Role of Transthoracic Impedance on the success of synchronized electrical cardioversion

By

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under the supervision of

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Masters Thesis Defense Presentation – August 23, 2012

Carleton UNIVERSITY
Canada's Capital University

UNIVERSITY OF OTTAWA
HEART INSTITUTE

In partial fulfillment of the requirements for the degree of

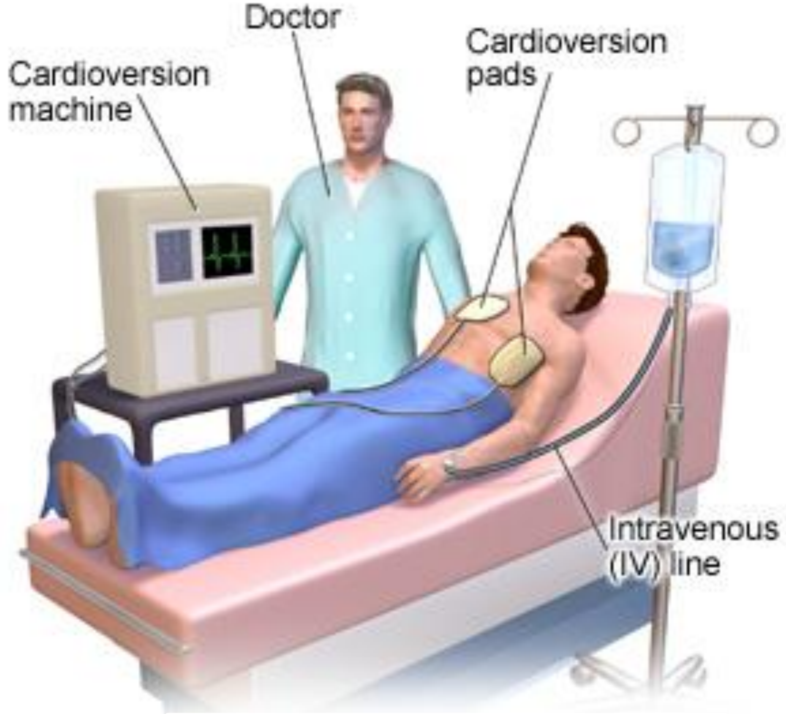
Masters of Applied Science

Motivation

- *Cardioversion* – Treatment to restore normal sinus rhythm for atrial fibrillation (AF), atrial flutter (AFL) and ventricular tachycardia (VT).

- **Successful cardioversion**
  ↓
  sufficient current (I) for depolarization

- $I \propto \frac{1}{Transthoracic\ Impedance\ (TTI)}$



Cardioversion setup

Motivation

- Biphasic defibrillators compensate for the TTI
- Low success rate for patients with high TTI.
- More shocks for high TTI patients – unbeneficial.
- Impedance compensating biphasic defibrillators improve the success rate for high TTI patients - ***UNCLEAR***

Thesis Objectives

1. **Effect of TTI on the success rate of cardioversion**

PART I:

Statistical Analysis on Clinical data

PART II:

3-D Finite Element Modeling (FEM)

Thesis Objectives

2. **Examine the effect of pad positions using FEM**

    - **Pad position clinician specific**
    - **No general agreement**

Overview of Contributions

1. Statistical Analysis
2. Current range
3. Current density distribution for different patient types (FEM)
4. Effect of Pad positions

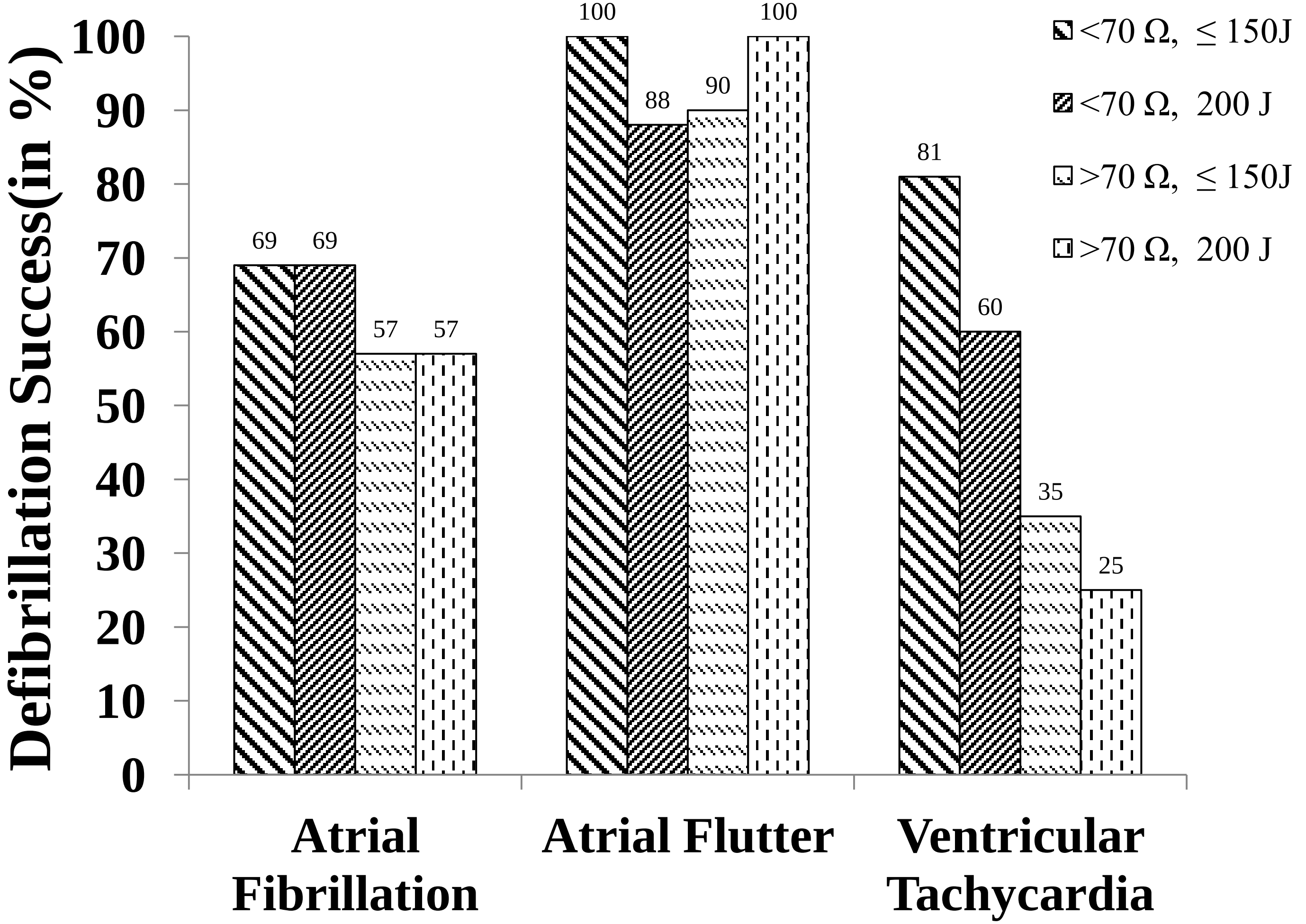
Effect of TTI and method to improve the success rate

Contribution #1 : Statistical analysis to examine the effect of TTI on the efficacy of cardioversion.

Methodology :

- 574 cases (952 shocks) for AF, 112 cases (125 shocks) for AFL, 89 cases (176 shocks) for VT.
- Shocks classified as “success” and “failure”.
- Divided into categories of low and high energy and impedance.
- Chi-square and Fischer’s exact test at $\alpha = 0.05$

Results :

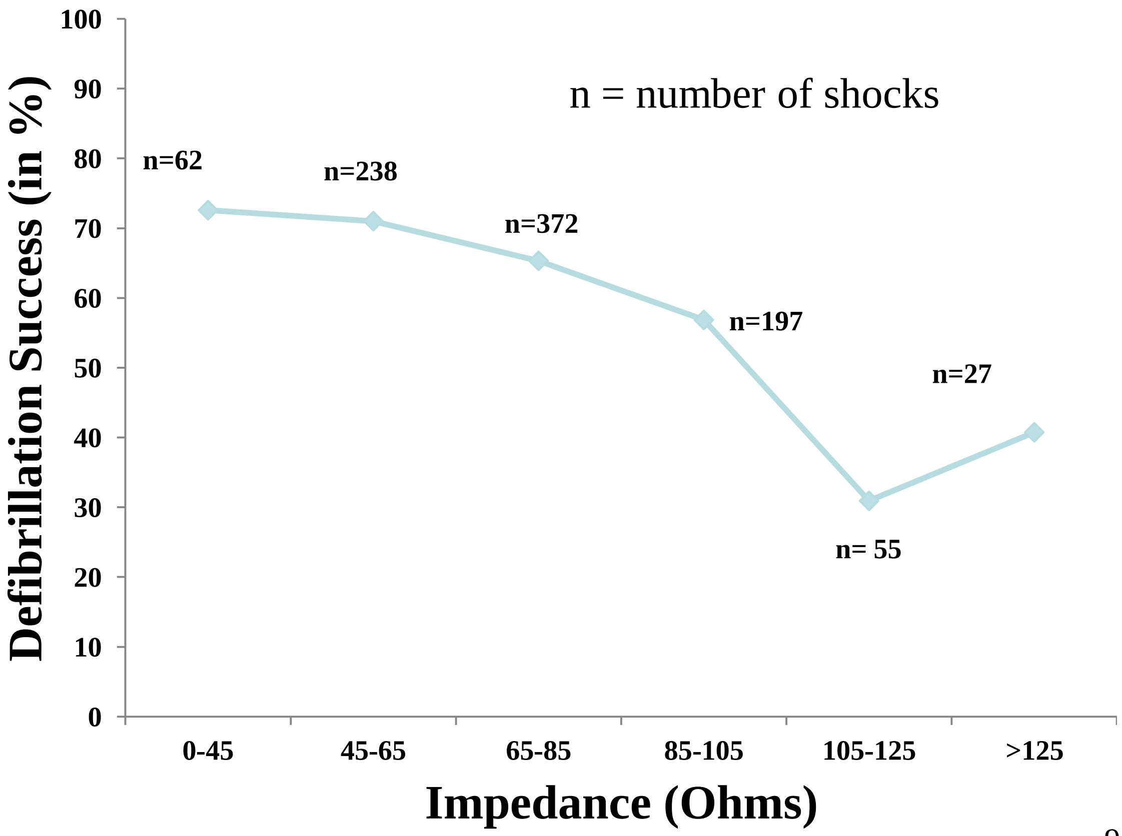


- Statistically significant results for AF and VT.

Conclusion :

- High TTI, lower success rate.

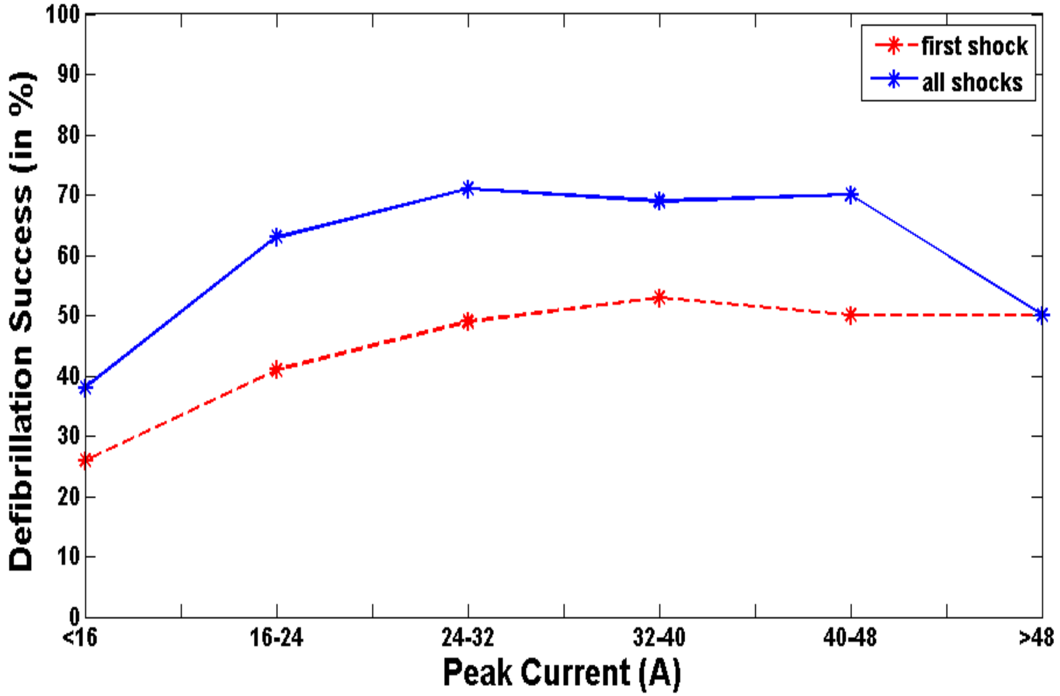
- Inefficient impedance compensation.



Contribution #2 : Determination of current amplitude for a successful cardioversion

Methodology :

- Clinical cardioversion data



Results :

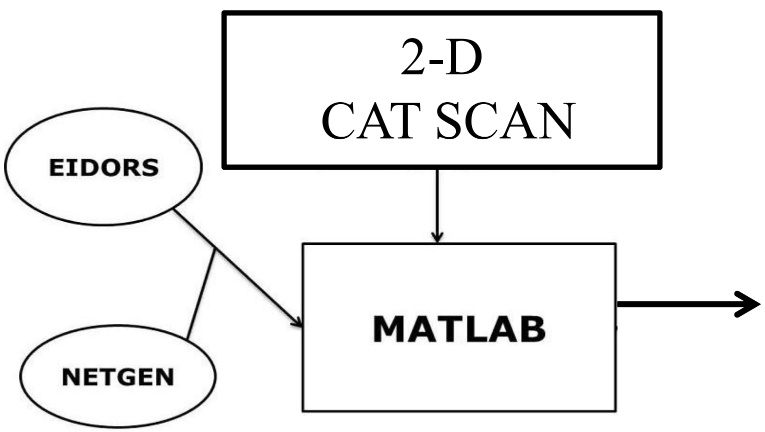
- Optimal current range between 24 A – 48 A

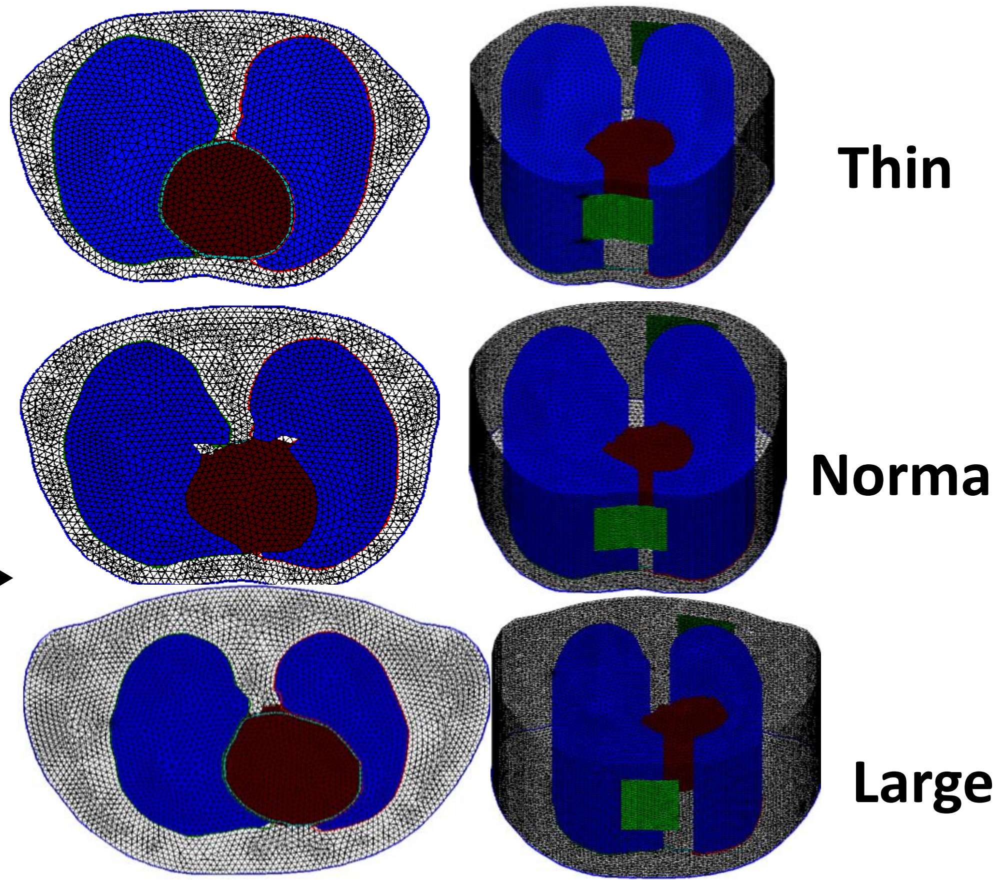
Conclusion :

- TTI influences → current → the success rate.

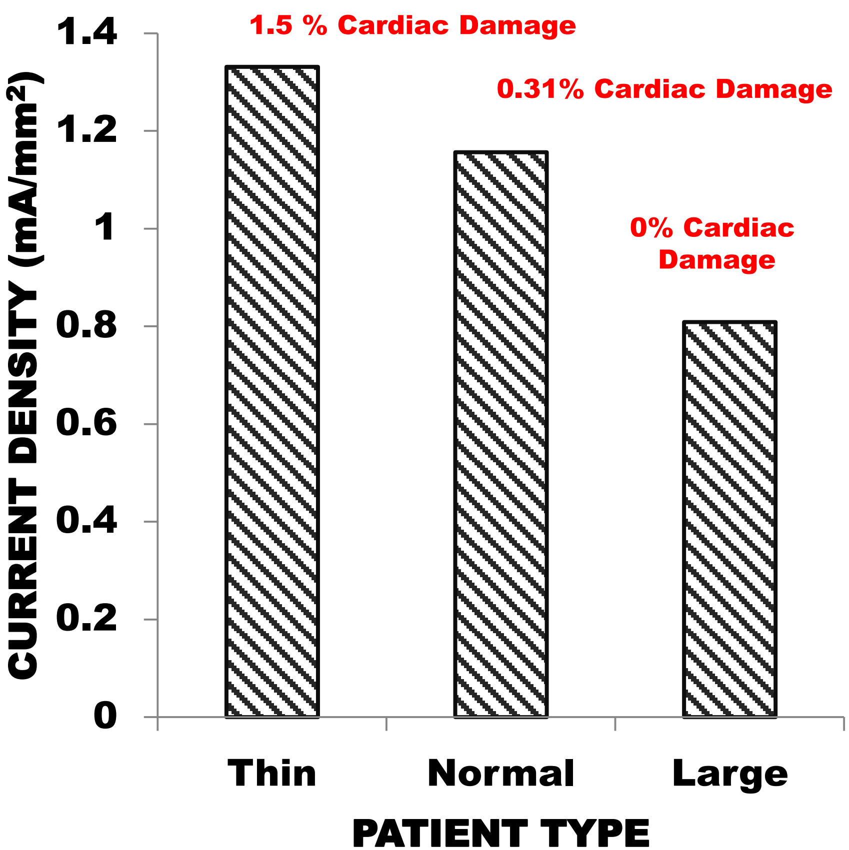
Contribution #3 : Effect of TTI on current density distribution in the thorax using FEM on different patient types

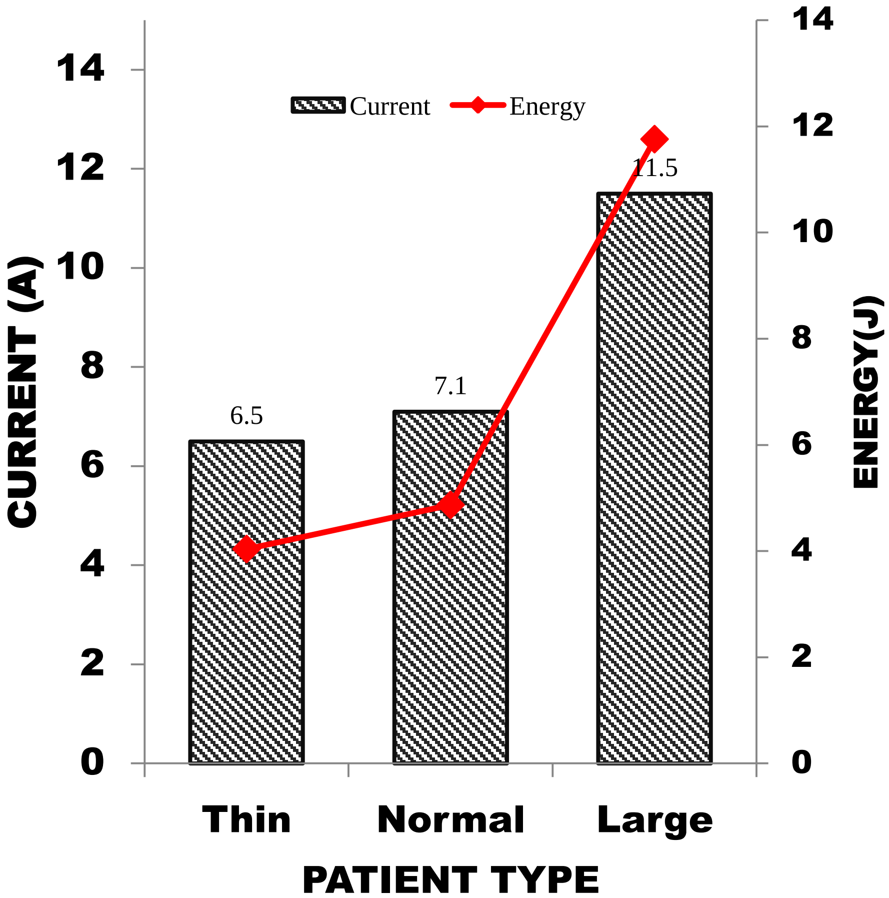
Methodology :





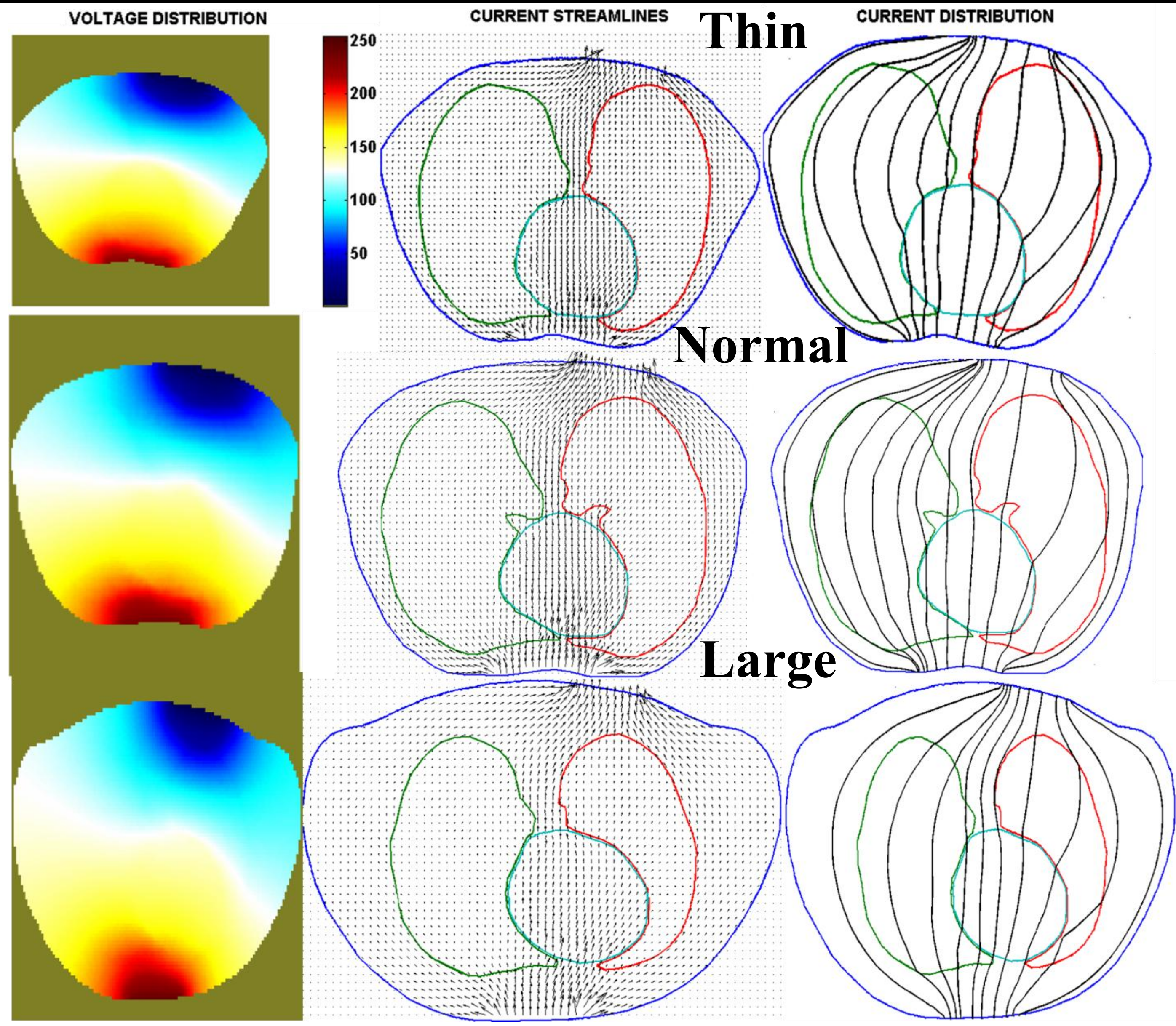
Results :


1.5 % Cardiac Damage
0.31% Cardiac Damage
0% Cardiac Damage
CURRENT DENSITY (mA/mm²)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Thin
Normal
Large
PATIENT TYPE


Current
Energy
CURRENT (A)
ENERGY(J)
14
12
10
8
6
4
2
0
6.5
7.1
11.5
Thin
Normal
Large
PATIENT TYPE

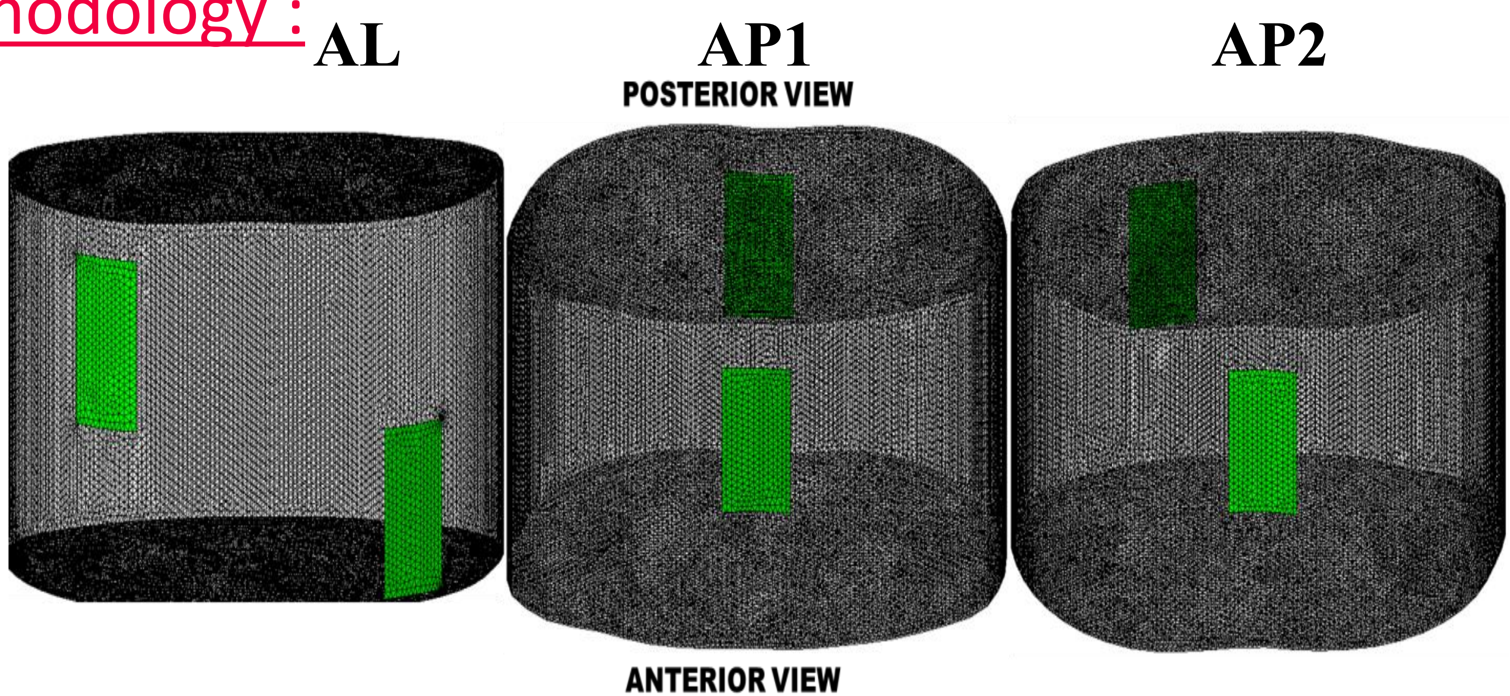
Conclusion :

- Effect of TTI on cardioversion



Contribution #4 : Effect of pad position on cardioversion

Methodology :

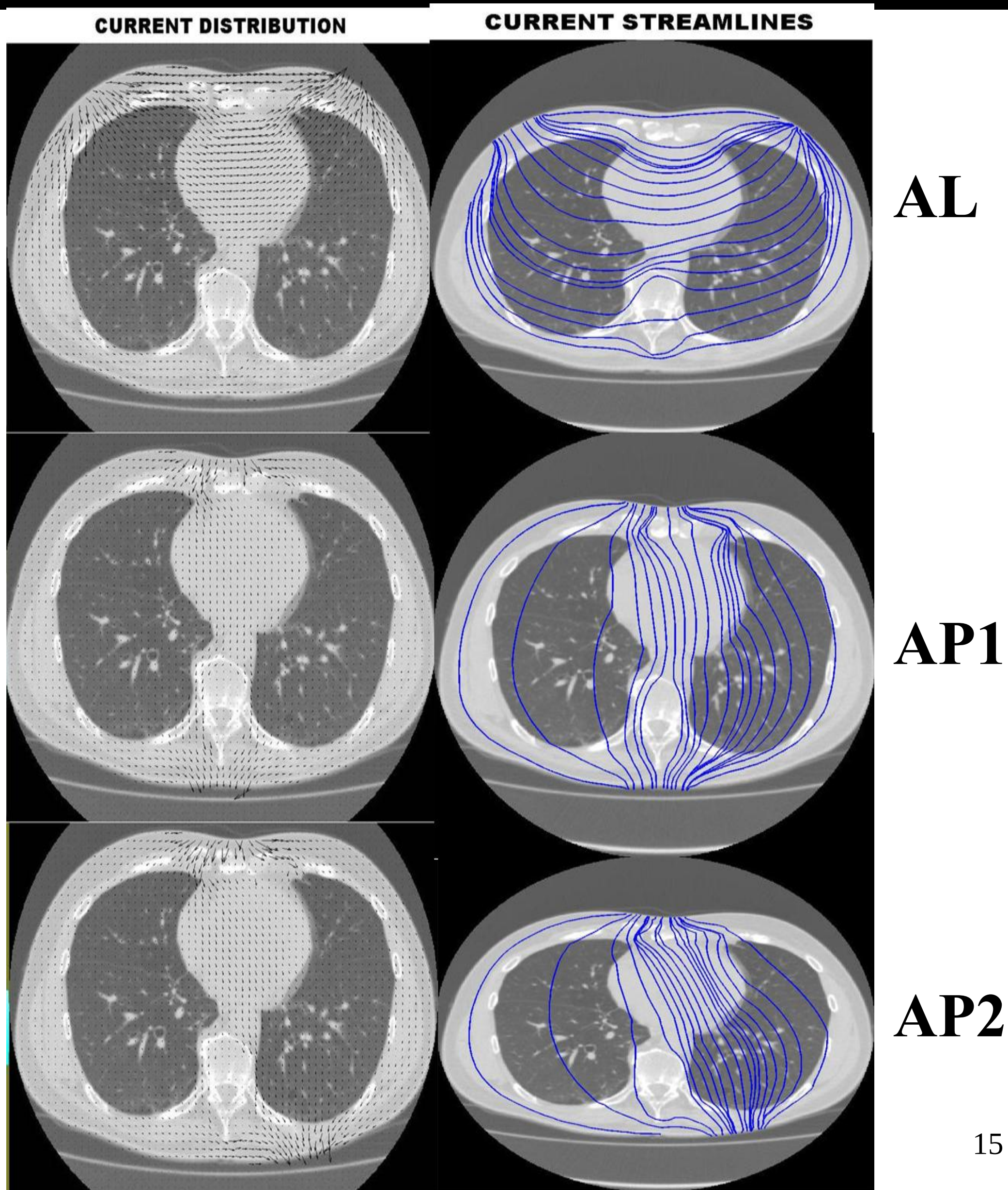


- Pad positions modelled using FEM

Results :

- Least current
- Low resistance
- Higher uniformity in current

} AP2



Conclusion:

- AP2 - most effective

Effect of pad position on patient size:

Methodology:

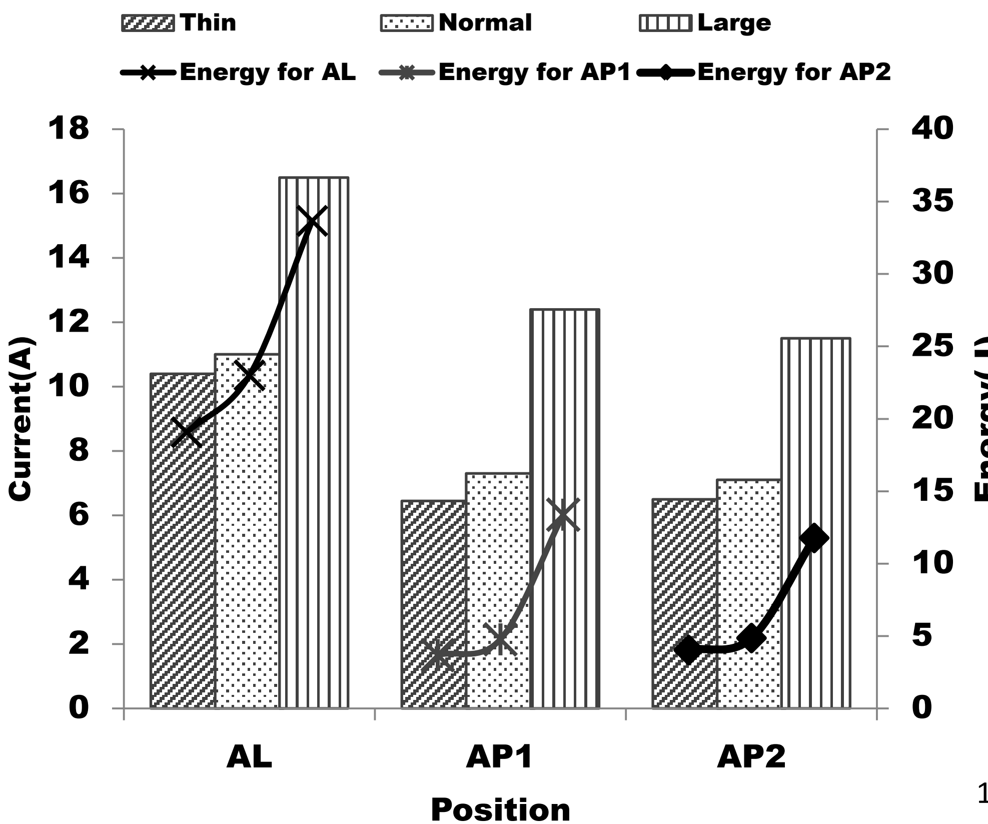
- Modelling the three positions on the three patient types.

Results:

- Less current and energy for large patients at AP2

Conclusion:

- Better defibrillation result in AP2



Thesis Conclusion:

- TTI plays an important role in success rate of cardioversion.
- Pad position also affects the cardioversion efficacy.
- One of the ways to increase the success rate for high TTI patients is to change the pad position to AP2 during cardioversion.

Publication:

Contribution #4: Conference paper

- Chaugai V, Adler A, Chan ADC, Zakutney T, "Estimation of effective pad positions during cardioversion using 3-dimensional finite element model", 35th Conference of the Canadian Medical & Biological Engineering Society, Halifax, Canada, 2012.

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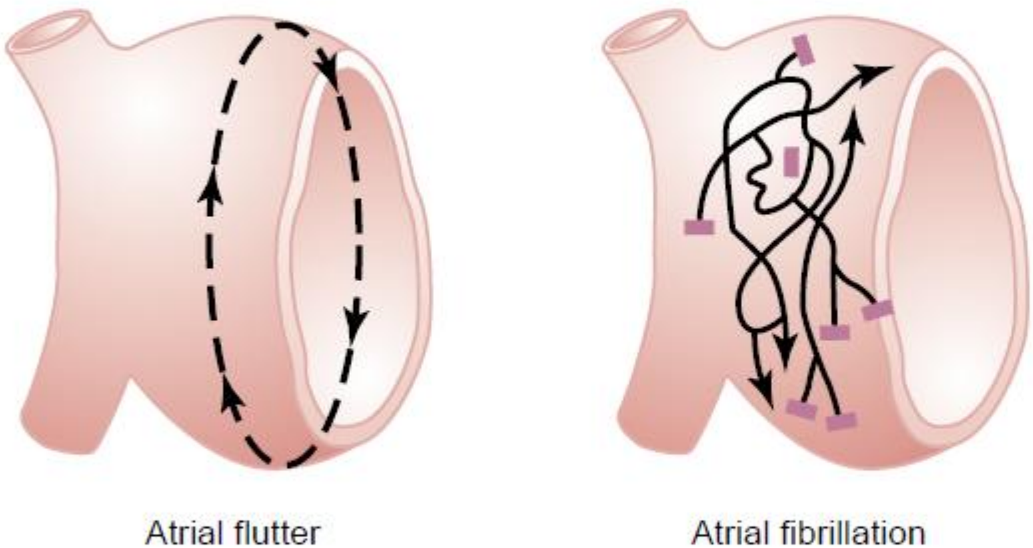
Future work:

1. ***Prospective Study***
2. ***Current based defibrillators***
3. ***Measurement of the impedance before the cardioversion procedure***
4. ***Refining the FEM model***
5. ***Analysis of pad shape and pad size***
6. ***Finding current in the heart***
7. ***Comparison of FEM results with the clinical data***
8. ***Inclusion of Defibrillation events***

Questions:

- Cardiac arrest – no electrical conduction in the heart



VT: rapid ventricular
Contractions, no blood
Pumped in the heart

- Pacemaker : something wrong with SA or AV node or during cardiac block

- true null hypothesis was incorrectly rejected (Type I error)
or where one fails to reject a false null hypothesis (Type II error).

Impedance does not affect but u say impedance affect (type I error)

Results show impedance affect, but u reject it and show the impedance doesnot affect (type II error)

- That's why we use 0.05 as we are less prone to make type II error

- Erroneous results if chi-square is used for <5

- Confounding effect – variables that affect dependent & independent Variable (for our case like age, gender, duration of arrhythmia, patient's Condition, drug(medicine) consumption history.

Disadvantage of retrospective analysis

Dysfunction – changed into different arrhythmia, harm is temporary

Damage/injury- damage to the myocardial cells and it is permanent.– Thromboembolism, ischemia, degeneration of the cells, myocarditis, Cell necrosis

How is giving more number of shocks harmful? Causes damage
Strength-duration relationship