# ELECTRA

## 5-6 DÉCEMBRE 2024

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**MARSEILLE I FRANCE**

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pratiques de rythmologie
& de stimulation cardiaque

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12.2024

# Radiothérapie, un traitement aussi pour les arythmies ventriculaires, réfractaires

*Promesse ou réalité ?*

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# 1

# *Rationel de la Radioablation Cardiaque*

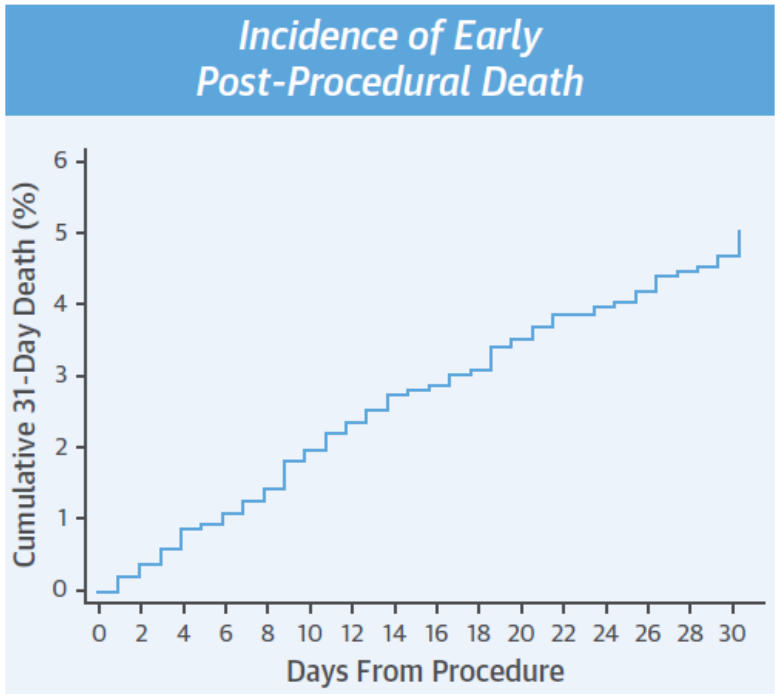
# Ablation par cathéter de TV

## *Les limites de la thérapie… !*

. Les procedures d'ablation de TV peuvent **être risquées**

. Les procedures d'ablation de TV peuvent être **complexes à réaliser**

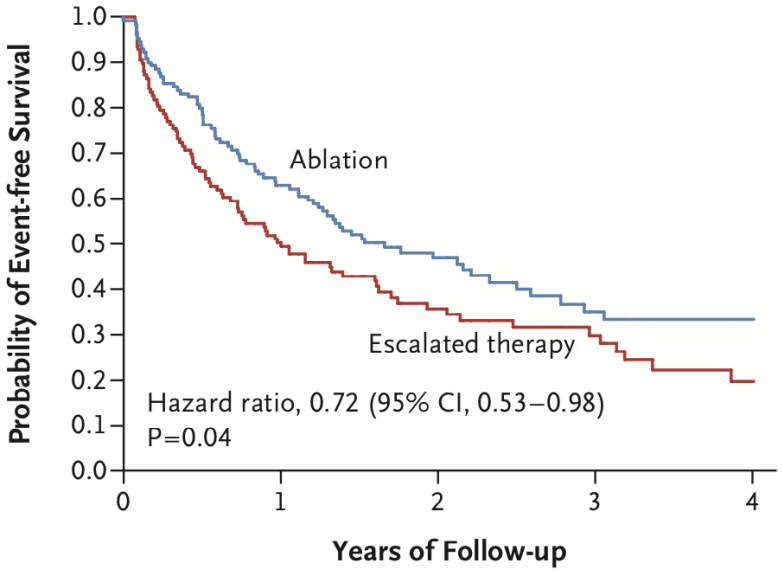
. Les procedures d'ablation de TV ne sont **pas toujours efficaces**




5% mortalité à 1mois

*Santangelli et al; JACC 2017*

Procédures chronophages



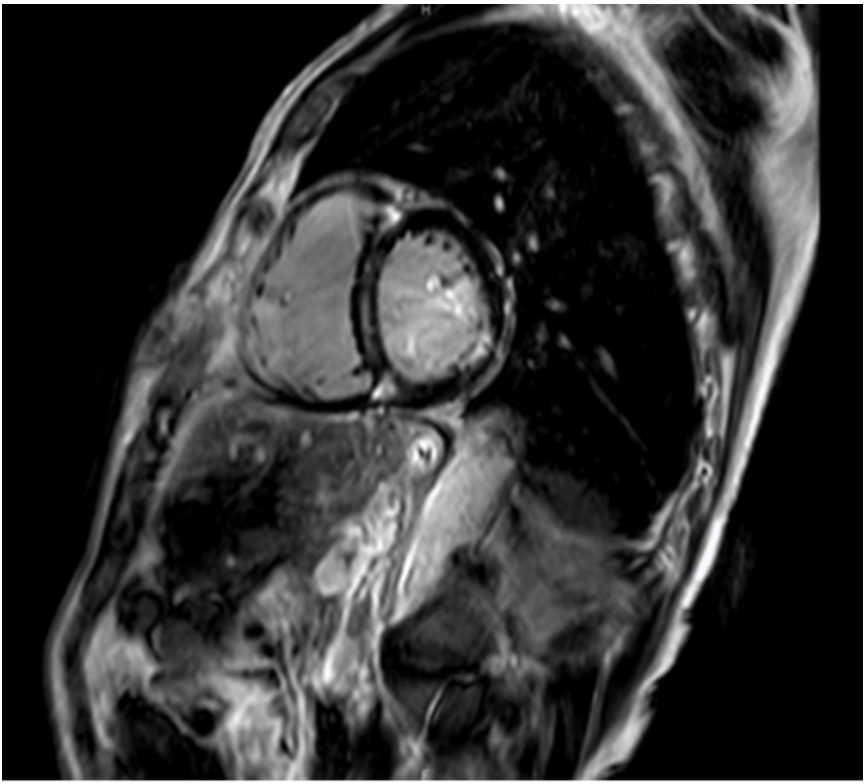

**Efficacité incomplète**

*Sapp et al; N Engl J Med 2016*

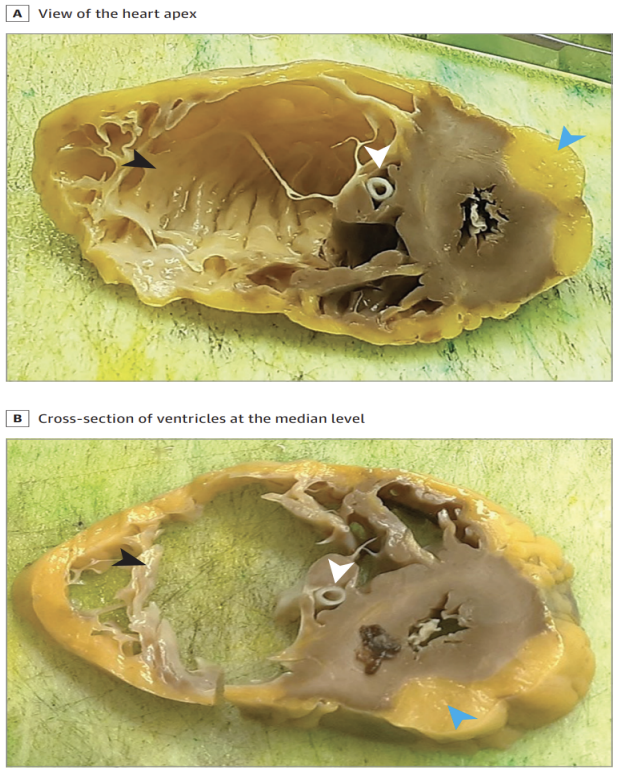
# Ablation par cathéter de TV

## *Les causes de ces échecs d'ablation*

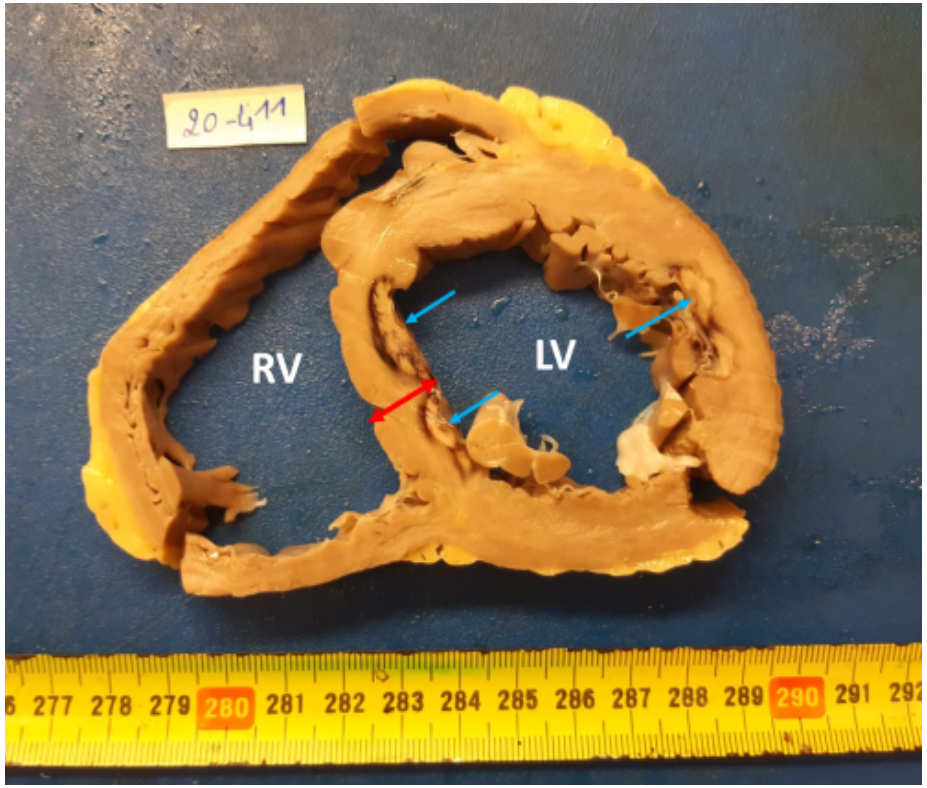
→ **Substrat midmyocardique**



→ **Substrats spécifiques**



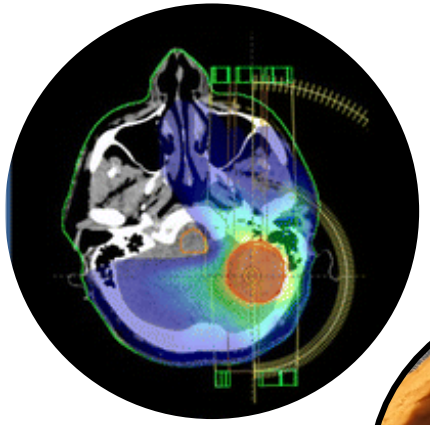

→ **Non transmuralité des lesions de RF**

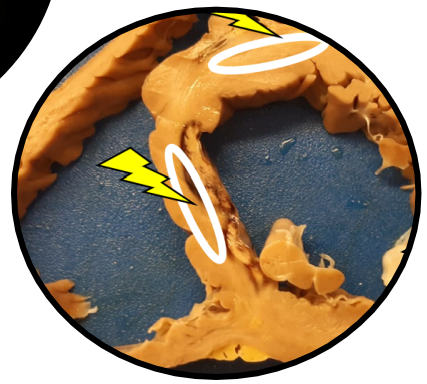



*Benali et al; JAMAcardio 2022*

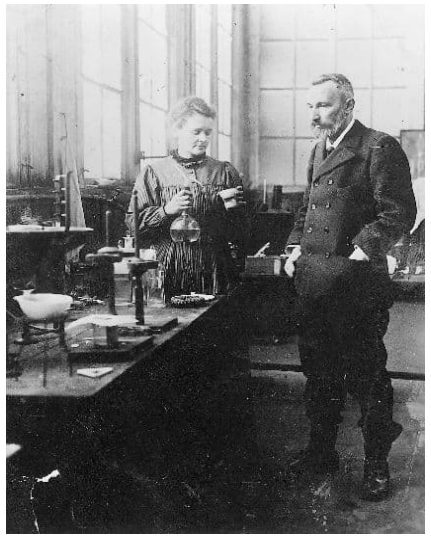
# Un besoin d'alternatives

## *Radiochirurgie pour les arythmies ventriculaires ?*



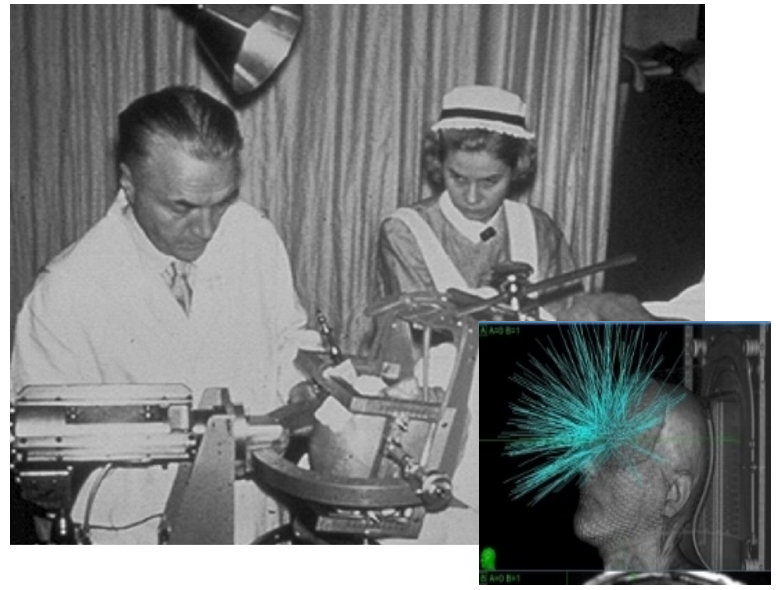


*M.Curie, 1895*



*Bertha Röngten, 1895*

*Lars Leksell, Stockholm 1967, Leksell Gamma Knife*



| Radiosurgery | Radiotherapy |
|---|---|
| 1-5 fractions | 30-45 fractions |
| high dose (6-25 Gy per fraction) | low dose (about 2 Gy per fraction) |
| 150-200 beams per fraction | 5-10 beams per fraction |
| < 1 mm targeting accuracy | 3-20 mm targeting accuracy |
| tumor ablation | tumor control |

. **Radiochirurgie** en *alternative non-invasie* pour cibler un substrat arythmogène

1 ⇒ **Très haute dose de radiation** *(dose ablative)*

2 ⇒ **Volulme cible très limité** *(haute précision)*

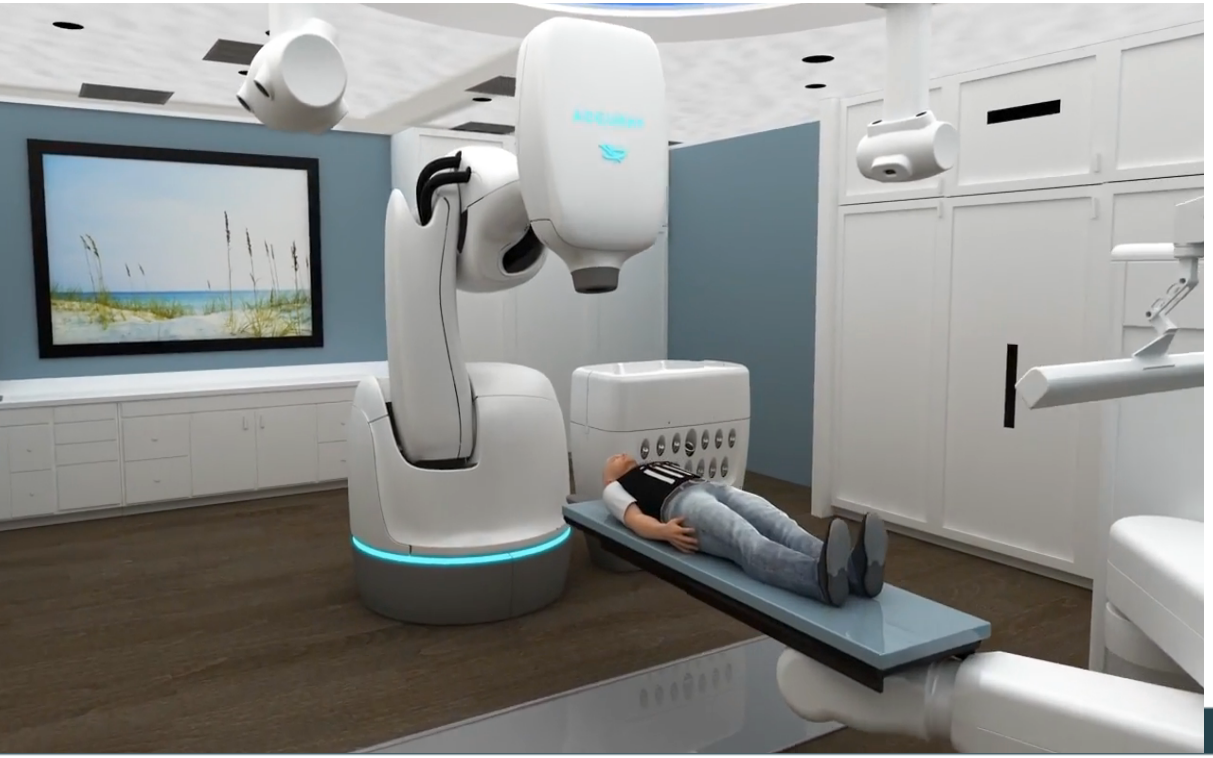
3 ⇒ **En une seule session** *(radioabaltion)*

# Radioablation cardiaque
## *Plateformes de traitement*

### *CyberKnife*

**25 Gy**
**to the target**

### *C-arm Linac*



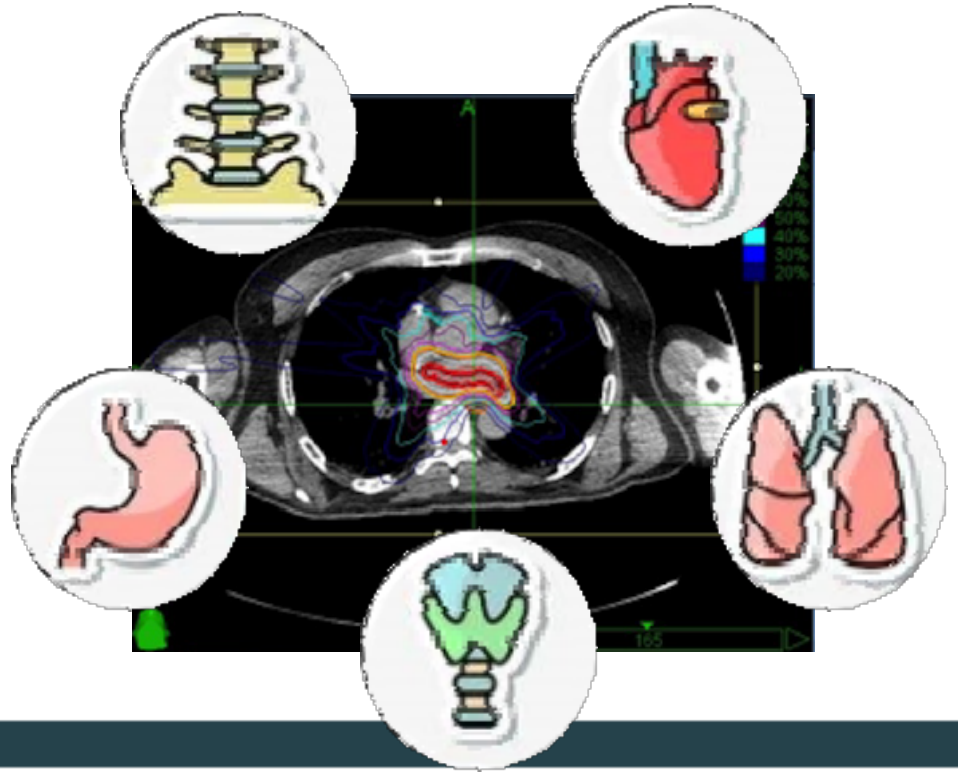
# Les problèmes potentiels
## *Organes à risque*

CATHETER ABLATION PROCEDURE

→ 0.025 Gy

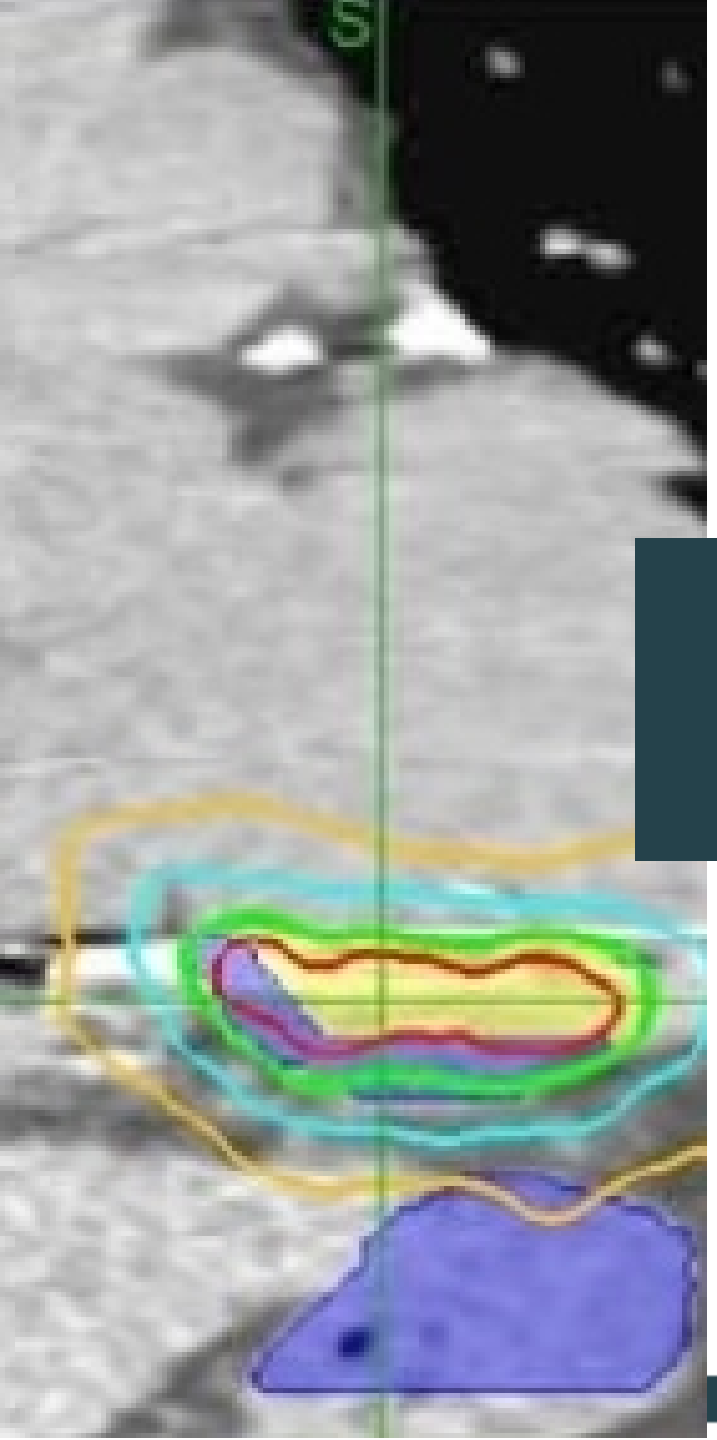
CYBERHEART TREATMENT

→ 25 Gy /100mm³



## Contraintes de dose pour les OAR

| Organs at risk | Dose recommendations/dose limitations |
|---|---|
| Aorta | Dose limitations: $D_{max} \leq 20.0$ Gy<br>Minor protocol deviation: 20 Gy $< D_{max} \leq 25$ Gy<br>Major protocol violation: $D_{max} > 25$ Gy |
| Left coronary arteries | Dose limitations: $D_{max} \leq 14.0$ Gy<br>Minor protocol deviation: 14 Gy $< D_{max} \leq 20$ Gy<br>Major protocol violation: $D_{max} > 20$ Gy |
| Superior vena cava | Dose recommendations: $D_{50\%} \leq 0.6$ Gy |
| Left atrium | Dose recommendations: $D_{max} \leq 4.4$ Gy |
| Whole heart minus PTV | Dose recommendations: $D_{50\%} \leq 5$ Gy |
| Esophagus | Dose limitations: $D_{max} \leq 14.5$ Gy and $V_{9Gy} \leq 1$ ccm<br>Minor protocol deviation: $D_{max} \leq 19$ Gy, $D_{1ccm} \leq 14.5$ Gy and $V_{9\,Gy} \leq 4$ ccm<br>Major protocol violation: $D_{max} > 19$ Gy ‖ $D_{1ccm} > 14.5$ Gy ‖ $V_{9\,Gy} > 4$ ccm |
| Trachea | Dose limitations: $D_{max} \leq 15$ Gy and $V_{10\,Gy} \leq 1$ ccm<br>Minor protocol deviation: $D_{max} \leq 20$ Gy, $D_{1\,ccm} \leq 15$ Gy and $V_{10\,Gy} \leq 4$ ccm<br>Major protocol violation: $D_{max} > 20$ Gy ‖ $D_{1\,ccm} > 15$ Gy ‖ $V_{9\,Gy} > 4$ ccm |
| Bronchial tree | Dose limitations: $D_{max} \leq 15$ Gy and $V_{10Gy} \leq 1$ ccm<br>Minor protocol deviation: $D_{max} \leq 20$ Gy, $D_{1\,ccm} \leq 15$ Gy and $V_{10\,Gy} \leq 4$ ccm<br>Major protocol violation: $D_{max} > 20$ Gy ‖ $D_{1\,ccm} > 15$ Gy ‖ $V_{9\,Gy} > 4$ ccm |
| Spinal canal | Dose limitations: $D_{max} \leq 7$ Gy and $V_{6\,Gy} \leq 0.1$ ccm<br>Minor protocol deviation: $D_{max} \leq 8$ Gy, $V_{6\,Gy} \leq 1$ ccm<br>Major protocol violation: $D_{max} > 8$ Gy ‖ $V_{6\,Gy} > 1$ ccm |
| Skin | Dose limitations: $D_{max} \leq 14.4$ Gy and $V_{10\,Gy} \leq 10$ ccm<br>Minor protocol deviation: $D_{max} \leq 16$ Gy, $V_{14.4\,Gy} \leq 10$ ccm<br>Major protocol violation: $D_{max} > 16$ Gy ‖ $V_{14.4\,Gy} > 10$ ccm |
| Whole lungs | Dose limitations: $V_{100\%} - V_{7Gy} \geq 1500$ ccm ($V_{7\,Gy}$ remaining volume > 1500 ccm) and $D_{5\%} \leq 20$ Gy and $D_{50\%} \leq 3.5$ Gy<br>Minor protocol deviation: $V_{100\%} - V_{7Gy} \geq 1000$ ccm ($V_{7\,Gy}$ remaining volume > 1000 ccm), $D_{6.5\%} \leq 20$ Gy and $D_{50\%} \leq 5$ Gy<br>Major protocol violation: $V_{100\%} - V_{7\,Gy} < 1000$ ccm ($V_{7\,Gy}$ remaining volume < 1000 ccm), $D_{6.5\%} > 20$ Gy and $D_{50\%} > 5$ Gy |
| ICD (major electronics) | Dose limitations: $D_{max} \leq 0.5$ Gy and blocked from primary beam irradiation<br>Minor protocol deviation: 0.5 Gy $< D_{max} \leq 1.0$ Gy<br>Major protocol violation: $D_{max} > 1.0$ Gy |



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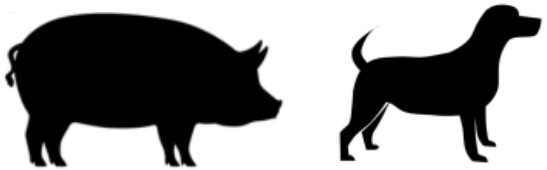
# *Ablation non-invasive de TV: Données chez l'homme*

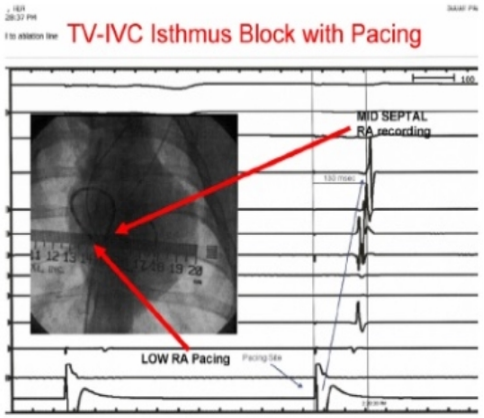
# Radioablation cardiaque

## *De la preuve de concept aux premiers essais*

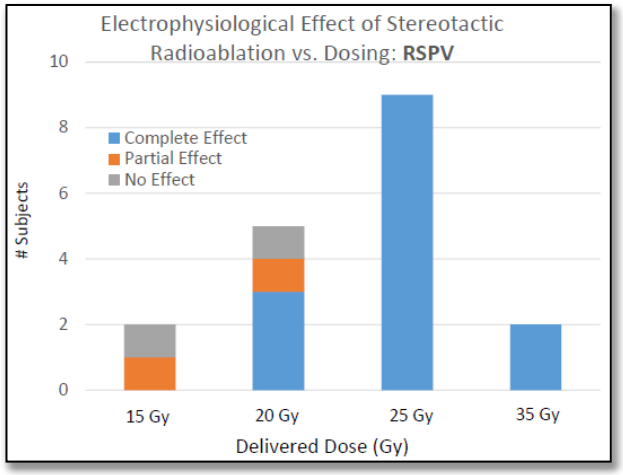
***Sharma et al, Heart Rhythm 2010***

***Zei et al, Heart Rhythm 2018***



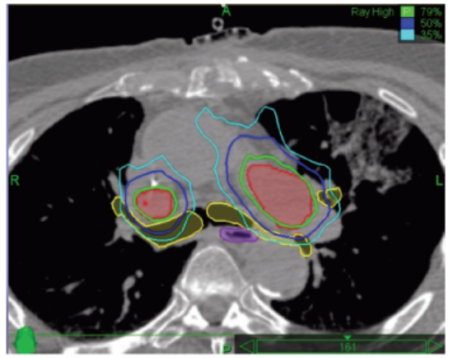







*A Case Report*

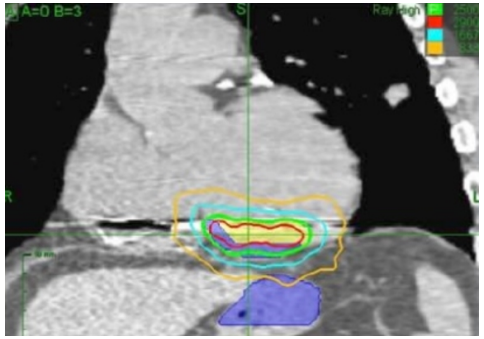
**Stereotactic Radiosurgery for a Cardiac Sarcoma: A Case Report**



***Soltys SG, Technol Cancer Res Treat 2008***

**Stereotactic Ablative Radiotherapy for the Treatment of Refractory Cardiac Ventricular Arrhythmia**

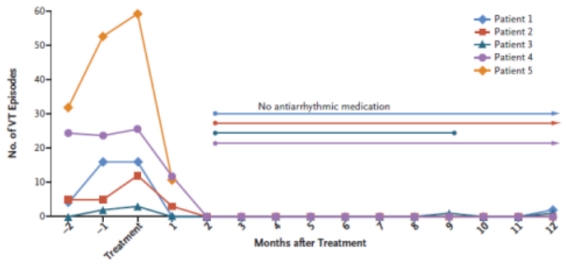
Billy W. Loo, Jr, MD, PhD*; Scott G. Soltys, MD*; Lei Wang, PhD; Anthony Lo, MS; Benjamin P. Fahimian, PhD; Andrei Iagaru, MD; Linda Norton, RN, MSN; Xin Shan, BS, BAH; Edward Gardner, PhD; Thomas Fogarty, MD; Patrick Maguire, MD, PhD; Amin Al-Ahmad, MD; Paul Zei, MD, PhD



***Loo BW, Circ AE 2015***

Noninvasive Cardiac Radiation for Ablation of Ventricular Tachycardia

Phillip S. Cuculich, M.D., Matthew R. Schill, M.D., Rojano Kashani, Ph.D., Sasa Mutic, Ph.D., Adam Lang, M.D., Daniel Cooper, M.D., Mitchell Faddis, M.D., Ph.D., Marye Gleva, M.D., Amit Noheria, M.B., B.S., Timothy W. Smith, M.D., D.Phil., Dennis Hallahan, M.D., Yoram Rudy, Ph.D., and Clifford G. Robinson, M.D.

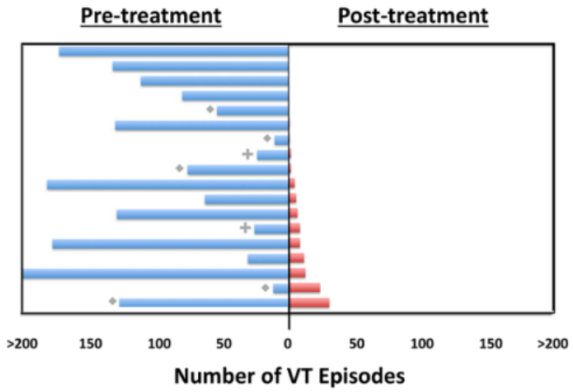



***Cuculich PS, NEJM 2017***

Circulation

ORIGINAL RESEARCH ARTICLE

**Phase I/II Trial of Electrophysiology-Guided Noninvasive Cardiac Radioablation for Ventricular Tachycardia**




***Robinson CG, Circulation 2019***

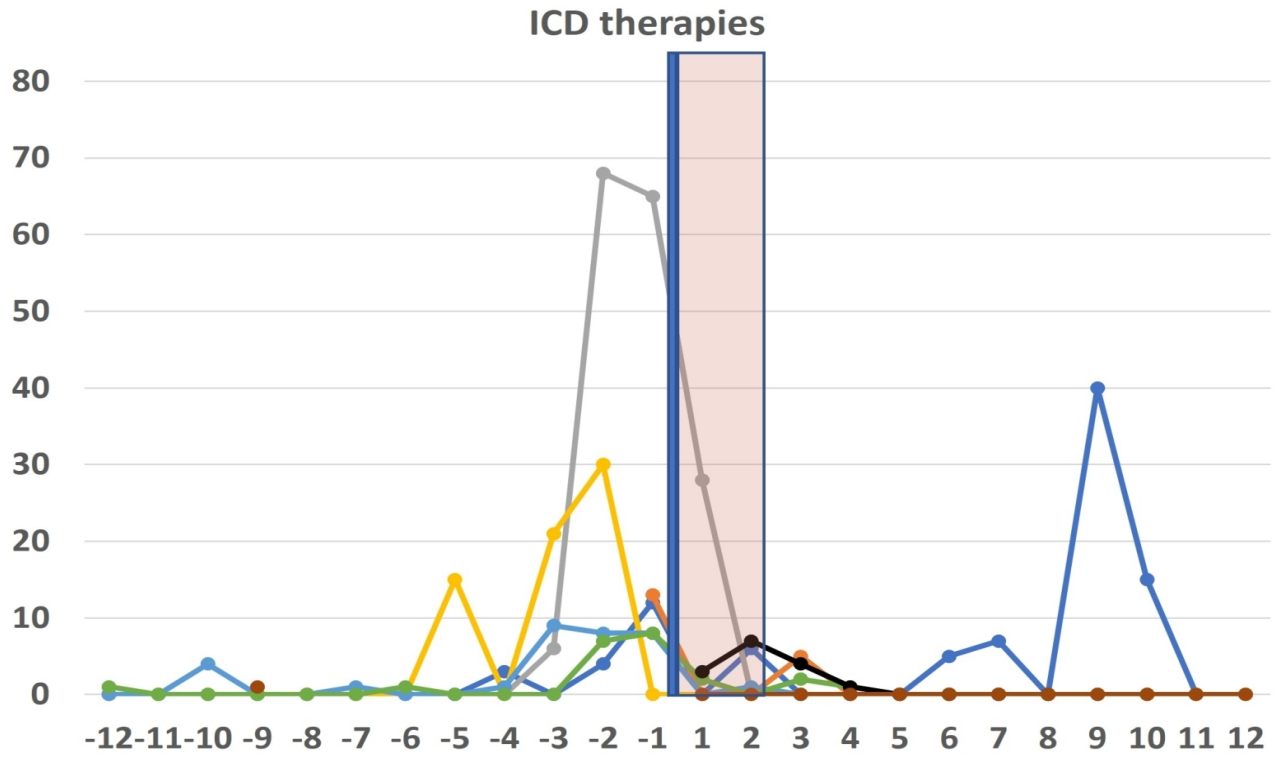
# Expérience locale

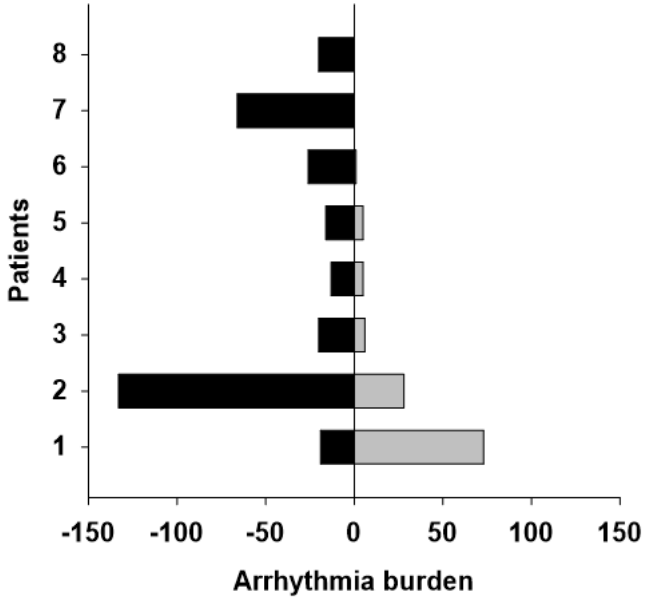
## *Super-répondeurs et non-répondeurs*

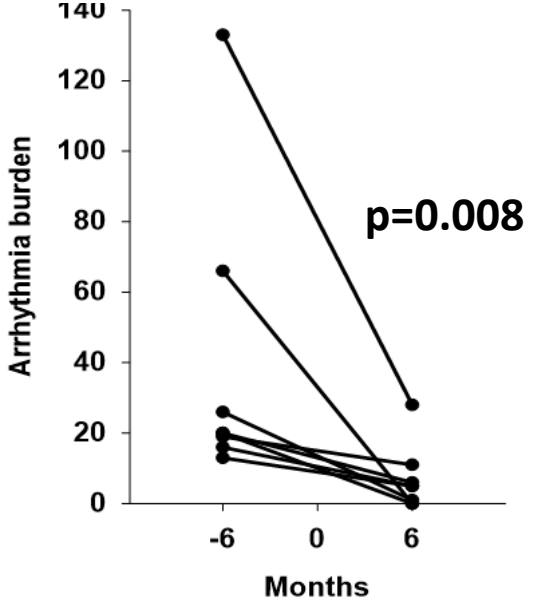
CHU Rennes

Centre Hospitalier Universitaire Saint-Etienne

CHU Centre Hospitalier Universitaire Dijon Bourgogne



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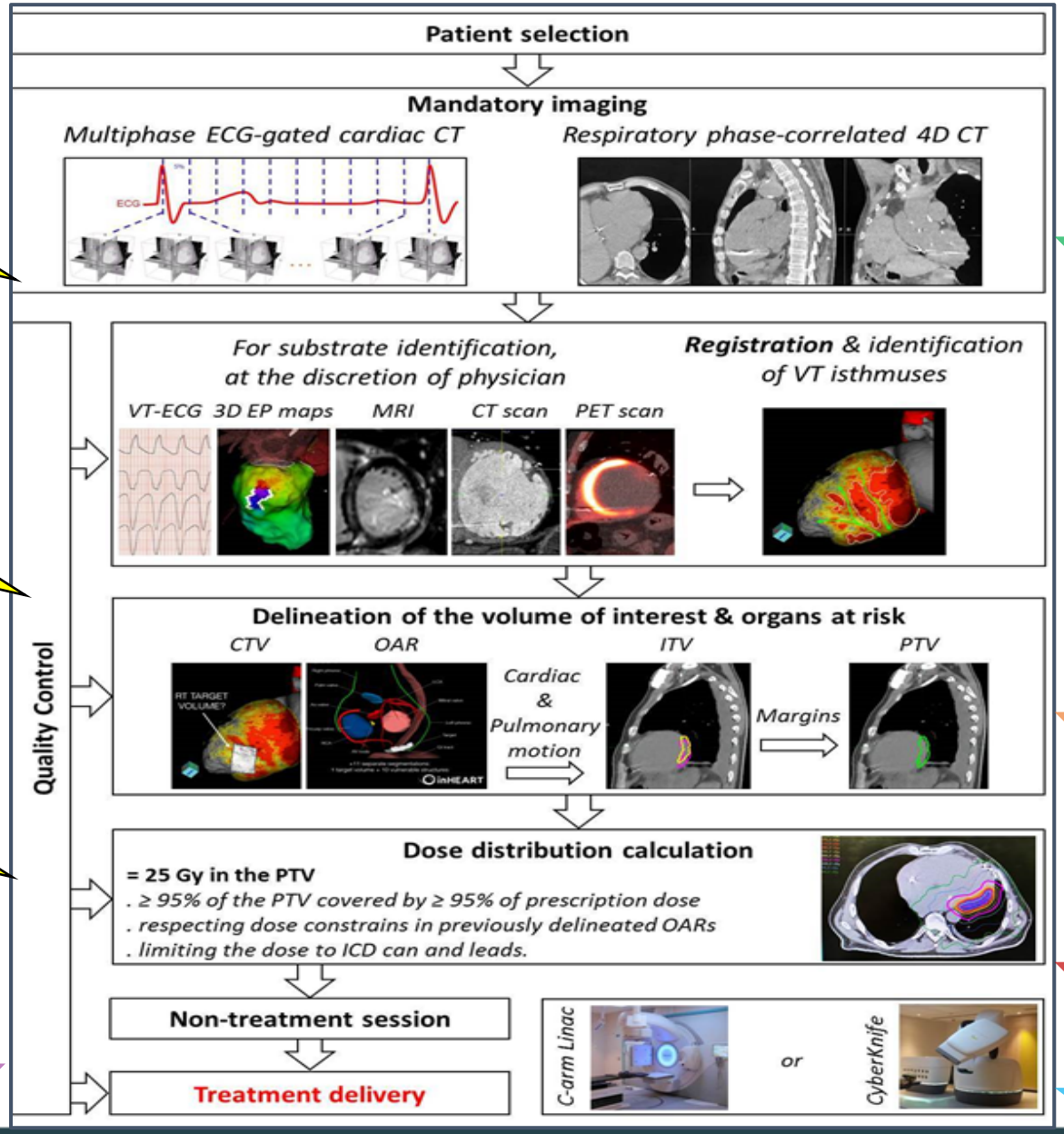
# *Comment réaliser une procédure de Radioablation cardiaque*

# Workflow radioablation cardiaque

## *Un traitement pour le jour suivant ?*




**Cardiologist**
**1 week**

**Cardiologist / Radiation oncologist**
**1-2 weeks**

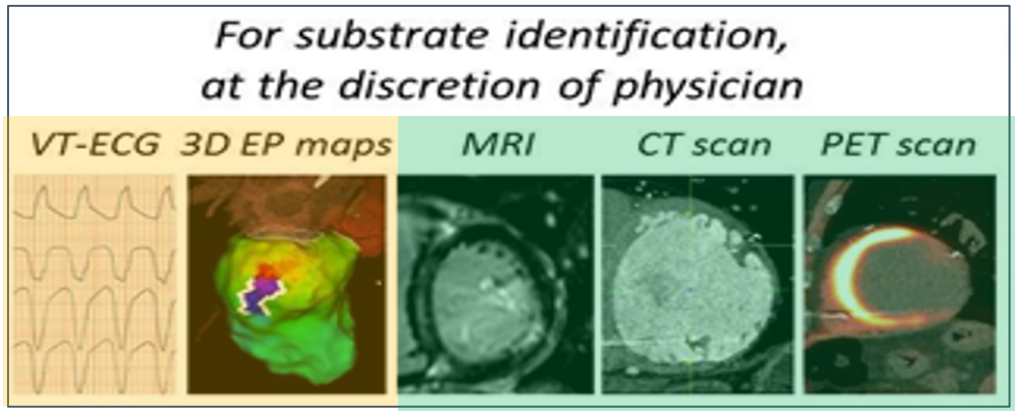
**Radiation oncologist**
**1 week**

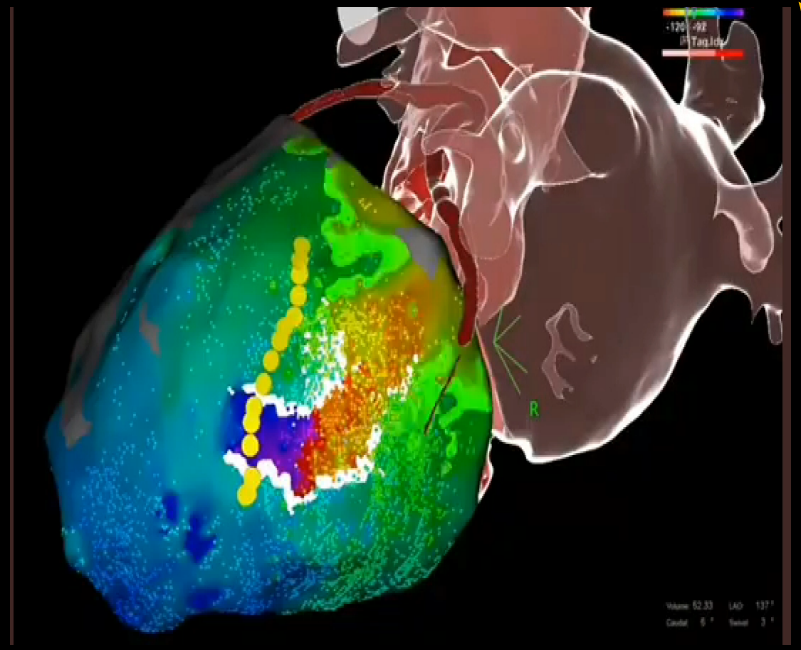
**Treatment**
**1 week**

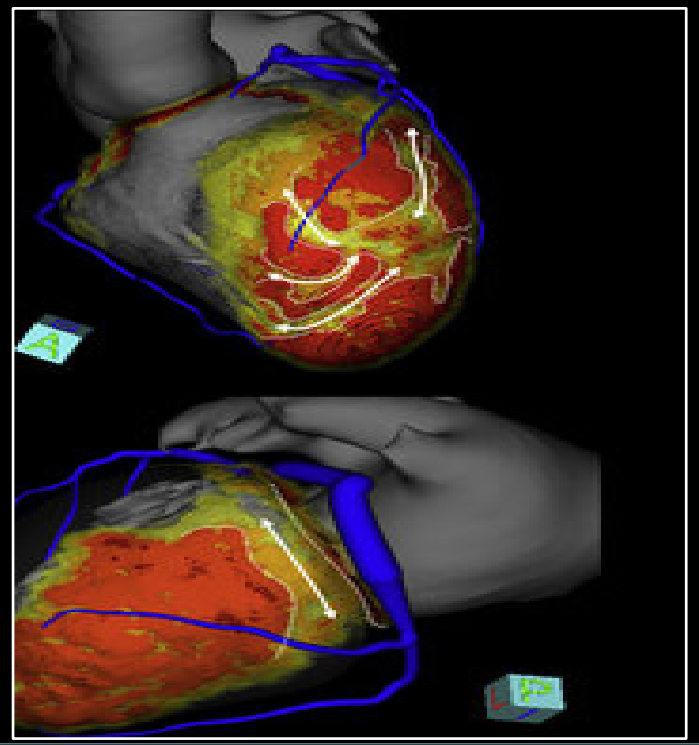
*Benali et al, J Med Imag Rad Sci 2021*

# Etape cardiologique majeure

## *Définition de la cible*



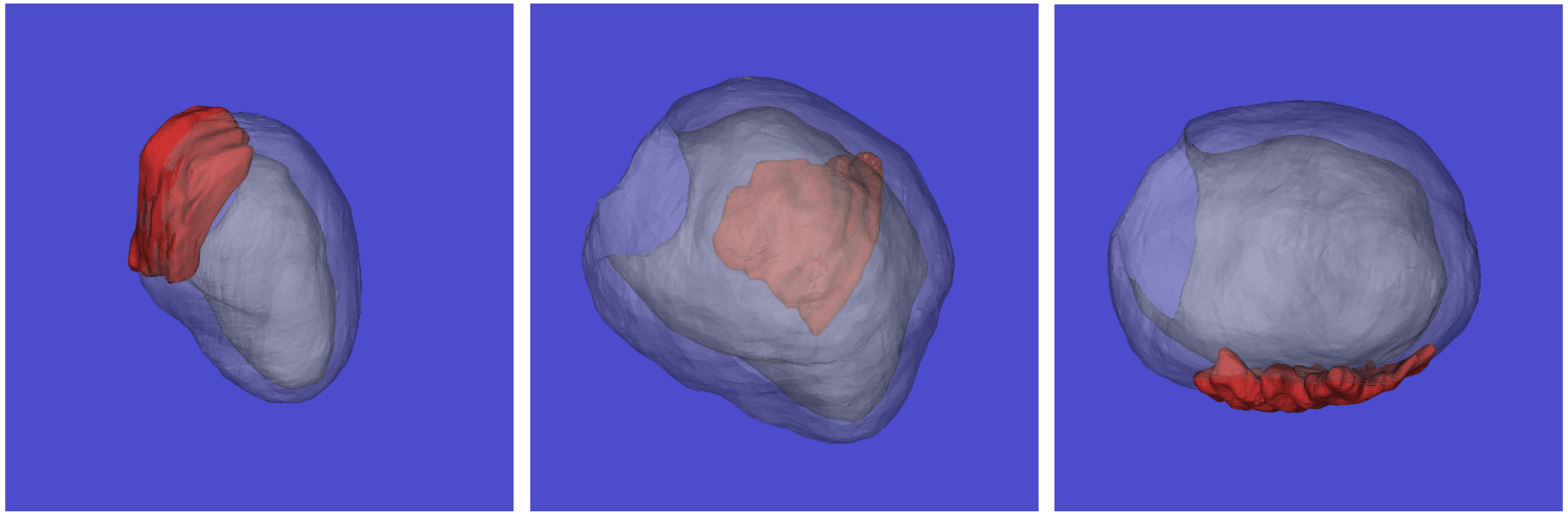





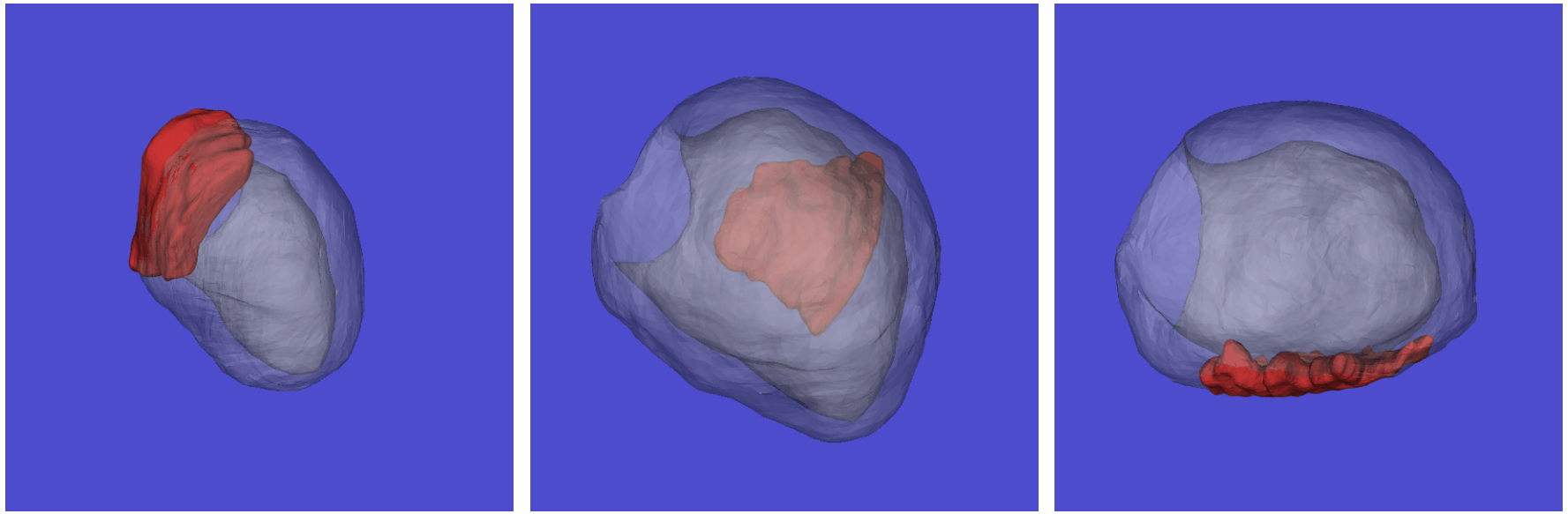
# Problématique majeure

## *Gestion du mouvement cardio-respiratoire*

Respiratory motion

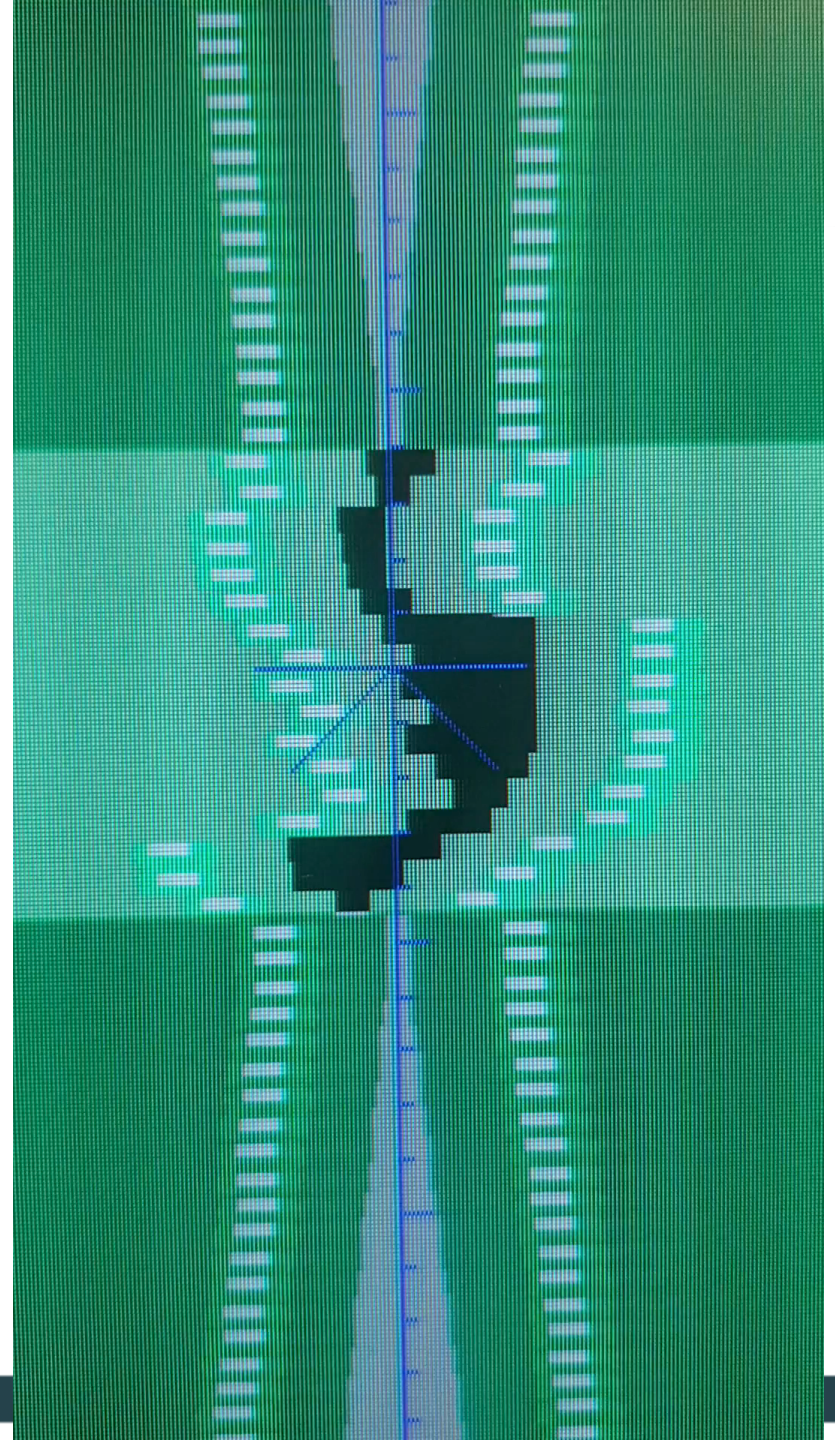


Cardiac motion



# Traitement= 15-20 minutes

**Painless / No Sedation / No Hospitalization ?**

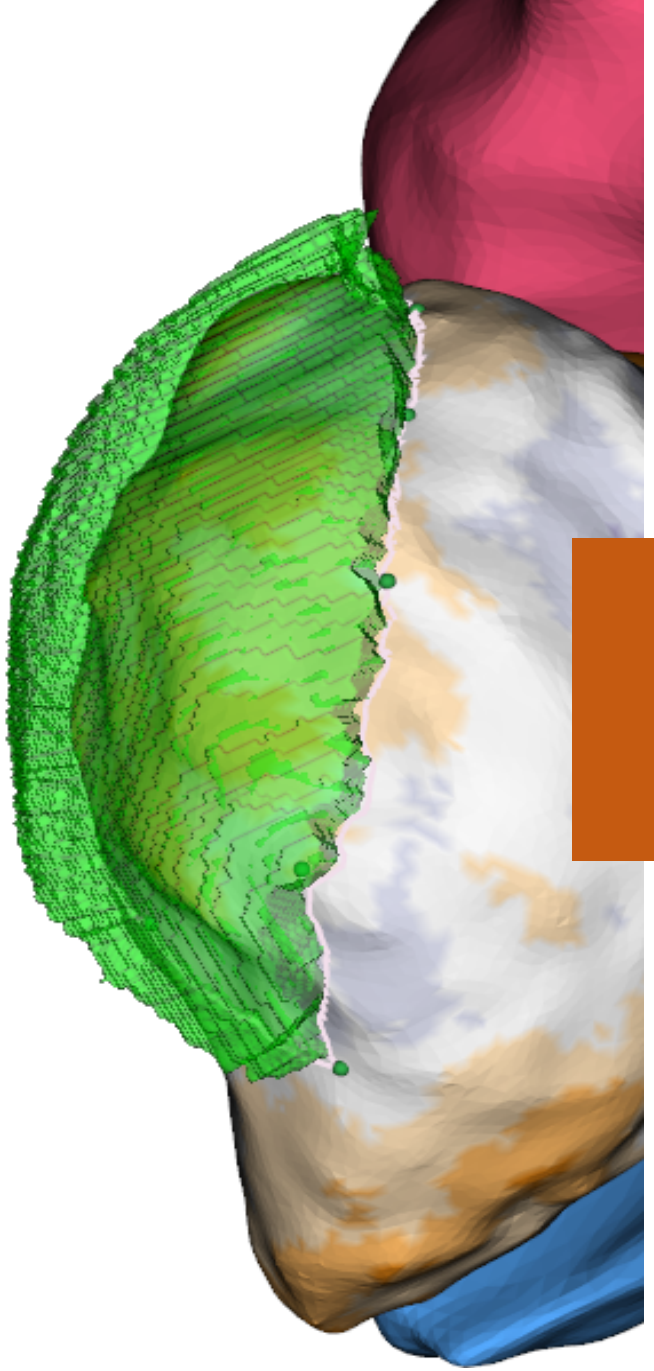



# Radioablation cardiaque

## *Le futur de l'ablation de TV ?*



VS



# 4 *Défis majeurs*

# Radioablation cardiaque

*Nombreuses questions sans réponse…*

## Ce que l'on sait

- **Efficace à court terme pour les patients avec arythmies réfractaires !!!**

## Ce que l'on ignore

- **Qui traiter et quand ?**
- **Doses limites pour les organes à risque ?**
- **Améliorer la sécurité de la thérapie -> Meilleur intégration des mouvements CR**
- **Durabilité ?**
- **Effets secondaires à long termes…**

# Question sans réponse claire

## *Mécanismes d'action*

**« Radio-guérison »**

nature communications

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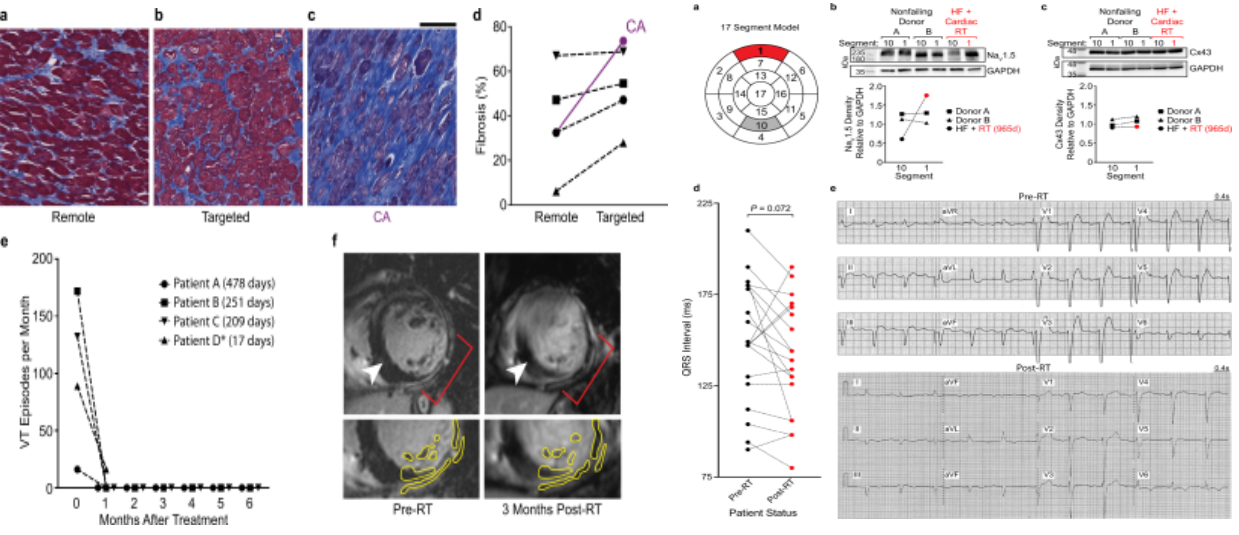
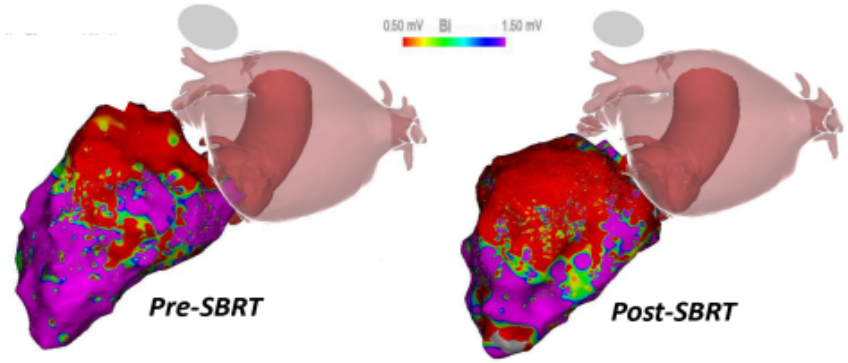
Article | Open Access | Published: 24 September 2021

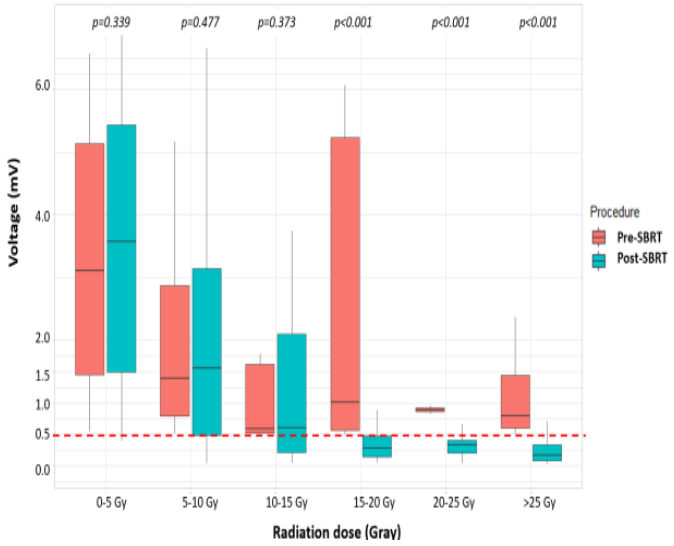
**Cardiac radiotherapy induces electrical conduction reprogramming in the absence of transmural fibrosis**




*Zhang et al; NatureCom. 2021*

**Ou radio-ablation…**




Today 25 Gy

↓

Tomorrow?

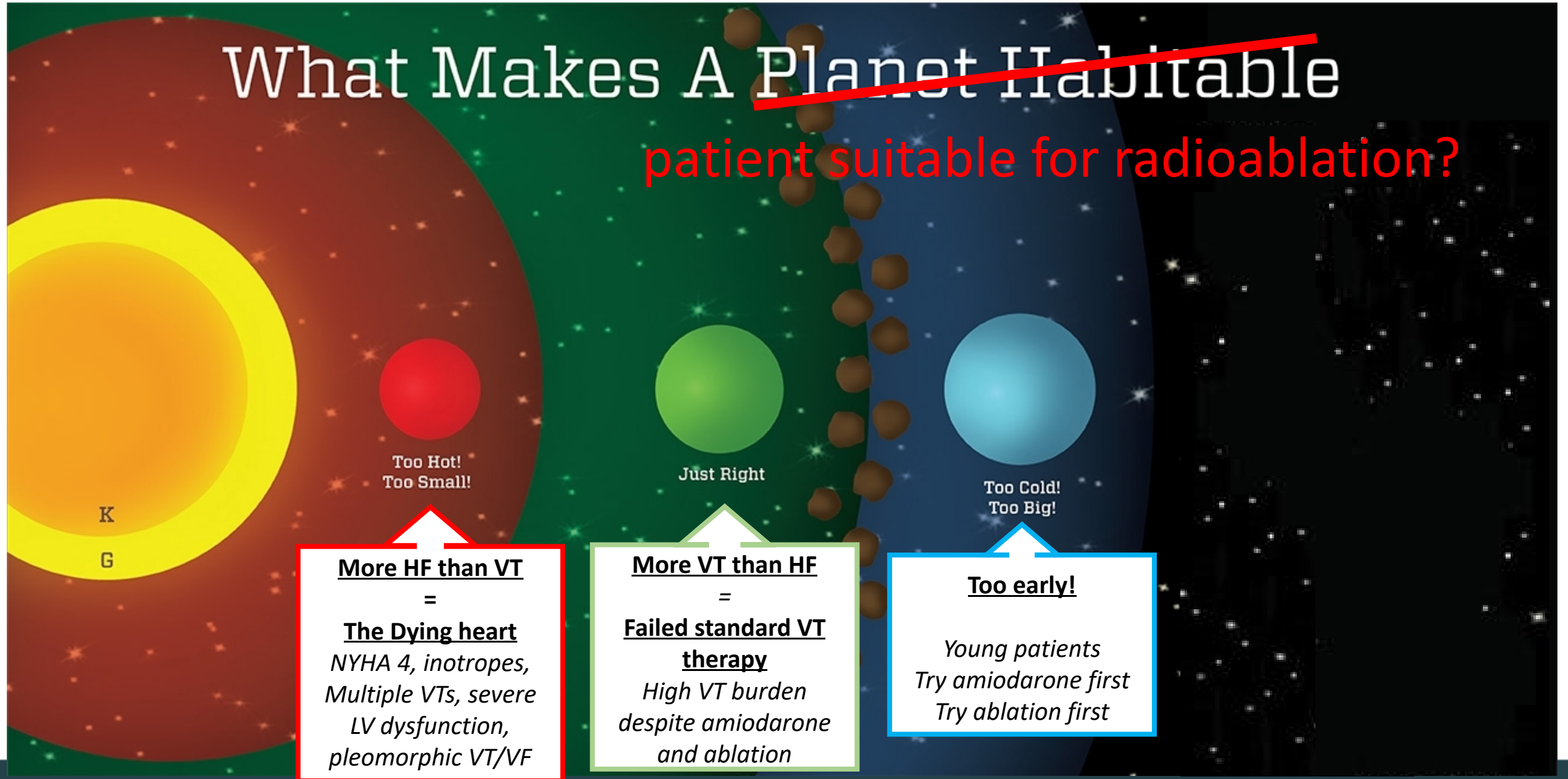
15 - 20 Gy?

A lower dose may be sufficient ?

*Benali et al; Heart Rhythm 2022*

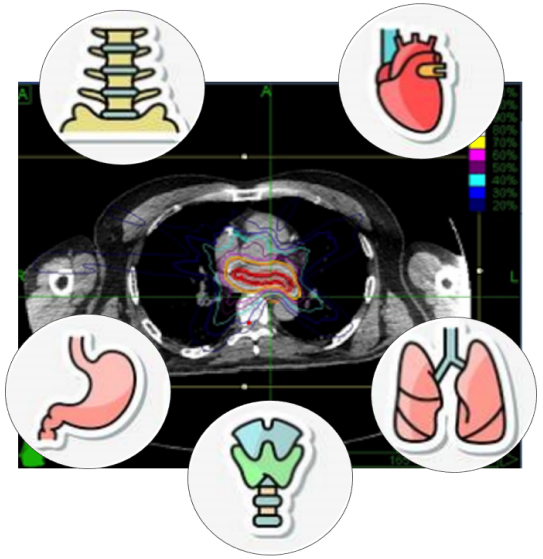
# Questions sans réponse claire

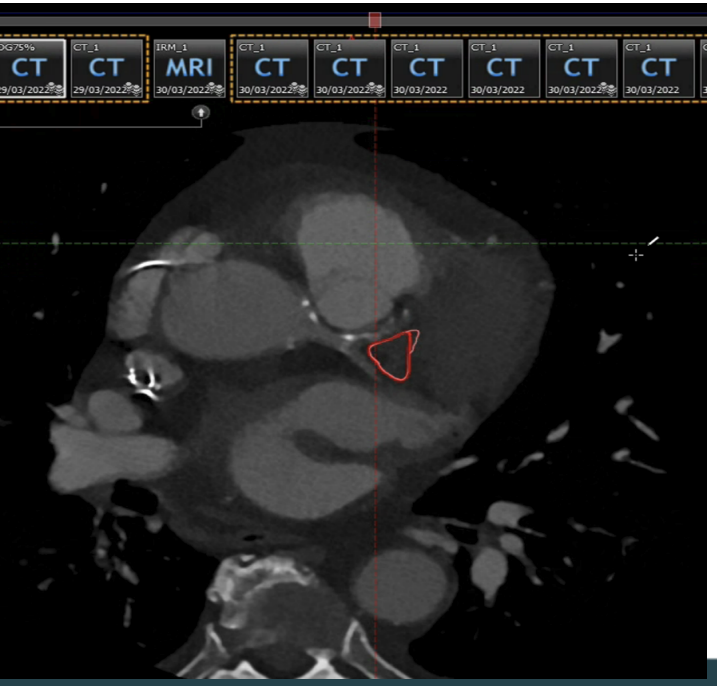
## *Qui traiter et quand traiter !*

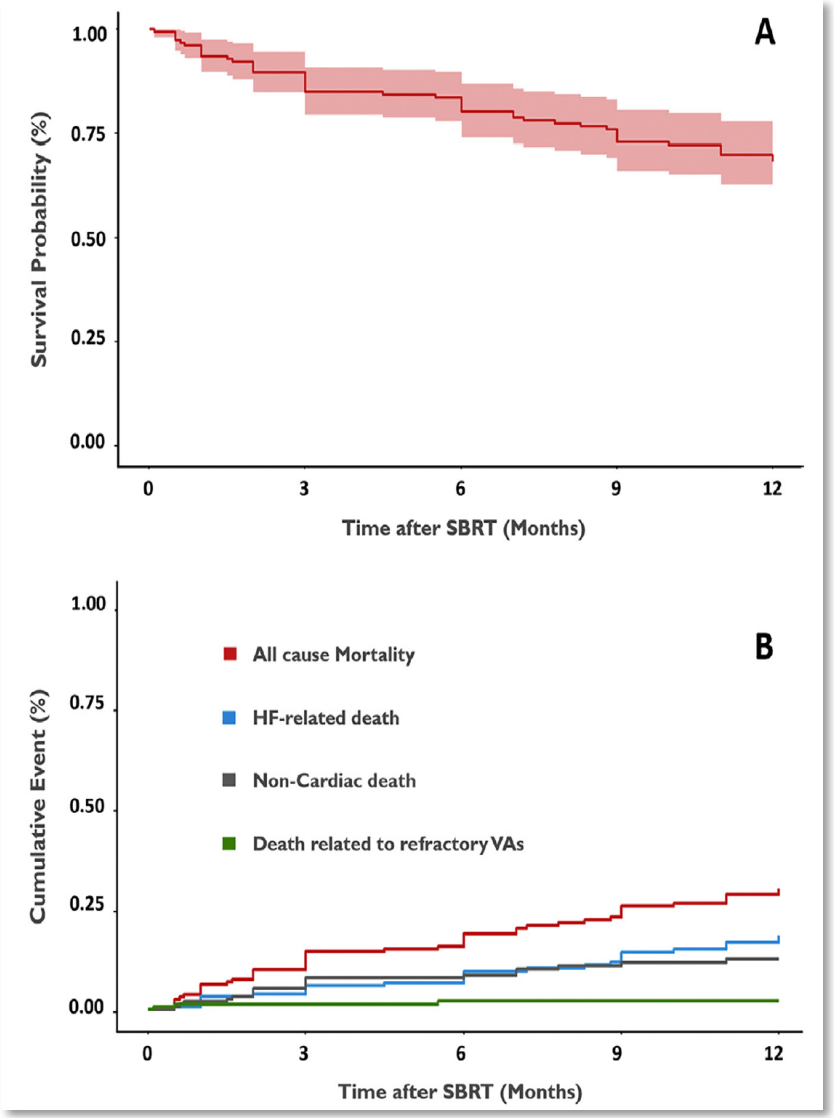


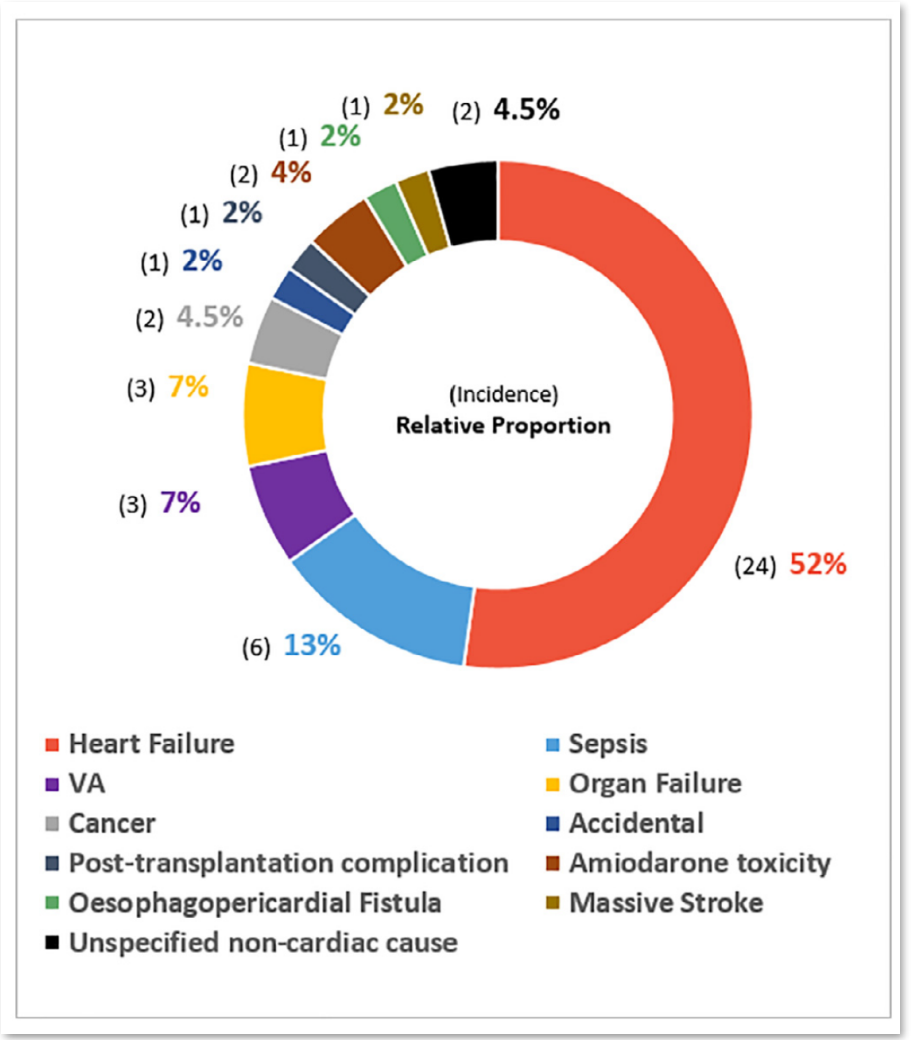
# Effets secondaires à long terme

## *Un vrai débat ?*





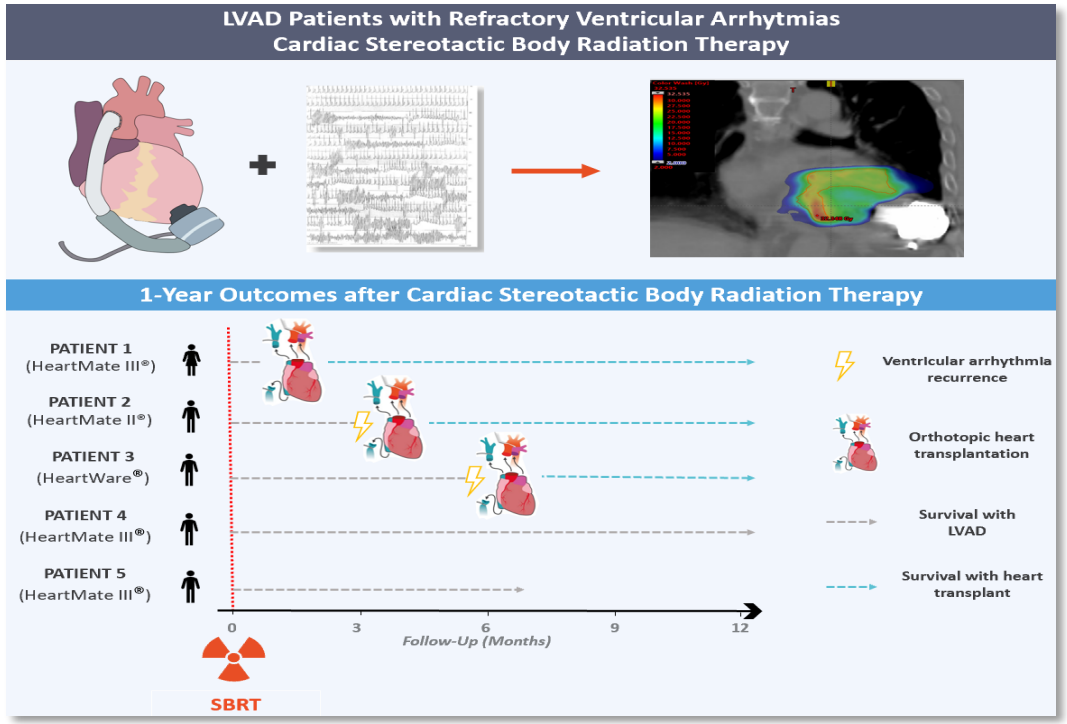


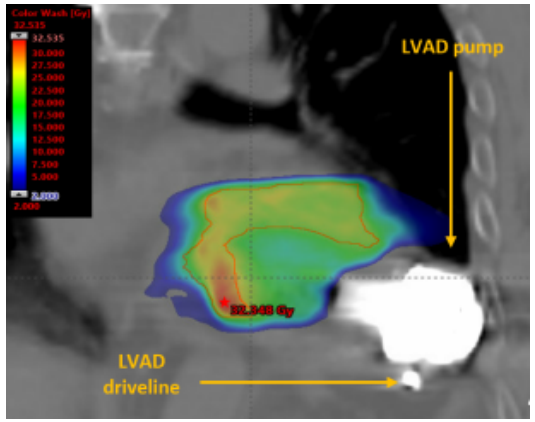



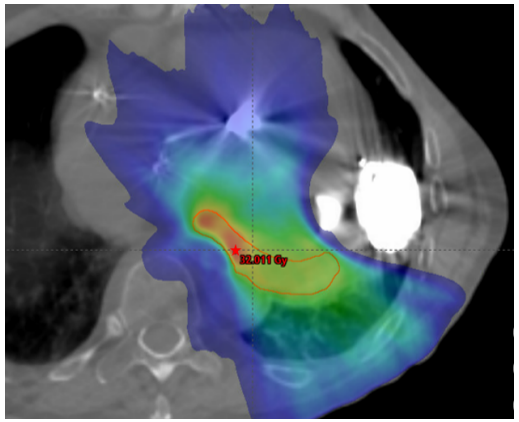

*Benali et al, Trends in Cardiovascular Med, 2023*

# Une niche condamnée à se réduire encore plus ?

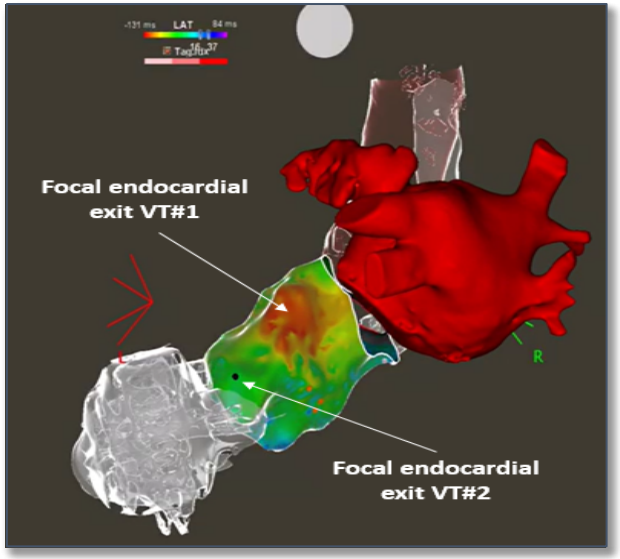
## *Arrivée de nouveaux outils*

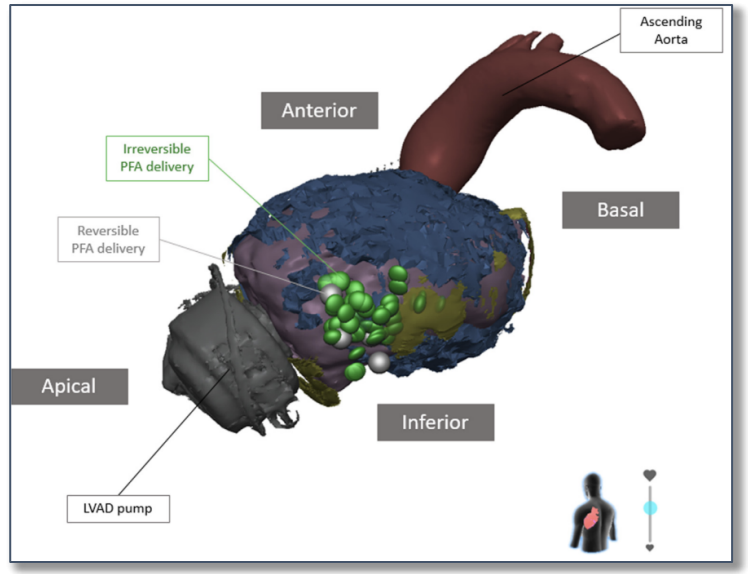


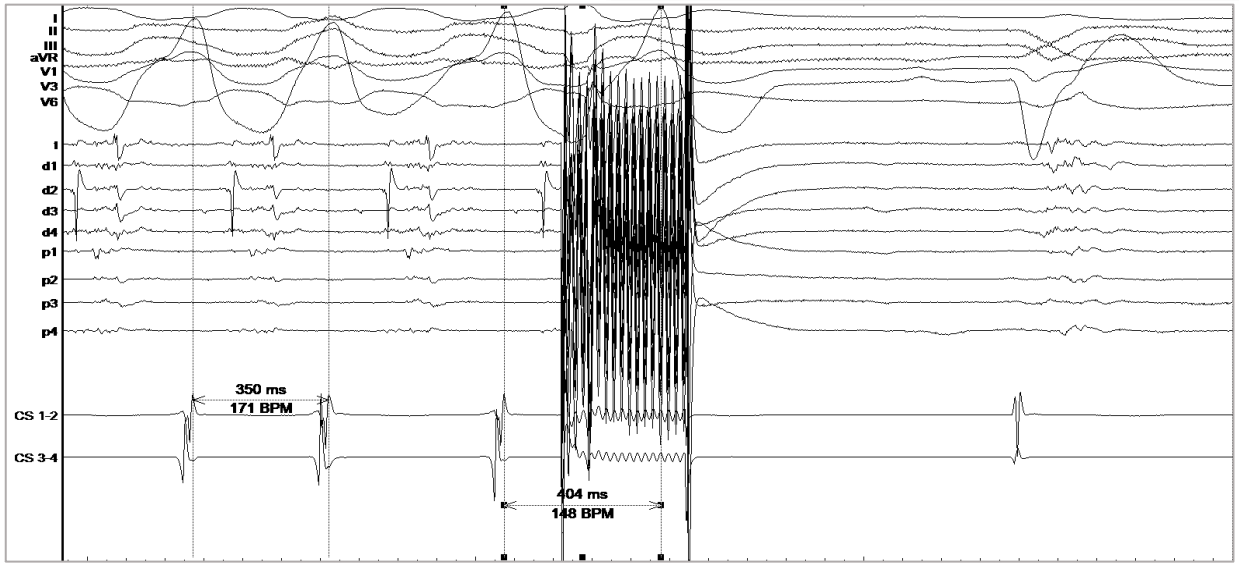



*Benali et al, JACCep 2022*




*Benali et al, JACCep 2024*

# Conclusion

## *Radioabaltion cardiaque: Promesse ou réalité ?*

*reality?*

### *Promesses de la Radioablation cardiaque*

→ **Rapide**
→ **Non-invasive**
→ **Efficace pour résoudre des impasses thérapeutiques**
**(Thérapie de dernière ligne !!!!!!!)**

**Ce qu'il faut éviter…**

PROMISE

REALITY

**-> Optimisation des contraintes de dose**
**-> Efficacité et sécurité à long termes**
**-> Collaboration radiothérapeutes/ cardiologue**

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# Thank you for your attention