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ISMRM & ISMRT ANNUAL MEETING & EXHIBITION
TORONTO 03-08 JUNE 2023

Declaration of Financial Interests or Relationships

Speaker Name: Kagayaki Kuroda

I have no financial interests or relationships to disclose with regard to the subject matter of this presentation.

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Topics

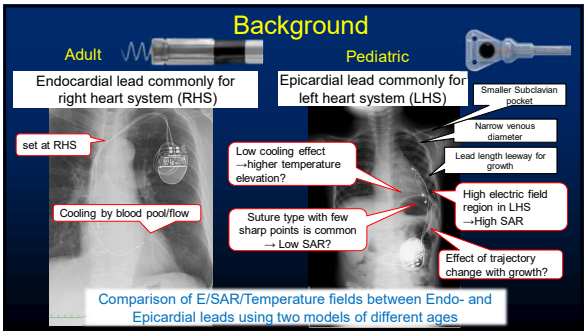
1. To assess MR safety of pediatric patient with cardiac pacemaker, difference and change of RF-induced tissue heating around epicardial and endocardial leads in growing patient were simulated.

2. To clarify how abandoned leads behave differently from connected leads, the heating property was evaluated in the light of inductive and conductive currents.

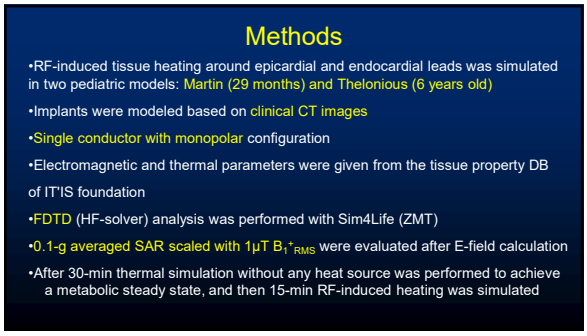
3

Epicardial and endocardial leads in growing patient

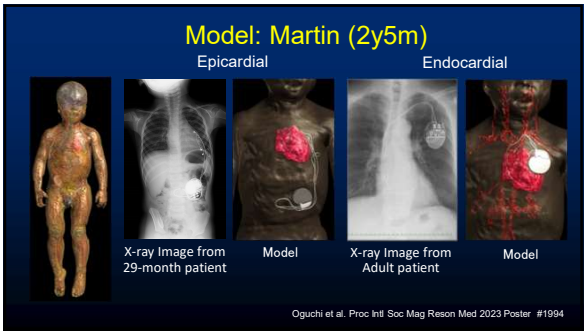
4


Background
Adult
Pediatric
Endocardial lead commonly for right heart system (RHS)
Epicardial lead commonly for left heart system (LHS)
Smaller Subclavian pocket
Narrow venous diameter
Lead length leeway for growth
set at RHS
Low cooling effect →higher temperature elevation?
Cooling by blood pool/flow
Suture type with few sharp points is common → Low SAR?
High electric field region in LHS →High SAR
Effect of trajectory change with growth?
Comparison of E/SAR/Temperature fields between Endo- and Epicardial leads using two models of different ages

5


Methods
•RF-induced tissue heating around epicardial and endocardial leads was simulated in two pediatric models: Martin (29 months) and Thelonious (6 years old)
•Implants were modeled based on clinical CT images
•Single conductor with monopolar configuration
•Electromagnetic and thermal parameters were given from the tissue property DB of IT'IS foundation
•FDTD (HF-solver) analysis was performed with Sim4Life (ZMT)
•0.1-g averaged SAR scaled with 1μT $B_1{}^+_{RMS}$ were evaluated after E-field calculation
•After 30-min thermal simulation without any heat source was performed to achieve a metabolic steady state, and then 15-min RF-induced heating was simulated

6


Model: Martin (2y5m)
Epicardial
Endocardial
X-ray Image from 29-month patient
Model
X-ray Image from Adult patient
Model
Oguchi et al. Proc Intl Soc Mag Reson Med 2023 Poster #1994

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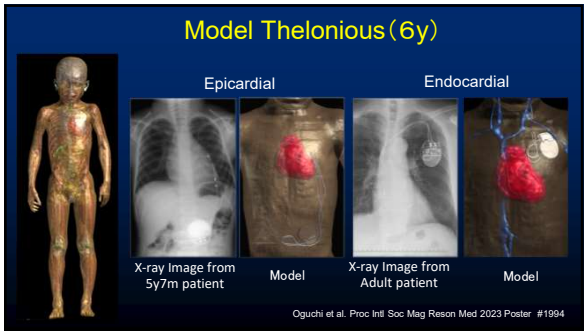
Model Thelonious（6y）
Epicardial
Endocardial
X-ray Image from 5y7m patient
Model
X-ray Image from Adult patient
Model
Oguchi et al. Proc Intl Soc Mag Reson Med 2023 Poster #1994

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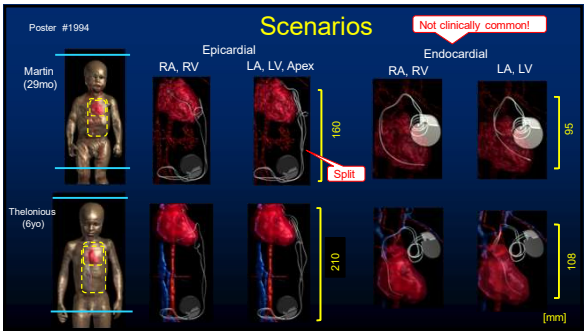
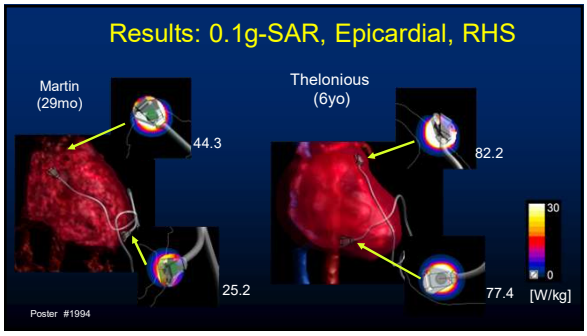
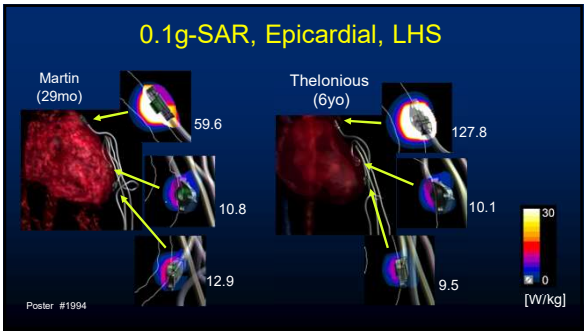

Poster #1994
Scenarios
Not clinically common!
Epicardial
RA, RV
LA, LV, Apex
Endocardial
RA, RV
LA, LV
Martin
(29mo)
Thelonious
(6yo)
160
95
210
108
Split
[mm]

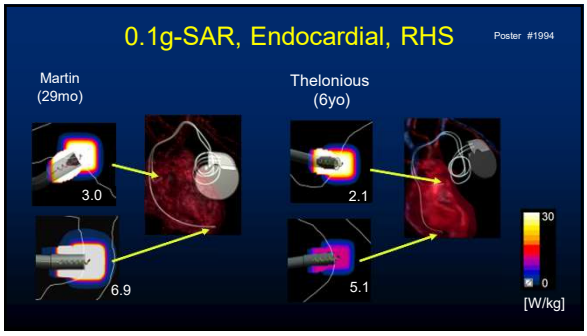
9


Results: 0.1g-SAR, Epicardial, RHS
Martin
(29mo)
Thelonious
(6yo)
44.3
25.2
82.2
77.4
30
0
[W/kg]
Poster #1994

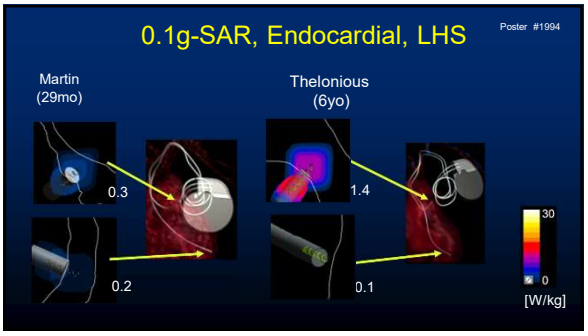
10


0.1g-SAR, Epicardial, LHS
Martin
(29mo)
Thelonious
(6yo)
59.6
10.8
12.9
127.8
10.1
9.5
30
0
[W/kg]
Poster #1994

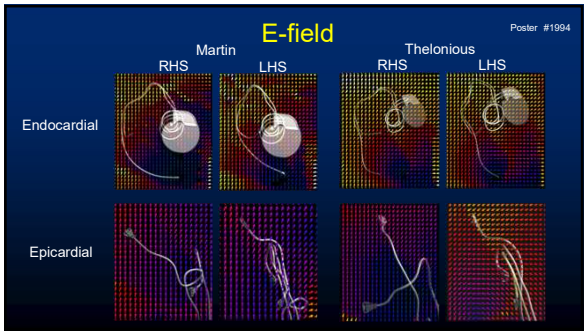
11


0.1g-SAR, Endocardial, RHS
Poster #1994
Martin
(29mo)
Thelonious
(6yo)
3.0
6.9
2.1
5.1
30
0
[W/kg]

12


0.1g-SAR, Endocardial, LHS
Poster #1994
Martin
(29mo)
Thelonious
(6yo)
0.3
0.2
1.4
0.1
30
0
[W/kg]

13


E-field
Poster #1994
Martin
Thelonious
RHS
LHS
RHS
LHS
Endocardial
Epicardial

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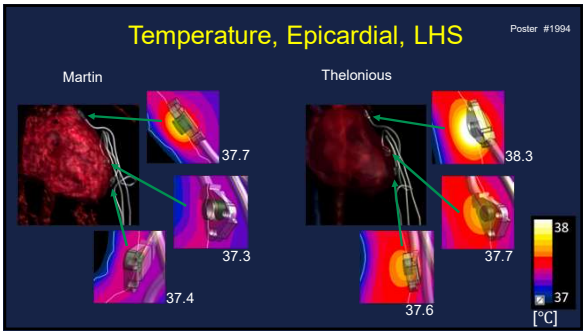
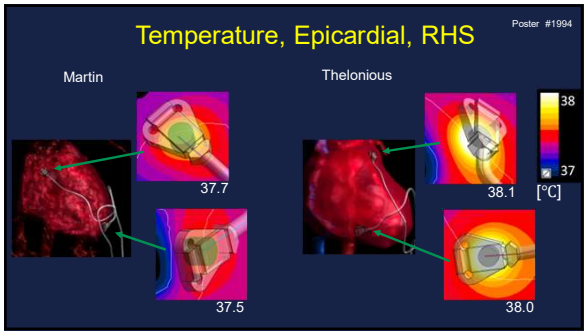
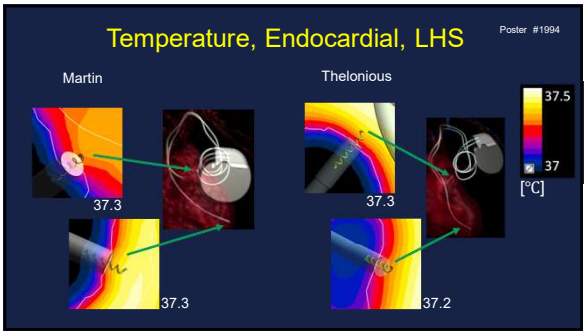

Temperature, Epicardial, LHS
Poster #1994
Martin
Thelonious
37.7
37.3
37.4
38.3
37.7
37.6
38
37
[°C]

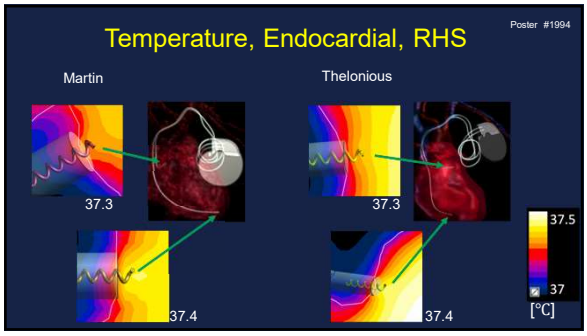
15


Temperature, Epicardial, RHS
Poster #1994
Martin
Thelonious
37.7
37.5
38.1
38.0
38
37
[°C]

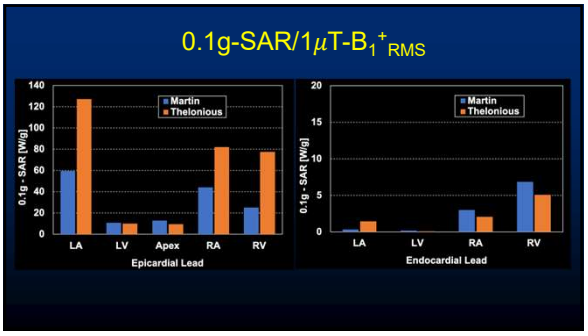
16


Temperature, Endocardial, LHS
Poster #1994
Martin
Thelonious
37.5
37
[°C]
37.3
37.3
37.3
37.2

17


Temperature, Endocardial, RHS
Poster #1994
Martin
Thelonious
37.3
37.3
37.5
37
[°C]
37.4
37.4

18


0.1g-SAR/1μT-B1+RMS
Martin
Thelonious
0.1g - SAR [W/g]
LA
LV
Apex
RA
RV
Epicardial Lead
Endocardial Lead

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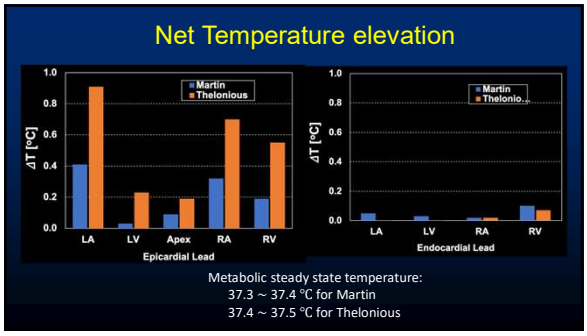
Net Temperature elevation
Martin
Thelonious
ΔT [°C]
LA
LV
Apex
RA
RV
Epicardial Lead
Endocardial Lead
Metabolic steady state temperature:
37.3 ~ 37.4 °C for Martin
37.4 ~ 37.5 °C for Thelonious

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Abandoned leads:
inductive *vs* conductive

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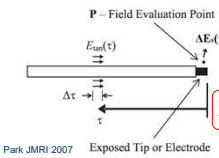
Kuroda K, Yatsushiro S. Magn Reson Med Sci 2022;21(1):110-131.

Inductive *vs* Conductive?

Induction by tangential electric force

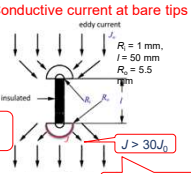


Park JMRI 2007

Position, angle and trajectory dependent

Tangential electric field around the insulated conductor induces electric motive force. The resultant current spread out from the bare tip

Conductive current at bare tips



$J > 30J_0$

Smith CD, 2007

$SAR \propto J^2 \approx 900J_0^2$

Conductive current flowing in from the bare tip will flow out from the other end

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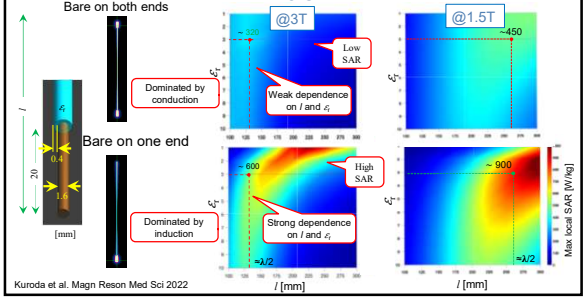
Inductive *vs* Conductive?

Bare on both ends

Dominated by conduction

Bare on one end

Dominated by induction



Kuroda et al. Magn Reson Med Sci 2022

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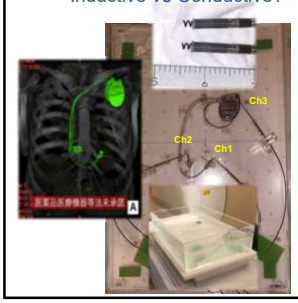
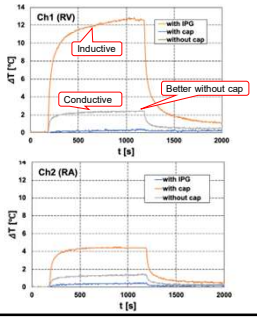
Inductive *vs* Conductive?





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SUMMARY

☞Epicardial leads possibly generate higher heat than the endocardial because
-Higher possibility to be implanted in the left heart system where E-field is higher
-Longer part of lead from the abdominal cavity tends to be tangential to the E-field

☞The difference in the electrode shape was not clearly recognized

☞ Patient growth may increase the risk of RF-induced heating because of the prolonged lead path with the body size increase

☞ Abandoned leads generate higher heat than those with IPG connections.

☞ Uncapping the electrode part may largely reduce heat generation at the lead tip because of the "dilution" of current density due to both bare-end configuration

Better MR conditionality of ICDs

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