Lecture 8

Therapeutic/Prosthetic Devices – Pacemakers & Defibrillators

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Introduction

• Major use of medical electronics is as a diagnostic tool
  – Most instruments sense, record and display a physiological signal
  – Therapeutic and prosthetic devices are used as a means of treating human ailments
    • Electric stimulators, ventilators, heart-lung machines, artificial organs, prosthetic devices, implantable devices, drug delivery pumps (e.g. insulin pump), etc.

• Two common and important electric stimulator devices used to detect and correct arrhythmias
  – Cardiac Pacemakers
  – Cardiac Defibrillators
Figure 4.9 The sinus node activation does not appear on the ECG. The vertical lines indicate sinus node activation instants. During 1° SA block there is a delay between sinus node activation and atrial activation. During 2:1 SA block the abnormality cannot be distinguished from sinus bradycardia. In third degree block only the ventricular escape rhythm is recorded. From Chou, T. C. 1986. *Electrocardiography in clinical practice*. 2nd Ed. Grune & Stratton.
Arrhythmias: Atrial Flutter

**Figure 4.20** Atrial flutter is manifested by F waves between QRS complexes. Some P waves are blocked in order to protect the ventricles from a high depolarization rate. From Chou, T. C. 1986. *Electrocardiography in clinical practice*. 2nd Ed. Grune & Stratton.
Arrhythmias: Ventricular Tachycardia and Fibrillation

(a) Requires a CARDIOVERTER
small shock needed
Low blood pressure

(b) Requires a DEFIBRILLATOR
large shock needed
No blood pressure

Needs a Cardioverter (essentially a small shock to ventricles)

Needs a Defibrillator (essentially a large shock to ventricles)

Figure 4.23 (a) Ventricular tachycardia, which is different from ventricular flutter, (b), in that the ventricular complex has a sharp angular morphology. From Chou, T. C. (1984). Electrocardiography in clinical practice. 2nd Ed. Grune & Stratton.
Arrhythmias: Ventricular Fibrillation

Uncoordinated beating of heart cells, resulting in no blood pressure. Needs an electrical shock urgently...else brain damage in 4+ minutes.

External or implantable defibrillator. In the mean time do CPR!
Cardiac Pacemakers

• An electric stimulator for inducing contraction of the heart
  – Very low-current, low-duty-cycle stimulator
• Electrical pulses are conducted to the various locations
  – On the surface (Epicardium)
  – Within the muscle (myocardium)
  – Within the cavity of the heart (endocardium)
• Needed when heart is not stimulating properly on its own (i.e. arrhythmias)
Cardiac Pacemakers

- Asynchronous device is free-running
  - Produces uniform stimulation regardless of cardiac activity (i.e. fixed heart-rate)
  - Block diagram (right) shows components of asynchronous pacemaker
    - Power supply – provides energy
    - Oscillator – controls pulse rate
    - Pulse output – produces stimuli
    - Lead wires – conduct stimuli
    - Electrodes – transmit stimuli to the tissue
  - The simplest form of the pacemaker; not common any longer
Pacemaker: Power Supply

- Lithium iodide cell used as energy source
- Fundamental reaction:
  
  **Anode Reaction:** \( \text{Li} \rightarrow \text{Li}^+ + e^- \)
  
  **Cathode Reaction:** \( \text{I}_2 + 2e^- \rightarrow 2\text{I}^- \)
  
  **Combined Reaction:** \( 2\text{Li} + \text{I}_2 \rightarrow 2\text{LiI} \)

- Open-circuit voltage of 2.8V
- Lithium iodide cell provides a long-term battery life
- Major limitation is its high source impedance

*Figure 7.1* Conventional current flows from anode to cathode. The lithium reacts with the iodine to form lithium-iodide, which grows in volume and increases the resistance.
Pacemaker: Power Supply

Pacemaker: Output Circuit

- Output circuit produces the electrical stimuli to be applied to the heart
- Stimulus generation is triggered by the timing circuit
- Constant-voltage pulses
  - Typically rated at 5.0 to 5.5V for 500 to 600μs
- Constant-current pulses
  - Typically rated at 8 to 10mA for 1.0 to 1.2ms
- Asynchronous pacing rates – 70 to 90 beats per min; non-fixed ranges from 60 to 150bpm
- With an average current drain of 30μW, a 2 A-h battery would last more than 20 years
Pacemaker: Output Circuit

Figure 6.4 Simple pacing system electrical model as correlated with exhibited physical characteristics of: device, materials, tissue, and electrochemical components. This model is based only upon measurable system components and excludes empirical assumptions. Components include: the pulse generator, stimulating cathode, anode, and tissue. From Bolz, A., Fröhlich, R., and Schaldach, M. 1993. Elektrochemische aspekte der elektrostimulation—ein beitrag zur senkung des energiebedarfs. In M. Hubmann and R. Hardt (eds.) Schrittmachertherapie und hämodynamik. München: MMVverlag.
Figure 11.4  (a) A representation of an ideal stimulation pulse from a constant voltage stimulator. The voltage is measured from the stimulating tip to the reference (either the ring or the pacemaker can). $V_{dd}$ can either be a fixed value, as in single voltage devices, or a programmable value, with variability dependent upon the pacemaker model. The period of stimulation $T$ is variable in all devices. (b) A realistic depiction of a waveform appearing across the heart emitted from a capacitor discharge output circuit. Note that the drop in pulse voltage magnitude is dependent upon the size of the output capacitor. A larger capacitor will have a waveform which more closely resembles an ideal constant voltage. The small rise and exponential decay after the stimulus pulse is an afterpotential, which is discussed in section 11.3.
Pacemaker: Leads

• Important characteristics of the leads
  – Good conductor
  – Mechanically strong and reliable
    • Must withstand effects of motion due to beating of heart and movement of body
  – Good electrical insulation

• Current designs
  – Interwound helical coil of spring-wire alloy molded in a silicone-rubber or polyurethane cylinder
  – Coil minimizes mechanical stresses
  – Multiple strands prevent loss of stimulation in event of failure of one wire
  – Soft coating provides flexibility, electrical insulation and biological compatibility
Pacemaker: Leads

Pacemaker: Electrodes

- **Unipolar vs. Bipolar Pacemakers**
  - **Unipolar:**
    - Single electrode in contact with the heart
    - Negative-going pulses are conducted
    - A large indifferent electrode is located elsewhere in the body to complete the circuit
  - **Bipolar:**
    - Two electrodes in contact with the heart
    - Stimuli are applied across these electrodes

- **Stimulus parameters (i.e. voltage/current, duration) are consistent for both**
Pacemaker: Electrodes

• Important characteristics of electrodes
  – Mechanically durable
  – Material cannot:
    • Dissolve in tissue
    • Irritate the tissue
    • Undergo electrolytic reaction due to stimulation
    • React biologically
  – Good Interface with leads

• Current designs
  – Platinum, platinum alloys, and other specialized alloys are used
Pacemaker: Electrodes

Figure 13.2 Two of the more commonly applied cardiac pacemaker electrodes  (a) Bipolar intraluminal electrode. (b) Intramyocardial electrode.
Pacemaker: Electrodes

Figure 6.1 A modern pacemaker electrode. The Medtronic [Medtronic, Inc., Minneapolis, MN U.S.A.] model 4003 CapSure® unipolar tined porous electrode is an example of a porous steroid elution electrode. Behind the porous tip surface is a silicone rubber plug filled with an inflammation suppressing steroid. The secretion of this drug through the tip surface decreases inflammation and resulting encapsulation. This increases the electrode’s pacing efficiency and efficacy and sensing sensitivity. From Mond, H., Stokes, K. B., Helland, J., Grigg, L., Kertes, P., Pate, B., and Hunt, D. 1988. The porous titanium steroid eluting electrode: a double blind study assessing the stimulation threshold effects of steroid. PACE, 11: 214–219.
Pacemaker: Electrodes

Figure 6.12 Examples of active and passive fixation electrodes. (a) Epicardial suture pad active fixation with disk-shaped, steroid eluting platinized porous platinum electrode in center (From Medtronic, Inc.); (b) Barbed epicardial polished platinum “fish-hook” electrode (Medtronic model 6917A, From Medtronic, Inc.); (c) Helical active fixation electrode; (d) Tined passive fixation electrode (BIOTRONIC, Inc. model DJP/JP, From BIOTRONIC, Inc.).
Pacemaker: Sensing Electrodes

- Unipolar and bipolar electrodes are also used as sensing electrodes
- Used in conjunction with advanced pacemaker technologies

Figure 8.2 Illustration of unipolar and bipolar sensing.
Pacemaker: Packaging

• Housing for the components must be compatible and well tolerated by the body
• Needs to provide protection to circuit components to ensure reliable operation
• Size and weight must be considered
• Common designs consist of hermetically sealed titanium or stainless steel
Advanced Pacemakers

- Synchronous Pacemakers
  - Used for intermittent stimulation as opposed to continuous stimulation as in asynchronous pacemakers
- Rate-Responsive Pacemakers
  - Used for variable rates of pacing as needed based on changes in physiological demand
Synchronous Pacemakers

• Prevents possible deleterious outcomes of continuous pacing (i.e. tachycardia, fibrillation)
  – Minimizes competition between normal pacing

• Two general types of synchronous pacemakers
  – Demand pacemakers
  – Atrial-synchronous pacemakers
Demand Pacemakers

- Consists of asynchronous components and feedback loop
- Timing circuit runs at a fixed rate (60 to 80 bpm)
- After each stimulus, timing circuit is reset
- If natural beats occur between stimuli, timing circuit is reset
- Normal cardiac rhythms prevent pacemaker stimulation
Atrial-Synchronous Pacemaker

- SA node firing triggers the pacemaker
- Delays are used to simulate natural delay from SA to AV node (120ms) and to create a refractory period (500ms)
- Output circuit controls ventricular contraction
- Combining the demand pacemaker with this design allows the device to let natural SA node firing to control the cardiac activity
Rate-Responsive Pacing

- Replicates cardiac function in a physiologically intact individual
- Sensor is used to convert physiological variable to an electrical signal that serves as an input
- Controller circuit changes heart rate based on sensor signal (demand-type pacing can be implemented here)
# Rate-Responsive Pacing: Physiological Variables

<table>
<thead>
<tr>
<th>Physiological Variable</th>
<th>Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right-ventricle blood temp</td>
<td>Thermistor</td>
</tr>
<tr>
<td>ECG stimulus-to-T-wave interval</td>
<td>ECG electrodes</td>
</tr>
<tr>
<td>ECG R-wave area</td>
<td>ECG electrodes</td>
</tr>
<tr>
<td>*Blood pH</td>
<td>Electrochemical pH electrodes</td>
</tr>
<tr>
<td>*Rate of change of right ventricular pressure</td>
<td>Semiconductor strain-gage pressure sensor</td>
</tr>
<tr>
<td>Venous blood $S_{O_2}$</td>
<td>Optical oximeter</td>
</tr>
<tr>
<td>Intracardiac volume changes</td>
<td>Electric-impedance plethysmography</td>
</tr>
<tr>
<td>Respiratory rate and/or volume</td>
<td>Thoracic electric-impedance plethysmography</td>
</tr>
<tr>
<td>Body vibration</td>
<td>Accelerometer</td>
</tr>
</tbody>
</table>

*Not commercially available*
Rate-Responsive Pacing: Sensors

• Impedance Measurements
  – Three electrode system (pacemaker case used as ground)
    • Unipolar with extra lead and Bipolar lead
  – Two electrode system
    • Single unipolar or bipolar lead
  – Voltage is applied across two electrodes and current is measured
    • Low-amplitude high-freq signal or low-amplitude pulse train is used
    • Pacing pulse can be used, but may not provide adequate sampling rate for some signals (e.g. if an inhibited pacemaker mode is used)

![Impedance measurement systems](image)

*Figure 13.1* Impedance measurement systems. (a) Extra lead configuration. The extra lead is placed in the subcutaneous tissue across the anterior chest wall. (b) Bipolar lead configuration. (c) Two-electrode configuration.
Rate-Responsive Pacing: Sensors

- **Atrial Sensing (Atrial-Synchronous Pacing)**
  - Signal commonly sensed via insertion of an extra lead in contact with atrial wall
  - Alternatively, a special lead used to stimulate the ventricle can be used

- **Direct Metabolic Sensors**
  - Used to measure metabolic activity of the body to correlate with cardiac output
  - Examples
    - Central Venous pH
      - Reference Ag-AgCl electrode placed in the pacemaker case and pH-sensitive Ir-IrO₂ electrode placed in right atrium
      - Can detect change in blood pH due to exercise or disease
      - Sensor problems and complexity of relationship between CO and pH are limitations
Rate-Responsive Pacing: Sensors

• Direct Metabolic Sensors
  – Examples (cont’d)
    • Mixed Venous $O_2$ saturation
      – Two LEDs and a photodiode are used to detect reflectivity of the blood
      – LEDs produce two distinct wavelengths detectable by photodiode
        » Red wavelength (660nm) used to detect $O_2$ saturation
        » Infrared (805nm) wavelength used as reference
      – Measurements taken in venous side of the cardiovascular system
      – Low $O_2$ saturation will result in low reflectivity and low sensor output, which triggers the pacemaker to increase the heart rate for increased cardiac output
      – Power requirements, lead placement and information lag due to time required to cycle through the body are limitations
Figure 13.2 Oxygen saturation sensor. Oxygenated hemoglobin in the right ventricle reflects the red LED’s light. Conversely the deoxygenated hemoglobin absorbs it. Both reflect infrared light.
Rate-Responsive Pacing: Sensors

• Indirect Metabolic Sensors
  – Allow for estimation of metabolic activity for control of cardiac output
  – Examples
    • Ventilation rate (estimation of oxygen intake)
      – Measured by analyzing the impedance between pacemaker electrode and pacemaker case
      – Three electrode system typically used
      – Changes in chest impedance occur with breathing
      – Signal requires filtering to obtain ventilation rate
      – Motion artifacts of the chest and inability to detect differences in shallow and deep breathing are limitations of this system
Rate-Responsive Pacing: Sensors

• Indirect Metabolic Sensors
  – Examples (cont’d)
    • Mixed Venous Temperature
      – A small ceramic thermistor in a lead is placed in the right ventricle
      – Blood temperature is a good indicator of metabolic need and the sensor is durable
      – A special pacing lead is required and the small and slow signal may result in a slower than desirable response (e.g. a short sprint will not increase body temperature much when heart rate would naturally increase)
Rate-Responsive Pacing: Sensors

Figure 15.6 Pacing/sensing electrode with integrated thermistor Adapted from Cook et al. (1985).
Rate-Responsive Pacing: Sensors

- Non-metabolic Physiological Sensors
  - Used to detect changes that would naturally cause an increased heart rate
  - Examples
    - Q-T Interval
      - Measures the time between the QRS wave and the T wave
      - During exercise or stress, the Q-T interval decreases due to natural catecholamine production
      - Pacing leads are used to detect intracardiac ventricular electrogram
      - This is the most successful physiological sensor
        » Standard leads are used
        » Little to no additional power is required
        » Rapid response time
      - Some problems occur with detection of repolarization signals
Rate-Responsive Pacing: Sensors

• Non-metabolic Physiological Sensors
  – Examples (cont’d)
    • Ventricular Depolarization Gradient (VDG) or Evoked Ventricular Potential
      – Similar to Q-T Interval sensors, but measure area under the paced QRS wave
      – The area is affected by heart rate
        » VDG is directly proportional to heart rate
      – Standard pacing electrodes are used
      – No additional power is required
      – Rapid response time
      – Can also detect emotion and stress
      – Are affected by some drugs and electrode polarization
Rate-Responsive Pacing: Sensors

• Non-metabolic Physiological Sensors
  – Examples (cont’d)
    • Systolic Indices
      – Stroke Volume
        » Measured via impedance measurements
        » Increases with exercise
      – Pre-ejection Phase
        » The time between the onset of ventricular depolarization and the opening of the aortic valve
        » Measured via impedance measurements
        » Decreases with exercise
    – Motion artifacts and power requirements are limitations
Rate-Responsive Pacing: Sensors

• Non-metabolic Physiological Sensors
  – Examples (cont’d)
    • Pressure
      – Mean arterial blood pressure is naturally maintained to be constant
      – Magnitude and rate of change of pressure increases with exercise
      – Piezoelectric sensor is placed in the right ventricle
        » Measures rate of change of pressure, from which mean pressure can be inferred
      – Silicon strain gage pressure sensor can be used to directly measure mean pressure
      – Specialized leads are required
Rate-Responsive Pacing: Sensors

Figure 13.3 Blood pressure derivative sensor. As the blood pressure changes around the sensor, the wall deflection will change. Deflections of the wall apply a force on the piezo element, which creates an electrical signal.
Rate-Responsive Pacing: Sensors

- **Direct Activity Sensors**
  - Most common is the Motion-Detecting Pacemaker
    - Uses an accelerometer or a vibration sensor placed in the case to estimate activity
    - Long-term reliability, minimal power requirements and rapid response are advantages
    - Current specificity level of the sensor is a problem
      - e.g. Going up stairs is harder work than going down; however, the latter causes heavier footsteps and thus stronger pressure waves in the chest, which could cause a higher heart rate when going down than when going up the stairs

- **Multiple Sensors**
  - A combination of sensors is often used
Commercial Examples

• Major Cardiac Rhythm Management Companies
  – Guidant (J & J)
  – Medtronic
  – St. Jude

• Standard pacemaker packaging and design

• Various lead designs serve several different purposes

Taken from www.guidant.com
Commercial Examples

- Typical size and shape of the implantable pacemaker
- Upper portion is used for interfacing with the leads

Taken from www.medtronic.com
Defibrillators

• Used to reverse fibrillation of the heart
• Fibrillation leads to loss of cardiac output and irreversible brain damage or death if not reversed within 5 minutes of onset
• Electric shock can be used to reestablish normal activity
• Four basic types of Defibrillators
  – AC Defibrillator
  – Capacitative-discharge Defibrillator
  – Capacitative-discharge Delay-line Defibrillator
  – Rectangular-wave Defibrillator
Defibrillators

• Defibrillation by electric shock is carried out by passing current through electrodes placed:
  - Directly on the heart – requires low level of current and surgical exposure of the heart
  - Transthoracically, by using large-area electrodes on the anterior thorax – requires higher level of current
Defibrillator: Capacitive-Discharge

- A short high-amplitude defibrillation pulse is created using this circuit.
- The clinician discharges the capacitor by pressing a switch when the electrodes are firmly in place.
- Once complete, the switch automatically returns to the original position.

Figure 13.9  (a) Basic circuit diagram for a capacitive-discharge type of cardiac defibrillator. (b) A typical waveform of the discharge pulse. The actual waveshape is strongly dependent on the values of $L$, $C$, and the torso resistance $R_L$. 
Defibrillator: Power Supply

• Using this design, defibrillation uses:
  – 50 to 100 Joules of energy when electrodes are applied directly to the heart
  – Up to 400 Joules when applied externally
• Energy stored in the capacitor follows:
  \[ E = \frac{CV^2}{2} \]
• Capacitors used range from 10 to 50\(\mu\text{F}\)
• Voltage using these capacitors and max energy (400J) ranges from 1 to 3 kV
• Energy loss result in the delivery of less than theoretical energy to the heart
Defibrillator: Power Supply

• Lithium silver vanadium pentoxide battery is used
  – High energy density
  – Low internal resistance provides information regarding the end of battery life (not easy to detect in some other batteries)

• Lithium iodine battery used to power low-voltage circuits
Defibrillator: Rectangular-Wave

- Capacitor is discharged through the subject by turning on a series silicon-controlled rectifier.
- When sufficient energy has been delivered to the subject, a shunt silicon-controlled rectifier short-circuits the capacitor and terminates the pulse, eliminating a long discharge tail of the waveform.
- Output control can be obtained by varying:
  - Voltage on the capacitor
  - Duration of discharge
- Advantages of this design:
  - Requires less peak current
  - Requires no inductor
  - Makes it possible to use physically smaller electrolytic capacitors
  - Does not require relays
Defibrillator: Output Pulses

- Monophasic pulse width is typically programmable from 3.0 to 12.0 msec
- Biphasic positive pulse width is typically programmable from 3.0 to 10.0 msec, while the negative pulse is from 1.0 to 10.0 msec
- Studies suggest that biphasic pulses yield increased defibrillation efficacy with respect to monophasic pulses

Figure 19.7 Defibrillation wave forms. The monophasic truncated exponential waveform is produced from a capacitor discharge that is truncated at about 5 ms. The biphasic truncated exponential waveform has its leads switched half way through.
Defibrillator: Electrodes

• Excellent contact with the body is essential
  – Serious burns can occur if proper contact is not maintained during discharge

• Sufficient insulation is required
  – Prevents discharge into the physician

• Three types are used:
  – Internal – used for direct cardiac stimulation
  – External – used for transthoracic stimulation
  – Disposable – used externally
Defibrillator: Electrodes

Figure 13.10  Electrodes used in cardiac defibrillation  (a) A spoon-shaped internal electrode that is applied directly to the heart. (b) A paddle-type electrode that is applied against the anterior chest wall.
Cardioverters

- Special defibrillator constructed to have synchronizing circuitry so that the output occurs immediately following an R wave
  - In patients with atrial arrhythmia, this prevents possible discharge during a T wave, which could cause ventricular fibrillation
- The design is a combination of a cardiac monitor and a defibrillator
Implantable Automatic Defibrillators

• Similar in appearance to the implantable pacemakers, consisting of:
  – A means of sensing cardiac fibrillation or tachycardia
  – A power supply and energy storage component
  – Electrodes for delivery of stimuli

• Defibrillation electrodes are used to detect electrophysiological signals

• Processing of signals is used to control stimulation
  – Mechanical signals are also used

• Energy storage is necessary to provide stimuli of 5 to 30 Joules
Figure 19.13 This cutaway view of a Jewel™PCD® Model 7219D implantable cardioverter-defibrillator from Medtronic, Inc., Minneapolis, MN shows that the battery and capacitor consume a large portion of the volume.
Commercial Examples

Taken from www.guidant.com

Taken from www.medtronic.com
References


Coronary Heart Disease and Heart Attack

Source: yourmedicalsource.com

Medtronic, MN

Normal ECG

Abnormal ECG

Atherosclerotic Coronary Artery Disease

Source: yourmedicalsource.com
Balloon Angioplasty and Stent Procedure

Computer model of blood flow in blocked artery

Blood Vessel Dilation with Balloon Catheter

- Guiding catheter
- Narrowed vessel
- Balloon catheter with uninflated balloon
- Balloon catheter with partially inflated balloon
- Balloon catheter with inflated balloon
- Dilated vessel

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http://www.med.umich.edu/llib
Thermal Imaging of the Heart: Can we “see” the heart attack?


Movie: Thermal Images of the heart
How do you alert someone of an impending heart attack?

% Heart saved: Time Matters!

Immediate: Implantable Myocardial Ischemia Detection Technology
Infinite Biomedical Technologies, MD
Minimally Invasive Robotic Bypass Surgery

ZEUS
By Computer Motion

da Vinci System
By Intuitive Surgical
MEMSurgery Test Bed

SYSTEM OVERVIEW - ASSISTANT

Visual Feedback

Force Amplification

Manipulation

Scaled Position

Force

Position

Strain-gauge signal

Strain gauge

Time (s)
Computer Modeling of Robotic of Blood Vessel Bypass Surgery
Future Work: MEMS Surgical Devices

Retracting Driver Arm

Impaling Driver Arm

Sliding Beam

Needle

Finger Suspension

Stator Slider

100 micron dimension!

Microneedle Simulation
Problems

Automatic Implantable Ventricular Defibrillator

1. Briefly review the history and literature of the automatic implantable cardioverter-defibrillator (AICD). Identify the earliest paper by Dr. Michelle Mirowski’s group, the first clinical implant, and the most recent studies demonstrating through the clinical trials the ever-widening utility of the AICD.

2. Describe two different ways for detecting ventricular fibrillation, VF, (both used by Dr. Mirowski, one in the very beginning and subsequently abandoned, and another more recent approach common to all defibrillator). Compare the pros and cons of the two approaches. Describe one algorithm, from literature or your own, to detect VF.

3. A primary goal of research and development of the modern AICD is to reduce the energy required for successful defibrillation. Describe the current ideas, discussed in the class or what you can find from literature, to achieve these (the ideas include electrode designs, defibrillation pulse strategies and more).

4. Give your idea for the next exciting research or development step in this field.
One of the major unsolved problems in heart disease is “HEART FAILURE.” Your task is to research this disease, identify potential technological solutions and come up with your own ideas. Focus on mechanisms, alternative solutions, devices/technology, and comparison/critique in your opinion and words.

Please research this disease and describe its source, mechanisms, physiology of heart failure (about 1 page with references).

Heart failure may be treated with drugs, gene therapy, surgical (myoplasty) or devices. What are the possible solutions? Medical literature search or text books will provide you answers. Describe each of these succinctly with references giving pros and cons (1 page).

Now let us focus on device oriented solution. That is, we would like to come up with suitable device that would “assist” the mechanically failing heart. Describe one such commercial/research grade “assist” device. Back it up by reference/patent/commercial information. Identify companies and products. Give specification/performance of one. (1.5 pages).

Lately pacemaker companies have come up with a pacing therapy for heart failure. The idea is to use electrical stimulation to help with heart failure. Please describe the technology and the solution. Literature, patent, or pacemaker company data will provide you the answer (1.5 pages).

Surgeons on the other hand recommended myoplasty. Describe the method briefly, and give your opinion on the suitability of this method vs. pacemaker vs. mechanical assist device.
Give the physiological basis of how either atrial or ventricular fibrillation is produced. Give 5 references citing the very current knowledge/theory on the subject.

What is the current state of the art in implantable pacemaker technology? You should review the literature/web to identify:

Companies involved in developing the latest generation of devices
Mention the key specifications of the latest generation devices.

What are the critical design features of implantable defibrillators? You should review patents (at least 5) to identify the key design aspects (give block diagrams and a very brief discussion).

Describe the latest electrode and waveform design that biomedical engineers have come up with? Why do they work better?

One of the emergent problems is to terminate atrial fibrillation. Describe 2 or 3 different approaches (clinical, surgical, device) that might be employed to treat atrial fibrillation. Give the pros & cons.

Describe either a) algorithm to detect atrial fibrillation, or b) electrode & shock pulse strategy to terminate atrial fibrillation.

Develop a novel design for either a) sensing physiological parameter (novel means other than ECG) to determine the incidence of ventricular fibrillation and resulting cardiac arrest so that based on the sensor design, the defibrillator can delivery a shock. b) novel design for sensing physiological measures of activity in a rate responsive pacemaker (novel means other than accelerometer & blood based sensors).