Impact of Trauma Center Care on Mortality in Gangwon Province in Korea

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Abstract

Background: Al though controversial, there has been a consensus that compared with non-regional trauma centers, regional trauma centers have survival benefits. In a predominantly rural province with a single regional trauma center, we compared the in-hospital mortality of all trauma patients and severely injured patients between regional and non-regional trauma centers.

Methods: Using data extracted from the National Emergency Department Information System in Korea, we examined all trauma patients who visited emergency departments in Gangwon province between January 2015 and December 2017. The International Classification of Disease-Based Injury Severity Score (ICISS) was used to categorize the severity of the patients. Propensity score matching was used for balancing the severity between the two groups.

Results: Of 23,510 trauma patients, 2,857 and 20,653 were treated in regional and non-regional trauma centers, respectively. After propensity score matching, all patients in the non-regional trauma center group had a 6.27-fold higher risk of mortality than those in the regional trauma center group; severely injured patients—defined as those with ICISS < 0.9—in the non-regional trauma center group had a 4.90-fold higher risk of mortality than those in the regional trauma center group. ICISS cutoff values for mortality were 0.9015 and 0.8737 for the non-regional and regional trauma center groups, respectively.

Conclusion: Conventional paradigms of trauma systems can be used in predominantly rural Korean provinces, because trauma care in regional trauma centers conferred better survival benefits than that in non-regional trauma centers. Additionally, severely injured patients should be transported to regional trauma centers from the trauma scene.

Background

Severe trauma is the major leading cause of death and social problems [1, 2]. In developing countries, which account for 85% of the global population, 11% of all disability-adjusted life years are caused by trauma [3]. Moreover, individuals in developing countries have more frequent trauma-related mortality before 70 years of age than those in developed countries, and their life expectancy is very low [4]. Various studies have assessed methods to increase the survival rate of trauma patients. As a result, the concept of level I trauma centers was developed and became increasingly common. Several studies have reported that compared with non-trauma centers, level I trauma centers significantly improve the survival rate of patients [5–7]. However, recent studies have shown that compared with non-trauma centers, level I trauma centers do not improve patient survival [8, 9].

In South Korea, the number of trauma patients visiting emergency medical centers has been steadily increasing, and the overall mortality rate of trauma patients has increased from 3.83% in 2014 to 4.09% in 2018. In addition, Korea has a preventable trauma mortality rate of > 30%, which may be because of the lack of definitive treatment facilities such as level I trauma centers and the regionalized trauma system [10]. Therefore, in 2012, the Korean government developed a master plan for building a national

trauma system that aims to reduce trauma mortality to < 20% by 2020 [11]. As a result, since 2014, a total of 17 hospitals have been designated as regional trauma centers (RTCs), which are facilities similar to Level I trauma centers in the United States, with 14 currently in operation. However, it remains undetermined whether RTCs, compared to non-RTCs, have increased the survival rate of trauma patients in Korea.

This study aimed to compare the mortality rate of trauma patients treated in RTCs with that of those treated in non-RTCs in Gangwon province of Korea, which is a typical rural area. We hypothesized that the risk of death in all trauma patients and severely injured patients would be lower in RTCs than in non-RTCs.

Methods

Study design and setting

This retrospective cohort study used data extracted from the National Emergency Department Information System (NEDIS), which has been operated by the National Emergency Medical Center of Korea since 2003. NEDIS collects data from all patients visiting the emergency room. Moreover, in South Korea, there is no registry that manages only trauma patients—NEDIS performs the trauma registry function.

The data from NEDIS contain patient demographics and clinical information, which were prospectively collected from 399 emergency medical facilities in Korea [12]. All patient-related information is automatically transferred to a server managed by the central government within at least 14 days after the patient's discharge. NEDIS is considered a dependable nationwide reference of emergency department (ED) information.

We retrospectively reviewed the data collected from NEDIS between January 2015 and December 2017. All trauma patients who visited EDs located in Gangwon province were included. We identified trauma patients on the basis of the International Classification of Disease (ICD) codes, which is included in the NEDIS data. Patients who 1) were not diagnosed with damage accident, 2) were aged < 15 years, 3) were not involved in an accident such as drowning or intoxication, 4) were transferred out after emergency medical care, 5) had a cardiac arrest before emergency medical care, and 6) had inadequate data for analysis were excluded from this study.

This study was approved by the institutional review board (IRB) of Wonju Severance Christian Hospital (CR319164). The requirement for the patients' informed consent was waived by the IRB owing to the retrospective nature of the study.

Gangwon Province And Designation Of Trauma Centers In Korea

According to the resource and capacity of medical institutions, the emergency medical facilities in Korea are categorized into three types (regional emergency medical centers, local emergency medical centers, and local emergency medical service institutions) by the Ministry of Health and Welfare. In 2019, there were 35 regional emergency medical centers, 126 local emergency medical centers, and approximately 240 local emergency medical service institutions. Since 2012, 17 regional emergency medical centers were designated as RTCs, of which 14 were operational at the time of this.

Gangwon province has the second largest area among the eight provinces of Korea and is approximately 16,875 km^2. However, its population and density are the lowest in Korea, at approximately 1.5 million and 90/km^2, respectively. Geographically, the mountain region accounts for most of the area; therefore, patient transportation usually takes longer than that in other provinces. Previously, there was 1 regional emergency medical center designated as an RTC, 2 regional emergency medical centers, 4 local emergency medical centers, and 15 local emergency medical service institutions in the province. Wonju Severance Christian Hospital was designated as a regional emergency medical center in 2002 and was officially opened as an RTC in 2015 (Fig. 1).

Definition Of Variables

Using data extracted from NEDIS, we examined basic demographic variables, types of hospitals, mechanism of injury, vising routes, types of transportation, and other medical information. The ED visiting route was categorized into two types: direct visit and visit via transfer. The type of transportation included ambulance, helicopter, other vehicles, walking, etc. Medical information included vital signs and level of consciousness at the time of ED arrival, patient's disposition after initial care at the ED, diagnosis based on the ICD codes, mortality, in-hospital death, and time factors such as injury time, ED visiting time, discharge time from ED, or after admission. Level of consciousness was divided into the following categories: alert, verbal response, painful response, and unresponsiveness. Using the time factors, we calculated the duration from injury to ED visit, length of stay at ED, and hospital length of stay. Moreover, the severity of the injury was assessed by calculating an ICD-based injury severity score (the International Classification of Disease-Based Injury Severity Score, ICISS) based on the diagnosis entered in NEDIS. The survival risk ratio was assigned on the basis of the individuals' ICD codes, and ICISS was finally calculated on the basis of the survival risk ratio. We defined major trauma as ICISS < 0.9 based on previous results [13]. Patients were analyzed according to the type of receiving hospital and then categorized into the RTC and non-RTC groups. The non-RTC group comprised regional emergency medical centers, local emergency medical centers, and local emergency medical service institutions.

Statistical analysis

To compare the characteristics of the patients who visited an RTC and those who had not, independent two-sample t test was used for continuous variables and chi-square test or Fisher's exact test were used to compare categorical variables. Univariate logistic regression analysis was used to test the association

between death and age, sex, mechanism of injury, visiting route, transportation, level of consciousness, systolic blood pressure, diastolic blood pressure, pulse rate, respiration rate, and oxygen saturation. Multivariate analysis was adjusted using the significant factors affecting death determined in univariate logistic regression analysis.

We also created a propensity score (PS)-matched cohort by attempting to match each patient who visited an RTC and non-RTC (a 1:2 match). To reduce the effects of potential confounding factors when comparing the prognosis of the patient between RTC and non-RTC, the PS was estimated using a multivariate logistic regression model with the group as the dependent variable and ICISS, age, and sex as covariates. A nearest neighbor matching algorithm with a “greedy” heuristic (one that always implements the best immediate or local solution) was used to match the patients. After matching, we also evaluated the degree of balance in measured covariates between the RTC and non-RTC. An additional file shows this in more detail [see Additional file 1].

All reported P values are two-sided, and P values < .05 were considered to indicate statistical significance. SAS software v 9.4 (SAS Inc., Cary, NC) was used.

Results

Of 1,294,609 patients who visited the ED in Gangwon province during the 3 years of the study, 23,510 individuals were considered trauma patients and included in the analysis. Patients were not diagnosed with damage accident (1,054,270 patients), those aged < 15 years (73,813 patients), those who visited the ED owing to an injury mechanism besides damage or accident (18,064), those who were transferred out after ED care (4,822 patients), those who had cardiac arrest before ED visit (318 patients), and those who had inadequate data for analysis (119,812 patients) were excluded. Among the included patients, 2,857 and 20,653 patients visited the EDs of RTCs and non-RTCs, respectively (Fig. 2).

We compared patient characteristics, including the demographic variables and clinical information, between the two groups (Table 1). Significantly older patients (52.8 versus 49.8 years of age) and a higher proportion of male patients (67.8%) were found in the RTC group than in the non-RTC group. Traffic accident was the most common mechanism of injury in both the groups (RTC versus non-RTC group: 44.1% versus 25.8%). Regarding the ED visiting route, significantly more patients were transferred from other facilities to RTCs than to non-RTCs (33.6% versus 12.6%). Ambulance was the most common type of transportation in the RTC group; however, other vehicles such as personal car or police car were the most frequent types in the non-RTC group. The RTC group showed a higher blood pressure, higher pulse rate, lower respiratory rate, and lower oxygen saturation than the non-RTC group, with a statistically significant difference. The ICISS in the RTC group was significantly lower than that in the non-RTC group (0.86 ± 0.20 versus 0.97 ± 0.09, $p < 0.001$).

Table 1
Characteristics of trauma patients who visited to the ED of RTC and non-RTC group, before and after propensity score matching

Variables	Before matching (n = 23,510)			After matching (n = 7,074)		
	Non-RTC (n = 20,653)	RTC (n = 2,857)	P-value	Non-RTC (n = 4,716)	RTC (n = 2,358)	p-value
Male	12,734 (61.7)	1,936 (67.8)	< 0.001	3,125 (66.3)	1,557 (66.0)	0.845
Age (year)	49.8 ± 18.5	52.8 ± 18.5	< 0.001	54.2 ± 18.6	52.0 ± 18.5	< 0.001
Injury mechanism			< 0.001			< 0.001
Traffic accident	5,319 (25.8)	1,260 (44.1)		1,471 (31.2)	993 (42.1)	
Falling	2,165 (10.5)	398 (13.9)		670 (14.2)	274 (11.6)	
Slip down	3,540 (17.1)	366 (12.8)		880 (18.7)	324 (13.7)	
Struck	3,212 (15.6)	337 (11.8)		625 (13.3)	284 (12.0)	
Firearm/cut/pierce	2,832 (13.7)	219 (7.7)		438 (9.3)	212 (9.0)	
Machine	469 (2.3)	25 (0.9)		96 (2.0)	23 (1.0)	
Others	3,116 (15.1)	252 (8.8)		536 (11.4)	248 (10.5)	
Visiting route			< 0.001			< 0.001
Direct visit	18,060 (87.4)	1,898 (66.4)		3,929 (83.3)	1,680 (71.3)	
Transferred	2,593 (12.6)	959 (33.6)		787 (16.7)	678 (28.8)	
Transportation			< 0.001			< 0.001
Ambulance	8,650 (41.8)	2,038 (71.3)		2,497 (53.0)	1,608 (68.2)	
Other vehicles	11,951 (57.9)	722 (25.3)		2,208 (46.8)	696 (29.5)	

Data are presented as frequency (percentage) and mean ± standard deviation.

RTC Regional trauma center, *BP* Blood pressure, *ICISS* The International Classification of Disease (ICD)-based injury severity score

Variables	Before matching (n = 23,510)			After matching (n = 7,074)		
	Non-RTC (n = 20,653)	RTC (n = 2,857)	P-value	Non-RTC (n = 4,716)	RTC (n = 2,358)	p-value
Helicopter	19 (0.1)	92 (3.2)		4 (0.1)	49 (2.1)	
Walking	26 (0.1)	5 (0.2)		2 (0.04)	5 (0.2)	
Others	8 (0.1)	-		5 (0.1)	-	
Level of consciousness			< 0.001			< 0.001
Alert	20,052 (97.1)	2,412(84.4)		4,437 (94.1)	2,107 (89.4)	
Verbal response	336 (1.6)	282 (9.9)		148 (3.1)	180 (7.6)	
Painful response	226 (1.1)	122 (4.3)		115 (2.4)	53 (2.3)	
Unresponsiveness	39 (0.2)	41 (1.4)		16 (0.3)	18 (0.8)	
Systolic BP	138.3 ± 25.3	139.9 ± 28.0	0.004	138.5 ± 26.6	141.8 ± 26.4	< 0.001
Diastolic BP	82.4 ± 15.0	80.9 ± 16.8	< 0.001	82.2 ± 15.6	82.1 ± 16.0	0.821
Pulse rate	83.3 ± 15.6	84.9 ± 17.5	< 0.001	83.1 ± 16.1	84.4 ± 16.8	0.002
Respiration rate	19.4 ± 2.6	19.1 ± 3.1	< 0.001	19.6 ± 2.5	19.1 ± 2.6	< 0.001
Oxygen saturation	97.7 ± 3.0	96.7 ± 4.1	< 0.001	97.4 ± 3.9	97.2 ± 3.2	0.001
Data are presented as frequency (percentage) and mean ± standard deviation.						
RTC Regional trauma center, *BP* Blood pressure, *ICISS* The International Classification of Disease (ICD)-based injury severity score						

After 1:2 PS matching for age, sex, and ICISS, 4,716 non-RTC patients and 2,368 RTC patients were analyzed. The severity- and outcome-related variables were analyzed between the two groups before and after PS matching (Table 2). Although ICISS was significantly lower in the RTC group than in the non-RTC group before matching (0.86 versus 0.97, $p < 0.001$), the difference became insignificant after matching (0.93 versus 0.93, $p = 0.620$). Similarly, the length of hospital stay was longer in the RTC group before matching (20.6 days versus 15.2 days, $p < 0.001$), but the length was similar after matching (16.3 days versus 17.7 days, $p = 0.129$). For all included trauma patients, a significantly lower in-hospital mortality was observed in the RTC group than in the non-RTC group (0.9% versus 2.4%, $p < 0.001$). In addition, for

severely injured trauma patients with ICISS < 0.9, the RTC group showed a lower mortality rate than the non-RTC group (3.2% versus 8.6%, p < 0.001).

Table 2
Comparison of severity and outcome-related variables of RTC group with non-RTC group

	Before matching			After matching		
	Non-RTC (n = 20,653)	RTC (n = 2,857)	p-value	Non-RTC (n = 4,716)	RTC (n = 2,358)	p-value
ICISS	0.97 ± 0.09	0.86 ± 0.20	< 0.001	0.93 ± 0.12	0.93 ± 0.12	0.620
Elapsed time to ED (min)	174.5 ± 236278.6	169.1 ± 233.6	0.262	173.0 ± 272.6	168.0 ± 241.1	0.429
Hospital length of stay (d)	15.2 ± 20.8	20.6 ± 30.4	< 0.001	17.7 ± 24.2	16.3 ± 25.6	0.129
All patients			< 0.001			< 0.001
Survival	20,446 (99.0)	2,774 (97.1)		4,605 (97.7)	2,338 (99.1)	
Death	207 (1.0)	83 (2.9)		111 (2.4)	20 (0.9)	
ICISS < 0.9			0.398			< 0.001
Survival	1,736 (91.2)	969 (92.2)		1,030 (91.4)	550 (96.8)	
Death	167 (8.8)	82 (7.8)		97 (8.6)	18 (3.2)	
Data are presented as frequency (percentage) and mean ± standard deviation.						
RTC Regional trauma center, *ED* Emergency department, *ICISS* The International Classification of Disease (ICD)-based injury severity score						

The univariate logistic regression analysis using data after PS matching revealed the following variables to be associated with in-hospital death: age, type of receiving hospital, type of transportation, patient's visiting route, level of consciousness, ICISS, SBP, DBP, HR, and oxygen saturation. To compare in-hospital deaths between the RTC and non-RTC groups, multivariate logistic regression analysis was performed after adjustment for the variables mentioned above (Fig. 3). After matching, the risk of in-hospital mortality for all patients was higher in the non-RTC group than in the RTC group (adjusted odds ratio [OR]: 6.27, 95% confidence interval [CI]: 3.30–11.94, p < 0.001). Furthermore, the risk of mortality for patients with ICISS < 0.9 was significantly higher in the non-RTC group than in the RTC group (adjusted OR: 4.90,

95% CI: 2.40–10.00, p < 0.001). According to the receiver operating characteristic (ROC) curve, ICISS cutoff values for mortality were 0.9015 and 0.8737 in the non-RTC and RTC groups, respectively.

Discussion

In this study, we demonstrated that trauma patients who visited the EDs of RTCs had a better chance of survival than those who visited non-RTCs in Gangwon province, even after PS matching with one of the indicators for the severity of injury, namely, ICISS. To our knowledge, this is the first province-wide study in Korea to include all trauma patients, and the largest study to assess the survival rate of trauma patients in RTCs of a rural area.

Conventionally, trauma patients, especially those with severe injury, have better survival outcomes when treated in RTCs than when treated in non-RTCs [14–16]. In Korea, because the upgradation of regional emergency medical centers to RTCs started only in 2014, the regional trauma system has not been completely developed; furthermore, a well-qualified national trauma registry has not yet been established. In this study, although we could not investigate all known outcome-related factors in detail, pre-hospital time in both groups showed no significant difference, and the severity of injuries was balanced by PS matching. Consequently, our study showed consistency with the conventional paradigm of a trauma system for all patients, including severely injured ones.

In this study, ICISS was used to classify the severity of patients, which has been shown to have a higher predictive power than other scoring systems, such as the injury severity score (ISS) and the trauma and injury severity score, according to previous studies [17, 18]. We defined severe trauma as ICISS < 0.9, which meant that the patient's survival rate was < 90% and that it could be equivalent to ISS > 15 [13, 19]. The risk of mortality for patients with ICISS < 0.9 in the non-RTC group was 4.90 times higher than that in the RTC group, and ICISS cutoff value for predicting mortality was < 0.9 in the RTC group but was > 0.9 in the non-RTC group. It implied that severely injured patients who could have had an ICISS value of < 0.9 needed to be directly transported to RTCs, instead of non-RTCs, to have a better chance of survival.

The trauma systems in rural environments have different characteristics than those in urban areas, which may contribute to the high injury mortality rate. Besides factors related to the injury mechanism, various other features might also play a role in the higher mortality rate, including unnecessary transfer of minimally injured patients and repetition of unnecessary imaging [20, 21]. In addition, a substantial portion of deaths occurred in the early phase of patient care such as pre-hospital and in the ED [22]. In Gangwon province—which has the lowest population density in Korea—most of the territory is composed of rural areas with only a single RTC, and this is probably why the transportation time was relatively longer. According to the 2018 statistics released by the Korean government, the national average rate of severely injured patients arriving in the ED within an hour is 39.9%, whereas in Gangwon province, the rate was 35.1%, and the average arrival time was 94.3 minutes [12]. Because we did not include prehospital death, the mortality rate of trauma patients could be underestimated, regardless of the type of receiving facility. In general, trauma patients are initially transported to the nearest and most eligible facility by

regional emergency medical services (EMS); therefore, the probability that more frequent prehospital deaths occurred for patients supposed to be transported to RTCs was unlikely. The trauma system of Korea is not completely developed, and the effective method to improve the overall outcomes of patients depends on the unique features of each area.

Our study had several potential limitations. First, the severity of the patient's injury was classified only by ICISS and not by any other indicators. Because the Glasgow Coma Scale (GCS) was not recorded for all patients in the registry, GCS-derived physiological indicators, such as the revised trauma score (RTS) or the mechanism of injury, age, and arterial pressure (MGAP) could not be analyzed. In addition, ISS and AIS scores, which are widely used for the classification of the severity of trauma patients, were not included in our registry and therefore could not be analyzed. However, ICISS has been widely utilized and is a well-validated scoring system according to recent studies [23, 24]. Second, our study could not obtain prehospital records from EMS, which are significant because prehospital factors could considerably affect patients' outcomes. However, the study population was restricted to one specific province; hence, it may be reasonable to assume that the level of prehospital treatment was somewhat uniform. In future studies, prehospital data from EMS should be appended to analyze the effect of prehospital factors on the outcome of trauma patients. Third, this study was conducted in a single predominantly rural province and not nationwide. However, Gangwon province is known as one of the typically rural areas of Korea and therefore could represent the population of other rural areas in the country.

Conclusion

In this study. conducted in a single predominantly rural province, we demonstrated that the trauma care in RTCs led to better survival benefits than that in non-RTCs for all patients, including the severely injured ones. Further studies will be needed for a nationwide population, including prehospital records and various severity scoring systems.

Declarations

Ethics approval and consent to participate : This study was approved by the institutional review board (IRB) of Wonju Severance Christian Hospital (CR319164). The requirement for the patients' informed consent was waived by the IRB owing to the retrospective nature of the study.

Consent for Publication : Data collection, analysis and publication was approved by the institutional review board (IRB) of Wonju Severance Christian Hospital (CR319164).

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Authors' contributions

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Formal analysis: Gyo A, Yoon K, Hey K, Oh kim

Investigation: Gyo A, Yoon K, Hey K, Chan K, Oh Kim

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Writing - original draft: Gyo A, Yoon K, Oh Kim

Writing - review & editing: Gyo A, Yoon K, Sung H, Kang L, Hyun K, Kyoung Cha, Yong Cha

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Figures

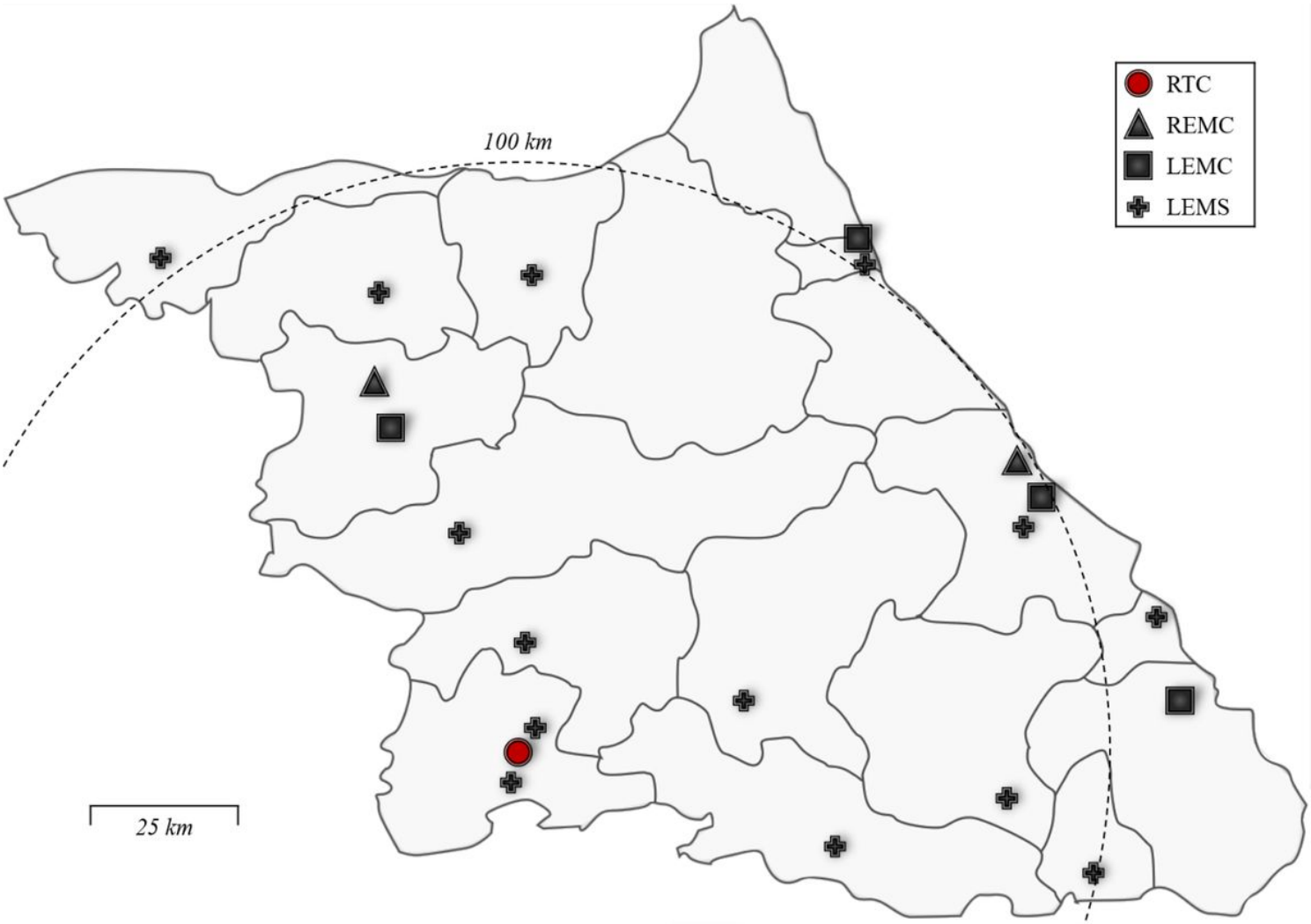

Figure 1

Regional trauma center and emergency medical facilities located in Gangwon province. RTC Regional trauma center, REMC Regional emergency medical center, LEMC Local emergency medical center, LEMS Local emergency medical service institution

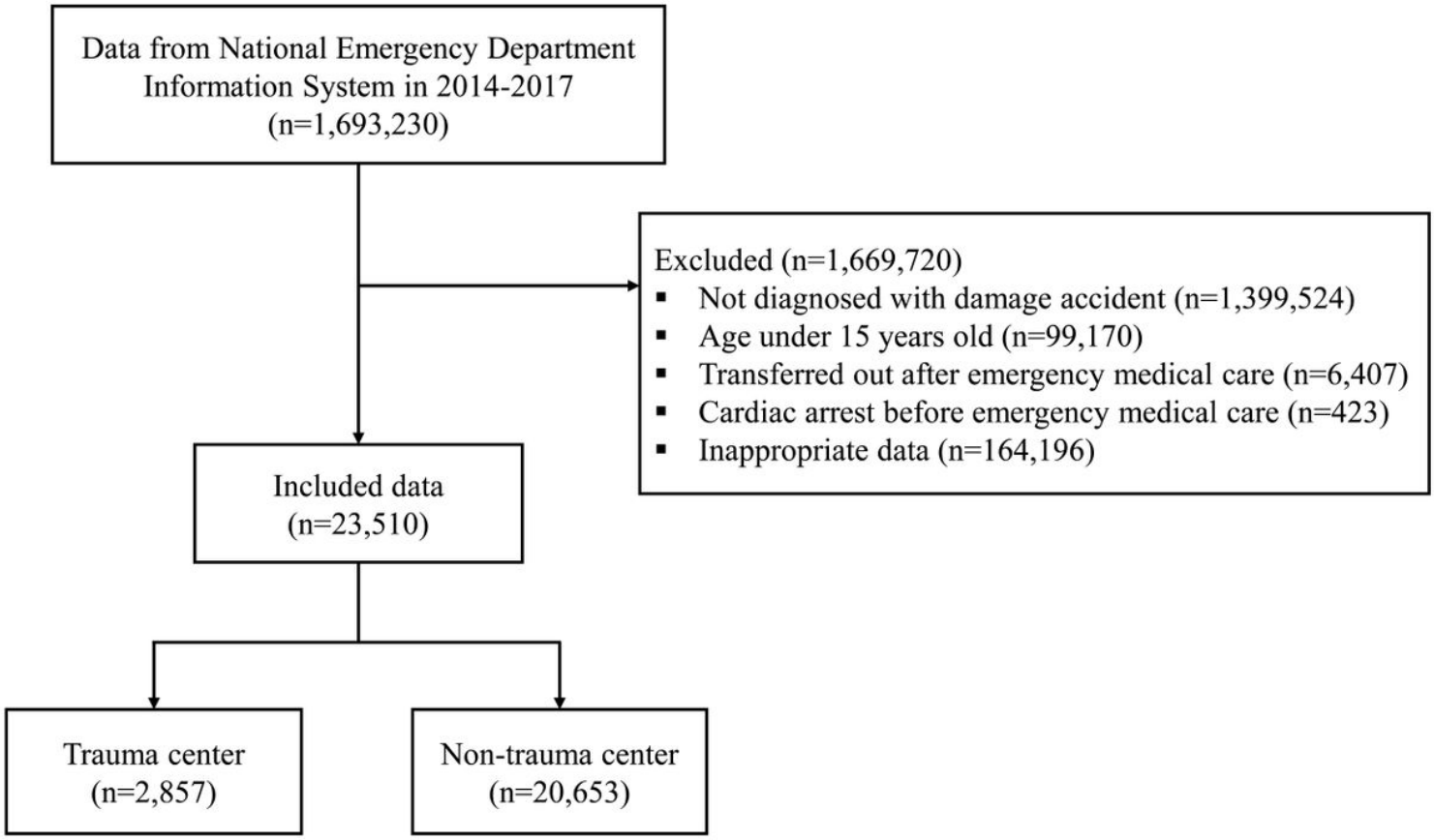

Figure 2

Flow chart of study enrollment

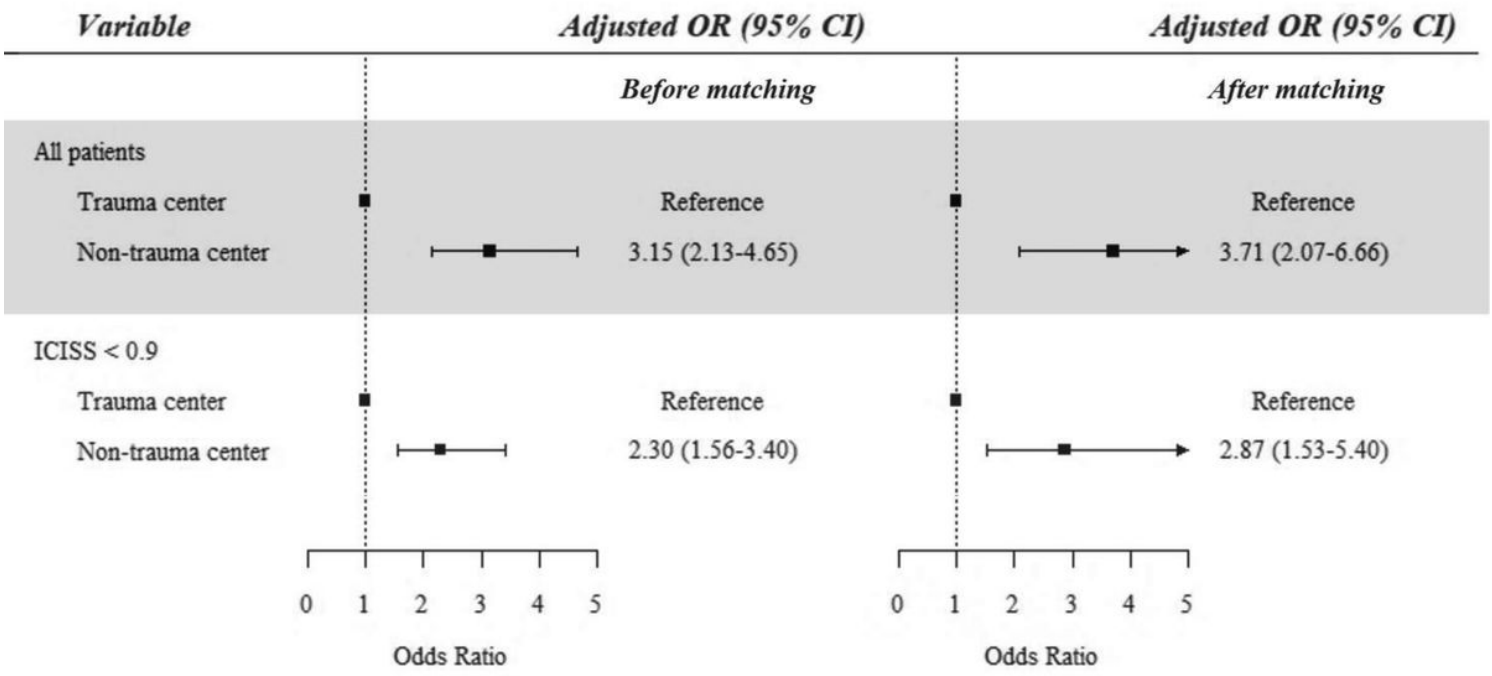

Figure 3

Forest plot of odds ratios for in-hospital mortality according to the type of receiving emergency facility OR Odds ratio, ICISS The International Classification of Disease-based injury severity score

Supplementary Files

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- Additionalfile1.docx