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Application of Bioelectronic Medicines on Cardiovascular System

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ABSTRACT: With regard to the diagnosis and treatment of illnesses and conditions, bioelectronic medicine promises to offer fresh perspectives.One of the therapeutic bioelectronic devices is a nano-implantable device.Bioelectric medicines is essential for properly treating several serious cardiovascular conditions.Bioelectronic medications could be used to treat patients in a personalised way for conditions like cardiac arrhythmias.

I. INTRODUCTION:

Electronic medical devices that control biological processes, treat diseases, or regain lost capability are known as bioelectronic medicines. Bioelectronic medicines are capable of causing, preventing, and sensing electrical activity in excitable tissue in three different ways. As it regulates a significant portion of the function in chronic disease, the peripheral nervous system will be at the centre of this advancement. A nano-implantable device is best application of the bioelectronic medicines.

It can be connected to specific peripheral nerves. In order to provide a therapeutic impact that is focused on the signal function of a particular organ, such gadgets will be able to understand & regulate brain signalling patterns. With the creation of increasingly advanced devices and innovative materials that have undergone nanoscale engineering, the bioelectronic sector has recently been able to advance.[3] These ground-breaking advances in the shrinking of device parts result in the development of flexible and biocompatible materials as well as more effective and expandable compute and power components, reducing side effects and lowering costs.

By offering treatments that may automatically alter during the day to deliver the best therapeutic effect to each patient, bioelectronic medicine promises to significantly improve the standard of care. These systems should ideally offer "closed-loop" control over physiological state variables to keep values within a therapeutic range.

1.1 HISTORY:

Cardiology's use of bioelectronic medicine is a never-ending story. The previous century has seen the development of numerous bioelectronic devices for patients with cardiovascular diseases. It has been fueled by urgent clinical needs and a tiara of emerald inventors. Electrical engineer John JackHopps utilized hypothermia in open-heart surgery in 1949 to stop it.[1] He learned that applying an electrical current to the heart using vacuum tubes and a small table radio powered radio powered by home current was in factconceivable.

The first pacemaker was put in a Swedish engineer named Arne HW Larson in 1958 at the age of 43 for total heart block thanks to the discovery of transvenous catheter electrodes.After that, electrical impulses, constant research into device miniaturisation, and incredible advancements were accomplished, there were also downsides like intravenous catheters, short battery life, and inevitable gadget replacement. Following that, the inventor of the implanted cardioverted defibrillator (ICD), Michel Mirowski, had a similar experience when he initially sought to implant a smaller version of an external defibrillator created by Zoll in order to reduce the risk of sudden cardiac death.[1]

The development of cardiac resynchronization therapy, which uses either a pacemaker (CRT-P) or a defibrillator (CRT-D), whose implantation is currently strongly advised in patients with heart failure (HF) and ventricular dyssynchrony (primarily due to left bundle branch block), represents another significant step in the clinical implementation of BM in cardiology. These devices are known for their acknowledged effects on quality of life and mortality. The effectiveness of alternative devices, however, such as cardiac contractility modulation, created for HF patients unsuitable for CRT, and phrenic nerve stimulation, designed for patients with central apnoeas, is still up for debate.

In actuality, the autonomic nervous system (ANS), sometimes known as "the wisdom of the

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body," plays a crucial role in maintaining homeostasis, and its imbalance is what causes the onset and progression of a number of cardiovascular diseases (e.g. hypertension, ischaemic heart disease, arrhythmias, HF).

Cardiovascular bioelectronic applications have mainly concentrated on RTH and HF. These conditions offer a compelling justification for ANS modulation because they are characterised by the so-called "autonomic imbalance," which is characterised by increased sympathetic tone and withdrawal of the vagal and parasympathetic nervous systems.New nonpharmacological approaches like invasive VNS (iVNS) and BAT have gained popularity as a result of inadequate progress in the development of new drug therapies and the identification of easily accessible anatomical targets acting as strategic switches of the ANS.

In order to expand the treatment toolbox for the most difficult patients, such as those with severe heart failure or resistant hypertension, BM devices have been conceptualised as a valid alternative to or complement to drugs in such settings.

Compared to their passive counterparts, active implants provide a number of development challenges. Despite the fact that integrated circuit production techniques use silicon-based penetrating electrode arrays, the Utah Slanted Electrode Array is a copy of the polymer-based fine,time,life and cuff electrode arrays. To the right of the image, on the scale bar for b, is a millimetre measurement. The sciatic nerve of a rat has all of the implants c-e. The reproductions of a–e were done with permission.

1.2 challenges:

(a) Ensuring that the implant has no negative effects on the tissue.
(b) Ensuring that the implant has no negative effects on the tissue while it is in use.
(c) Achieving the spatial selectivity necessary for the application.
(d) Maintaining the implant's flexibility (or bendability) despite the rigid silicon ASIC.
(e)Securely attaching the ASIC to the electrodes so that failure due to movement doesn't happen.
(f)Reliably protecting the ASIC and interconnects from the body so that failure does not occur.

1.3Mechanism:

As the heart beats, oxygenated blood is pumped to the peripheral tissues and deoxygenated blood is pumped away from them. This process results in blood circulation. The earlier electrical activation is extremely important for this.This is highly dependent on the controlled activation and recovery of electrical excitation through the myocardium.Risk factors for practically any type of arrhythmia include narrowed heart arteries, a heart attack, faulty heart valves, prior heart surgery, heart failure, cardiomyopathy, and other heart problems.
The electrical language of diseases should theoretically be able to be deciphered because all bodily organ functions are controlled by neural circuits that communicate via electrical impulses. Bioelectronic medicines help includes:
(1)Understanding Molecule/Cell-Electronic Interfaces is one way BEMs can be helpful.
(2) Being aware of the differences between cellular reactions to stimulation (such as electrical, mechanical, chemical, thermal, and similar stimuli).
(3) Capability to gather and analyze crucial data on the (chemical, physical, structural, and functional) state of cells and bimolecular structures.
(4). The capacity to continuously Atrack the biochemistry of a single cell or a population of cells, which necessitates an understanding of molecule interactions. Ability to detect, identify, and quantify thousands of different biomarkers at once, as well as the ability to deliver appropriate therapeutic materials and stimuli in real-time.

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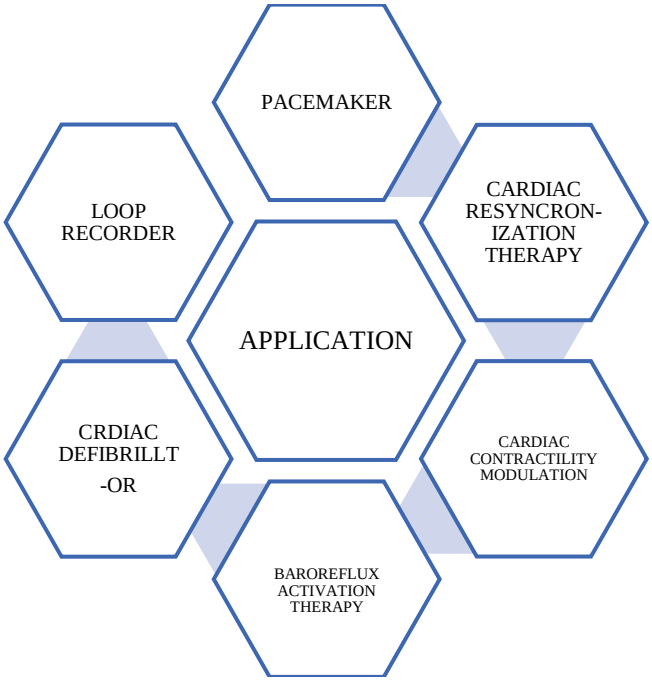
II. APPLICATION:



2.1 PACEMAKER:

2.1.1Introduction: A pacemaker is a tiny, battery-powered medical gadget that sends electrical impulses to the heart to ensure regular contractions.It serves as a safeguard against the heart beating slowly. The majority of pacemakers are used to treat "bradycardia," or a painfully slow heartbeat.[9]The heart typically beats between 50 to 70 times per minute while at rest, and this pace can go up by two to three times while stressed or working out.The placement of a pacemaker in the chest necessitates surgery.

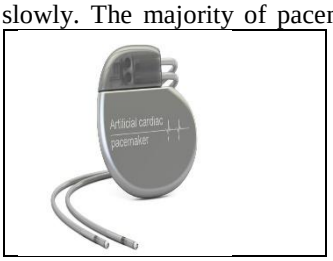


Fig.1: Pacemaker

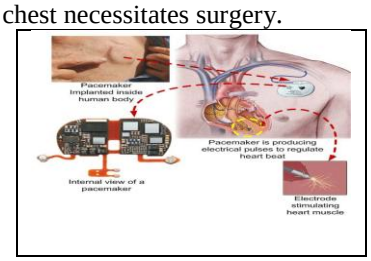


Fig.2: Mechanism

2.1.2 Mechanism:The pacemakers can be single chamber, dual chamber, or bi-ventricular, depending on how many active leads are present. Passive fixation leads, which have the benefit of being placed at the bedside, have been utilised for purpose for years. The pacemaker's optionl mode is determined by paced chamber, sensed chamber,reaction to a perceived electrical signal and rate modulation.[9]

2.1.3 Advantages: Having a pacemaker can significantly improve your quality of life if anyone has problems with a slow heart rate. The device can be lifesaving for some people.

2.2 LOOP RECORDER:

2.2.1 Introduction: ILR devices allow for continuous monitoring of arrhythmias and are placed subcutaneously on the chest.As they make it possible to record cardiac electric activity during symptomatic episodes and detect asymptomatic arrhythmic events, they play a crucial part in the treatment of patients with suspected or underlying cardiac arrhythmia. These implants can be completed in under 20 minutes while using local anaesthesia, making them simpleto place.

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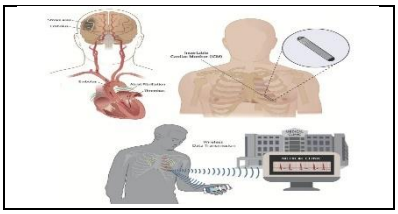

Fig.3:Loop Recorder Fig.4: Working

2.2.2 Mechanism: A tiny loop recorder that is implanted under the skin of the left side of the chest is used to monitor cardiac rhythm. Unlike a pacemaker, the device does not contain leads that go via veins into the heart. It is significantly more compact than a pacemaker and has a battery Cardiac Resynchronization Therapy Dilated heart failure with discoordinate contraction is treated with cardiac resynchronization treatment (CRT). A common cause of such dyssynchrony is electrical lag, which ultimately results in mechanical lag between the septal and lateral walls life of three to four years.[5]

2.2.3 Advantages: A normal electrocardiogram (ECG) or Holter monitor may miss certain information if an implantable loop recorder is used, especially if there are brief or infrequent arrhythmias.

ILR is used for a variety of conditions, including:
1. Heart Failure and Post-Myocardial Infarction
2. Adult Congenital Heart Disease
3. Cardiac Light Chain Amyloidosis
4. Postural Orthostatic Tachycardia Syndrome
5. Cryptogenic Stroke
6. Elderly Patients with Risk Factors for Stroke
7. Obstructive Sleep Apnea
8. AF Ablation
9. Coronary Artery Bypass Graft.

2.3 CARDIAC RESYNCRONIZATION THERAPY:

2.3.1 Introduction: Cardiac Resynchronization Therapy Dilated heart failure with discoordinate contraction is treated with cardiac resynchronization treatment (CRT). A common cause of such dyssynchrony is electrical lag, which ultimately results in mechanical lag between the septal.

2.3.2 Mechanism: Cardiac Resynchronization Therapy Dilated heart failure with discoordinate contraction is treated with cardiac resynchronization treatment (CRT). A common cause of such dyssynchrony is electrical lag, which ultimately results in mechanical lag between the septal and lateral walls.CRT is utilised to restore equilibrium to the two ventricles when the left bundle branch is bloked.

Fig.5: CRT Device

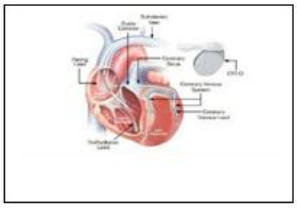

Fig.6: CRT Implantation

2.3.3 Advantages:Cardiac resynchronization therapy with a defibrillator (CRT-D) can increase functional status, morbidity, and survival in a few patient populations who have heart failure, a low left ventricular ejection fraction (EF), and QRS prolongation.[7]

2.4 AUTOMATIC IMPLANTABLE CARDIAC DEFIBRILLATOR:

2.4.1Introduction: The automated implantable cardioverter-defibrillator continuously monitors the heart and locates malignant ventricular tachyarrhythmias before delivering an electrical countershock to restore normal rhythm. It is being

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used to treat people who are at high risk for sudden arrhythmic death.

Fig.7:ICD

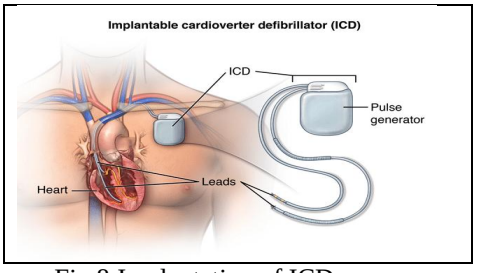

Fig.8:Implantation of ICD

2.4.2 Mechanism:Defibrillation and waveform analysis are performed using two defibrillating electrodes, one over the cardiac apex and the other in the superior vena cava. A third bipolar right ventricular electrode is used for rate counting and R wave synchronisation. When ventricular fibrillation occurs, a 25 J pulse is delivered;[8]when ventricular tachycardia that is faster than the target rate is discovered, the discharge is R wave-synchronized.

2.4.3 Advantages: According to the data now available, automated cardioverter-defibrillators may effectively identify and treat potentially fatal ventricular tachyarrhythmias, which significantly increases survival in carefully selected high-risk patients.

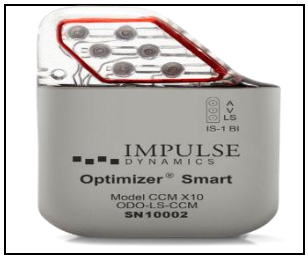

Fig.9:CCM

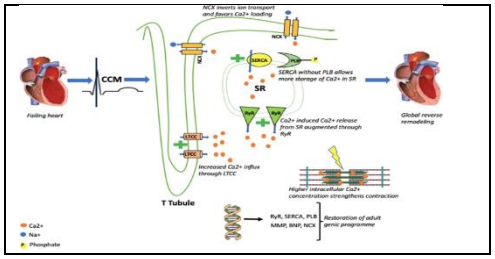

Fig.10:CCM Mechanism

2.5 CARDIAC CONTRACTILITY MODULATION:

2.5.1 Introduction: Patient with heart failure uses this device. The contractile strength of isolated rabbit papillary muscle strips and trabeculae derived from human hearts removed from patients is increased by cardiac contractility modulation signals.[6]

2.5.2 Mechanism:Cardiac contractility modulation (CCM) signals are biphasic, 22-ms-long, relatively high-voltage impulses that are sent to the right ventricular septum during HF's absolute refractory period.[6]The sarcoplasmic reticulum's capacity to sequester calcium was improved by CCM because it also quickly returned to normal phospholamban phosphorylation.[13]

2.5.3 Advantages: Patients with baseline EFs between 35% and 45%, which includes 50% of HF patients with mid-range EFs, benefit most from CCM (HFmrEF).[6]In HFrEF patients, it has been demonstrated that CCM improves calcium handling, inhibits the HF-related foetal myocyte gene programme, and promotes reverse remodelling at the cellular level.

2.6 BAROREFLUX ACTIVATION THERAPY:

2.6.1 Introduction:BAT is a technique for electrical stimulation that is administered by a pacemaker-like implant. By stimulating the carotid baroreceptor with BAT, sympathetic outflow is decreased centrally while parasympathetic activity is raised, increasing arterial and venous compliance and decreasing peripheral resistance.

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Fig.11:BAT

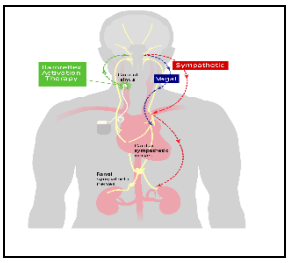

Fig.12:BAT Mechanism

2.6.2 Mechanism:In individuals with heart failure, the arterial baroreflex can be controlled to rebalance sympathetic nerve activity. By stimulating the carotid baroreceptor with BAT, sympathetic outflow is decreased centrally while parasympathetic activity is raised, increasing arterial and venous compliance and decreasing peripheral resistance.[11]

2.6.3 Advantages: In comparison to the 12 months before to the BAT system's installation, the rate of HF hospitalisation was also markedly reduced.[12] BAT has been demonstrated to be secure and efficient for decreasing high blood pressure in people with resistant hypertension (BP).

ADVANTAGES OF BEM:

(a)Bioelectronic medicine promises to offer fresh perspectives on the diagnosis and management of a wide range of illnesses and conditions, includingcardiovascular disease, cancer, rheumatoid arthritis, inflammatory bowel disease, obesity, diabetes, asthma, paralysis, blindness, bleeding, ischemia, organ transplantation, neurodegenerative diseases, and others.

(b) BEM has less side effects as compared to therapeutic drugs.

(C)Most beneficial for elderly folks with cardiovascular disease.

DISADVANTAGES:

(A)BEM Devices are especially dangerous in extreme circumstances like car crashes.

III. CONCLUSION:

The construction of adaptable BEms for accessing cardiovascular diseases has certain major technological considerations, which covered in this study.This review aims to provide the reader with a comprehensive picture of the various applications of BEms in arrhythmias rather than to be exhaustive.The review's primary emphasis is on the devices' mechanism and benefits.Human health can be improved by BEm's innovative technology.

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