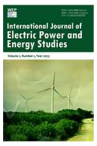
International Journal of Electric Power and Energy Studies
ISSN: 3006-2004 (Print), ISSN: 3006-0826 (Online) | Volume 3, Number 3, Year 2025
DOI: https://doi.org/10.62051/ijepes.v3n3.04
Journal homepage: https://wepub.org/index.php/IJEPES/index



Intelligent Public Health Platform: A Multi-Stage Operational Process for Emergency Prevention and Health Management

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ABSTRACT

The deep integration of IoT technology and 5G communication is reshaping the public health emergency response system. This paper centers on the construction of an intelligent public health prevention and control platform, focusing on its operational process and expected results. The platform covers three stages: pre-hospital emergency response, in-hospital treatment and post-hospital rehabilitation. It constructs a multi-level collaborative intelligent medical system, integrating core modules such as 5G emergency vehicle dynamic dispatching, real-time transmission of multimodal vital signs, and intelligent allocation of regional resources. The platform realizes precise positioning of pre-hospital patients and ambulance path optimization, dynamic allocation of ICU and emergency beds within the hospital, and post-hospital remote health monitoring and personalized rehabilitation management. The platform not only supports highly effective response to public health emergencies, but also promotes the intelligence and refinement of medical processes by optimizing the allocation of medical resources and improving the level of health management.

KEYWORDS

Intelligent Public Health; IoT(Internet of Things); Regional Collaborative Treatment; Personalized Health Management.

1. INTRODUCTION

With the increasing complexity of infectious disease prevention and control and critical care emergency work, the traditional manual monitoring and early warning system has been difficult to meet the needs of modern public health management. In recent years, the combination of Internet of Things (IoT) technology and mobile Internet has provided new technical support for real-time monitoring, data collection, analysis and early warning. In recent years, the development trend of smart healthcare has focused on data-driven decision-making, intelligent resource scheduling and whole-process collaborative optimisation. It has been shown that IoT combined with 5G communication can enhance the real-time collection and transmission of medical data, making the exchange of information between ambulances, hospitals and patients more efficient. Meanwhile, distributed machine learning technology has been widely used in the field of medical data analysis, enabling cross-organisation data sharing while ensuring data privacy. In addition, AI decision-making systems improve the accuracy of disease prediction, emergency scheduling, and medical resource optimisation through deep and reinforcement learning techniques. However, most of the current research focuses on the optimisation of individual links, and a complete framework for the collaborative management of pre-hospital, in-hospital and post-hospital processes has yet to be formed.

In order to improve the response efficiency of public health emergencies and the whole-cycle health management of patients, this study constructs an intelligent public health prevention and control platform covering three stages: pre-hospital (regional collaboration, optimal emergency pathway, 5G ambulance), in-hospital (5G emergency linkage, real-time planning of ICU and emergency department, and smart ward monitoring), and post-hospital (remote monitoring by wearable devices, smart rehabilitation management, and short-term health follow-up). The platform is aimed at four core groups: first responders, hospital managers, government public health departments and patients in recovery, and achieves closed-loop functionality through the following technical paths: the pre-hospital phase optimises the emergency paths relying on the BeiDou/GIS positioning system, and strengthens cross-institutional resource synergy by combining the 5G EMS multi-modal data fusion and federated learning technology. In the in-hospital stage, ultra-wideband (UWB) positioning and intelligent scheduling algorithms are used to dynamically allocate ICU/emergency resources, and real-time monitoring of critically ill patients is realised through intelligent ward IoT sensors. In the post-hospital phase, wearable devices are used to remotely track patients' recovery status, and AI personalised health management solutions are combined to reduce the risk of recurrence. The platform can provide timely and accurate early warning information for medical institutions, emergency systems, and government public health departments, which can not only respond to major epidemics, acute infectious disease outbreaks and other public health emergencies, but also support short-term health follow-up after patients are discharged from hospitals, and realise the full-process coverage from emergency prevention and control to rehabilitation management.

2. PLATFORM OPERATION PROCESS

The operation process of this platform covers three stages: pre-hospital emergency treatment, in-hospital treatment and post-hospital rehabilitation, and achieves full process coverage from emergency warning to rehabilitation management through multi-level collaboration and intelligent management. The system adopts edge computing and cloud computing architecture, combining AI decision centre, federated learning, digital twin and other technologies to achieve an intelligent medical treatment system for pre-hospital, in-hospital and post-hospital. Among them, accurate data collection and efficient data transmission ensure real-time synchronisation of medical information, intelligent scheduling combined with AI-assisted diagnosis improves pre-hospital response speed and in-hospital treatment efficiency, while remote monitoring and personalised rehabilitation management optimise post-hospital health management and reduce the risk of recurrence of chronic diseases. This architecture ensures the rational use of medical resources, improves the success rate of treatment, optimises the patient's recovery experience, and realises the comprehensive upgrade of intelligent healthcare. The following is the specific operation flow of each stage:

2.1. Pre-hospital Emergency Stage

2.1.1. Accurate Patient Positioning and Path Optimisation

Through the BeiDou satellite navigation system and GIS geographic information system [1], the patient's location is determined in real time and combined with the information of the surrounding environment (such as traffic conditions, road control, etc.) for comprehensive analysis. The emergency command centre quickly starts the emergency response mechanism according to the patient's location and the severity of the condition. The Implementation approach for this functionis is to improve the positioning accuracy by fusing multi-source data (such as mobile phone GPS, smart bracelet, intelligent community monitoring equipment), and with the help of AI to predict the development trend of the patient's condition, and give priority to arranging for the treatment of high-risk patients.

2.1.2. Ambulance Scheduling and Path Planning

The platform will use AI algorithms to dynamically calculate the optimal emergency path based on real-time traffic data and hospital resource status to ensure that the emergency vehicle arrives at the patient's location in the shortest time [2]. Simultaneously, the system monitors the location of the emergency vehicle in real time and dynamically adjusts the path to cope with unexpected traffic conditions. The idea of this part of the function is to combine historical traffic flow data, event-driven simulation (such as road construction, weather impact), training deep learning models to improve the efficiency of path optimisation. By using on-board sensors and intelligent traffic signal control, the travelling time of the emergency vehicle is further reduced.

2.1.3. Pre-hospital Vital Signs Monitoring and Data Transmission

The 5G ambulance will be equipped with multi-parameter monitoring equipment to collect real-time patient vital signs data (e.g., ECG, oxygen saturation, blood pressure, etc.) and transmit the data in real-time to the emergency department of the hospital through the 5G network [3]. The edge computing unit preprocesses the data to ensure the efficiency and accuracy of transmission. The implementation concept of this function is to use adaptive data compression algorithms to reduce the data transmission delay, and to identify sudden changes in the patient's condition through the AI abnormality detection model at once, issue early warnings, and improve the response speed of emergency decision-making.

2.1.4. ICU Resource Prediction and Early Warning

The system predicts the demand for ICU beds and sends early warning information to the target hospitals to ensure that the hospitals are ready to receive patients in advance based on the patient's condition and the real-time resource status of the hospital [4]. The implementation approach for this function is to establish a bed usage prediction model, combine historical data, real-time patient admission and epidemiological trends, dynamically adjust the ICU bed allocation strategy, and improve the efficiency of emergency response.

The operation flow of the pre-hospital emergency dispatching and decision-making module is shown in Figure 1 below:

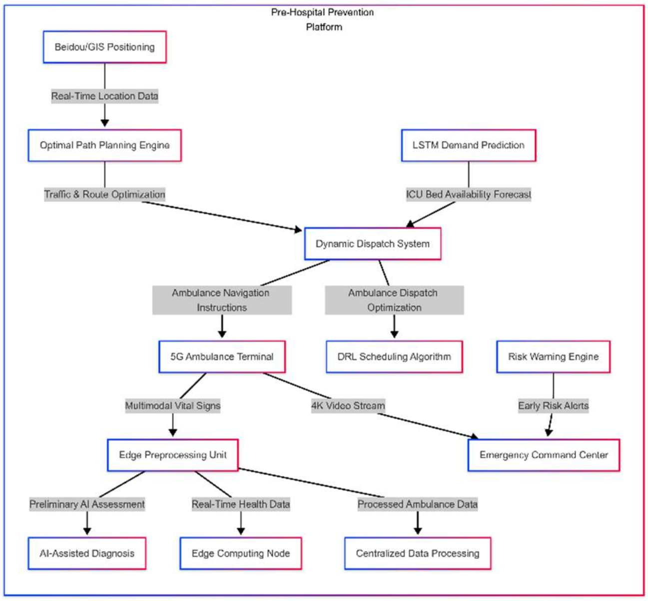

Figure 1. Pre-hospital emergency care module flowchart

2.2. In-hospital Treatment Stage

2.2.1. Seamless Pre-hospital and In-hospital Care

On the one hand, the system is enabled with 5G linkage. The platform traffic through the 5G network to achieve real-time data sharing between ambulance and hospital emergency departments to ensure that before the patient arrives at the hospital, healthcare personnel have already grasped the information about the patient's condition and prepare for the appropriate treatment. The idea of implementing this part of the function is to adopt blockchain technology to ensure the safety and traceability of medical data, while using AI to intelligently analyse patient data and formulate personalised treatment plans in advance. On the other hand, it is to optimise patient flow. The patient's location is tracked in real time through the ultra-wideband (UWB) positioning system to optimise the in-hospital flow path and reduce the patient's waiting time [5]. The system intelligently allocates emergency department or ICU beds according to the patient's condition and the state of hospital resources to ensure that critically ill patients are given priority treatment. The concept behind the implementation of this function is based on dynamic task allocation algorithms (e.g. reinforcement learning), intelligent matching of patient demand and medical resources, reducing the waiting time of patients in the hospital, and improving the efficiency of in-hospital flow.

2.2.2. Intelligent Bed Scheduling and Resource Allocation

The AI algorithm will dynamically allocate ICU and emergency beds according to the severity of the patient's condition, the hospital's bed usage rate and the configuration of healthcare personnel [6], so as to improve the efficiency of resource utilisation. The implementation concept of this function is to accurately allocate medical resources through intelligent queuing optimisation algorithms (e.g. Markov decision-making process), combined with the patient risk assessment system, to achieve the best treatment results.

2.2.3. Smart Ward Monitoring

After critically ill patients are admitted to the smart ward, IoT sensors monitor their vital signs data (such as heart rate, respiratory rate, body temperature, etc.) in real time [7] and analyse them through AI algorithms to detect abnormalities and warn them in time. The concept behind the implementation of this function is to introduce deep learning models (e.g. LSTM time series analysis) to predict the development trend of the patient's condition in real time and trigger automated nursing interventions.

2.2.4. AI-assisted Diagnosis

The functional module flow of in-hospital treatment is shown in Figure 2 below:

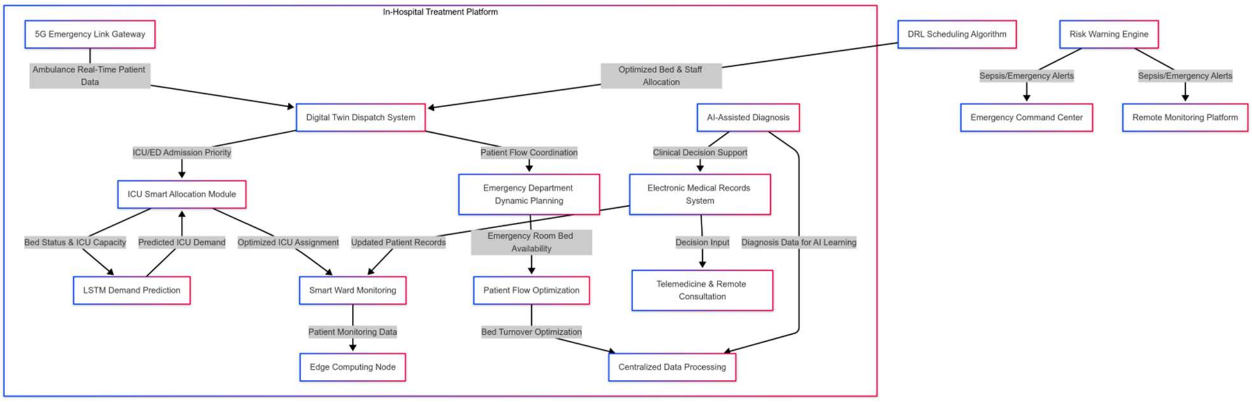

Figure 2. Flow chart of in-hospital treatment module

The system combines the patient's medical history, real-time monitoring data and medical images to provide assisted diagnosis suggestions and help doctors quickly formulate treatment plans. The implementation approach for this part of the function is to apply multimodal AI analysis technology to integrate medical images, medical history text and real-time monitoring data to improve the accuracy of disease identification and diagnosis [8].

2.3. Post-hospital Rehabilitation Stage

2.3.1. Remote Health Monitoring

On the one hand, the system is the use of wearable devices for data collection. After the patient is discharged from the hospital, they wears a flexible wearable device to monitor his or her vital signs data (e.g., heart rate, blood oxygen, activity level, etc.) in real time, and uploads the data to the remote monitoring platform through the mobile network. The implementation strategy of the function is to combine biometric sensors and adaptive health analysis models to achieve personalised monitoring and reduce false alarms and omissions [9]. On the other hand, it is regular health data analysis and warning. By regularly analysing the patient's health data, potential risks (e.g. abnormal heart rate, blood oxygen drop, etc.) can be identified, and timely warning messages can be sent to the patient and the doctor. The methodology for implementing this function is to train personalised health prediction models based on the federated learning method, under the premise of protecting data privacy, to improve the prediction accuracy.

2.3.2. Personalised Rehabilitation Management

According to the patient's recovery progress and health data, the AI algorithm generates a personalised recovery plan, including exercise plans, dietary recommendations and medication guidance. The implementation methodology of this function is to use reinforcement learning algorithms to dynamically adjust the rehabilitation plan according to the patient's feedback [10], so as to improve the rehabilitation effect.

2.3.3. Remote Doctor Consultation

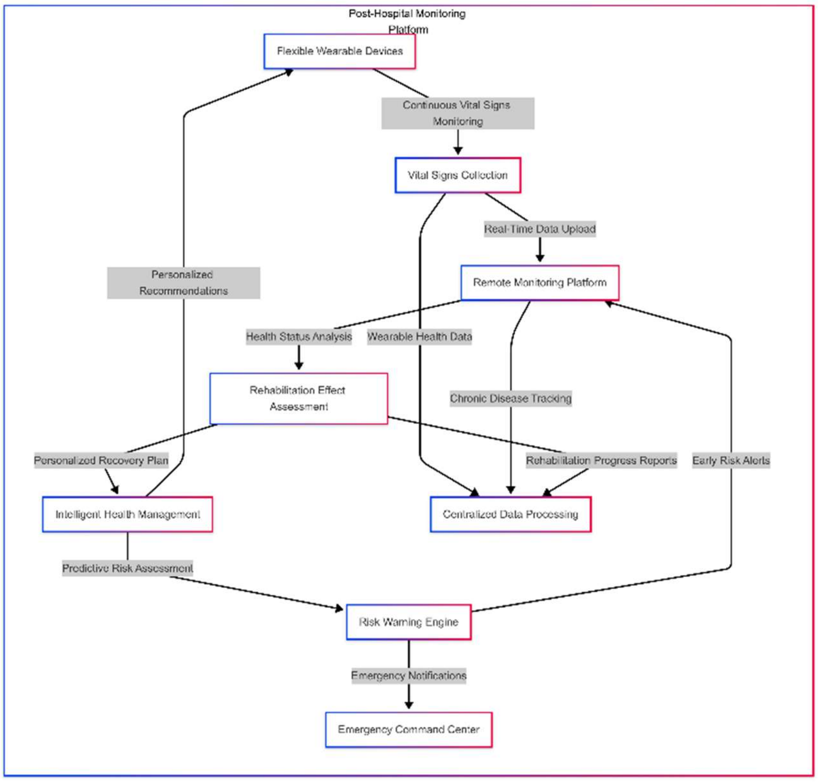

Figure 3. Flowchart of Post-hospital Monitoring Module

Through the telemedicine platform, patients can have a video consultation with the doctor, who adjusts the treatment plan according to the patient's recovery to ensure the recovery effect. This function is implemented by improving the intelligence of the teleconsultation system based on Natural Language Processing (NLP) technology to recommend accurate medical advice.

The flowchart of the functional module for post-hospital monitoring is shown in Figure 3 below.

2.4. Collaboration and Optimisation of the Whole Process

This platform achieves information interconnection and interoperability among pre-hospital emergency, in-hospital treatment and post-hospital rehabilitation phases, and ensures efficient deployment of medical resources and accurate decision-making by data sharing and collaborative decision-making. Relying on the federal health data lake, medical institutions, emergency systems, and remote monitoring platforms are able to achieve cross-institutional and cross-regional data synergy [11], break traditional medical information silos, and improve the availability and completeness of medical data under the premise of safeguarding data security and privacy.

The AI Decision Center conducts in-depth analysis based on global data to optimise key aspects such as ambulance dispatching, ICU bed allocation, remote monitoring response, etc., to improve the overall synergistic efficiency of the healthcare system, thus enhancing the accuracy and accessibility of healthcare services. The platform adopts a federal data governance architecture to ensure the security of data sharing, and improves the efficiency of medical decision-making, enabling each medical unit to achieve intelligent resource deployment and diagnosis and treatment optimisation with the support of unified data. At the same time, the system is capable of dynamic adjustment and continuous optimisation, intelligently adjusting the allocation of medical resources, optimising diagnosis and treatment paths, and providing accurate health management solutions based on real-time data and feedback information. By leveraging the AI adaptive learning framework, the platform continuously analyses historical data and real-time feedback to continuously optimise disease diagnosis and treatment plans, emergency paths and post-hospital rehabilitation plans, improving overall treatment efficiency, reducing resource wastage, and achieving the optimal allocation of medical resources. Apart from that, the platform can dynamically adjust medical strategies according to changes in public health risks, such as rapidly coordinating medical resources, optimising the treatment process, improving emergency response capabilities, and providing efficient and accurate decision support for the smart healthcare system in the event of epidemic outbreaks or public health emergencies.

3. EXPECTED RESULTS

The intelligent public health prevention and control platform proposed in this study provides significant theoretical benefits and expected results by improving response time, optimizing resource utilization and improving patient prognosis. These improvements are achieved through advanced technology integration, intelligent data management, and adaptive decision-making algorithms, and are mainly in the areas of emergency response time, resource utilization, and treatment efficiency. In terms of response time, it integrates BeiDou satellite navigation, GIS geographic information and AI dynamic path planning technology, and combines real-time traffic sensing and 5G communication network to realize accurate positioning of emergency vehicles and adaptive route optimization, ensuring seamless integration of the whole process of pre-hospital emergency care. At the resource management level, an intelligent prediction model is established based on deep reinforcement learning and digital twin technology, and a federated learning framework is used to realize the dynamic deployment of cross-institutional medical resources, build a hierarchical diagnosis and treatment system that gives priority to the treatment of critically ill patients, and optimize the turnover of beds and the efficiency of equipment use. In terms of treatment quality improvement, the platform relies on 5G mobile monitoring equipment and edge computing to realize real-time analysis and warning of vital signs, combines multi-modal data fusion with AI-assisted diagnostic system to strengthen clinical decision-making capability, and extends post-hospital personalized rehabilitation management through wearable devices to form a full-cycle intelligent medical closed-loop covering “pre-hospital early warning, in-hospital diagnosis and treatment, and post-hospital tracking”. The system reconfigures the traditional emergency response process through technological integration, creating synergistic gains in three dimensions: shortening response delay, balancing resource allocation and improving treatment accuracy, providing innovative solutions for building a resilient public health prevention and control system.

The intelligent public health prevention and control real-time early warning platform builds an efficient and coordinated medical emergency response system through multi-dimensional technological innovation. This smart public health prevention and control platform is expected to reduce ambulance arrival times by 30-40%, increase hospital bed utilization by 25-35%, and reduce peak hour pressures by implementing AI-powered route optimization, real-time traffic analysis, and dynamic scheduling. Personalized recovery plans and remote monitoring are expected to reduce readmission rates by 20-30% and identify complications in time to improve recovery outcomes. AI-powered systems can shorten time-to-treatment by as much as 20%, significantly enhancing the speed of intervention and improving outcomes in critical cases [12,13].Edge computing and federated learning will increase data processing speeds by 40%, enable cross-system data sharing, and enhance collaborative care. The platform will also support real-time surveillance of infectious diseases and collaborative regional response to build a resilient and adaptive healthcare system that drives sustainable and efficient health services.

4. DISCUSSION

Based on the above architecture, this system achieves optimised results in several aspects. In the first place, in terms of medical data sharing, the federal health data lake effectively solves the problem of data silos and achieves cross-agency data collaboration. Subsequently, the AI decision centre uses distributed computing + edge computing technology to ensure the high efficiency of the data flow while safeguarding patient privacy. In terms of emergency response optimisation, LSTM demand prediction combined with DRL scheduling algorithm predicts the demand for ICU beds in advance, improves the efficiency of linkage between ambulances and hospitals, and reduces the rescue time. Meanwhile, UWB precise positioning technology ensures the optimal flow path of patients in the hospital and improves treatment efficiency. In terms of post-hospital health management, the AI personalised rehabilitation system provides early intervention based on patients' long-term health trends to reduce the risk of recurrence of chronic diseases. However, there are still challenges with the system, such as the standardisation of data interconnectivity, with inconsistent data formats and governance standards across different healthcare organisations. Additionally, the interpretability of AI prediction models remains to be optimised, and there is a need to improve doctors' trust in AI diagnostic recommendations.

In order to further improve the system performance, this study plans to optimise the following aspects. Firstly, in terms of computational efficiency, the study will further optimise the computational architecture of the federal health data lake to improve the efficiency of cross-institutional data training, while exploring more efficient decentralised data storage solutions to reduce data transmission costs. Secondly, in terms of the interpretability of AI prediction models, an interpretable AI (XAI) approach will be introduced in the future to make AI decision-making more transparent and improve doctors' trust in AI-assisted diagnostic results. And the reasoning ability of AI models will be enhanced by combining with medical knowledge mapping, so that they can not only provide predictions, but also explain decision logic. What is more important is that, in terms of telemedicine application expansion, new applications such as AI teleconsultation and remote rehabilitation training will be explored in the future in combination with 5G network and VR/AR technology, so as to enhance the coverage of the intelligent medical system, especially the application effect in remote areas.

5. CONCLUSION

Based on IoT, 5G communication and AI technology, this study constructs a real-time early warning platform for public health prevention and control with pre-hospital, in-hospital and post-hospital three-level linkage, integrating data sharing, intelligent decision-making and dynamic optimisation. The platform embodies the concept of whole-process intelligent optimisation, realising safe and efficient data sharing through the federal health data lake, and the AI decision-making centre provides accurate medical resource scheduling and risk prediction; and the AI health management system provides personalised rehabilitation programmes, thus constructing a pre-hospital, in-hospital and post-hospital whole-chain medical optimisation system. The implementation of this platform not only optimises the scheduling of medical resources and improves the response ability to public health emergencies, but also effectively improves the efficiency of medical resource utilisation, shortens the response time for emergency treatment, and optimises the long-term health management process. In the future, with the further development of AI, 5G, edge computing and other technologies, it can further optimise the intelligent diagnostic model, enhance the ability of cross-institutional data synergy, and expand to more public health scenarios in order to enhance the level of public health emergency management, and provide strong technical support for the innovative development of the intelligent healthcare system.

ACKNOWLEDGMENTS

This work is one of the research outcomes of the Key Research and Development Program of Jiangxi Province, China (Grant No. 20212BBG73043): Research and Application of a Multi-Source Big Data-Based Platform for Infectious Disease and Critical Care Prevention and Regional Collaborative Treatment Decision-Making. It was also supported by the China Scholarship Council Postdoctoral Program (Grant No. CSC 202208360098).

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