviations as in Tables 1 and 2.

Figure 2 Correlation Between PVC Burden and EF Change Following Ablation

- Frequent PVCs are a less common but important and treatable cause of nonresponse to CRT. Successful RFA of PVC foci improves LV function and NYHA class and promotes reverse remodeling in CRT nonresponders.

Lakkireddy D et al. J Am Coll Cardiol. 2012 Oct 16;60(16):1531-9

Device-detected Rhythm problems in CRT

- AF → OAC, AAD, ablation (AF or AVN, or both) , DC cardioversion

- Sinus tachycardia > UTL → drugs (beta blocker, ivabradin), reprogramming (higher UTR)

- Shortening of intrinsic AV conduction → reprogramming to shorter AV delay

- Endless loop tachycardia → reprogramming of PMT intervention, PVC reaction, PVARP

- PVCs, NSVT → AAD, ablation

- VT/VF/ ICD shock → AAD, ablation, reprogramming

Stroke prevention with RM
: Controversial

- Computer Monte Carlo model, simulating 4,000 virtual subject with the same AF and CHADS$_2$ score.

- Daily RM significantly reduces the risk of stroke (9 to 18%) compared with 6-12months standard visit.

- IMPACT study : 2718 ICD/CRT-D patients

- RM guided initiation/interruption of OAC vs conventional FU → similar event rates
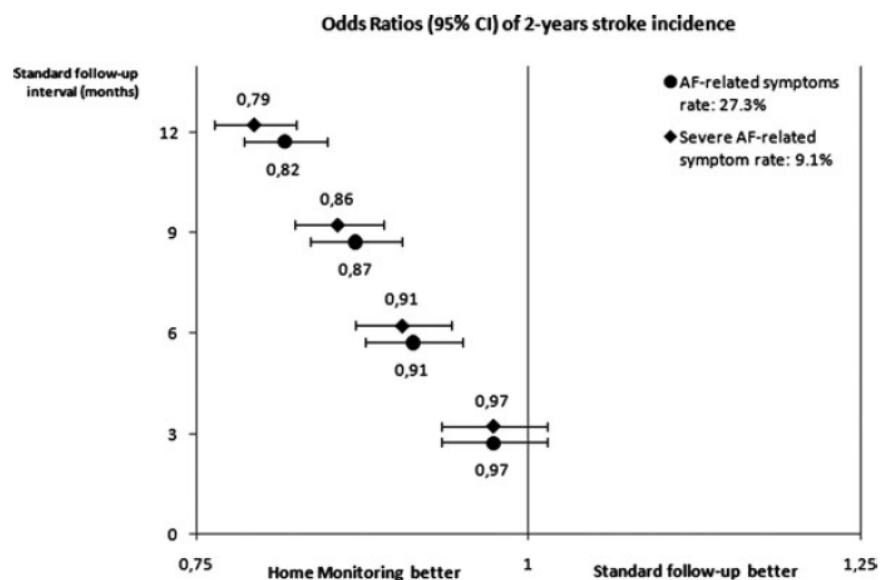
Ricci RP et al. J Cardiovasc Electrophysiol. 2009 Nov;20(11):1244-51,
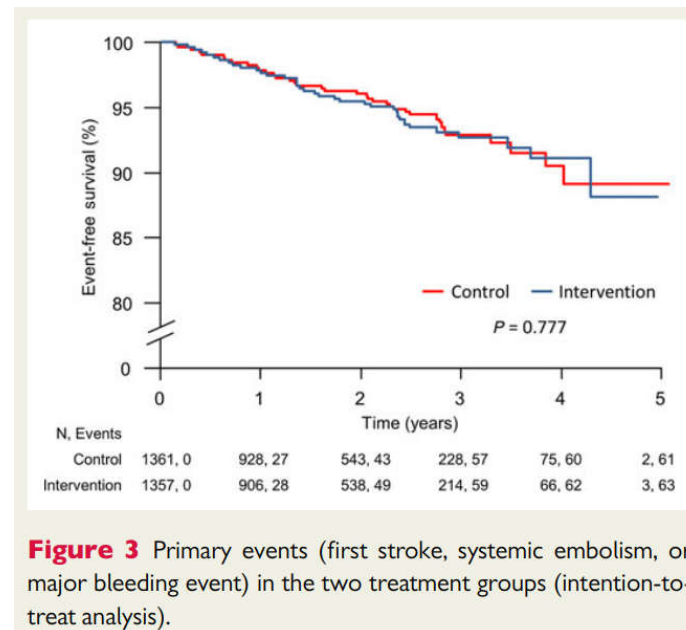
Figure 3 Primary events (first stroke, systemic embolism, or major bleeding event) in the two treatment groups (intention-to-treat analysis).

Martin DT et al. Eur Heart J. 2015 Jul 7;36(26):1660-8

Remote Interrogation/Remote monitoring

CARELINK
(Medtronic)

CardioMessenger
(Biotronik)

LATITUDE
(Boston)

Remote Interrogation/Remote monitoring

MERLIN.net
(ABBOTT)

주호소 및 현재질병상태

2017년 9월에 기절 해서 [ ] 병원

4번 쓰러짐..

최근 2번은 좀 다르다..
12월 20일, 1월 1일.
누워 있다가 반대쪽으로 돌아 누우려는데 숨이 탁 멈추는 기분 --> 숨이
헐떡 거리면서 세번 쉬다가 바로 기억을 잃고...
1-2분정도...
눈에 촛점이 없고 숨을 안쉬었다가 한번에 몰아 쉬고...2분 정도 있다가
깨어남...
깨면 눈 앞이 뿌옇고 잘 안 보이다가 시간이 되면되돌아옴
귀도 처음에는 안 들렸다가 서서히 들리고
숨도 가쁘다가 서서히 돌아오고...
방에서 쿵 소리가 나서 가보니 벽이 찌그러지고 머리를 부딪히고...가슴
에 금이 갔고...

한번은 아침에 일어나자 마자 영화를 보고 나왔는데 눈앞이 핑 돌더니
쓰러짐...
한번은 자다가 눈 떴는데 소파에서.. 일어나보니 바닥에 침을 흘려 놓
고 .. 귀가 잘 안 들리고 앞이 흐리고 심장이 빨리 뛰고...

처음, 두번 째는 조짐 없었던 것 같고...

과거력 (others)

신체검진 (others)   HUT (2017.09) - positive, 그러나 증상이 다르다.

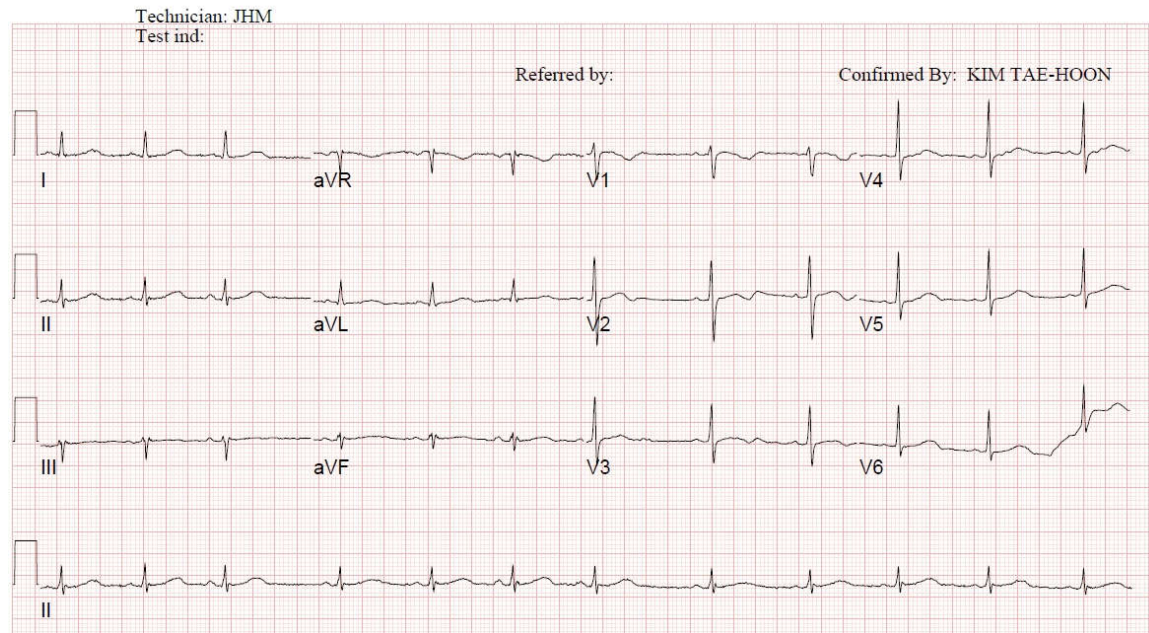ECG - SR 71bpm, sinus arrhythmia
CXR - ok

추정진단   Recurrent syncope, unknown origin
계획
2/2 입원해서 telemetry
TMT, TTE, HUT again
약물 검사 고려

신경과 협진

19 yr
Female Oriental

Room:
Loc:11

Vent. rate	71	BPM
PR interval	140	ms
QRS duration	82	ms
QT/QTc	416/452	ms
P-R-T axes	28 -5	37

Normal sinus rhythm with sinus arrhythmia
Normal ECG

Technician: JHM
Test ind:

Referred by: Confirmed By: KIM TAE-HOON

I   aVR   V1   V4

II   aVL   V2   V5

III   aVF   V3   V6

II

05-JUN-2000 (19 yr)
Female Oriental

Room:EP
Loc:9
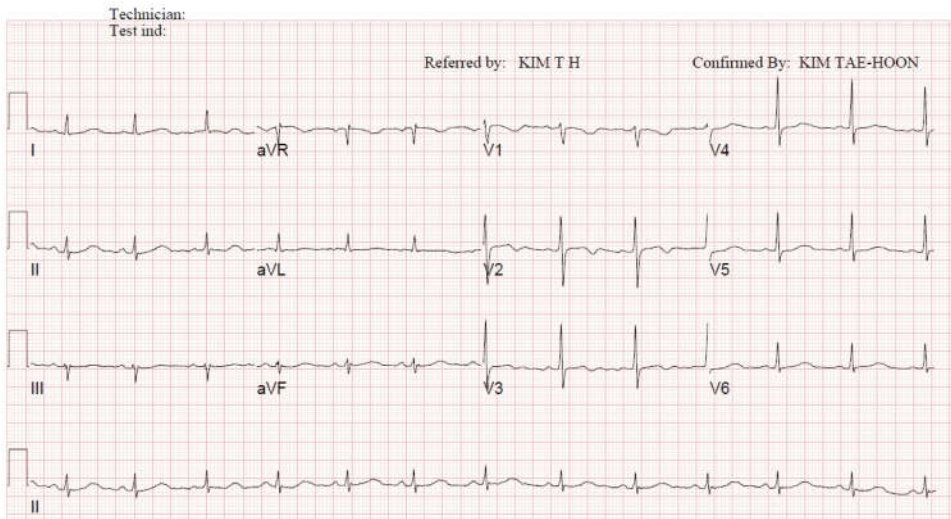
Vent. rate   76 BPM
PR interval   152 ms
QRS duration   84   ms
QT/QTc   452/508   ms
P-R-T axes   63 -6   48

Normal sinus rhythm
Prolonged QT
Abnormal ECG

Technician:
Test ind:

Referred by: KIM T H   Confirmed By: KIM TAE-HOON

I   aVR   V1   V4
II   aVL   V2   V5
III   aVF   V3   V6
II

Subjective

long QD syndrome 강력 의증 하에 유전자 검사 진행, ILR implantation, beta blocker start.
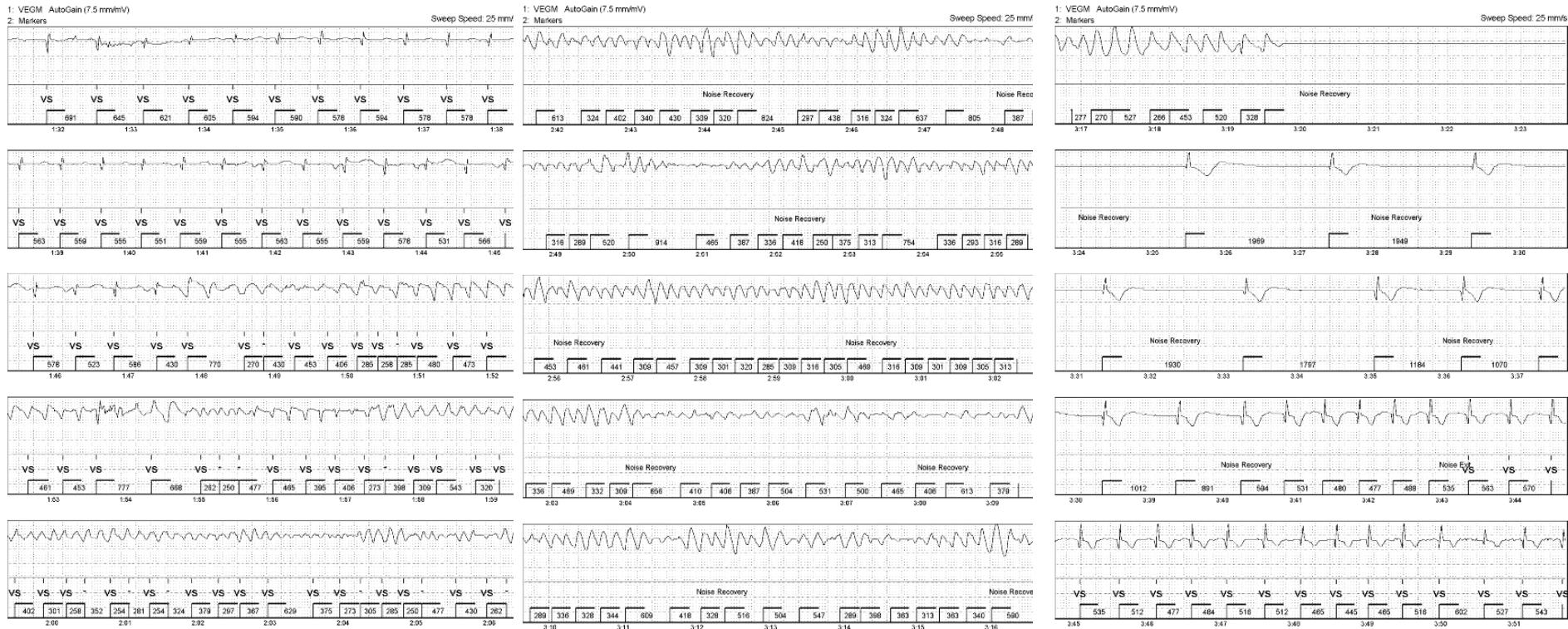
조금 기운 없긴 하다..

경남대 - 문화콘텐츠....

Objective

ECG - SR 72bpm, QTc 475ms

#TTE (2002) - normal
#TMT (2002) - 11.0mets neg no arrhythmia

#Epinephrine test (2002) - positive
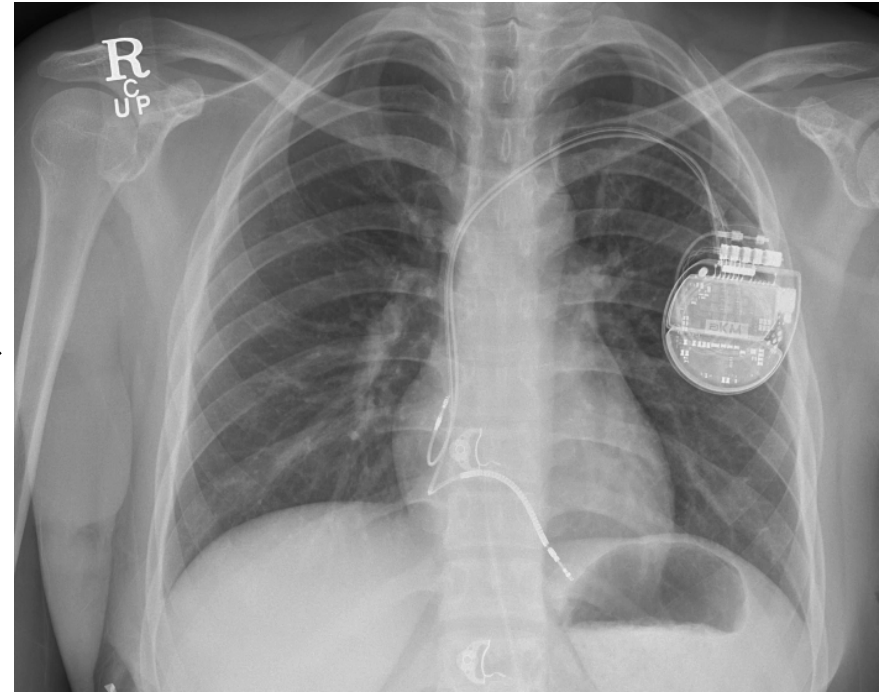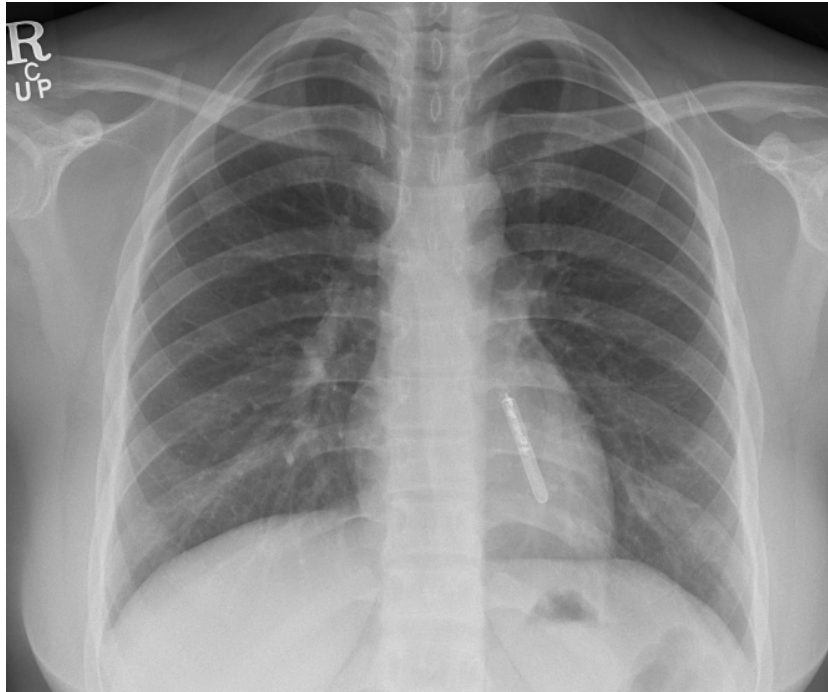#HUT (2017.09) - positive (병원) -> HUT (2020.02) - negative (본원)

HEART PANEL REPORT

PATIENT INFORMATION			
PATIENT NAME:		TYPE OF SPECIMEN:	Whole blood
PATIENT ID:		DATE COLLECTED:	2020/02/05
DATE OF BIRTH:	2000/06/05 SEX: Female	DATE REPORTED:	2020/02/21
REFERRING DIAGNOSIS:	r/o Long QT syndrome	REFERRING PHYSICIAN:	김태훈

VARIANTS OF INTEREST

ACMG Classification	Gene	Accession	Nucleotide	Amino acid	Zygosity	dbSNP	Disorder (OMIM, HGMD)	Inheritance	Global (ExAC)	Korean (KRGDB)	Comments
Likely pathogenic	KCNH2	NM_000238.3	.2353G>T	p.Gly785Cys	Hetero		Long QT syndrome 2, 613688 (3), Autosomal dominant; {Long QT syndrome 2, acquired, susceptibility to}, 613688 (3), Autosomal dominant; Short QT syndrome 1, 609620 (3)	AD			

ILR interrogation (2020.10.27 4am) – VF for 1min

제세동기를 이용한 원격 모니터링의 임상적 및 경제적 이점을 평가하기 위한 전향적, 다기관, 무작위 배정 임상시험

연구의 목적
- 제세동기 (삽입형 제세동기 [이상 ICD] 혹은 동기화 치료 [이상 CRT-D])를 삽입한 국내 환자에서 원격 모니터링의 임상적 및 경제적 이점, 사용자 편의성을 알아보고자 함

연구기간
- IRB 승인 이후부터 2025년 12월 31일까지 (Enrollment : 2023년 12월)

Defibrillation Device Implant (n=556)

RMo (Remote Monitoring only Arm (n=278)

Conventional Follow up Arm (n=278)

Remote Monitoring Follow-up Arm (n=278)

- 0 to 45 days enrollment in RM after implant. Patient should be seen at clinic once a year, or if there is any adverse event notification.

Conventional Follow-up Arm (n=278)

- Patients should be seen at clinic according to center's custom but no longer than 6 months between each visit

Follow-up of 2 years

Clinical & Economic Benefits by different indication subgroups

BENEFIT-RM study (2020.11 ~) (국내 19개 기관)

변호	시험기관명	시험책임자	등록 수
1	세브란스병원	정보영 / 김태훈	58
2	서울대병원	최의근	5
3	고려대 안암병원	최종일	0
	고려대 안암병원	심재민	8
4	대구 가톨릭대 병원	이영수	5
5	이대목동병원	박준범	2
6	중앙대병원	강기운 / 신승용	IRB심의중
7	계명대 동산병원	박형섭 / 한성욱 / 황종민	0
8	서울아산병원	조민수	0
9	전남대 병원	박형욱	3
10	분당서울대병원	오일영	4
11	삼성서울병원	박승정 / 박경민	12
12	동아대 병원	박종성	2
13	차의대 분당차병원	성정훈	3
14	원광대병원	고점석	11
15	경희대 병원	김진배	1
16	은평 성모병원	장성원	6
17	원주세브란스기독병원	안민수 / 박영준	11
18	양산부산대병원	황기원 / 최진희	계약서진행중
19	충북대병원	김민	IRB심의중
TOTAL			131

Center 별 Enroll Unit 분포도 (%)

- 10%~
- 5%~10%
- 3%~5%
- 0%~3%

동아대, 1.7%
전남대, 1.9%
충북대, 2.2%
삼성 서울, 1.3%
경희대, 2.2%
양산부산대, 2.2%
서울 아산, 2.2%
계명대 동산, 2.2%
중앙대, 2.2%
차의대 분당차, 2.4%
이대 목동, 3.3%
대구 가톨릭대, 3.7%
서울대, 4.1%
은평성모, 5.0%
분당 서울대, 6.7%
고려대 안암, 7.4%
원광대, 8.1%
원주세브란스 기독, 9.1%
세브란스, 32.0%
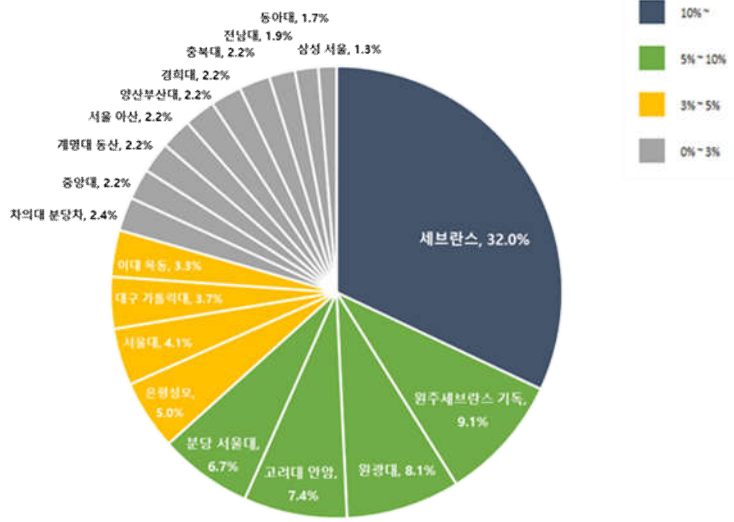
Conclusions : The Ideal and the challenge

◆ Based on several RCTs, in comparison to standard care, RM can:

◆ Detect device problems and arrhythmia events earlier → early action possible

◆ Decrease hospital visits/hospitalizations

◆ Decrease hospital cost

◆ Decrease inappropriate ICD shock

◆ 국내 허가 기준 (BENEFIT-RM trial result 를 근거로 제시할 예정)

◆ 인력 문제 (data overload)

◆ Hard outcome 개선 - uncertain

Thank you for your attention!