Advancing S-ICD through clinical evidence & contemporary implant management

Kyungpook National University Hospital

Bae Myung Hwan

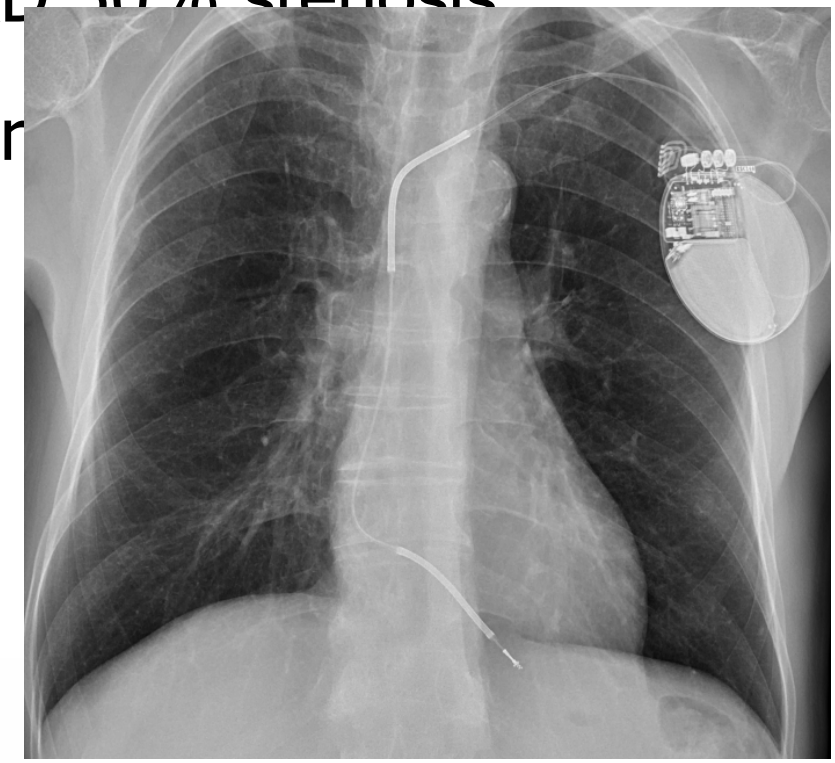
Korean Heart Rhythm Society
COI Disclosure

Myung Hwan Bae

The authors have no financial conflicts of interest to disclose concerning the presentation

Case

- M/65
- Sudden cardiac arrest d/t ventricular fibrillation
- HTN/DM/dyslipidemia (+/+/+), CVA
- CAG: RCA CTO, proximal LAD 50% stenosis
- 2D-UCG: LVEF 34%, RCA ter
  abnormality
- TV-ICD insertion



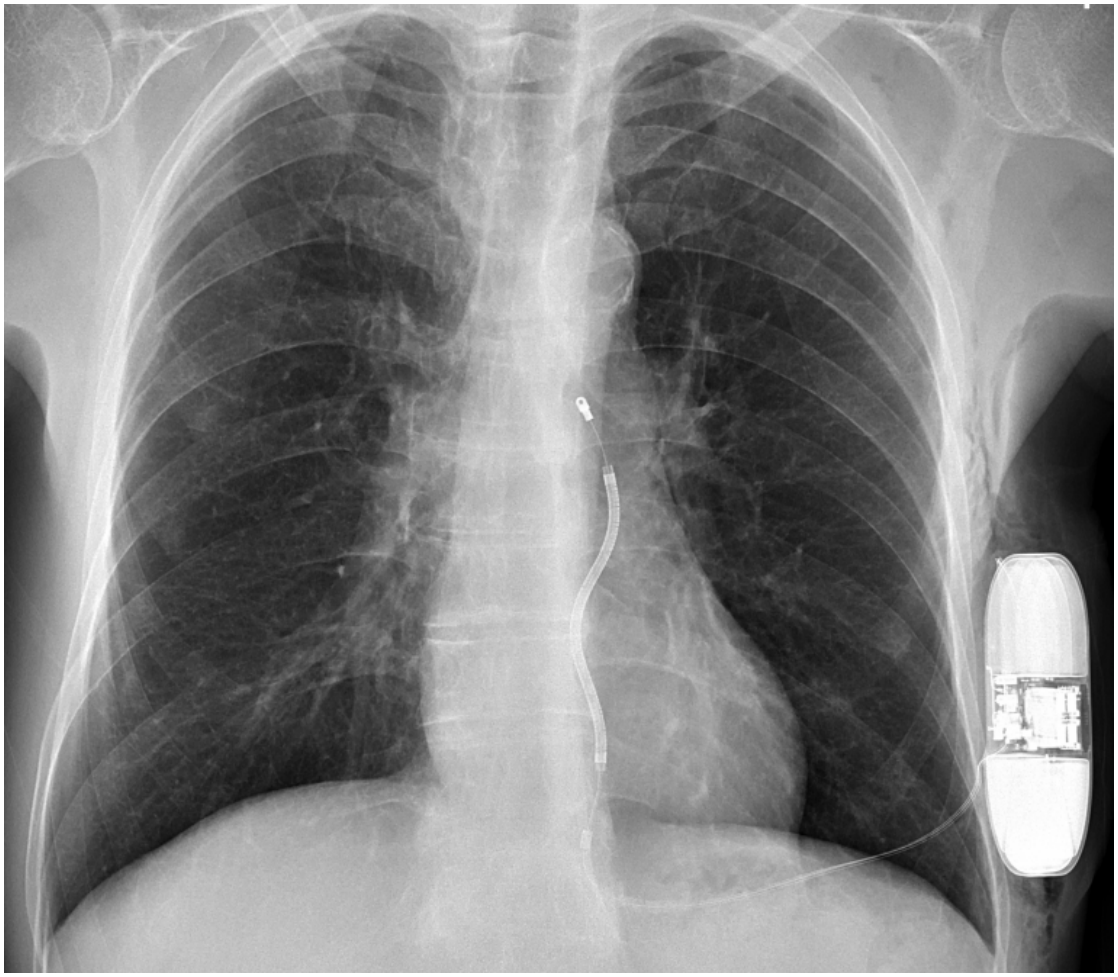
Case

- 3 month later

HbA1c 14.%→11.8%

- ICD removal

Case



- S-ICD implantation

TV-ICD infection

CLINICAL RESEARCH Heart Rhythm Disorders

16-Year Trends in the Infection Burden for Pacemakers and Implantable Cardioverter-Defibrillators in the United States

1993 to 2008

Arnold J. Greenspon, MD,* Jasmine D. Patel, PHD,†‡ Edmund Lau, MS,†‡ Jorge A. Ochoa, PHD,‡
Daniel R. Frisch, MD,* Reginald T. Ho, MD,* Behzad B. Pavri, MD,* Steven M. Kurtz, PHD†‡
Philadelphia, Pennsylvania

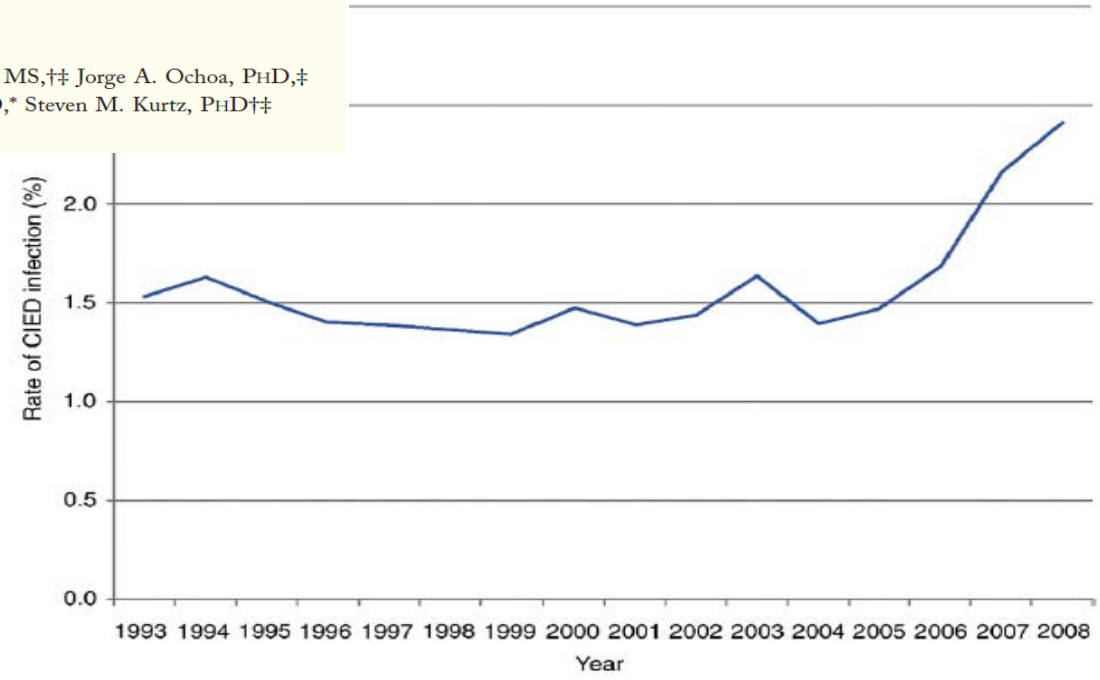


Figure 3 Rate of CIED Infection

The annual rate of cardiac implantable electrophysiological device (CIED) infection remained fairly constant until 2004 when there was a marked incre
The infection rate increased from 1.53% in 2004 to 2.41% in 2008 ($p < 0.001$).

- Despite technology advances, TV- ICD infections are increasing

Greenspon et al. JACC 2011;58:1001-1006.

TV-ICD infection

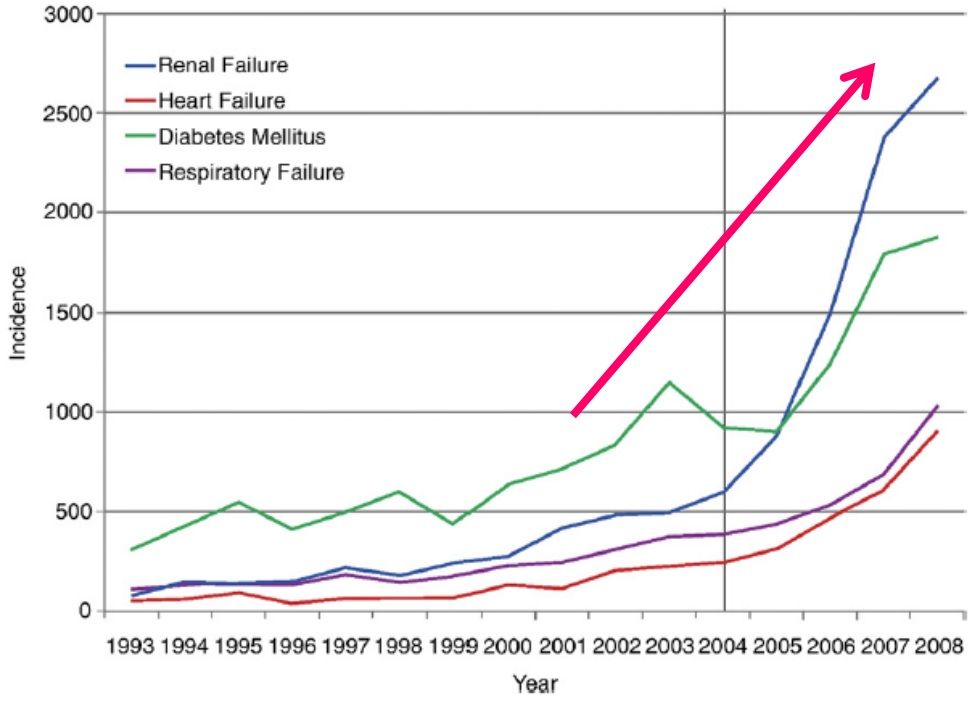


Figure 5 **Incidence of Comorbidities in Patients With CIED Infection**

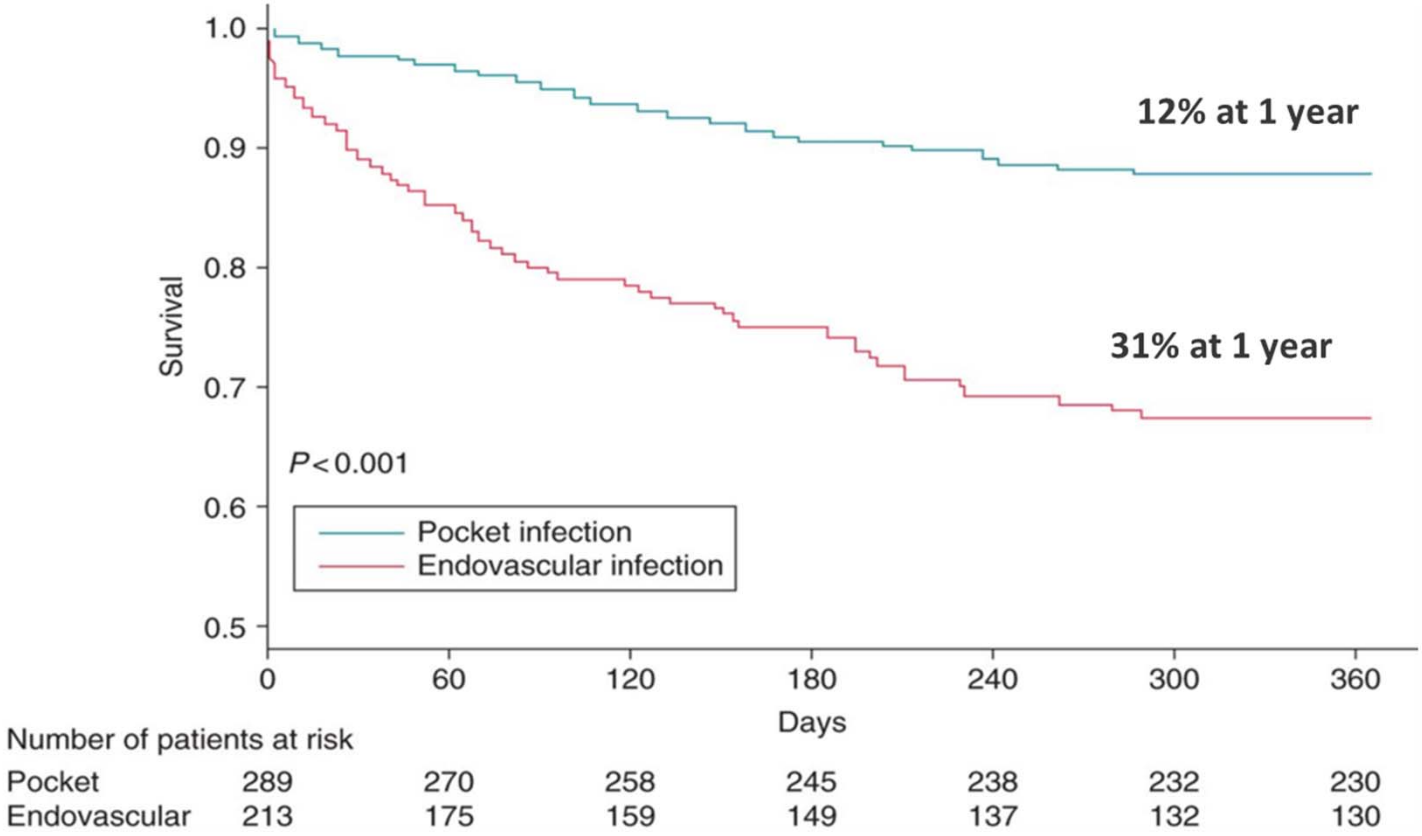
The incidence of 4 major comorbidities (renal failure, respiratory failure, heart failure, and diabetes) remained fairly constant until 2004 when a marked increase was observed. This paralleled both the observed increase in implantable cardioverter-defibrillator implantation and the increased infection rate. CIED = cardiac implantable electrophysiological device.

- One theory is that patients with more comorbidities associated with infection are being implanted with ICD

Greenspon et al. JACC 2011;58:1001-1006.

TV-ICD infection

- The mortality rate: 12-31% mortality rate at 1 year



Tarakji KG, et al. Euoapce 2014;16:1490-1495.

Current guidelines

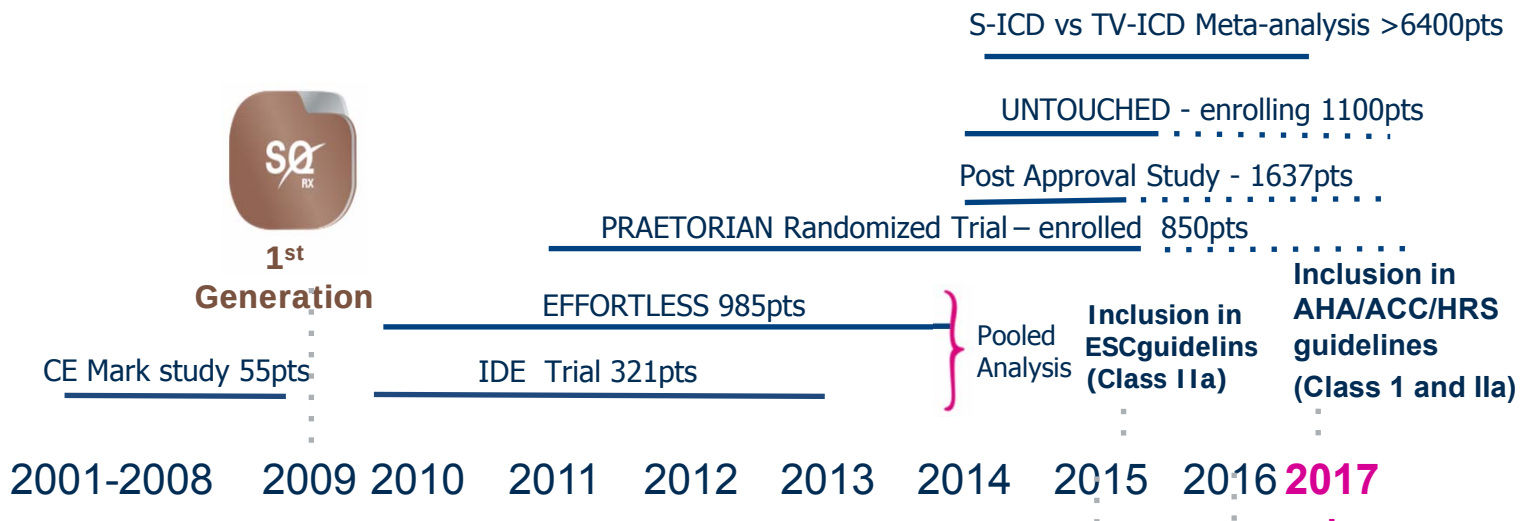
Recommendations for Subcutaneous Implantable Cardioverter-Defibrillator References that support the recommendations are summarized in Online Data Supplement 55.		
COR	**LOE**	**Recommendations**
I	B-NR	1. In patients who meet criteria for an ICD who have inadequate vascular access or are at high risk for infection, and in whom pacing for bradycardia or VT termination or as part of CRT is neither needed nor anticipated, a subcutaneous implantable cardioverter-defibrillator is recommended (1-5).
IIa	B-NR	2. In patients who meet indication for an ICD, implantation of a subcutaneous implantable cardioverter-defibrillator is reasonable if pacing for bradycardia or VT termination or as part of CRT is neither needed nor anticipated (1-4).
III: Harm	B-NR	3. In patients with an indication for bradycardia pacing or CRT, or for whom antitachycardia pacing for VT termination is required, a subcutaneous implantable cardioverter-defibrillator should not be implanted (1-4, 6-8).

- The risk of infection appears to be lower with S-ICD than with TV-ICD. Therefore, a **S-ICD** may be preferred in patients who are at high risk of infection, such as those with a **prior device infection, ESRD, diabetes mellitus**, or who are chronically **immunosuppressed.**

2017 AHA/ACC/HRS Guideline for Management of Patients With Ventricular Arrhythmias and the Prevention of Sudden Cardiac Death

The S-ICD Journey

Over 15 years of clinical data and experience with S-ICD technology



- **43,000+ patients implanted WW**
- **4,000+ patients** enrolled in completed and on-going S-ICD clinical studies

2nd Generation

3rd Generation

S-ICD and TV-ICD efficacy

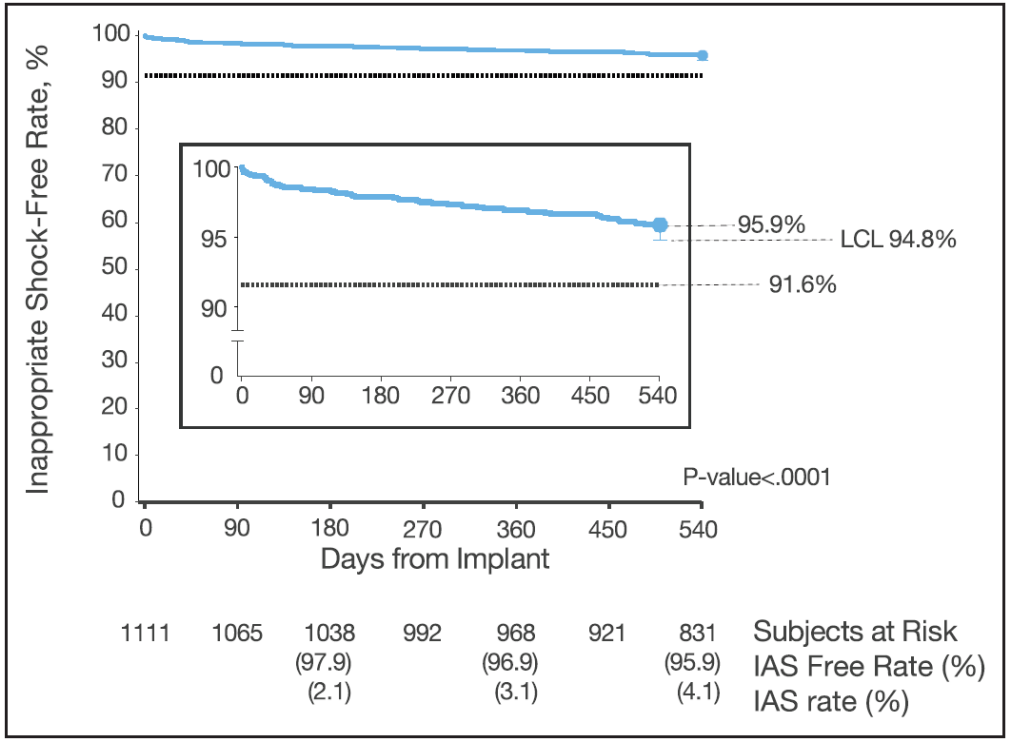
	Patients number	Shock efficacy
IDE and EFFORTLESS (S-ICD)	882	**98.2%**
SIMPLE (DFT group) (TV-ICD)	1,242	95.7%
SIMPLE (no DFT group) (TV-ICD)	1,236	94.8%
ALTITUDE first shock study (TV-ICD)	2,000	99.8%
LESS (TV-ICD)	636	97.3%

Burke, M.C. et al. J Am Coll Cardiol . 2015;65:1605–15.
Healey, J, et al. The Lancet. 2015;385:785-91
Cha YM et al. Heart Rhythm 2013;10:702–708.
Gold MR et al. Circulation 2002;105:2043-2048.

UNTOUCHED trial

Primary Results From the Understanding Outcomes With the S-ICD in Primary Prevention Patients With Low Ejection Fraction Trial

- Primary prevention, LVEF ≤35%,1,111 patients, generation 2 or 3 S-ICD
- Primary end point: inappropriate shock-free rate



Gold et al. Circulation. 2021;143:7–17.

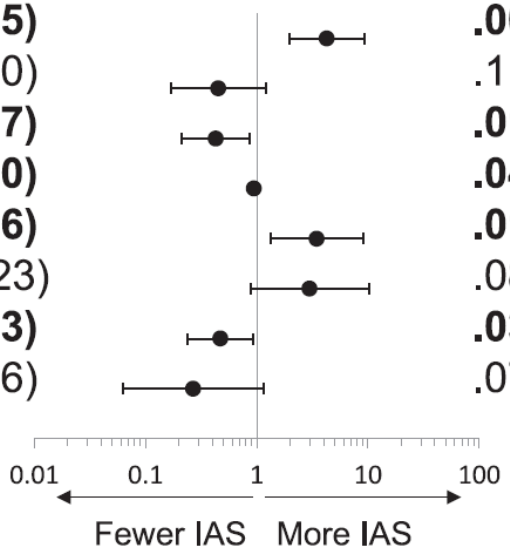
UNTOUCHED trial

Predictors of inappropriate shocks

Multivariable

Variable	Hazard Ratio	P-value
History of AF	**4.24 (1.95-9.25)**	**.0003**
Black Race	0.45 (0.17-1.20)	.11
Ischemic etiology	**0.43 (0.21-0.87)**	**.019**
LVEF, %*	**0.94 (0.89-1.00)**	**.042**
Two-incision technique	**3.47 (1.33-9.06)**	**.011**
DFT performed within first 30 days	3.00 (0.88-10.23)	.080
Gen 3 device	**0.47 (0.24-0.93)**	**.031**
Prescribed programming throughout study	0.27 (0.06-1.16)	.078

n=1040

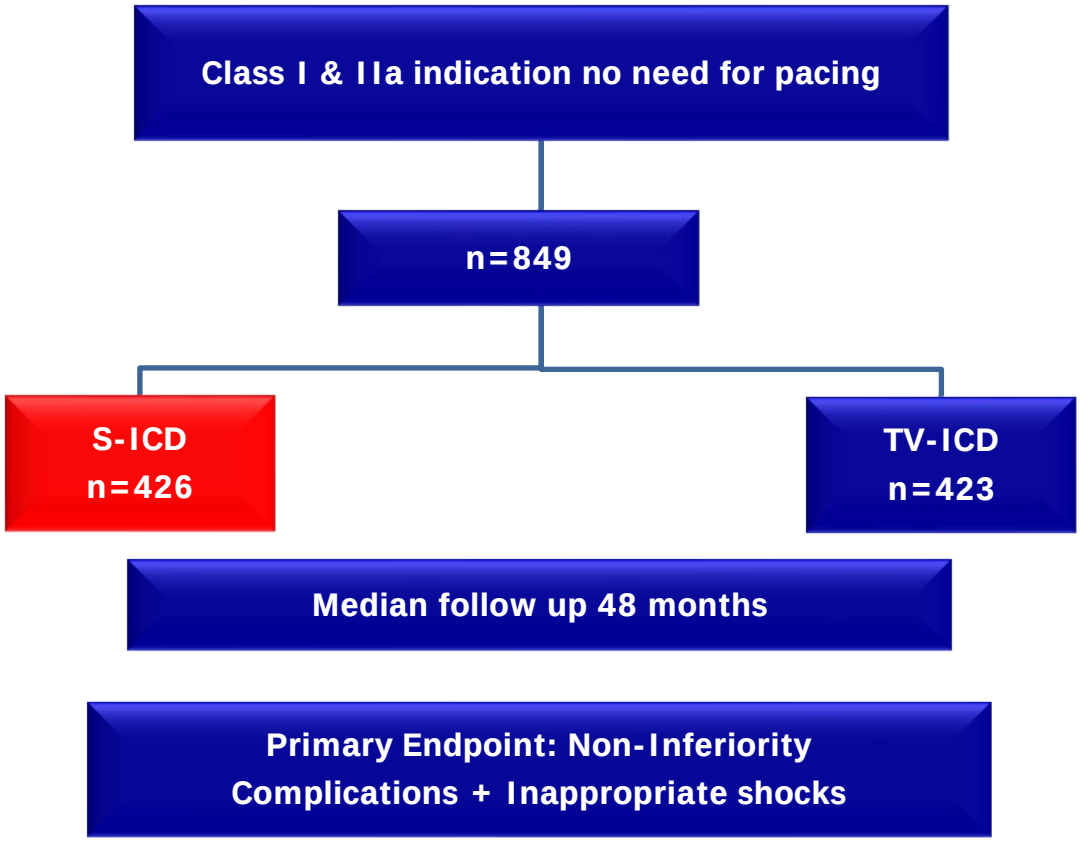


Gold et al. Circulation. 2021;143:7–17.

PRAETORIAN Trial

Subcutaneous or Transvenous Defibrillator Therapy

- Prospective, randomized

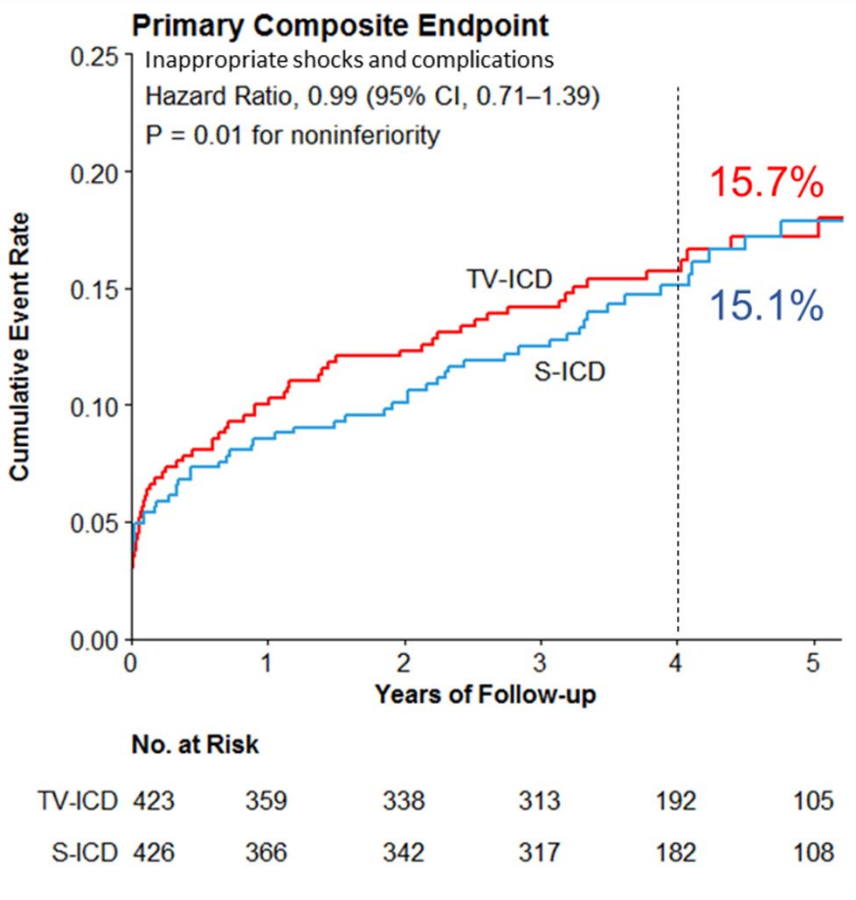


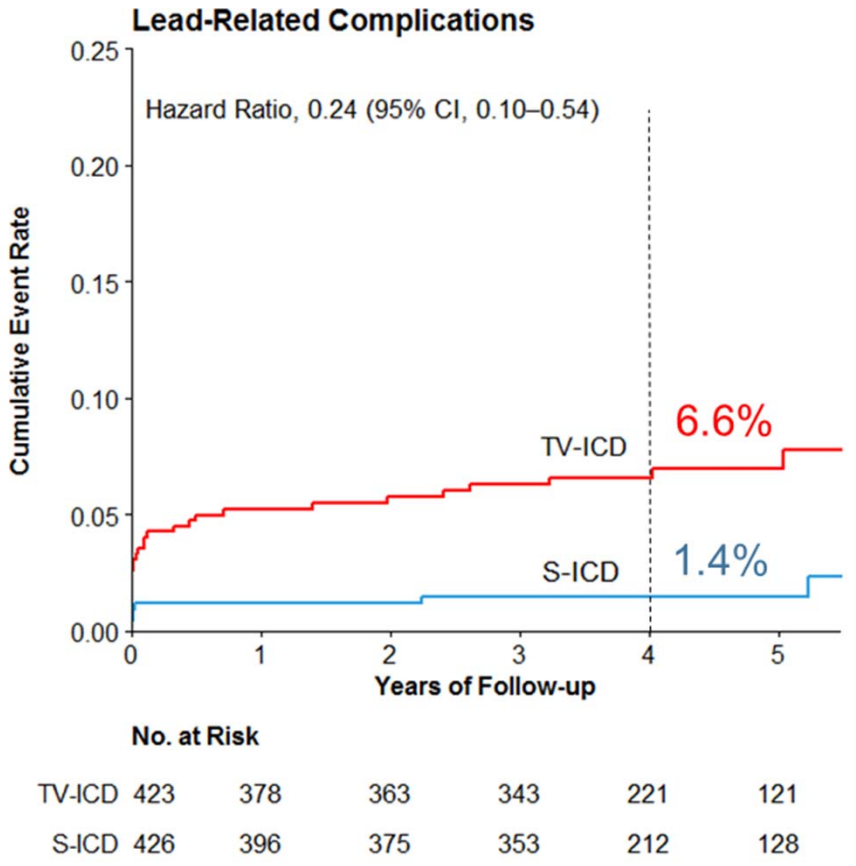
- Mean age: 63 yrs
- Ischemic CMP: 69%
- 2nd prevention: 19%
- LVEF 30%

Knops RE et al. N Engl J Med 2020; 383:526-536

PRAETORIAN Trial

Primary Outcome: Non-inferiority demonstrated

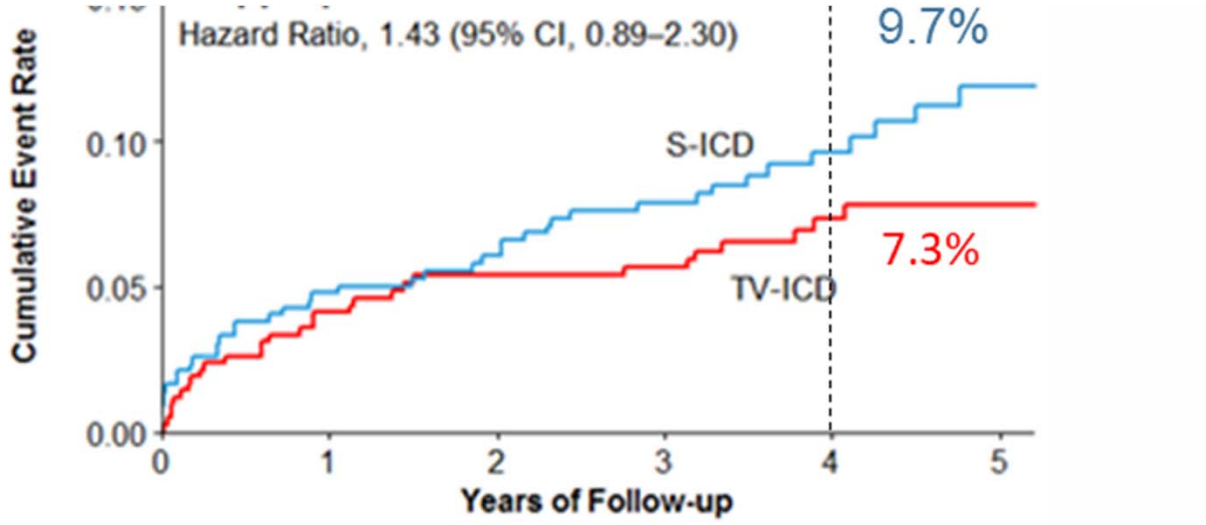




Knops RE et al. N Engl J Med 2020; 383:526-536

PRAETORIAN Trial

Inappropriate shock



At 4 years (median)	S-ICD (n = 426)	TV-ICD (n = 423)
Primary composite endpoint	68 (15.1%)	68 (15.7%)
Inappropriate shock	41 (9.7%)	29 (7.3%)
– AF/SVT	15	27
– Cardiac oversensing	20	2
– Noncardiac oversensing	8	0

Knops RE et al. N Engl J Med 2020; 383:526-536

Meta-analysis

Subcutaneous versus transvenous implantable defibrillator: An updated meta-analysis

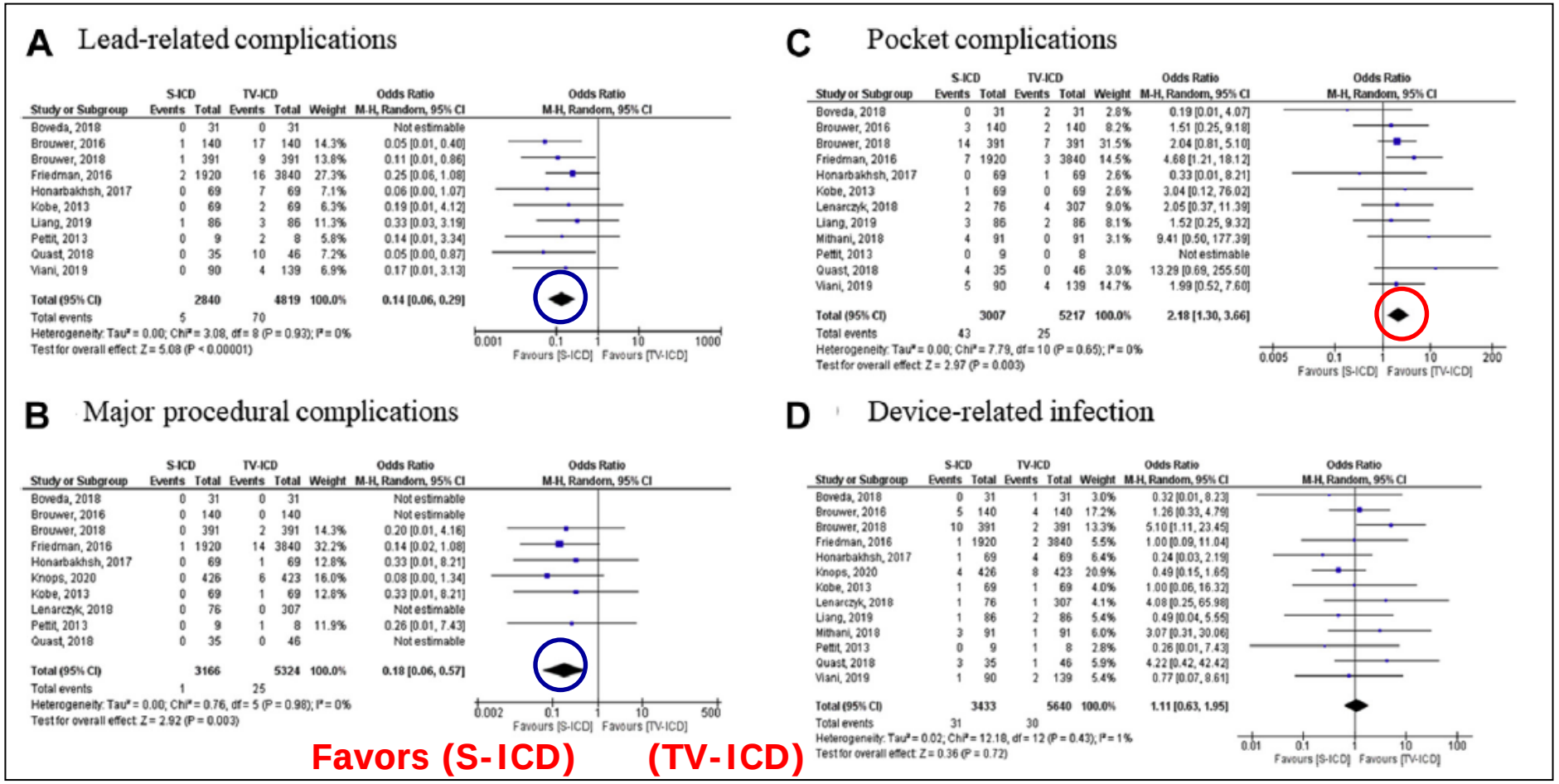
Roberto Rordorf, MD,*[1] Matteo Casula, MD,*†[1] Laura Pezza, MD,*†
Federico Fortuni, MD,† Antonio Sanzo, MD,* Simone Savastano, MD,*
Alessandro Vicentini, MD*

- 13 studies, 9,073 patients
- Primary outcomes
  - clinically relevant complications

(lead, pocket, major procedural complications, device-related infections)

  - Inappropriate shocks

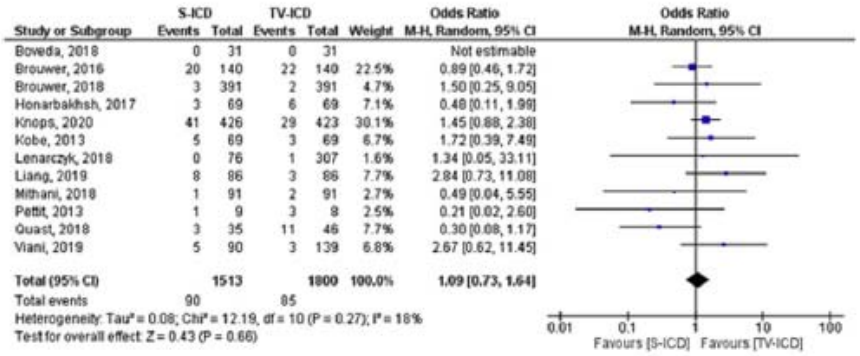
Meta-analysis



Rordorf R et al. Heart Rhythm 2021;18:382–391

Meta-analysis

A Inappropriate shock

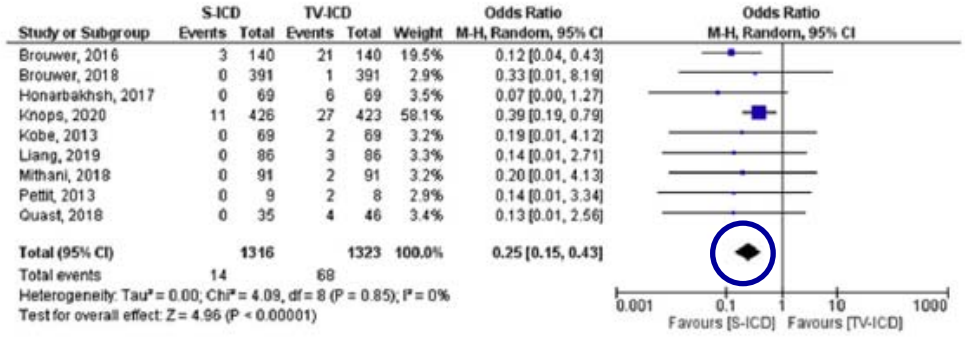


Study or Subgroup	S-ICD Events	S-ICD Total	TV-ICD Events	TV-ICD Total	Weight	Odds Ratio M-H, Random, 95% CI
Boveda, 2018	0	31	0	31		Not estimable
Brouwer, 2016	20	140	22	140	22.5%	0.89 [0.46, 1.72]
Brouwer, 2018	3	391	2	391	4.7%	1.50 [0.25, 9.05]
Honarbakhsh, 2017	3	69	6	69	7.1%	0.48 [0.11, 1.99]
Knops, 2020	41	426	29	423	30.1%	1.45 [0.88, 2.38]
Kobe, 2013	5	69	3	69	6.7%	1.72 [0.39, 7.49]
Lenarczyk, 2018	0	76	1	307	1.6%	1.34 [0.05, 33.11]
Liang, 2019	8	86	3	86	7.7%	2.84 [0.73, 11.08]
Mithani, 2018	1	91	2	91	2.7%	0.49 [0.04, 5.55]
Pettit, 2013	1	9	3	8	2.5%	0.21 [0.02, 2.60]
Quast, 2018	3	35	11	46	7.7%	0.30 [0.08, 1.17]
Viani, 2019	5	90	3	139	6.8%	2.67 [0.62, 11.45]
Total (95% CI)		**1513**		**1800**	**100.0%**	**1.09 [0.73, 1.64]**
Total events	90		85			

Heterogeneity: Tau² = 0.08; Chi² = 12.19, df = 10 (P = 0.27); I² = 18%
Test for overall effect: Z = 0.43 (P = 0.66)

Odds Ratio M-H, Random, 95% CI
0.01 0.1 1 10 100
Favours [S-ICD] Favours [TV-ICD]

C Inappropriate shock due to SVT

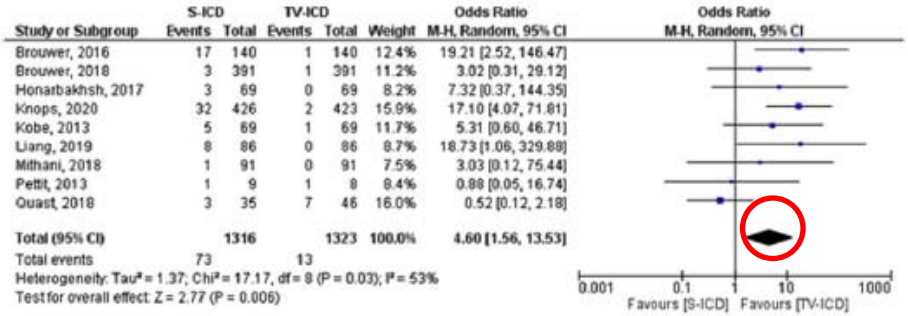


Study or Subgroup	S-ICD Events	S-ICD Total	TV-ICD Events	TV-ICD Total	Weight	Odds Ratio M-H, Random, 95% CI
Brouwer, 2016	3	140	21	140	19.5%	0.12 [0.04, 0.43]
Brouwer, 2018	0	391	1	391	2.9%	0.33 [0.01, 8.19]
Honarbakhsh, 2017	0	69	6	69	3.5%	0.07 [0.00, 1.27]
Knops, 2020	11	426	27	423	58.1%	0.39 [0.19, 0.79]
Kobe, 2013	0	69	2	69	3.2%	0.19 [0.01, 4.12]
Liang, 2019	0	86	3	86	3.3%	0.14 [0.01, 2.71]
Mithani, 2018	0	91	2	91	3.2%	0.20 [0.01, 4.13]
Pettit, 2013	0	9	2	8	2.9%	0.14 [0.01, 3.34]
Quast, 2018	0	35	4	46	3.4%	0.13 [0.01, 2.56]
Total (95% CI)		**1316**		**1323**	**100.0%**	**0.25 [0.15, 0.43]**
Total events	14		68			

Heterogeneity: Tau² = 0.00; Chi² = 4.09, df = 8 (P = 0.85); I² = 0%
Test for overall effect: Z = 4.96 (P < 0.00001)

Odds Ratio M-H, Random, 95% CI
0.001 0.1 1 10 1000
Favours [S-ICD] Favours [TV-ICD]

B Inappropriate shock due to oversensing

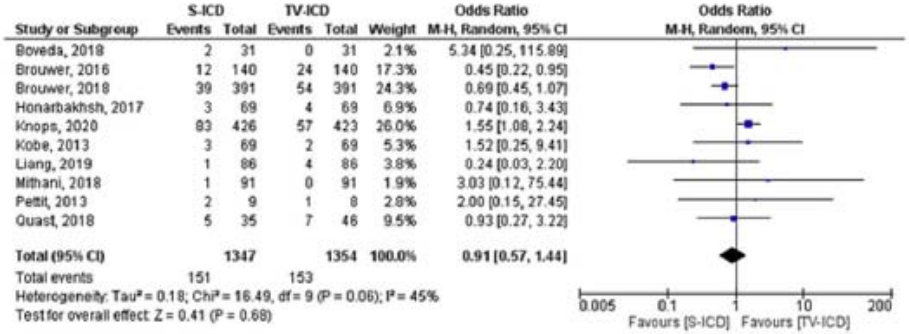


Study or Subgroup	S-ICD Events	S-ICD Total	TV-ICD Events	TV-ICD Total	Weight	Odds Ratio M-H, Random, 95% CI
Brouwer, 2016	17	140	1	140	12.4%	19.21 [2.52, 146.47]
Brouwer, 2018	3	391	1	391	11.2%	3.02 [0.31, 29.12]
Honarbakhsh, 2017	3	69	0	69	8.2%	7.32 [0.37, 144.35]
Knops, 2020	32	426	2	423	15.9%	17.10 [4.07, 71.81]
Kobe, 2013	5	69	1	69	11.7%	5.31 [0.60, 46.71]
Liang, 2019	8	86	0	86	8.7%	18.73 [1.06, 329.88]
Mithani, 2018	1	91	0	91	7.5%	3.03 [0.12, 75.44]
Pettit, 2013	1	9	1	8	8.4%	0.88 [0.05, 16.74]
Quast, 2018	3	35	7	46	16.0%	0.52 [0.12, 2.18]
Total (95% CI)		**1316**		**1323**	**100.0%**	**4.60 [1.56, 13.53]**
Total events	73		13			

Heterogeneity: Tau² = 1.37; Chi² = 17.17, df = 8 (P = 0.03); I² = 53%
Test for overall effect: Z = 2.77 (P = 0.006)

Odds Ratio M-H, Random, 95% CI
0.001 0.1 1 10 1000
Favours [S-ICD] Favours [TV-ICD]

D Appropriate shock



Study or Subgroup	S-ICD Events	S-ICD Total	TV-ICD Events	TV-ICD Total	Weight	Odds Ratio M-H, Random, 95% CI
Boveda, 2018	2	31	0	31	2.1%	5.34 [0.25, 115.89]
Brouwer, 2016	12	140	24	140	17.3%	0.45 [0.22, 0.95]
Brouwer, 2018	39	391	54	391	24.3%	0.69 [0.45, 1.07]
Honarbakhsh, 2017	3	69	4	69	6.9%	0.74 [0.16, 3.43]
Knops, 2020	83	426	57	423	26.0%	1.55 [1.08, 2.24]
Kobe, 2013	3	69	2	69	5.3%	1.52 [0.25, 9.41]
Liang, 2019	1	86	4	86	3.8%	0.24 [0.03, 2.20]
Mithani, 2018	1	91	0	91	1.9%	3.03 [0.12, 75.44]
Pettit, 2013	2	9	1	8	2.8%	2.00 [0.15, 27.45]
Quast, 2018	5	35	7	46	9.5%	0.93 [0.27, 3.22]
Total (95% CI)		**1347**		**1354**	**100.0%**	**0.91 [0.57, 1.44]**
Total events	151		153			

Heterogeneity: Tau² = 0.18; Chi² = 16.49, df = 9 (P = 0.06); I² = 45%
Test for overall effect: Z = 0.41 (P = 0.68)

Odds Ratio M-H, Random, 95% CI
0.005 0.1 1 10 200
Favours [S-ICD] Favours [TV-ICD]

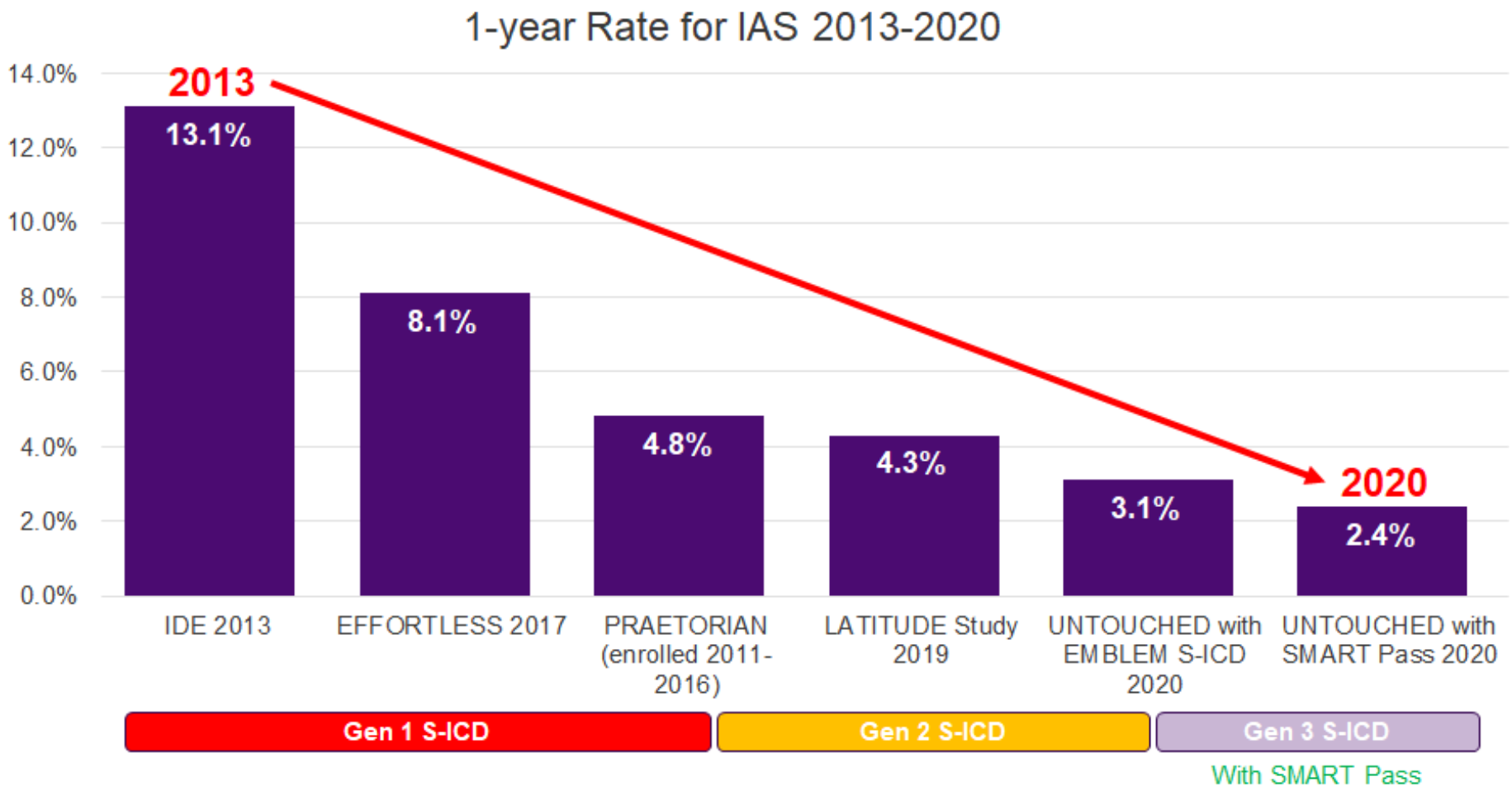
Favors (S-ICD) (TV-ICD)

KNUH 경북대학교병원

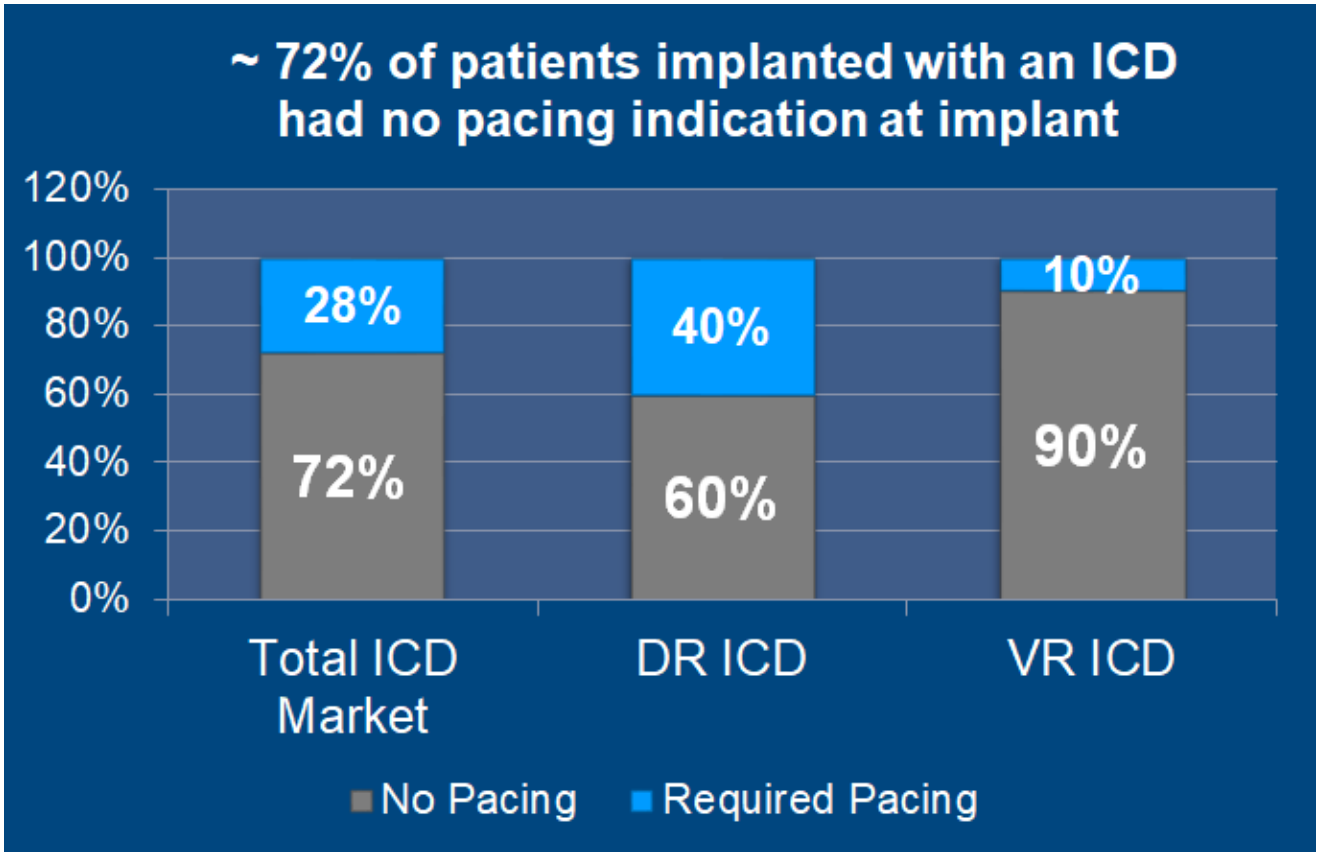
Rordorf R et al. Heart Rhythm 2021;18:382–391

Inappropriate shock for S-ICD

Rate of IAS for S-ICD continues to decline



The need for brady pacing in ICD

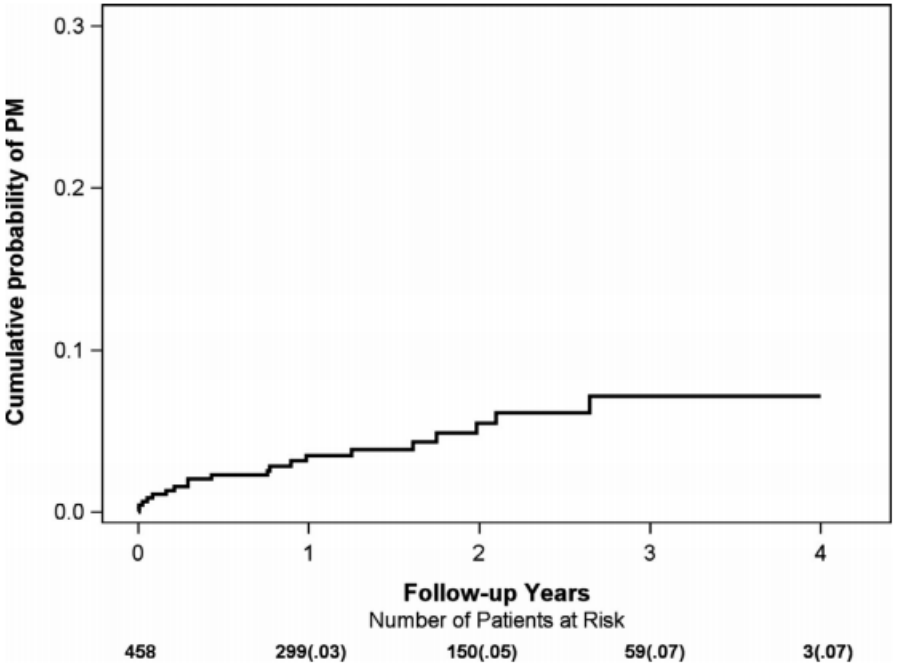


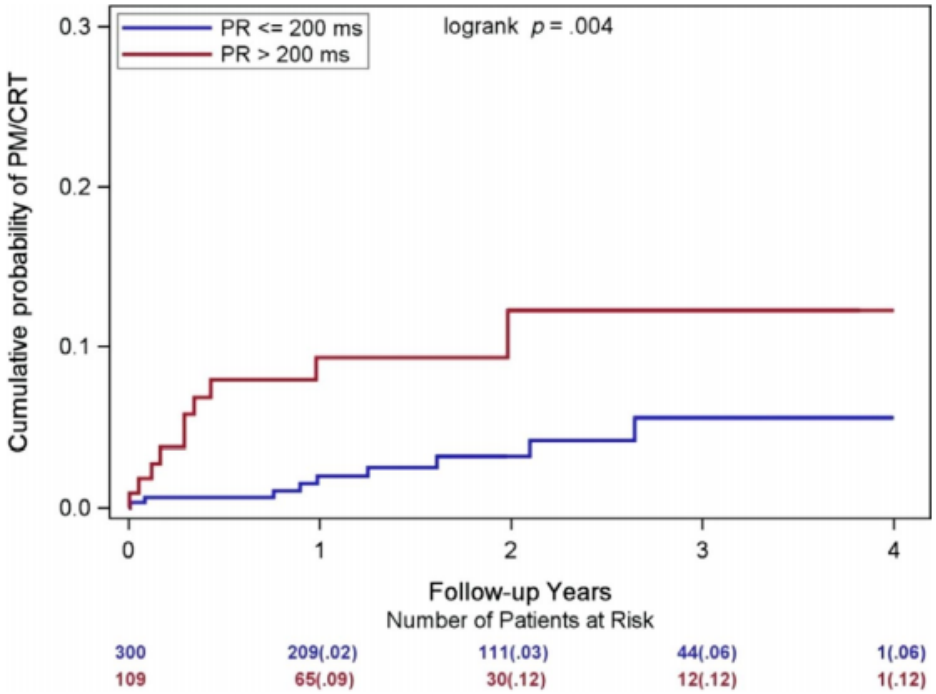
- While 60% of patients received a DR ICD, only 40% had a pacing indication at implant.
- ~90% of patients under 75 implanted with a VR ICD were programmed to VVI 40 of less

Gasparini, et al. JACC: Clinical Electrophysiology, 2017

The need for brady pacing in ICD

MADIT-II trial



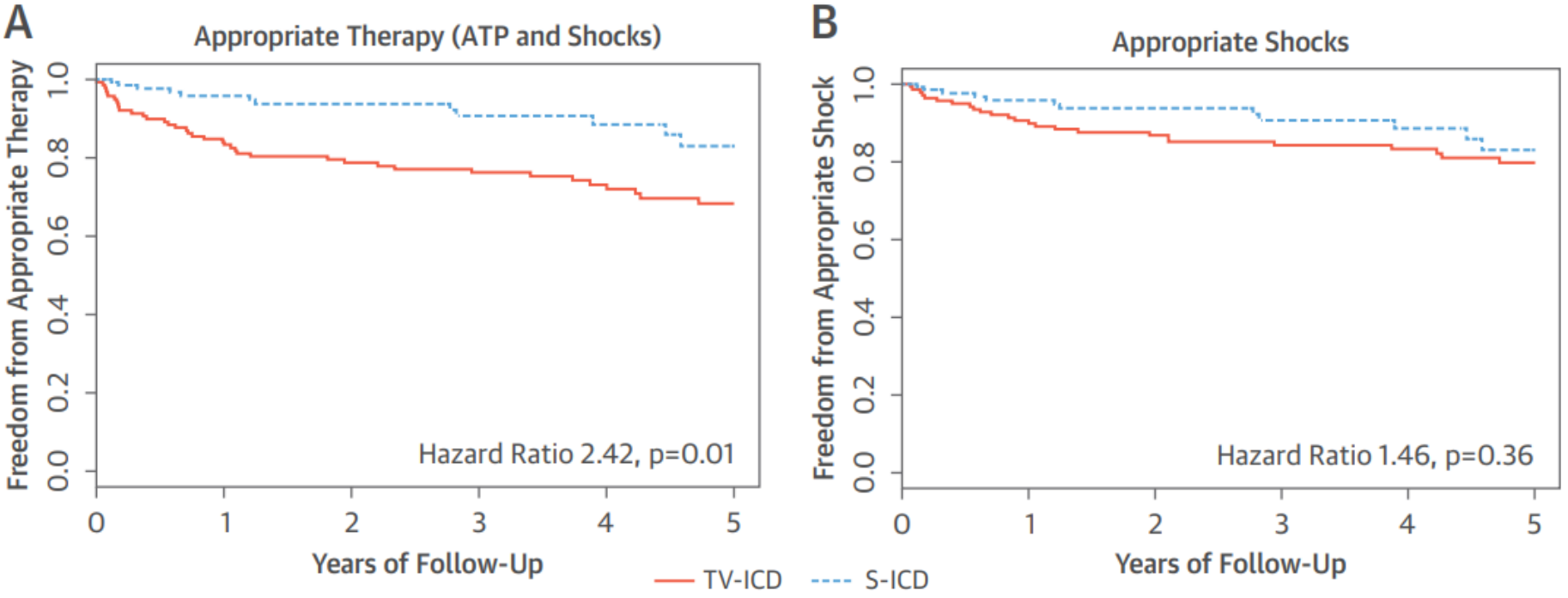


- Mean FU: 20 months
- 19/458 PM (4.1%)

Ann Noninvasive Electrocardiol 2020;25: e12744

The need for ATP

- Retrospective study, 1,160 patients



- ATP has been demonstrated to successfully terminate ~70 % of VT episodes, but, it did not result in fewer appropriate shocks

- SCD-HeFT ICD patients: monomorphic VT, 1.8% per year risk

Brouwer, T.F., et al. J Am Coll Cardiol 2016;68:2047-2055.
Poole, et al. Circulation:Arrhythmia and Electrophysciology 2013;6:12361245.

S-ICD in Korea: increasing but still low

- Concern about efficacy and safety
- Need for ATP
- Need for bradycardia
- Defibrillation Threshold (DFT) Test ?

DFT test in S-ICD

KNUH 경북대학교병원 KYUNGPOOK NATIONAL UNIVERSITY HOSPITAL

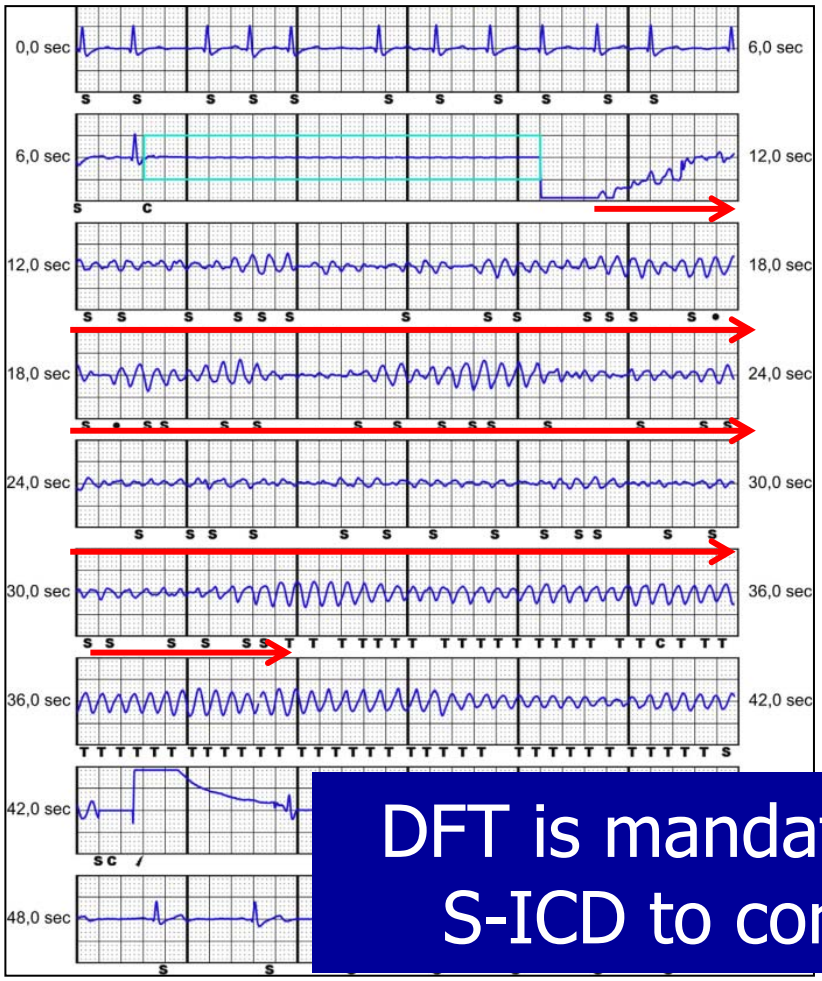
Defibrillation testing is mandatory in patients with subcutaneous implantable cardioverter–defibrillator to confirm appropriate ventricular fibrillation detection CME

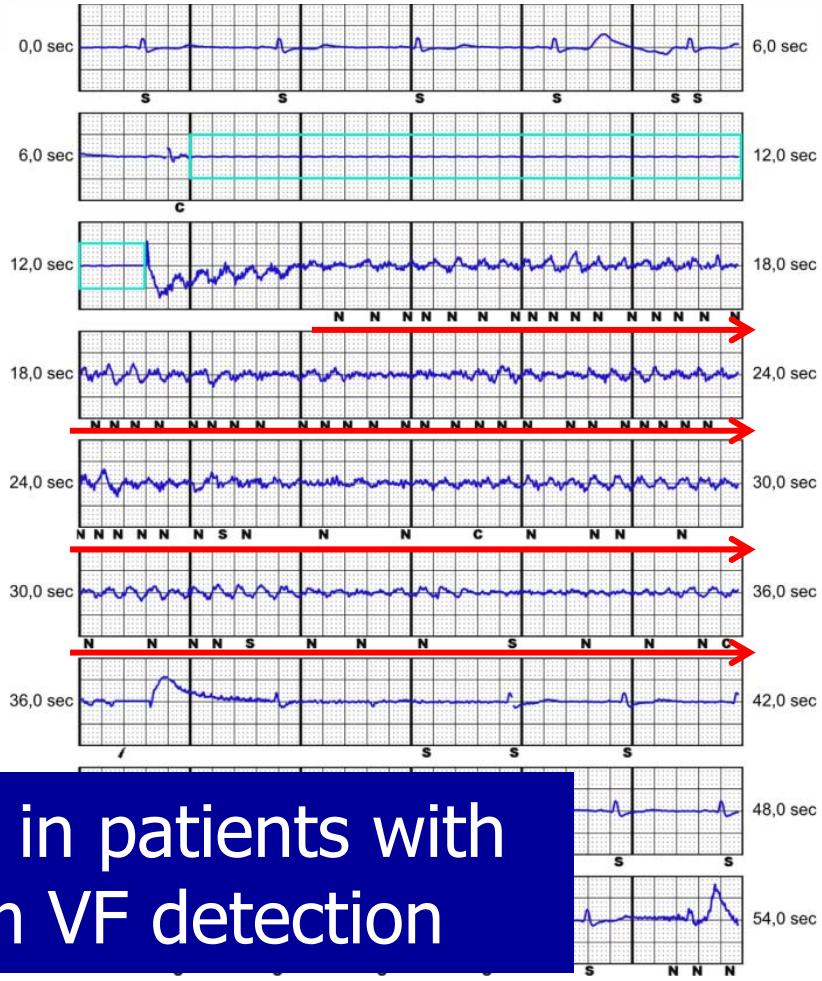
- Single center, 137 S-ICD patients
- VT induction: 133 (97%)
- Detection profiles

1) optimal detection: n=39 (29%)
2) undersensing with moderate prolongation of time to therapy (<18secs)
   : n=68 (51%)
3) undersensing with significant prolongation of time to therapy (>18secs)
   : n=19 (14%)
4) absence of therapy or prolonged time to therapy related to noise oversensing: n=7 (6%)

Heart Rhythm 2018;15:642–650

DFT test in S-ICD





DFT is mandatory in patients with S-ICD to confirm VF detection

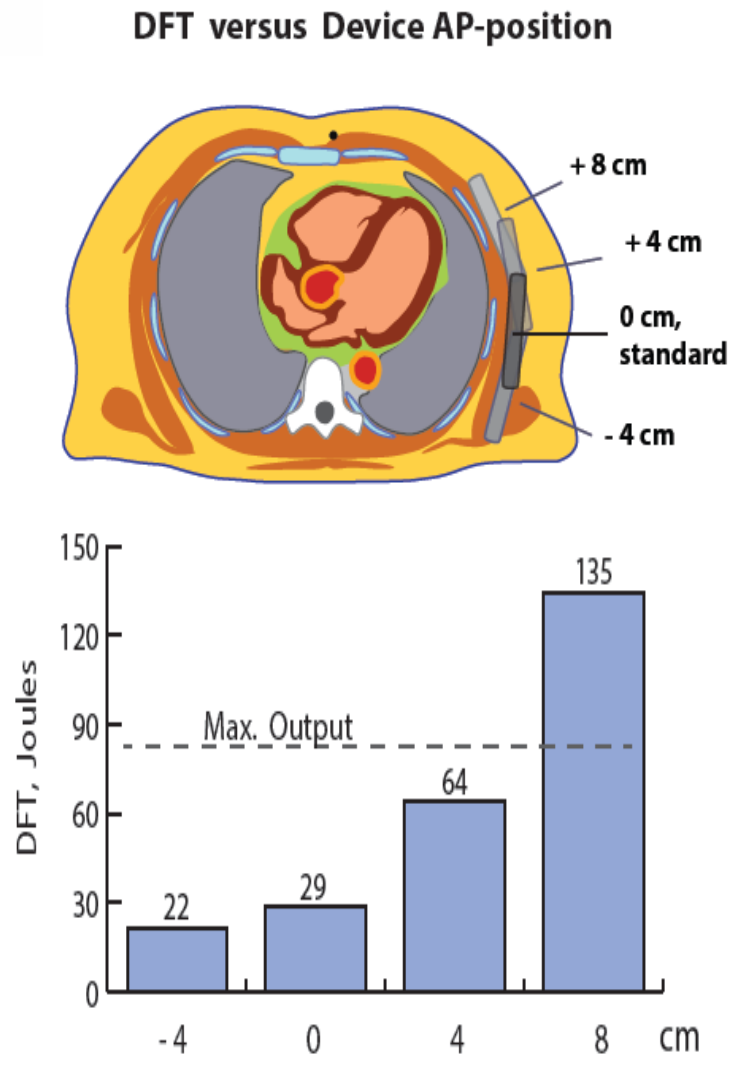
- Delayed VF detection

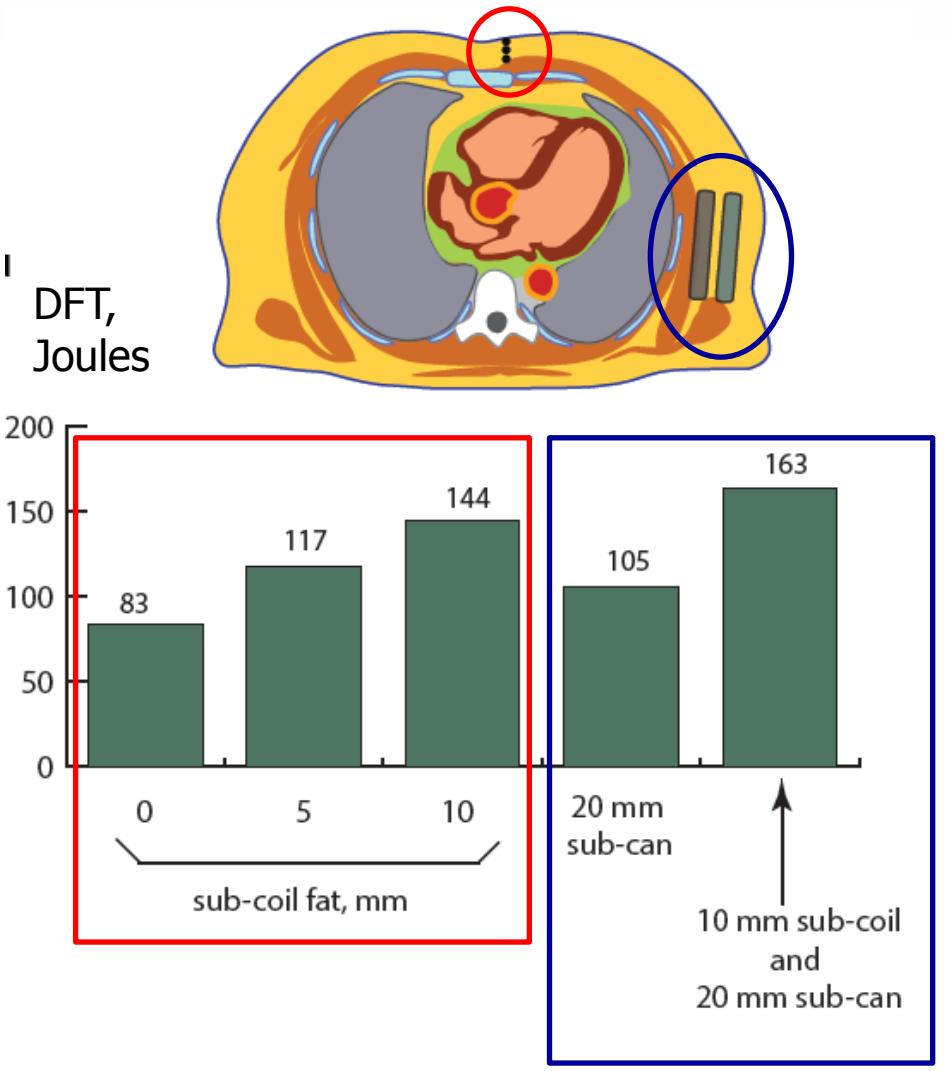
→ need to a different vector

- Noise oversensing during VF
- No therapy

Heart Rhythm 2018;15:642–650

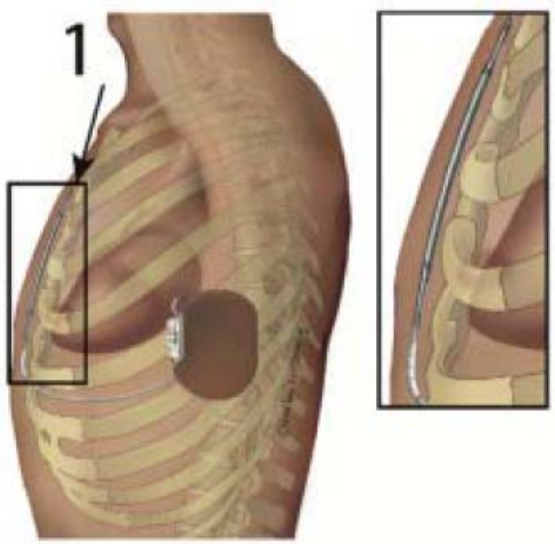
Determinants of S-ICD defibrillation efficacy

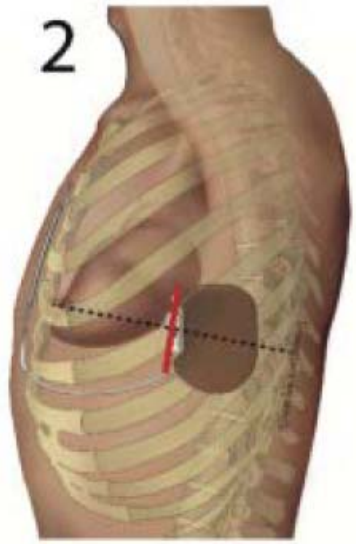


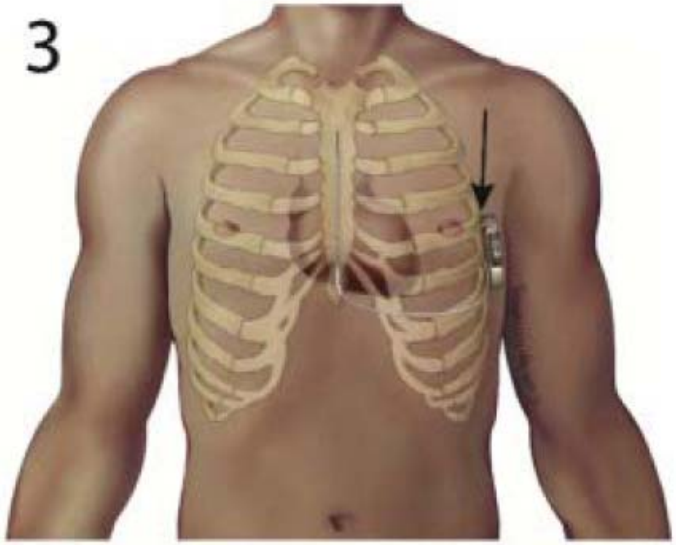


JACC Clin Electrophysiol. 2017;3:405-414.

PRAETORIAN score







Step 1)
Determine the number of coil widths of fat tissue between the **nearest** half of the S-ICD coil and the sternum or ribs.

≤ 1	coil-width	**30**
> 1 ≤ 2	coil-widths	**60**
> 2 ≤ 3	coil-widths	**90**
> 3	coil-widths	**150**

Step 2)
Determine the position of the S-ICD generator in relation to the mid-line (red line).

Generator is on or posterior of the mid-line	**x 1**
Entire generator is anterior of the mid-line	**x 2**
Entire generator is > 1/2 length anterior	**x 4**

Step 3)
Determine the amount of fat tissue between the **nearest** point of the generator and the thoracic wall.

< 1 generator-width	**x 1**
≥ 1 generator-width	**x 1.5**

Step 4)

PRAETORIAN score ≥ 90:

BMI ≤ 25 kg/m²	**- 40**
BMI ≥ 25 kg/m²	**= Final score**

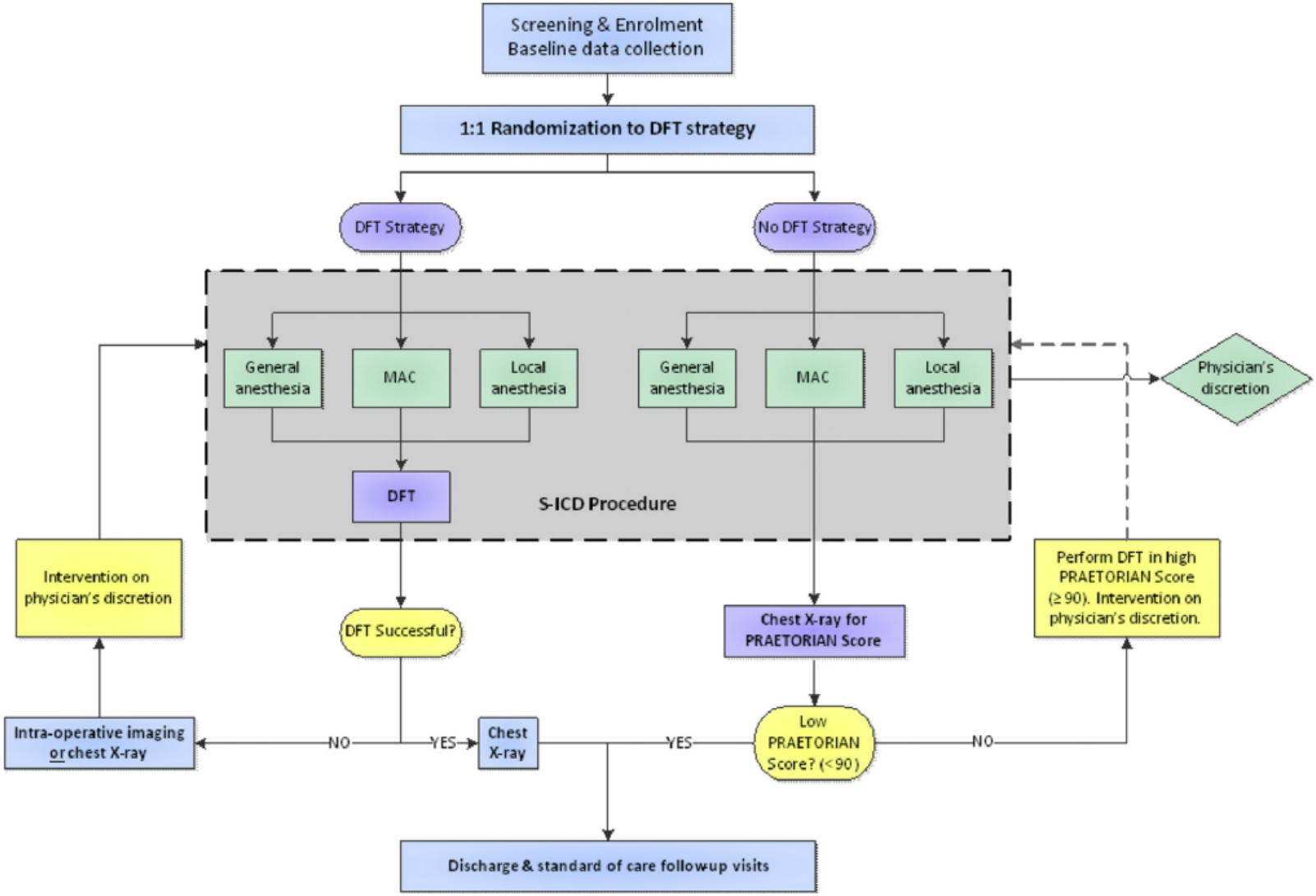
Final PRAETORIAN score

< 90	**Low risk of conversion failure**
90 < 150	**Intermediate risk of conversion failure**
≥ 150	**High risk of conversion failure**

Am Heart J 2019;214:167-74

Ongoing trial

PRAETORIAN-DFT trial (Prospective, randomized)



Am Heart J 2019;214:167-74

Summary

- S-ICD system and implant management have been evolving

- The efficacy and safety of S-ICD has been proven through several studies (randomized, real world, and meta-analysis).

- S-ICD: inadequate vascular access or are at high risk for infection (no need pacing, ATP, CRT).

KNUH 경북대학교병원

Thank you for your attention !!

TV-ICD infection

Trends in Complications Related to Infection Indication for TV Lead Extraction

	With Device Infection								
Complications, %	2006	2007	2008	2009	2010	2011	2012	Overall	*P* Value
Mortality	4.5	3.1	3.8	3.6	4.1	3.2	3.5	3.6	0.1859
Any complications	7.3	6.5	9.1	8.6	11.2	10.5	9.9	9.2	<0.001
Any complications and mortality	10.1	8.9	11.6	10.9	14.0	12.3	12.2	11.5	<0.001

Trends in Complications Related to Non-infection Indication for TV Lead Extraction

	Without Device Infection								
Complications, %	2006	2007	2008	2009	2010	2011	2012	Overall	*P* Value
Mortality	0.8	0.8	1.2	1.3	1.5	1.3	1.4	1.2	<0.001
Any complications	4.0	6.8	7.2	9.6	9.8	8.3	11.2	7.8	<0.001
Any complications and mortality	4.3	7.2	8.0	10.2	10.4	8.9	11.9	8.4	<0.001

- In hospital mortality was 3.6% for those with infection versus 1.2% without infection (p<0.001).

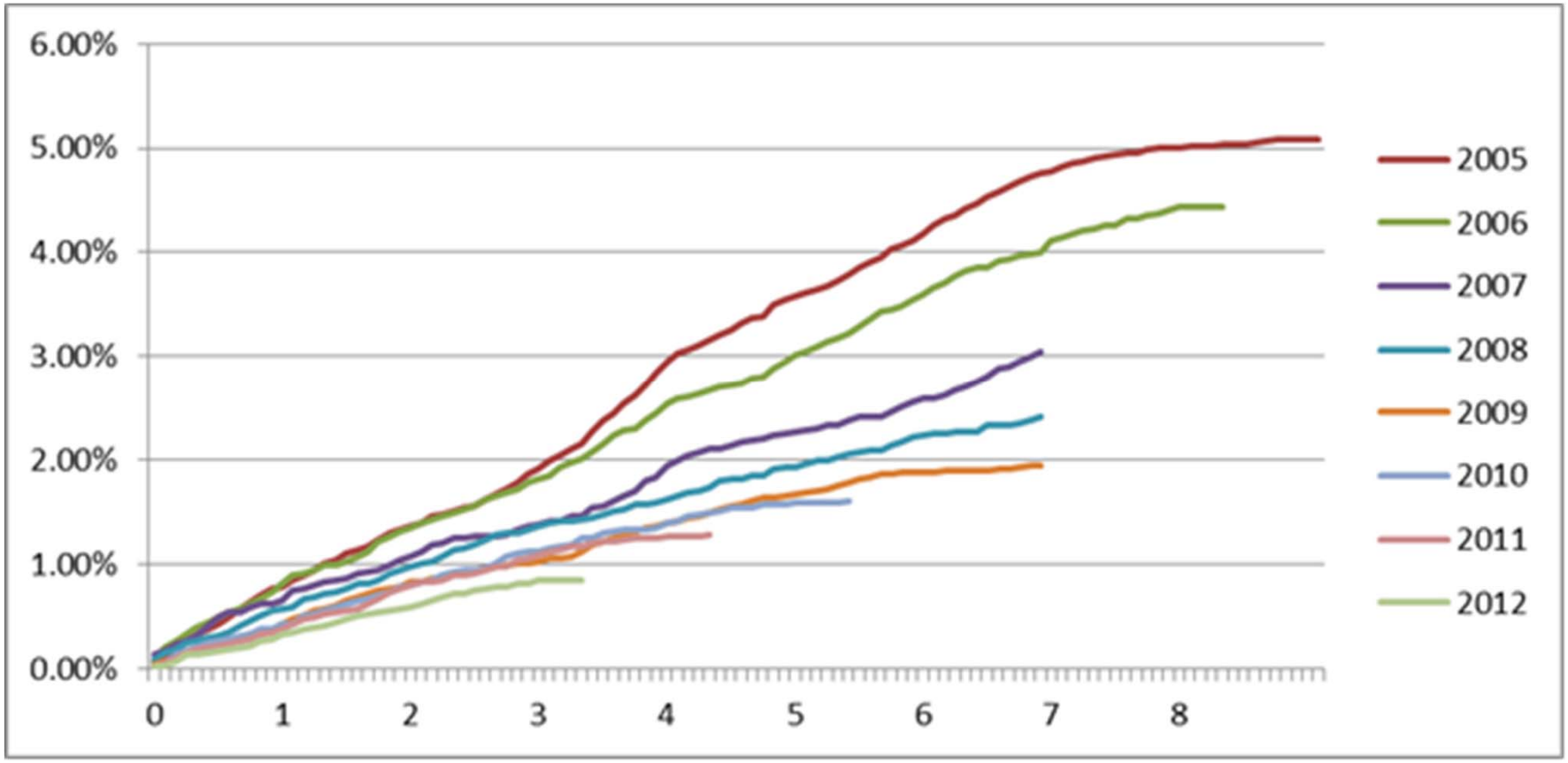
Deschmuck et al. Circulation, 2015;132:2363-71

PRAETORIAN Trial

Demographics

	S-ICD (n = 426)		TV-ICD (n = 423)	
Median age (IQR) – yr	63	(54 – 69)	64	(56 – 70)
Female sex – no. (%)	89	(20.9)	78	(18.4)
Diagnosis – no. (%)				
– Ischemic cardiomyopathy	289	(67.8)	298	(70.4)
– Nonischemic cardiomyopathy	99	(23.2)	98	(23.1)
– Other	38	(9.0)	27	(6.5)
Secondary prevention – no. (%)	80	(18.8)	84	(19.9)
Median ejection fraction (IQR) – %	30	(25 – 35)	30	(25 – 30)
Median BMI (IQR) – kg/m^2	27.0	(24.5 – 30.5)	27.9	(25.2 – 31.7)
NYHA class – no. (%)				
- Class I	144/423	(34.0)	136/421	(31.8)
- Class II	205/423	(48.5)	223/421	(53.0)
- Class III/IV	74/423	(17.5)	64/421	(15.2)

The need for brady pacing in ICD



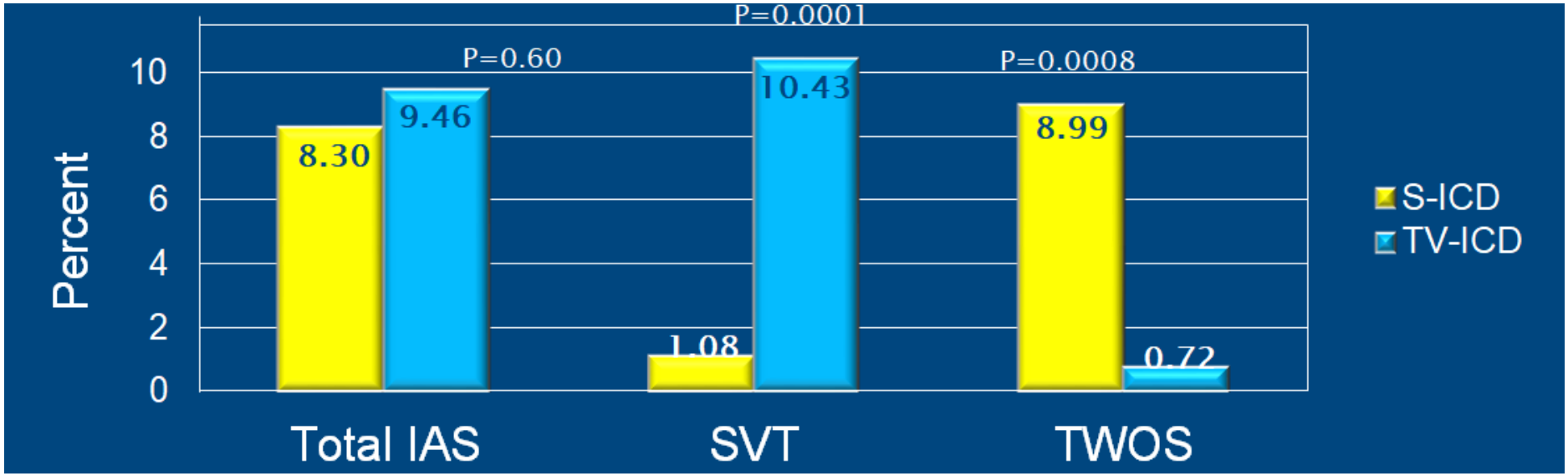
- Only 4-5% of patients implanted with a VR ICD were upgraded to a DR ICD at 8 years following implant

S-ICD in Korea: increasing but still low

- Concern about efficacy and safety
- Need for ATP
- Need for bradycardia
- Defibrillation Threshold (DFT) Test
- Unfamiliar implant technique

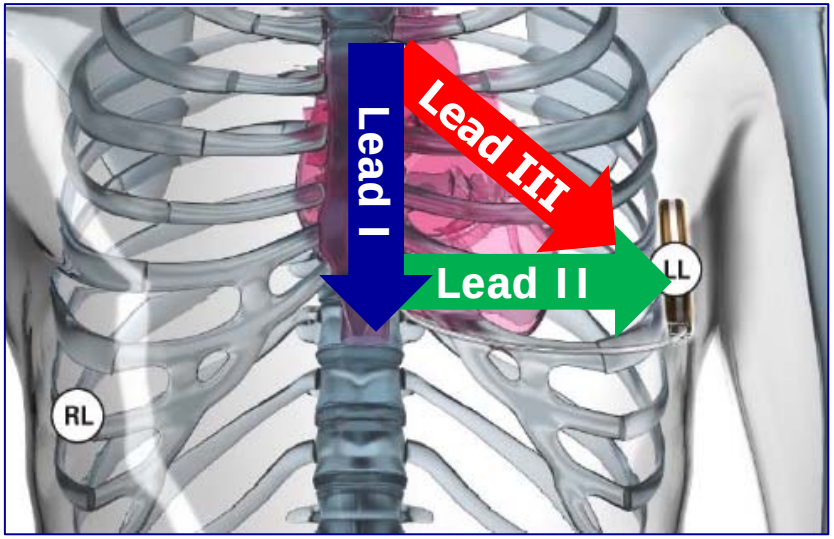
Meta-analysis (SAFETY)

Clinical outcomes: Inappropriate shocks



- Overall rate of inappropriate shocks: S-ICD = TV-ICD.
- **SVT: TV-ICD** > S-ICD.
- **T-wave oversensing (TWOS): S-ICD** > TV-ICD.

Patient screening



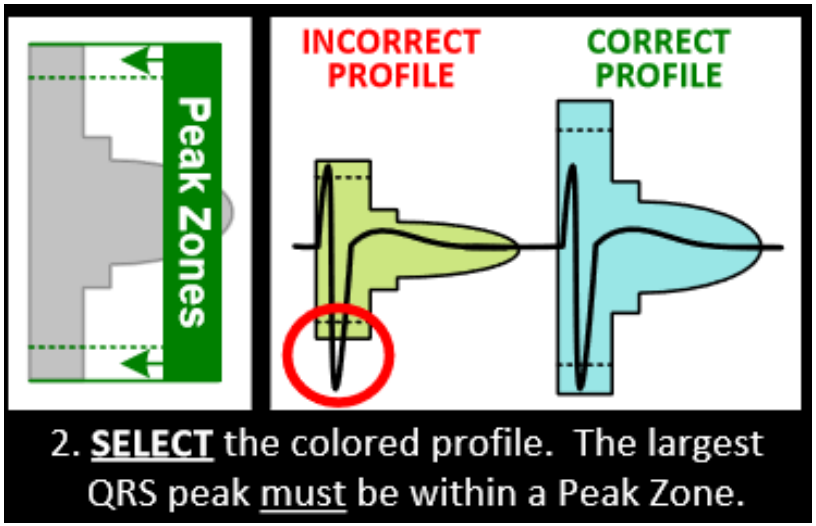
- Extended bipolar (Far-field sensing)
- Outside of heart

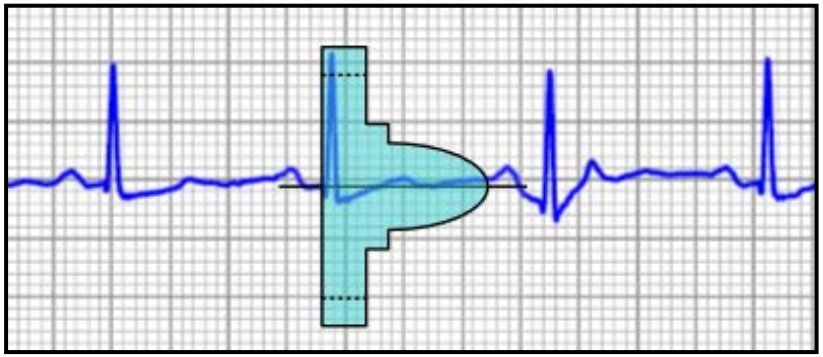
  - small R wave

  - cardiac axis affected by position or physiologic changes

→ ECG screening necessary

- At least one common ECG lead must be deemed acceptable for all tested





Manual screening tool

Automated screening tool

- Incorporation of vector select and digital filtering

  - better reflect S-ICD function

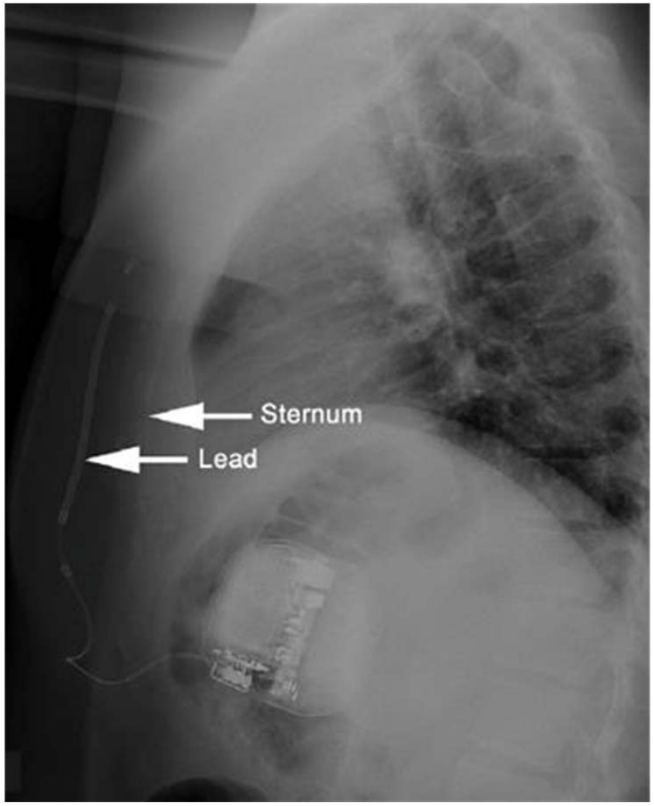
  - more tolerant of large T wave than manual screening tool

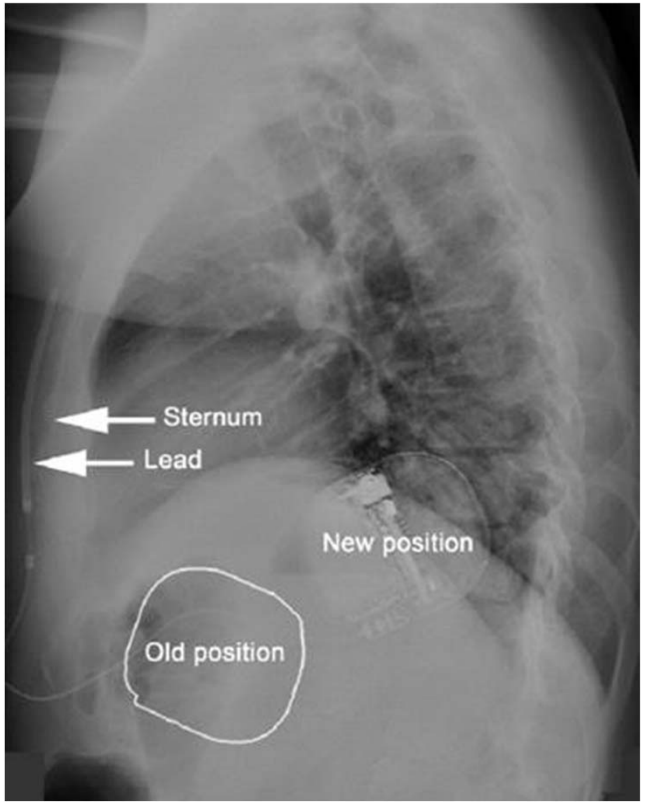
  - provide more consistent outcomes by removing operator subjectivity

EMBLEM Automated Screening Tool is available through the Zoom Programmer (3120)

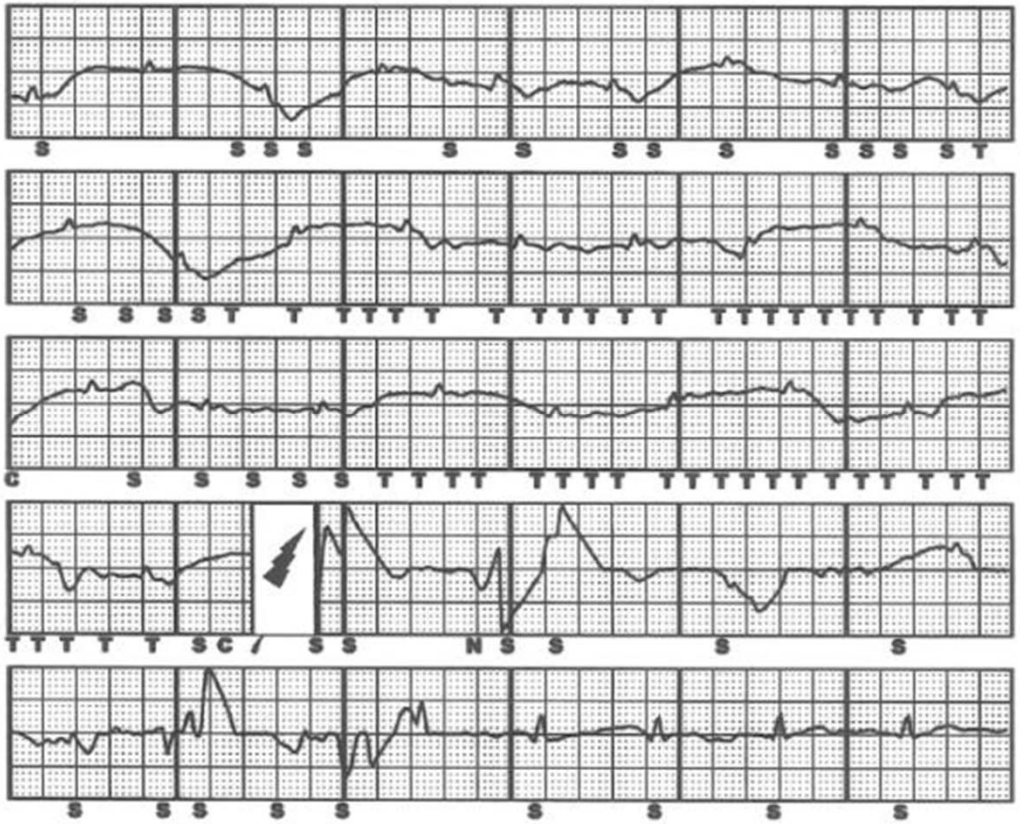
Failed DFT

If DFT fails, check PG and electrode positioning

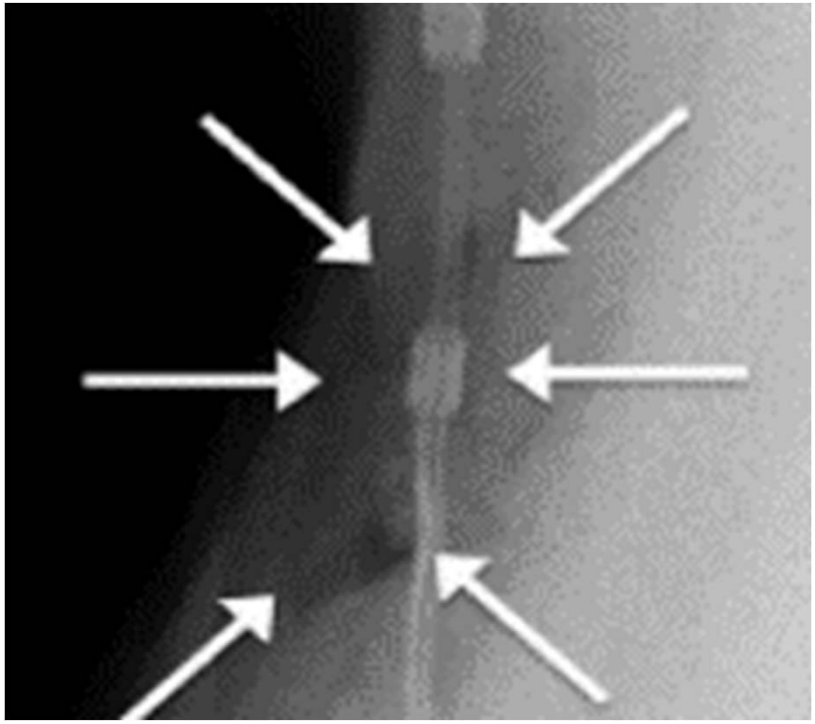




Air entrapment



A wandering baseline→ air entrapment



The x-ray shows trapped air at the proximal electrode

Zipse MM, et al. Circ Arrhythm Electrophysiol. 2014;7:768-770.
Yap SC, et al. Heart Rhythm Case Rep. 2015;1:156–158.