Power from the beat of the heart

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Energy Harvesting From Human Power

Imperial College London

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Introduction

- SIMM collaboration funded in part by the TSB(1) to develop energy harvesting technology for next generation pacemakers
- Consortium of Engineers and Cardiac Surgeons
- A prototype has been developed and proven to generate power during a clinical trial
- Showcased at the prestigious American Heart Association conference in New Orleans November 2008
- Patented design won the IET Emerging Technologies award in London November 2009

(1) The consortium wish to acknowledge the Financial & Managerial support received from The Technology Strategy Board

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Design Brief

- Active cardiac implant market circa 0.75M units per annum
- 50% of pacemaker is battery; reducing or removing allows better treatments and patient comfort
- Pacemaker works down to 2.1V consumes circa 25-30µW
- Operating temp 37^{o}C
- Must be reliable – 7 yr operation life

Sounds good many EH option can generate required energy

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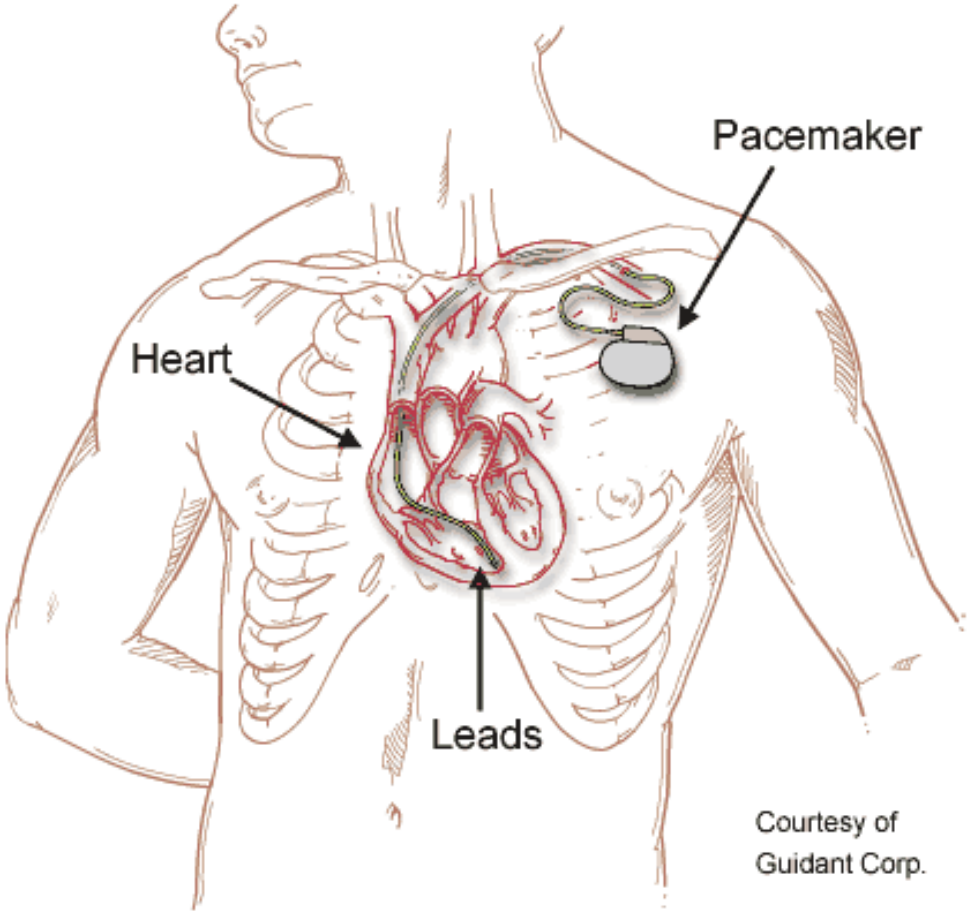
Background - Implant Procedure



- The lead is inserted via sub-clavian vein
- The lead is guided along the sub-clavian vein, in & through the right atrium & tricuspid valve, into the apex of the right ventricle
- The pacemaker control box (with integrated battery) is placed under the skin below the left collarbone
- Procedure takes 1hr or so

Design Brief - Clinical

- **Must not impact the patient physically or clinically, more than the current device when generating power**
  - **Heat damage max 1^{o}C**
- **Must be compatible with existing medical procedures**
  - **If not, will lead to training issues cost**
  - **Delayed or non existent market take up**
- **Must work from involuntary human activity**
  - **Patient may have restricted mobility (heart condition)**
  - **Can't rely on patient applying external devices**
  - **Needs to generating power even when sleeping and lay down**

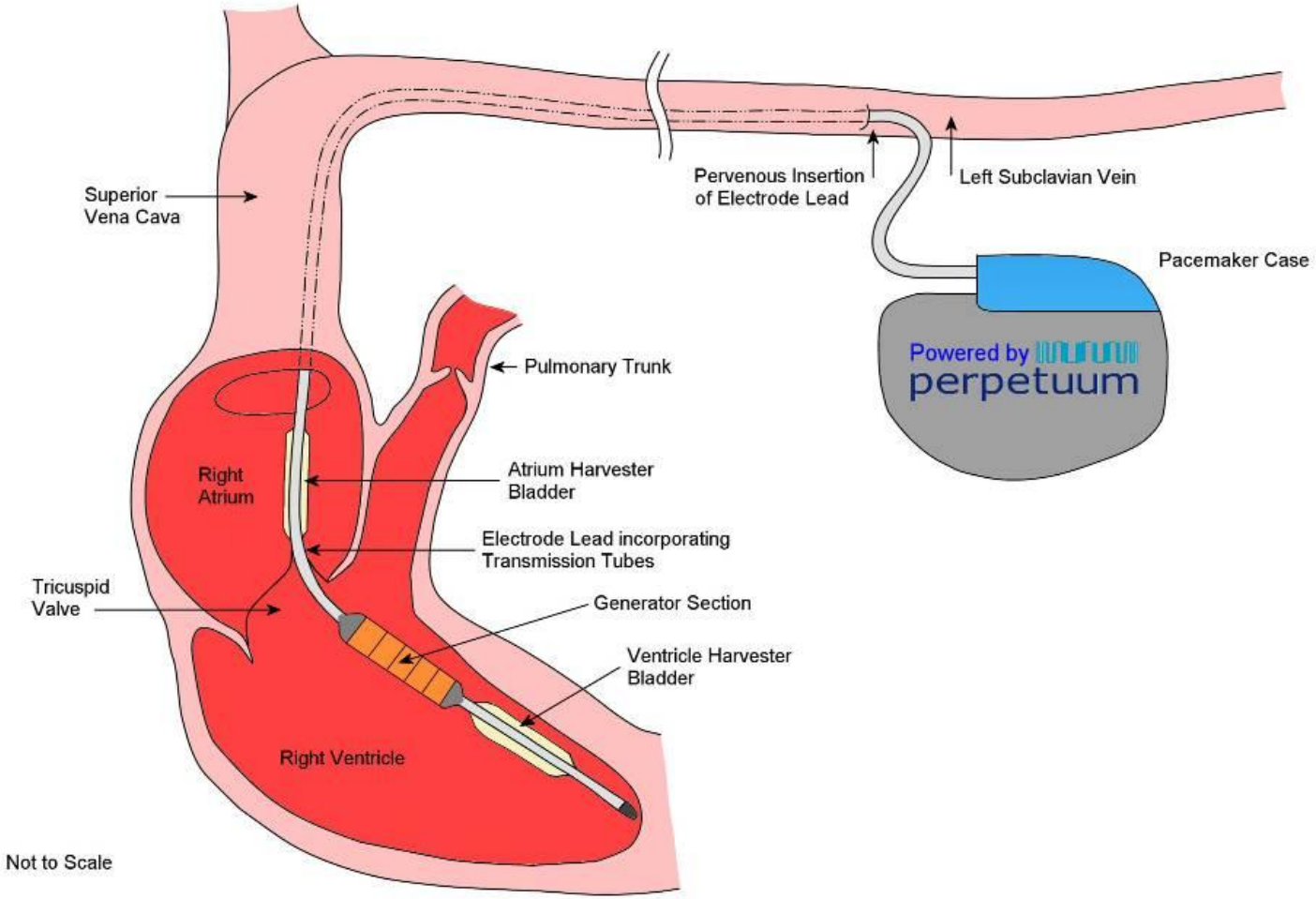
Design Options 1

- **Piezoelectric devices**
  - **Could work but piezoelectric device must be placed in relation to implant procedure; can't go outside of heart, for example**
- **Vibration**
  - **Biological frequencies 10s of Hz and irregular**
  - **Heart rate 40—120bpm and variable, rules out vibration type scavengers (typically kHz)**
- **Thermal**
  - **Heart is deep in the chest cavity thermal gradient low**

Design Options 2

- **Solar**
  - **Patent for using solar to power an implant – how will it be placed without impacting implant procedure**
- **Magnetic Induction**
  - **Would work but relies on patient which can't be guaranteed**
- **Offset Mass**
  - **Relies on patient movement, largest motion away from the heart**
- **Glucose fuel cell**
  - **Development from University Freiburg interesting runs for 200days**

Proof of Concept Solution



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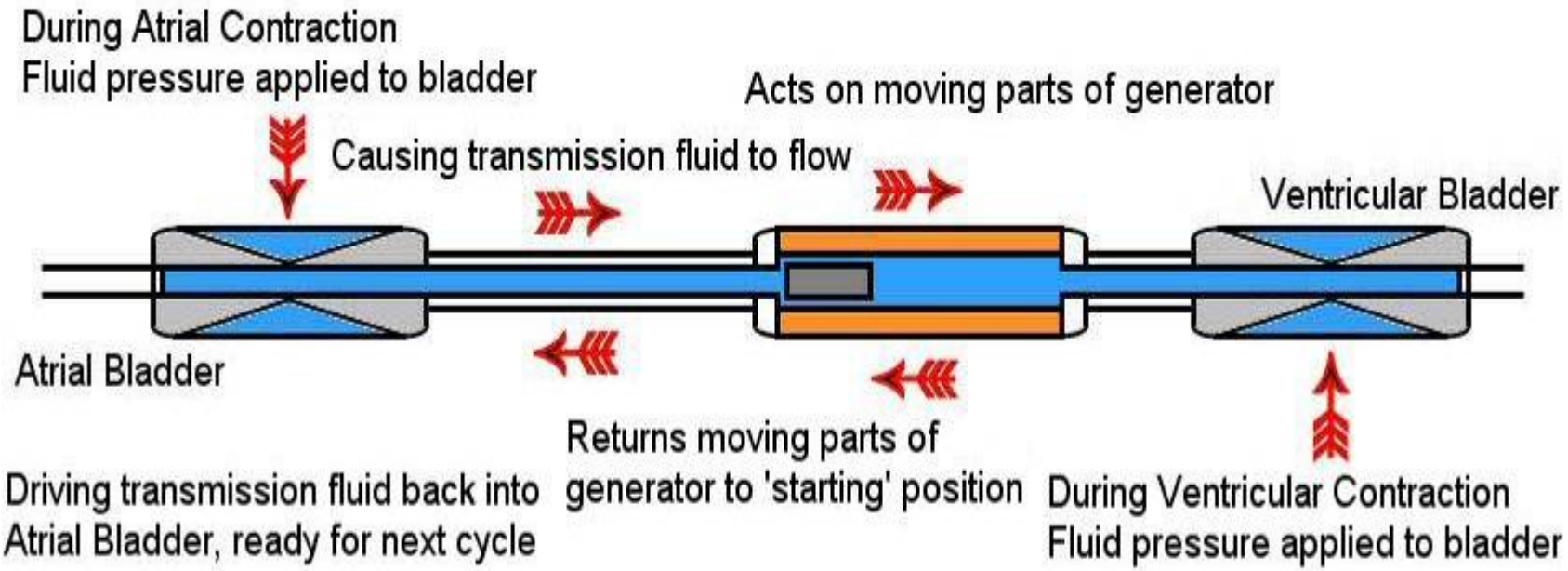
Principal of Operation



Areas for Design Improvement

- **Induction Coils**
  - **Small dia (4mm) large number of turns to generate significant voltage- fine wire gauge required <25um (high resistance loss)**
- **Energy conversion**
  - **Need efficient methods to convert energy generated into usable form local to generator**
- **Balloon Bladders**
  - **Trade-off between biocompatible materials and amount of energy transferred. Some OEM's have exclusive rights to materials**
- **Fluid Flow**
  - **Small diameters give + magnet assembly give irregular fluid flow**
- **Magnetic Field**
  - **Magnet and travel is longitudinal does not give optimised field pattern**

Key Lessons

- Involve and clinical partner early
- Consider the design from system level - factor in loss due to energy conversion
- Size is key limitation - fine wire, small components, high motion resistance
- Biocompatible materials – OEMs hold licence rights
- Long gestation period – OEMs like low risk, TTM circa 5yrs

Key Areas for Research

- P of C generated 8-16uW @ 200-300mV, challenge Increase voltage 10x, Increase power 2x

- Mechanical - more efficient transfer of energy to moving part
  - Bladders absorbed energy
  - Reduce energy loss in moving part
  - Optimisation of magnetic field

- Electronic- need efficient conversion of generated energy into usable form local to generator
  - Multi-source generator
  - Multi-input high efficiency energy conversion chip required **

- MRI Compatibility ????

Self-energising Implantable Medical Microsystems

http://www.implantgen.com/

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