

ChatGPT: AI-Driven Patient Education on Pacemaker Monitoring and Recent Trends in Upcoming Treatments, Along with Future Innovations

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Dear Editor

Open AI is at the forefront of artificial intelligence research, based in California. This organization aims to design software for the benefit of humans, prioritizing safety and ethics, and conducting research to align AI with human values and mitigate risks. Chat Generative Pre-Trained Transformer 4 Omni (ChatGPT-4o) is the newest flagship language model that uses deep learning techniques to produce human-like responses to natural language inputs. It is part of the Generative Pre-Training Transformer (GPT) family, currently one of the largest publicly available language models with faster and improved capabilities in text, voice, and vision (1). Developing virtual assistants for patient health management, keeping them updated on their medical conditions and treatment modalities, represents a key application of ChatGPT in the medical field. ChatGPT's potential in medicine includes identifying

research topics and assisting professionals in clinical and laboratory diagnostics (2).

Machine Learning (ML) methods for Electrocardiography (ECG) interpretation show high sensitivity and specificity for detecting normal sinus rhythm but lag behind expert cardiologists in identifying arrhythmias. This gap may be due to noise, tremors, or untrained ML algorithms. Utilizing unsupervised Deep Neural Networks (DNNs) with advanced ML algorithms, including noise reduction and optimized selection, has significantly improved the accuracy of computerized ECG interpretation for arrhythmia detection, reaching 95% accuracy.

Unsupervised DNN algorithms excel at detecting hidden disease states and complex changes in ECGs, such as myocyte hypertrophy, fibrosis, and chamber dilation, often unrecognizable to the human eye. This capability is vital for early identification and prevention of adverse events like embolic

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stroke (3). Most implantable devices, like pacemakers and defibrillators, use human-designed rule-based algorithms with biosensor-driven decision-making. Continuous remote monitoring utilizes ML algorithms, including random forests and convolutional neural networks, providing superior sensitivity and specificity in predicting embolic stroke compared to the CHA2DS2-VASc score (4).

Permanent pacemakers have advanced with smaller sizes, longer battery life, better quality, and refined pacing algorithms for better lead fidelity. However, they still encounter problems like lead displacement, fracture, cardiac tamponade, and pneumothorax due to the transvenous approach with subcutaneous leads (3). New

advanced strategies provide solutions by surface coated implantable cardiac medical devices with biocompatible-polymer leads, antibacterial silver nanoparticle-coating leads, and smart biomaterial tissue-engineered leads (5,6). Leadless pacemakers have been developed to eliminate these complications, particularly benefiting hemodialysis patients by preserving the upper limb venous system (7). Future medical advances focus on regenerative medicine and gene therapy to modify non-pacemaker myocytes for automaticity (8). Additionally, pacemakers powered by heartbeats could increase device longevity, although they are currently limited due to the need for open-heart surgery.

Table 1. Describes a brief conversation comprising of FAQs, between a common man and ChatGPT about pacemaker - digital monitoring, updates, safety and do's and don'ts with an internal cardiac device.

QUESTIONS	Chat GPT4o RESPONSES.
1. What is a Pacemaker?	A pacemaker is a medical device implanted in the body to regulate the heartbeat. It sends electrical impulses to the heart to ensure it beats at a normal rate and rhythm, particularly in cases of arrhythmias or heart block.
2. Patients with what Heart condition need Pacemaker?	Individuals who may need a pacemaker include those with Bradycardia (abnormally slow heart rate), Heart block (a condition where the electrical signals are partially or completely blocked between the heart's upper and lower chambers), Certain types of heart failure, Atrial fibrillation with slow ventricular response, Syncope (fainting) due to heart rhythm issues.
3. How is a patient evaluated for the need for pacemaker?	<ul style="list-style-type: none"> • Medical History and Physical Exam: Reviewing symptoms, medical history, and conducting a physical examination. • Electrocardiogram (ECG): Recording the heart's electrical activity to detect irregularities. • Holter Monitor: A portable device worn for 24-48 hours to continuously monitor the heart's activity. • Echocardiogram: An ultrasound of the heart to check its structure and function. • Electrophysiological Study (EPS): Testing the electrical conduction system of the heart. • Stress Test: Observing the heart's function under physical exertion.
4. What are the Alternative treatment options for pacemaker	<ul style="list-style-type: none"> • Medication: Drugs such as beta-blockers, calcium channel blockers, and antiarrhythmics can help manage heart rhythm issues. • Lifestyle Changes: Dietary modifications, exercise, and quitting smoking can improve heart health. • Catheter Ablation: A procedure that destroys small areas of heart tissue causing abnormal rhythms. • Implantable Cardioverter-Defibrillator (ICD): A device similar to a pacemaker but also capable of delivering shocks to correct dangerous arrhythmias. • Surgical Procedures: Corrective surgeries to address underlying structural heart issues.

Continue Table 1.

QUESTIONS	Chat GPT4o RESPONSES.
5. How is a pacemaker placed in human body ?	<p>There are primarily two ways a pacemaker can be placed in the human body:</p> <p>Transvenous (Endocardial) Approach:</p> <p>Common Method: Leads are inserted through a vein (usually the subclavian vein) and guided to the heart's chambers.</p> <p>Device Placement: The pacemaker is placed under the skin near the collarbone.</p> <p>Usage: This method is widely used for most permanent pacemakers.</p> <p>Epicardial Approach:</p> <p>Surgical Method: Leads are attached directly to the heart's outer surface (epicardium) through a small chest incision.</p> <p>Device Placement: The pacemaker can be placed under the skin in the abdomen or chest.</p> <p>Usage: This method is often used in pediatric cases or when transvenous access is not possible.</p>
6. How can we personalize pacemaker?	<p>Yes, pacemakers can be personalized to meet individual patient needs by:</p> <p>Programming: Adjusting the settings to regulate heart rate, rhythm, and response to physical activity.</p> <p>Rate Response: Tailoring the device to increase heart rate during exercise or physical activity.</p> <p>Dual-Chamber Pacing: Coordinating pacing between the atrium and ventricle for optimal heart function.</p> <p>Advanced Features: Incorporating features like remote monitoring, multiple sensors, and algorithms to adapt to the patient's lifestyle and health conditions.</p> <p>Personalization ensures the pacemaker effectively addresses the specific heart rhythm issues of the patient.</p>
7. What are the complications of pacemaker?	<p>Complications that can occur with a pacemaker include:</p> <p>Infection: At the site of the incision or around the device.</p> <p>Bleeding or Hematoma: Blood collection at the implant site.</p> <p>Lead Displacement: Leads can move from their intended position.</p> <p>Device Malfunction: The pacemaker may not work properly due to hardware issues.</p> <p>Pneumothorax: Air leaks into the space between the lung and chest wall.</p> <p>Cardiac Perforation: Leads can puncture the heart muscle.</p> <p>Thrombosis: Blood clots can form in the veins used for lead placement.</p> <p>Allergic Reactions: Reaction to the materials used in the pacemaker or medications given during the procedure.</p> <p>Regular follow-ups with a healthcare provider can help detect and manage these complications.</p>

Continue Table 1.

QUESTIONS	Chat GPT4o RESPONSES.		
8. What are the recent advancements in pacemaker?	<p>Recent advancements in pacemakers include:</p> <p>Leadless Pacemakers: Smaller devices implanted directly into the heart without the need for leads, reducing infection and displacement risks.</p> <p>Magnetic Resonance Imaging (MRI)-Compatible Pacemakers: Devices designed to be safe for patients undergoing MRI scans.</p> <p>Remote Monitoring: Wireless technology allows for real-time monitoring and data transmission to healthcare providers.</p> <p>Extended Battery Life: Improvements in battery technology extending the lifespan of pacemakers.</p> <p>Advanced Algorithms: Enhanced software that optimizes pacing based on the patient's activity levels and physiological needs.</p> <p>Biological Pacemakers: Research into using genetically modified cells to create a natural pacemaker function.</p>		
9. What is difference between traditional pacemaker and the new technology pacemaker?	Feature	Traditional Pacemakers	New-Generation Pacemakers
	Pulse Generator	Standard lithium batteries, 5-10 years	Advanced lithium batteries, 10-15 years
	Leads	Insulated wires with electrodes	Leadless designs available, reducing complications
	Rate Responsiveness	Basic activity sensors	Advanced sensors (accelerometers, breathing sensors)
	Pacing Mode	Single or dual-chamber	Dual-chamber, multi-site, and leadless options
	Size	Larger, typically implanted under the skin	Smaller, some implanted directly in the heart (e.g., Micra)
	Communication	Limited telemetry, often requiring in-clinic visits	Wireless communication via Bluetooth or RF, remote monitoring via mobile apps
	Remote Monitoring	Basic data collection for in-office review	Continuous remote monitoring, real-time alerts, apps for patient use
	Arrhythmia Detection	Limited detection capabilities	Advanced arrhythmia detection, automatic adjustment and therapy
	Programming	In-clinic programming only	Remote and in-clinic programming, patient-specific customization
	Security	Basic security features	Enhanced encryption, regular firmware updates
	MRI Compatibility	Limited or non-existent	MRI-conditional, safe under specified conditions
10. What is remote monitoring and how does it work for a pacemaker?	<p>Remote monitoring for a pacemaker is a technology that allows healthcare providers to track and manage a patient's pacemaker function remotely. Here's how it works:</p> <p>Data Transmission: The pacemaker transmits data wirelessly to a home monitoring device.</p> <p>Data Upload: The home monitoring device sends the data over the internet or a telephone line to a secure server.</p> <p>Healthcare Access: Healthcare providers access the data through a secure web portal.</p> <p>Continuous Monitoring: The system allows for continuous or periodic checks of the pacemaker's performance and the patient's heart activity.</p> <p>Alerts and Notifications: If there are any irregularities or issues, the system can alert healthcare providers immediately. This technology enables early detection of potential problems, reduces the need for in-person visits, and allows for timely adjustments to pacemaker settings.</p>		

Continue Table 1.

QUESTIONS	Chat GPT4o RESPONSES.
11. Benefits of remote monitoring and how can a patient use with smart device like mobile device or watch?	<p>Remote monitoring offers several benefits for patients, such as:</p> <p>Convenience: Patients can track their health parameters from home, reducing the need for frequent clinic visits.</p> <p>Real-time Feedback: Continuous monitoring provides immediate feedback on health metrics, allowing for early intervention if necessary.</p> <p>Improved Care Coordination: Healthcare providers can access up-to-date patient data remotely, leading to more timely and informed decisions.</p> <p>Patient Empowerment: Enables patients to actively engage in managing their health by monitoring trends and making informed lifestyle choices.</p> <p>Patients can use smart devices like mobile phones or watches for remote monitoring by syncing them with health apps or wearable sensors. These devices can track vital signs, activity levels, medication adherence, and other health metrics, sending data securely to healthcare providers for analysis and feedback.</p>
12. What data are collected from a patient and is it safe with remote monitoring?	<p>In remote monitoring, various types of data are typically collected from patients, including:</p> <p>Vital Signs: Such as heart rate, blood pressure, temperature, and oxygen saturation.</p> <p>Activity Levels: Including steps taken, exercise duration, and movement patterns.</p> <p>Medication Adherence: Tracking whether patients are taking prescribed medications on schedule.</p> <p>Symptom Reporting: Patients can report symptoms like pain levels, fatigue, or mood changes.</p> <p>Regarding safety, remote monitoring systems prioritize data security and privacy through encrypted transmission and secure storage practices. Healthcare providers adhere to regulations like Health Insurance Portability and Accountability Act (HIPAA) in the United States) to safeguard patient information from unauthorized access or breaches. Thus, while data is collected extensively, efforts are made to ensure its confidentiality and integrity.</p>
13. Can a pacemaker be hacked? how to detect and what can be done to prevent it?	<p>Yes, pacemakers and other medical devices with wireless capabilities can potentially be hacked. Here's a brief overview:</p> <p>Detection: Detecting hacking attempts on pacemakers involves monitoring for unusual device behavior, such as unexpected changes in settings or abnormal battery drain.</p> <p>Prevention: Several measures can mitigate hacking risks:</p> <p>Encryption: Implementing strong encryption protocols for wireless communication.</p> <p>Authentication: Using robust authentication methods to ensure only authorized devices can communicate with the pacemaker.</p> <p>Firmware Updates: Regular updates to device firmware to patch vulnerabilities.</p> <p>Physical Security: Ensuring physical access controls to prevent unauthorized tampering.</p> <p>Regulatory Compliance: Adhering to cybersecurity standards and regulations specific to medical devices.</p> <p>Actions if a Hack is Suspected</p> <p>Contact the Manufacturer Consult Healthcare Providers Disconnect Remote Monitoring. Report the Incident</p>

Continue Table 1.

QUESTIONS	Chat GPT4o RESPONSES.
14. What precautions should a person with pacemaker be aware of ?	<ul style="list-style-type: none"> • Avoid Electromagnetic imaging (EMI): Stay away from strong electromagnetic fields, such as MRI machines and metal detectors (Eg: Airports/shopping mall). • Manage Devices: Keep mobile phones and other devices at least 6 inches away from the pacemaker. • Inform Providers: Always inform healthcare providers about the pacemaker before medical procedures or tests. • Monitor Health: Attend regular check-ups and report any unusual symptoms promptly. • Be Cautious: Stay clear of strong magnets, high-voltage equipment, and certain consumer electronic devices.

Advantages, Disadvantages and Limitations

ChatGPT provides valuable insights into advancements in pacemaker technology, enhancing patient education and supporting clinicians with real-time information on device usage, remote monitoring, and data security, while emphasizing their role in preventing medical incidents. It underscores the importance of safety protocols and confidentiality, encouraging timely reporting of concerns such as radiology-related and cybersecurity issues. These capabilities promote improved patient protection and foster interdisciplinary collaboration in device selection, complication minimization, and prompt intervention. While ChatGPT offers benefits including personalized treatment guidance and the facilitation of medical innovation, its limitations must be acknowledged. Privacy risks associated with sensitive health data and dependence on input quality may impact output accuracy. Importantly, ChatGPT is not a substitute for clinical judgment, and ongoing ethical and legal considerations necessitate careful integration to maintain human oversight and ensure patient safety.

Abbreviations

AI : Artificial Intelligence; **ChatGPT-4o**: Chat Generative Pre-Trained Transformer 4 Omni; **DNNs**: Deep Neural Networks; **ML**: Machine Learning; **ECG** : Electrocardiogram; **CHA₂DS₂-VASC**: Congestive Heart Failure, Hypertension, Age ≥75 (doubled), Diabetes

Mellitus, Stroke/Transient Ischemic Attack (doubled), Vascular Disease, Age 65–74, and Sex Category (female); **EPS**: Electrophysiological Study; **ICD**: Implantable Cardioverter-Defibrillator; **MRI**: Magnetic Resonance Imaging; **HIPAA**: Health Insurance Portability and Accountability Act.

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Conflicts of Interest:

There are no conflicts of interest.

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