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Opportunities and Challenges Faced by IoB in Digital Medical and Health Communication

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Abstract: The Internet of Body (IoB) is changing the global digital medical ecological environment. As many connected, implanted, or ingested IoB devices generate massive biometric and human behavior data to monitor, analyze and even improve health, scientific decisions and actions are urgently needed to address the ethical and legal issues. Amid the global COVID-19 pandemic, numerous IoB technologies and data are being used to monitor and track the novel coronavirus. In the post-pandemic era, the IoB has become the focus of public attention, arousing people's expectations for application prospects and sparking debate about potential risks. Can these devices help public health departments predict, strengthen management, avoid damage to personal health, and protect user personal information data from misuse? This paper mainly adopts the method of literature survey and case study to discuss what is an IoB device, the classification, characteristics of the devices, and the social benefits and risk control of the devices to ensure data rights, data security, network security, user privacy, which will promote the healthy development of IoB in the health care, work, and life of the people. While supporting the development of IoB technology, we should strengthen supervision, make predictions, strengthen management, protect the health of individuals and groups, maintain network security and data security, and keep users' personal information and data from being abused.

Keywords: IoB, Digital Medicine, Health Communication, Post-Epidemic Era, Social Benefit, Risk Control

1. Introduction: IoB Is Changing the Global Digital Healthcare Ecosystem

Based on the deep Internet soil, the Internet of Body (IoB) is changing the global digital medical ecological environment and bringing benefits to patients with diseases. On July 6 this year, Synchron, a brain-computer interface (BCI) startup, implanted a connected device for the first American patient with amyotrophic lateral sclerosis – a 1.5-inch-long implant inserted into the patient's brain blood vessels [1]. The device translates the thoughts of a patient who has lost the ability to move and speak into commands sent to a computer, helping them browse the web, email, and text with their minds. Prior to this, Synchron had successfully implanted its device in four patients in Australia with no side effects. The Hongbo research team of Tsinghua University in China has developed a more miniaturized invasive brain-computer interface solution, using three intracranial electrodes to achieve text input through minimally invasive implantation of the brain-computer interface [2].

IoB is also widely used in the fight against the new coronavirus pneumonia (COVID-19). For example, an American health startup VivaLNK has cooperated with Alibaba to design a remote monitoring solution that can safely monitor patients' body temperature, electrocardiogram, heart rate, respiratory rate, and exercise to prevent cross infection [3]. In addition to playing a role in routine medical care, epidemic crises, and daily health, the IoB will also be widely used in an aging society. From now to the next ten years, China will usher in the most significant "retirement tide" in history, and the post-60s group will continue to enter retirement life at an average rate of 20 million people per year [4].

IoB devices are usually in the form of being worn, implanted in, or ingested into the human body, acquiring and generating massive amounts of biometric and human behavior data through sensors. It promotes artificial intelligence analysis and machine learning and facilitates digital medical research and the transformation of the health industry. At the same time, the management of massive amounts of personal data poses new challenges to IoB due to the vast and dramatic increase in the number of sensors connected, implanted, or ingested into the human body to monitor, analyze and even modify the human body and behavior, which not only involve personal privacy and autonomy. It also involves essential areas such as employment, education, finance, medical insurance, and other social resource allocation. Scientific decisions and actions are urgently needed to solve IoB's ethical and legal issues.

2. Characteristics of IoB and Devices

Over the past decade, medical technology and data science advances have led to massive growth in IoB medical devices. IoB devices are widely used to treat a wide range of diseases and conditions, including hearing and visual impairment, heart disease, diabetes, epilepsy, and Parkinson's, providing more detailed and precise data to support patient care and improve healthcare efficiency and level.

(1) What is IoB and the Devices

What is body networking? It is generally believed that IoB is a network that integrates cutting-edge technologies such as artificial intelligence, biotechnology, and nanotechnology. With the help of IoB devices, the body is connected to a specific network to collect and generate biological individual characteristic data. With the help of its software or cloud computing capabilities, it detects disease or enhances human function [5].

IoB devices can be closed to the body and collect vast amounts of personal biometric data. These come in many forms, such as wristwatch fitness monitors or pacemakers that transmit a patient's heart data directly to a cardiologist. These ingestible products collect and transmit information about the human gut, microchip implants, brain stimulation devices, networking Smart toilets, etc.

Specifically, an IoB device's software or computing power can be simple or complex. Simple enough to execute simple instructions to a few lines of code on a microchip implant, complex enough to be as complex as artificial intelligence (AI) and machine learning algorithms. Networking refers to connecting to the Internet via a Bluetooth, cellular or Wi-Fi network, not necessarily a direct connection. Personally generated health data refers to clinical or health data collected, recorded, or analyzed through technology. Biometric or behavioral data refers to measurements of a person's unique physical or behavioral characteristics. Improvements in physical function refer to enhancements or improvements in the user's physical performance, such as cognitive enhancement and memory improvements provided by a brain-computer interface or the ability to record anything the user sees through the computer.

IoB devices do not include devices not connected to the Internet, such as ordinary heart monitors or refrigerators that store COVID-19 vaccines. IoB devices often, but not always, require a physical connection to the body, which can be ingested, implanted, attached to, or embedded in the body. Whether it belongs to IoB or not depends on its application scenario. For example, a Wi-Fi-connected smartphone itself is not part of IoB, but once installed and activated, health applications such as Apple Health, WeChat Sports, and Tianfu Health Link Mini Programs track the user's location, body temperature, etc., the phone becomes an IoB device.

(2) The Difference and Connection between IoT and IoB

Internet of Things (IoT) devices are connected to the Internet either directly or through a local network and must have human-machine interaction to provide some benefit to the user. Second, IoT devices have at least one of the following functions: the ability to sense some change or change the physical state of an object and to acquire, retrieve, provide, and store data directly to the user. A device not connected to the Internet cannot be called an IoT device. For example, we can set the air conditioner to turn on at 7:00 pm without connecting to the Internet, and the air conditioner is not an IoT device only if it is connected to another IoT device (such as a smartphone) via cellular, Wi-Fi, or Bluetooth. It is only part of the IoT when users can remotely control the air conditioner outdoors.

IoT and the IoB are the relationships of containment and inclusion. Any IoB device is an IoT device, but not all IoB devices are IoT devices. Likewise, not every healthcare IoT device is considered an IoB device. Electronic health record programs, robotic surgery systems, and intelligent ventilators for medical use are all part of the healthcare IoT ecosystem. These devices collect patient information or change physical conditions and belong to IoB. The refrigerator that stores the COVID-19 vaccine belongs to the IoT, but it is not an IoB device because it does not meet the definition of IoB.

(3) The future development trend of IoB

The application prospect of IoB technology is extensive. Advances in Internet technology will allow more IoB and IoT devices to connect and communicate with each other at faster speeds. The fifth generation mobile communication network technology (5G) can support about 1 million devices per square foot, while the previous 4G network could only support about 4000 devices in the same area. The sixth generation mobile communication network technology (6G) will have better connectivity and transmission efficiency. IoB devices will be smaller, lighter, and more sensitive, and the data transfer rate will improve further.

Technological advancements have made it more common for consumer IoB devices, such as smart home devices, to connect to IoB devices. For example, it automatically connects an intelligent thermostat to smart clothing to adjust the temperature. Brain-reading and signaling neural devices can improve cognition, memory, and control through brain-computer interfaces. Women's health technology products can protect women's physiological and reproductive health; weight scales integrated with health applications are used to track and analyze fluctuations in body weight and body mass index; smart beds can record sleep data and evaluate sleep quality.

The Internet of Things is advancing medical and other fields in unexpected ways. For example, the U.S. Department of Defense uses an infrared laser that can detect a person's electrical heart rhythm with more than 95 percent accuracy over a distance of 200 meters [6]. When paired with electronic medical records, the laser could be used to monitor a patient's heart condition in a hospital or accurately identify a specific patient from a distance. Brain-computer interface (BCI) implants currently in development are small and can simultaneously engage up to a million neurons. For example, a team at the University of California, Berkeley, has created implantable sensors about the size of a grain of sand. They call these sensors "neural dust." [7]

(4) Brief classification of IoB devices and applications

Technological advancements have ushered in a new era of IoB, with connected devices and sensors widely used in medical wearables for cardiovascular monitoring, diabetes management, temperature, sweat and motion sensing, and other types of data monitoring. The number of IoB around the world is vast and multiplying. In 2018, electronic skin patches brought in more than $7.5 billion in revenue, which is expected to grow to more than $20 billion annually by 2029 [8].

The table below briefly summarizes the implantable medical IoB technologies, wearable and self-contained medical IoB devices and applications, and consumer IoB devices and applications (as shown in *Table 1*).

Table 1. *Brief classification of IoB devices and applications.*

Implantable medical IoB equipment and applications	Wearable and stand-alone medical IoB and applications	Consumer IoB devices and applications
1) Artificial pancreas system 2) Implantable pacemaker 3) Implantable glucose monitor 4) Ingestable digital pills 5) Implantable smart stent 6) Cochlear implant equipment 7) Brain-Computer Interface (BCI) 8) Brain stimulation device for Parkinson's syndrome EEG signals	1) Electronic medical records 2) Independent infusion pump 3) Wearable insulin pump 4) Wearable epilepsy monitor 5) Wearable prosthetics 6) Hospital beds with sensors	1) Attention monitor 2) Body implanted sensors 3) Visual and auditory capture aids 4) Wearable bracelets, watches, rings, etc. 5) Mental and emotional sensors 6) Wearable neurological devices 7) Women's health technology products 8) Clothes with sensors 9) Connected smart furniture and appliances

3. Social Benefits and Risk Control of IoB

Elon Musk's neuroscience company is dedicated to research in the field of brain-computer interfaces, developing products that allow computers to translate human thinking into specific behaviors [9]. On July 19 this year, Billy Markus tweeted: "Would you be good friends if you could upload your brain to the cloud and talk to your virtual version?" "It has been done," Ske replied. That was probably a joke, at least for now. An adult brain is estimated to have 14 billion cells and about 100 billion neurons, equivalent to 95 million 8TB hard drives [10]. Uploading whole brain data to the cloud is still a dream, although scientists claim to have entered the metaverse era.

The Metaverse is the fourth era of computing and networking. The first era was after the mainframe from the 1950s to the 1970s; the second ranges era the personal computer and the Internet from the 1980s to the mid-2000s; and the third era covers the mobile and cloud era we experience today [11]. Each era has changed who, when, where, why, and how to access computing and network resources. Currently, the Internet connects about 40,000 networks, millions of applications, more than 100 million servers, nearly 2 billion websites, and tens of billions of devices worldwide.

These changes have far-reaching implications for healthcare communication in the digital age. In the era of big data, protecting data rights and ensuring transparency and fairness is complex, and the specific challenges posed by connected technologies in this area are growing. While the digital empowerment of IoB has brought great benefits to society, the problems faced by IoB have become more acute. How to protect data rights, data security, network security, user privacy, and physical health has become an urgent problem to be solved.

(1) Social benefits of digital empowerment

The wide variety of data collected through IoB technologies is driving the transformation of health research and the industry. In addition to patient-oriented medical devices, direct-to-consumer non-medical devices in the consumer sector also belong to the digital health market. At the same time, IoB technology is also used to ensure work safety in high-risk scenarios and benefit society.

a. Enable remote patient tracking and reduce cross-infection

Remote monitoring is widely applied to the fight against the COVID-19 epidemic. California-based connected health startup VivaLNK has collaborated with Alibaba to design a multi-patient remote monitoring solution that can safely monitor patients' body temperature, electrocardiogram (ECG), heart rate, respiratory rate, and movement, reducing cross-infection and protecting medical workers. The solution allows caregivers to monitor many patients while minimizing physical contact. Clinical patients are equipped with wearable sensors that send data to an internal server or the cloud, allowing medical staff to remotely monitor the patient's temperature to avoid physical contact or proximity. The solution has been deployed in at least 14 hospitals in Shanghai, Zhengzhou, and other places.

Based on measuring the patient's temperature, it can be extended to track other vital signs and biometrics, including electrocardiogram, heart rate, respiratory rate, exercise parameters, etc., according to the law. The solution was initially designed for the new coronavirus but is also suitable for monitoring patients with other infectious diseases, such as SARS, influenza A (H1N1), and Middle East respiratory syndrome (MERS). Such IoB devices with continuous monitoring will play a huge role in China's aging population and healthcare for chronic patients.

The COVID-19 outbreak has seen a surge in demand for connected devices to monitor and manage personal health 24/7. With IoB monitoring vital signs, healthcare workers can better track patients' conditions, obtaining blood pressure, oxygen levels, glucose levels and heart rate, sleep, steps, and other relevant health data. In addition to monitoring in the hospital, patients can also be monitored remotely at home or in other settings. Doctors took the initiative to follow up and treat and avoid re-hospitalization due to the worsening of the condition.

b. Increase patient engagement and promote healthy lifestyles

IoB facilitates the expansion of healthcare. In a virtual rehabilitation program launched in Southern California in 2019, health professionals remotely monitor heart patients' rehabilitation exercises and medication habits. The wearable smartwatches share patients' vital and activity data with healthcare workers, and regular doctor-patient interaction improves the relationship, with telerehabilitation program completion rates increasing from less than 50% to 87%. It effectively reduces the recurrence rate of heart attacks while reducing readmission rates and medical costs.

Consumer wearables offer new data types and possibilities for scientific research and clinical trials. Health fitness bracelets create personalized health and fitness programs to help users change their health concepts and behaviors. From 2012 to 2017, more than 500 published studies have explored the use of Fitbit Trackers, including studies conducted in various research populations and settings [12]. China's Huawei Bracelet [13] and Xiaomi Band [14] have also explored and launched a series of products to help people improve their health behaviors and habits.

Centers for Disease Control and Prevention of America estimates that as many as 6.1 million Americans have atrial fibrillation, which is expected to increase as the population ages. Apple Inc. designed a single-lead ECG test for the Apple Watch to help wearers for screening atrial fibrillation [15]. After analysis and development of these big data outside the traditional medical environment, research can extended from individual health to population health, understanding human behavior, community characteristics, living environment conditions, and systems and policies contributing to the overall health of social groups and ensuring Equitable access to health care for marginalized groups.

c. Advance preventive care and precision medicine

The data provided by IoB technology enables doctors to detect diseases early and provide preventive measures. In addition, by linking individual lifestyle and environmental data with genetic and biological data, the amount and variety of data may help advance precision medicine research, leading to deeper insights into disease drivers and treatments.

In 2021, neurosurgeons at Johns Hopkins University performed the hospital's first live patient surgery using an augmented reality headset, giving surgeons an interactive display of a patient's internal anatomy. On July 6 this year, brain-computer interface startup Synchron implanted the first American patient with amyotrophic lateral sclerosis with an IoB device that helps them browse the web, send emails, and text with their minds.

Before that, in 2020, the Second Affiliated Hospital of Xi'an Jiaotong University and the School of Mechanical Engineering of Xi'an Jiaotong University of China used BCI technology to make high paraplegic aphasia "say" "Hello!" in text. At present, China's brain-computer interface technology is still in its infancy. It is mainly used in the medical field to improve brain power or diagnose some neurological diseases of the brain. However, its application in critical care medicine is relatively limited progress [16].

d. Ensure a safe and comfortable working environment

In addition to health applications, hazardous workplaces such as construction sites, mines, and factories are embracing IoB technologies to track the location of workers, monitor environmental risks, and reduce musculoskeletal injuries or other injuries. High-quality real-time sensor data guides workers in complex situations and adjusts to rapidly changing conditions. Brain-worn devices combined with neurotechnology can improve pilot and driver alertness for safe flying or driving. Wearable devices include hats, vests, bracelets, and glasses to measure the driver's fatigue level and promptly prevent fatigued driving and deviation from the course or road.

When integrated with the Industrial IoT ecosystem, the IoB can protect the health of the workplace and workers. Equipped with corresponding temperature, fatigue, pressure, position, activity, and toxic gas monitoring sensors in workers' vests, helmets, shoes, and watches, they can monitor and warn workers of possible dangers. IoB can also protect firefighters, miners, and soldiers from working in extreme conditions from danger in time.

The quality of life can be improved with the assistance of IoB. By analyzing user activity patterns using inertial and environmental sensors from wearable devices, heating systems can maintain a comfortable temperature while minimizing energy costs. Wearable IoB devices can also continuously measure body and physiological data without interference, propose dietary habits adjustment suggestions, remind office workers not to sit for long periods, and encourage moderate exercise and fitness. Wearable devices have become an integral part of modern everyday life.

(2) Risks related to IoB

IoB has brought about profound changes in telemedicine. Doctors can test and improve new diagnoses and treatment methods through sensors and big data analysis. However, in addition to the societal benefits and innovations of IoB data, there are risks if data on personal health and behavioral details are misused. IoB technologies face challenges such as consumer trust, device and data security, and interoperability between different body-connected devices. IoB security risks and privacy issues have become focused, sparking discussions on the multifaceted legal, social, ethical, and policy issues related to technology governance.

a. Interoperability and data accuracy

Medical and consumer-type IoB devices are subject to different standards. However, as consumer tracking devices are being integrated into healthcare, consumers increasingly rely on wearables to self-assess their health based on wearable data. For example, for monitoring heart rate and energy expenditure in patients with cardiovascular disease, assessing whether the measurements achieve a clinically acceptable level of accuracy requires assessment and judgment. However, these consumer-grade IoB devices are not as accurate as medical IoB devices. Medical devices connected to consumer devices may risk misdiagnoses, such as false positives and overtreatment. Strengthen the supervision of production enterprises, encourage them to increase investment in scientific research, improve the quality of IoB devices, and ensure that medical and consumer-type IoB devices can communicate smoothly and exchange health data safely.

Data interoperability is a prerequisite for the smooth functioning of every device of IoB. Adequate data is the basis for its operation, judgment, and decision-making. Accurate data prevents errors from expanding and issuing wrong instructions. Using mutually compatible language codes and unified standards supports IoB devices of different brands and models, which is conducive to good compatibility and interoperability between products manufactured by different suppliers and ensures fast and safe data dissemination. Also, it is necessary to set emergency and critical applications to take precedence over other applications.

b. Cybersecurity and privacy protection

Like the Internet, the Internet may also have loopholes in a specific link, which may be attacked or controlled by hackers, resulting in leakage of user privacy or personal injury. The growing adoption of IoB devices outside traditional healthcare facilities has raised new concerns about security and privacy. "In 2021, 45 million individuals were affected by healthcare attacks, up from 34 million in 2020. That number has tripled in just three years, growing from 14 million in 2018." [17] The problem is equally severe for consumer IoB devices.

IoB systems security and user privacy are critical, as processing biometric data expose sensitive personal information that can easily be abused by targeted marketing, surveillance, malicious attacks, and more. Biohackers can remotely eavesdrop, intercept, and even alter raw unencrypted data using high-gain antennas. Biohackers could hack a pacemaker to deliver a lethal shock to the heart or hack an insulin pump to cause fatal damage by manipulating insulin levels to cause a diabetic coma. Therefore, authentication and encryption protocols must always keep IoB devices and data uncompromised and available.

Since 2013, the U.S. Food and Drug Administration (FDA) has overseen device manufacturers identifying and reducing cybersecurity vulnerabilities in their products, preventing hackers from jeopardizing the health and life of patients and other consumers. In terms of privacy protection on IoB, in addition to our country's existing laws and regulations on citizens' health rights, privacy rights, and information security, we may wish to refer to the practice of the United States in this regard. To address these issues related to wearable devices and promote standardization of the methods for manufacturers worldwide. The Institute of Electrical and Electronics Engineers (IEEE) and its standards association have been working with the FDA and National Institutes of Health (NIH) since 2016, as well as university and industry collaborations to establish TIPPSS (Trust, Identity, Privacy, Protection, Safety, and Security) as the principle of ensuring patient safety and protection [18].

In the context of the global outbreak of the COVID-19 epidemic, the privacy protection of health data has attracted attention. When a public health emergency arises, balancing personal privacy data protection and the data transparency required by the epidemic remains controversial. For example, on the evening of July 13, 2022, a community in Beijing notified people who were under quarantine for the epidemic at home that they must wear electronic bracelets received complaints, and the bracelets were withdrawn by the neighborhood committee the next day [19]. Dongyan Lao, a professor at the Law School of Tsinghua University, believes that if the wristband has both a positioning function and is used to restrict residents' travel, residents must be informed following the law on what information the bracelets have collected and how to process it.

At the consumer level, geolocation data displayed by wearables can be misused by bad actors. For example, researchers have discovered serious security flaws in children's smartwatches that could allow hackers to track children, capture audio, and make phone calls to them. By the end of 2021, "smart watches, as a representative product of new smart terminals, have reached 25.3% of underage netizens." [20]. This year's CCTV "3.15" party exposed information security loopholes in children's "smartwatches," which can easily obtain private information such as the location, face images, audio recordings, and address books of children wearing without users' authorization. The State Administration for Market Regulation and the National Standards Commission of China soon released the recommended national standard "Children's Watch," covering critical quality safety and performance indicators such as positioning performance, communication, electromagnetic radiation, and information security and proposed relevant evaluation and testing methods [21].

c. Discrimination and risk in data analysis

Due to the lack of transparency of algorithms and the source of data used to train such algorithms, biologically derived data generated by IoB users may be subject to misuse. Algorithmic analysis is used to make essential decisions in areas such as insurance, employment, finance, education, criminal justice, social services, and other types of social resource allocation.

Analyzing and formulating policies or decisions based on inaccurate and incomplete data and private data may be biased and discriminatory, damaging the legitimate rights and interests of individuals, general groups, and vulnerable groups. Let us take insurance and employment discrimination as examples to discuss discrimination and risks in data analysis.

Insurance discrimination. IoB data includes personal life and health data. Some insurance companies mine vast amounts of personal data, from home addresses and possessions and education levels to lifestyle data such as eating habits, daily activities, and exercise. Misuse of this data will lead to insurance and employment discrimination, making it harder for marginalized people to obtain basic health insurance and find suitable jobs. Privacy data on health conditions and lifestyle habits could undermine the foundations of insurance and shake socioeconomic and ethical foundations.

Employment discrimination. Wearables devices are used to monitor employee movement, communication, and behavior patterns in employee health programs and employment scenarios. Due to the relatively weak regulations and limited legal protection in this area, employees are exposed to a higher risk of misuse of data and black-box algorithms, as managers may make unfair assessments based on these monitoring data, which can lead to recruitment, promotion, and decisions such as retention are biased or discriminatory.

China's *Labor Law*, *Employment Promotion Law*, *Infectious Disease Prevention Law*, and other laws and regulations stipulate that workers have equal employment rights to choose occupations under the law. However, some employers still consider whether applicants have ever been infected with COVID-19 when recruiting. In response to this, the State Council executive meeting on July 13 prohibited employment discrimination against those who had recovered from a positive nucleic acid test for the new coronavirus. Thepaper News reported on July 21 that the "Government Online-Offline Shanghai" mobile application could only check the acid of the current month something. Previously, the nucleic acid test records for the past three months can be traced back [22]. Now, it eliminates employers' recruitment discrimination from the source of information.

4. Conclusion

IoB has broad application prospects in health care, work, and life. Many types of IoB technologies, devices, and applications connect specific personal body data and networks to reduce or eliminate human pain and improve and enhance human function. At the same time, personal data forms big data, which can be calculated and analyzed under legal norms, which is conducive to promoting the progress and renewal of digital medical care and IoB and creating a more equitable and just digital environment, policy environment, working environment and living environment for individuals and groups. In the process of fighting against the COVID-19 epidemic globally, the IoB technology is widely used in monitoring and tracking the new coronavirus, which has made significant contributions to preventing the spread of the epidemic; in general medical care, severe illness treatment, and rehabilitation services, the IoB technology is even more critical. It plays an indispensable role; everyone enjoys the convenience and well-being brought by advanced technology in daily life and work. In the post-epidemic era, it has become the focus of public attention, and people have infinite expectations for its application. Of course, we cannot ignore the potential risks and challenges of IoB. While supporting the development of IoB technology, we should strengthen supervision, make predictions, strengthen management, protect the health of individuals and groups, maintain network security and data security, keep users' personal information and data from being abused, and let cutting-edge technology continue to be based on humanistic care, for the benefit of all the people.

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Biography

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