Power from the beat of the heart

Zarlink Semiconductor

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Energy Harvesting From Human Power

Imperial College London

9th Nov 2010

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

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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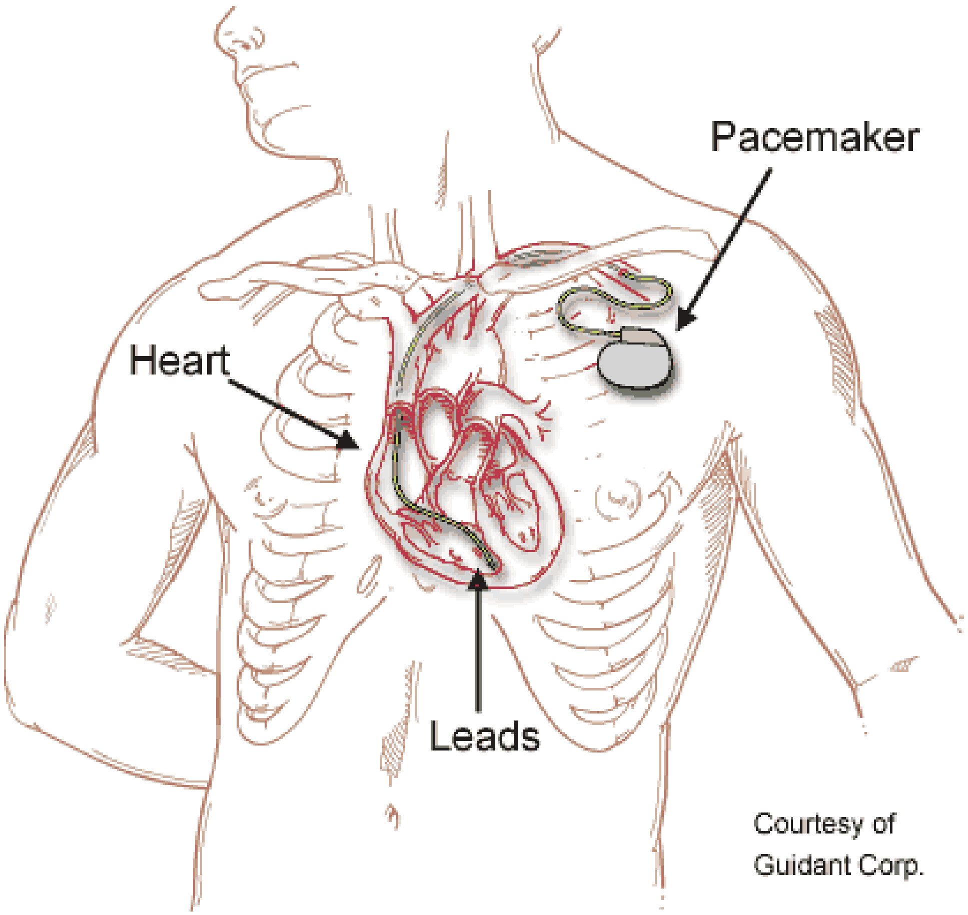
Background - Implant Procedure



- 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

- <u>Must not</u> impact the patient physically or clinically, more than the current device when generating power
  - Heat damage max 1^{o}C

- <u>Must</u> be compatible with existing medical procedures
  - If not, will lead to training issues cost
  - Delayed or non existent market take up

- <u>Must</u> 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

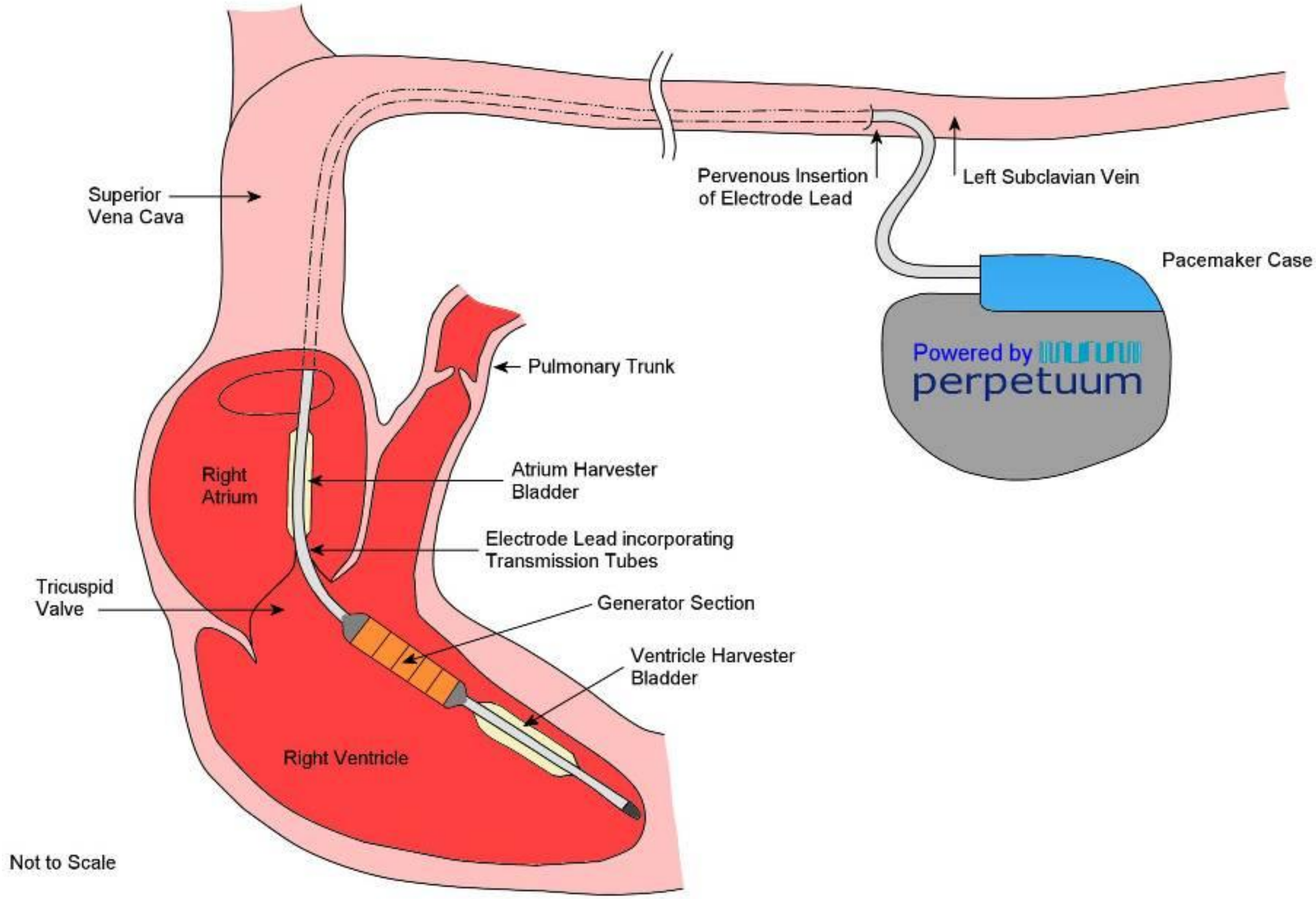
Design Options 1

- 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

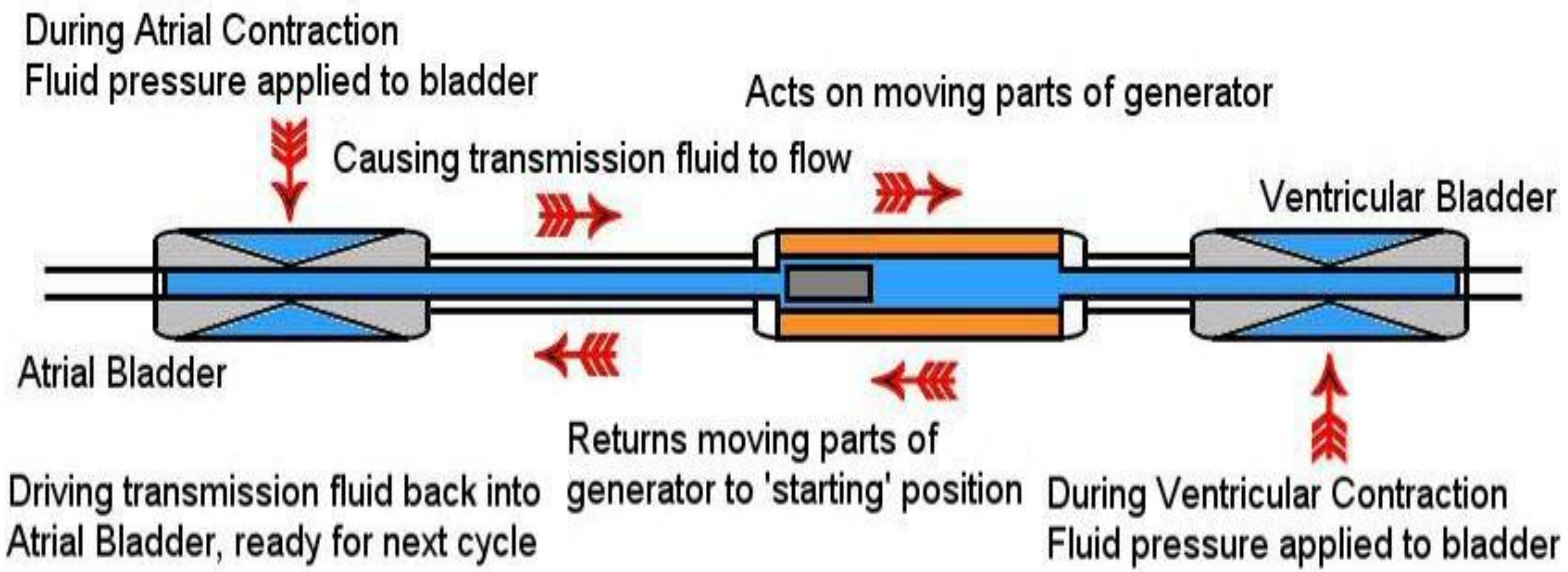
Design Options 2

- 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



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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