REVIEW

# Construction of an integrated emergency treatment platform for chemical injuries Exploration and Prospectinjury

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**Keywords**: Chemical injuries; Integrated; Emergency treatment; Intelligent chemical park; Intelligent platform

ABSTRACT

**Background:** The treatment of chemical injury patients is becoming increasingly complicated. Analyzing the chemical and hazardous chemical accidents that have occurred in China in recent years and the future construction direction of the smart chemical zone and building an integrated emergency treatment platform for chemical injury are of great significance to improve the level of emergency treatment of chemical injury, especially the emergency treatment capability of group chemical injury, and guarantee the safe and high-quality development of the smart chemical zone.

**Methods:** Based on the preliminary research results of the subject group and the summary of the practical experience of chemical injury treatment in hospitals, this study adopts the expert consultation method and literature research method to gain an in-depth understanding of the construction direction and content of the intelligent chemical injury integrated emergency treatment platform. Explore the establishment of "information, data, network, intelligent" as the center of the future chemical injury integrated emergency treatment platform.

**Results:** By integrating technologies such as the Internet of Things, big data, cloud computing, artificial intelligence (AI), 5G digital communication, and information interaction, the concept of building an integrated chemical injury emergency rescue prehospital warning platform, an integrated wisdom platform for chemical injury emergency rescue prehospital and in-hospital treatment, and an intelligent platform for chemical injury emergency command and dispatch and decision making are proposed.

**Conclusion:** The integrated chemical injury emergency treatment platform provides strong theoretical and application support to comprehensively improve the regional chemical injury emergency rescue and protection capability and provides professional advice to the government in the governance and decision-making of smart chemical parks.

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**What do we already know about this topic?**
Hazardous chemicals are chemical substances that are toxic, explosive, corrosive, combustible, flammable, etc., and are prone to cause casualties, property damage and environmental pollution during production, transportation and storage
**What is the main contribution to Evidence-Based Practice from this article?**
An integrated chemical injury emergency treatment platform provides strong theoretical and application support to comprehensively improve the regional chemical injury emergency rescue and protection capability.
**What are this research's implications towards health policy?**
The article provides professional advice to governments in the governance and decision-making of smart chemical parks.

Authors' Contributions Statement:
GZ and LW did study design, analyzed and submitted this manuscriptr. WS, YZ, ZP, CZ and XZ revised the manuscript. All authors contributed to manuscript checking and approval the final manuscript.

## Introduction

At present, China's total chemical production value accounts for approximately 40% of the world's value, has surpassed the United States to become the world's first producer of chemicals and is also a major user of chemicals. China now imports and produces more than 45,000 kinds of chemicals, including approximately 2,800 kinds of hazardous chemicals (hereafter referred to as hazardous chemicals) [1-2]. Hazardous chemicals are chemical substances that are toxic, explosive, corrosive, combustible, flammable, etc., and are prone to cause casualties, property damage and environmental pollution during production, transportation and storage [3-4]. During the 13th Five-Year Plan period (2016-2020), a total of 929 chemical and hazardous chemical accidents occurred in China, resulting in 1176 deaths, including major accidents such as the "11-22" Huangdao pipeline leakage and explosion, the "8-12" Tianjin port explosion, and the "3-21" Jiangsu Yancheng explosion, which caused more than 300 deaths and direct economic losses of tens of billions of yuan [5-8]. From the occurrence, development and rescue process of the abovementioned serious accidents in the hazardous chemical industry in China, accidents in the hazardous chemical industry reveal the characteristics of complicated and complex causative mechanisms and unpredictable scientific development and evolution, which in turn lead to injuries caused by chemical accidents, which are often manifested as mass events, diverse sources of injuries, complex injuries, and critical conditions. The rapid onset and change of patients are the main reasons for high morbidity and mortality rates [9-10].

On January 29, 2022, China's Ministry of Emergency Management issued the "Guide to the Construction of Intelligent Safety Risk Control Platforms in Chemical Parks (for Trial Implementation)" and "Guide to the Construction of Intelligent Safety Risk Control Platforms in Hazardous Chemical Enterprises (for Trial Implementation)" to guide chemical parks and hazardous chemical enterprises to build and use platforms, use information digitization and other advanced technological means to strengthen safety risk prevention and control capabilities, and promote the transformation of chemical parks and hazardous chemical safety risk control to digitalization and intelligent upgrading. It is important to analyze the causes of chemical and hazardous chemical accidents and the future construction direction of smart chemical zones and to build an integrated chemical

injury emergency treatment platform to improve the level of chemical injury emergency treatment, especially the emergency treatment capability of mass chemical injury, and to guarantee the safe and high-quality development of smart chemical zones.
Based on the research results of the group and the practical experience of chemical injury treatment in hospitals, this study proposes the construction of a prehospital warning platform for chemical injury emergency rescue, an integrated intelligent platform for prehospital and in-hospital treatment of chemical injury emergency rescue, and an intelligent platform for chemical injury emergency command and dispatch and decision making through the integration of technologies such as the Internet of Things, big data, cloud computing, artificial intelligence (AI), 5G digital communication and information interaction. The concept of a regional integrated chemical injury emergency treatment platform, exploring the establishment of a future integrated chemical injury emergency treatment platform centered on "informationization, data, networking and intelligence", providing strong theoretical and application support to comprehensively improve the regional chemical injury emergency rescue and protection capacity, and providing the government with strong theoretical and application support in the governance and decision-making of smart chemicals will provide professional advice to the government in the governance and decision making of intelligent chemical parks.

2.The need for the construction of an integrated emergency treatment platform for chemical injuries
Chemical injuries often manifest as mass events, and the critical condition of patients, rapid onset and rapid changes are some of the main reasons for high morbidity and mortality rates, especially when mass chemical injury accidents occur. Government managers cannot grasp first-hand on-site information in a timely manner, and objective factors such as delayed decision-making information, traffic congestion, complex patient etiology and cross-disciplinary nature lead to the loss of the best time for resuscitation. Delivering leadership decisions and expert treatment techniques to the scene of treatment quickly and effectively is the primary challenge to achieve smooth emergency care [11]. At present, the following problems often exist in the resuscitation of chemical injuries: (1) data on patients' vital signs and types of toxic exposure during prehospital emergency care cannot be shared to the attending hospital in a timely manner, while the lack of professionalism in the treatment of chemical injuries may lead to the inability of prehospital emergency personnel to give timely and effective symptomatic treatment measures in the absence of remote guidance from professional chemical injury treatment experts. (2) Chemical injury involves a wide range of clinical techniques and a long period of specialized training, resulting in a lack of clinical personnel for the comprehensive treatment of chemical injuries, coupled with the lack of familiarity with the standardized process of hospital emergency care, which makes it difficult to preside over the rescue of groups of chemical injuries, especially critically ill patients. (3) Chemical injury patients need to receive timely and effective life support in the first instance, and imperfect emergency plans can lead to poor coordination of treatment, untimely emergency response, and a disconnect in the coherent medical treatment process caused by the consultation of physicians from various specialties before treatment, which may delay the best medical treatment time. (4) The refinement of

specialties in modern hospitals leads to a lack of overall assessment of the patient's life-threatening condition after consultation with each specialty alone, which may lead to confusion in the order of treatment, surgical arrangements and medication selection, requiring multidisciplinary collaborative treatment led by trauma specialists [12]. (5) The emergency treatment of chemically injured patients lacks technical support before surgery, such as the need for respiratory and circulatory support before transfer, the need for postoperative organ function assessment and support, and the need for the full involvement of acute and critical care professionals. Chemical injury is a class of time-sensitive diseases, and the requirements for time and overall coordination are often greater than the technical requirements. The above problems can lead to inefficient treatment at the early stage of resuscitation, loss of the best time for resuscitation or increase the incidence of possible complications at a later stage. Therefore, it is indispensable to establish an efficient, scientific and standardized chemical injury treatment system, whether for single or group of serious chemical injuries. Currently, the more applied and effective management systems are mainly various chemical accident rescue systems, such as the Chemtrac system, CheriS system and Chlorep system in the United States [13], and the chemical accident rescue database established mainly in Shanghai, China, except for containing information on tens of thousands of chemicals, including manufacturers, properties, reserves and hazards and emergency measures, also has a large number of expert systems and consultation hotlines and query systems with many functions, which have played an important role in the existing chemical accident rescue work. Nevertheless, there are still shortcomings in these systems, such as too many chemicals, failure to highlight common chemicals and major chemicals possessed by a certain region, inadequate and friendly query system functions, and often limited to the guidance of rescue and treatment of known chemical accidents, while lacking early warning of chemical injuries, judgment of possible toxicants, and multidimensional judgment of time and space. In the medical rescue for the source of injury, the scope of injury is very important, which requires us in the process of chemical injury treatment, not only to have the ability to quickly diagnose and identify the nature of the poison but also the ability to integrate multidisciplinary treatment. For patients with difficult and serious chemical injuries of unknown etiology, unclear diagnosis, or involving multiple specialties or critical patients whose conditions involve multiple disciplines, systems, and organs and require the collaborative treatment of multiple specialties, there is an urgent need to build medical services that meet cross-regional, cross-hospital, cross-disciplinary, multispecialist interactive/noninteractive remote emergency integrated treatment based on in-hospital multidisciplinary treatment [11, 15].

In summary, by using technologies such as the Internet of Things, big data, cloud computing, artificial intelligence (AI), 5G digital communication and information interaction, the establishment of a future integrated chemical injury emergency treatment platform centered on "informationization, data, networking and intelligence" is the current research prospect of chemical injury treatment. Based on the integrated chemical injury emergency treatment platform, it will ensure that chemical injury patients receive high-level, timely, effective and continuous medical treatment, provide strong theoretical and application support to comprehensively

improve the regional chemical injury emergency rescue and protection capability, and provide professional advice to the government in the governance and decision-making of smart chemical parks.

## 3. Chemical injury integrated emergency treatment platform construction content

### 3.1. Chemical injury emergency rescue prehospital warning platform.

Carry out the work led by government departments, information companies to provide technical support, chemical companies to provide toxic data, and the establishment of the region's chemical toxic database. The main content includes the following: SQL Server, C# language and other technologies to build a hazardous chemical query management system; three-dimensional WebGIS and SQL Server; and other technologies to build a chemical injury rescue and treatment early warning system based on employee vital signs. The alarm system is based on the detection of employees' vital signs, the establishment of the data platform and the hospital data to form a linkage, data interoperability to provide early warning, toxic identification, patient identification, data support, and predictive model construction support for chemical injury emergency treatment. The specific construction content is as follows:

3.1.1. Build the query management system of hazardous chemicals. The query management system of hazardous chemicals is built by the comprehensive use of SQL Server, B/S architecture, C# language and other technologies, including the PC version developed based on Net platform and the Android app developed based on Xamarin framework to realize real-time query of hazardous chemicals data [16-17], open port data entry authority, and enterprises update the regional hazardous chemicals in time. Data directory in the region. At the same time, it realizes data integration with the national hazardous chemical safety production risk monitoring and early warning system.

3.1.2. A chemical injury rescue and treatment early warning system was built. Comprehensive application of sensor technology, wireless communication technology, three-dimensional WebGIS, SQL Server and other technologies to build the establishment of chemical injury early warning system, dynamic simulation and analysis of the range of hazards, the number of exposed personnel and casualties after exposure to chemical toxins on WebGIS maps, visualization of the occurrence of the accident site, the use of spatial analysis technology to assist command and dispatch and decision-making [18- 20]. Interconnecting with the IOT data of enterprises in the chemical zone, installing hazardous chemical leakage sensing devices in key areas and high-risk areas of the chemical zone, once hazardous chemical leakage is detected, automatically recording the type, time span, quantity and other information of the leaking hazardous chemicals, and at the same time can provide timely early warning to enterprises and hospitals according to the preset rule model, and combining the early warning module detection results for correction, timely and accurately Determine the rescue plan, evacuation range and evacuation path for the personnel at the accident site, and finally output a complete hazard assessment and medical rescue plan for chemical injury events, providing auxiliary decision support for medical rescue and laying the theoretical and practical foundation for establishing a high-level chemical injury rescue and treatment system.

3.1.3. Construction of an alarm system based on employee vital sign monitoring. First, wearable mobile monitoring devices are used to monitor human vital characteristics and

information about the environment in which they operate, and the main monitoring indicators are heart rate, respiration, blood pressure, ECG, blood oxygen, and other core human physiological parameters [21-22]. Vital sign detection equipment must be worn before entering the high-risk area to detect and upload vital sign data in real time. Likewise, the system can provide timely warnings to enterprises and hospitals according to a preset rule model. Second, a complete employee personal health database is constructed. The SSM framework and MySQL database technology were used to design the employee personal health file management system, which mainly realized the functions of collecting and querying personal health file information, doctor's network consultation, publishing health knowledge, personalized health improvement plan development and early warning [23]. For the employees engaged in chemical areas exposed to occupational hazards, a whole life cycle personal health file is established, which includes not only basic health guardianship management files such as occupational history, past history and occupational disease hazard exposure history of workers, monitoring results of occupational hazard elements in corresponding workplaces, and reports of occupational health examination results but also medical records based on daily personal vital sign monitoring data and medical institutions [24]. The purpose is to provide more accurate data analysis as a late chemical injury emergency treatment, while medical institutions can rely on personal health data for accurate analysis and develop more scientific occupational disease prevention and treatment measures.

3.2. Chemical injury emergency rescue prehospital and in-hospital treatment integration wisdom platform.

The integrated intelligent platform of chemical injury emergency rescue and in-hospital treatment is built by using technologies such as the Internet of Things, big data, cloud computing, artificial intelligence (AI), 5G digital communication and information interaction to integrate the patient information interaction system, prehospital transfer command system, intelligent prescreening and triage system, diagnosis and treatment process management system, multidisciplinary remote consultation system, human resource allocation system and material deployment system. Out-of-hospital hospitals and 120 command centers, neighboring hospitals and other regional coordination to achieve information interaction and sharing, the relevant business departments within the hospital to form a cooperative linkage, to achieve seamless and efficient linkage between prehospital emergency and in-hospital treatment integration, to achieve chemical injury remote consultation, emergency vehicle scheduling, emergency command, remote emergency guidance, remote surgical demonstration, two-way referral, exchange of expert technical experience and resource sharing and other functions [11]. The main functional modules of the platform are briefly described as follows:

3.2.1. Patient information interaction system (infrastructure platform construction).

3.2.1.1. Prehospital information interaction. Based on the Geographic Information System (GIS), the map dynamically simulates and analyzes information such as the exposure range of chemical toxicants and the number of personnel exposed and initially forms the hazard assessment and medical rescue plan for chemical injury events. After arriving at the scene, first responders wore portable wireless monitoring devices to patients and implemented monitoring of body temperature, pulse, respiration, blood oxygen, blood pressure, ECG, blood sugar and other

indicators through biosensing and other technologies. On the one hand, it realizes real-time location sharing of patients to provide an accurate time basis for in-hospital preparation, and on the other hand, it continuously transmits the physiological indicators and vital sign data of patients to the in-hospital remote monitoring system in real time through information technology. During the whole period from the arrival of emergency personnel to the time of admission to the emergency room, doctors can monitor the changes in patients' conditions in real time so that "information arrives before the patient arrives", which is conducive to the hospital providing accurate medical services for the treatment of patients on this basis.

3.1.2.2. In-hospital information interaction. By wearing intelligent monitoring devices on patients, realizing the full monitoring of patients in the in-hospital treatment process, applying advanced emergency medical Internet of things and management platform for time management, real-time collection of time spent by patients in each process of consultation, such as building automatic time collectors in key areas of medical departments such as emergency prescreening tables, resuscitation rooms, emergency CT, emergency testing, catheterization rooms, ICU, operating rooms, etc. Automatically record the arrival and departure time of patients and automatically realize the tracking of patients' medical treatment trajectory [25]; meanwhile, automatically record the collection of vital signs during the transfer process to facilitate the observation and recording of patients' conditions during the transfer process and realize rapid reception, rapid examination, rapid diagnosis, and rapid resuscitation (surgery) to improve the success rate of rescue and treatment.

3.2.2. Preadmission transfer command system. By installing a panoramic camera, audio, microphone equipment and related software in the ambulance to share information with the command center and receiving hospital in real time, experts in the hospital make etiology and diagnosis judgments through the chemical database, toxic database, chemical enterprise information and workshop surrounding environment database of the rescue and treatment platform and directly participate in guidance. The command center notifies the relevant departments and personnel to arrive at the scene in time to prepare for the treatment and open green channels according to the vital signs and other information of the patients reported by the accompanying doctors to improve the rescue efficiency of each department. At the same time, by configuring the Global Positioning System (GPS) terminal in the vehicle, the command center can grasp the specific location of the ambulance in real time, grasp real-time road information through linkage with the traffic department, avoid traffic congestion, intelligently plan the optimal route for the ambulance to and from the hospital, estimate the time required to arrive at the hospital, and accurately wait for medical treatment in the hospital, which greatly improves the efficiency of emergency treatment.

3.2.3. Intelligent prescreening and triage system. After the patient arrives at the emergency clinic, the patient's vital signs and other information are automatically imported into the intelligent emergency prescreening and triage system based on the vital signs combined with the collected clinical symptom indexes, and the system automatically analyzes the patient's indexes and makes an intelligent condition classification (grade I to grade IV) after a comprehensive judgment, classifies, subspecializes and partitions the patient according to the condition classification,

generates the patient's wristband information simultaneously, and marks the condition classification with different colors (grade I, grade II in red, grade III in yellow and grade IV in green). The patient wristband information is generated simultaneously, and the condition grading is marked with different colors (red for grades I and II, yellow for grade III, and green for grade IV). The green channel system is activated for this type of patient, and the "green channel" mark is given in the system to give priority treatment in all ambulance links [10]. On the other hand, the patient assessment information is shared in the emergency medical information system, and patients are given priority treatment in the prescreening system. On the other hand, patient assessment information is shared within the emergency information system, and key information such as vital signs, symptoms, and triage levels collected by patients during the prescreening and triage process are synchronously transferred to the physician's electronic medical history interface, reducing the process of reinterrogation and recording by the physician and directly importing it into the electronic medical record to achieve seamless integration of information from different time periods [26].

3.2.4. Medical process management system. When the ambulance arrives at the accident scene, the accompanying doctor will put on the intelligent monitoring device for the patient, which can record all the basic physical data of the patient on the one hand and serve as a process management device to realize the tracking management of the whole process of treatment based on IoT technology on the other hand. After the intelligent monitoring device is put on, it starts to work and records the patient's transit time. After the patient is admitted to the hospital, the timers set by each key department will sense the intelligent monitoring device in turn according to the actual treatment process of the patient and automatically record the arrival and departure time of the patient to realize the tracking and recording of the whole process of the patient's medical treatment.

3.2.5. Multidisciplinary teleconsultation system. The patient's imaging, laboratory and pathology information was shared, and expert diagnosis and treatment opinions were transmitted to the rescue site. The remote multidisciplinary consultation system can provide the most accurate information by collecting the first scene, such as the ICU and resuscitation room, which can be transmitted to the emergency command center by organically combining the scene images and real-time physical sign information through the platform so that experts can make accurate judgments [27]. The remote multidisciplinary consultation system can remotely provide the emergency command center with on-site rescue images, patient imaging, laboratory and pathology information, and various vital monitoring indicators in real time to help remote consultation experts quickly analyze the patient's condition and formulate rescue plans, and the receiving hospital can also respond in time to take corresponding measures. At the same time, with a real-time communication function, consultation experts can communicate with the patient and family members to understand the patient's past medical history and other conditions.

3.2.6. Human resource allocation system. Medical and nursing personnel are deployed according to the grading of patients' conditions, and priority is given to the deployment of emergency rescue teams, critical care physicians, emergency physicians, burn physicians, and occupational physicians in the hospital as emergency echelon personnel. At the same time, the number of management

department warnings is set in the intelligent triage system, and when the number of admissions reaches the warning line, data are automatically uploaded to the medical management department so that functional departments can respond in a timely manner. Prehospital emergency response teams and in-hospital rescue teams should be established, and an "in-hospital chemical injury emergency rescue microletter work group" should be established to facilitate work deployment, command coordination, information collection and communication. Improve and refine the regional chemical injury treatment expert database, which should cover labor and occupational health, critical care medicine, imaging, laboratory science, nuclear medicine and other related disciplines to provide technical support for chemical injury treatment.

3.2.7. Material deployment system. According to the chemical database, toxic database, chemical enterprise information and environmental database in the region, the command center formulates the material guarantee plan for different chemical injury event categories in advance in daily management and establishes relevant mathematical models. When a chemical injury event occurs, the receiving hospital can immediately calculate the type and quantity of medical supplies required through the material allocation system and present them in the form of an adjustable list. The daily management of chemical injury medical supplies follows the medical supplies supply chain logistics management mode (Supply Processing & Distribution, SPD), the conventional medical supplies are managed by SPD low-value supplies, and the SPD warehouse personnel make quantitative replenishment according to the lower limit of conventional supplies usage drawn up in advance by the department.

3.3. Chemical injury emergency command and dispatch and decision-making wisdom platform.

3.3.1. Construction of an intelligent emergency command and dispatch platform under the theory of three-dimensional GIS-based large-screen visualization of the whole process design strategy. Based on the visualization of multiple view designs to show in the form of large screens and other forms, GIS and video modules are added according to the demand to enhance real-time supervision and command scheduling capabilities, and information real-time notification modules are added on the basis of multiple integrated data sources to enhance the real-time nature of displayed information [28]. The platform docks to various business systems, collects monitoring video data, geographic information data, emergency material data, etc., and dispatches through video linkage, GIS linkage, cell phone visual intercom dispatch, SMS dispatch, fax dispatch, emergency business system linkage, etc. [29]. It provides channel support such as PC Internet, mobile Internet, communication Internet, and Internet of things to realize omnichannel emergency command and dispatch.

3.3.2. Construction of an intelligent decision-making platform based on the "Big data + AI" system. Empower the scientific decision-making of chemical injury emergency management with "Big Data + AI"; build emergency big data governance and intelligent application systems; provide decision-making support in the four stages of monitoring and early warning, command and rescue, decision support, and comprehensive management [30]; continuously promote emergency decision-making on the basis of data and networks to leap to intelligence; and comprehensively improve the rapid response and command and rescue capability of chemical injury emergency response. Network-based leap to intelligence

and comprehensively improve the rapid response and command and rescue capability for chemical injury emergency disposal.

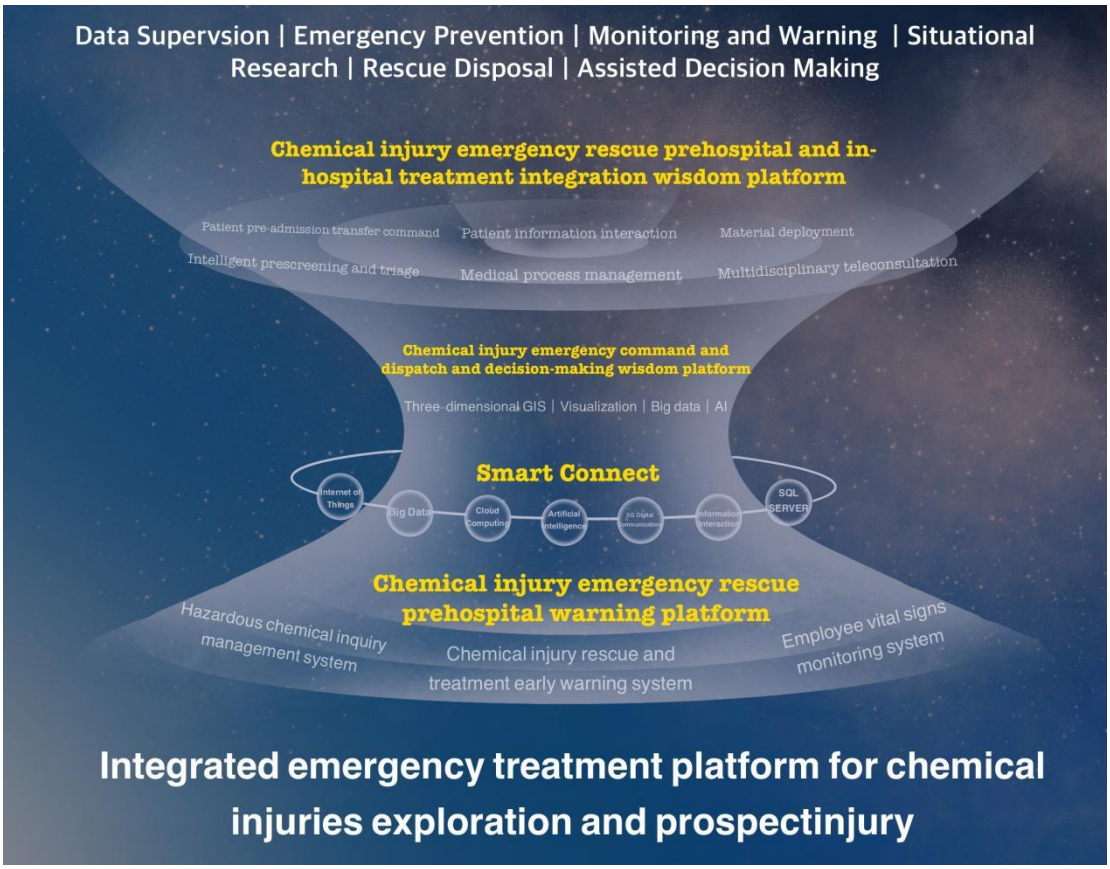


FIGURE 1: Integrated emergency treatment platform for chemical injuries exploration and prospect injury

## 4. Conclusion

The integrated chemical injury emergency treatment platform is an important link to realize the radiation extension of high-quality chemical injury emergency critical care services to the grassroots. The platform takes medical institutions in the region as the core, integrates chemical injury treatment expert resources within the medical association, builds a multidisciplinary remote diagnosis platform, and combines green transfer routes, prehospital intelligent triage, optimal allocation of human resources, and rapid deployment of supplies [11], reports real-time information on the treatment of chemical injury patients and environmental information of the accident site, and realizes a full record of the medical treatment process, which eliminates information silos and achieves scalable digital medical emergency model provides a new model and opportunity to greatly improve rescue efficiency and accelerate the embodiment and overall level of first-line medical treatment of expert resources [31]. Without changing the existing clinical organizational structure and function of the hospital [12], this treatment platform can integrate regional chemical injury treatment resources in time and space and has good replicability. At the same time, we should also note that because chemical injuries are classified as occupational injuries [32], there are significant differences in terms of expertise and number of physicians between emergency

departments in dealing with routine treatment and batches of chemical group injuries, and the disease diagnosis and treatment methods required for the latter need to be changed [33-34]. Regardless of the model adopted and the platform based, the training of professionals and the standardized implementation of the rescue process are the key to effective rescue [35]. This gap can be bridged, and a better chemical injury rescue team structure can be formed if a corresponding talent echelon from the in-hospital emergency rescue team can be established, trained and engaged [36]. In addition, since the standardized and holistic construction of an integrated chemical injury emergency treatment platform requires the participation of multiple management departments and institutions, the difficulty to be overcome lies in how to coordinate the responsibilities and authorities of all parties to ultimately achieve the overall goal of continuously improving the level of chemical injury emergency treatment and ensuring the safe and high-quality development of smart chemical parks.

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