

Construction of a Safety Prevention and Control System for Inter-hospital Transport of Critically Ill Patients in a Multi-campus Hospital Based on the Reason Model

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Abstract: The aim is to evaluate a Reason Swiss-Cheese-model-based multi-layer safety system for inter-campus transport of critically ill patients in multi-campus hospitals lacking dedicated intelligent transport dispatching platforms. This controlled study enrolled 242 patients receiving conventional transport (control group, Oct-Dec 2025) and 260 patients receiving Reason-model-guided interventions (observation group, Jan-Mar 2026). Interventions covered cross-department teamwork, a five-dimensional risk-assessment scale, emergency protocols, hierarchical training, joint drills and an RCA-driven improvement closed-loop via a lightweight QR-code-enabled online form-collection module. Baseline profiles, adverse-event rate, handover error rate, transport time expenditure, staff safety-cognition scores and patient satisfaction were compared. Groups were well-matched at baseline ($P > 0.05$). The observation group showed significantly lower adverse-event (3.46% vs 16.12%) and handover-omission rates (2.31% vs 14.46%), shortened transport-related durations, elevated staff safety-cognition scores (82.74 ± 3.96 vs 73.52 ± 5.17), and higher patient satisfaction (94.62% vs 78.10%) ($P < 0.05$ for all). This low-cost Reason-model-based safety system reduces transport risks and improves clinical outcomes. It is feasible and generalizable for grassroots multi-campus hospitals with limited IT resources.

Keywords: reason model; critically ill patients; inter-hospital transport; multi-hospital campus; patient safety

1. Introduction

With the expansion of multi-campus tertiary hospitals in China, cross-campus transport of critically ill patients has grown. Outside ward-based monitoring, transported patients face multiple risks including road vibration, disjointed inter-campus information, inconsistent emergency equipment standards and insufficient inter-departmental collaboration, potentially leading to clinical deterioration, catheter dislodgement and defective handover. Accordingly, cross-campus transport represents a high-risk link in healthcare risk management[1].

Conventional transport management emphasizes individual staff performance and post-incident accountability, yet ignores systemic risks involving organization, supervision and resource allocation[2]. The Reason Swiss-Cheese model posits that medical adverse events stem from sequential breakdowns of multi-layer safety barriers and highlights proactive systemic risk control, which fits the multi-party, cross-department workflows of multi-campus transport[3-5].

Existing well-established transport safety strategies mostly depend on costly digital dispatching systems. Restricted by budget and information technology constraints, numerous multi-campus hospitals cannot implement standardized low-cost protocols[6-8]. Moreover, heavy reliance on information technology in international guidelines impedes grassroots-level application[9]. Targeting local gaps such as absent risk-assessment tools, verbal handover practices and poor quality-control traceability, this study established a Reason-model-driven transport safety system based on lightweight online form modules, instead of fully-functional dispatching platforms, to offer risk-management evidence for multi-campus hospitals with limited resources.

2. Materials and Methods

2.1 Study Participants

This study enrolled 502 critically ill patients undergoing cross-campus inter-ward transport at our hospital between October 2025 and March 2026. Inclusion criteria: critically ill patients from the emergency department or ICU requiring cross-campus transport, escorted by dedicated medical personnel, with complete medical and transport documentation. Exclusion criteria: short-distance intra-hospital transport for examinations, voluntary discharge with cancelled transport, and patients diverted to third-party hospitals during transfer.

The control group comprised 242 patients managed with routine transport protocols (October-December 2025). Following December 2025 preparatory work (staff training, form development, policy roll-out), 260 patients transported

from January-March 2026 formed the observation group. This was an in-hospital quality-improvement project; informed consent was obtained from patients or proxies prior to transfer, satisfying ethical standards[10].

Baseline characteristics including age (56.82 ± 14.37 vs 55.47 ± 15.02 years), sex, source departments, critical-illness risk stratification, transport distance (14.63 ± 4.27 vs 14.28 ± 4.15 km), transport timing (day-/night-time), and count of indwelling invasive catheters (2.13 ± 1.25 vs 2.08 ± 1.19) were comparable between groups ($P \geq 0.05$).

2.2 Transport Protocols

2.2.1 Control Group: Conventional Transport Protocol

Physicians assessed patients and arranged ambulances. Emergency equipment and medications were prepared empirically. Cross-campus handover mainly adopted the Emergency Department's self-designed paper-based handover form[11].

2.2.2 Observation Group: Safety-control System Based on Reason Four-layer Defensive Barriers

Four defensive layers were established: organizational-level defense, routine-supervision defense, pre-emptive risk-intervention defense, and on-site standardized-operation defense. A lightweight online form-collection module allowed QR-code-based mobile data entry with back-end export. Six intervention components were implemented.

2.2.2.1 Organizational-framework establishment

A cross-department transport-safety task force was chaired by the vice-hospital director for medical affairs, with representatives from Medical Affairs, Nursing Department, Emergency Department, branch-campus nursing units and the transport fleet. Sub-groups handled protocol formulation, training-drill organization, data management and quality-control inspection. Monthly review meetings were held. Two institutional documents were issued: Management Regulations for Inter-campus Transport of Critically Ill Patients and Four-level Emergency Response Plan for Transport-related Incidents. A non-punitive adverse-event-reporting policy encouraged near-miss reporting with organizational-procedural corrective actions[12]. All transport requests and dispatching assignments were recorded for full-process traceability.

2.2.2.2 Three-tier quality-control and RCA-driven supervision

Before transport, accompanying nurses completed the online risk-assessment scale via QR-code scanning. The quality-control team monthly audited scale completeness and filled out inspection forms. Root-cause analysis (RCA) was completed within seven days for adverse events and high-risk near-miss events; corrective-action outcomes were archived, and unresolved items were added to the next-month inspection agenda[5]. Quarterly multi-campus on-site joint emergency drills were performed.

2.2.2.3 Pre-emptive stratified risk intervention

① A five-dimensional risk-assessment scale was developed via literature review and two-round Delphi expert consultation, covering patient clinical status, transport environment, equipment-medications, inter-team communication and organizational workflow. Items were scored 0-2 for risk stratification; dual-provider confirmation was mandatory before transport. High-risk patients required one-physician-one-nurse escort plus full backup emergency equipment. The scale had $CVI = 0.89$ and $ICC = 0.82$ [7]. ② The ISBAR structured handover form documented patient information, interventions, catheter risks, monitoring priorities and special medications to reduce information-omission errors[13-15]. ③ Stratified training covered Reason-model and RCA theory for administrators; scale completion, verification workflows and emergency management for transport staff; and transport-cooperation plus route-planning for drivers and dispatchers.

2.2.2.4 Four-level standardized emergency-response protocol

Response workflows targeted four frequent hazards: equipment failure, acute patient deterioration, road-traffic delays, and cross-campus-communication breakdown. The dispatch centre and receiving department were simultaneously notified during emergencies; all management steps were documented and included in monthly RCA reviews[1].

2.2.2.5 PDCA-cycle continuous quality improvement

Monthly aggregation of quality-control and RCA-correction outputs guided dynamic revision of risk-assessment scales, handover forms, institutional regulations and training materials to reinforce safety barriers.

2.3 Outcome Measures

① Transport-safety outcomes: overall incidence of transport-related adverse events (clinical deterioration, catheter dislodgement, equipment malfunction, patient injury); handover-omission-error rate. ② Transport-efficiency outcomes: pre-transport-preparation duration; inter-campus-handover time consumption. ③ Personnel competency: self-developed transport-safety-cognition questionnaire (risk identification, protocol implementation, emergency management; $CVI = 0.86$,

test-retest reliability = 0.81), administered pre- and post-intervention. ④ Patient satisfaction: post-transport questionnaire; score ≥ 90 defined as satisfied; overall satisfaction rate calculated.

2.4 Statistical Analysis

SPSS 26.0 was used for analyses. Continuous variables were reported as mean $\pm$ SD; independent-samples t-test for between-group comparisons; paired t-test for pre-post-intervention comparisons. Categorical variables were described as n (%), compared using χ^2 test. $P < 0.05$ was defined as statistical significance.

3. Results

3.1 Comparison of transport-safety indicators between the two groups

The observation group demonstrated significantly lower rates of adverse events and handover-omission errors than the control group ($P < 0.001$) (Table 1).

Table 1. Comparative Analysis of Adverse Transport Events and Handover Errors Between the Two Groups

Group	Cases (n)	Adverse events [n (%)]	Handover information omission [n (%)]
Control group	242	39 (16.12)	35 (14.46)
Observation group	260	9 (3.46)	6 (2.31)
χ^2 value	–	23.471	22.158
p value	–	<0.001	<0.001

3.2 Comparison of transport-efficiency indicators between the two groups

Pre-transport-preparation duration and inter-campus-handover time were significantly shorter in the observation group ($P < 0.001$) (Table 2).

Table 2. Comparison of transport efficiency indicators between the two groups

Group	Pre-transport preparation time	Inter-hospital handover time
Control group	20.41 $\pm$ 3.52	11.86 $\pm$ 2.43
Observation group	13.27 $\pm$ 2.85	6.14 $\pm$ 1.72
t value	24.136	29.752
p value	<0.001	<0.001

3.3 Safety-cognition scores among healthcare workers before and after intervention

Pre-intervention score = 73.52 $\pm$ 5.17; post-intervention score = 82.74 $\pm$ 3.96; paired t = 18.359, $P < 0.001$. Risk-identification, protocol-implementation and emergency-management capabilities improved markedly after intervention.

3.4 Patient satisfaction with transport

Control-group satisfaction = 78.10% (189/242); observation-group satisfaction = 94.62% (246/260); $\chi^2 = 32.615$, $P < 0.001$. Reduced anxiety among patients and surrogates and improved healthcare experience were observed in the observation group.

4. Discussion

4.1 Advantages of the Reason model in multi-campus critically-ill-patient transport

Conventional transport management focuses on individual operator errors and post-hoc correction and cannot resolve systemic deficiencies including poor cross-campus collaboration, unequal resource allocation and inconsistent standards[2]. The Reason model shifts away from individual-blame management and achieves multi-layer proactive risk blocking, matching the complexity of multi-campus transport[3–4]. Most existing transport-safety solutions rely on high-cost large-scale digital dispatching platforms difficult for grassroots hospitals to adopt[9]. This study applied a low-cost lightweight online form-collection module without dedicated transport-dispatching software, expanding Reason-model applicability for IT-limited medical institutions.

4.2 Five-dimensional risk-assessment scale for combined physiological-systemic risk identification

Traditional transport-risk-assessment tools mainly focus on patients' physiological indicators while neglecting

managerial risks such as dispatching communication, equipment endurance and organizational workflows[11]. Our five-dimensional scale captures both patient-centred physiological risks and systemic-management hazards. Risk-stratified allocation of staff and emergency equipment reduces adverse-event origins. The scale is simple to complete and shows good clinical acceptability.

4.3 Standardized documentation plus RCA review constructing a full quality-control closed loop

Without dedicated transport-business systems, transport workflows may suffer omitted steps, missing handover evidence and difficult adverse-event tracing[12]. In our study, the lightweight online-form module recorded full-process transport information with mandatory dual-person confirmation. Combined with three-tier quality-control inspection and seven-day RCA reviews, a closed-loop workflow (“risk assessment-standardized implementation-inspection-root-cause analysis-process optimization”) compensated for IT-related supervisory gaps[16-17]. Replacing verbal handover, ISBAR structured handover reduced information-transmission errors, consistent with our study results[13-14].

4.4 Practical strengths of the proposed prevention-and-control system

This system has three major merits. First, implementation costs are low, requiring only deployment of the lightweight online form-collection module without large-scale hardware-software investment. Second, it does not require an integrated intelligent transport-dispatching platform and suits multi-campus hospitals with under-developed IT infrastructure. Third, it covers the full workflow: organizational management, risk assessment, on-site operation, emergency response, and continuous quality improvement, granting high replicability[16].

4.5 Study limitations and future perspectives

This is a single-centre controlled study, limiting generalizability. Self-developed assessment tools have only undergone small-sample single-centre reliability-validity testing, lacking multi-centre evidence. Follow-up lasted only six months; long-term quality-control data are unavailable to judge whether procedural adherence decays over time. Future work will expand multi-centre samples to validate scale psychometric properties; connect the form-collection module to hospital business systems when IT resources permit; extend follow-up duration; and formulate special risk-mitigation strategies for extremely-high-risk transport patients.

5. Conclusions

For multi-campus hospitals without operational intelligent transport-dispatching platforms, a multi-layer safety-prevention-and-control system for inter-campus critically-ill-patient transport can be built based on the Reason Swiss-Cheese model, via establishing cross-department transport-safety organizations, deploying the five-dimensional risk-assessment scale, and constructing an RCA-PDCA closed-loop workflow. This system identifies full-chain transport risks, lowers adverse-event and handover-error rates, shortens transport-related time expenditure, improves staff emergency competency and enhances patient healthcare experience. Implemented through the lightweight online form-collection module, this low-investment, highly operable solution can serve as a reference for multi-campus hospitals without intelligent transport-dispatching systems.

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