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Dutch trauma system performance: Are injured patients treated at the right place?

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ABSTRACT

Background: The goal of trauma systems is to match patient care needs to the capabilities of the receiving centre. Severely injured patients have shown better outcomes if treated in a major trauma centre (MTC). We aimed to evaluate patient distribution in the Dutch trauma system. Furthermore, we sought to identify factors associated with the undertriage and transport of severely injured patients (Injury Severity Score (ISS) >15) to the MTC by emergency medical services (EMS).

Methods: Data on all acute trauma admissions in the Netherlands (2015-2016) were extracted from the Dutch national trauma registry. An ambulance driving time model was applied to calculate MTC transport times and transport times of ISS >15 patients to the closest MTC and non-MTC. A multivariable logistic regression analysis was performed to identify factors associated with ISS >15 patients' EMS undertriage to an MTC.

Results: Of the annual average of 78,123 acute trauma admissions, 4.9% had an ISS >15. The nonseverely injured patients were predominantly treated at non-MTCs (79.2%), and 65.4% of patients with an ISS >15 received primary MTC care. This rate varied across the eleven Dutch trauma networks (36.8%-88.4%) and was correlated with the transport times to an MTC (Pearson correlation -0.753, p=0.007). The trauma networks also differed in the rates of secondary transfers of ISS >15 patients to MTC hospitals (7.8% - 59.3%) and definitive MTC care (43.6% - 93.2%). Factors associated with EMS undertriage of ISS >15 patients to the MTC were female sex, older age, severe thoracic and abdominal injury, and longer additional EMS transport times.

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Conclusions: Approximately one-third of all severely injured patients in the Netherlands are not initially treated at an MTC. Special attention needs to be directed to identifying patient groups with a high risk of undertriage. Furthermore, resources to overcome longer transport times to an MTC, including the availability of ambulance and helicopter services, may improve direct MTC care and result in a decrease in the variation of the undertriage of severely injured patients to MTCs among the Dutch trauma networks. Furthermore, attention needs to be directed to improving primary triage guidelines and instituting uniform interfacility transfer agreements.

Introduction

In the late 1980s, Dutch trauma surgeons expressed their concerns about the quality of care, especially for severely injured patients in the Netherlands [1]. A major issue was that those severely injured patients were often directly transported from the injury scene to the closest hospital regardless of the patients' injuries and the available resources. In 1998, following the United States' example, the Dutch government decided on the implementation of an organised "inclusive" trauma care system [2] composed of regional trauma networks [3]. The government designated ten (eleven in 2008) highly specialised, regional, major level one trauma centres (MTCs) and instructed them to care for severely injured individuals, establish regional trauma networks, exchange knowledge and skills, and monitor the quality of trauma care by setting up a trauma registry. The designation of the MTCs was mainly based on available resources in existing hospitals, such as trauma, thoracic and neurosurgical specialities. The number of severely injured patients was unknown at that time. The eleven Dutch trauma networks differ in geography, the number of hospitals, and the population to be served. The geographic layout of the regional trauma networks in the Netherlands and the dispersion of all trauma receiving hospitals are displayed in Fig. 1.

Treatment of severely injured patients in designated MTCs has proven to be associated with a significant survival benefit [4,5]. Moreover, studies have shown that immediate transport of severely injured individuals to an MTC is associated with less morbidity and improved survival than the transport of severely injured individuals to a non-MTC [6,7]. Accordingly, efforts should be made to get the patient to the right place the first time [8] to ensure the best possible outcome for the patient and to make the best use of available resources. In support of this principle, in 2015, the Dutch National Health Care Institute set the norm that within each of the 11 trauma networks, at least 90% of the severely injured patients with an Injury Severity Score (ISS) of >15 should be taken directly to the nearest MTC [9]. Non-MTCs play an essential role in the trauma system by providing effective care for patients with minor and moderate injuries. This helps to preserve MTC resources for the care of severely injured individuals.

The Netherlands includes over 17 million inhabitants living on 33,682 square kilometres of land, with approximately 92% of the entire population living in urban areas, being 13th on the list of the most urbanised countries in the world [10]. The Dutch population has good access to emergency care, and approximately 98% of the inhabitants can be taken to an MTC within 90 minutes. Dutch standards mandate that an ambulance must arrive at the incident scene within 15 minutes. Furthermore, emergency departments (EDs), regardless of their level of trauma care, need to be located in such a manner that an ambulance can deliver a patient to a hospital ED within 45 minutes after the emergency call [11]. Consequently, a relatively large number of EDs, mainly non-MTCs, are dispersed over the Netherlands (Fig. 1). To direct the severely injured patient directly to an MTC, it is rather likely that a non-MTC has to be bypassed.

To assist patient triage to the appropriate level of care, the Dutch national protocol of ambulance services has a trauma field triage decision scheme. The triage criteria include vital signs, injury type, and the mechanism of injury and are largely based on the Field Triage Decision Scheme of the American College of Surgeons Committee on Trauma [8]. In severe trauma, one of the four 24/7 Dutch mobile medical teams (MMTs) and two German MMTs (for the border regions) can be dispatched to provide prehospital on-scene medical assistance. The MMT doctor (a specially trained trauma surgeon or anaesthesiologist) decides on hospital triage and often accompanies the patient during transport to the hospital in the ambulance. Air medical transport does not often occur in the Netherlands.

This study evaluates to what degree Dutch trauma networks succeed in centralising the treatment of severely injured patients (ISS >15) at MTCs and non-severely injured (ISS 1-15) patients at non-MTCs. Specifically, we were interested in factors associated with the direct transport of severely injured patients by emergency medical services to an MTC, including MTC transport times as well as patient and trauma characteristics.

Methods

Patients

For this study, we included all patients reported to the Dutch National Trauma Registry (DNTR) for the hospital admission years 2015-2016. The DNTR inclusion criteria were treatment at the ED within 48 hours after the trauma, followed by direct admission, transfer to another hospital, or death at the ED. Patients without signs of life upon arrival at the ED were excluded [12].

The DNTR dataset includes the Utstein template items for uniform reporting of data following major trauma [13]. Injuries are coded according to the 2008 update of the Abbreviated Injury Scale (AIS) [14]. Severely injured patients were defined as patients with an Injury Severity Score >15 [15].

Primary and MTC definitive care

For the analyses on the primary disposition of injured patients, interfacility transfers were excluded. For the calculations of the percentage of severely injured patients with definitive MTC care, we have added the severely injured patients transferred from another hospital to an MTC to the numerator. We assumed that (the vast majority of) these severely injured patients were transferred from a non-MTC to receive a higher level of trauma care at the MTC.

Trauma network characteristics and prehospital transport times

The population and the amount (square kilometres) of land area (excluding rivers and lakes) within the 11 trauma networks were calculated based on the statistics per four-digit postal code published by Statistics Netherlands (CBS). Moreover, the availability of MTC care within one hour was calculated for Dutch inhabitants

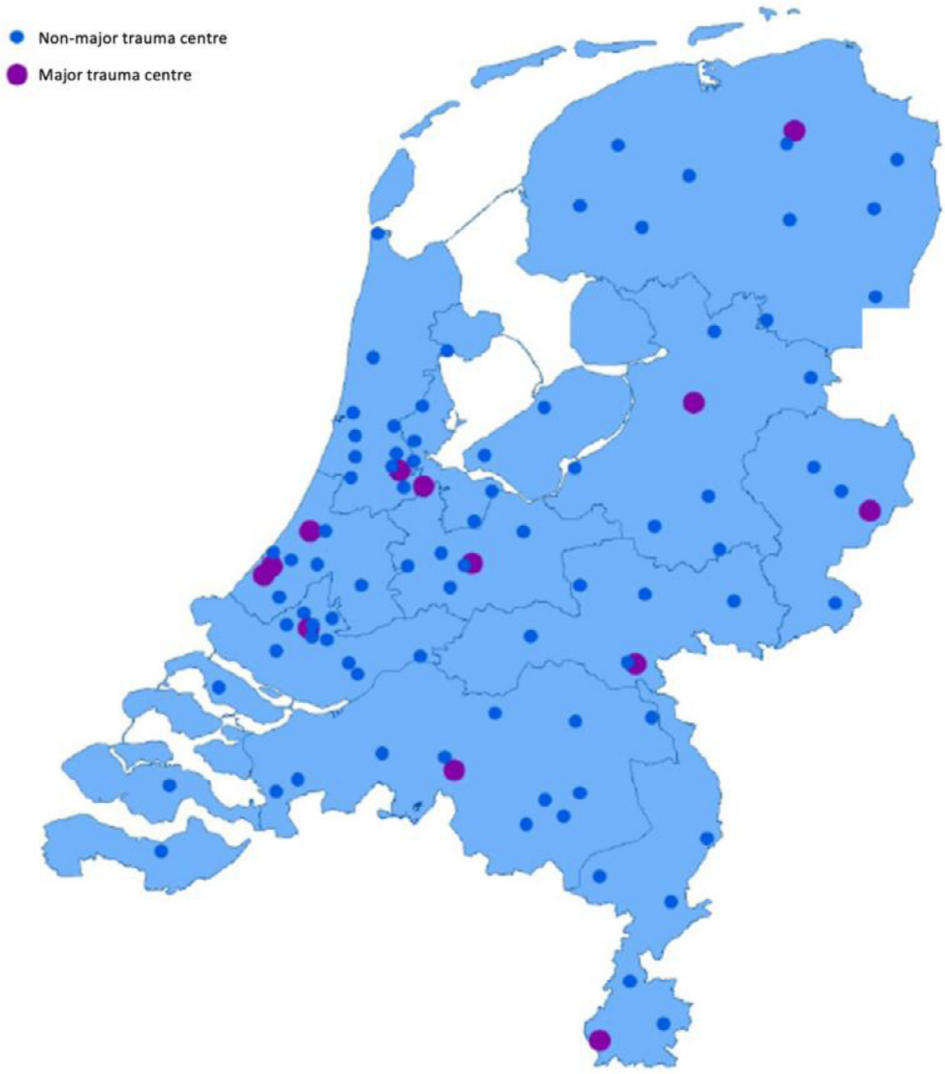

Fig. 1. Dutch trauma receiving hospitals and their distribution within the trauma network

based on their home address postal codes and was displayed in time intervals of 10 minutes.

The Dutch National Institute for Public Health and the Environment applied an ambulance driving time model to calculate the population-weighted mean transport time by ground ambulance (GEMS) to the MTC per trauma network. This model is based on measurements of actual driving times of ambulances 'using lights and sirens' throughout the Netherlands. This model was also applied to calculate the ground ambulance transport times for ISS >15 patients from the injury location (four-digit postal code) to the closest MTC and non-MTC. The additional transport time to the closest MTC was computed by subtracting the transport time from the injury location to the closest MTC from the transport time to the closest non-MTC; if the difference was positive, the MTC was the closest hospital.

Data analysis

Descriptive statistics were used to summarise the data. Differences between proportions were analysed using $\chi 2$ tests for categorical variables. Pearson's correlations were calculated to determine the relationship between the trauma network's percentage of ISS >15 patients with direct MTC care and the trauma network's mean population-weighted transport time to the MTC and the number of non-MTC hospitals.

A multivariable logistic regression analysis was used to determine which factors are associated with a severely injured patient's direct EMS transport to an MTC. The following patient characteristics were included: age; sex; injury cause; the type of injury; severe (AIS ≥4) injury of the head, spine, thorax, abdomen, lower extremity and external body regions; and ISS. Furthermore, we included the additional GEMS transport time to the closest MTC. Missing data were imputed with multiple imputations (5 imputation cohorts). Injury cause, the type of injury, and/or additional transport time were missing for 44.9% of the patients. We compared results without and with the imputation of missing values. The multiple imputations and multivariable regression analyses were conducted in R with the lme4 package [16,17]. A p-value <0.05 was considered statistically significant.

Results

The DNTR consisted of 165,847 patients in 2015 and 2016. A total of 1,843 (1.1%) of these patients were excluded due to missing ISS scores. Furthermore, 7,759 (4.7%) patients who were transferred from another hospital were excluded from the analyses on the primary distribution of the patients as well as for the num-

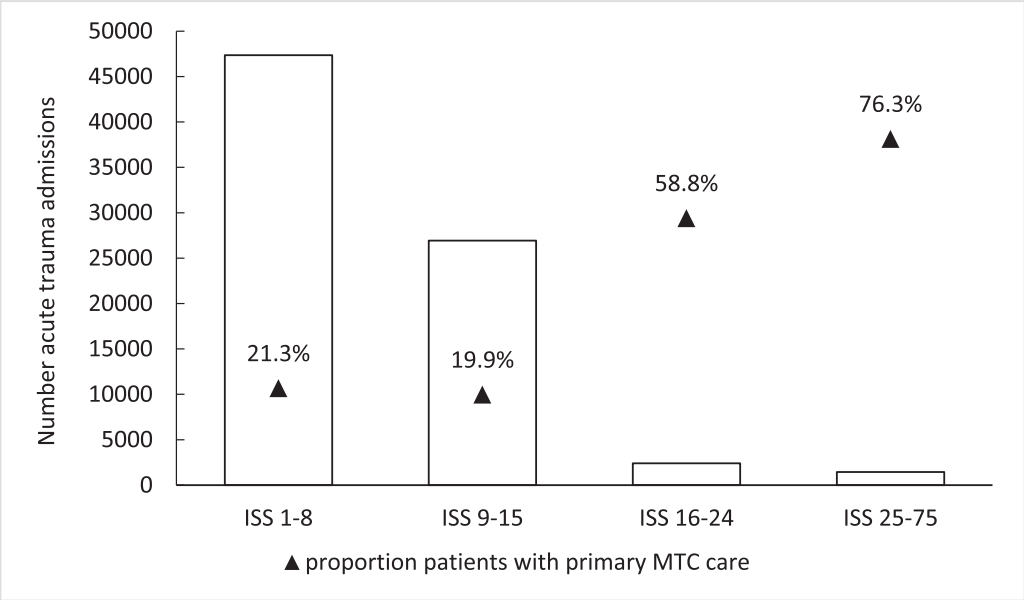

Fig. 2. Annual number of acute trauma admissions in the Netherlands and percentage with primary MTC care vs. injury severity

Table 1
Number of Dutch inhabitants and their transport times to the nearest major trauma centre.

Transport time (minutes)	Number of inhabitants (x1000)	Cumulative (%)
0 – 10	3532	21.1
10 – 20	5739	55.3
20 – 30	4272	80.7
30 – 40	2044	92.9
40 – 50	670	96.9
50 – 60	166	97.9
> 60	352	100.0

ber of trauma admissions per trauma network and on a national level. This resulted in an annual average of 78,123 acute trauma admissions in the Netherlands, giving an incidence rate of 457 per 100,000.

Fig. 1 illustrates the geographical layout of the Netherlands and the distribution of MTCs and non-MTCs within the 11 trauma networks. In the Netherlands, just over half of the Dutch people can reach an MTC within 20 minutes, and 80% can reach an MTC within 30 minutes (Table 1). Approximately 2% of Dutch inhabitants cannot reach a level one trauma centre within 1 hour.

Fig. 2 shows the ISS distribution and the percentage of patients with direct MTC care. The more severely injured patients are more often treated at MTCs. Overall, an annual average of 3,842 (4.9% of all acute trauma admissions) patients were severely injured, with an ISS >15. Almost two-thirds of these patients (65.4%) received primary MTC care.

Table 2 describes the trauma network characteristics, including the annual number and primary distribution of injured patients. The 11 Dutch trauma networks differ in terms of land area (range 1,216 - 8,001 sq. km), population to be served (range 756,920 - 2,512,320), the population-weighted mean GEMS transport times to the MTC (range 9.6 - 28.7 minutes), and the number of hospitals (range 4 - 15). Large variations between the networks were observed in the number and distribution of patients to MTC and non-MTC hospitals. The degree to which the trauma network succeeded in providing direct MTC care for severely injured patients ranged between 36.8% and 88.4%.

Shorter population-weighted mean GEMS transport times to the MTC within the trauma network, as a metric of MTC access per trauma network, were significantly correlated with higher percentages of severe injuries with direct MTC care (Fig. 3) (Pearson correlation -0.753, p=0.007). The number of non-MTC hospitals per trauma network was not significantly correlated with the percentage of severely injured patients receiving direct MTC care (Pearson correlation -0.100, p=0.770).

Factors associated with direct EMS transport of severely injured patients to an MTC

Most (87.6%) of the severely injured patients were transported by ambulance to the hospital. An additional 3.1% were transported by helicopter. Furthermore, 5.3% of the severely injured patients came by their own transportation means and did not receive EMS treatment at the scene. Finally, for 3.9% of the severely injured patients, the transportation mode was not recorded.

The MMT provided assistance for 25.0% of the ISS >15 patients (ISS 16-24: 16.8%; ISS 25-75: 38.6%). Almost all ISS >15 patients with MMT care were directly triaged to an MTC (93.4%). Only 12.6% of the patients who received MMT care were transported by helicopter.

The incident location (four-digit postal code) was registered in the DNTR for 4,174 (59.9%) ISS >15 patients transported by EMS. Fig. 4 shows that longer ground transport times resulted in lower percentages of severely injured patients directly transported to an MTC. Overall, the most severely injured patients with an ISS >24 were more often directly transported to an MTC than severely injured patients with an ISS 16-24; this finding was also true in cases of longer transport times.

An MTC was the closest hospital for 26.8% of the ISS >15 patients with a recorded incident location. Almost all these patients were directly transported to an MTC (93.6%). If a non-MTC was the closest hospital, EMS decided to bypass this hospital and transport the patients directly to an MTC for 62.1% of the ISS >15 patients.

Table 3 shows that the severely injured patients with direct EMS transport to MTCs differed from their counterparts with direct EMS transport to a non-MTC in all patient and injury characteristics. Multivariable regression analysis (Table 4) demonstrated that females, older patients, patients with severe injuries of the thorax

Table 2
Dutch trauma network characteristics and patient distribution.

Trauma network	Inhabitants	Land area (km^2)	Non-MTCs	MTCs	Population-weighted mean GEMS transport time to MTC (min)	Annual number of trauma admissions						
						Total n	ISS 1-15 n	ISS 1-15 primary MTC care n	%	ISS >15 n	ISS >15 primary MTC care n	%
TN 1	756,920	2094	3	1	15.2	3649	3435	1590	(46.3)	214	160	(74.8)
TN 2	1,096,795	3674	6	1	20.0	5463	5236	1643	(31.4)	227	128	(56.4)
TN 3	1,117,330	2146	5	1	25.3	6036	5729	1152	(20.1)	307	113	(36.8)
TN 4	1,290,450	2547	5	1	22.7	7030	6619	954	(14.4)	411	291	(70.8)
TN 5	1,364,500	2098	9	1	21.6	6124	5922	774	(13.1)	202	148	(73.3)
TN 6	1,392,305	1640	5	1	14.2	4945	4545	890	(19.6)	400	282	(70.5)
TN 7	1,665,030	8001	10	1	28.7	7713	7356	894	(12.2)	357	198	(55.5)
TN 8	1,852,490	1979	9	1	18.7	8531	8192	1249	(15.2)	340	224	(65.9)
TN 9	1,866,735	1216	6/7†	3	9.6	7421	6980	3348*	(48.0)	441	390**	(88.4)
TN 10	2,164,815	3383	14	1	23.1	9543	9021	956	(10.6)	522	352	(67.4)
TN 11	2,512,320	4903	11	1	26.0	11670	11247	2017	(17.9)	423	229	(54.1)
NL	17,079,690	33,681	83.5	13	20.9	78,123	74,281	15,464	(20.8)	3842	2,511	(65.4)

Abbreviations: TN, Trauma network; ISS, Injury Severity Score; MTC, Major trauma centre.
* total number of ISS 1-15 patients treated at three MTC hospitals.
** total number of ISS >15 patients treated at three MTC hospitals.
† one ED of a non-MTC was closed in 2016.

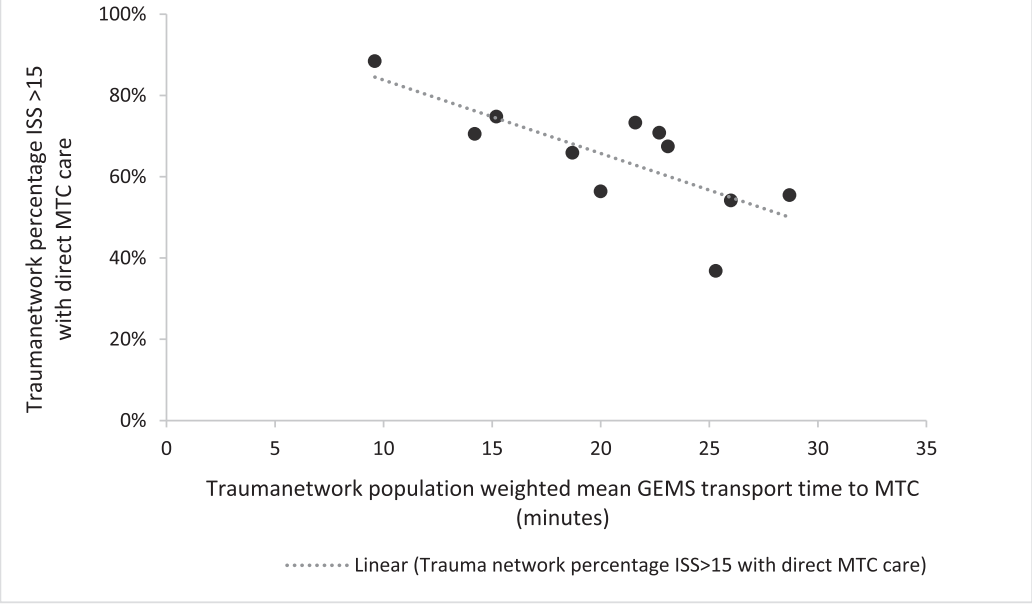

Fig. 3. Trauma network percentage of severely injured with primary MTC care vs. MTC access

and abdomen, patients injured due to ground-level falls, and patients with longer additional transport times to the closest MTC were less likely to be transported directly to an MTC. Patients injured due to a road traffic accident or a high-level fall were more likely to be directly transported to an MTC. Additionally, higher ISS scores, penetrating injuries, and severe head or spine injuries were associated with a higher proportion of direct EMS transport to an MTC.

Definitive MTC care for severely injured patients

The MTCs recorded a total of 840 severely injured patients who were secondarily transferred into the MTC within 48 hours after the incident. Following the assumption that these patients were transferred from non-MTC hospitals, almost one-third (31.6%) of the severely injured patients initially treated at a non-MTC did receive definitive MTC care (trauma network range 7.8%-59.3%). This eventually resulted in 76.3% of all severely injured patients receiving MTC treatment within 48 hours after the incident (trauma network range: 43.6% - 93.2%). The percentage of severely injured patients with secondary triage to the MTC within the trauma network was not correlated with MTC access in terms of the trauma network population-weighted mean transport time (Pearson r=0.369; p=0.264).

Discussion

Our study reveals that even in a highly urbanised country such as the Netherlands with good access to emergency care, one-third of all severely injured patients do not receive primary MTC care. This rate is comparable to multiple retrospective studies on the undertriage of severely injured patients in the United States [18–22]. A systematic review of prehospital trauma triage systems reported undertriage percentages for severely injured patients ranging between 1% and 68% [23]. A recent meta-analysis found an evident association between the level of trauma care and in-hospital mortality for major trauma patients. Unfortunately, this meta-analysis included only two European studies, which leaves the levels of undertriage in Europe relatively unattended [24]. Therefore, correct and early identification of severely injured patients in the field is

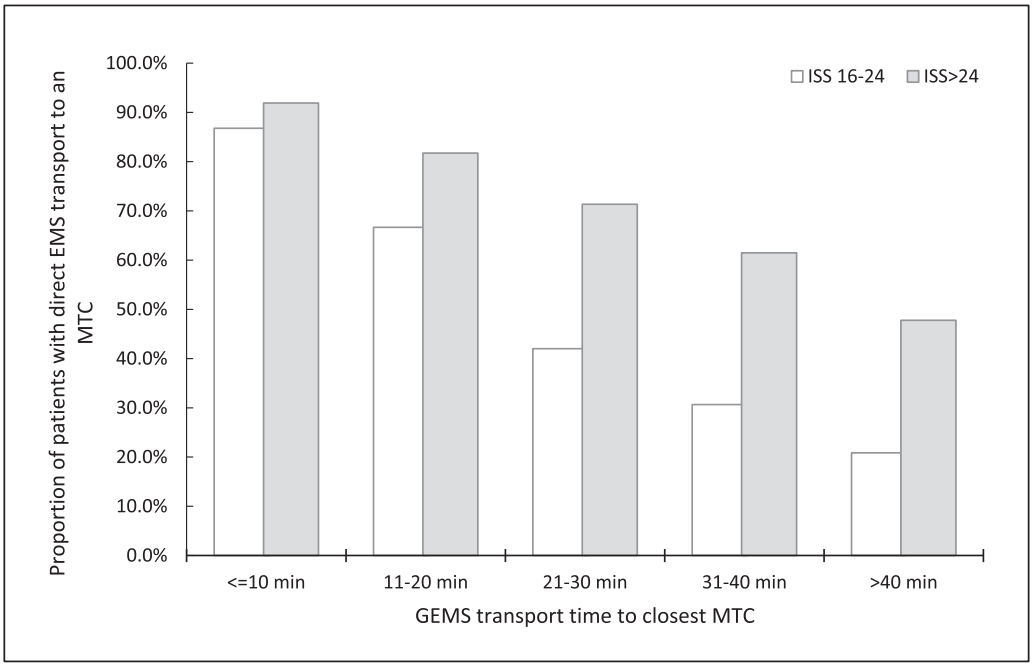

Fig. 4. Percentage of severely injured patients directly transported to an MTC versus GEMS transport time to the closest MTC

Table 3
Characteristics of severely injured patients with direct EMS transport to non-MTCs vs. MTCs.

	Non-MTC(n=2121)		MTC(n=4852)		Univariate
	n	(%)	n	(%)	p-value
Sex					<0.001
male	1284	(60.5)	3267	(67.3)	
female	837	(39.5)	1585	(32.7)	
Age					<0.001
0-54 y	699	(33.0)	2488	(51.3)	
55-69 y	499	(23.5)	1107	(22.8)	
70-84 y	592	(27.9)	955	(19.7)	
> 84 y	331	(15.6)	302	(6.2)	
Injury mechanism					<0.001
low-energy fall	606	(28.6)	887	(18.3)	
motor vehicle accident	126	(5.9)	649	(13.4)	
other RTA	487	(23.0)	1564	(32.2)	
high-energy fall	193	(9.1)	831	(17.1)	
other accident	206	(9.7)	662	(13.6)	
unknown	503	(23.7)	259	(5.3)	
Type of injury					<0.001
blunt	1809	(85.3)	4654	(95.9)	
penetrating	30	(1.4)	170	(3.5)	
unknown	282	(13.3)	28	(0.6)	
Severity of injury					<0.001
head AIS≥4	759	(35.8)	2081	(42.9)	
spine AIS≥4	79	(3.7)	272	(5.6)	
lower extremity AIS≥4	99	(4.7)	241	(5.0)	
thorax AIS≥4	325	(15.3)	718	(14.8)	
abdomen AIS≥4	136	(6.4)	277	(5.7)	
external AIS≥4	77	(3.6)	220	(4.5)	
ISS					<0.001
ISS 16-24	1549	(73.0)	2694	(55.5)	
ISS 25-75	572	(27.0)	2158	(44.5)	
Additional transport time to closest MTC					<0.001
≥0 min	90	4.2	1174	24.2	
1-10 min	341	16.1	1049	21.6	
11-20 min	345	16.3	491	10.1	
>20 min	455	21.5	229	4.7	
unknown	890	42.0	1909	39.3	

Abbreviations: RTA, Road traffic accident; AIS, Abbreviated Injury Score; ISS, Injury Severity Score; MTC, Major trauma centre; non-MTC, non-major trauma centre.

Table 4
Factors associated with direct EMS transport of severely injured patients to MTCs.

	Multivariate logistic regression model		
	Adjusted OR (95%CI)		p-value
Sex			
male	ref		
female	0.851	(0.746 - 0.971)	0.017
Age			
0-54 y	ref		
55-69 y	0.662	(0.563-0.778)	<0.001
70-84 y	0.422	(0.357-0.500)	<0.001
> 84 y	0.264	(0.209-0.334)	<0.001
Injury mechanism			
low-energy fall	ref		
motor vehicle accident	4.261	(3.333-5.448)	<0.001
other RTA	2.120	(1.788-2.512)	<0.001
high-energy fall	2.791	(2.274-3.426)	<0.001
other accident	1.793	(1.393-2.308)	<0.001
Type of injury			
blunt	ref		
penetrating	1.712	(1.089 - 2.693)	0.020
Severity of injury			
head AIS≥4	1.386	(1.183-1.623)	<0.001
spine AIS≥4	1.589	(1.160-2.177)	0.004
lower extremity AIS≥4	1.072	(0.793-1.449)	0.650
thorax AIS≥4	0.703	(0.583-0.848)	<0.001
abdomen AIS≥4	0.505	(0.382-0.667)	<0.001
external AIS≥4	0.779	(0.535-1.133)	0.191
ISS			
ISS 16-24	ref		
ISS 25-75	2.642	(2.268 - 3.078)	<0.001
Additional transport time to MTC			
≥0 min	ref		
1-10 min	0.247	(0.205-0.297)	<0.001
11-20 min	0.085	(0.070-0.104)	<0.001
>20 min	0.029	(0.023-0.036)	<0.001

Abbreviations: RTA, Road traffic accidents; AIS, Abbreviated Injury Score; ISS, Injury Severity Score; MTC, Major trauma centre.

of foremost importance in getting the ISS >15 patients to the MTC the first time.

Compared with other triage protocols, the Dutch triage scheme has shown relatively poor accuracy in identifying severely injured patients [25–27]. Previous studies indicated that the Dutch triage scheme correctly identified approximately one-third of ISS >15 patients [25,26]. Although large differences were observed between trauma networks, a far larger percentage of ISS >15 patients were directly transported to an MTC. Consequently, it seems that the ambulance paramedics outperformed the triage protocols in appraising the potential benefit of trauma centre care for injured patients. This stems from the inaccuracy of field triage tools in predicting post hoc injury severity scoring, such as the ISS, which limits the triage performance metrics [28]. The ISS is widely implemented and therefore of interest for many; however, it should not be used as a system goal but rather as a benchmark to compare networks and performance over time or to calibrate new triage decision tools.

Our results point towards the following injury and patient characteristics associated with prehospital undertriage of ISS >15 patients: female sex, older age, ground-level falls, severe thoracic or abdominal trauma, and lower injury severity scores. These factors have also been mentioned in studies across multiple countries [23]. Improving the identification of high-risk elderly patients has gained interest from the perspective of the ageing population [29]. Older trauma patients differ from younger patients: they can incur life-threatening injuries from low-velocity mechanisms, they have a higher prevalence of comorbid conditions, they take more medications, and they have different physiological responses to injury [29,30]. Innovations are needed to improve triage accuracy and may include novel physiological measurement or diagnostic technologies [25]. Attention needs to be directed towards prehospital health-care providers' education and feedback loops regarding their decision-making [31,32].

In addition to identifying severely injured patients, other factors, such as the distance to the MTC, may play an important role in triage decision-making. With long travel times to an MTC in remote and rural areas, severely injured patients may be transported first to a non-MTC hospital for initial management and subsequently transferred to an MTC. However, the Netherlands is a small, flat, and densely urbanised country with a very dense road and motorway network [33,34]. Areas within 30 minutes of driving proximity to level one or two trauma centres are generally considered urban [31,35]. The Dutch National Institute for Public Health and the Environment has estimated that, on average, within 30 minutes, 81% of the Dutch population can be transported by ground ambulance to an MTC [36]. Given the good access to MTC care in the Netherlands, it is not to be expected that many severely injured patients will be transported to a non-MTC for initial stabilisation. This assumption is supported by our finding that the most severely injured patients (with a higher risk of deterioration of vital signs and haemodynamic instability) were more often directly transported to an MTC, even in the case of longer transport times. Moreover, the mean population-weighted GEMS transport times to the MTC of the trauma networks were not correlated with higher secondary transfer rates of severely injured patients. Nevertheless, an important factor that needs to be further investigated is the growing demand for ambulance services and shortages of paramedics in the Netherlands. This may affect paramedics' choice for a destination hospital during field triage because a longer travel distance impacts ambulance service availability.

To overcome long travel times due to large distances to the MTC or traffic problems, more frequent MMT support and transport may be considered. Two Dutch studies on the impact of on-scene MMT assistance among severely injured patients showed an odds ratio for survival of approximately two in favour of those aided by MMT [37,38]. This beneficial effect of MMT assistance is likely to originate from the additional expertise and therapeutic options in airway management brought to the scene. Further optimisation of on-scene assistance could simultaneously increase the number of severely injured patients with primary MTC care when MMT physicians decide to transport the patient by helicopter. A study by Mommsen showed a significant decrease in transportation time in cases of multiple trauma, traumatic brain injury and burn injuries; therefore, it was suggested that parallel dispatching of helicopter emergency medical and ambulance services should be considered if the flight distance is more than 35-40 km [39]. However, to date, helicopter transport is not a common practice in the Netherlands. Only the northern Wadden Islands are covered by a routine helicopter ambulance service.

This study shows substantial variability in the percentage of severely injured patients with primary MTC care within the trauma networks. Additionally, we found differences between the trauma networks in the degree to which severely injured patients were secondarily transported to an MTC and the percentage of severely injured patients with definitive care at the MTC. Together, these findings point towards a variation in transfer practices and reveal an important area of improvement. Guidelines for transferring trauma patients between institutions are an essential part of the trauma system [8]. There are no uniform criteria for transfer from a non-MTC to an MTC based on the patients' needs in the Netherlands. These criteria need to be developed, and appropriate training of emergency department physicians at non-MTCs may be essential.

The initial designation of the Dutch MTC was meant to result in the centralisation of care for severely injured patients at the MTCs.

However, in the current situation, most Dutch MTCs do not meet the volume requirements of at least 240 yearly trauma admissions with an ISS above 15. Furthermore, depending on the geographical location of an MTC hospital, e.g., centralised in a large city without a non-MTC close by, significant numbers of patients with minor injuries could ultimately be treated at the MTC. Most likely due to insufficient numbers of patients, previous work from the Netherlands has been unsuccessful in showing convincing evidence of a difference in mortality between severely injured patients treated at an MTC and those treated at a non-MTC [26,40]. Moreover, this seemingly inevitable overtriage can have adverse effects on system performance through the overuse of limited resources within the MTC infrastructure and increased costs. One of the priorities in trauma system development has been to minimise the potential delays in definitive care and the risk of morbidity and mortality to individual patients [41]. To secure further concentration of severely injured patients and efficient use of resources, one may think of introducing alternative services for less severely injured patients for whom the MTC is the nearest hospital.

An important strength of our study is that the Dutch trauma registry has national coverage, records all acute trauma admissions, and includes prehospital data. Because all hospitals participate in the Dutch trauma registry and it has broad inclusion criteria, we were able to evaluate patient distribution on a national level and benchmark trauma networks.

Our analysis also has several limitations, including the retrospective design and missing data. Retrospective evaluations of system triage performance should always be interpreted with caution. Because actual triage decisions are governed by clinical guidelines and limited information, triage performance is evaluated using definitions with complete information. For example, an ISS >15 was used as a criterion to define severe injury, but it cannot be measured on the scene. We attempted to mitigate the missing data for the regression analysis by using multiple imputations. Another limitation is that for the transferred patients, the referring hospital was unknown. We made the assumption that severely injured patients transferred to an MTC were referred from a non-MTC. Some of these transfers may have been between MTCs, but we expected this to be only a very small proportion. However, this may have resulted in a slight overestimation of definitive MTC care for severely injured patients. To follow a patient closely through the care chain, a personal pseudonymised identification number and Dutch legislation record are needed. An additional limitation of our data analyses is that for the calculations of the GEMS transport times to the closest MTC and non-MTC hospitals, we did not include weather conditions or rush-hour conditions (i.e., traffic congestion), which can impact the transport times. Finally, for the evaluation of 'getting the patient to the right place at the right time', it is essential to be able to identify severely injured patients in need of MTC care. In this study, we chose to define severely injured patients requiring MTC care as patients with an ISS >15. These patients have been shown to have better outcomes after MTC treatment [5]. Moreover, an ISS >15 is the most common measure applied in trauma triage evaluation studies to identify patients in need of trauma centre care [23]. However, the ISS >15 criterion may misclassify several injured persons requiring or perhaps not requiring critical trauma resources [42]. It is possible that to define patients who need MTC care and have a high risk of morbidity and a low survival probability, anatomic injury severity (determined with the AIS) should be a criterion, and pathological conditions such as those included in the 'Berlin polytrauma definition' should be taken into consideration [43]. This definition includes not only anatomic injury severity (i.e., significant injuries in two or more different anatomic AIS regions) but also pathological conditions (e.g., hypotension, unconsciousness, acidosis, coagulopathy, and age).

Conclusion

Despite the facts that the Dutch trauma system was implemented twenty years ago and the Netherlands is a highly urbanised country with good access to MTC care, approximately one-third of severely injured patients are not primarily managed at an MTC. Although a system-wide prehospital triage tool is used, large differences were observed among regional trauma networks in the transportation of severely injured patients directly or secondarily to the MTC.

This study revealed that, in addition to patient and injury characteristics, the distance to the MTCs is of great importance. Healthcare providers and policymakers need to prioritise the improvement of the prehospital primary and secondary triage of severely injured patients. Their efforts should focus on improving field triage, the awareness of factors that affect undertriaging, interfacility transfer guidelines, and the provision of resources to overcome longer transport times to an MTC.

Authorship

Sturms, van Klaveren and Kommer performed the data analysis.

Interpretation of the data and drafting of manuscript: Sturms, Driessen, van Klaveren, ten Duis, Poeze, Leenen, de Jongh.

All authors participated in critically reviewing the final manuscript.

Disclosures

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