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A Novel Large-Capacity Supine Casualty Transport Vehicle: Design, Validation and Application for Mass Casualty Evacuation

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Abstract

Background

Conventional supine casualty evacuation vehicles are characterized by limited transport capacity, and patient loading and unloading fully depend on manual lifting. This operation mode is time-consuming and labor-intensive, and is inadequate to address the demands of mass casualty scenarios.

Methods

This study presents a novel large-capacity supine casualty transport vehicle. The vehicle is designed to accommodate and evacuate 14 supine casualties in a single batch. Patient loading and unloading are achieved via a fully controllable electromechanical transmission system. The system integrates real-time vital sign monitoring and bidirectional secure data connectivity with base hospitals, enabling immediate emergency intervention in the event of acute clinical decompensation. The system architecture consists of four core modular components: a base transport platform, an electric conveyor subsystem for supine casualties, a central integrated vital sign monitoring system, and an on-board emergency care module. Field validation was performed to verify the practical performance of the system.

Results

The field validation confirmed that the developed system can effectively enhance casualty evacuation efficiency and reduce manpower requirements during the evacuation process.

Conclusions

The application of this large-capacity supine casualty transport system can provide significant advantages in scenarios requiring mass supine casualty transport, and has practical application value for mass casualty incident response.

Background

Sudden natural disasters (e.g., earthquakes, tsunamis, debris flows) generate a surge of traumatic casualties in a compressed timeframe, necessitating urgent triage and rapid evacuation [1]. This challenge is exacerbated in modern high-intensity warfare: as conflict duration increases, casualty volumes rise exponentially, imposing overwhelming burdens on medical evacuation and treatment systems [2] [3] [4].

Following initial resuscitation, emergency care, and damage control surgery, hemodynamically stable frontline casualties are evacuated to rear base hospitals for definitive specialized treatment and

subsequent rehabilitation. Evacuation modalities include medical trains, medical aircraft, medical transport vessels and land vehicles (Fig. 1). Beyond direct land transport, vehicular shuttle services are indispensable for connecting casualty collection points (CCPs) to transportation hubs (railway stations, airports, seaports) and for subsequent transfer from these hubs to definitive care facilities. Ambulatory casualties may be transported using a wide range of vehicles; in contrast, supine casualties—particularly those with spinal, pelvic, or multiple traumatic injuries—remain almost exclusively dependent on military transport trucks and ambulances for land-based evacuation and shuttle services [5].

In wartime scenarios or following catastrophic natural disasters, evacuating mass supine casualties using conventional ambulances is associated with excessive manpower and vehicle resource utilization, low throughput, and repeated mobilization of emergency medical services (EMS) assets, which can disrupt routine pre-hospital care. Although military transport trucks offer higher carrying capacity, they are plagued by labor-intensive manual loading/unloading, prolonged turnaround times, inadequate patient comfort, lack of continuous vital sign monitoring, and inability to provide timely intervention for in-transit clinical decompensation [6]. Accordingly, there is a critical unmet need for innovative land-based transport systems that can deliver efficient, comfortable, and safe evacuation for mass supine casualties.

We developed a novel, large-capacity transport vehicle to meet the urgent need for mass supine casualty evacuation in disasters and high-intensity combat. The system adapts advanced civilian mechanized and intelligent conveyor technologies for medical use. The system efficiently evacuates up to 14 supine casualties per mission, with fully mechanized electrically powered loading/unloading. Continuous real-time vital sign monitoring is provided, with secure data transmission to base hospital command centers, facilitating immediate on-board emergency care and remote telemedicine support during in-transit clinical events. The system is suitable for rapid, comfortable shuttle transport of mass supine casualties at diverse CCPs (railway stations, seaports, airports), significantly reducing manual labor requirements while enhancing evacuation throughput, patient safety, and comfort.

Methods

Design and System Architecture

The large-capacity supine casualty transport vehicle is a modular system comprising four core integrated components (Fig. 2). The base transport platform is derived from a front-engine civilian passenger bus, but can also be retrofitted onto heavy-duty trucks or shipping containers to accommodate diverse operational requirements, providing structural support, propulsion, and electrical power for the remaining three subsystems (Fig. 2A). The electric conveyor subsystem facilitates automated patient loading, unloading, and in-transit positioning, with a maximum design capacity of 14 supine casualties. Fully controllable electromechanical conveyance eliminates manual lifting, thereby improving evacuation efficiency and reducing occupational musculoskeletal strain on medical personnel (Fig. 2B). The central vital sign integration subsystem provides continuous real-time monitoring of

patient vital signs and visual surveillance via high-definition cameras (Fig. 2C). The on-board emergency care module is equipped with a full complement of emergency medications, disposable supplies, and advanced life support equipment to ensure optimal patient safety during evacuation (Fig. 2D).

Core System Components and Technical Specifications

Base Transport Platform

The platform requires a front-engine configuration to accommodate a fully flat interior floor spanning the entire length of the vehicle and a rear-loading door design. The interior floor height is specified to be no more than 1.3m above ground level to facilitate seamless docking with external transfer platforms. The minimum interior dimensions are 10.0m in length, 2.4m in width, and 3.0m in height (Fig. 3). All vehicles must meet national motor vehicle safety standards for propulsion, braking, and roadworthiness.

Electric Conveyor Subsystem for Supine Casualties

The subsystem features a dual-layer conveyor line integrated with a vertical elevator mechanism, with each layer capable of holding 7 patients immobilized on dedicated orthopedic loading pallets to maintain spinal alignment during transport. Both the conveyor lines and elevator support bidirectional operation at a constant speed of 0.2m/s, calibrated to ensure patient stability and operator safety. A global one-touch emergency stop system is installed for immediate halting of all operations in case of safety hazards. The lower conveyor line incorporates an electric telescopic extension that enables seamless docking with external patient transfer platforms and fully retracts into the vehicle interior during transit (Fig. 4). The subsystem is powered by an independent lithium-ion battery pack, which provides sufficient energy for a minimum of 5 full-load loading/unloading cycles (one cycle = complete forward loading and reverse unloading) when fully charged.

Central Integrated Vital Sign Monitoring System

Each patient is monitored using a portable multi-parameter monitor that continuously acquires heart rate, non-invasive blood pressure, oxygen saturation, and respiratory rate. Eight high-definition cameras are strategically positioned throughout the vehicle to provide real-time visual monitoring of patient posture and facial expressions. All physiological data and video feeds are integrated into a central touchscreen display located in the dedicated medical staff workstation, and securely transmitted to the combat trauma care command center at the receiving base hospital via 5G wireless networks. In the event of acute clinical decompensation, on-board medical staff can initiate immediate life support interventions while accessing real-time telemedicine consultation from remote specialists.

On-Board Emergency Care Module

Standardized electrical outlets and central oxygen supply ports are installed at each patient position on both the upper and lower conveyor layers to provide uninterrupted oxygen therapy and electrical power for patient monitoring devices. The module contains a comprehensive inventory of emergency medications, disposable medical supplies, and advanced life support equipment, including endotracheal intubation trays, portable mechanical ventilators, electric suction devices, and integrated defibrillator-monitors. This enables on-board medical personnel to manage a wide range of acute medical emergencies, including cardiac arrest, respiratory failure, hemorrhagic shock and other medical conditions requiring emergency management.

Field Validation and Performance Evaluation

The performance of the large-capacity supine casualty transport vehicle was evaluated during a large-scale joint military-civilian emergency drill focused on mass casualty evacuation, where it demonstrated significant advantages in speed, efficiency, and labor reduction, providing robust validation of its clinical effectiveness and operational practicality. During the drill, the system was used for the shuttle transport of more than 300 supine casualties to a medical train staging area. It significantly outperformed conventional ambulance-based transport in terms of total vehicle requirements, manpower utilization, and total evacuation time, confirming that the transport vehicle and its integrated information system meet all pre-specified design and tactical performance criteria. In comparison with conventional ambulances and military transport trucks, the novel transport vehicle offers multiple advantages while also having certain limitations (Table 1). These findings provide valuable insights for advancing the modernization and evidence-based development of military and civilian medical evacuation equipment.

Table 1
Performance comparison between the novel transport vehicle and conventional ambulances or military transport trucks

Parameter	Novel Large-Capacity Transport Vehicle	Conventional Ambulances (Civilian/Military)	Traditional Military Transport Trucks
Evacuation Capacity (Supine Patients)	14 casualties per mission	1 (civilian ICU) / up to 2–4 (military armored)	10–20 casualties (unstructured)
Loading/Unloading Method	Fully mechanized electric conveyor system with one-touch control	100% manual lifting and carrying	100% manual lifting and carrying
Manpower Requirement per Mission	2–3 medical personnel (no manual lifting)	4–6 personnel per casualty (for loading/unloading)	8–12 personnel for full load
Evacuation Throughput	High (fast turnaround, high single-vehicle capacity)	Very low (small capacity, long loading times)	Medium (high capacity but extremely long loading/unloading times)
Off-Road Mobility	Good (tested bus platform); Excellent potential (with heavy-duty truck chassis)	Fair (civilian); Excellent (military armored)	Excellent
Operational Range	Equivalent to base platform (bus/truck); Independent battery for 5 + full loading/unloading cycles	Medium (civilian); Long (military)	Very long
Vital Sign Monitoring	Continuous real-time monitoring for all 14 patients; 5G data transmission to base hospital	Limited to 1–2 patients only	None
In-Transit Emergency Care	Comprehensive advanced life support with integrated telemedicine	Basic to advanced life support for 1–2 patients	None
Patient Safety Features	Orthopedic loading pallets (spinal alignment); global emergency stop; secure patient restraint	Standard stretcher with restraints	No dedicated restraints; no injury prevention features
Patient Comfort	High (stable conveyance, dedicated patient positions)	Medium (standard ambulance stretcher)	Very low (typically transported on floor or simple cots)

Parameter	Novel Large-Capacity Transport Vehicle	Conventional Ambulances (Civilian/Military)	Traditional Military Transport Trucks
Risk of Secondary Injury	Very low	Very low	High (manual handling, lack of immobilization)

By integrating advanced civilian intelligent manufacturing, mechanized conveyor technology, and medical information systems, the vehicle represents a significant advancement in supine casualty evacuation, offering a solution designed for labor efficiency, high throughput, and operational simplicity. It addresses the key limitations of conventional evacuation systems, including excessive resource consumption, low throughput, and limited operational sustainability. It not only improves evacuation efficiency but also accelerates the integration of intelligent, mechanized, and information technologies into the entire continuum of supine casualty evacuation and care, with the goal of improving survival and functional outcomes for trauma casualties requiring supine transport.

Discussion

Since the beginning of the 21st century, the global incidence of catastrophic earthquakes has increased significantly, resulting in unprecedented loss of life and property. Single earthquake events have caused more than 300,000 combined fatalities and injuries. It is estimated that at least 584 destructive earthquakes have occurred worldwide since 2000, resulting in approximately 900,000 deaths and millions of non-fatal injuries. Traumatic fractures are the most prevalent injury type in these events, encompassing long-bone fractures (femur, tibia, fibula), spinal fractures, and pelvic fractures [1] [7].

The 8.0-magnitude Wenchuan earthquake that struck Sichuan Province, China, on May 12, 2008, resulted in 69,227 confirmed deaths, 17,923 missing persons, and 374,643 non-fatal injuries, including more than 10,000 severely injured casualties. Trauma was the overwhelming cause of morbidity, with fractures comprising 74% of all reported injuries [8]. The 7.1-magnitude Yushu earthquake in Qinghai Province on April 14, 2010, caused 2,698 deaths, 270 missing persons, and 11,135 injuries, including 3,143 severe injuries, with fractures accounting for 58.4% of all injuries [1]. In the 2023 Turkey-Syria earthquakes, 65% of hospitalized trauma patients presented with fractures, with the tibia/fibula (27%), femur (17%), and foot/ankle (16%) being the most frequently affected anatomical sites [9].

Contemporary armed conflicts have similarly resulted in catastrophic numbers of trauma casualties. Notably, the ongoing Russia-Ukraine conflict (since February 2022) has caused hundreds of thousands of casualties on both sides. Blast injuries are the predominant mechanism of trauma, with extremity injuries being most common, and a disproportionately high prevalence of polytrauma and combined injuries [10]. Collectively, these data demonstrate that both natural disasters and armed conflicts generate overwhelming numbers of trauma casualties who require supine transport due to spinal, pelvic, or multiple injuries. Inadequate or inappropriate evacuation systems inevitably result in delayed definitive care, increased morbidity, and higher mortality rates [11].

Currently, land-based evacuation and shuttle transport between CCPs and major transportation hubs remain heavily reliant on conventional ambulances. Most civilian intensive care ambulances are limited to transporting 1 supine casualty per trip, while military armored ambulances typically accommodate up to 2–4; however, all conventional ambulances require manual lifting and carrying for patient loading and unloading. This limited capacity is rapidly overwhelmed during mass casualty incidents (MCIs). Furthermore, the acute shortage of medical personnel involved in evacuation is also a critical consideration when there is a demand for mass casualty transport [12] [13]. In the Russia-Ukraine conflict, air medical evacuation has been severely restricted due to the high risk of aircraft loss from contested air superiority, dense integrated air defense systems, and widespread unmanned aerial vehicle (UAV) threats. Consequently, both sides have become increasingly dependent on ground evacuation, which is hampered by critical shortages of armored medical evacuation vehicles. As of 2025, the Russian military's armored ambulance fleet only meets 86% of operational requirements, leaving a significant gap in evacuation capacity [14]. These real-world challenges underscore the urgent need for innovative, high-capacity ground transport systems that can deliver efficient, safe, and comfortable evacuation for mass supine casualties in both military and civilian emergency scenarios.

In this study, we present the first comprehensive report of a novel large-capacity supine casualty transport vehicle, which fully automates the entire patient transfer workflow—including pallet loading, horizontal conveyance, vertical lifting, and empty pallet return—through integrated telescopic conveyor, automatic pallet transfer, and electric elevator systems. The system enables rapid, high-throughput shuttle transport of mass supine casualties at various CCPs and transportation hubs, combining high transport capacity, superior patient comfort, labor-free automated loading/unloading, and integrated real-time monitoring and emergency care capabilities. Its deployment is expected to significantly improve evacuation throughput, reduce the risk of secondary injury during transport, and enhance overall patient comfort and safety [15]. This dual-use system fulfills the strategic goal of "peacetime emergency response and wartime combat readiness", with broad application prospects in both civilian disaster relief and military medical support operations.

Lastly, the vehicle described in this study also has certain limitations. The field validation was conducted in a single, large-scale emergency drill. Real-world performance may differ under extreme weather, hostile fire, or chaotic MCI scenes. The system's reliance on a front-engine, low-floor chassis may limit off-road mobility, a limitation partially addressed by the potential for truck chassis retrofitting, which was not tested yet.

Abbreviations

EMS
Emergency medical services
CCPs
Casualty collection points
5G

5th generation mobile communication technology
MCI/MCIs
Mass casualty incident/incidents
UAV
Unmanned aerial vehicle.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Author Contribution

DY conceived and designed the study. YW wrote the paper. YZ, ZF, ZX and XH contributed to technical or material support. All authors read and approved the final manuscript.

Availability of data and materials

All data generated or analysed during this study are included in this published article.

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Figures

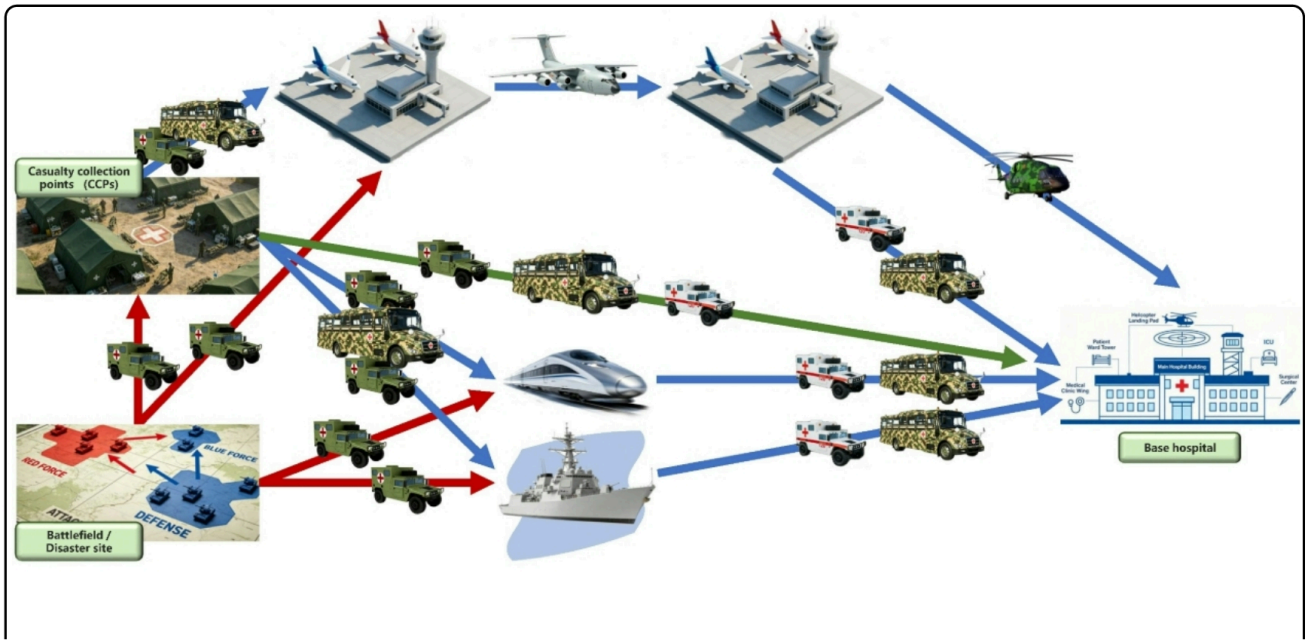


Figure 1

Schematic diagram of the mass casualty evacuation process. Currently, the main modalities for mass casualty evacuation include medical trains, medical aircraft, medical transport vessels, and land vehicles. Red arrows indicate primary evacuation from combat/disaster scenes (most commonly performed by ambulances); blue arrows indicate evacuation from CCPs to subsequent transportation hubs and further transfer (with diverse modalities but often low efficiency); green arrows indicate direct land evacuation from CCPs to base hospitals (with fewer steps and relatively high efficiency).

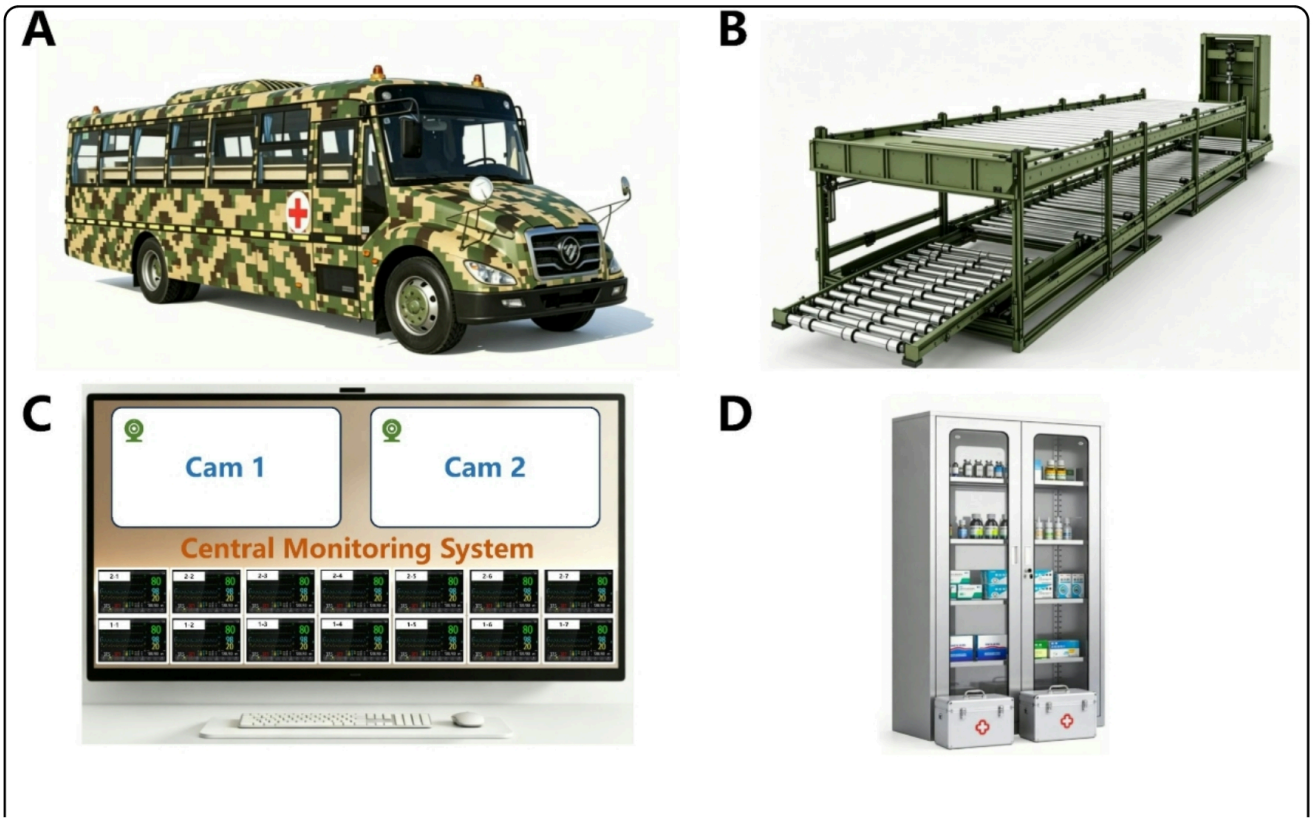


Figure 2

Overall system architecture of the novel large-capacity supine casualty transport vehicle. (A) Base transport platform: adaptable to buses, trucks, or containers, providing structural support, propulsion, and power. **(B)** Electric conveyor subsystem: automates loading/unloading for 14 supine casualties, eliminating manual lifting. **(C)** Central vital sign subsystem: provides continuous real-time monitoring and HD surveillance. **(D)** On-board emergency module: equipped with medications and life support equipment for patient safety.

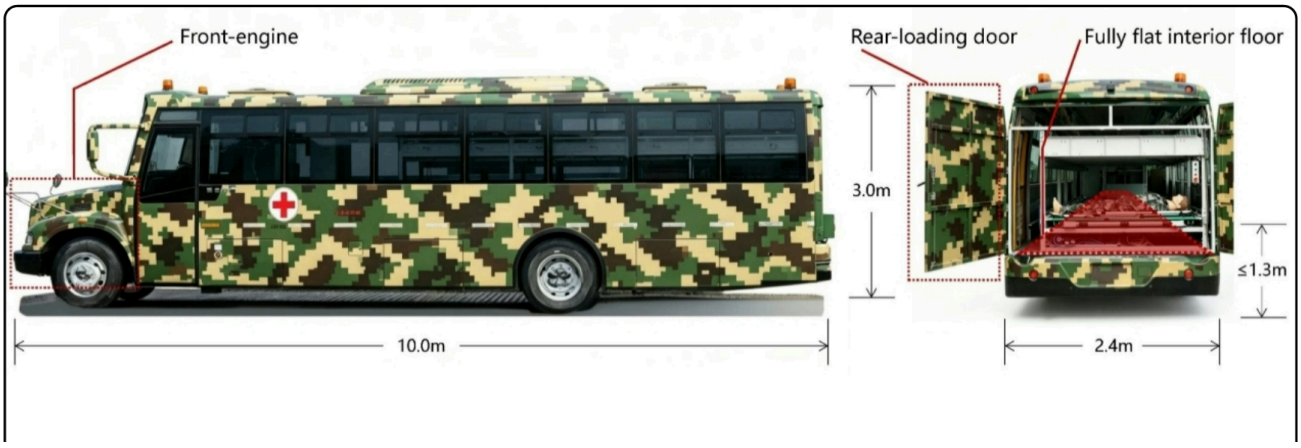


Figure 3

Main structure of the novel large-capacity supine casualty transport vehicle. (A) Actual vehicle side view; **(B)** Actual vehicle rear view. The platform adopts a front-engine configuration to enable a fully flat interior floor and rear-loading door design. The interior floor height is limited to≤1.3m above ground level for seamless docking with external transfer platforms. The minimum interior dimensions are 10.0m (length)×2.4m(width)×3.0m(height).

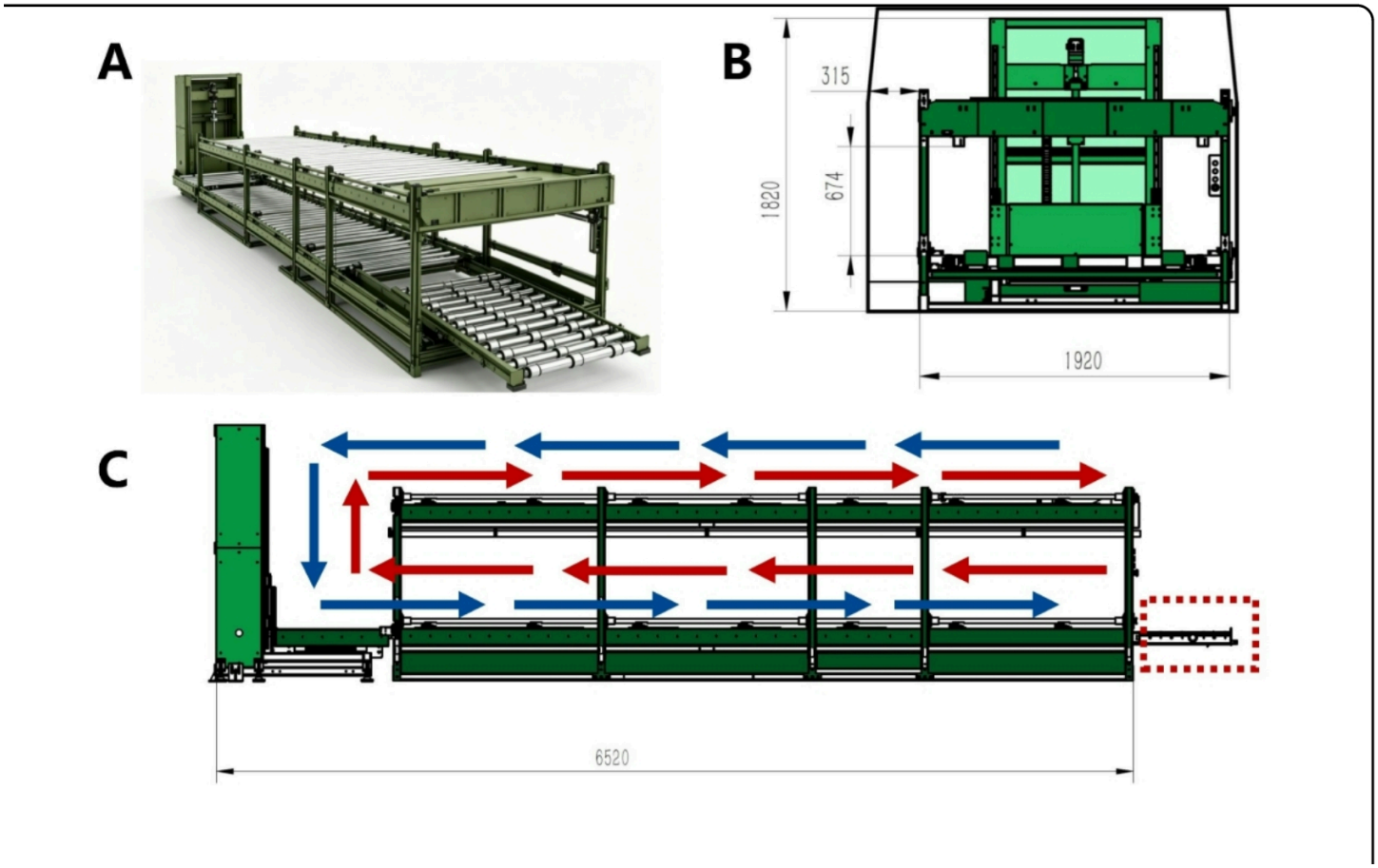


Figure 4

Schematic diagram of the electric conveyor subsystem for supine casualties. (A) Gross view; **(B)** Front view; **(C)** Side view. The subsystem consists of a dual-layer conveyor line integrated with a vertical elevator mechanism, with each layer accommodating 7 patients on dedicated orthopedic loading pallets to maintain spinal alignment. It supports bidirectional operation at 0.2m/s and is equipped with a global one-touch emergency stop system. The lower conveyor line features an electric telescopic extension for seamless docking with external transfer platforms (red dashed box); red arrows show the flow path of casualties being loaded onto the transport vehicle, while blue arrows show the flow path of casualties being unloaded from the vehicle. All dimensions in mm.