ORIGINAL ARTICLE

The impact of receiving hospitals on the management and outcomes of injured patients in traffic accidents causing mass casualty incidents

Neslihan Ergun Suzer,[1] Gülbin Aydoğdu Umaç,[2] Sarper Yilmaz[3]

[1]Department of Emergency Medicine, University of Health Sciences, Kocaeli Darıca Farabi Training and Research Hospital, Kocaeli-*Türkiye*

[2]Department of Emergency Medicine, İzmir City Hospital, İzmir-*Türkiye*

[3]Department of Emergency Medicine, University of Health Sciences, Kartal Dr. Lutfi Kirdar City Hospital, İstanbul-*Türkiye*

ABSTRACT

BACKGROUND: The medical management of mass casualty incidents (MCIs) requires the strategic application of triage methods from the prehospital phase to patient discharge, ensuring the simultaneous and effective treatment of multiple injured individuals. This study aims to examine the transport processes of trauma patients to tertiary hospitals following traffic accidents that result in MCIs, and to evaluate the impact of these processes on patient outcomes.

METHODS: This retrospective study investigates the prehospital, inter-hospital transfer, and in-hospital processes of trauma patients injured in traffic accidents causing MCIs over a five-year period within a single province. A comprehensive analysis was conducted from multiple perspectives. A supervised artificial neural network model was employed to predict patient mortality, selected for its ability to identify complex, non-linear patterns in high-dimensional clinical data.

RESULTS: A total of 606 patients were included in the study. Of these, 212 (35.0%) underwent secondary transfer to a tertiary hospital, while 394 (65.0%) were directly admitted to a tertiary hospital following traffic accidents causing MCIs. The secondary transfer group experienced longer prehospital times (106.0 vs. 74.7 minutes, p<0.001) and received fewer correct triage decisions (75.0% vs. 92.4%, p<0.001). They also had higher rates of blood transfusion (60.8% vs. 38.8%, p<0.001), vasopressor use (43.9% vs. 22.1%, p<0.001), massive transfusion (36.8% vs. 19.0%, p<0.001), and mechanical ventilation (62.3% vs. 39.8%, p<0.001). In-hospital mortality was higher in the secondary transfer group (20.3%) compared to the direct admission group (8.1%), with an unadjusted odds ratio (OR) of 0.348 (95% confidence interval [CI]: 0.205-0.585, p<0.001). The trained neural network model demonstrated excellent predictive performance for mortality (Training area under the curve [AUC]: 0.947; 95% CI: 0.928-0.966, Testing AUC: 0.841; 95% CI: 0.782-0.899). A stratified analysis examining the impact of correct vs. incorrect triage decisions on mortality revealed that among correctly triaged patients, mortality was significantly higher in the secondary transfer group (22.6%) compared to direct tertiary admission (8.0%), with an OR of 3.38 (95% CI: 1.99-5.78, p<0.001). Overall, patients who underwent secondary transfer had a higher mortality risk compared to direct admissions (OR: 2.35; 95% CI: 1.12-5.10, p=0.0265). A direct comparison between all correctly and incorrectly triaged patients showed that correct triage significantly reduced mortality risk (OR: 4.19; 95% CI: 2.15-8.48, p<0.001).

CONCLUSION: In the management of trauma patients following traffic accidents causing MCIs, transferring patients to hospitals that lack adequate trauma care increases mortality. Secondary transport negatively affects hemodynamic stability and leads to a greater need for blood transfusion, vasopressor support, massive transfusion, and mechanical ventilation.

Keywords: Mass casualty incidents; trauma; transport; prehospital; hospital.

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Address for correspondence: Sarper Yilmaz

Department of Emergency Medicine, University of Health Sciences, Kartal Dr. Lutfi Kirdar City Hospital, İstanbul, Türkiye

E-mail: sarperyilmaz08@gmail.com

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INTRODUCTION

Injuries account for approximately 4.4 million deaths globally each year, with road traffic accidents being a leading cause.[1-3] While most current injury control strategies focus on primary prevention (i.e., preventing injuries from occurring or minimizing their severity), once an incident has occurred, secondary prevention strategies (such as providing adequate medical intervention to minimize harm after injury) become essential. This highlights the importance of trauma guidelines, which emphasize implementing effective steps and processes to reduce mortality and morbidity from the point of injury to the patient's discharge from the healthcare system.[4]

As the number of injured individuals increases in an incident, local resources may become overwhelmed, prompting its classification as a mass casualty incident (MCI).[5] The World Health Organization defines MCIs as events that produce more casualties than local systems can manage using standard procedures.[6] However, due to variations in national systems and response capabilities, the definition of an MCI remains inconsistent, leading to ongoing debate in the literature.[7] The numerous challenges posed by working in disaster and MCI settings affect every stage and level of care, from the point of injury to the evacuation and treatment of the injured patient at a modern tertiary care center.[8] The management of trauma patients (from the scene of the incident to the healthcare facility and through to advanced treatment) is often affected by the inherent challenges of MCIs. Therefore, early identification of an incident as an MCI and the establishment of an activation system are fundamental strategies. Moreover, it is essential that all healthcare providers involved in post-MCI care to understand how these limitations critically impact trauma management, underscoring the need for further research to mitigate these disadvantages.

Despite the World Health Organization's (WHO) global guidelines in recent years, many countries, including several in Europe, Japan, and the United States, have developed distinct protocols and activation systems for MCIs. However, the designation of an incident as an MCI and the activation of corresponding response mechanisms are still governed by local regulations.[5,9] In Türkiye, recognizing this need, the Health Disaster and Coordination Center (SAKOM) was established within the healthcare system to manage MCIs and disasters. Specific criteria were introduced to determine which incidents require intervention by this organization, thereby providing an indirect framework for defining MCIs within the Turkish healthcare system.[10]

Although the triage criteria for transferring trauma patients to more advanced centers are outlined in the Advanced Trauma Life Support (ATLS) guidelines, in MCI situations, the management of trauma patients is shaped by the unique dynamics of such incidents.[11] Accurate assessment and stabilization of trauma patients are crucial even outside of MCI contexts, as it has long been established that 91% of preventable trauma deaths occur during the initial phase of resuscitation.[12] Therefore, evaluating the correlation between decisions made under MCI dynamics and ATLS criteria could contribute significantly to improving trauma care. However, research on the impact of receiving hospitals on the management and outcomes of injured patients following MCIs remains limited.[13]

Prehospital trauma patients are typically transported by ambulance crews to the nearest hospital, regardless of its trauma center designation. However, EMS teams consider various factors at the scene, such as the mechanism of injury, the medical capacities of available hospitals, and the preferences of the patient's family, when making the final transport decision. In the context of an MCI, this process becomes more complex, as EMS teams must also account for additional parameters, including hospital bed availability, the capability to provide necessary care, road conditions, and safety. In MCIs, EMS personnel and managers assess not only the patients' conditions through on-site triage but also the suitability of receiving hospitals, resulting in a dual-level triage system that evaluates both patient and facility compatibility.[14,15] Patients are transported to hospitals, and if the receiving hospital lacks adequate resources, they are subjected to secondary transfer to tertiary hospitals. This process presents resource challenges related to time, staffing, and coordination. Research on the impact of these challenges on patient management is limited due to documentation constraints, difficulties in patient follow-up, incomplete patient information, and challenges in obtaining informed consent, particularly in MCIs, where medico-legal processes often coincide with medical care. Nevertheless, a clear, simple, and organized approach is essential for the effective management of injured patients following MCIs.

This study aims to evaluate the hospital processes, transfers, and treatment of injured patients following traffic accidents that resulted in MCIs, and to examine the impact of hospital triage decisions made by prehospital Emergency Medical Services (EMS) teams and managers on patient outcomes.

MATERIALS AND METHODS

Study Design and Setting

This study was designed as a retrospective, comparative, diagnostic study. After obtaining permission from the Manisa Provincial Health Directorate, ethical approval was granted by the S.B.Ü. Tepecik Training and Research Hospital Ethics Committee (Approval No: 2024/03-27; Approval Date: 3 April 2024). The study was conducted in accordance with the principles of the Declaration of Helsinki. Following ethical approval, patient data recorded in the electronic information system of the Ambulance Chief Physician's Office, under the Emergency Health Directorate, were utilized. Due to the retrospective nature of the study, the requirement for informed consent was waived.

Categorization of Receiving Hospitals Based on Trauma Capability

In Türkiye, hospitals are not classified based on a formal trauma center designation, but rather according to the level of interventions they can provide and their overall capacity. These are categorized into three levels: Primary (Level 1), Secondary (Level 2), and Tertiary (Level 3). As the level increases from one to three, so does the capacity to deliver advanced trauma care. While primary and secondary-level hospitals can provide basic trauma care in their emergency departments (ED), patients requiring more advanced interventions and treatments are transferred to tertiary hospitals, typically upon a physician's decision. Trauma care is not provided at primary-level hospitals. Secondary-level hospitals offer 24-hour basic trauma care, usually with a trauma team composed of a physician and a nurse. In contrast, tertiary centers have trauma teams that include emergency physicians, trauma surgeons, specialized surgeons, emergency nurses, respiratory therapists, technicians, and social workers. Even when a formal trauma team is not officially established, these hospitals are large enough to incorporate these key personnel.

Population Selection and Data Collection

This study included injured patients over the age of 18 who were transported by ambulance from the MCI site to a public hospital, in incidents reported to SAKOM (according to regional MCI criteria) in the province of Manisa over a five-year period.

Injured patients were identified from EMS electronic records submitted to SAKOM. According to SAKOM criteria, traffic accidents are classified as MCIs if there are at least five deaths or 10 or more injured individuals. Information regarding the hospitals to which these patients were transferred, on-site injury assessments, the receiving hospitals, the teams responsible for transport decisions, and patients who required secondary transfers was obtained from EMS records. Patient data identified in EMS records were retrospectively collected from tertiary healthcare facilities in the city. Trauma treatments administered during hospital management, along with patient outcomes, were recorded. Patients with incomplete or inconsistent data were excluded from the study.

The initial transfer of injured patients from the MCI site to hospitals was made by EMS personnel. In this study, these transport decisions were evaluated independently of formal criteria. This approach was taken because, although the transfer of trauma patients to the nearest or most appropriate hospital is recommended in Türkiye, there is no specific protocol for managing MCI situations. Data from the initial receiving healthcare institutions and the Ministry of Health's hospital classification system were used to determine hospital levels.[16]

Patient transfers were classified into two types: vertical and horizontal transfers.[17] Vertical transfers involve moving patients from hospitals with limited resources to highly specialized healthcare facilities (i.e., stroke centers, cardiac centers, trauma centers, or high-risk obstetric units). In contrast, horizontal transfers typically occur within the same level of the healthcare system. Although horizontal transfers were initially identified in the dataset, they were excluded from the analysis due to their relatively low frequency and high heterogeneity. These transfers often occurred between hospitals of similar capacity and were typically driven by non-clinical factors such as bed availability or geographic proximity, rather than by differences in clinical severity. Including them could have introduced variability and confounded the analysis of triage accuracy and mortality outcomes, which were central to this study. Therefore, in this study, all transfers other than vertical transfers were excluded from the analysis.

In this study, secondary interfacility transfers were evaluated based on the criteria outlined in Interfacility Transfer of Injured Patients: Guidelines for Rural Communities, prepared by the American College of Surgeons Committee on Trauma (by Scott R. Petersen, MD, FACS, and the Ad Hoc Committee on Rural Trauma, ACS Committee on Trauma).[17]

Patients were excluded if they had more than 10% missing data overall or lacked essential variables required for triage assessment. The evaluation of triage accuracy required, at minimum, documentation of the mechanism of injury and core prehospital physiological parameters (systolic blood pressure, respiratory rate, and Glasgow Coma Scale score). If any of these were completely missing or inconsistently recorded, a reliable assessment of triage correctness was not possible. A total of 64 such patients were excluded.

Triage accuracy was assessed in the remaining 606 patients.

Machine Learning Approach and Neural Network Implementation

Machine learning is a class of computational methods that enables models to learn patterns from data without relying on explicit programming or predefined rules.[18] It is particularly useful in situations where outcomes are influenced by multiple, potentially interacting variables. Among these methods, artificial neural networks are layered structures composed of interconnected units ("neurons") that mimic the way information is processed in the human brain.[19] They are especially effective at capturing non-linear and complex relationships between inputs and outcomes.

In this study, a feedforward neural network was used to estimate the probability of in-hospital mortality. This model was selected for its ability to simultaneously incorporate both physiological variables and logistical elements, without assuming linear relationships. The output was a continuous risk score ranging from 0 to 1, reflecting the model's confidence in predicting patient mortality. To improve interpretability, Garson's algorithm was employed to calculate variable importance, identifying which features contributed most to the prediction. Clinically, this provided insight into how various patient- and system-level factors influenced survival probability and helped identify areas where triage or transfer decisions might affect outcomes.

Statistical Analysis

Continuous variables were assessed for normality using the Kolmogorov-Smirnov test, and their distributions were visualized with histograms. Normally distributed variables were reported as mean ± standard deviation, while non-normally distributed variables were summarized as median [interquartile range, 25th – 75th percentiles]. Comparisons between groups were performed using the independent samples t-test for normally distributed variables and the Mann-Whitney U test for non-normally distributed variables. Categorical variables were analyzed using the Chi-square test or Fisher's exact test, as appropriate. For continuous variables, unadjusted odds ratios (ORs) with 95% confidence intervals (CIs) were calculated by dichotomizing each variable at its overall median value. Each variable was categorized into two groups: values above the median and values at or below the median. ORs were then computed using logistic regression models, comparing the proportion of patients with values exceeding the median across groups. For categorical variables, ORs were directly computed from contingency tables using univariate logistic regression, and results were reported with 95% confidence intervals.

A feedforward artificial neural network model was developed using the neuralnet package in R. The dataset was randomly divided into a training set (80%) and a testing set (20%) using stratified sampling to preserve the mortality ratio. The model architecture included two hidden layers with 10 and 5 neurons, respectively, and was optimized using backpropagation. Model performance was assessed using the area under the receiver operating characteristic (ROC) curve with 95% confidence intervals, accuracy with 95% confidence intervals, sensitivity, specificity, and McNemar's test for comparing classification errors. Variable importance was analyzed using Garson's algorithm, which quantifies the contribution of each input variable to the neural network's output and was visualized using a ranked bar plot.

To evaluate the effect of triage accuracy on mortality, a stratified analysis was conducted by transfer pathway. Mortality rates were compared using Chi-square tests, and logistic regression models were fitted within each stratum to estimate odds ratios with 95% confidence intervals. Additionally, an interaction term was included in the regression model to determine whether the effect of transfer status on mortality varied by triage accuracy. For variables with minor missingness (≤10%) and that were not directly used in triage determination, multiple imputation by chained equations (MICE) was applied.

All statistical tests were two-tailed, and a p-value <0.05 was considered statistically significant. Data processing, modeling, and visualization were performed using R software (version 4.4.2; R Foundation for Statistical Computing, Vienna, Austria), utilizing the ggplot2, dplyr, neuralnet, and broom packages.

RESULTS

A total of 606 patients were included in the study, with 212 (35.0%) undergoing secondary transfer to a tertiary hospital and 394 (65.0%) being directly admitted to a tertiary hospital. Baseline demographic and physiological characteristics are presented in Table 1. Patients in the secondary transfer

Table 1. Baseline characteristics of patients transferred from secondary to tertiary hospitals vs. direct tertiary admission

Variable	Secondary Transfer to Tertiary (n=212)	Direct Tertiary Admission (n=394)	p	Unadjusted OR (95% CI)
Patient Age (years)	55.2 (41.4-64.7)	43.2 (33.6-55.4)	<0.001	0.34 (0.24-0.49)
Sex (Male, %)	106 (50.0%)	190 (48.2%)	0.740	0.931 (0.658-1.319)
Systolic Blood Pressure (mmHg)	89.2 (84.3-95.1)	99.7 (94.0-105.3)	<0.001	8.25 (5.46-12.66)
Diastolic Blood Pressure (mmHg)	60.0 (55.5-65.2)	70.3 (65.7-75.5)	<0.001	10.23 (6.67-16.02)
Shock Index	1.1 (0.9-1.2)	1.0 (0.9-1.0)	<0.001	0.33 (0.23-0.48)
Serum Lactate (mmol/L)	4.2 (3.8-4.7)	3.2 (2.6-3.6)	<0.001	0.06 (0.04-0.10)
Base Deficit	-4.0 (-4.2--3.5)	-2.0 (-2.2--1.5)	<0.001	75.34 (35.79-182.93)
Oxygen Saturation (SpO2, %)	86.5 (81.1-91.9)	94.9 (88.7-100.0)	<0.001	4.84 (3.30-7.15)
Respiratory Rate (breaths/min)	21.3 (17.4-24.3)	17.0 (14.4-20.3)	<0.001	0.28 (0.19-0.41)
Injury Severity Score (ISS)	31.1 (22.6-38.3)	19.0 (9.2-28.9)	<0.001	0.23 (0.16-0.33)
Revised Trauma Score (RTS)	5.8 (3.1-8.6)	9.2 (6.4-12.0)	<0.001	3.80 (2.62-5.55)

OR: Odds ratio; CI: Confidence interval.

Table 2. Procedural and clinical outcomes by transfer group

Variable	Secondary Transfer to Tertiary (n=212)	Direct Tertiary Admission (n=394)	p	Unadjusted OR (95% CI)
Time in Emergency Department (minutes)	106.0 (71.2-127.5)	74.7 (49.9-99.7)	<0.001	0.36 (0.25-0.52)
Correct Triage Decision (%)	159 (75.0%)	364 (92.4%)	<0.001	4.034 (2.428-6.806)
Blood Transfusion (%)	129 (60.8%)	153 (38.8%)	<0.001	0.409 (0.286-0.583)
Vasopressor Requirement (%)	93 (43.9%)	87 (22.1%)	<0.001	0.363 (0.249-0.529)
Massive Transfusion (%)	78 (36.8%)	75 (19.0%)	<0.001	0.405 (0.273-0.599)
Mechanical Ventilation (%)	132 (62.3%)	157 (39.8%)	<0.001	0.402 (0.280-0.574)
In-Hospital Mortality (%)	43 (20.3%)	32 (8.1%)	<0.001	0.348 (0.205-0.585)

OR: Odds ratio; CI: Confidence interval.

group were older (55.2 vs. 43.2 years, p<0.001) and had lower systolic (89.2 vs. 99.7 mmHg, p<0.001) and diastolic blood pressures (60.0 vs. 70.3 mmHg, p<0.001). Furthermore, they had a higher shock index (1.1 vs. 1.0, p<0.001), higher serum lactate levels (4.2 vs. 3.2 mmol/L, p<0.001), worse base deficit (-4.0 vs. -2.0, p<0.001), and lower oxygen saturation (86.5% vs. 94.9%, p<0.001). Injury severity also differed significantly, with the secondary transfer group exhibiting higher Injury Severity Scores (ISS) (p<0.001).

Table 2 presents the procedural interventions and clinical outcomes between the groups. The secondary transfer group had longer prehospital times (106.0 vs. 74.7 minutes, p<0.001), were less likely to receive correct triage decisions (75.0% vs. 92.4%, p<0.001), and had higher rates of blood transfusion (60.8% vs. 38.8%, p<0.001). Similarly, the need for vasopressors (43.9% vs. 22.1%, p<0.001), massive transfusion (36.8% vs. 19.0%, p<0.001), and mechanical ventilation (62.3% vs. 39.8%, p<0.001) was significantly greater in the secondary transfer group. Notably, in-hospital mortality was higher among patients transferred secondarily (20.3%) compared to those admitted directly (8.1%), with an unadjusted odds ratio of 0.348 (95% CI: 0.205-0.585, p<0.001).

The trained neural network model demonstrated excellent predictive performance for mortality (Table 3). The training area under the curve (AUC) was 0.947 (95% CI: 0.928-0.966), and the testing AUC was 0.841 (95% CI: 0.782-0.899). Model accuracy was 96.6% (95.1%-98.1%) in the training set and 86.3% (81.9%-90.7%) in the testing set. Sensitivity was 97.6% (training) and 95.3% (testing), while specificity was lower at 95.5% (training) and 77.4% (testing). McNemar's test indicated a statistically significant difference in classification errors between the two groups (training: p=0.0002; testing: p=0.0446). Additionally, Figure 1 presents the variable importance derived from the neural network model. The transfer pathway was the most influential predictor of mortality, followed by mechanical ventilation, blood transfusion, and shock index.

Table 3. Neural network model performance in predicting mortality

Metric	Training Set	Testing Set
AUC (95% CI)	0.947 (0.928-0.966)	0.841 (0.782-0.899)
Accuracy (%, 95% CI)	96.6 (95.1-98.1)	86.3 (81.9-90.7)
Sensitivity (%, 95% CI)	97.6 (96.1-99.1)	95.3 (92.2-98.4)
Specificity (%, 95% CI)	95.5 (93.8-97.2)	77.4 (70.8-84.0)
McNemar's Test p-value	0.0002	0.0446

AUC: Area under the curve; CI: Confidence interval.

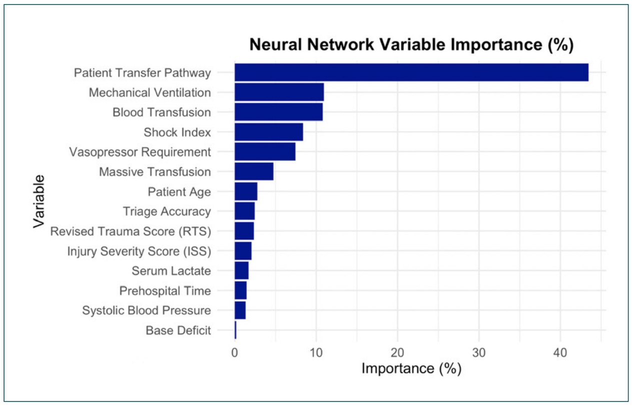

Figure 1. Baseline characteristics of patients transferred from secondary to tertiary hospitals vs. direct tertiary admission.

A stratified analysis was conducted to examine the impact of correct vs. incorrect triage decisions on mortality within each transfer group (Table 4). Among patients who received a correct triage decision, mortality was significantly higher in the secondary transfer group (22.6%) compared to those directly admitted to tertiary care (8.0%), with an OR of 3.38 (95% CI: 1.99-5.78, p<0.001). Among patients who received an incorrect triage decision, mortality was 13.2% in the secondary transfer group vs. 10.0% in the direct admission group, with an OR of 1.37 (95% CI: 0.35-6.76, p=0.667). These results

Table 4. Stratified analysis of the effect of transfer pathway on mortality by triage accuracy

Triage Accuracy	Transfer Pathway	Mortality Rate (%)	OR (95% CI)
Correct	Secondary Transfer to Tertiary	22.6%	3.38 (1.99-5.78)
Correct	Direct Tertiary Admission	8.0%	Reference (Baseline)
Incorrect	Secondary Transfer to Tertiary	13.2%	1.37 (0.35-6.76)
Incorrect	Direct Tertiary Admission	10.0%	Reference (Baseline)
Overall Comparison	Secondary Transfer (All) vs. Direct Admission (All)	—	2.35 (1.12-5.10)
Impact of Correct Triage	Correct vs. Incorrect (All Patients)	—	4.19 (2.15-8.48)

OR: Odds ratio.

suggest that incorrect triage decisions are associated with increased mortality risk overall. When comparing all secondary transfer patients to all direct admissions, regardless of triage accuracy, the unadjusted OR for mortality was 2.35 (95% CI: 1.12-5.10, p=0.0265). Furthermore, a direct comparison between correctly and incorrectly triaged patients revealed a significant effect of triage accuracy, with an OR of 4.19 (95% CI: 2.15-8.48, p<0.001).

DISCUSSION

Our study analyzed the clinical outcomes of secondary transfer in trauma patients and demonstrated that those initially transported by EMS teams to secondary-level hospitals following traffic accidents resulting in MCIs, and subsequently requiring inter-hospital transfer to tertiary centers, exhibited higher mortality rates, more pronounced hemodynamic instability, and greater needs for critical interventions such as vasopressor support, mechanical ventilation, and blood transfusion. Patients requiring secondary transfer to tertiary centers also presented with severe physiological derangements, including lower blood pressure, higher shock indices, and worse metabolic parameters upon arrival. Our artificial neural network analysis further demonstrated that correct hospital triage at the scene significantly reduced mortality among MCI patients, whereas inaccurate triage decisions markedly increased the risk of death, particularly in the secondary transfer group.

Mass casualty incident management and trauma management are two distinct algorithmic approaches in which time management is critical, as emphasized by the golden hour theory. When there are injured patients following an MCI, these algorithms aim to improve the quality of patient care through shared components.[20,21] Therefore, time is a critical factor in the management of injured patients during MCIs. In our study, two time-related parameters were analyzed: (1) the initial hospital admission and transfer distribution according to hospital level, and (2) transfer durations. When hospital admissions following MCIs were examined in our study, we observed that one-third of the patients admitted to tertiary hospitals had been transferred from other hospitals. While previous trauma studies have reported a secondary transfer rate of approximately 20%, the higher rate observed in our study was attributed to resource management challenges during MCIs.[22] Furthermore, we evaluated the accuracy of hospital triage in our study using ATLS criteria and found the Correct Triage Decision rate to be 75%. Similar to the study by Zhou et al., which found that one in five trauma patients meeting ATLS transfer criteria were not transferred to a higher-level center, we observed that one in four patients in our cohort was not transferred due to under-triage decisions.[22] These findings suggest that similar triage deficiencies may occur during the decision-making process for hospital selection and the transfer of patients from secondary to tertiary hospitals following MCIs, highlighting the importance of managing secondary waves of resource allocation in tertiary hospitals. The second time-related parameter examined was the time to admission at tertiary hospitals. In our study, when injured patients were initially transferred to a secondary hospital before reaching a tertiary hospital, the total transfer time averaged 106 minutes, whereas direct admission to a tertiary hospital took 74 minutes, representing a statistically significant difference between the two values. It is widely accepted that completing the prehospital process and initiating treatment in an ED within the first 60 minutes for trauma patients reduces mortality and morbidity, and prehospital protocols are planned accordingly.[23] In our study, delays beyond this target time were associated with MCI conditions, and a time delay was observed in patients transferred from secondary to tertiary hospitals. Although the average delay was approximately 30 minutes, when considered within the context of the critical phase of trauma, where every minute matters, and given its impact on patient outcomes, the critical importance of hospital triage becomes evident.

When the systolic blood pressure (SBP), diastolic blood pressure (DBP), shock index, serum lactate level, base deficit, oxygen saturation, respiratory rate, and trauma severity scores such as ISS and Revised Trauma Score (RTS) were analyzed for patients transferred from secondary to tertiary hospitals, it was observed that these secondary transfers to tertiary hospitals involved more critically injured patients. This finding is likely due to three possible factors: (1) the exacerbation of shock symptoms due to delays in transfer time; (2) patients transferred from secondary hospitals undergo multiple assessments (both in the prehospital setting and at the secondary hospital) before being referred to a tertiary center, whereas those directly admitted to tertiary hospitals are typically triaged only at the scene, potentially leading to over-triage; (3) documentation errors may have occurred during the transport processes.[24] A limitation of our study arises at this point: we did not have access to the initial vital signs and trauma scores of patients transferred to tertiary hospitals, due to documentation deficiencies resulting from the chaotic nature of the MCI environment. Ideally, the decision to transfer an unstable patient should be made jointly by the transferring and receiving physicians,[25] especially considering that our study found higher mortality rates among patients who underwent secondary transfer to tertiary hospitals. This increased mortality may be due to the re-engagement of unstable patients in the transfer process. Furthermore, when the clinical presentations and outcomes of patients transferred from secondary to tertiary hospitals were evaluated, it was concluded that cost-effectiveness and outcome assessments should ideally be conducted while patients are still in secondary hospitals, with close monitoring of their hemodynamic status. Incorrect hospital triage during the prehospital phase increased the vulnerability of these patients, and both the transfer process to tertiary hospitals and the subsequent admission process at these hospitals should be managed with an awareness of this increased risk.

Following disasters and MCIs, transfer strategies from nearby hospitals to more distant centers have become increasingly common due to the expansion of transportation modalities.[26] In Türkiye, after an MCI, the nearest hospital is designated as a "referral hospital" or "transport health center." In the early phase, walk-in patients and injured individuals brought in by ambulance are primarily stabilized at these centers before being transferred to more distant facilities for advanced care. During the February 6 Kahramanmaraş earthquake, which affected 11 provinces and 12 million people, a large number of buildings were destroyed, particularly in Hatay, Adıyaman, and Kahramanmaras, and healthcare facilities also sustained significant damage.[15,27] At that point, some provinces and health centers with larger healthcare infrastructure were less affected by the earthquake. In these centers, patients transported from the three most severely affected provinces received initial stabilization and advanced treatment (such as blood transfusion, vasopressor support, massive transfusion, and mechanical ventilation) before being transferred to more distant provinces by air. In our study, when transfer groups were analyzed, the rates of blood transfusion, vasopressor use, massive transfusion, and mechanical ventilation were higher in the secondary transfer to tertiary care group. This observation was consistent with the patients' hemodynamic status and mortality outcomes. These findings suggest that patients transferred from transport centers after MCIs may be in more critical condition and require more advanced trauma care than those who present as walk-ins or are brought directly by ambulance. This is an important consideration for disaster planning.

In MCIs, injured patients undergo dynamic triage processes beginning at the incident site, with the goal of providing the most accurate diagnosis and effective treatment for the greatest number of patients despite limited resources. At this stage, accurate triage selection and proper implementation are critically important for the injured patients. Currently, MCI triage is classified into three stages: primary, secondary, and tertiary triage.[15,20] Primary triage includes the initial assessment and intervention conducted at the scene of the MCI. Secondary triage refers to the evaluation and management of the patient after admission to the emergency department. Tertiary triage involves determining the need for ward admission, surgery, intensive care, or transfer after the patient has undergone emergency interventions. In this study, we examined hospital triage performed by EMS for hospital selection, based on field observations at the end of the primary triage process, as well as tertiary triage based on ATLS criteria for patients undergoing secondary transfer to tertiary hospitals. In this context, we evaluated triage at two critical points in the MCI care pathway and observed that both correct and incorrect triage decisions for patients transferred from secondary to tertiary hospitals were associated with higher mortality rates compared to direct tertiary admissions. We also found that 7.6% of injured patients directly transported from the incident site to tertiary healthcare facilities did not meet ATLS criteria, indicating over-triage at the scene. In contrast, 75.0% of the secondary transfer to tertiary group met these criteria, indicating a 25% over-triage rate. These findings suggest a need to reassess and evaluate triage algorithms to better manage potential overcrowding and surges in tertiary healthcare facilities during MCIs.

Our findings are consistent with previous global studies evaluating the impact of hospital triage systems and interfacility transfers on patient outcomes following MCIs. Research from high-income countries, including the United States and Europe, has demonstrated that early and accurate triage decisions significantly reduce mortality and improve patient management during MCIs. For instance, a study by Hirshberg et al. highlighted that coordinated hospital trauma care during MCIs can significantly reduce preventable deaths when timely and accurate triage protocols are followed.[13] Similarly, research from Japan and Australia highlighted the importance of coordinated hospital transfer protocols, particularly in resource-limited settings. Turner et al. reported that effective prehospital management and interfacility coordination can improve patient outcomes.[25] Our study contributes to this body of knowledge by providing evidence from Türkiye, a country whose healthcare system has undergone significant transformations to enhance disaster response. While previous studies have focused on single-institution data or specific geographic regions, our study uniquely evaluates triage accuracy and transfer decisions in a multi-hospital setting during MCIs.

In summary, post-MCI injuries, like injuries encountered in routine trauma care, can influence patient mortality depending on appropriate trauma center selection. However, given the limited EMS and hospital resources during MCIs, the decision regarding which hospital the injured patient should be transported to becomes critically important in balancing resource allocation. Under MCI conditions, under-triage and the subsequent need to transfer patients to higher-level centers are associated with increased mortality rates and greater hemodynamic instability, making both the transfer process and its planning critical aspects that require careful consideration.

Limitations

This study has several limitations: 1) The retrospective design of the study inherently carries a risk of documentation bias, as data accuracy depends on the completeness and correctness of recorded information. Variability in the quality and detail of medical records across different hospitals could have influenced the observed clinical outcomes. 2) Selection bias may be present, as patients requiring secondary transfer to tertiary hospitals were likely more critically ill than those directly transported, which could partly explain the higher observed mortality rates, independent of transfer delays. 3) The study was conducted in a single province, which may limit the generalizability of the findings to other regions with different healthcare infrastructures and MCI response capabilities.

CONCLUSION

The decision to direct injured patients to hospitals with adequate medical care following MCIs is a critical factor influencing patient mortality. When making this decision, the resource limitations inherent in MCI conditions, as opposed to the management of daily trauma patients, must be taken into account. In cases where secondary transfer to higher-level centers is necessary, it should be recognized that these patients often require more intensive interventions such as blood transfusions, vasopressor support, massive transfusion, and mechanical ventilation. They also face a higher risk of in-hospital mortality compared to those directly transferred to tertiary hospitals from the incident site. Incorporating these considerations into pre-established MCI management strategies is critically important.

To enhance patient outcomes in MCI scenarios, several policy recommendations emerge from our findings: 1) Healthcare authorities should prioritize the development of triage guidelines that account for the increased resource needs of patients requiring secondary transfer, aiming to reduce delays in definitive care. 2) Training programs should include scenarios that address secondary transfer challenges, focusing on the early recognition of patients likely to require advanced care. 3) To support evidence-based practices, further research is needed to explore the clinical outcomes associated with various transfer pathways, especially in settings with limited resources. 4) Implementing standardized data recording during MCI management would enable ongoing assessment of triage accuracy and transfer efficiency, thereby guiding continuous quality improvement.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Trafik kazalarına bağlı kitlesel yaralanmalı olaylarda hastane kabulünün yaralı hastaların yönetimi ve sonuçları üzerindeki etkisi

AMAÇ: Kitlesel yaralanmalı olaylarının (KYO) tıbbi yönetimi, birçok yaralının eş zamanlı ve etkin bir şekilde yönetimini sağlamak için hastane öncesi aşamadan taburculuğa kadar uzanan süreçte triyaj yöntemlerinin stratejik olarak uygulanmasını gerektirir. Bu çalışmanın amacı, trafik kazalarına bağlı KYO sonrasında travma hastalarının üçüncü basamak hastanelere nakil süreçlerini incelemek ve bu süreçlerin hasta sonuçları üzerindeki etkisini değerlendirmektir.

GEREÇ VE YÖNTEM: Bu retrospektif çalışma, bir ilde beş yıllık bir dönem boyunca trafik kazalarına bağlı KYO'larda yaralanan travma hastalarının hastane öncesi, hastaneler arası transfer ve hastane içi süreçlerini çok yönlü bir bakış açısıyla kapsamlı bir şekilde analiz etmektedir. Hasta mortalitesini öngörmek amacıyla, yüksek boyutlu klinik veri setlerinde karmaşık ve doğrusal olmayan ilişkileri belirleme kapasitesi nedeniyle denetimli bir yapay sinir ağı modeli kullanılmıştır.

BULGULAR: Çalışmaya toplam 606 hasta dahil edilmiştir. Bu hastaların 212'si (%35.0) üçüncü basamak bir hastaneye ikincil transfer edilirken, 394'ü (%65.0) doğrudan üçüncü basamak bir hastaneye kabul edilmiştir. İkincil transfer grubundaki hastalar, daha uzun hastane öncesi süreler (106.0 vs. 74,7 dakika, $p<0.001$) ve daha düşük doğru triyaj oranlarına (%75.0 vs. %92.4, $p<0.001$) sahipti. Ayrıca, bu grupta kan transfüzyonu (%60.8 vs. %38.8, $p<0.001$), vazopresör kullanımı (%43.9 vs. %22.1, $p<0.001$), masif transfüzyon (%36.8 vs. %19.0, $p<0.001$) ve mekanik ventilasyon (%62.3 vs. %39.8, $p<0.001$) oranları daha yüksekti. Hastane içi ölüm oranı ikincil transfer grubunda %20.3 iken, doğrudan kabul edilen grupta %8.1 olarak bulundu (düzeltilmemiş olasılık oranı [OR]: 0.348; %95 GA: 0.205-0.585, $p<0.001$). Eğitilmiş sinir ağı modeli, ölüm tahmininde mükemmel bir performans sergiledi (Eğitim AUC=0.947; %95 GA: 0.928-0.966, Test AUC=0.841; %95 GA: 0.782-0.899). Doğru ve yanlış triyaj kararlarının mortalite üzerindeki etkisini inceleyen tabakalı analizde, doğru triyaj yapılan hastalar arasında ikincil transfer grubunda mortalite oranı (%22.6), doğrudan üçüncü basamak kabul edilenlere göre (%8.0) anlamlı olarak daha yüksekti (OR: 3.38; %95 GA: 1.99-5.78, $p<0.001$). Genel olarak, sekonder transfer edilen hastalar, doğrudan kabul edilenlere kıyasla daha yüksek ölüm riskine sahipti (OR=2.35; %95 GA: 1.12-5.10, $p=0.0265$). Doğru ve yanlış triyaj yapılan tüm hastalar arasında doğrudan karşılaştırma yapıldığında, doğru triyajın mortalite riskini anlamlı ölçüde azalttığı görüldü (OR=4.19; %95 GA: 2.15-8.48, $p<0.001$).

SONUÇ: Trafik kazalarına bağlı KYO sonrası travma hastalarının yönetiminde, yeterli travma bakımına sahip olmayan hastanelere nakledilmeleri mortaliteyi artırmakta; ikincil transfer ise hemodinamik stabiliteyi olumsuz etkilemekte ve kan transfüzyonu, vazopresör desteği, masif transfüzyon ve mekanik ventilasyon ihtiyacını artırmaktadır.

Anahtar sözcükler: Hastane; hastane öncesi; kitle yaralanması olayları; nakil; travma.

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