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Ventricular Synchronous Demand Pacemaker

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Abstract

The aim is to provide information about the artificial pacemakers and also information about the available pacemakers, their features and the need of pacemakers.

1. Introduction

Artificial pacemakers, also called pacemakers, discharge electrical impulses in two ways. They can be programmed to emit electrical impulses at a steady rate that does not respond to the activity of the heart. These are known as fixed-rate pacemakers. Alternatively, demand pacemakers can discharge electrical impulses when the heart rate falls outside of a predetermined zone or skips a beat. Demand pacemakers are thus used to regulate arrhythmias, which are heart rhythms that are irregular, where the heart beats either too rapidly or too slowly.

Pacemakers that work on demand are known as permanent pacemakers. They are implanted to regulate heart-rate problems that occur over extended periods of time. In 1958, Wilson Greatbatch and W.M. Chardack created the first implantable permanent pacemaker. Just six years later in 1964, Greatbatch designed the demand pacemaker, which became available for use in 1966.

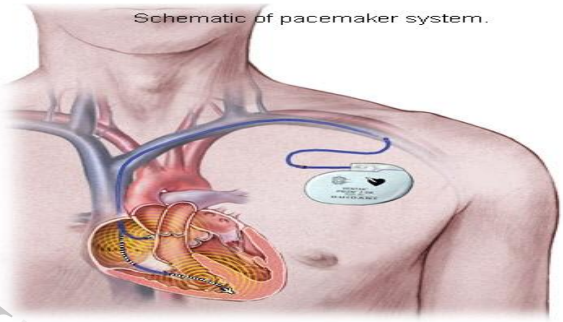
The advantages of using demand pacemakers are realized shortly after this.

One advantage of a demand pacemaker is that they prevent the occurrence of what are known as competitive beats. They occur when the heart's intrinsic pace-making mechanism and an fixed-rate pacemaker stimulate a heartbeat at the same time. This simultaneous firing usually happens because arrhythmias are only intermittent. When they are not occurring, the heart's intrinsic pacemaker fires and the heart beats normally. A fixed-rate pacemaker cannot detect intrinsic heartbeats and will emit electrical impulses at the same time that the hearts own pacemaker fires, causing the competitive beats. Once thought to be harmless, competitive beats have been associated with higher mortality rates and health problems in pacemaker patients.

The demand pacemaker senses the activity of the heart, which allows it to refrain from emitting electrical impulses while the heart is intrinsically firing. This eliminates the possibility for competitive beats to occur. Doing so has increased the clinical applicability of pacemaker treatment for conditions that would elicit a competitive beat from a fixed-rate pacemaker, but would benefit from some sort of pacing nonetheless.

Another advantage of the demand pacemaker is that firing less often allows it to reserve its battery power for a much longer period of time than fixed rate pacemakers. Demand pacemakers are also advantageous because they protect against a condition known as ventricular asystole. Ventricular asystole refers to the lack of mechanical and electrical activity in the heart—a condition that can cause a person to faint and is in many cases fatal. In sensing the absence of a heartbeat, the demand pacemaker sends an electrical impulse to catalyse the heart to prevent fainting or death from occurring

Figure



This pacemaker is one with "a ventricular stimulating pulse generator delivering its output synchronously with the natural ventricular activity and asynchronously in the absence of natural ventricular activity". Ventricular synchronous pacemakers are modifications of atrial synchronous pacemakers. They have a similar upper and lower safeguard escape rate, but utilize a single ventricular electrode for sensing and stimulation. We have a lower trigger sensitivity, an almost immediate response to a trigger stimulus, logic to differentiate the QRS from the P and T waves, refractory period of about 400 millisecond, and a magnetic-switch asynchronous mode. They are non-competitive with ventricular activity except in very rare instances and insensitive to non-transmitted atrial activity.

Special problems or deficits associated with the use of pacemaker include the following:

(1) During sustained synchronous stimulation, the threshold to pace is uncertain, and its adequacy must be checked periodically by overdrive stimulation or magnetic conversion to asynchronous pacing.

(2) Failure to sense (electrode malposition ,battery depletion, or signal decrement) results in fixed-rate pacing and, if the pacing threshold is sustained, competition with spontaneous rhythms.

(3) The synchronous-pacer artefact consistently distorts the electrocardiogram even during sinus rhythm. Magnetic mode pacing allows occasional breakthrough of un paced spontaneous beats if the

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rhythm is at or over the escape rate, but this engenders competition and is avoided when the need to see a true complex is the highest, i.e., during an acute coronary.

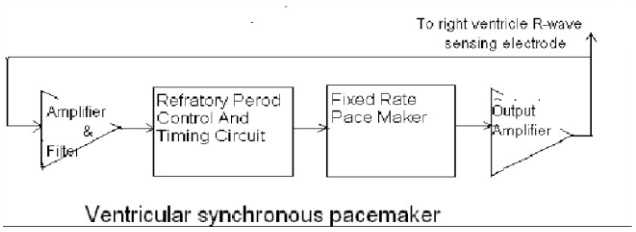
(4) Extra systoles that come within the refractory period of a paced beat are not sensed, and the next paced beat, cycling at the escape rate from the previous paced beat, results in a tachycardia triplet. Prolongation of the refractory period enhances this effect and allows the paced "escape" beat to come uncomfortably close to the T wave of the "missed" spontaneous beat. These mixtures of spontaneous and ectopic beats, with synchronous and paced beats, are difficult to interpret and often alarming to the uninitiated

(5) A wide variety of transient "interference"currents, including those produced by the magnetic or radiofrequency tripping of the magnetic switch, wire breaks, faulty connections, short circuits, whipping catheter motions, and tall T waves, are equated with QRS signals by the sensor circuit. This results in an erratic, frequently competitive, pacing output. With repetitive stimuli, however, the response rate cannot exceed the top design output of the pacemaker (a fail-safe feature). A positive effect of this interference sensitivity is that these pulse generators may be externally triggered to overdrive rates (to their upper escape limits), which is useful in the treatment of post implantation multifocal extra systoles or intermittent tachyarrhythmia's.

(6) Late synchronization occasionally occurs with the stimulus rate in the QRS. Rarely , it reaches the vulnerable zone and initiates early or repetitive contractions. In right-sided trans venous pacing, it has been ascribed to origination of the contraction on the left with delayed conduction to the right .There may also be a specific latency, with either ventricle, particularly in recent infarction

(7) The ventricular synchronous pacemaker has the shortest mean longevity of battery life due to constant pacing, often above the escape rate, and the additional current drain of the sensing circuit.

Figure



Ventricular synchronous pacemaker

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VENTRICULAR SYNCHRONOUS PACEMAKERS

They are preferred for short periods of AV block. Using sensing electrode heart rate is detected & is given to timing circuit of pacemaker. If the heart rate is below a min rate then pacemaker is turned on.The lead used to detect the R wave is now used to stimulate the heart. If natural contraction occurs then asynchronous pacer's timing circuitis reset so that it will tie its next pulse to detect the heart beat else produce pulse at its present rate

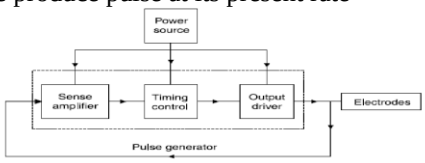

Fig. 2.8. Basic demand pacemaker functional block diagram

ADVANTAGES

1. To arrest the ventricular fibrillation, this circuit can be used.
2. Power consumption is reduced

DISADVANTAGES:

1. Atrial and ventricular contractions are not synchronized.
2. The circuit is more sensitive to eternal electromagnetic interference

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Demand Mode Pacing

In demand mode pacing, the pacer senses the patient's intrinsic heart rate, and will pace if the intrinsic signal is slower than the rate programmed by the clinician. For example, if the patient's heart rate becomes slower than the prescribed setting, the pacer will send an electrical stimulus. If the pacer senses that the heart rate is faster than the pacing rate, it inhibits an electrical signal.

The advantages of demand mode pacing are: competition between the pacemaker stimuli and the intrinsic heart rate is minimized, decreasing the risk of R on T and the number of pace pulses introduced is minimized reducing patient discomfort. For this reason, demand mode pacing is primarily used as the default setting. During demand mode pacing, Philips' ALS defibrillators detect R waves, or beats. Intrinsic beats are defined as those that are generated naturally by the patient. Paced, or captured beats are defined as those that are a result of delivered pacing energy. Philips' ALS defibrillators also define the paced refractory period, which is simply a period of time after the delivery of a pace pulse. The refractory period is approximately 340 ms for pacing rates less than or equal to 80 pulses per minute (PPM), and approximately 240 ms for pacing rates greater than or equal to 90 PPM.The Philips' ALS defibrillator pacer uses a very simple algorithm for determining if a detected R wave is intrinsic or paced. If the detected QRS falls within the refractory period of a pace pulse the beat is considered paced, otherwise it is considered intrinsic. With the pacer on, the defibrillator marks intrinsic beats with a dot the R-wave Clinicians must not rely solely on the defibrillator's classification of beats as intrinsic or paced to determine electrical capture. Consider the situation where the patient's intrinsic HR is 62, and the pacer is set at a rate of 60. Since the two rates are very close, pacer spikes and intrinsic beats may occur very close to each other for several seconds. In this circumstance, the defibrillator may think the beats are paced based on its simple timing algorithm, but in fact the beats are intrinsic and the timing coincidental. There may also be cardiac conditions which can cause a truly paced beat to fall outside of the refractory period

ADVANTAGES

1. Pacemaker implantation is a safe procedure**.**
2. It controls the pumping action of the ventricles at a set rate.
3. It restores "communication" between the atria and ventricles, making them work together correctly.
4. It increases the heart rate, when required, in response to physical activity demands, when your heart is beating normally, the new types of pacemakers(demand pacemakers) will not be activated. It will only activate when your natural heart rate is slower than the programmed rate. The rate can be changed to meet your needs. This is done via an external device that communicates to your pacemaker. The pacemaker can also be programmed to not activate at times when your natural heart rate would normally slow down, e.g. when sleeping.

DISADVANTAGES

1) Some discomfort and bruising around your pacemaker site. Paracetamol is required to ease this pain, Although rare complications may include infection at the implantation site, introduction of air into the space between the lung and chest wall, perforation of the heart (requiring urgent drainage of the blood from the sac, stroke, heart attack, and damage to blood vessels).

2) There are only a few devices in the environment today that which can interfere with a pacemaker. Arc welding equipment and equipment with powerful magnets have the potential to interfere with the pace generator. Most home appliances, such as a microwave, do NOT interfere with a pacemaker. Cell phones in the U.S. do NOT interfere with pacemakers, but you should still keep them away from the pacemaker area

COMPANIES DEALING WITH PACE MAKERS

PHILIPS
sense and simplicity

Royal Philips Electronics launched a new service that provides 24-hour, web-based remote monitoring follow up services for patients with

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pacemakers. The new service, which was made available to cardiology practices in August, is the first large-scale service of its kind in the U.S.Pacemakers are a critical part of treatment for patients with a wide range of heart conditions, and they must be checked frequently to ensure proper function.

Philips has offered Trans telephonic (data transmission via phone)follow-up services for 35 years. Leveraging this experience, Philips is expanding its portfolio to include the latest pacemaker technology. Remote monitoring is becoming the gold standard of care for surveillance of patients with cardiac implantable electronic devices. Scientific data has demonstrated remote monitoring allows earlier detection of patient issues than standard in-clinic follow up.

Philips brings unprecedented convenience and patient care quality to cardiology practices by conducting web based remote monitoring of their pacemaker patients. Philips technicians review, summarize and triage each pacemaker test and provide clinically appropriate, customized notification to support timely and informed patient management for the physicians. Philips will be applying to its web-based service the same robust ,proprietary follow-up processes that they've used for all remote monitoring services, which have increased patient compliance (i.e., patients completing regular checks of their pacemaker function) from 60 per cent to greater than 90 per cent. “With the Philips web-based remote monitoring service, we can do more with less. We get more frequent

Clinical information without using staff resources, allowing our staff to re-focus their time on other bill able services. And, the service has helped us improve our billing processes," said Syed Samee, M.D., F.A.C.C.,Cardiologist, Blessing Physician Services, Quincy.

The team of Philips certified cardio graphic technicians undergo intensive training and average more than 15years of experience in pacemaker and implantable cardioverter defibrillator (ICD) follow-up. The technicians analyze and interpret more than 1,000 pacemaker transmissions per day, which enables them to spot even subtle abnormalities. This keen analysis resulted in a .009% per cent error rate over the past 12 months. And with 24/7surveillance, the cardiologists are alerted to critical patient data in real-time, without having to be on-call.

ELITE

The heart's natural pacemaker is an electrical timing device that controls the rate of the heart's muscular contractions, enabling the heart to pump blood under the wide range of demands encountered in daily life. Everyone’s heart speeds up or slows down under different conditions and may on occasion appear to flutter or miss a beat. However, sometimes the heart's electrical system malfunctions and serious rhythm disorders result. These cardiac arrhythmias can be debilitating and even life-threatening, but the recent availability of artificial pacemakers and the recent advent of implantable defibrillators have revolutionized treatment. Today, physicians can help patients by using electronic devices that directly counter these serious rhythm disturbances. Implantable electronic devices have been developed to treat both abnormally slow heart rates (bradycardias) and excessively rapid heart rates (tachycardia). Such rhythm disorders arise because of disruptions to the normal production or transmission of electrical impulses within the heart.

The heart's natural pacemaker is the sinus node (SN), located in the upper right atrium near the point where blood returning from the head and limbs re-enters the heart. Specialized cells in this node emit electrical impulses at the rate of about 70

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per minute. These impulses spread throughout the atria and travel to the ventricles via the atrio-ventricular node (AV node).The electrical system ensures that impulses reach the right part of the heart at the right time and at the right pace, coordinating the contraction of the heart muscle so that it can pump effectively. When the sinus node fails to generate impulses or transmission is blocked in some part of the electrical system, an abnormally slow heart rate can result. Assuming that this bradycardia is not the side effect of a medication or produced by some other reversible condition, the most likely cause is disease in the sinus node, the AV node, or some other part of the conduction pathway.

If the patient is experiencing these symptoms and the heart rate is extremely slow (below 45 or 50), the condition may be markedly improved by an artificial pacemaker. There are, however, many people who function normally with slow heart rates of 40-50 and evidence of some degree of heart block. Pacemakers are generally reserved for those with symptoms and advanced degrees of block.

ST JUDE MEDICAL PACE MAKERS

The St. Jude Medical product portfolio includes implantable cardioverter defibrillators (ICDs), cardiac resynchronization therapy (CRT) devices, pacemakers, electrophysiology catheters, mapping and visualization systems, vascular closure devices, structural heart products, heart valve replacement and repair products, spinal cord stimulation and deep brain stimulation devices.

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SEIMENS

It was in autumn 1958: At the age of only 43, Swede Arne Larsson's life appears to be almost over. He suffers from arrhythmia, which is further aggravated due to a virus infection. 28 beats per minute is his heart rate – the heart of a healthy adult beats 70 times a minute. Larsson passes out perpetually and must be reanimated 20-30 times every day. There is in fact no prospect of cure. However, his wife Else-Marie is not willing to put up with her husband's imminent destiny. She learns from the newspapers that the cardiologist Professor Åke Senning at Karolinska Hospital in Stockholm is working on the development of an implantable cardiac pacemaker together with the physician and engineer Rune Elmqvist. Mrs. Larsson is convinced that this will be her husband's rescue – although there was actually no adequate device available for human beings at that time, and experiments had so far only been performed on animals.

First pacemaker from Siemens

Thanks to the untiring persuasiveness of his wife, Arne Larsson received the first cardiac pacemaker implant on October 8, 1958 in a secretly performed emergency surgery. Rune Elmqvist, who developed

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this first pacemaker worldwide, was an engineer at Siemens-Elema and had also worked as a cardiologist before. Due to the urgency, he cast the components of this first device with epoxy resin in a shoe polish tin. Two electrodes connected to the pacemaker released the stimulation energy to the heart. However, this first model had to be replaced with a new pacemaker after only several hours. Yet the technology advanced rapidly. There were ever complex models providing for an unsound heart's specific requirements. Today, the pacemaker is standard in modern cardiology and has a life cycle of ten years.

COMPARISON BETWEEN VARIOUS COMPANIES

COMPANY	LIFE*	BATTERY	COST
SEIMENS	25 YEARS	LI-IODINE BATTERY	Rs 60000/-
PHILIPS	25 YEARS	LI-IODINE BATTERY	Rs 45000/ to 50000/-
ELITE	APPROX 50 YEARS	RADIO ACTIVE	NOT AVAILABLE IN INDIA
ST JUDE	30 JUDE	LI-IODINE	Rs 80000/-

*(LIFE REFERS TO THE LIFETIME OF THE PACE MAKER ONLY)

PACEMAKER IMPLANTATION IN INDIA

This procedure is done under local anaesthesia and is usually an outpatient procedure. A small incision is made just under the collarbone. The pacemaker is inserted into the heart through a blood vessel which runs under the collarbone. Once the lead is in place it is tested to make sure it is in the right place and it's functional. The lead is then attached to the generator, which is placed just under the skin through the incisions made earlier. Once the procedure has been completed the patient goes through a recovery period of several hours and often is allowed to go home the day of the procedure.

In India the cost starts around Rs 45000/- and goes up to Rs 1, 80,000/-depending on the requirement and quality.

CONCLUSION

After studying the various types of pace makers and their applications, we selected Ventricular Synchronous Demand Pace maker. We got an opportunity to go through the working and development of the pace maker. This topic also increased my curiosity in the field of Bio Medical Instrumentation.

The various aspects covered in this Topic are history, working, development, advantages and dis-advantages, companies dealing with pace makers and comparison between them. In the course of my study we found out that demand pace makers are in large demand in India, around 3 lakh people in India are using this type of pace maker. Also the cost of it is significantly higher when compared to other types.

Also, the quality of pace makers available in India is lesser than that available abroad. For example .The pace maker ELITE which runs on Radio active battery is not available in India. So there is a dearth of good pacemakers in India.

Thus we conclude our topic with the following observations:

1) The pace makers of this type are being very widely used around the world and with newer and newer technologies pace makers which take energy from the heart and work are being invented.

2) A large amount of work is in progress in development of more efficient type of batteries. But the cost and quality of Pace maker in India is a cause of concern.

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