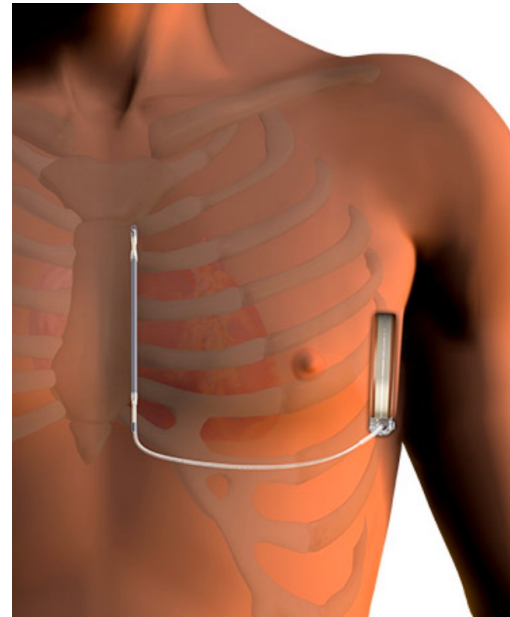


# DÉFIBRILLATEURS DANS LA POPULATION PÉDIATRIQUE



**Victor WALDMANN**

*Hôpital Européen Georges Pompidou — Hôpital Necker*



# DAI — POPULATION PÉDIATRIQUE



**Population & Indications**



**Techniques**



**Outcomes**



**Perspectives**



# DAI — POPULATION PÉDIATRIQUE



**Population & Indications**



Techniques



Outcomes



Perspectives

## DAI — INDICATIONS

### Prévention secondaire

- = après arrêt cardiaque récupéré sans cause réversible
- A discuter dans LQTS et CPVT

Recommendations	Class <sup>a</sup>	Level <sup>b</sup>
ICD implantation is recommended for paediatric patients who are survivors of cardiac arrest in the absence of reversible causes.	I	B

## Prévention primaire

### Cardiomyopathies

#### CMD

- FEVG ++ (IRM - fibrose ?)

#### CMH

ICD implantation should be considered in children with two or more major paediatric risk factors<sup>d</sup> after appropriate counselling and when an assessment of the lifelong risk of complications and the impact of an ICD on lifestyle and psychological health suggests a net benefit from ICD therapy.

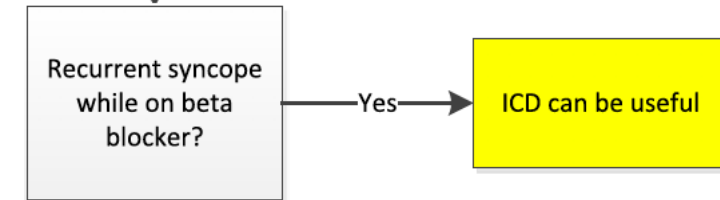
Ila

C

<sup>d</sup>Major paediatric risk factors: Maximum left ventricular wall thickness  $\geq 30$  mm or a Z-score  $\geq 6$ , unexplained syncope, non-sustained ventricular tachycardia ( $\geq 3$  consecutive ventricular beats at  $\geq 120$  BPM lasting  $< 30$  seconds), family history of SCD (one or more first-degree relatives with SCD aged  $< 40$  years with or without the diagnosis of HCM, or SCD in a first-degree relative at any age with an established diagnosis of HCM).

### Canalopathies

#### LQTS



#### Brugada



#### CPVT

3. ICD implantation **is recommended** in patients with a diagnosis of CPVT who experience cardiac arrest, recurrent syncope or polymorphic/bidirectional VT despite optimal medical management, and/or LCSD.

## Prévention primaire

### *Cardiopathies congénitales*

ICD is recommended in adults with CHD and a systemic LVEF  $\leq 35\%$ , biventricular physiology and NYHA functional Class II or III.

ICD implantation should be considered in patients with CHD and syncope of unknown origin in the presence of either advanced ventricular dysfunction or inducible sustained VT or VF on VPS.

ICD implantation should be considered in selected patients with TOF and multiple risk factors for SCD, including LV dysfunction, non-sustained VT, QRS duration  $\geq 180$  ms, or inducible sustained VT on VPS.

ICD therapy may be considered in patients with advanced single or systemic RV dysfunction in the presence of risk factors such as non-sustained VT, NYHA functional Class II or III, QRS duration  $\geq 140$  ms or severe systemic AV valve regurgitation.

ICD therapy may be considered for non-hospitalized adults with CHD awaiting heart transplantation.



# POPULATION & INDICATIONS

**TABLE 2. Clinical Characteristics**

	Patients	
	<i>n</i>	%
<b>Indication for ICD</b>		
SCD survivor	95	76
Drug refractory VT	13	10
Syncope, +EP test	12	10
Familial SCD	5	4
<b>Cardiovascular disease</b>		
Cardiomyopathy		58
Hypertrophic	44	
Dilated	22	
Restrictive	2	
Ischemic	2	
Primary electrical		26
Idiopathic VF	19	
Long QT	14	
Congenital heart		18
D-TGA	9	
Tetralogy of Fallot	5	
Aortic stenosis	5	
L-TGA	1	
Anomalous PV return	1	
VSD-PHT	1	
<b>Ventricular function</b>		
Normal		54
Hyperdynamic		6
Decreased		40

- **125 patients, rétrospectif**
- **85% prévention II<sup>aire</sup>**
- **15,2 ans (22 mois – 20 ans)**
- **48 kg (9 – 115 kg)**

# POPULATION & INDICATIONS

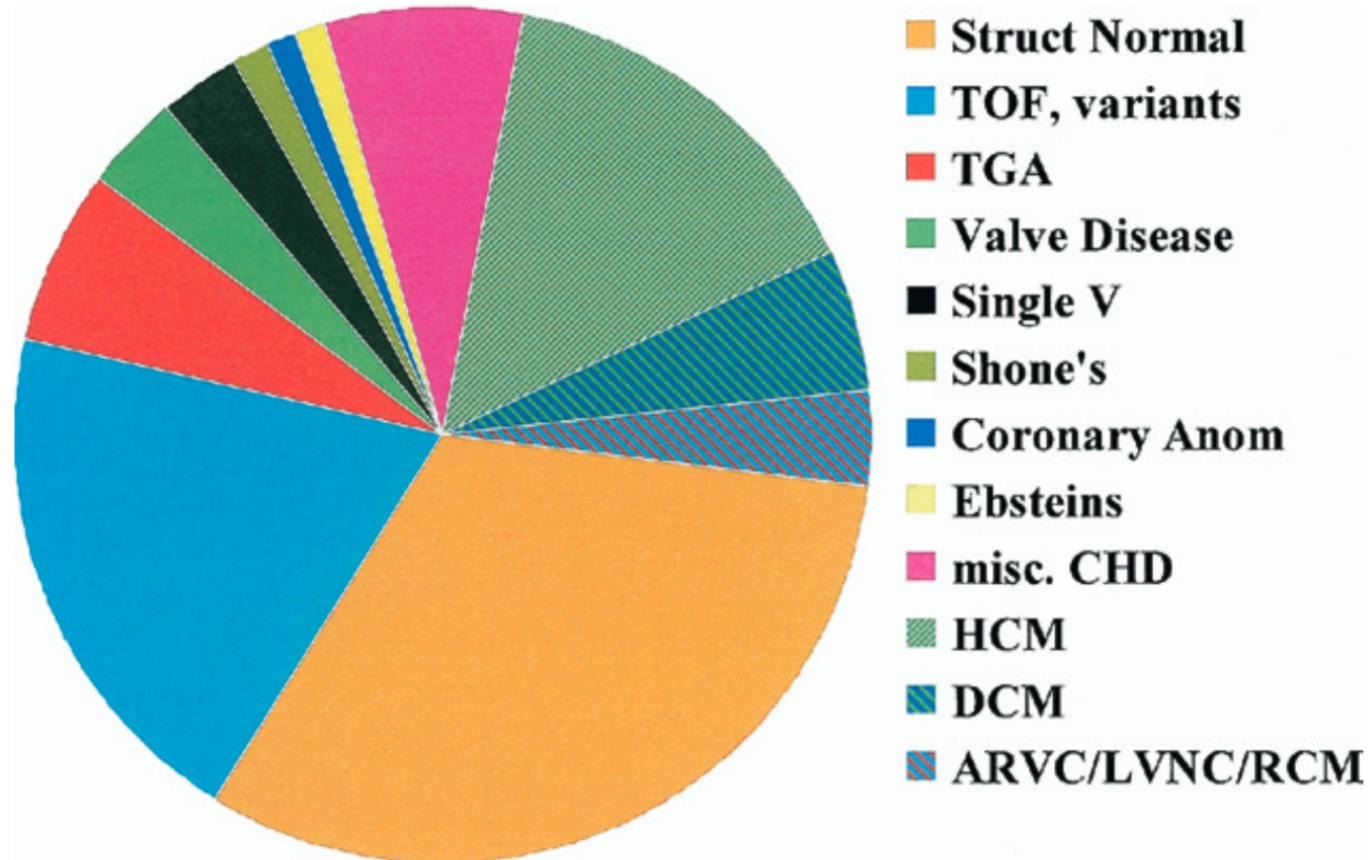
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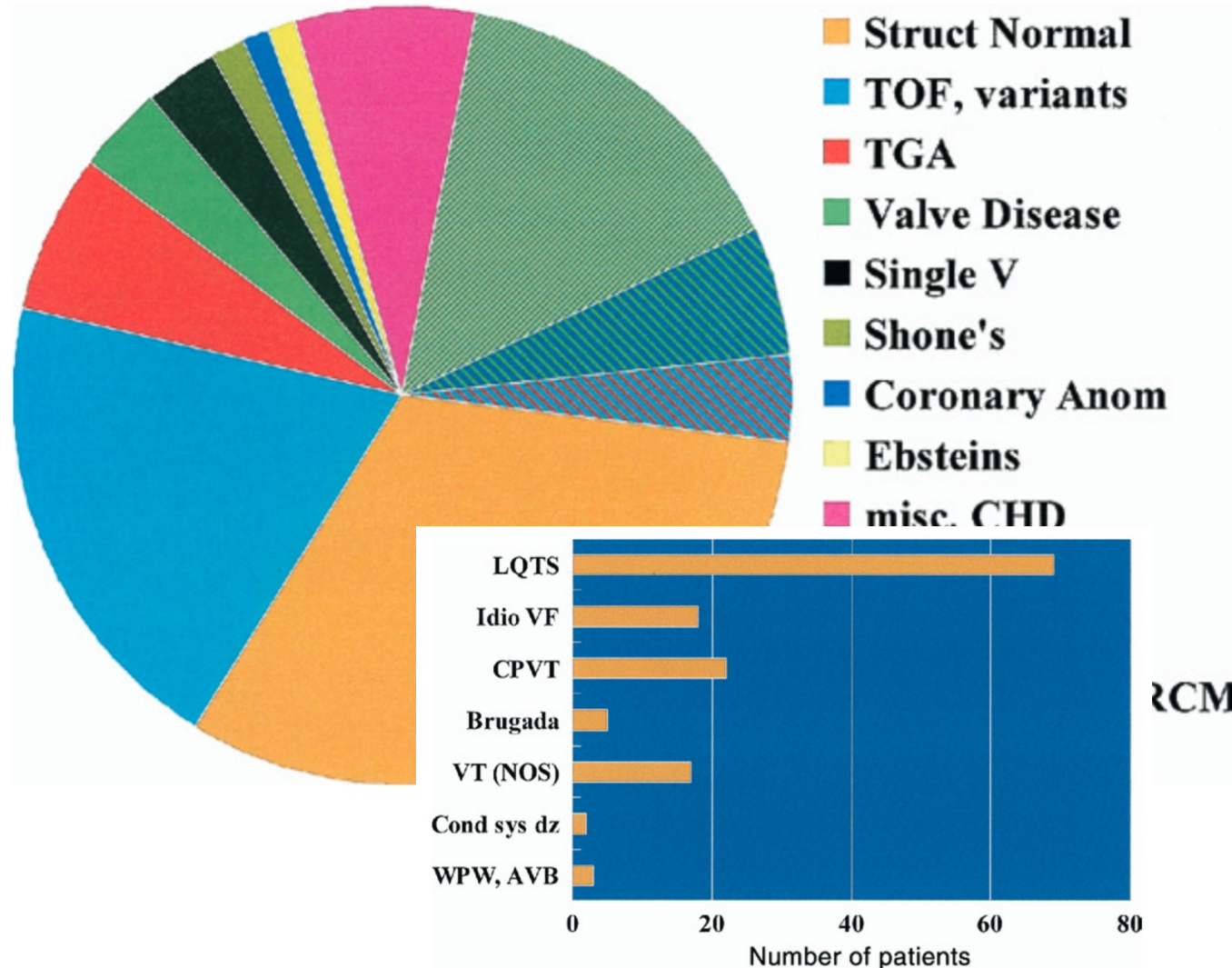


# POPULATION & INDICATIONS



- **443 patients, rétrospectif**
- **75% enfants**
- **50% prévention I<sup>aire</sup>**

# POPULATION & INDICATIONS



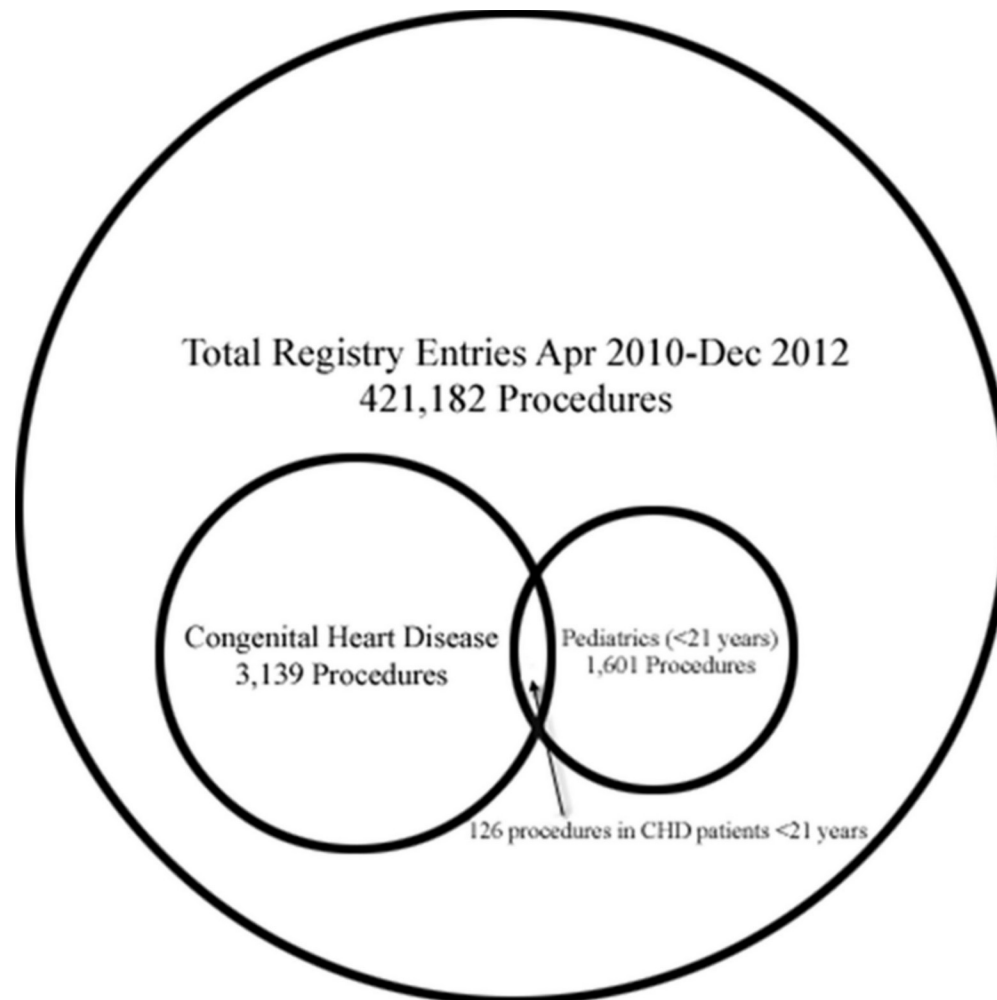
- **443 patients, rétrospectif**
- **75% enfants**
- **50% prévention I<sup>aire</sup>**

**Table 2** Age at First ICD Implantation

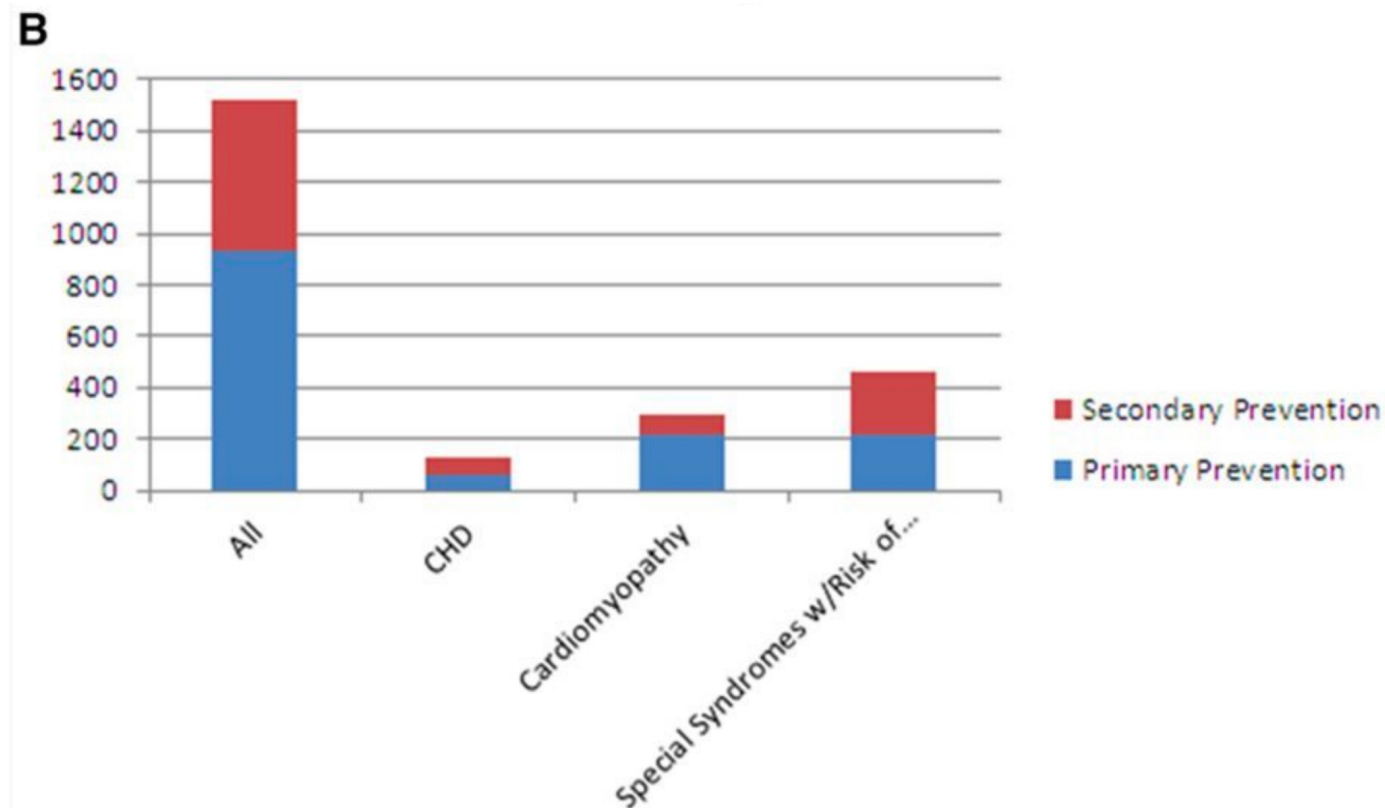
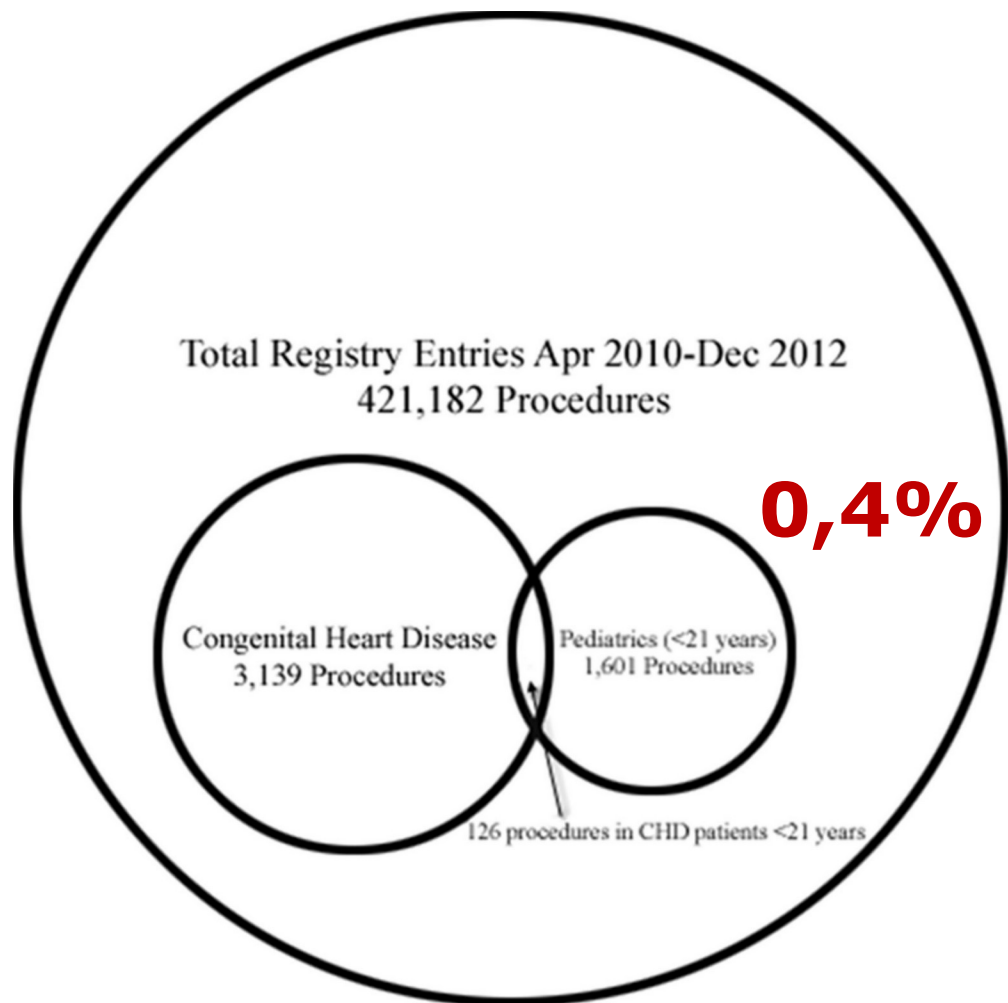
Age (yrs)	CHD	EM	CM	Total
<1	2	2	3	7 (1.5%)
1-5	4	12	3	19 (4.2%)
6-10	9	30	14	53 (12%)
11-15	35	55	56	146 (33%)
16-21	48	35	24	107 (24%)
>21	96	4	11	111 (25%)

- **443 patients, rétrospectif**
- **75% enfants**
- **50% prévention I<sup>a</sup>ire**

# POPULATION & INDICATIONS

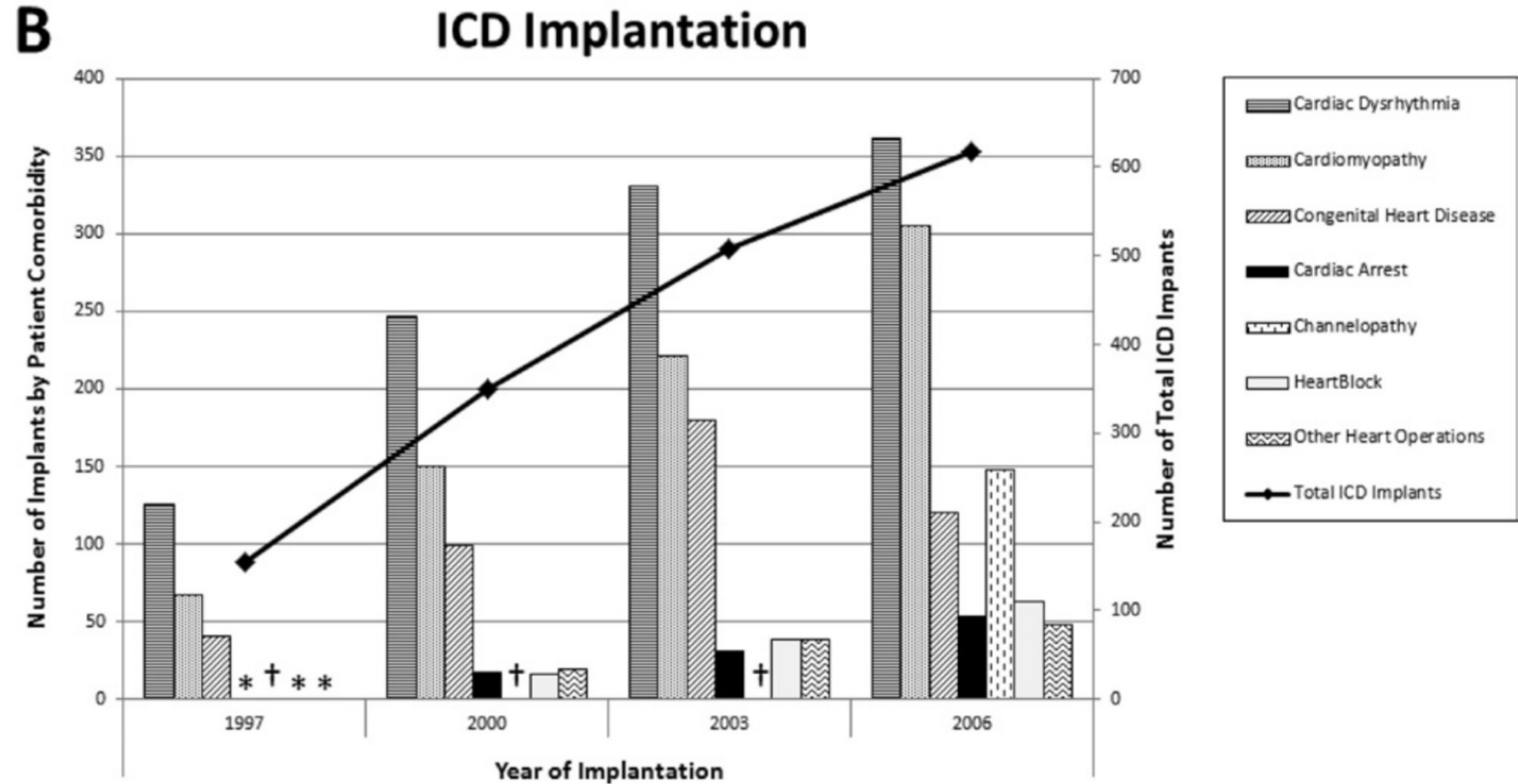
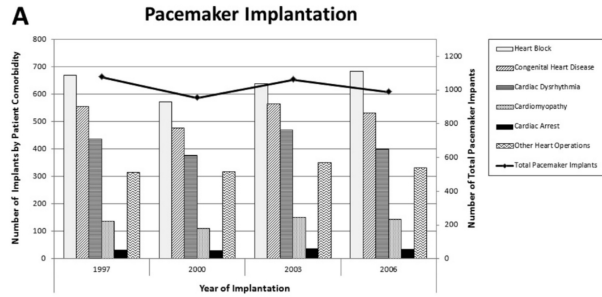


# POPULATION & INDICATIONS

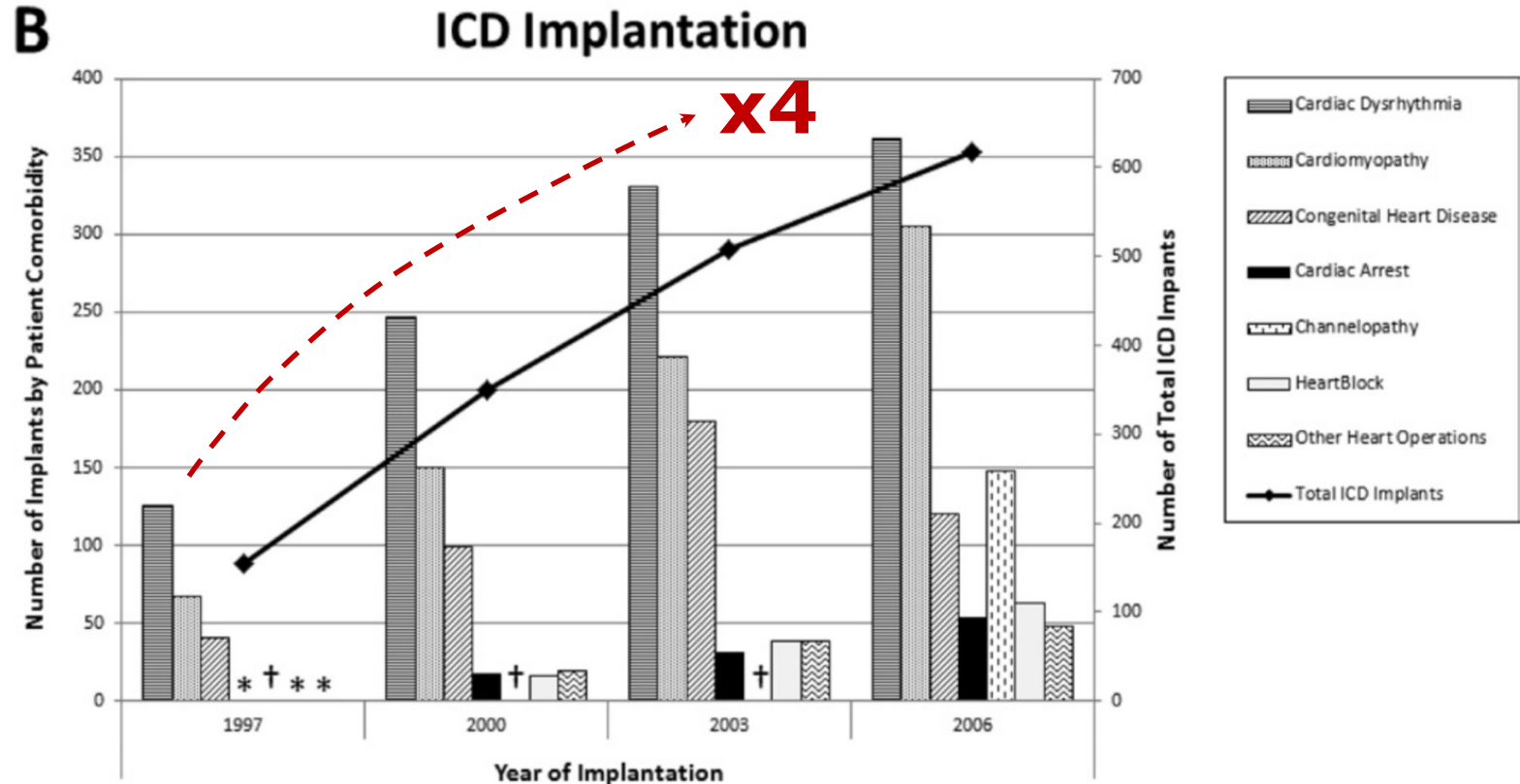
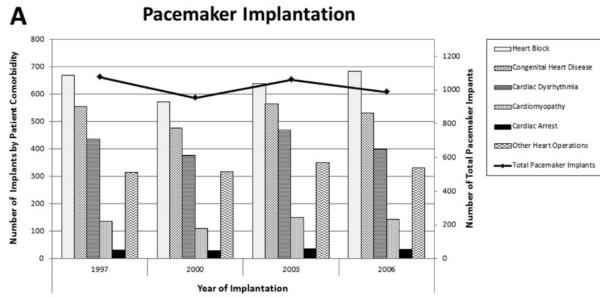




# POPULATION & INDICATIONS



# POPULATION & INDICATIONS



**13%**



**39%**

***des devices***



# POPULATION & INDICATIONS



- **Relativement rare mais en augmentation**
- **Adolescents >> petits enfants**
- **Cardiomyopathies et canalopathies > cardiopathies congénitales**
- **Prévention primaire en augmentation**





# DAI — POPULATION PÉDIATRIQUE



Population & Indications



**Techniques**



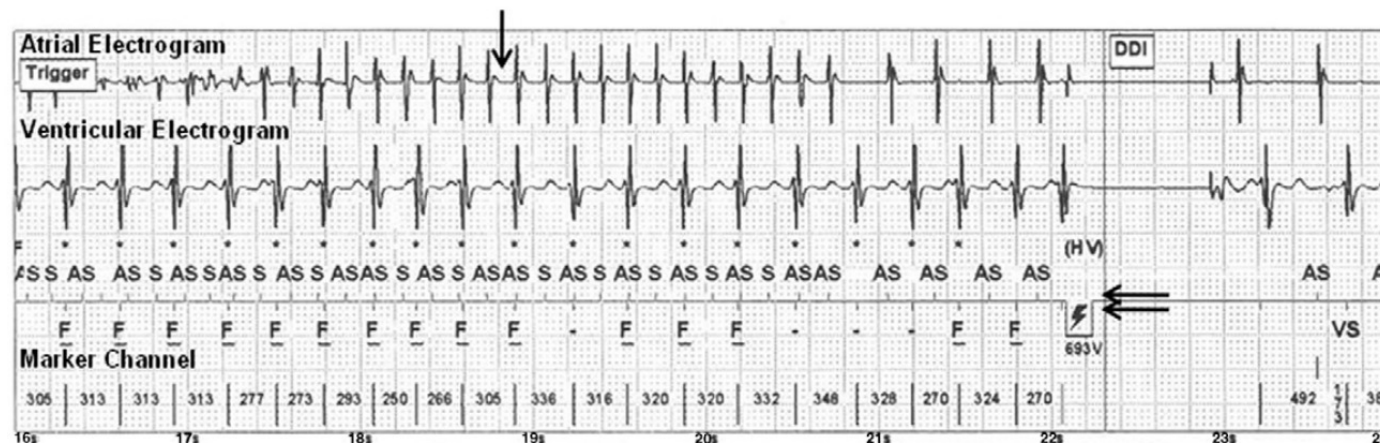
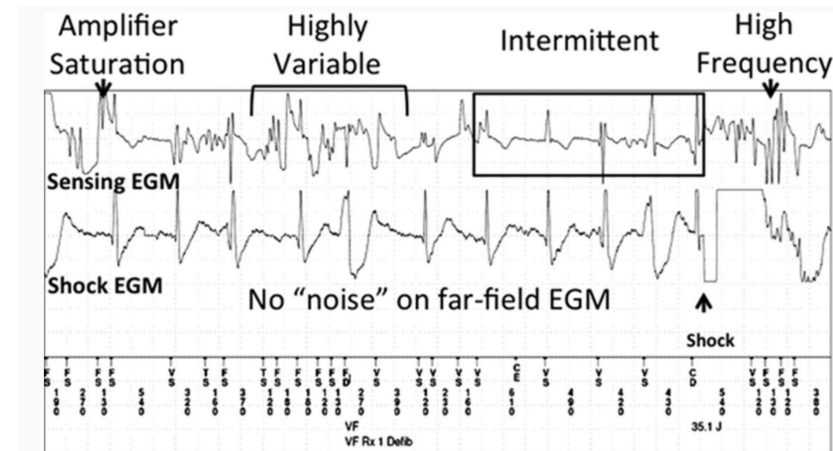
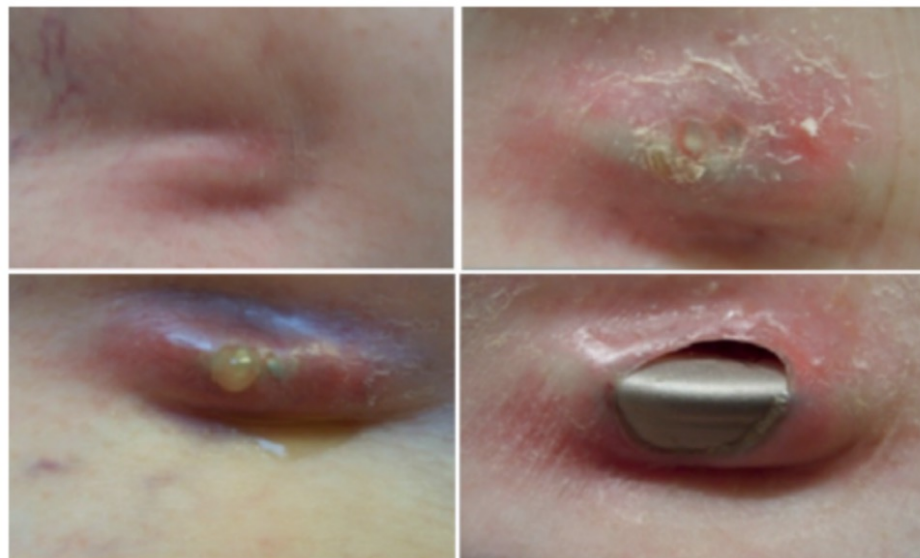
Outcomes



Perspectives

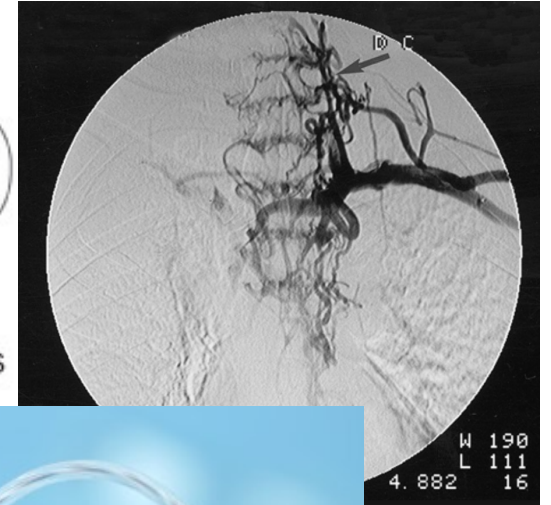
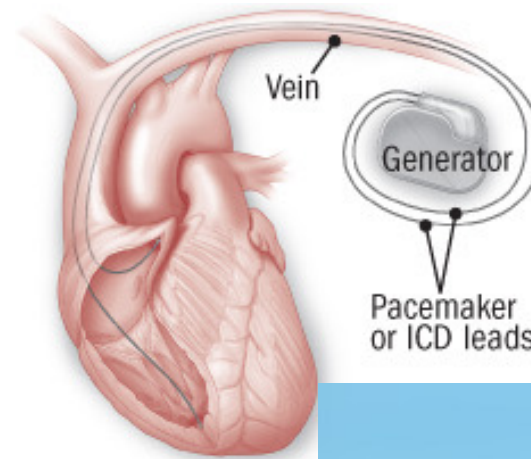
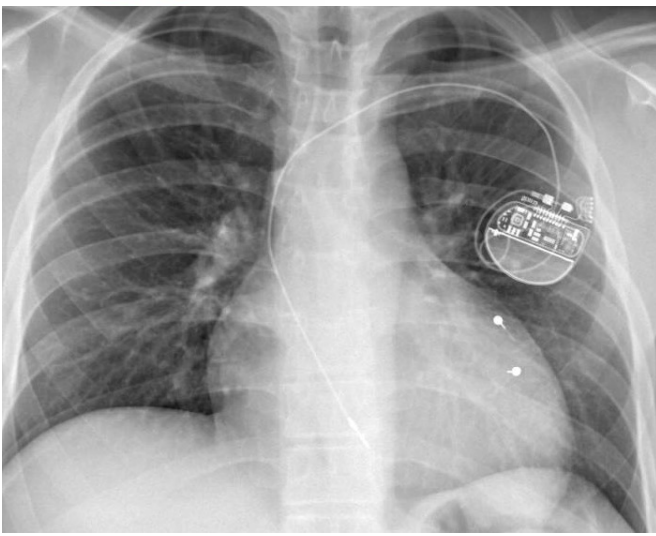
# TECHNIQUES

## DAI endovasculaire



# TECHNIQUES

## DAI endovasculaire



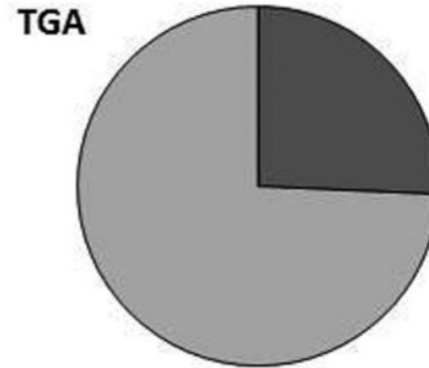
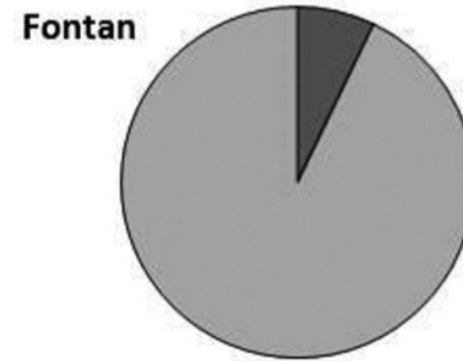
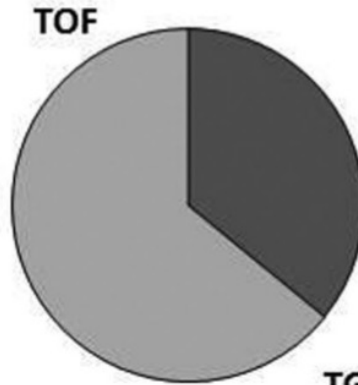
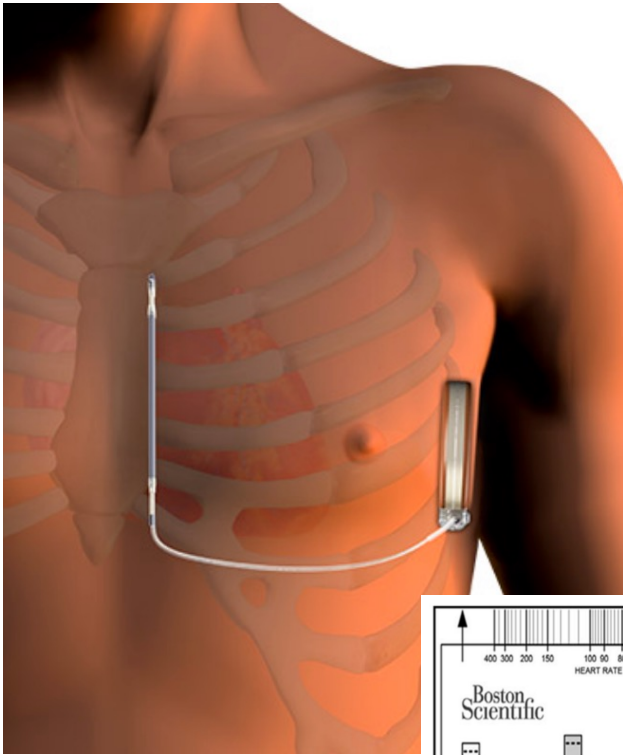
~ 3 mm

DAI VR	Abbott Ellipse	Medtronic Visia AF	Boston Resonate EL	Biotronik Ilivia	Microport Platinum
Volume (cc)	30	33	29,5	31	31,2
H x W x D (mm)	66 x 51 x 12	66 x 51 x 13	73,6 x 53,7 x 9,9	65 x 54 x 11	65.8 x 54.3 x 11.1
Poids (g)	67	77	68,9	81	84
Epaisseur (mm)	12	13	9,9	11	11

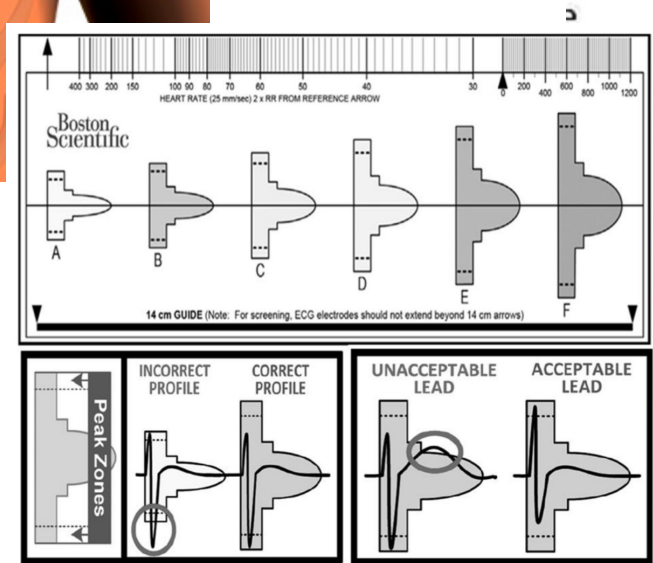


# TECHNIQUES

## S-ICD

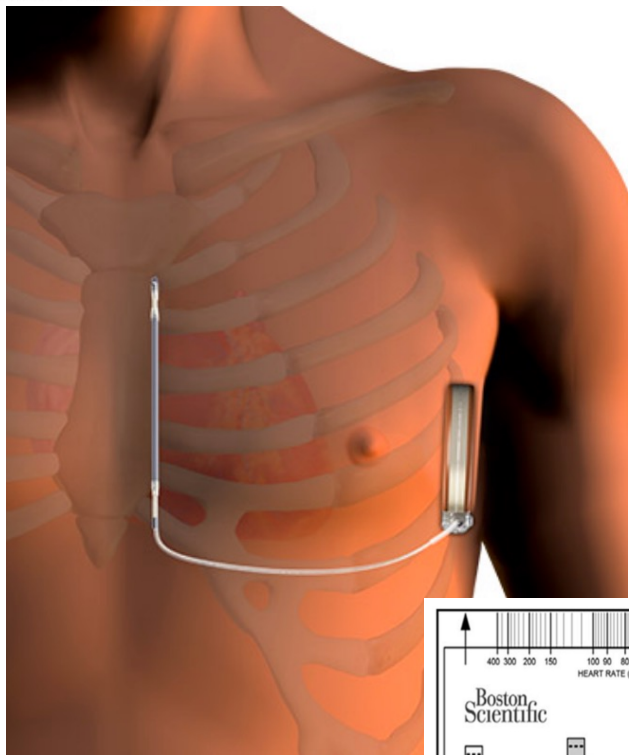


■ Ineligible  
■ Eligible



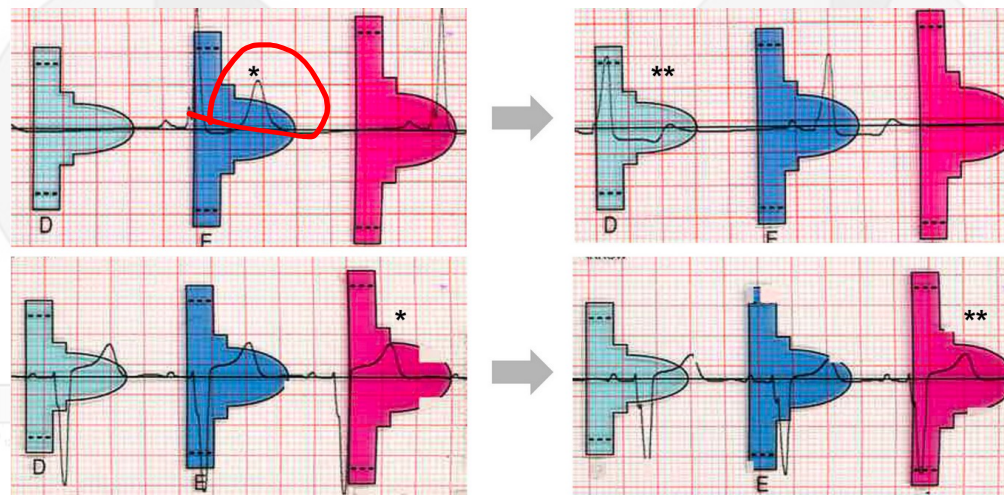
# TECHNIQUES

## S-ICD

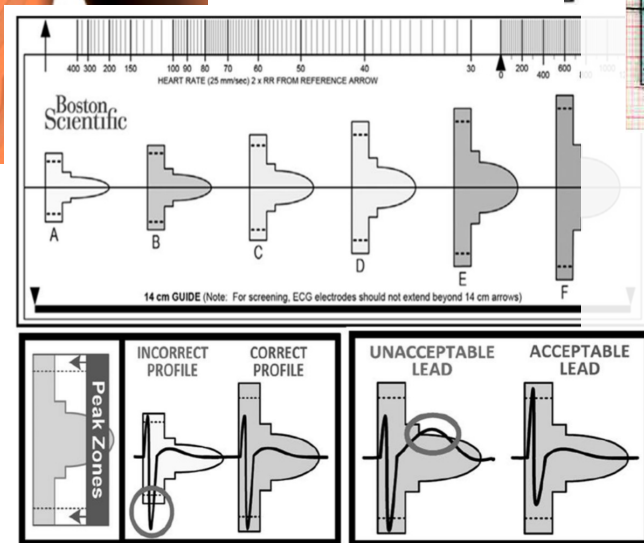


### Screening à droite

TOF

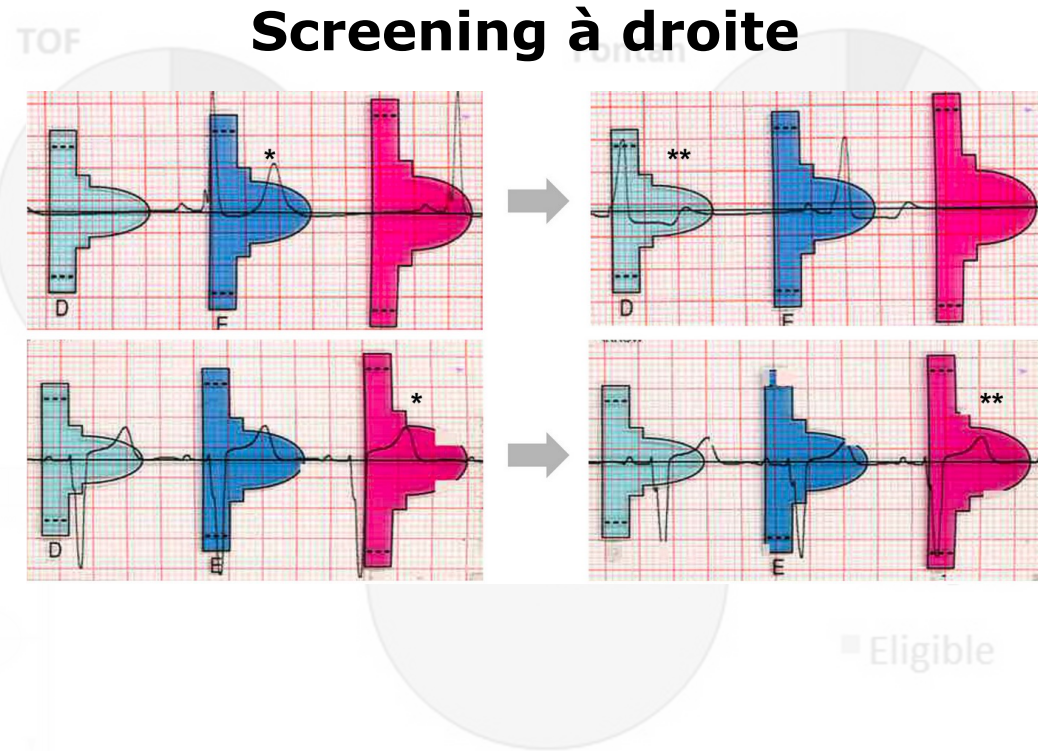
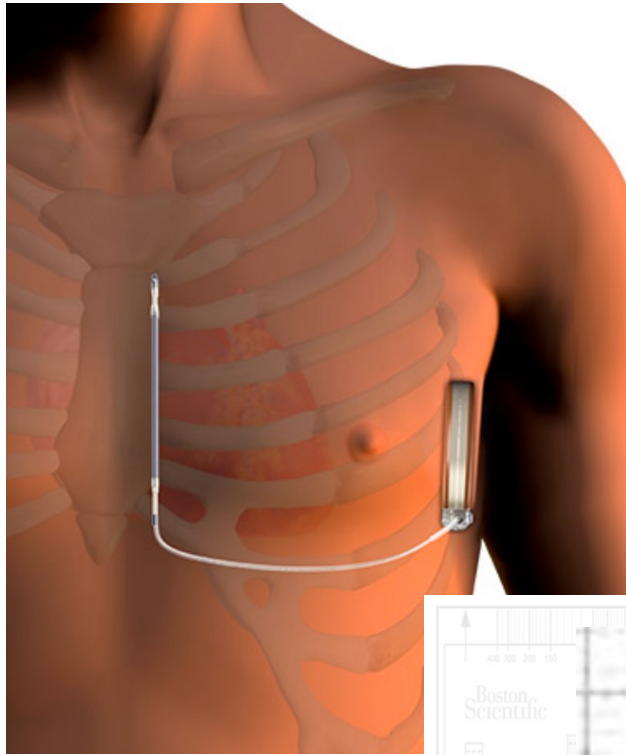


Eligible



# TECHNIQUES

## S-ICD

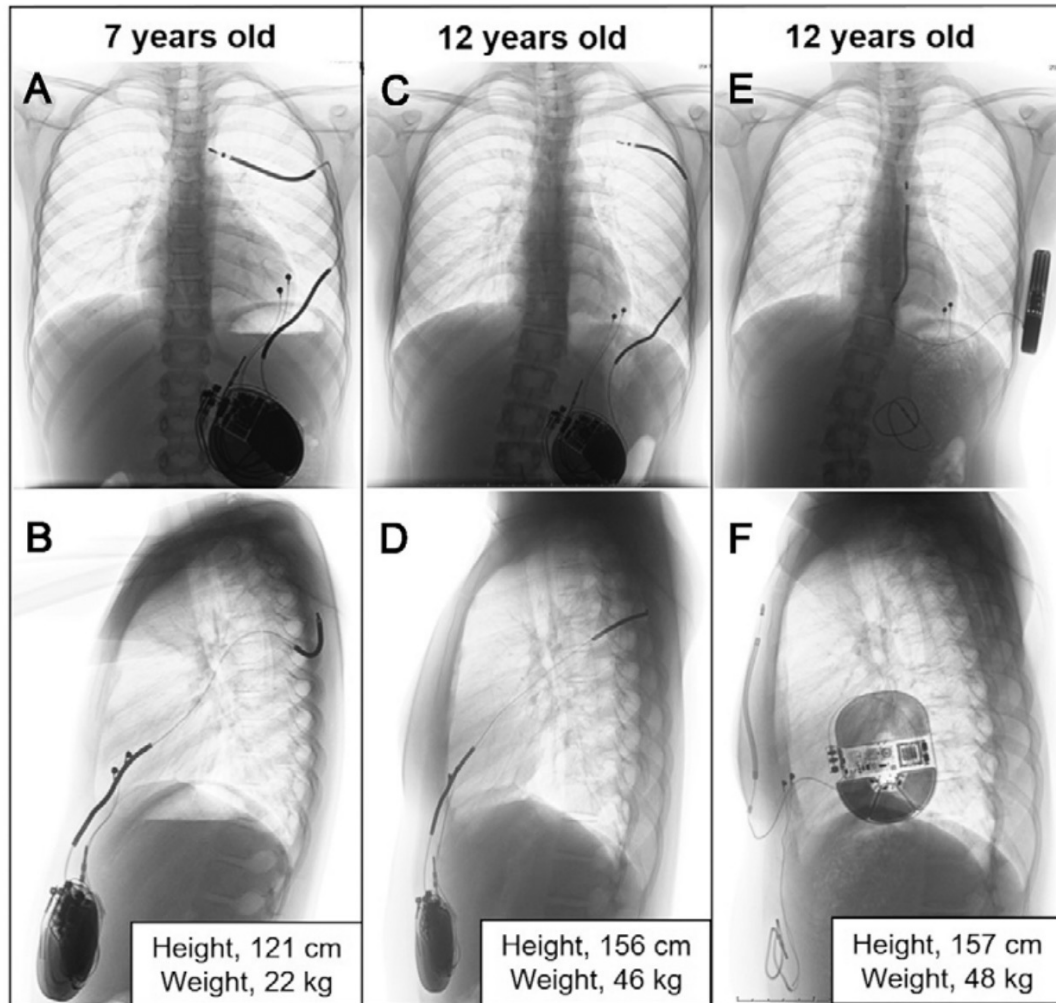


**Non-éligible si stim épi unipolaire !**



# TECHNIQUES

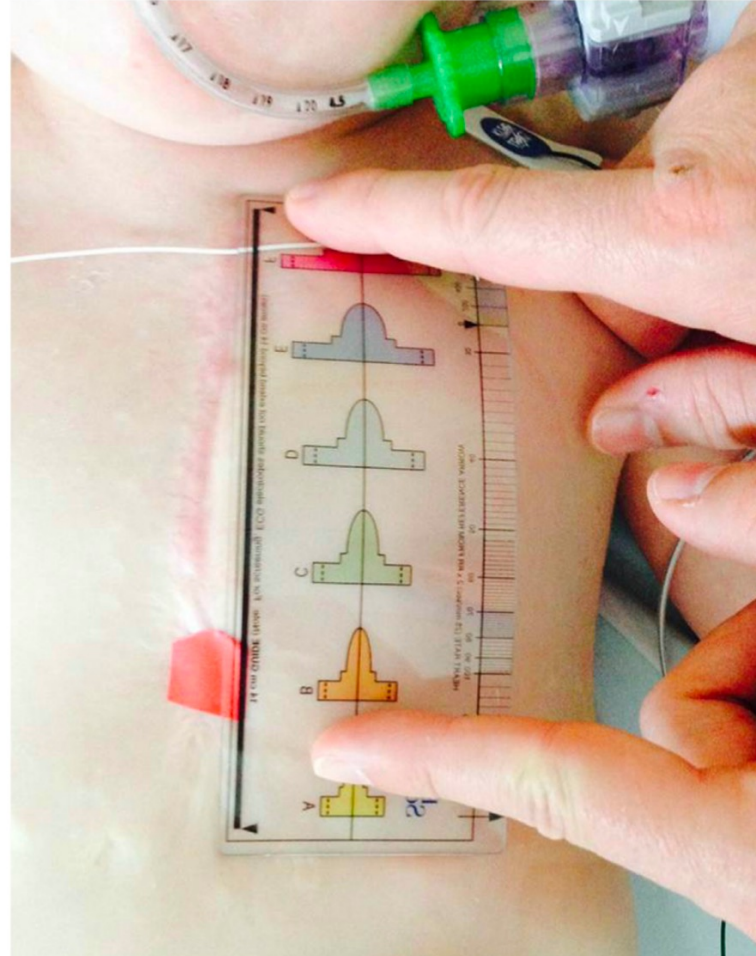
**S-ICD** 130 gr, 60 cc, 83x69x13 mm



**Table I** Baseline patient characteristics and therapy

No.	Gender	Arrhythmia symptom	Age (years)	Height (cm)	Weight (kg)	BSA (m <sup>2</sup> )	BMI	Heart disease
1	Male	SND, AFL, NSVT	30	175	83	2.03	27.1	TGA s/p Mustard
2	Male	SND, AFL, NSVT	29	180	70	1.86	21.6	TGA s/p Mustard
3	Female	NSVT	17	174	82	2.01	27.1	ARVC
4	Male	NSVT	10	139	38	1.23	19.7	Familial HOCM
5	Female	PVC	15	153	43	1.36	18.4	AT, TGA s/p Glenn
6	Female	NSVT, syncope	15	142	49	1.43	24.3	ARVC
7	Female	NSVT	14	169	52	1.55	18.2	Familial HNOCM
8	Female	No	11	156	52	1.52	21.4	Familial HNOCM
9	Female	VT, CA	15	164	75	1.88	27.9	Familial ARVC
10	Female	SND, VT, syncope	28	160	65	1.73	25.4	UVH s/p Fontan
11	Male	LQT >500 ms	15	170	55	1.60	19.0	LQTS2
12	Male	NSVT	31	170	60	1.69	20.8	PA, VSD, MAPCA s/p repair, PH
13	Female	NSVT, syncope	20	171	62	1.72	21.2	Familial ARVC
14	Female	VF inducible	10	151	61	1.64	26.8	ARVC
15	Female	PVC	15	166	58	1.63	20.7	ALCAPA, DCM

- 3 ans
- 13,5 kg
- Hypo VG DCPT
- 4 sternotomies



**Figure 2** The patient's chest demonstrating a sternal length shorter than the 14-cm proprietary mapping ruler for the subcutaneous implantable cardioverter-defibrillator.



**Figure 3** Plain radiograph after the implantation of subcutaneous implantable cardioverter-defibrillator, with the left-sided retroperitoneal generator and the subcutaneous lead overlying the right chest wall.



# TECHNIQUES

## DAI épicardique

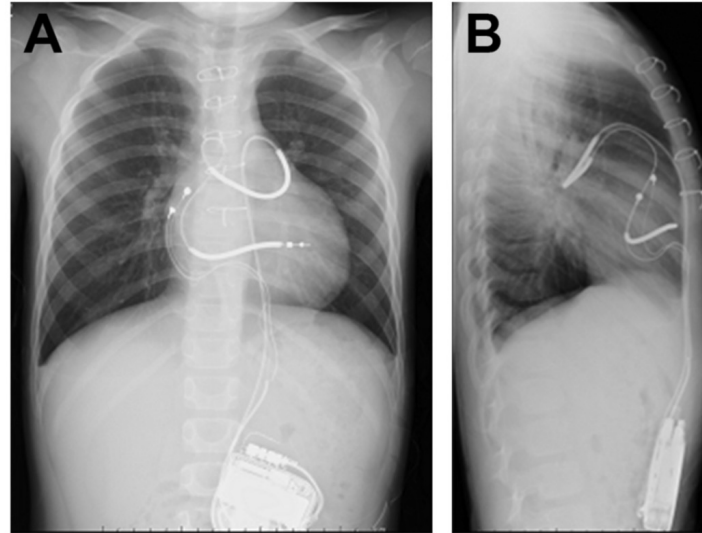
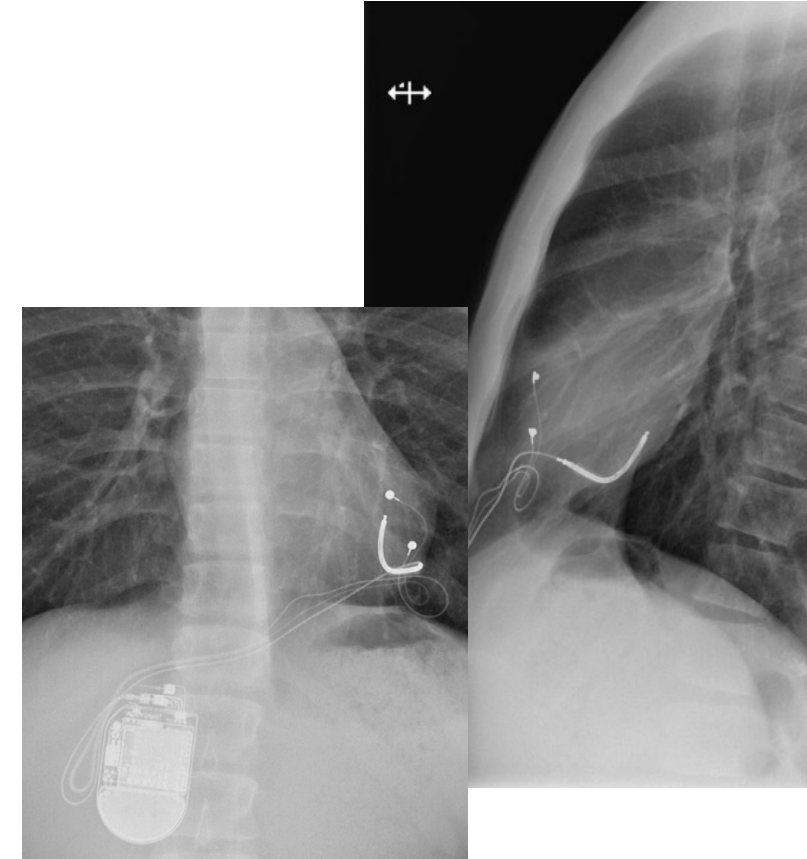


Fig 2. (A) The endocardial electrode implanted into the right ventricular apex through the right atrial appendage through transverse sinus and (B) the implantable cardioverter defibrillator device placed in the intraperitoneal space.



## Multiples approches

*Tomaske et al. Europace 2008*  
*Schneider et al. Heart Rhythm 2016*  
*Kanaya et al. Annals of Th Surg 2014*



# TECHNIQUES

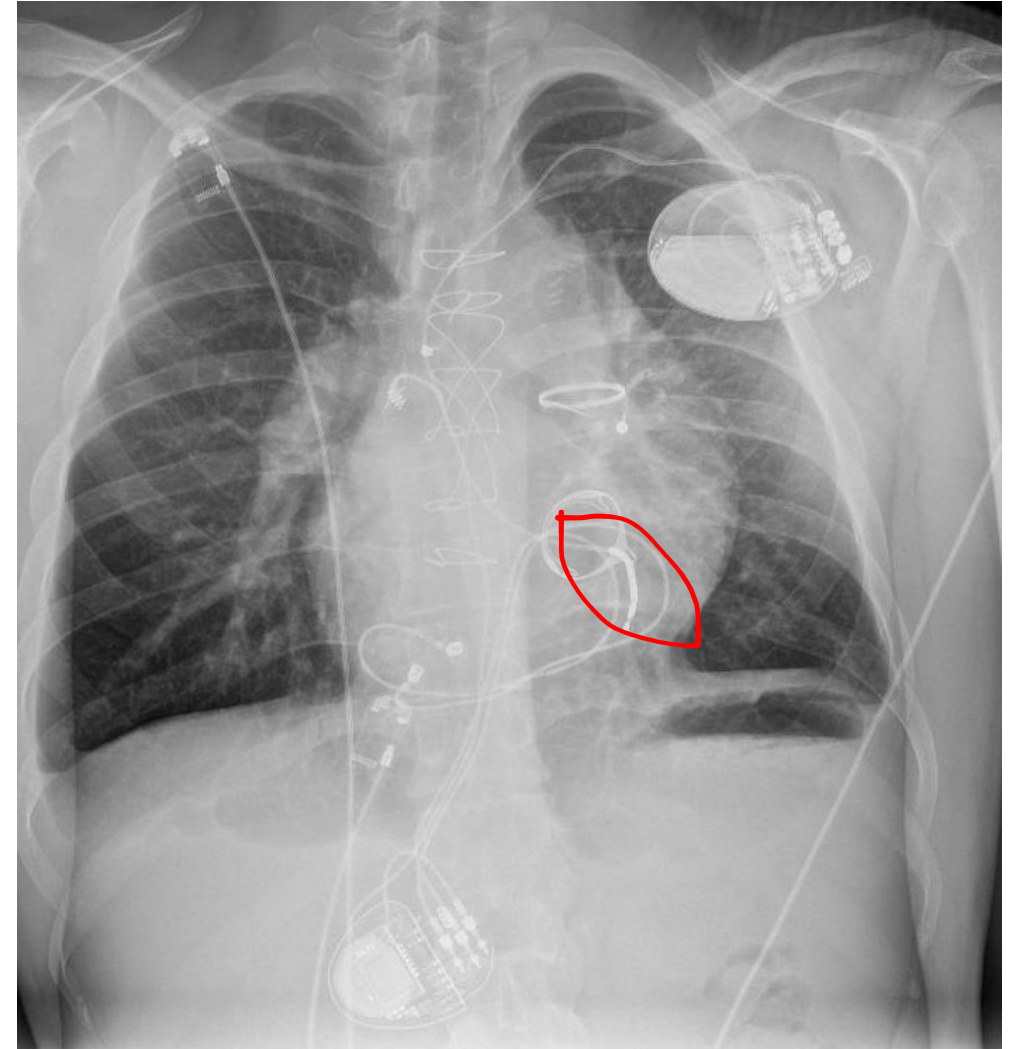
## Approches hybrides



- **Double discordance CIV atrésie pulmonaire**
- **Double switch**
- **Refection Senning pour fuite + obstacle**
- **Bioprothèse tricuspide + Bentall mécanique**
- **... 5 sternotomies**
- **PM endo puis épicardique triple pour endocardite**
- **TV soutenue 170 bpm symptomatique**

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- TV soutenue 170 bpm symptomatique

→ Non éligible S-ICD !!





# **TECHNIQUES**

## **Approches hybrides**



- **Double discordance + CIV + sténose pulmonaire**
- **BAV néonatal avec PM triple endo puis épicardique**
- **Plusieurs endocardites**
- **Dysfonction sévère du VD systémique, TVNS**

# TECHNIQUES

## Approches hybrides

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- **Plusieurs endocardites**
- **Dysfonction sévère du VD systémique, TVNS**

**→ S-ICD !!**



# TECHNIQUES

➤ **DAI endovasculaire**

- **Croissance**
- **Occlusion veineuse**
- **Endocardite**

➤ **S-ICD**

- **Eligibilité**
- **> ~ 30 kg**
- **Pas de stimulation ni ATP**

➤ **DAI épicaudique**

- **Techniques hétérogènes**
- **Fiabilité ?**



# DAI — POPULATION PÉDIATRIQUE



Population & Indications



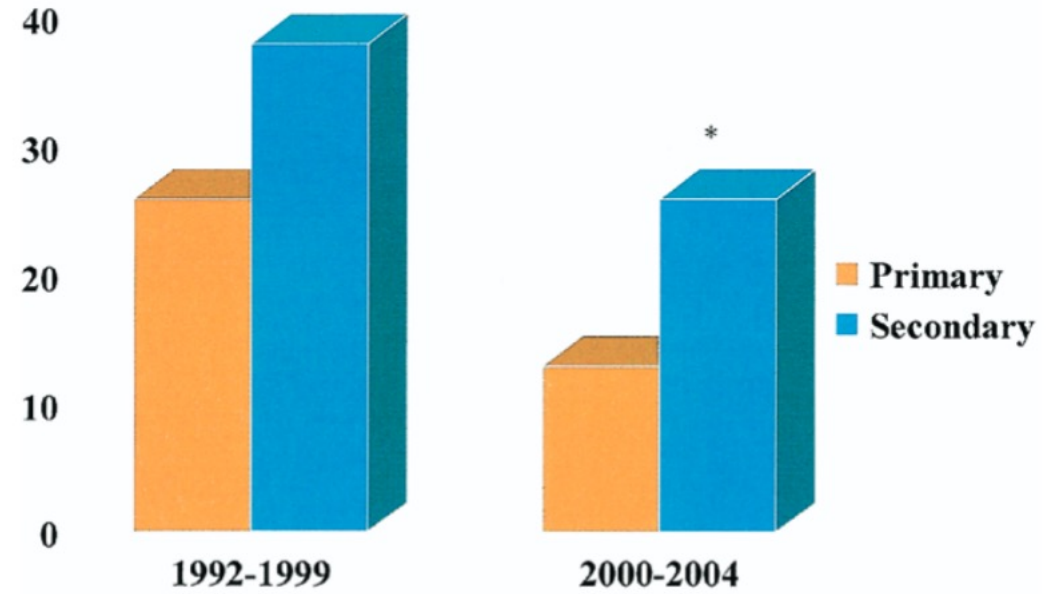
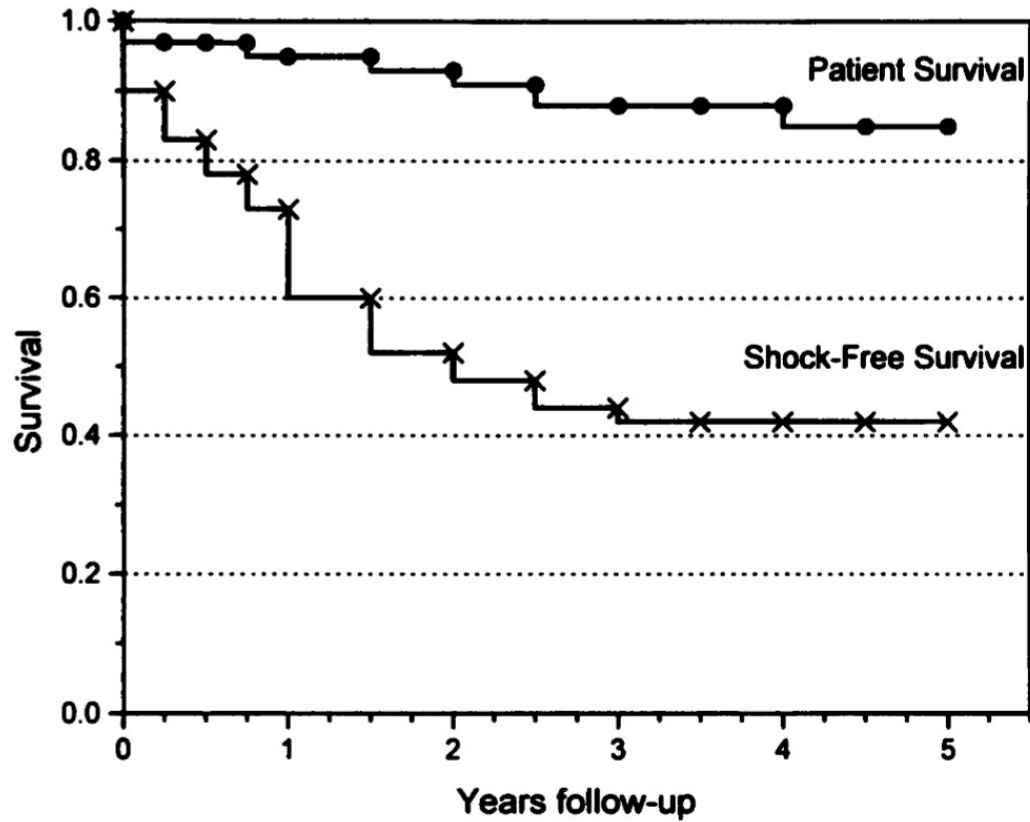
Techniques



**Outcomes**



Perspectives



**Figure 4** Shock Frequency by Center and Era

*Suivi moyen 7.5 ans*



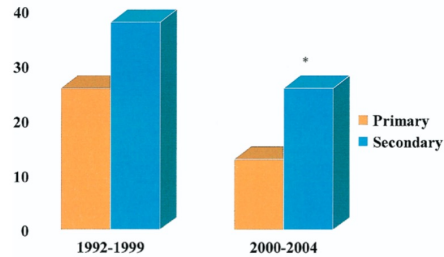


Figure 4 Shock Frequency by Center and Era

# OUTCOMES



**Table 3 ICD-Related Complications**

	No. of Complications
<b>Acute Complications (Perioperative or Within 30 Days of Implant)</b>	
Lead dislodgement	13
Inability to defibrillate or unacceptable DFT	9
Bleeding or pocket hematoma	8
Infection	7
Unsuccessful transvenous lead placement	6
Electrical storm	5
Hemothorax or pneumothorax	4
EMD/PEA	4
Skin erosion	3
SVC syndrome	2
Skin burns	2
Pneumonia and ileus	1
<b>Total acute complications</b>	<b>64 (in 55 patients)</b>
<b>Chronic Complications (More Than 30 Days After Implant)</b>	
<b>Lead-related problems overall</b>	<b>68</b>
Lead conductor fractures	20
Lead insulation breach	28
Lead late dislodgement	7
Lead-related change in capture, sensing, or DFT	13
Electrical storm	23
Inappropriate shocks (not related to lead failure)	22
Infection	13
Generator malfunction	2
Manufacturers' advisories/FDA recalls – device failure	1
<b>Total chronic complications</b>	<b>130 (in 116 patients)</b>

**Complications aiguës**

**55/443 = 12,4%**

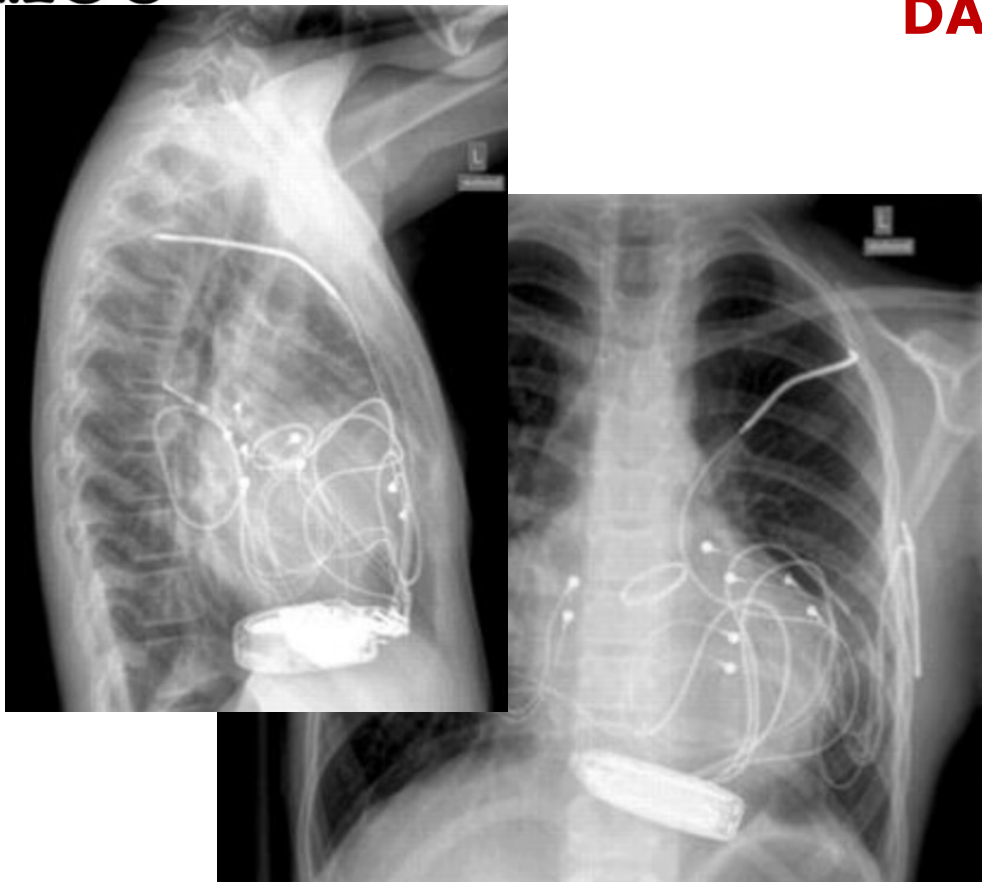
**Complications chroniques**

**116/443 = 26,2%**

*Berul et al. JACC 2008*

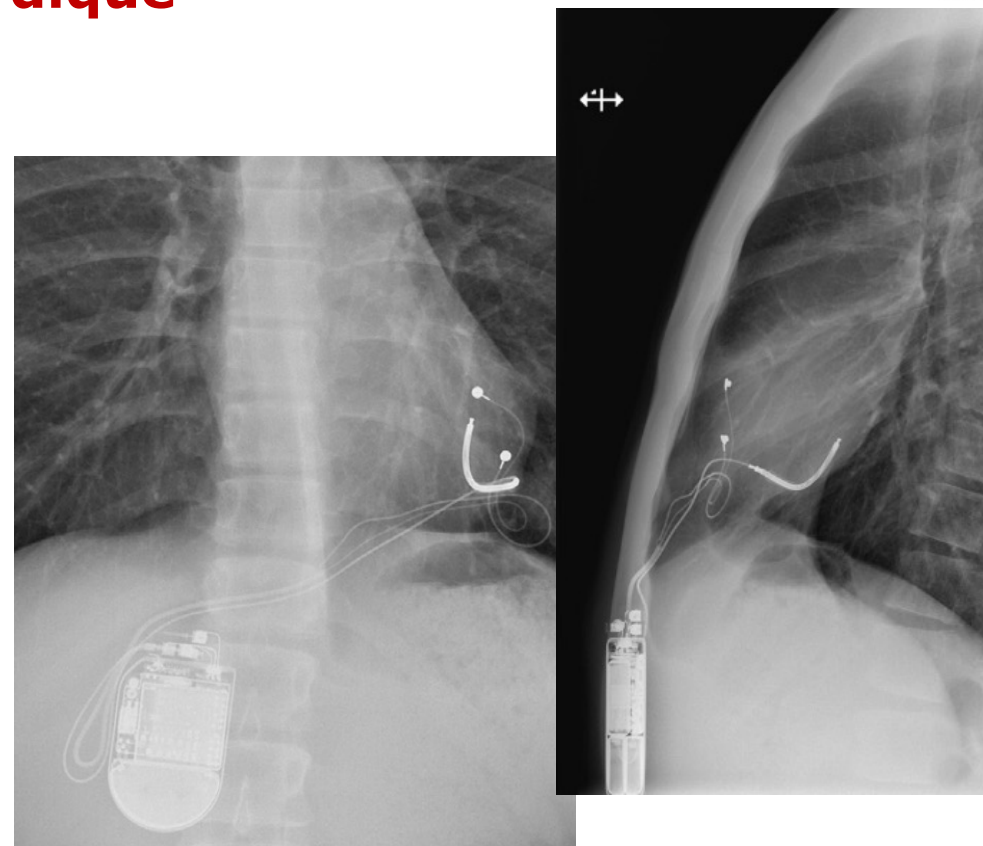
# OUTCOMES

## DAI épicardique



**4/15 revisions in 5 years**

*Tomaske et al. Europace 2008*



**7/46 ICD failures in 2 years**

*Schneider et al. Heart Rhythm 2016*

# OUTCOMES

## DAI épicardique

**Table 4** Summary of published literature on outcomes with hybrid nontransvenous systems

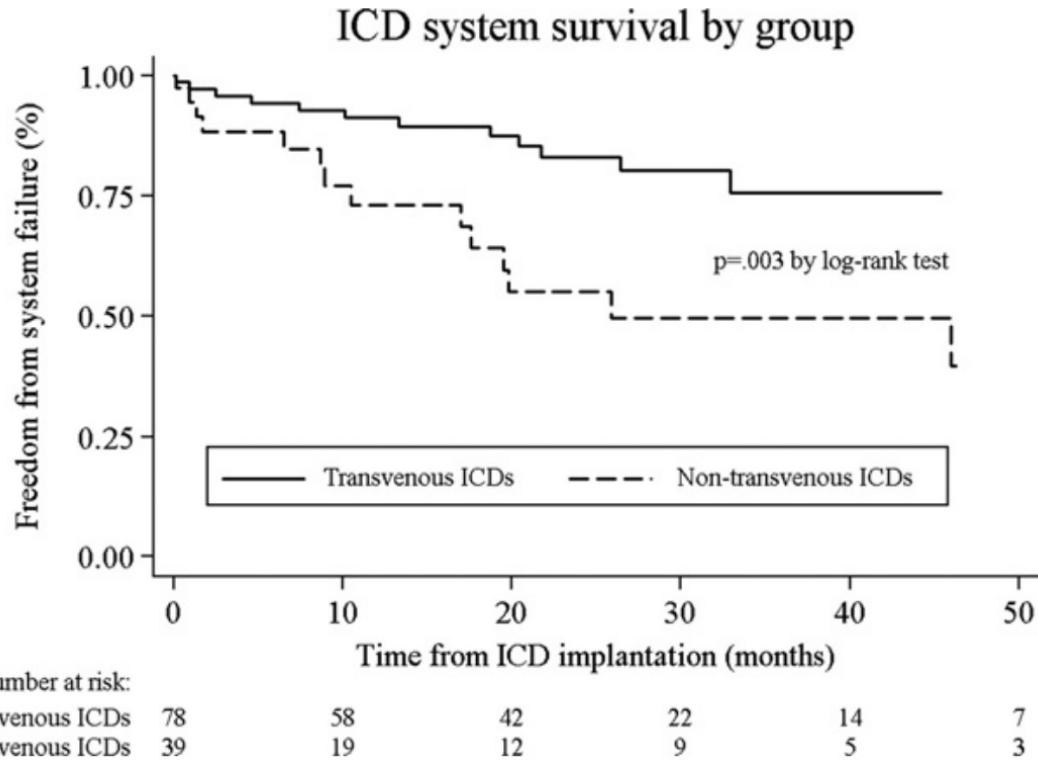
	Year	n	Median follow-up (months)	System failures*
Stephenson et al <sup>13</sup>	2006	22	23	5/22 (23%)
Cannon et al <sup>14</sup>	2006	8	22	1/8 (13%)
Kriebel et al <sup>18</sup>	2006	7	15 (mean)	2/7 (29%)
Kaltman et al <sup>17</sup>	2007	4	22 (mean)	1/4 (25%)†
Tomaske et al <sup>15</sup>	2008	15	22	4/15 (27%)
Hsia et al <sup>16</sup>	2009	7	20	0/7 (0%)
Current report	2009	39	17	14/39 (36%)

4/15 re

2 years

# OUTCOMES

## DAI épicardique



**Figure 2** Freedom from first system failure in nontransvenous implantable cardioverter-defibrillator (ICD) systems compared to conventional transvenous ICD systems.  $P = .003$  by log rank test.

**Table 2** Proximate causes of implantable cardioverter-defibrillator system failures

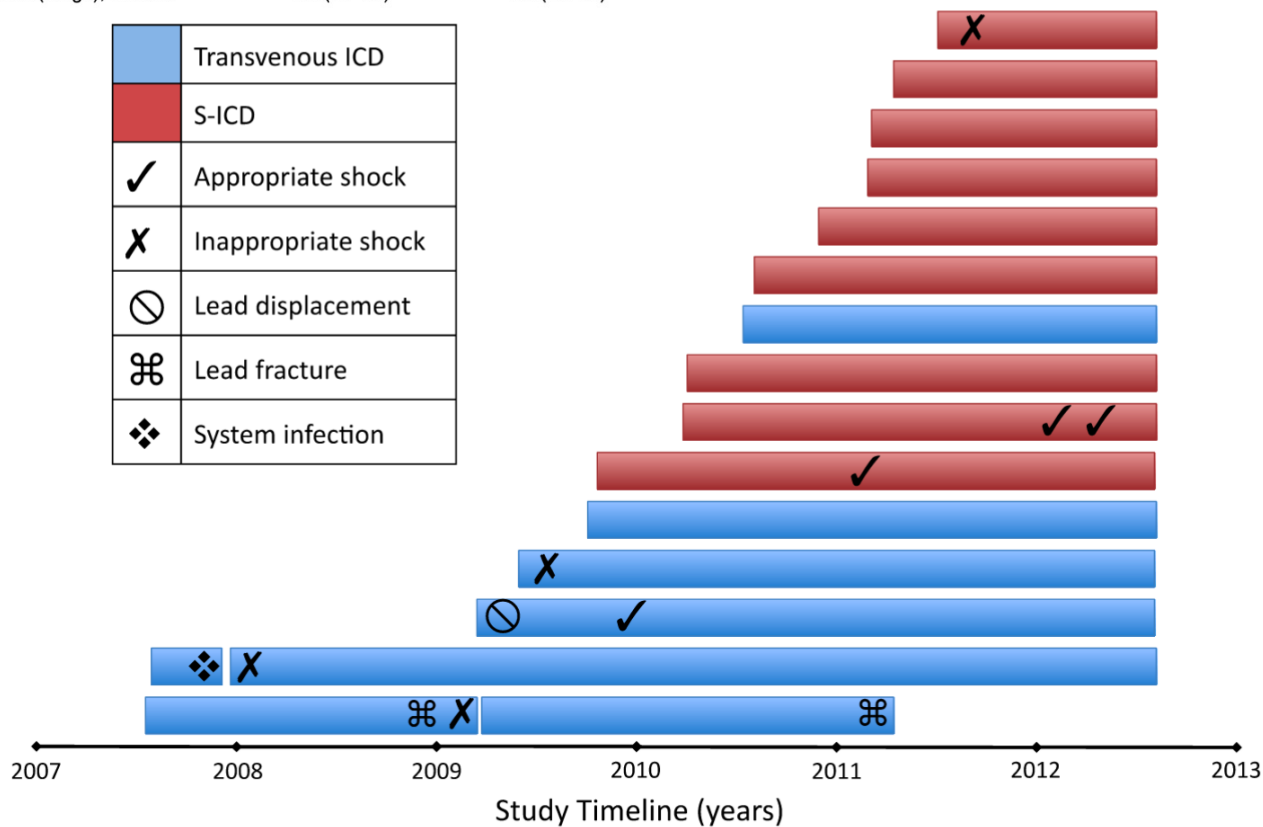
	Nontransvenous (n = 39)	Transvenous (n = 78)
Pace-sense lead failure	4	7
Inappropriately high defibrillation thresholds	4	2
Shock coil failure	4	0
Death secondary to failed shock	0	1
Generator migration	1	0
Loosened set-screw connection	1	1
Lead malposition	0	1
Twiddling	0	1
<b>Total first system failures</b>	<b>14</b>	<b>13</b>

# OUTCOMES

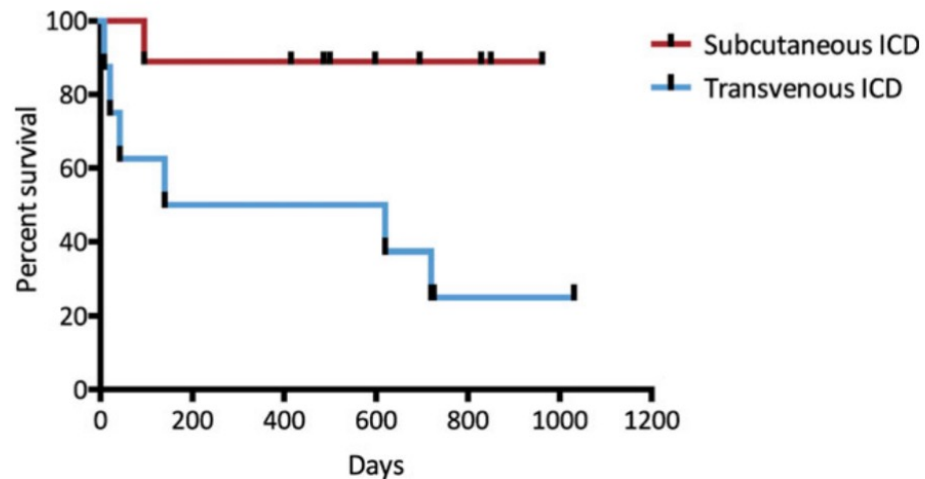
## DAI endo vs. S-ICD

	Transvenous ICD n = 8	S-ICD n = 9
Male sex, n (%)	6 (75%)	5 (56%)
Age: median (range), years	11 (5–17)	15 (10–18)
Weight: median (range), kg	54 (17–90)	54 (34–102)
Pathology, n (%)		
HCM	3 (38%)	4 (50%)
ARVC	1 (13%)	0 (0%)
LQTS	0 (0%)	1 (11%)
Brugada	2 (25%)	1 (11%)
CPVT	2 (25%)	1 (11%)
Idiopathic VF	0 (0%)	2 (22%)
Primary prevention, n (%)	1 (13%)	5 (56%)
Redo procedure, n (%)	2 (25%)	0 (0%)
Follow-up: median (range), months	36 (24–55)	20 (12–32)

	Transvenous ICD	S-ICD
✓	Appropriate shock	
✗	Inappropriate shock	
⊘	Lead displacement	
⌘	Lead fracture	
⚡	System infection	



**15 patients ( 8 endo, 9 S-ICD)**



**Figure 2.** Kaplan-Meier curve showing survival free of inappropriate therapy or reoperation for transvenous ICD (blue line) and S-ICD (red line). S-ICD = subcutaneous implantable cardioverter defibrillators.

# OUTCOMES

- **Taux de thérapies appropriées important**
- **Complications très fréquentes**
- **Beaucoup de ré interventions, notamment DAI épiscardique**
- **S-ICD semble plus favorable**





# DAI — POPULATION PÉDIATRIQUE



Population & Indications

Techniques

Outcomes

**Perspectives**



# DAI — POPULATION PÉDIATRIQUE

## Conclusions



- **Rare mais en augmentation**
- **Cardiomyopathie et canalopathies > cardiopathies congénitales**
- **Taux important de thérapies mais aussi de complications ++**
- **Avantages et inconvénients des différentes approches**
- **Discussion collégiale entre DAI endoveineux, DAI épi, et S-ICD**

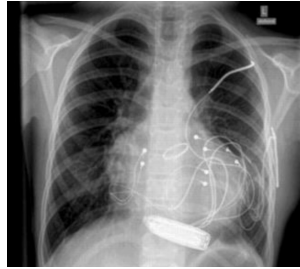


# DAI — POPULATION PÉDIATRIQUE

## Algorithme

1/ Poids ?

< 25-30 kg



# DAI — POPULATION PÉDIATRIQUE

## Algorithme

1/ Poids ?

< 25-30 kg

> 25-30 kg



**Besoin stim ou ATP ?**  
**Occlusion veineuse ?**  
**Valve prothétique ?**  
**Risque infectieux ?**  
**Eligibilité S-ICD ?**

## Algorithme

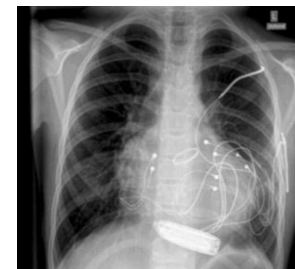
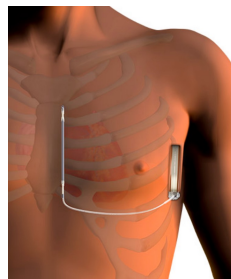
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Besoin stim ou ATP ?  
Occlusion veineuse ?  
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# DAI — POPULATION PÉDIATRIQUE

## Algorithme

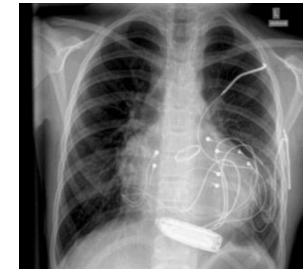
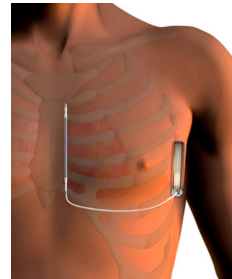
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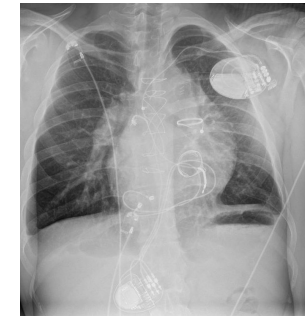
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Besoin stim ou ATP ?  
Occlusion veineuse ?  
Valve prothétique ?  
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Eligibilité S-ICD ?



Approche hybride ?



# DAI — POPULATION PÉDIATRIQUE

## Algorithme

1/ Poids ?

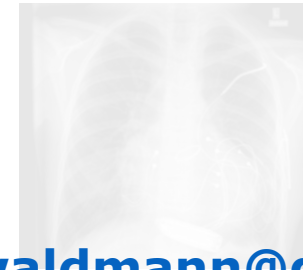
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Besoin stim ou ATP ?  
Occlusion veineuse ?  
Valve prothétique ?

**Merci pour votre attention !**



Victor WALDMANN

[victor.waldmann@gmail.com](mailto:victor.waldmann@gmail.com)

06 76 09 80 07

01 56 09 37 84

Hôpital Européen Georges Pompidou — Hôpital Necker

Approche hybride ?

