

# TOWARDS THE SELECTION OF PATIENTS REQUIRING ICD IMPLANTATION BY AUTOMATIC CLASSIFICATION FROM HOLTER MONITORING INDICES

Cappelaere CH.<sup>1,2</sup>, Dubois R.<sup>3</sup>, Roussel P.<sup>2</sup>, Baumann O.<sup>1</sup>, Amblard A.<sup>1</sup>, Dreyfus G.<sup>2</sup>

<sup>1</sup>Sorin CRM SAS, Clamart, France

<sup>2</sup>SIGnal processing and MACHine learning (SIGMA) lab, ESPCI ParisTech, Paris, France

<sup>3</sup>IHU LIRYC, Bordeaux, France

## What about sudden cardiac death ?

**Sudden Cardiac Death (SCD):** unexpected death due to cardiac causes that occurs in a short time period (generally within 1 hour of symptom onset) in a person with known or unknown cardiac disease.

Main causes of SCD are ventricular tachyarrhythmias:  
ventricular tachycardia (VT) and ventricular fibrillation (VF)

Main preventive treatments:  
antiarrhythmic drugs and implantable cardioverter defibrillator

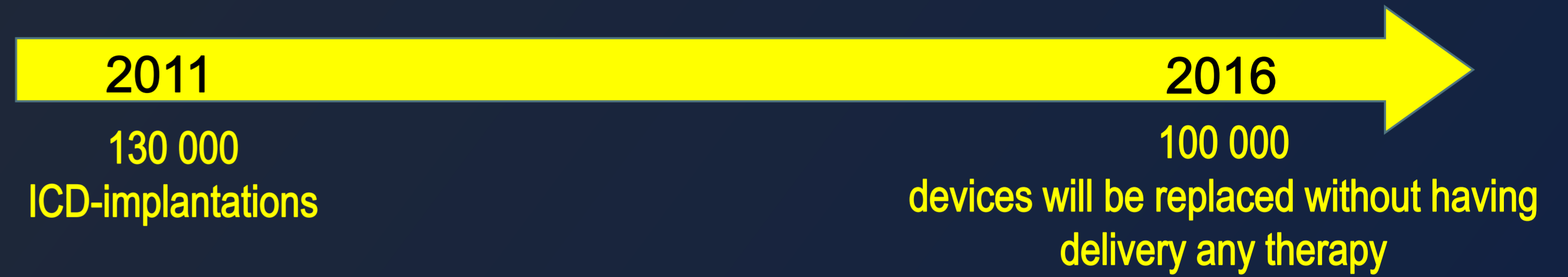
325 000 SCD / year in the USA :

- 80% of high coronary-risk profile or post-infarction patients
- 30% of post-infarction patients with ejection fraction < 35% and congestive heart failure (recommended to implantation)
- 15% of patients with previous cardiac arrest or ventricular tachycardia (recommended to implantation)

## Performances of the implantation guidelines

Among patients implanted in primary prevention, only 2% to 5% per year suffer a ventricular arrhythmia resulting in SCD

In the USA, in primary prevention:



Health issues due to the peri- and postoperative complications

Economic issue caused by unnecessary implantations

**The selection of prophylactic ICD-implantation candidates must be improved**

## Purpose of this study

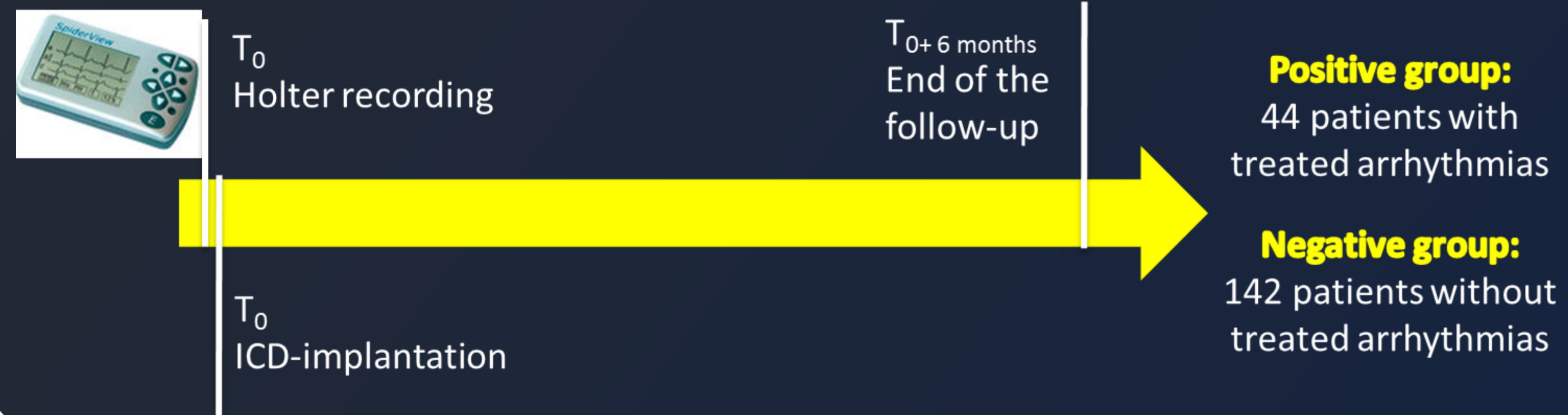
Design a **neural network classifier**, the inputs of which are the descriptors obtained from Holter recordings, to select patients who do not need implantation during the next 6 months with a NPV\* > 90% and a PPV\*\* > 20%

\* negative predictive value (NPV) = true negatives / all negatives

\*\*positive predictive value (PPV) = true positives / all positives

## Database

186 pre-implantation 30-min Holter recordings of patients equipped with an implantable cardioverter defibrillator (67±11 years of age, 163 males)



## Feature grouping & Feature selection

"There are always three main ingredients required for the production of a clinical arrhythmia, the arrhythmogenic substrate, the trigger factor and the modulation factors of which the most common is the autonomic nervous system." Dr. P. Coumel

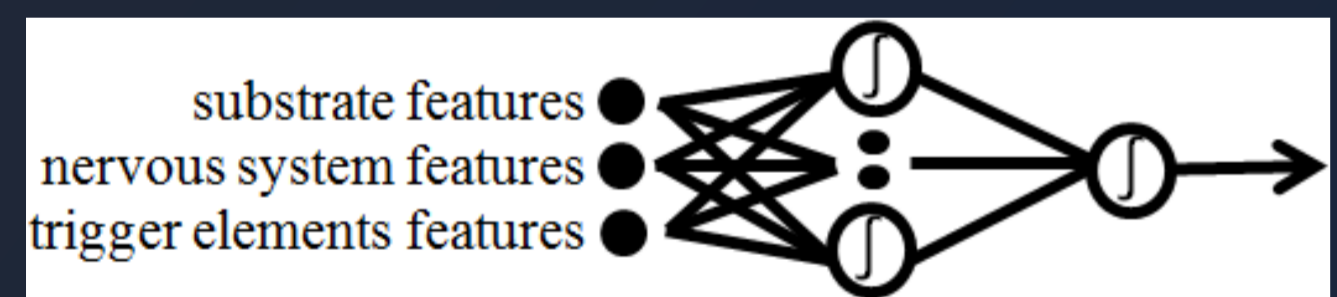
The features are grouped according to the arrhythmogenic factor they describe.

In each of the 3 groups, the most relevant features for a classification between recordings that lead or not to treated event are selected thanks to the **random probe method** (Stoppiglia *et al.*, "A random feature for variable and feature selection", Journal of Machine Learning Research 2003;3:1399-1414)

## Classifier design

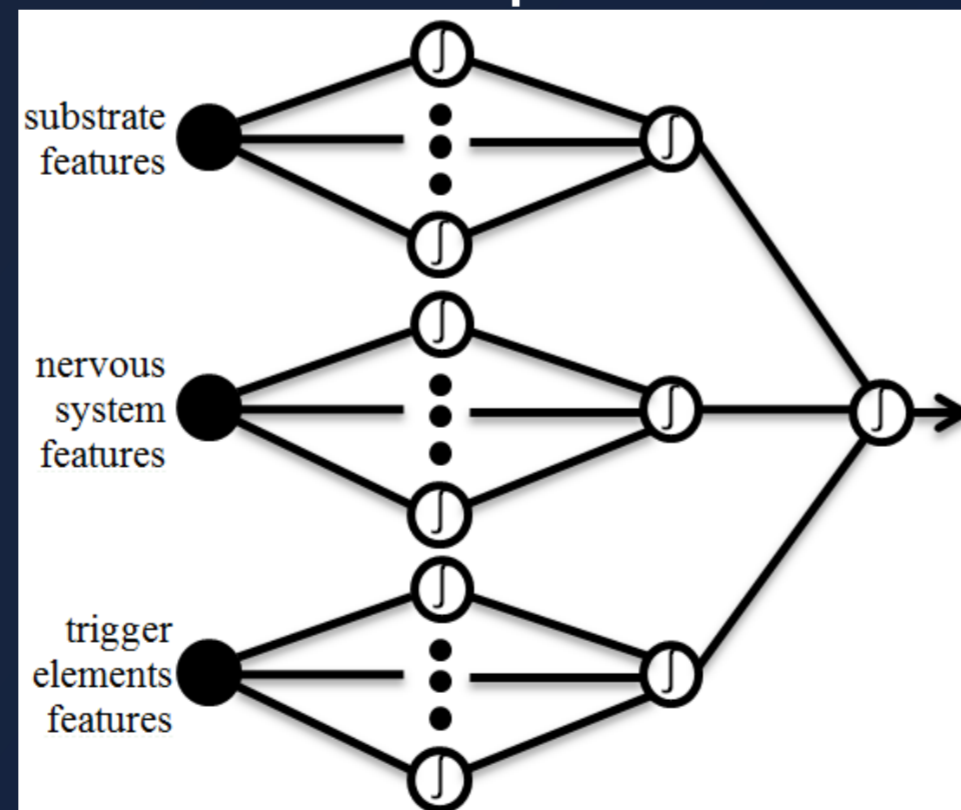
Estimate the probability for a patient to undergo ventricular arrhythmia

Conventional classifier:  
Single hidden layer neural network



Complexity determined by Cross-validation

Ad hoc classifier:  
Classifier capitalizing on the arrhythmogenic decomposition of the inputs



One subnetwork per hub of inputs  
Complexity of each subnetwork determined by cross-validation  
Each subnetwork outputs merged into a nonlinear output neuron

Performances of both designed classifiers estimated by a cross-test procedure

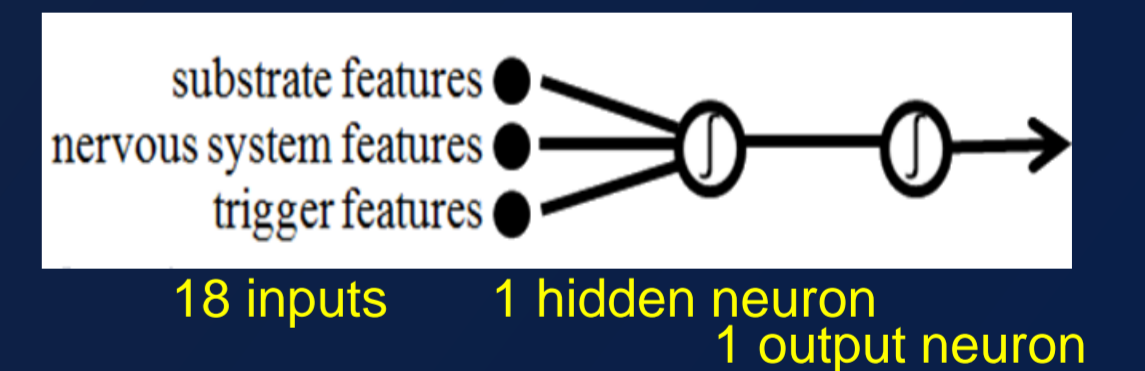
## Results

### Selected features

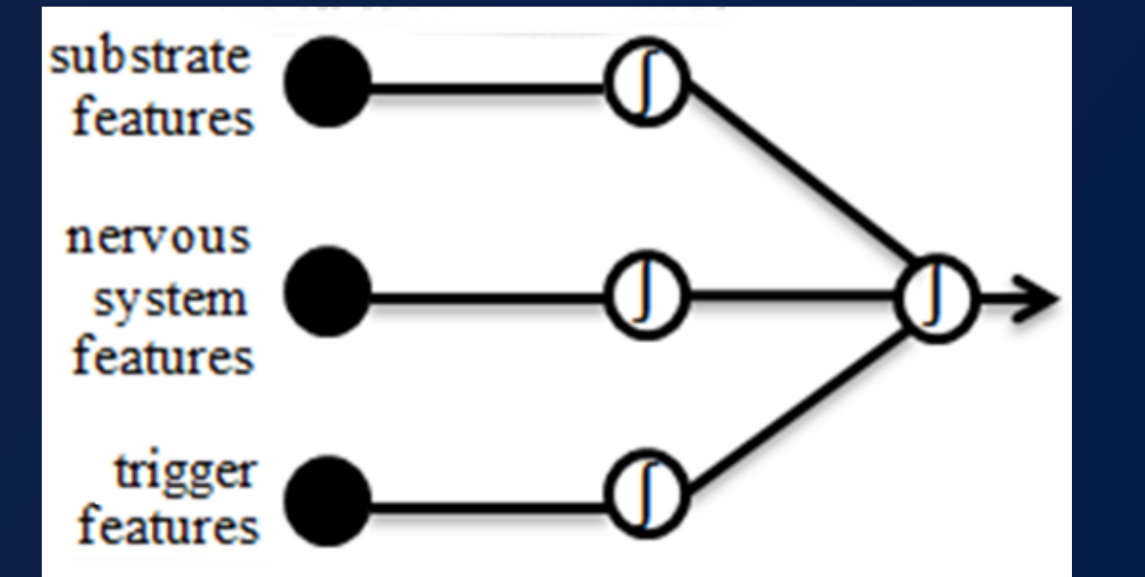
Myocardial Substrate	QRS residuum † QRS-T angle † T-Wave residuum † QT end † QT apex † QT slope † ST elevation / depression †
Autonomic Nervous System	Minimum heart rate † Mean RR interval † SDANN Poincaré Plot Analysis SD2 Heart rate variability index ‡ Turbulence Onset
Trigger elements	Ventricular bigeminy Ventricular trigeminy Non-sustained ventricular tachycardia Premature Atrial Contraction (PAC) Couple of PAC

† averaged over the signal duration  
‡ heart rate variability index is the percentage of averaged differences between two successive complexes.

### Conventional classifier



### Ad hoc classifier



- 3 subnetworks:
- 7 inputs, 0 hidden neuron, 1 output neuron
  - 6 inputs, 0 hidden neuron, 1 output neuron
  - 5 inputs, 0 hidden neuron, 1 output neuron

## Performances

Performances	Current position	Conventional classifier	Ad hoc classifier
Reduction of the ICD-implantations	n.a.	52% ± 19%	59% ± 15%
Unnecessary implantations at 6 months	95% – 98%	75% ± 20%	69% ± 19%
Positive Predictive Value	2% – 5%	25% ± 20%	31% ± 19%
Missed implantations	n.a.	32% ± 13%	23% ± 13%
Negative Predictive Value	n.a.	68% ± 13%	77% ± 13%

## Performances reading & Limitations

Objective of Positive Predictive Value reached  
Objective of Negative Predictive Value close to be obtained  
Slight improvement due to the arrhythmogenic decomposition of the inputs

The non negligible amount of missed required implantations could be due to the database limitations: few examples  
30-min recordings at any time in the daytime

Preventing any circadian analysis of the descriptors  
Avoiding the study of time period of interest such as the hour before awakening

## Conclusion

**Improving ICD-implantation candidates selection may be possible  
But getting a more suitable and larger database is essential**