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Chapter 7: Revolutionizing emergency response and critical care management with artificial intelligence-augmented systems

7.1. Introduction

This systematic literature review investigates potentialities to exploit AI-supported technologies in Chinese hospital emergency departments. Modern digital medical tools combined with artificial intelligence technologies enable rapid acquisition, gathering and analysis of extensive medical data, providing timely insights for emergency physicians to make timely treatment decisions that can improve patient outcomes. Correction of motion artefacts can be achieved in medical imaging using artificial intelligence technologies without the need for rescanning, while at the same time preserving patient safety by minimizing the amount of ionizing radiation. The possibilities are to produce a high-quality medical image being corrected from motion artefacts by artificial intelligence models and methods to increase the diagnostic accuracy of medical images. Medical radiation imaging and computer tomography imaging are currently the two categories of imaging modalities responsible for ionizing radiation dose, involved in at least 80% of medical ionizing radiation dose for an average patient. Acquisition of enough CDS is difficult in fast spinning imaging sequence, e.g. 0.5 seconds for Gastrografin X-ray CT imaging scan sequence, a patient motion artefact greatly reduces its image quality and makes its follow-up diagnosis difficult or even impossible. Critical care services will be significantly improved, more accessible, and more cost-effective by using artificial intelligence (AI) (Nguyen & Nguyen, 2020; Patel & Cushing, 2021; Shaik et al., 2023). Remote monitoring could be on-time and in-time monitoring and treatment without the need for admission, dramatically decreasing emergency department (ED) admission times, especially the bed-constrained situations can realize a patient immediately sent to still available bed. Automated triage of non-urgent patients by the AI-based artificial intelligent emergency department platform by symptom extraction and monitoring. Machine-learning models including the support vector machine classifier, random forest classifier, adaptive boost classifier, and decision tree classifier generate models with good performance. A multi-agent system constructed with traditional machine-learning algorithms performs better than a single traditional machine-learning model. Very good scalability in the computation execution framework is created by using the ensemble learning from local agents to overall model levels.

Fig 7.1: Revolutionizing Emergency Response and Critical Care Management

7.1.1. Research design

This section describes the design and implementation of emergency triage and telemedicine advice in the pre-hospital emergency service. A multi-agent system (MAS) was developed that integrates with telemedicine advice provided by emergency care specialists and provides enhanced services for the pre-hospital emergency service. This enhanced telemedicine service is connected with and provides data management, data analysis algorithms, and data presentation for an online emergency assessment system. In a study involving medical trials with this enhanced service, data on the utility of geographic temporal data are to be collected. This system will be implemented in the framework of a Smart City pilot project.

In recent years, there has been increasing interest in the development and design of intelligent systems to provide individualized medical assistance throughout the health enhancement course for an aging society to promote active and healthy aging. The application was initiated in Latvia, where uniform data patients monitoring from home is used for long-lasting diseases. To link the expert systems with the medical intelligent decision support system, remote monitoring, and individual findings presentation to a patient. There is an interest in improving healthcare service delivery of location-based telematics expert systems to support on-site medical care. The system has been developed by the connection of Smart City systems and cloud computing for supporting real-time information exchange among patients, the expert system, and medical personnel. However, the implementation of new information and communication technologies in pre-hospital services is still insufficient, and telematics expert systems have potential for location-based services. When examining medical data, including emergency visits, and studies on the individual challenges and opportunities in respective locations have been identified. On-site emergency pharmacist support is responsible for a significant portion (3%) of patients visiting in Riga emergency departments.

7.2. The Role of AI in Healthcare

The increasing availability of digital medical tools combined with constantly improving artificial intelligence applications could lead to a radical revolutionization in healthcare, particularly impacting emergency response and critical care management (Smith & Roberts, 2021; Zhang et al., 2022). Effortlessly combining digital medical data and effortlessly analysing it, AI technology will allow emergency physicians to gain timely and insightful perspectives for decisions on how to best manage each patient. That will, in turn, improve the treatment outcomes that patients receive, and has been a “hotcake” topic researched in the last couple of years. Some efforts in this regard are correcting motion artefacts of routinely acquired medical images with AI, or using AI-based systems for the triage, diagnosis, and prognosis of emergency or critical care events. It is expected that these and similar applications will be progressively introduced into a growing number of hospitals across different countries, thus fostering the general advancement of the healthcare system. The safety of emergency service workers is maintained because the 119 scene is the most dangerous area. There is a sense of waste from a layman’s point of view that a fire engine, an ambulance, four emergency service personnel went to and from the scene of the case, and filed a document after two hours. Of course, I am grateful and happy that the people involved in the case were safely rescued. Employees of emergency rooms filled with critical conditions and blood, many tragic encounters, and exhausted faces-as if life is worn out. One of the reasons for the desensitization is the occurrence itself, but it is also caused by numerous redundant treatments and the intake process that fill the emergency room with sick people who have different degrees of illness. Additionally, the treatment of patients with the same lesion everyday is somewhat inevitable for the workers who provide treatment. Wishing for the health of our family leads to a decline in hospital services, primarily in emergency rooms. With this app, he stated that it would be possible for emergency room workers to make accurate first aid decisions within minutes of arriving at the scene of an incident.

7.2.1. Current Applications in Healthcare

During the COVID-19 pandemic, companies and educational organizations developed various webcam and thermal sensing biotelemetry systems. An educational institution is incorporating a similar emergency telemedicine system into an integrated platform in collaboration with military and industry partners. This project comprises a portable, self-cleaning, isolation pod equipped with temperature sensor arrays, an airflow system, and telemedicine units. Algorithms analyze vitals to expediently decide bed availability and infection control strategies. A communication network is used by onsite and offsite personnel to manage the patient.

The exponential growth of the elderly population has resulted in social consequences both in the workforce and healthcare system. Higher demands for nursing care along with the implementation of new technologies are likely to create missed care. Consequently, it is important to develop strategies to fully utilize current resources with a focus on delivering nursing care efficiently. Dynamic scheduling of nurses, residents, and care beneficiaries was considered by formulating the problem as a mixed-integer programming model. The objective was to maximize the overall prosperity of beneficiaries defined by the total number of services received by nursing care. This work neglected the preferences of individuals. The assignment and scheduling of emergency nurses considering personal preferences and temporal constraints were studied. Each nurse might prefer different days off during different periods of a week. In order to model this, preference lists were used. Three greedy algorithms were proposed. Although the proposed greedy construction and local search algorithms produce quality solutions in a reasonable time, the optimality of the assignment was not guaranteed. A hybrid approach combining genetic and greedy algorithms was suggested to solve larger-sized instances.

Wearable biodevices implicitly contain physical and chemical data such as body temperature, hydration, and blood pressure. The biodevice described is made of biocompatible materials, sensors to estimate material properties and analytes, and conductive ink functions as a virtual biosensor. Once the biodevice is worn, a custom algorithm is initiated to determine physiological states from multi-physical data inputs measured by a conductivity scanner. More efforts have gone into applying computer vision and artificial intelligence algorithms to smart-vision solutions. These algorithms have included connected component labeling and a blob analysis function. A field programmable gate array and the microcontroller were used together to divide and number label each region detected by the webcam. The labeled objects were sent to the control room for post-strategy and immediate action.

7.3. Emergency Response Systems

In recent years, an increasing number of AI algorithms and technologies have been established; they are either supervised or unsupervised, and are explicitly or automatically developed. Because of these developments in AI, it is possible to construct a particular machine learning algorithm that could automatically produce a summary of the unruly unstructured clinical data; however, just because it is possible to design such an algorithm, this is not to say that it would necessarily be valuable or useful. With only a very few exceptions, AI technologies simply do not engage with ethical issues in a meaningful way. These fears have a great deal of historical precedent, and there is a canon of critically reflective science fiction literature that warns about these dangers.

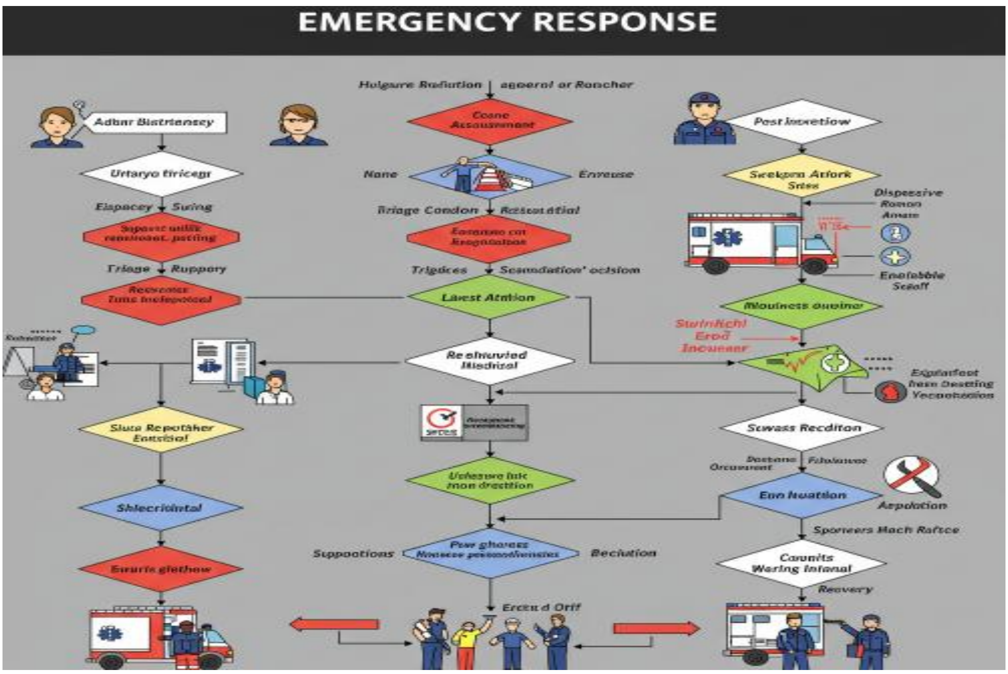

Fig 7.2: Emergency response process

7.3.1. Traditional Emergency Response Models

Designing effective emergency response management (ERM) systems to respond to incidents such as road accidents, building fires, hazardous spills, etc., is a major problem faced by communities. Additionally, such systems are also needed to support response during natural hazards that can cause or be of a scale similar to typical incidents. Given these needs, there has been a consistent interest from the research community in recent years in building decision support and optimization tools that can help emergency responders provide more efficient and effective response. Broadly, such tools can be envisioned as a network of several decision support subsystems (DSS), each tasked with providing support for a different aspect of the emergency response (ER) process and performing at a different spatio-temporal granularity. The ultimate goal of such development of systems is to enhance the overall situational awareness of emergency responders. The rationale is that increased situational awareness will enable more effective and coordinated management of the response and improve outcomes in terms of reduced number of injuries, fatalities and lesser damage to physical infrastructure. Such a system would also increase the safety of the emergency responders themselves, by improving the timeliness, reduce the levels of uncertainty and ambiguity and optimize the use of the available resources during the response.

Two of the subsystems will inform and monitor the actions taken by the ER teams during the response phase. The ER monitoring DSS will maintain an up-to-date situation awareness model of the response operations, track the metadata information associated with the sensor data and derive the best effort estimates on the quantities of interest. The same DSS models will also track the actions taken by individual ER teams and the results of these actions. This info will be available for post-incident review, helping to produce more accurate and timely incident reconstruction reports and improving future training of the emergency responders. The Resources DSS will be responsible for deriving the recommendations on the structure and output capacity of the transmission lines network that is likely to maximize the ER performance.

7.3.2. Limitations of Current Systems

Patient care in critical settings is complex and error-prone involving time-, response-time-, and safety-critical transport under severe conditions. Prehospital emergency care has become increasingly important over the recent years, and emergency systems are facing increasing challenges since morbidity and mortality rates are not solely depending on the patient's clinical condition, but rather on the care they receive. Incidents of large-scale disasters or major events emphasizing the health infrastructure can be observed across Europe. Advancements in technologies and methodologies have revolutionized many sectors and industries, particularly in the health domain for emergency transport -

by means of autopilots, improved electronics and materials, miniaturization, robotics and tele-operation - and on the clinical and organizational silos.

The inclusion of concepts and methodologies related to Big Data and Artificial Intelligence into the transportation and logistic aspects of emergency response can significantly contribute to lifesaving. Despite the relevant research carried out and the previous advances achieved, there is a need to further develop and refine the latest technological developments bringing closer their application in civil society and emergency response organizations. Common approaches in emergency response management are often hampered by a lack of comprehensive or accurate information and the difficulties of coordinating the efforts of the various actors in a joint manner. Natural and man-made complex and often mobile incidents underline the need for technological advances, which allow responsible authorities the rapid generation and reconfiguration of response strategies. The current interoperability of existing response tools and models is often found to hamper overall disaster management effectiveness. Planners are usually unable to predict how a given emergency event will evolve, let alone its effects on the built environment and societal infrastructure together with the effect that protective measures, such as evacuations, will have.

7.4. AI-Augmented Emergency Response

The integration and development of AI-augmented systems in medical practices is changing emergency department operations for the better. The inclusion of smart devices not only rapidly and effortlessly gather vast medical data but also bring powerful AI technologies into play, which can provide immediate analytical results based on such data. Alongside reports of high accuracy in indicating risk of diseases or injuries, the deployment of such tools can significantly bolster patient treatment outcomes in emergency departments, surrounded by medical hazards and a dearth of supervision resources at the same time.

The ubiquitous nature of smart devices, combined with the advancement of the Internet of Things (IoT) technology, enables a wide range of physiological data to be continuously and wirelessly collected from an individual. At the same time, AI-based applicability and efficiency in analysing and learning from this data bring in transformative medical prospects. From a clinical perspective, AI-edited data can provide clinical decision-making, enabling non-invasive and continuous patient supervision. This might significantly improve the treatment outcomes of non-critical monitoring patients before the commencement of a serious condition. For emergency cases, the combination of real-time analysis of real-time data could alert medical personnel to possible issues before patient danger arises, thus considerably improving emergency patient treatment end results. Either way, such AI data could provide one more method of supervision for the optimal standard of treatment to hospitals and healthcare providers.

On the other hand, despite likely life-saving medical possibilities, there are concerns that blurred protection and ethical practices mean their development must be cautiously encouraged. Moreover, from a practical viewpoint, it is pivotal to use knowledge of privacy protection and data control to promote this emerging domain, as it will perhaps be up to regulators to control such a continuous and powerful technology.

7.4.1. Predictive Analytics for Emergency Situations

Recent breakthroughs in artificial intelligence (AI) have enabled innovative solutions to address quiet but important challenges. Among potential applications, maybe one of the most crucial is emergency response and critical care management. In an emergency situation, every moment matters, but sometimes it is challenging for first responders and emergency staff to make quick and accurate decisions. By implementing computer intelligence to monitor real-time data and assist in decision-making, the first critical minutes of the care process may be significantly enhanced, leading to better patient outcomes. To showcase the advantages of an AI-augmented system in an emergency situation, two application areas are provided. One discusses how predictive analytics can identify high-risk areas and help prepare for possible accidents, while the other explores AI-assisted triage to lessen the burden on emergency departments and allow faster lifesaving actions. Combined, these AI-enhanced solutions could greatly improve both emergency preparedness and post-event responses.

7.4.2. Real-Time Decision Support Systems

The healthcare ecosystem is undergoing a transformation by the rapid advancement of artificial intelligence (AI) technologies, imbued with potentials to revolutionize emergency response management and the field of critical care medicine. AI-based systems can be employed to analyze vast volumes of data that can help predict or monitor physiological status or clinical outcomes and provide decision support to care providers. Wearable sensors or advanced imaging devices can help monitor evolving health status; machine-learning models can be trained and deployed to predict future health conditions. Additionally, real-time decision support systems may help in translating this prediction to a better outcome; given specific projected health conditions of a particular patient, what care actions may result in an optimized patient outcome.

Two fundamental concepts that AI-based decision support tools must adhere to in order to be deemed useful and trusted by end-users are timely and actionable information, privacy-preserving data use. There are two primary challenges associated with the use of AI-based clinical decision support tools at the bedside. The first challenge is a lack of clinician trust in the system. The other challenge relates to the over-reliance on AI-based decision support, rather than considering other relevant aspects of the patient's condition and disease context. It is essential that these tools are developed using sound human factor engineering principles to minimize considerations of any AI tool, also to minimize information overload, and to operate cohesively within the clinical workflow.

Regardless of the success of clinical decision support systems, it is still unknown whether these improved processes and outcomes are a result of offering better recommendations or a combination of behaving better and instilling general improvement. Overall, strict good practice methodological reporting and evaluation procedures typically improves clinician acceptance. Summarizing expert recommendations in the form of simple and explicit instructions, introducing a knowledge interface to interrogate the entity, setting bounds to recognize and act should recommendations progressively worsen, and a mechanism to reevaluate and modify advice are facilitators for clinician acceptance.

7.5. Critical Care Management

There is a need for Artificial Intelligence (AI)-based tools in acute care environments to aid in the early detection and assessment of cardiorespiratory insufficiency (CRI). The new onset of CRI is common in acutely ill hospitalized patients. Misdiagnosis and/or delayed treatment lead to increased morbidity, mortality, and cost of care. Patient condition, although deteriorating in nature, frequently remains unstable or highly variable. Instability manifests through acute but frequently subtle changes in vital signs indicative of attempted compensation and the evolving decompensation. The longer a patient is in a decompensated state, the more difficult it is to mitigate or reverse resultant damage at the organ and cellular levels. Therefore, detecting impending instability could permit timely stabilization, reducing morbidity, mortality, and resource use. However, the requisite technology is not yet available. Many early alerting approaches have subsequently been rolled back for various reasons, including unacceptable performance and increased clinician documentation burden. There is a clear need for better performing, trustworthy models that can be effectively melded into the clinical workflow. There is a clear need for Artificial Intelligence (AI)-augmented systems in critical care environments to support the preparation, planning, response, mitigation, and recovery associated with time-critical emergency management. Critical care capabilities in urban environments are uncommon and solely present in centralized locations. As a result, a specialized unit centered on the intensive care unit (ICU) and emergency department (ED) is used for patients with high acuity or requiring rapid management.

This centralized care model creates several challenges. The distance between a patient and care provider leads to delays when time is crucial. The ratio of patients to nurses and physicians is small compared to the volume; monitoring and treating patients are simply insufficient. The cost of care is high, and the infrastructure is massive. Emergency admits in hospitals occur without notice and often overwhelm the capacity of the care unit. And the COVID-19 global pandemic reveals that even the developed health infrastructure has its limits, revealing the need for new mechanisms and models to support the care of critically ill patients.There is a compelling need for AI-based tools in acute care environments to assist in the early detection and assessment of cardiorespiratory insufficiency (CRI), typically manifesting in the form of unstable vital signs. Instability in these same physiological parameters is also a hallmark of the onset of the most severe forms of this insufficiency implying that if this instability could be quickly and accurately quantified it might provide a means to predict impending crises and permit timelier and more effective interventions. If untreated, CRI leads to life-threatening medical conditions, often with irreversible consequences, and it is among the most common causes of morbidity and mortality in hospital environments. Early detection and assessment of CRI is challenging due to the complexity and highly non-linear nature of these physiological systems as well as multiple existing patient states and conditions that can confound the interpretation of vital signs. Early detection of CRI is an even greater challenge, as inherent compensation mechanisms can quickly obscure the more severe forms of this insufficiency.

Fig : Revolutionizing healthcare

7.5.1. Understanding Critical Care Needs

This fast-growing field is mainly supported by the growth of digital data that accompany many aspects of daily life. A large fraction of this data is linked to health, and includes vital signs collected by wearables, mobile phone-paired devices, health and wellness monitors, and consumer products for home use. The motivation for this technology is the belief that analysis of these data could lead to timely intervention in disease to prevent worsening and/or reverse outcomes. Unfortunately, to date, very simple methods are used to interpret these data, leading frequently to over- and under-utilization of the human and other capital resources devoted to healthcare.

This positioning paper will review the status of free-living monitoring of the physiological data of relevance to the early detection and assessment of acute illness. The analysis of such data, including approaches, limitations, and several outstanding challenges, will be described. Since translation of the analysis of this data into actionable information requires a feedback between the health status of an individual and the actions taken in their care, the requirements necessary to create the desired loop will also be discussed. Finally, it will be suggested that these devices could be improved to foster interventions, especially if they feed intelligent adaptive algorithms to autonomous systems capable of suggesting or even implementing interventions.

7.5.2. Challenges in Critical Care Management

Several U.S. Department of Defense (DoD) deployed Critical Care Air Transport Teams (CCATTs) have in recent years not been accredited by the Commission on Accreditation of Medical Transport Systems. Consequently, care provided on long-haul flights or helicopters when fundamental care facilities are hours away may be compromised. Given the efficacy and pace of life in the modern world, mobile intensive care systems are a necessity for disaster response, rural areas, long-haul medevac flights, and military transports. The challenge is that current protocols, equipment, and skill sets are based on principles that are antithetical to these platforms. To the best of the authors knowledge, the current system design, representing over thirty critical care systems in use or review, was developed without input from the recipients of these services but rather was vested in a desire to represent the state of the art as it exists on the ground in hospitals. The goal is to move beyond a hospital oriented equipment list and skill set into the realm of practical and deployable critical care systems. This realm is limited by the physical structure of transport vehicles, the endemic goals of transport systems, and the physiology of fixed-wing and rotary wing transportation. While there has been notable work comparison of ICUs and protocols, there appears to be no literature examining existing critical care transport systems or protocols. The current system design is based on a survey of critical care physicians and flight nurses who staff such platforms, interviews with CCATT faculty and physicians at tertiary care hospitals, and literature review of the specialization of critical care transport, air ambulance and telemedicine companies. Compatibility of care provider equipment with the patient monitoring equipment used on flights is a recurring challenge. Analysis of available equipment fails to identify a common installation or operating format across patients, both military and civilian. As applied to DoD CCATT platforms, the aircraft can support a ventilator stack with 3.5 h of mixed O2 capacity and 3.7 h of liquid O2 capacity, hemodynamic module for cardiac output measurement with negative ionization air filtration, and non-invasive cardiac output monitors.

In the U.S., standards for the production of medical devices are mandated by the FDA. However, the defense medical community is not required to employ FDA-approved devices. Such devices are acquired and upgraded through a complex Defense Acquisition System. USAF and Army medical equipment employed on CCATT missions do not interchange unless force fitted. Regardless, it is necessary that new supplies be FDA approved and purchased through Sterile Supplies. Negative ion air filtration and space ionizers intended for human use are not FDA approved, but are marketed for use in homes and vehicles. Developed filtration systems intended only for the supplemental air, hemodynamic module already in use, are prohibitively costly and use a non-standard data out format preventing use with the current transport electronic integrative. While air purification can have clinical benefits, CCATT patient population is generally not specified in air transport device trials. Critical care transport patient populations are generally those who can tolerate shorter cycle 100% O2 treatment.

7.6. Conclusion

Emergency department (ED) is the primary gateway to critical care services for most critically ill patients. However, with only an estimated 5-7% increase in staff and resources, ED visitations in China have risen by 167 million over the past decade. There is an urgent need for technological support to address these challenges and improve care efficiency and quality. Digital medical tools can rapidly gather vast amounts of medical data for AI systems to analyse. However, Chinese EDs have difficulty adopting such tools due to specific challenges. AI is promising to address issues without the need to revisit said systems or collect additional data, and preliminary pre-clinical results indicate that, in comparison to existing techniques, AI systems rival off-site automated systems in comparison. By enabling wearables such as Earables or other AI-equipped tools, mobile technology may render these systems.

Transferring critical care beyond the doors of the ED—Time-sensitive care and monitoring are the cornerstones of EDs. Such services are commonly unavailable outside hospitals. As a result, suitable EDs play a vital role in preventing life-threatening health crises underway to other clinical services. Nevertheless, a recent study indicates that hospitals in China account for 42% of all chief fatalities nationwide, which indicated a less successful delivery of critical care services in general wards. This is consistent with similar practices in other countries, where patients in rural areas or areas with socioeconomic inequalities are often at elevated risk of poorer care.

Recent publications have highlighted how AI applications can assist patient triage in mass casualty events and as an efficient decision-making tool for diagnosing undifferentiated diseases due to the vastness of medical data. Such topics have been previously addressed in other settings and focused specifically on Chinese EDs. Instead, the discussion concentrates on how AI applications augment medical personnel in Chinese ED settings in the context of critical care delivery and management.

7.6.1. Future Trends

Facing more challenges, the future trend could include: (1) Digital medical devices combined with AI technologies are able to collect big medical data and analyze it quickly enough to have immediate impact on patient treatment outcome. AI can address domain adaptation on transthoracic echocardiogram four-chamber view images and build a robust method on different ultrasound machines. In that way, AI can help bridge monitoring gaps for critical situations to collect continuous data; (2) A new method brings attention to informatic approaches to improve the analysis of image artifacts and to enhance the data quality and diagnostic accuracy of wide ranges of medical imaging tests; (3) By 2050, trend projections suggest that critical care services will be used most of all types of hospitalization care available. Emergency departments represent now the main source of financial deficit in public hospitals; (4) A classic concern is that in a mass casualty incident, where the patient flow is rapid and unpredictable, the traditional sort-and-send triage technique only leads to concentrated patients waiting and treatment delays; (5) Chest pain monitoring model is used to schedule patient service and predict heart attack states to reduce door-to-balloon time in catheterization laboratories; (6) Risk score is estimated using exponential values computed from each group. The proposed model generates risk scores to predict clinical deterioration efficiently and accurately. Features are extracted in temporal and frequency domains, while line length is calculated to extract signal patterns; (7) Medical supply-demand balance play a very significant role in the efficient management of hospital emergency response. An AI model is addressed to allocate medical supplies to hospitals efficiently, responding to the peaks of medical need, with the subsequent intention to mitigate its impact on public health; (8) A novel AI model to evaluate the severity of mass casualty incidents in the very early stages, suggests that efficient reallocation of available medical and rescue resources might have high effects of disaster reduction; (9) A comprehensive AI-based algorithm to assist on mass casualty assessment in the very early stages. The proposal automatically assesses the presence of a mass casualty incident as well as its evolution over time, providing situational awareness data for policy and decision makers to drive the crisis response and alleviate its consequences.

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