Risk Stratification for Sudden Death in ACHD

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Living with the Risk of Sudden Death

Queenstown, New Zealand
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SUDDEN DEATH IN CONGENITAL HEART DISEASE

- *US and Canada:*
  - 4000 to 5500/year
- *Australia and New Zealand*
  - 300 to 450/year

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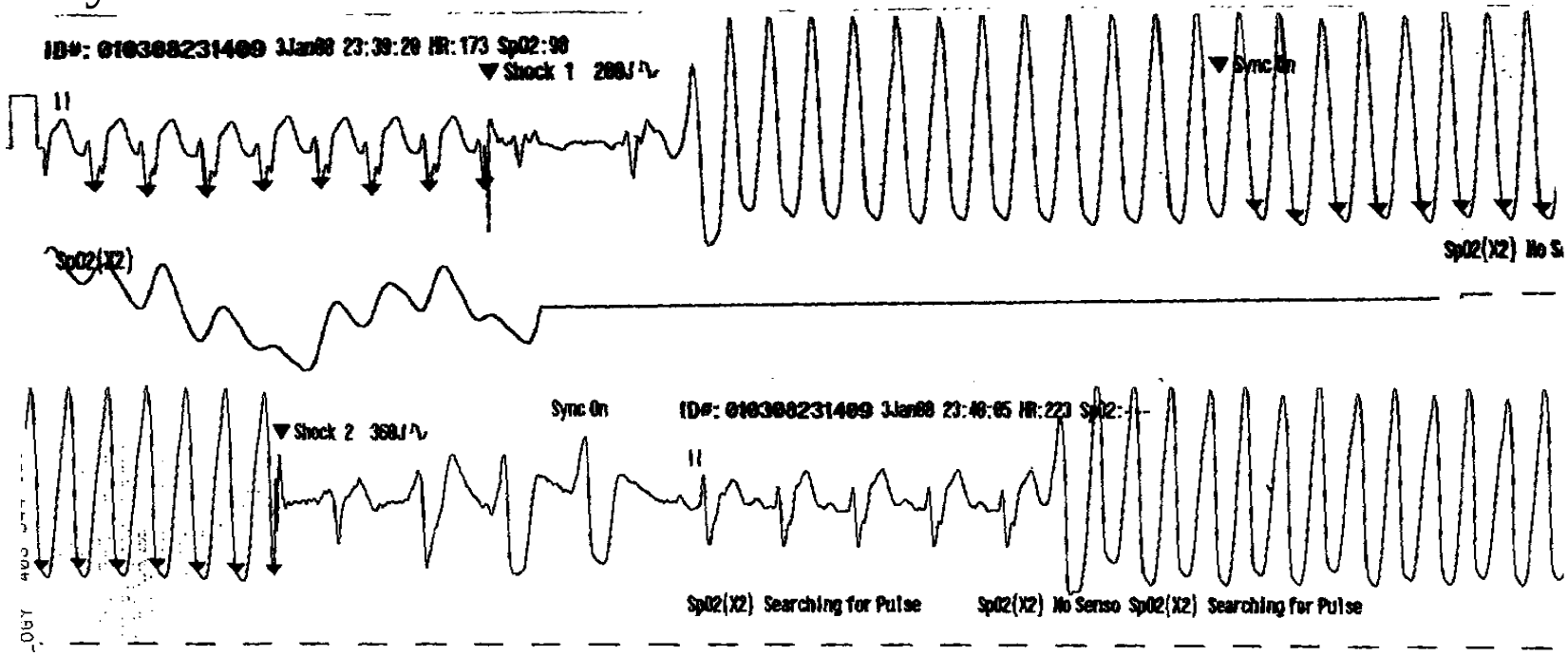
CARDIAC ARREST/UNSTABLE VT/VF

40 year-old man with TOF



ICD INDICATIONS: SECONDARY PREVENTION

COR	LOE	Recommendation
I	B	ICD therapy is indicated in adults with CHD who are survivors of **cardiac arrest** due to VF or hemodynamically unstable VT after evaluation to define the cause of the event and exclude any completely reversible etiology
I	B C	ICD therapy is indicated in adults with CHD and **spontaneous sustained VT** who have undergone hemodynamic and EP evaluation. Catheter ablation or surgery may offer a reasonable alternative or adjunct to ICD therapy in carefully selected patients.

PACES/HRS. *Heart Rhythm* 2014;11:e102-65

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Ben Nevis Inn
WEATHER FORECASTING STONE
CONDITION
FORECAST
Stone is Wet
Rain
Stone is Dry
Not Raining
Shadow on Ground
Sunny
White on Top
Snowing
Can't see Stone
Foggy
Swinging Stone
Windy
Stone Jumping Up & Down
Earthquake
Stone Gone
Tornado

OVERVIEW

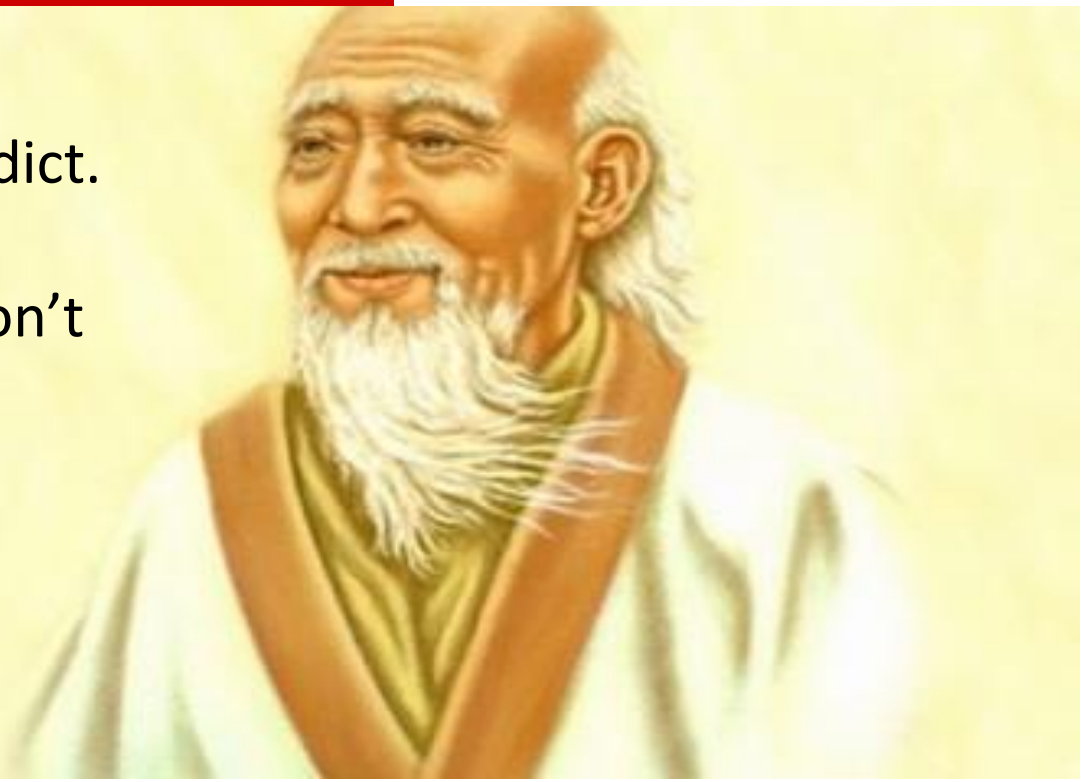
1. What are we trying to achieve?
2. Are we on the right track?
3. How can we do better?

WHAT ARE WE TRYING TO ACHIEVE?

LAO TSU (6th century BC)

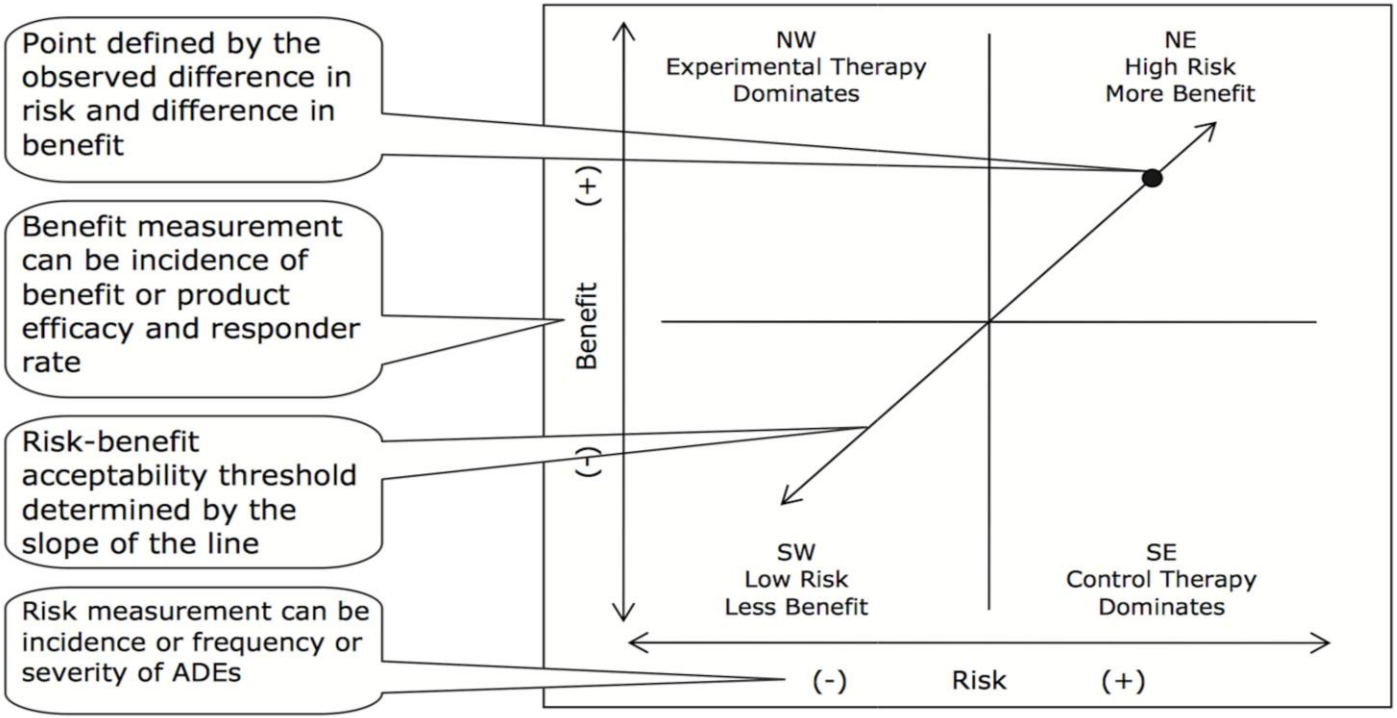
"Those who have knowledge don't predict.

Those who predict don't have knowledge"




ICD

RISK-BENEFIT ASSESSMENT



Shaffer et al. BMC Med Res Methodology 2006;6:48

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KEY FACTORS IN ASSESSING RISKS AND BENEFITS

BENEFIT
Probability of sudden death due to a malignant ventricular arrhythmia
Competing risks for mortality
Effectiveness of therapy in preventing sudden death

RISK
Morbidity and mortality associated with ICD therapy
Cost considerations

Khairy P. *Heart* 2016;102(71):7103-9

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COST PER QALY

Treatment	€/QALY	USD/QALY
Enalapril for heart failure	83	113
Intensive insulin therapy for a 25-years-old	6907	9394
Liver transplantation	18,678*	25,402
Heart transplantation	20,115*	27,356
Primary prevention ICD in MUSTT	28,500	38,760
Primary prevention ICD in MADIT I	29,254	39,785
Primary prevention ICD in COMPANION	42,163	57,342
Primary prevention ICD in DEFINITE	43,001	58,481
Primary prevention ICD in MADIT II	45,348	61,673
Lung transplantation	55,317*	75,231
Primary prevention ICD in SCD-HeFT	58,842	80,025
ACEI for hypertension in echo-LVH	143,680	195,404
Screening at 50 years for proteinuria, then ACEI	203,177	276,321
ACEI for hypertension in unselected patients	502,880	683,917
Statin for primary prevention	38,793—1,005,760	52,758 – 1,367,834
Intensive insulin therapy for an 85-years-old	1,508,640	2,051,750

Thijssen J et al. *PACE* 2014;37:24-34
Leyva F et al. *Europace* 2011;13:ii25-31

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"WHO RULE": COST-PER-QALY THRESHOLD OF 3X PER-CAPITA GDP

COUNTRY	2016 GDP PER CAPITA	$THRESHOLD/QALY
United States	$57,467	$172,401
Australia	$46,790	$140,370
Canada	$44,025	$132,075
New Zealand	$39,059	$117,177
Russia	$23,163	$69,489
China	$15,535	$46,605
Egypt	$11,132	$33,396
India	$6,572	$19,716
Haiti	$1,784	$5,352

Baltussen RM et al. Global Programme on Evidence for Health Policy. Geneva, Switzerland: World Health Organization; 2002

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ARE WE ON THE RIGHT TRACK?

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ICD RECIPIENTS WITH CHD

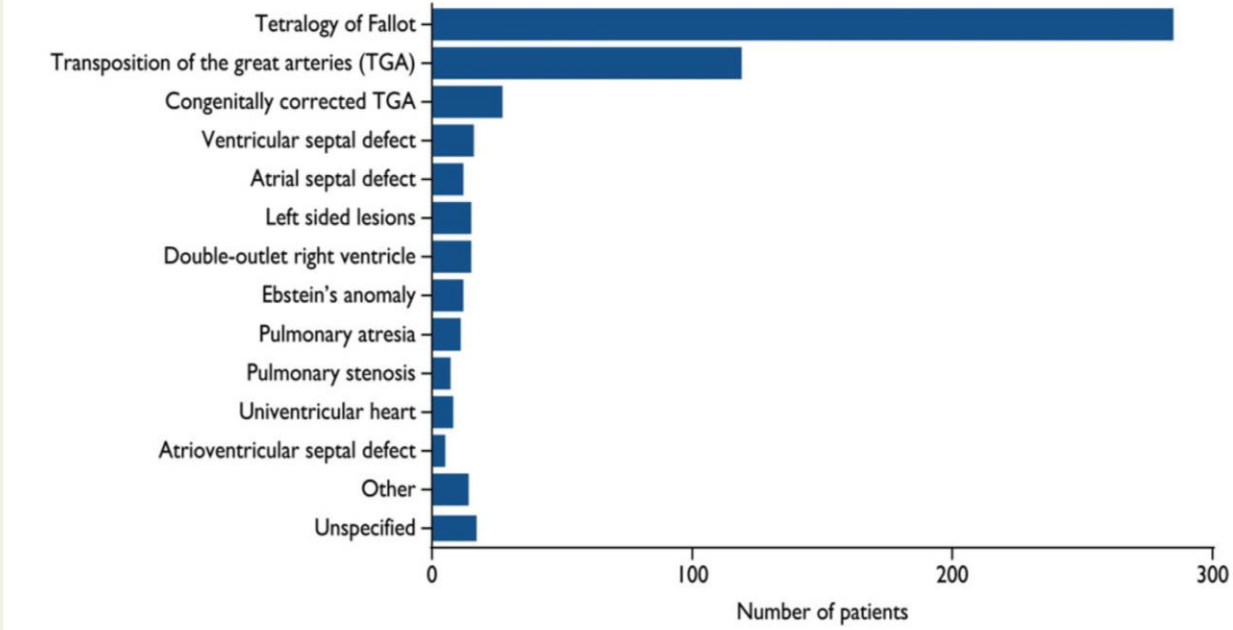

Figure 2 Distribution of congenital heart diseases across 20 studies ($n = 563$).

Vehmeijer JT et al. *Eur Heart J* 2016;37:1439-48

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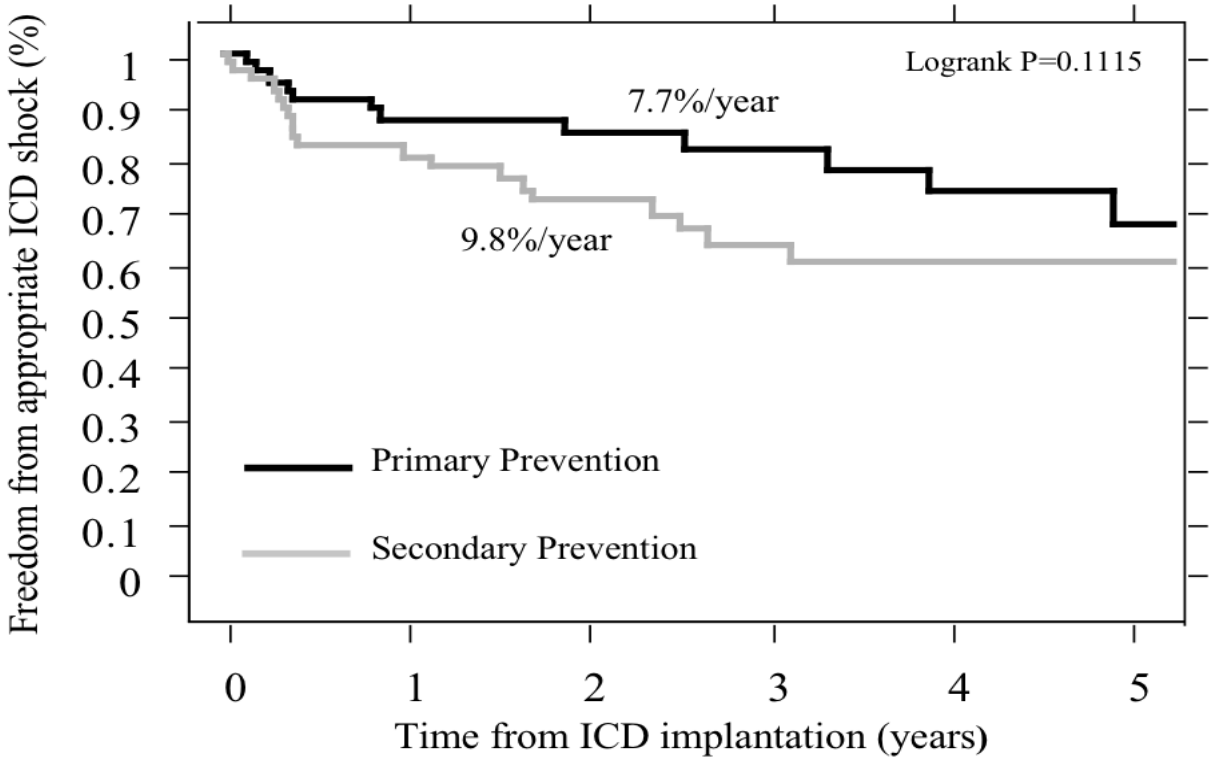
TOF: APPROPRIATE ICD SHOCKS



Khairy P et al. *Circulation* 2008;117:363-370

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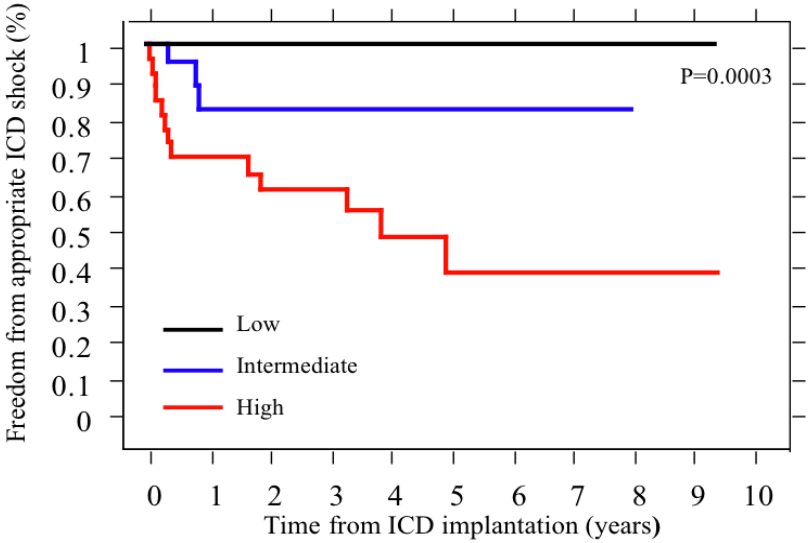
TOF: RISK SCORE FOR PRIMARY PREVENTION

Variable	Points
Prior palliative shunt	2
Inducible sustained VT	2
QRS ≥180 ms	1
Ventriculotomy incision	2
Non-sustained VT	2
LVEDP ≥12 mmHg	3
TOTAL POINTS	**0-12**



Risk score	Risk category	N	Annualized rate of appropriate shocks
0-2	Low	18	0%
3-5	Intermediate	24	3.8%
6-12	High	26	17.5%

Khairy P et al. *Circulation* 2008;117:363-370

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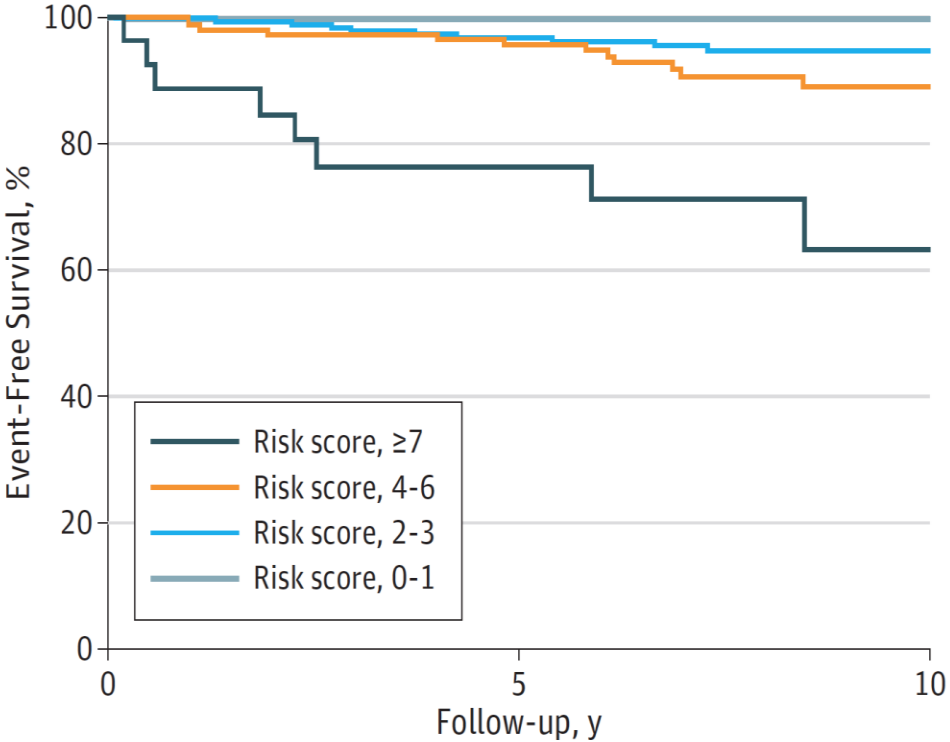
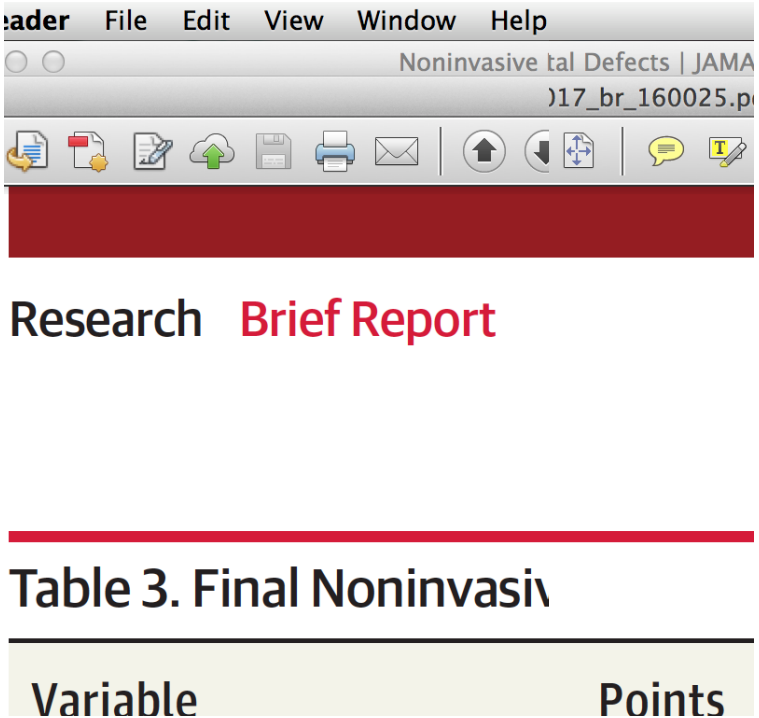
TOF: NONINVASIVE RISK SCORE





Bokma JP et al. *JAMA Cardiol* 2017;117:678-83

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REFINING RISK STRATIFICATION IN TOF

- Strain measures of the right ventricle
- QRS fragmentation
- QRS vector magnitude
- Neurohormonal activation
- RV electroanatomic voltage mapping
- Slow conduction across anatomical isthmuses
- Genetic polymorphisms

ICD INDICATION: TOF

COR	LOE	Recommendation
IIa	B	ICD therapy is reasonable in selected adults with **tetralogy of Fallot** and multiple risk factors for sudden cardiac death such as LV systolic or diastolic dysfunction, non-sustained VT, QRS duration ≥180 ms, extensive RV scarring, or inducible sustained VT at EP study

PACES/HRS. *Heart Rhythm* 2014;11:e102-65

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D-TGA/ATRIAL SWITCH

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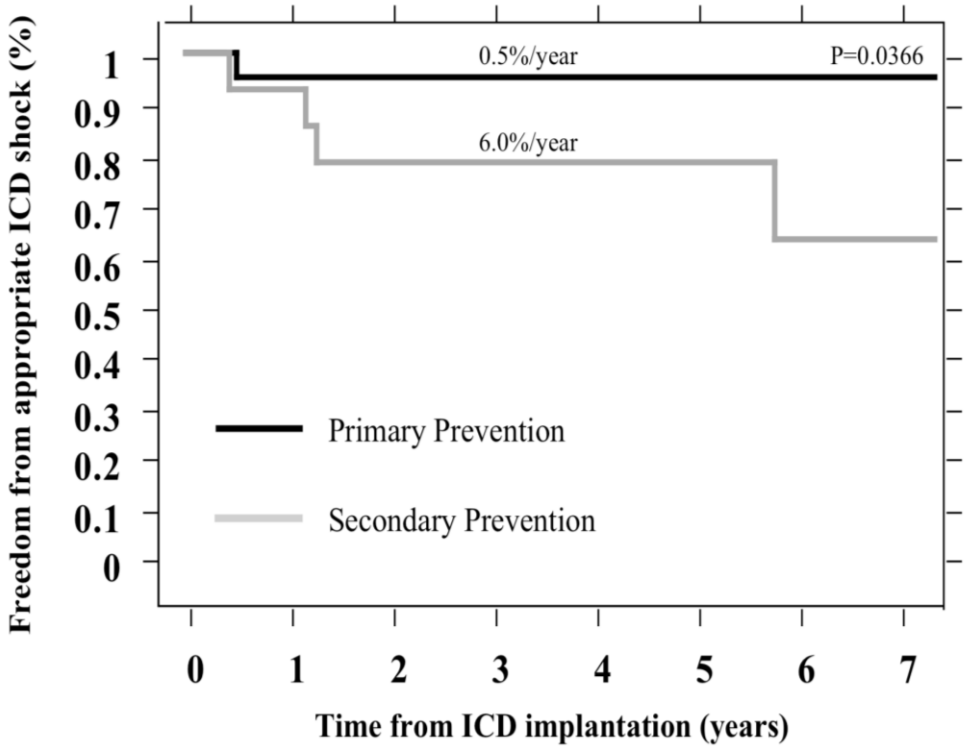
SCD IN D-TGA/ATRIAL SWITCH



- Syncope: 35%
- NSVT: 48%
- RVEF<35%: 35%
- QRS ≥180 ms: 30%
- Inducible VT: 30%

Khairy P et al. *Circulation EP* 2008;1:250-257

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GERMAN COHORT WITH PRIMARY AND SECONDARY PREVENTION ICDs

- N=33

Patient No.	Age at ICD Implantation (Years)	Follow-Up with ICD (Years)	Appropriate ICD Therapies	ICD Implantation due to	NYHA @ Implantation	Duration of QRS @ Implantation (ms)
#1	30.8	11.6	5 × ATP @ fast VT	VT on Holter	II	160
#2	26.0	3.5	1 × ATP @ slow VT	Impaired RV function	II	100
#3	26.9	4.1	1 × shock @ fast VT	VT on Holter	II	120

- Appropriate shock rate overall: 1.9%/year
- No patient with inducible VT/VF (N=11) had an appropriate shock

Backhoff D et al. *PACE* 2016;39:1070-6

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IMPROVING RISK STRATIFICATION FOR TGA/SYSTEMIC RV

RISK STRATIFICATION IN D-TGA/ATRIAL BAFFLE

Year	Author	Complex TGA	AV block	NYHA >2	RV dysfunct	Severe TR	QRS ≥140	QTc/ JTc	Atrial tachy	No beta-blocker
1994	Janousek				M	M			M	
1997	Gelatt		M						M	
1998	Wilson									
1998	Bernie								U	
2004	Sun				U			U	U	
2004	Kammeraad			U					U	
2005	Dos			M		U			M	
2007	Michael									
2008	Khairy								U	M
2009	Schwerzmann	U		U	U	U	U			
2014	Wheeler			U		U			U	

U= Univariable analysis
M= Multivariable analysis

EXERCISE AND SCD IN D-TGA

- 5 of 7 SCD events occurred during exercise

  Silka MJ et al. *JACC* 1998;32:245-51

- 18 of 22 (82%) of SCD events occurred during exercise

  Sun ZH et al. *Am J Cardiol* 2004;94:138-41

- 47 SCD events: 81% occurred during exercise
  - AF degenerating into VF on exercise test

  Kammeraad et al. *JACC* 2004;5:1095-102

Sudden cardiac death in transposition of the great arteries with a Mustard or Senning baffle: the myocardial ischemia hypothesis

Paul Khairy

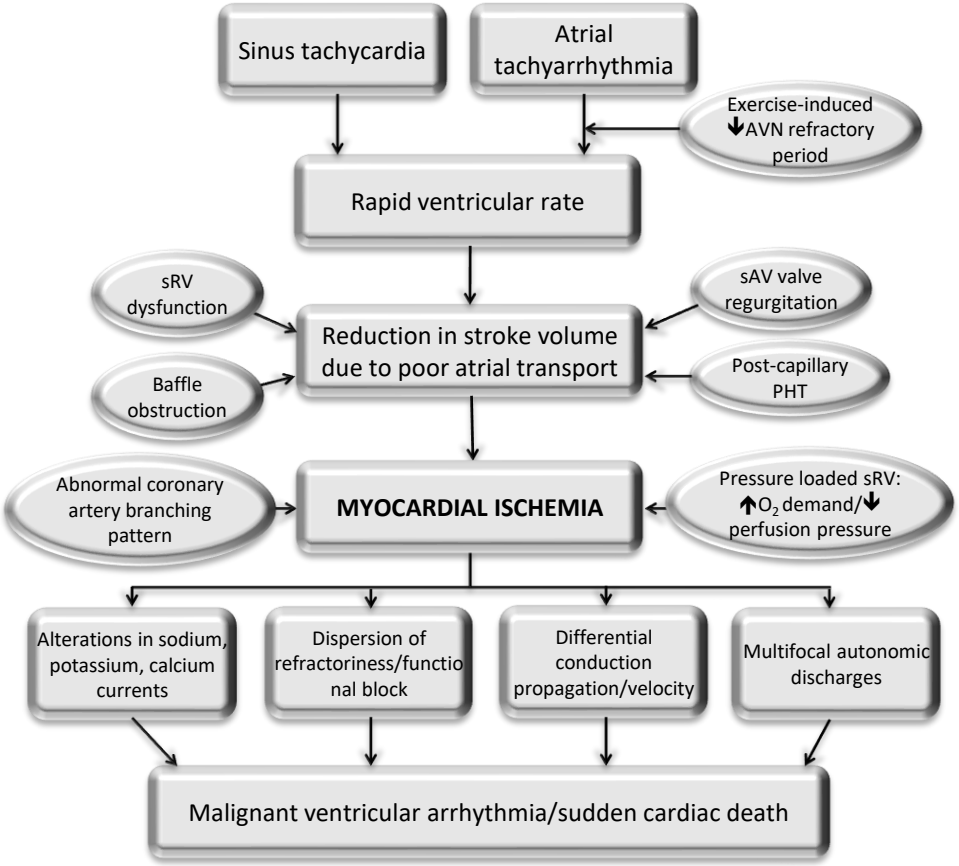
Curr Opin Cardiol. 2017;32:101-7

Purpose of review
The literature on sudden death in transposition of the great arteries (D-TGA) with atrial switch surgery is reviewed and a pathophysiological mechanism is proposed.

Recent findings
Over 80% of sudden deaths in patients with D-TGA and Mustard or Senning baffles occur during exercise. Factors most consistently associated with ventricular arrhythmias and sudden death include heart failure parameters and atrial arrhythmias. Atrial arrhythmias have been observed to trigger malignant ventricular arrhythmias. Exercise may promote 1 : 1 conduction, with inordinately high ventricular rates. Reconstructed intra-atrial pathways are associated with an impaired stroke volume response to increased heart rates. A high prevalence of perfusion defects has been reported despite the absence of coronary atherosclerosis, particularly involving the inferior wall of the systemic right ventricle. Beta-blockers have been independently associated with a lower rate of ventricular arrhythmias in patients with implantable cardioverter-defibrillators.

Summary
It is hypothesized that ischemia-related ventricular arrhythmias are a common mechanism for sudden death in patients with D-TGA and atrial baffles. Ischemia may be provoked by rapid heart rates from sinus or atrial arrhythmias. Myocardial oxygen supply/demand mismatch may be exacerbated by the impaired stroke volume response, hypertrophic remodeling of the pressure-loaded systemic right ventricle, and inefficient coronary circulation.

Keywords
Mustard baffle, myocardial ischemia, Senning baffle, sudden cardiac death, transposition of the great arteries



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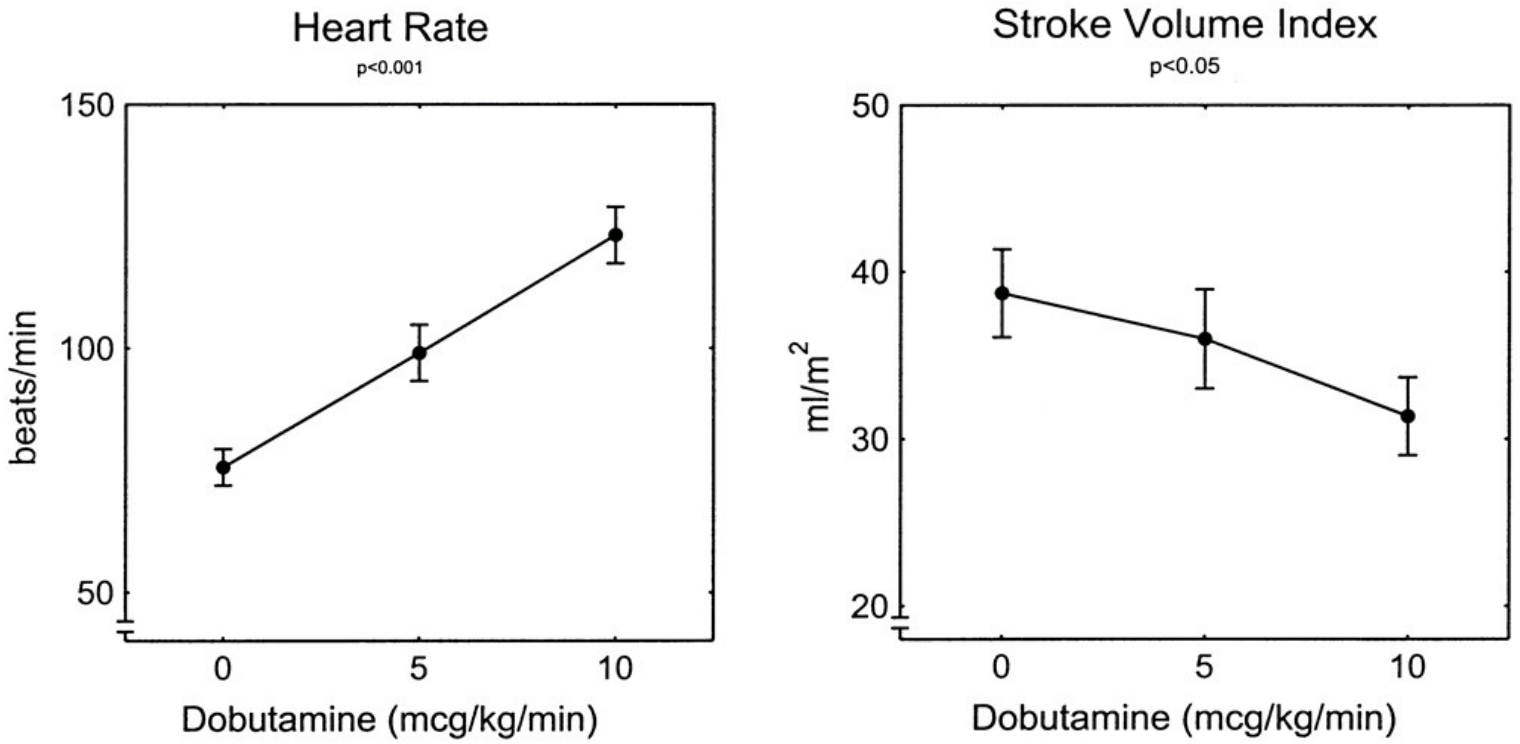
HEART RATE AND STROKE VOLUME



Bender HW Jr et al. *Ann Thorac Surg* 1989:47:281-23
Derrick GP et al. *Circulation* 2000;102:154-9

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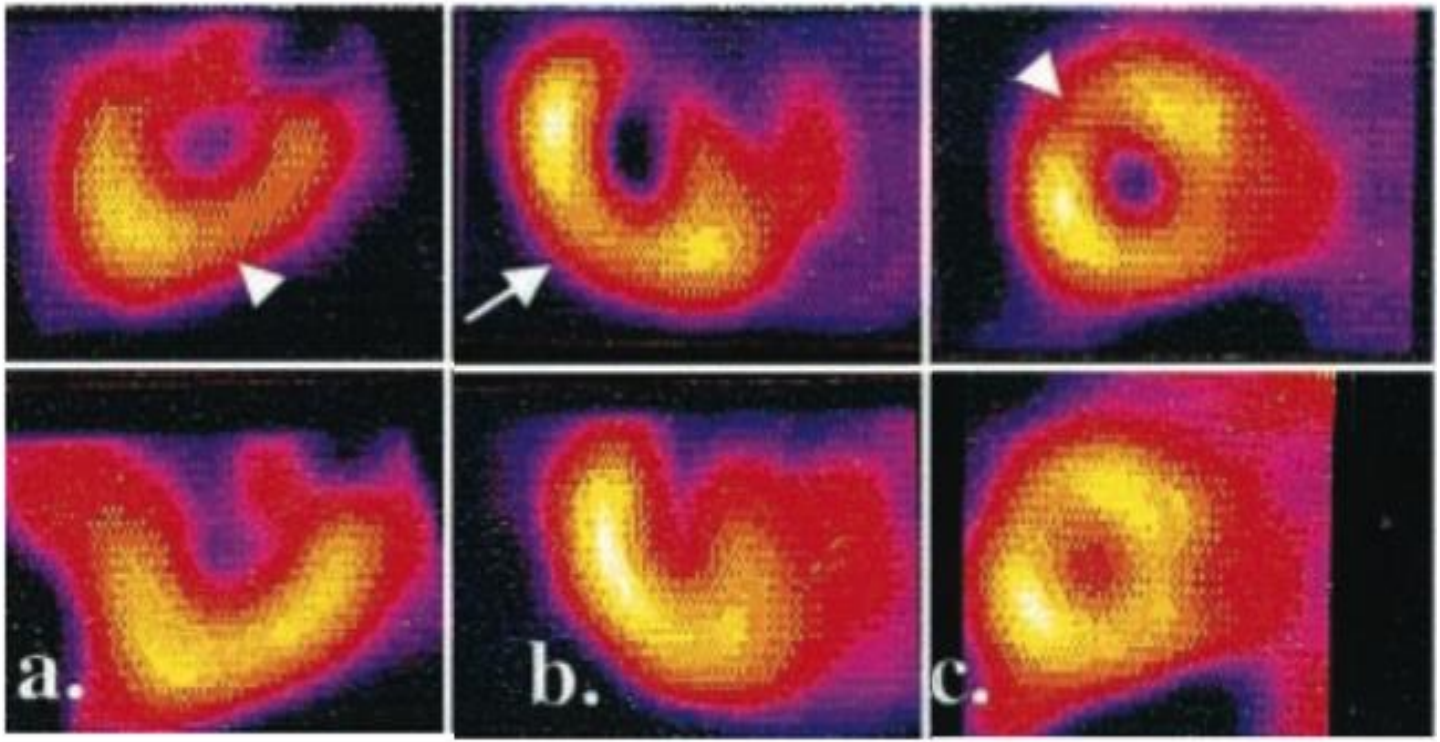
D-TGA AND PERFUSION DEFECTS



Lubiszewska B et al. *JACC* 2000;36:1365-70

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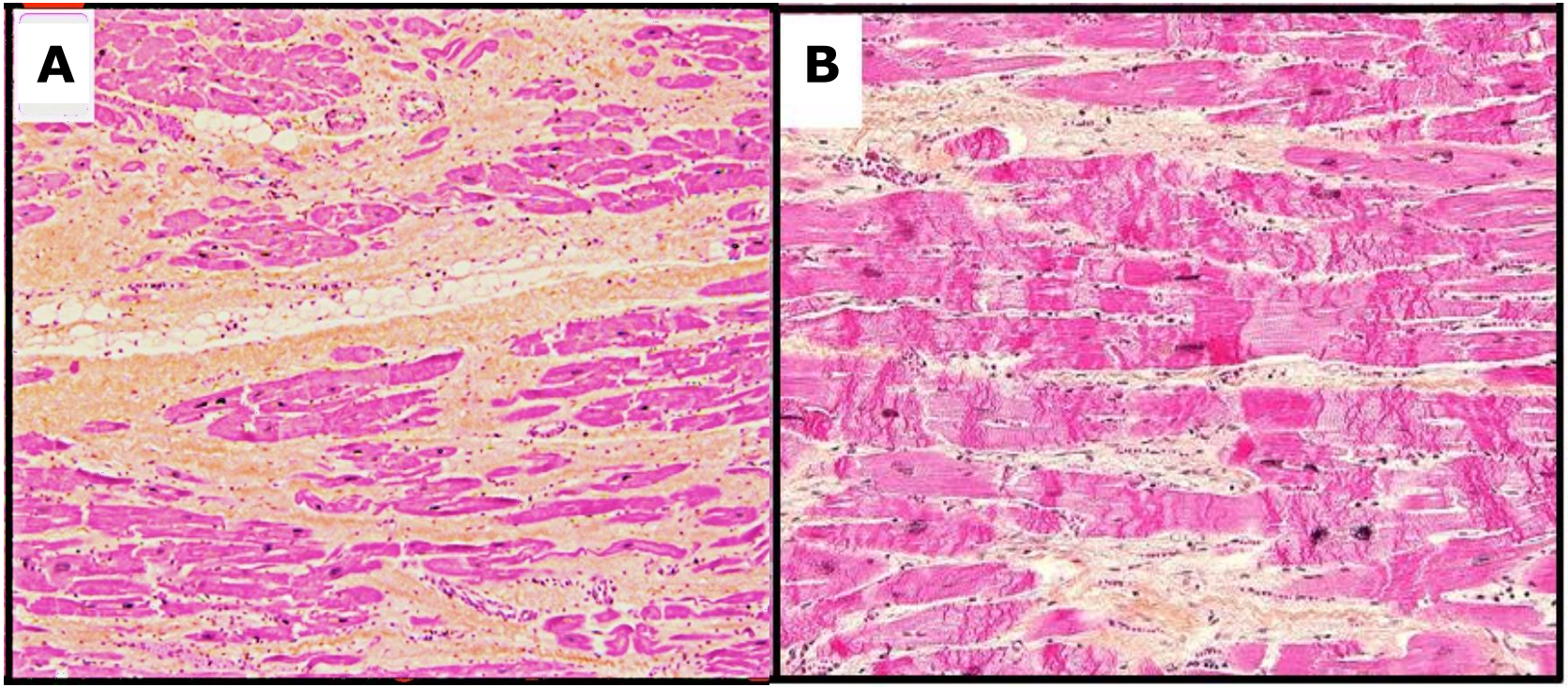
AUTOPSIES: SCD IN TGA/ATRIAL SWITCH



Unpublished, Montreal Heart Institute

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RISK MARKERS AND RISK REDUCTION

Category	Potential risk marker	Risk reduction
Sinus tachycardia	• Exercise-induced syncope	• Avoid high-intensity dynamic sports • Pacemaker: limit high upper sensor rate
Atrial tachycardia	• Inducible atrial tachycardia • Increased P-wave duration, dispersion	• Catheter ablation • Pacemaker: limit high upper tracking rate; program mode-switch • Beta-blockers
AV node	• Short AV node refractory period	• Beta-blockers
Abnormal SV response	• Decreased SV or O_2 pulse response • Blunted/hypotensive BP response	• Address hemodynamic issues: obstruction to PV/SV return, increased PCWP
Perfusion defects	• Exercise-induced ECG changes • Stress-induced reversible perfusion defects, SWMA	• Beta-blockers

Khairy P. *Curr Opin Cardiol*. 2017;32:101-7

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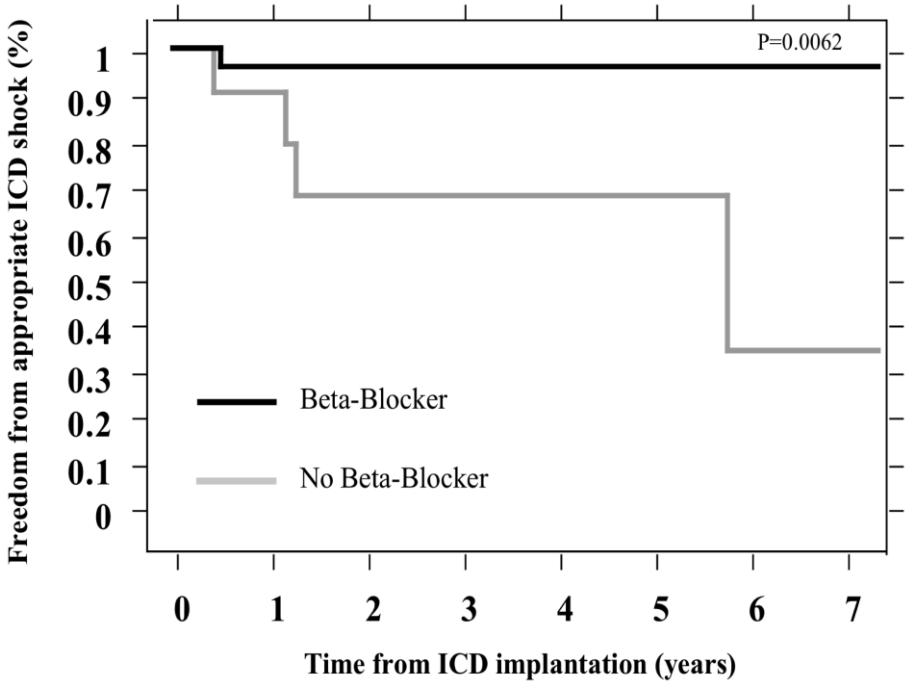
β-BLOCKERS



COR	LOE	Recommendation
IIb	B	It may be reasonable to liberalize the use of **beta-blockers** in patients with TGA and atrial switch surgery to protect against ventricular arrhythmias and SCD

Khairy P et al. *Circulation EP* 2008;1:250-7
PACES/HRS. *Heart Rhythm* 2014;11:e102-65

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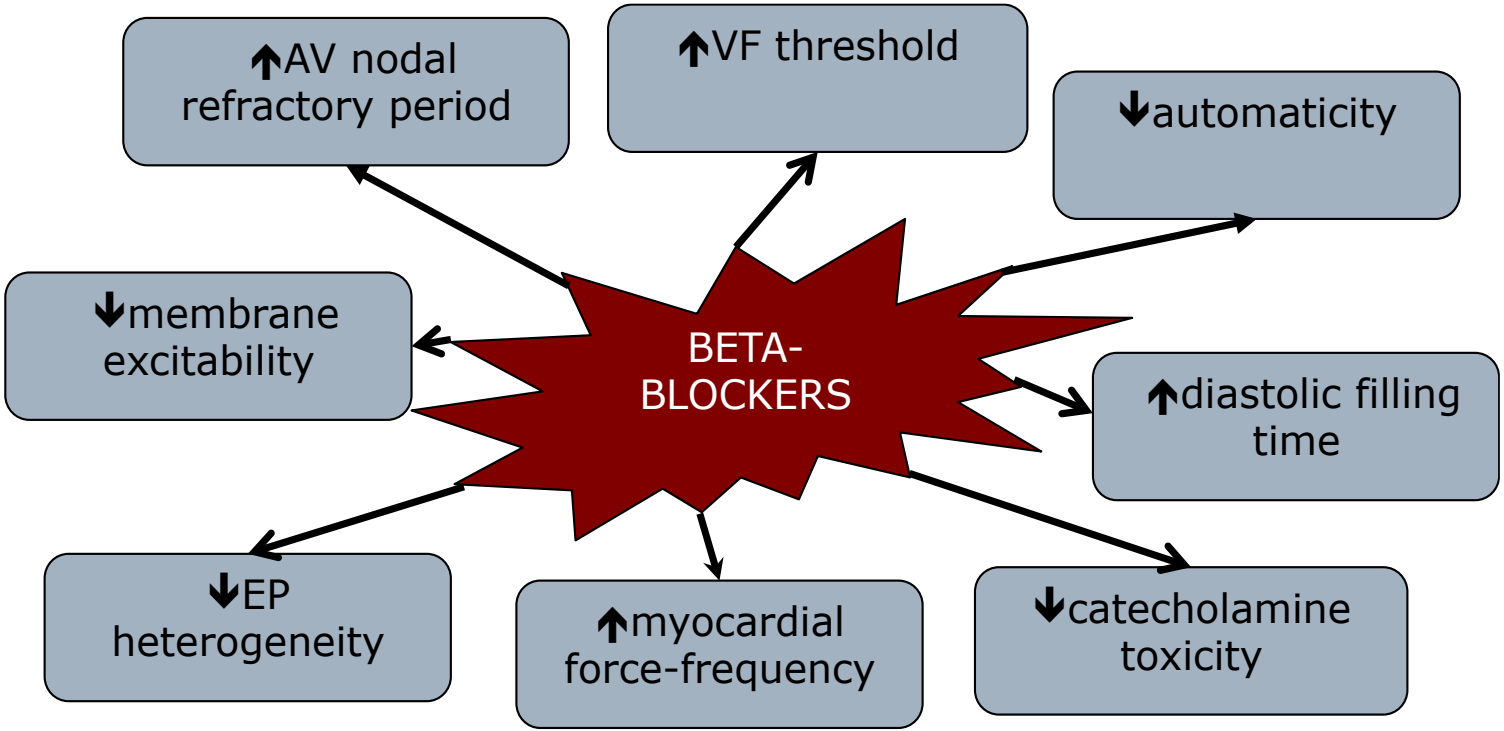
β-BLOCKERS IN D-TGA/ATRIAL BAFFLE



CONCLUSION

- Risk stratification for SCD is no simple task!
  - Risks and benefits must be weighed, including competing risks, in establishing the ideal threshold for ICD implantation, which is also dependent on economic considerations

- On the whole, we appear to be on the "right track" in risk stratifying TOF but should intensify and broaden our approach in TGA/atrial switch

- Future progress will require:
  - TOF: refining risk stratification schemes, prospective validation, demonstration of clinical improvement
  - TGA: incorporating additional markers (e.g., myocardial ischemia)

THANK YOU!

International Society for
Adult Congenital Heart Disease

www.isachd.org

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