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Research Article

Application of Internet of Things in Smart Factories under the Background of Industry 4.0 and 5G Communication Technology

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The key identification element of the smart factory is the interconnection between devices, which solves the production method and development dilemma of the factory under Industry 3.0 and previous models. The new article published by Xinhua News Agency on January 16, 2022, advocates the idea of industry+ Internet, and its main goal is to realize intelligent production. At present, smart factories have become the main development direction of industrial enterprises in the world. 5G technology has been rapidly deployed with the development of mobile communication, and its performance has also been greatly improved compared to previous communication technologies. After China put forward the smart manufacturing 2025 plan, although a large number of enterprises are still lingering in the process of research, learning, and exploration, the idea of Industry 4.0 has taken root in various intelligent manufacturing enterprises, and the development route of Chinese manufacturing enterprises in the future has been ahead of schedule. *Direction.* Based on the basic theory of Industry 4.0, 5G wireless communication, Internet of Things, and smart factories, this paper firstly distributed questionnaires to 20 enterprises with smart factories by means of network and interview and reanalyzed the collected questionnaires by regression analysis method and then used the questionnaire scale analysis method to analyze the reliability and validity of the questionnaire and combined with the results of the questionnaire analysis to analyze the problems existing in the current smart factory. Finally, based on the background of Industry 4.0 and 5G communication technology, combined with the Internet of Things technology, the development layout of the smart factory is designed; that is, based on the elliptic curve encryption algorithm, the signature mechanism of mutual trust of all electronic devices in the IoT smart factory is set to improve the smart factory.

1. Introduction

1.1. Industry 4.0. Industry 4.0 and 5G communication are the same concept of the fifth generation of communication, which represents the fourth generation of industrial technology. Industry 4.0 is not only the fourth generation of technology but also represents that the development model and the competition mode between industrial enterprises need to be modified [1, 2]. At present, domestic and foreign governments have successively issued white papers on the guidance of Industry 4.0. China's 2025 intelligent manufacturing strategy also shows the current country's emphasis on the era of Industry 4.0 [3–5]. In fact, the development of intelligent manufacturing is also a key breakthrough in industrial development. It mainly focuses on workshops, logistics, and products. The main goal is to develop intelligent production. The first time that Industry 4.0 appeared was at the German expo. It is also necessary to reduce the work intensity of the factory assembly line workers and realize the production intelligence while ensuring the production speed and efficiency. The goal of China's development of Industry 4.0 is to connect multiple separate manufacturing enterprises, so that most enterprises can cooperate, exchange, and promote technology [6, 7]. The progress also accelerates the development of the overall manufacturing market. After the concept of Industry 4.0 is proposed, the world's industrial level will also improve with the gradual progress of technology. It is foreseeable that in the future, almost all factories can realize full robot operation, and the factory will only use some employees with equipment operation knowledge, which will greatly save the cost of enterprises [8–10].

1.2. 5G Communication Technology. Compared with the previous generation of communication technology, 5G communication has made great progress. It has the characteristics of content distribution, software definition, full-duplex and co-frequency, network self-organization, and multiple input and multiple output. At present, 5G technology has been applied on a large scale in life [11–13]. You can see 5G base stations on the street, and mobile phones can also open 5G packages. In the future, 5G will further combine automatic driving, 8 K high-definition video, VR metaverse, and the Internet of Things. Technology and industry are developing together [14, 15]. Compared with other types of communication technologies, the biggest feature of 5G technology is the change in speed, but the data traffic usage rate has also increased by nearly a thousand times. 5G technology can provide key technical support in industries such as telemedicine, and it has gradually become an important technology in smart cities with real-time data and extremely stable networks [16–18].

1.3. Internet of Things. The Internet of Things technology has swept the academic world 30 years ago. In recent years, after various applications of the Internet of Things have penetrated into different industries, people have begun to understand and accept the idea of the Internet of Everything [19–21]. The Internet of Things is defined as the communication between two terminals through electronic components with basic computing capabilities and communication protocols established by the International Telecommunication Union. The soul of the Internet of Things lies in the communication protocol, while the eyes of the Internet of Things lie in the basic processing unit of the device itself [22, 23]. The more common IoT communication protocols are similar to Zigbee, Bluetooth, GPRS, and NB-IoT. Common applications of IoT include devices such as smoke sensors, smart light poles, smart water and electricity meters, temperature sensors, environmental testers, and smart switches. In fact, the current Internet of Things only realizes the interconnection between specific devices in specific scenarios. In the future, with the continuous development of Internet of Things technology, the Internet of Everything can be truly realized [24–26].

1.4. Smart Factory. The smart factory is a sign of the factory's development in the direction of intelligence. At present, with the rapid development of electronic components and computer software technology, various sensors and software systems are used to realize the informatization of the whole process of factory informatization; and all processes in the production workshop are remotely controlled, and the output after the product is manufactured is then completed [27–30]. The logistics of goods sales also realizes the whole process tracking. The more common features of smart factories include collaboration between machines and humans, self-learning capabilities of factory handling robots, visualization of the entire factory process, and self-healing capabilities [31–33]. Self-healing capability represents the ability of a factory to achieve self-healing of production lines in extreme weather or other catastrophic environments. Even in the event of a power outage, the factory can resume normal operation as soon as communication is restored. This is the self-healing ability that a smart factory needs to have [34, 35].

In the process of research, this paper first analyzes the development status of smart factories and understands that there are problems, such as slow communication speed of equipment, insufficient level of production information acquisition, and inability to guarantee equipment information security, in order to improve the communication quality and communication efficiency between devices and promote the development of smart factories.

2. Problems Existing in the Development of Smart Factories

2.1. Device Communication Speed Problem. In order to understand the current development of various smart factory enterprises, this paper conducted a network questionnaire and an on-site questionnaire survey on 40 relevant persons in charge of 20 enterprises. The questionnaire objects mainly include enterprise network operation and maintenance specialists, procurement specialists, information security IT engineers, and employees in positions such as financial managers [36, 37]. The content of the questionnaire is mainly about the factory network architecture, intelligence situation, equipment situation, and security issues. Through the analysis of the questionnaire content, this paper draws the following conclusions.

At present, the number of electronic devices in smart factories is gradually increasing, but most of the smart factories have poor network communication capabilities [38, 39]. According to the data of visits to multiple smart factories and network questionnaires, even though 5G has become popular in a small part, more than 90% of smart factories are still using 4G networks. The specific situation is shown in Figure 1.

As shown in Figure 1, with the continuous development of 5G technology in recent years, many smart factories are also continuously applying this network technology. The reasons for the continuous decline in the application rate of the 4G network include two aspects: one is the further popularization of smart phones. The continuous decline in the price of large smartphones and the continuous reduction in the operator's data package fees have led to the continuous increase of 4G users. The number of users has surged, but the base station is not expanding, which makes the network load larger and the network operation speed slower; the second is that 5G is used as emerging network technologies that have made great progress in recent years and are now relatively stable. 5G NSA networking has reduced the ability of 4G networks to seize resources. Based on this, more smart

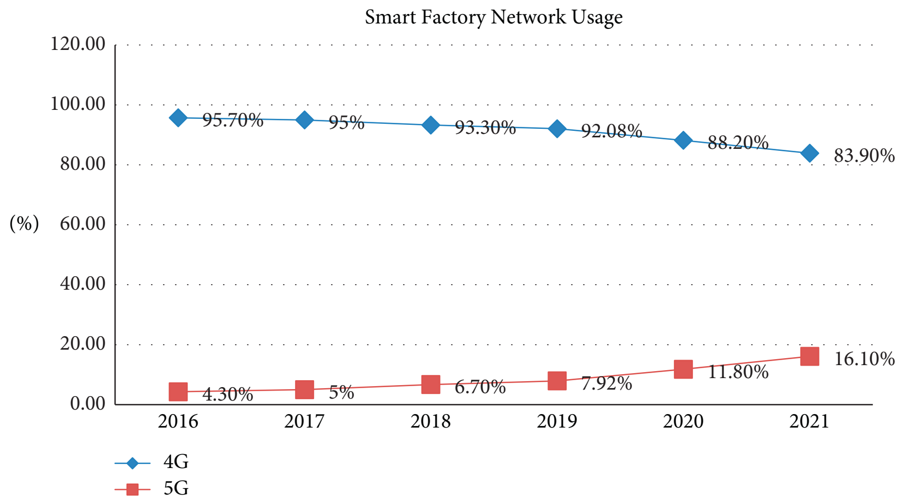

Figure 1: Smart factory network usage 2016–2021.

factories will be more inclined to apply emerging technologies, resulting in a decline in 4G utilization.

Most of the visited smart factory network leaders said that sometimes the production speed slows down due to network problems in the factory, and even the production line is suspended in severe cases. In particular, some smart factories that use robots and robotic arms for production and handling have higher requirements for network communication speed [40–43]. In order to meet the communication speed of electronic equipment in the factory, a small number of enterprises have opened the corresponding operator's dedicated line network [44, 45]. However, with the rapid development of big data and cloud computing technology, the ratio of data processing and transmission in smart factories has also increased accordingly, and traditional private line networks cannot meet the network transmission rate required by equipment [46–48]. In fact, the communication cost is not expensive. A survey of smart factories using the latest communication technology and their communication costs is shown in Table 1.

Through reliability and validity analysis, it is found that the reliability and validity of this questionnaire satisfies the set value in the theory, which proves that the reliability and validity of this questionnaire is normal. The specific values are shown in Table 2.

Table 1: 2014–2021 smart factory enterprise network update.

Year	Network type	Expended capital (10000 yuan)
2014	4G	5
2016	4G	7
2019	4G-special line	11
2021	5G	16

Table 2: Reliability and validity analysis.

	Reliability	Validity
Value	Alpha = 0.92	KMO = 0.73

2.2. The Level of Production Intelligence is not Enough. At present, enterprises with smart factories are some more traditional production factories which have gone through the process of replacing mechanical equipment without computing capabilities to electronic mechanical equipment with computing processing capabilities. In equipment replacement, some key equipment could not be replaced in time, resulting in the need for manual operation in the production process [49, 50]. In addition, even if some devices are replaced by electronic devices with computing processing capabilities, their intelligence is still low. For example, most devices still cannot implement cloud connectivity. Many key data in the current smart factory need to be transmitted to the cloud for storage and processing. If all the devices in the factory can be connected to the cloud, the operation efficiency of the smart factory will be greatly improved. In addition, the equipment protocols are not interoperable, and various electronic equipment is used in the current smart factory [51–54]. However, there are currently no enterprises that can provide unified protocol solutions for smart factories, so enterprises corresponding to smart factories can only use electronic and mechanical equipment with different protocols [55–57]. The difficulty of interconnecting devices with different protocols will increase. The key to realizing intelligence in a smart factory is the interconnection and mutual cooperation between devices. In order to achieve collaboration, smart factories must hire a large number of programmers and engineers to study electronic devices with different types of protocols, and the corresponding production costs and maintenance costs of factories and enterprises will also increase [58–60].

2.3. Equipment Information Security Issues. All devices in the current smart factory have become electronic devices with network communication and computing processing capabilities. Being able to communicate with other networked terminals means that device information may be eavesdropped or hijacked. At present, confidential information of enterprises is transmitted through the network, and relatively important files or data are also transmitted between equipment in the smart factory workshop. At present, computer hackers have become more rampant, and they are constantly attacking the databases of various companies. From time to time, there are news that hackers have obtained corporate customer data and leaked it at will. In this situation, enterprise data and information are extremely vulnerable to attack and loss, especially for enterprises with factory production capabilities, which currently use simple encryption methods for communication, such as key information and further control the operation of other equipment in the smart factory. The resulting data leakage problem and loss of factory operations are huge. After some giant enterprises are attacked and their operations are suspended, the loss is calculated in units of 10,000 yuan per second. An investigation into the information security of smart factories found that factories are facing various cyberattacks, as shown in Table 3.

Through reliability and validity analysis, it is found that the reliability and validity of this questionnaire satisfies the set value in the theory, which proves that the reliability and validity of this questionnaire are normal. The specific values are shown in Table 4.

Table 3: Types of device attacks faced by smart factories.

Number	Type of attack	Possible losses (ten thousand yuan)
1	Camouflage attack	11
2	Monitor	5
3	Brute force	4
4	DDOS	2

Table 4: Reliability and validity analysis.

	Reliability	Validity
Value	Alpha = 0.82	KMO = 0.79

3. Application Strategy of IoT in the Smart Factory under the Background of Industry 4.0 and 5g Communication Technology

3.1. IoT Smart Factory Solution Combined with 5G Communication Technology. Various characteristics of the 5G network can ensure the communication quality of the application test and the transmission test in smart factory system architecture, thereby ensuring that the interconnection of the manufacturing process is not disturbed. For example, some high-end smart factories have begun to adopt technologies such as VR, AR, and robotics. Combined with 5G network communication technology, P2P, software-defined, and MIMO features of 5G can provide strong support for the interconnection of devices in smart factories. The P2P slicing method of the 5G network can provide the electronic equipment of the smart factory to refine the service. For example, RFID label patching and identification in smart factories need to be carried out through the network. After 5G marks various sensors, especially the core in the core cloud is used to complete the network connection. Its millimeter wave technology can guarantee extremely high data upload and download rates, which can provide conditions for cloud storage and processing of equipment and systems in smart factories. The big data and edge computing capabilities that 5G can provide can also help with other smart services required by smart factories. In the future, the number of sensors and robots in smart factories will increase significantly, and with the support of 5G technology, smart factories will combine technologies such as big data, cloud computing, virtual reality, artificial intelligence, and blockchain to finally achieve real of intelligence. Through institutional data analysis, it is found that the production efficiency of smart factories after adopting 5G communication technology has been greatly improved. Its specific situation is shown in Figure 2.

3.2. IoT Smart Factory Solution based on the Industry 4.0 Concept. The concept of Industry 4.0 is to informatize the whole process of products manufactured by enterprises. This involves intelligent collaboration in product production and logistics tracking after the shipment. As one of the key technologies in the concept of Industry 4.0, the Internet of Things can provide solutions for the complete intelligence of smart factories. The technical situation involved in the concept of Industry 4.0 is shown in Figure 3, of which the Internet of Things accounts for a very high proportion.

First, the customizable mode of IoT devices can solve the current situation of inconsistent device protocols in smart factories. For example, the relatively simple ModbusRtu protocol devices in the Internet of Things can cover almost all types of devices required by smart factories. Working in a unified device mode, the production efficiency of smart factories will also be greatly improved. Regarding the ability of cloud connection processing, IoT devices can be connected to a software system to realize the connection with the cloud. Among them, the connection between devices similar to ModbusRtu and the software system is easier, and the NB-IoT device of the narrowband Internet of Things type is easier to realize the cloud connection function. Moreover, ModbusRtu type equipment is relatively inexpensive, and it can also provide strong support for the development of smart factories. After combining the concept of Industry 4.0 and the Internet of Things technology, the production efficiency improvement of smart factories is shown in Figure 4.

3.3. Smart Factory Information Security Solution Combining the Blockchain Algorithm and IoT Technology. The essence of blockchain is a digital distributed database. It relies on a series of storage technologies, encryption algorithms, and peer-to-peer networks. It first appeared as the underlying technology of Bitcoin. It guarantees the authenticity of all transaction records with immutable characteristics. In the past few years, benefiting from the development of communication and computer technology, the Internet of Things has achieved rapid development in the fields of medical care,

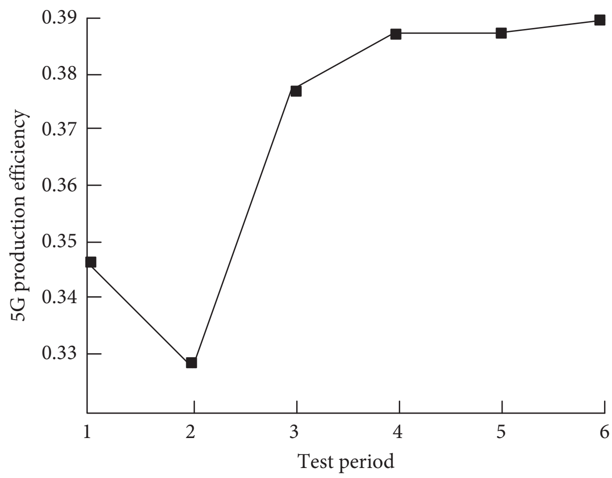

Figure 2: Smart factory production efficiency after adopting 5G communication technology.

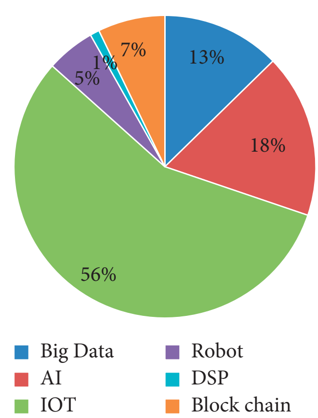

Figure 3: Technologies and utilization rates involved in the concept of industry 4.0.

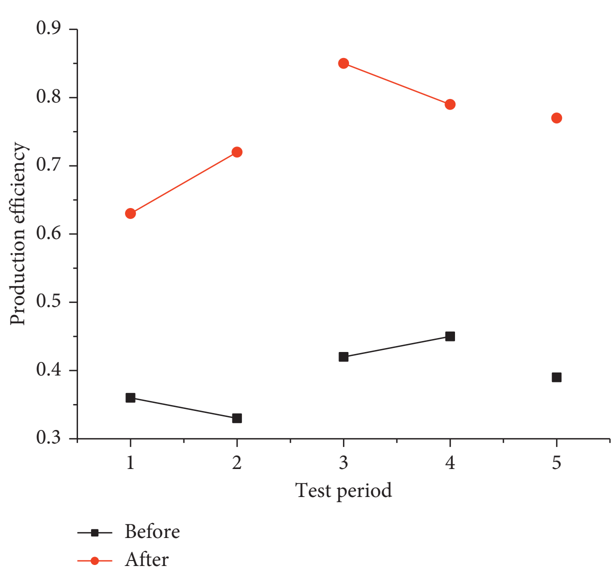

Figure 4: Productivity improvements incorporating industry 4.0 concepts.

intelligent driving, and the Internet of Things. The Internet of Things is the "Internet of Everything," which combines the Internet with various sensor devices to achieve the goal of interconnecting everything at all places and at all times. Usually, the IoT system is divided into three-layer architecture: one is the application layer, which provides readable and actionable data to IoT users according to the data collected by the sensor devices and the data processing results of the server. Common applications such as the Internet of Things and the Internet of Vehicles. The second is the network layer, which communicates between devices through the Internet. The layer that carries the communication between the devices is the network layer, and the key technologies include Bluetooth, WIFI, GPS, and RFID. In current IoT applications, the storage and management of IoT device data is mainly provided by third-party organizations, that is, a centralized management model. IoT devices within a certain range must have a server to manage all their data. The Internet of Things can be made more secure through blockchain, and the Internet of Things can make smart factories smarter. After the application of blockchain, the improvement of IoT security is shown in Figure 5.

The layering of IoT device data under the blockchain management mode is shown in Table 5.

This paper proposes an improved method based on the blockchain elliptic curve signature algorithm. The main improvements include parameter initialization, registration of all electronic devices, distributed generation of signatures of all electronic devices, generation of trust signatures of all electronic devices, verification of all electronic devices trust signatures, retrospectively sign devices, and revoke participants.

In the parameter generation stage, the system is initialized first, and then the user's public and private keys are generated. User x randomly selects parameter $a \in \{a_0, a_1, \ldots, a_{t-2}, a_{t-1}\}$ from the finite field, then the $t-1t-1$ order polynomial $f(x)$ can be expressed as

$$f(x) = a_{t-1} \cdot x^{t-1} + a_{t-2} \cdot x^{t-2} + \cdots + a_2 \cdot x^2 + a_1 \cdot x + a_0. \quad (1)$$

Its Lagrangian interpolation coefficient can be expressed as

$$r_i = \prod_{ij} \frac{NM_{i2}}{NM_{i2} - NM_{j2}}, \quad (2)$$

where NM_j is the unique identity of user x_i. After the user determines to receive the key split sent by other members, he will determine the validity of the verification parameters and key shares, and then determine his own private key and public key after the determination is completed. After determining the user's public and private keys, it is necessary to generate share signatures, synthesize threshold signatures, and verify threshold signatures. After the threshold signature verification is completed, if the verification fails, the threshold signature is rejected. When the verification is passed, the threshold signature is received and the members of the signature group are added. In the signature

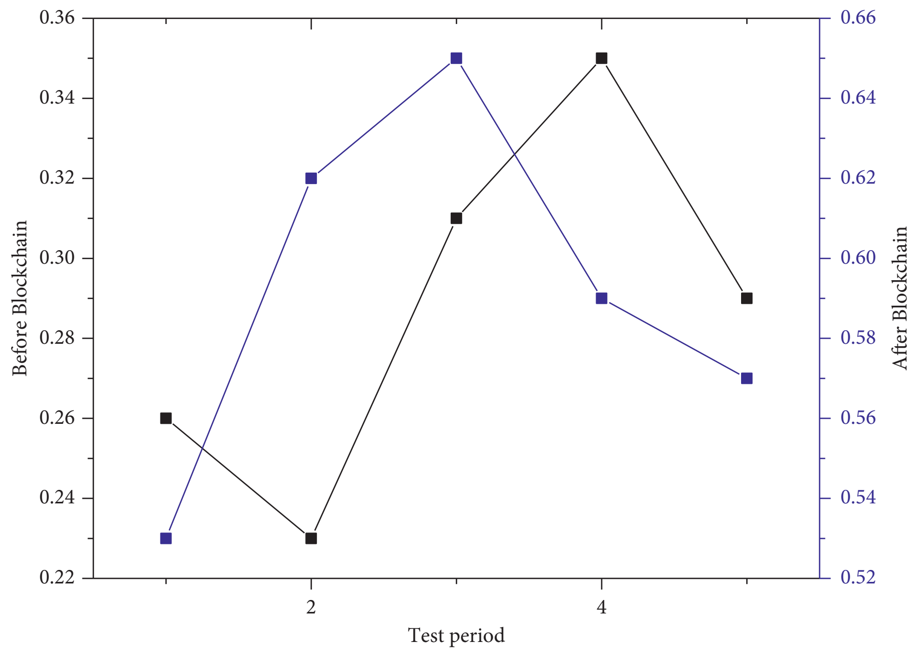

Figure 5: After the application of blockchain, the security of the internet of things is improved.

Table 5: Data sharing framework structure.

Level	Composition
Distribution layer	IoT data distribution
Chaincode layer	Code execution rules
Consensus layer	PBFT algorithm
Data layer	Block data

mechanism of mutual trust of all electronic devices in the IoT smart factory based on the elliptic curve encryption algorithm, the key generation and storage of the signature mechanism are distributed, and the corresponding signature also requires distributed nodes for formula verification. When an abnormality occurs in the device, it can also be traced back to the original signature device and the electronic device according to the content of the signature. Factory information can use the multi-participant key to remove individual dishonest electronic devices from all device sets, thereby ensuring the authenticity of signatures and continuously updated characteristics when electronic devices exchange information in smart factories.

4. Conclusion

The Internet of Things industry occupies the electronic hardware equipment market in various industries with an annual growth rate of no less than 20% of the application landing. The rapid expansion of IoT applications has provided the possibility of technological innovation for all industries. The current IoT sensing protocols mainly include Zigbee, Wifi, Modbus, MQTT, NB-IoT and other types. The IoT can provide smart factories with more intelligent production and shipping modes, and make factories and enterprises operate more intelligently. At present, the popularity of 5G technology in my country is extremely fast, and its characteristics of fast speed, many base stations, and high transmission efficiency have attracted the attention of consumers. If the current 5G technology is to be applied to intelligent manufacturing, it is mainly deployed through the corresponding applications generated in the context of 5G technology. Among them, the most widely used applications include technologies such as massive MIMO and signal processing. Industry 4.0 means that the entire process from the production of raw materials to the delivery and sale of products is informatized and reached the level of intelligent production to complete the efficient processing and supply of industrial product production. This paper analyzes the theories of 5G, Industry 4.0, smart factories, and the Internet of Things, combined with the results of the questionnaire data analysis, and sorts out the problems existing in the current smart factories and combines 5G, Industry 4.0, and the Internet of Things. Factory operation strategy, through follow-up agency investigations, found that the efficiency of the entire production process of smart factories transformed by new technologies has improved. Through the research in this paper, the communication efficiency and communication quality of the equipment in the smart factory can be improved. However, the project considered in this paper does not consider the impact of different geographical environment interference on its communication quality. This is also the next research method according to the actual completion of 5G technology and the application of Internet of Things theory to improve the quality of device communication in smart factories.

Data Availability

The datasets used and/or analyzed during this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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