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Use of Helicopters to Reduce Health Care System Delay in Patients With ST-Elevation Myocardial Infarction Admitted to an Invasive Center

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Timely reperfusion in ST-elevation myocardial infarction (STEMI) is essential. This study aimed to evaluate the reduction in system delay (time from emergency medical service [EMS] call to primary percutaneous coronary intervention [PPCI]) in patients with STEMI when using helicopter EMS (HEMS) rather than ground-based EMS (GEMS). This was a retrospective, nationwide cohort study of consecutive patients with STEMI treated with PPCI at 5 PPCI centers in Denmark. Polynomial spline curves were constructed to describe the association between system delay and distance to the PPCI center stratified by transportation mode. A total of 26,433 patients with STEMI were treated with PPCI between January 1, 1999, and December 31, 2016. In 16,436 patients field triaged directly to the PPCI center, the proportion treated within 120 minutes of the EMS call was 75% for those living 0 to 25 km from the PPCI center compared with 65% for all patients transported by GEMS (median transport distance 50 km [interquartile range 23 to 90]) and 64% for all patients transported by HEMS (median transport distance 119 km [interquartile range 99 to 142]). The estimated reduction in system delay owed to using HEMS rather than GEMS was 14, 16, 20, and 29 minutes for patients living 75, 100, 125, and 170 km from a PPCI center. In conclusion, this study confirmed that using HEMS ensures that most patients with STEMI, living up to 170 km from a PPCI center, can be treated within 120 minutes of their EMS call provided they are field triaged directly to the PPCI center. **(Am J Cardiol 2022;171:7−14)**

In patients with ST-elevation myocardial infarction (STEMI), primary percutaneous coronary intervention (PPCI) is recommended in preference to fibrinolysis, provided it can be performed within 120 minutes after diagnosis.[1] In Denmark, PPCI has been the recommended national reperfusion strategy since 2003.[2,3] Rather than establishing multiple PPCI centers, a centralized strategy has prevailed with field triage directly to high-volume PPCI centers bypassing local hospitals.[2,4] Centralization has increased travel distances and time to specialized treatment for citizens in sparsely populated areas of Denmark.[5] To counterbalance this, preceded by pilot studies in May 2010, a national helicopter emergency medical service (HEMS) was implemented from October 2014. However, the efficacy and benefit of HEMS in STEMI remain uncertain. The present study aimed to evaluate the association between distance to PPCI center and system delay in patients with STEMI transported by HEMS compared with ground-based emergency medical service (GEMS) and to describe the potential reduction in system delay achieved by field triage and direct transport to a PPCI center with HEMS compared with GEMS for patients living in rural areas.

Methods

This was a multicenter, observational, retrospective nationwide study conducted from January 1, 1999, to December 31, 2016. A total of 4 centers performed PPCI in

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See page 13 for disclosure information.

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the entire study period (Aalborg University Hospital, Aarhus University Hospital, Odense University Hospital, and Copenhagen University Hospital). One center (Gentofte University Hospital) performed PPCI from study start until June 1, 2011 (Supplementary 1). The study was approved by the Danish Data Protection Agency (reference 2012-41-1289). In Denmark, register-based research requires neither informed consent nor approval from the National Committee on Health Research Ethics.

This study included all consecutive patients with STEMI transported by either HEMS or traditional GEMS and treated with PPCI at a Danish PPCI center within 12 hours of symptom onset. Patients with a system delay >6 hours, self-presenters, and patients without emergency medical service (EMS) data were excluded. Patients were stratified into time periods defined as before and after HEMS implementation (historical and contemporary group) and the estimated transport distance from the scene of the event to the PPCI center by ground transportation. Distance was estimated based on Google Maps by calculating the ground distance from the scene of the event to the nearest PPCI center.

The historical control group comprised 13,596 patients with STEMI transported by GEMS from January 1, 1999, to April 30, 2010, and has been described previously.[3]

The Danish EMS consists of a basic tier of ambulances (GEMS) and a second tier of physician-staffed prehospital critical care teams that are either ground-based or helicopter-based. GEMS ambulances are staffed by paramedics or medical technicians. Mobile emergency care units are staffed by paramedics and an anesthesiologist. The HEMS crew comprises an experienced prehospital-trained anesthesiologist, a paramedic, and a pilot. Regional emergency medical coordinating centers are responsible for the dispatch of all prehospital units and use a criteria-based dispatch system (Danish Index for Emergency Medical Dispatch).[6] In cases of suspected acute STEMI, GEMS ambulances and mobile emergency care units are dispatched routinely. HEMS are dispatched if the estimated distance to the PPCI center is >75 km or if the patient resides on an island. The Danish EMS and dispatch protocols were described in detail in previous studies.[6–9]

On May 1, 2010, a daytime visual flight rule HEMS operating from sunrise until sunset was launched in the Eastern part of Denmark. On June 1, 2011, a second 24 to 7 special visual flight rule and instrument flight rule, HEMS was launched in the Western part of Denmark. A third HEMS was launched October 1, 2014 and located in the Southern part of Denmark.

The study population was identified based on diagnostic codes for STEMI registered in the Western Denmark Heart Registry and the Patient Analysis & Tracking System used in Eastern Denmark and cross-referred with the Danish National Patient Registry. The Western Denmark Heart Registry comprises data on baseline characteristics and all invasive cardiac procedures from Aalborg University Hospital, Aarhus University Hospital, and Odense University Hospital. In Eastern Denmark, the patient analysis & tracking system previously collected data on all invasive cardiac procedures from Gentofte University Hospital and Copenhagen University Hospital. Prehospital data were identified from the EMS logistic systems. The national HEMS organization provided detailed HEMS mission data.

The primary outcome was the proportion of patients field triaged and treated within 120 minutes of EMS call when using GEMS compared with HEMS stratified by distance to the center. Secondary outcomes included the estimated time reduction in relation to distance and regional variances when comparing GEMS with HEMS.

Categorical variables are presented as numbers or percentage and compared using the chi-square test. Continuous variables are presented as mean and SD if normally distributed and as median with interquartile range (IQR) in case of skewed data. A second-order polynomial regression analysis (quadratic) was performed to evaluate the association between transportation distance and system delay in 3 groups of patients: (1) transported by GEMS before HEMS was introduced (GEMS historical 1999 to April 2010), (2) transported by GEMS after HEMS was introduced (GEMS contemporary May 2010 to 2016), and (3) transported by HEMS (May 2010 to 2016). Statistical tests were conducted using STATA/IC Statistical Software Version 16.0 for Mac (College Station, Texas. StataCorp LLC.).

Results

Between January 1999 and December 2016, a total of 79,812 patients with STEMI were admitted to the hospital (Figure 1). In these patients, 22,107 (28%) were treated locally, mainly with fibrinolysis in previous years, and 33,887 (43%) were transported to an invasive center. Self-presenters, patients with missing data on coronary angiography, and patients with missing prehospital GEMS and HEMS triage data were excluded. The proportion of patients field triaged directly to an invasive center increased from 16% (603 of 3,690) in 1999 to 68% (2,789 of 4,133) in 2016 (Figure 2). The number of patients transported by HEMS increased from 56 patients in 2010 to 325 patients in 2016 (Figure 2).

A total of 26,433 patients with STEMI with a mean age of 65 ± 13 years (73% male) were admitted to a PPCI center and received PPCI within 6 hours (Table 1). During the study period, 10,012 of 15,401 patients (65%) were field triaged and treated within 120 minutes of first medical contact if transported by GEMS, and 661 of 1,035 (64%) if transported by HEMS with related median transport distances of 50 km (IQR 23 to 90) km and 119 (IQR 99 to 142), respectively.

Table 2 lists the distance to the PPCI center, and corresponding outcomes for the entire population field triaged and treated within 6 hours. The rate of field triage to PPCI center was higher in patients living closest to invasive centers. In patients living within 25 km from a PPCI center, 75% received timely reperfusion within 120 minutes of first medical contact and did so at a median system delay of 89 (IQR 72 to 121) minutes. System delay was remarkably higher in patients living >75 km from a center.

Table 3 lists the various delays stratified by distance to a center for different time periods (historical vs contemporary) and according to transport mode (GEMS vs HEMS). The median system delay for patients field triaged to a PPCI center with GEMS contemporary varied from 86

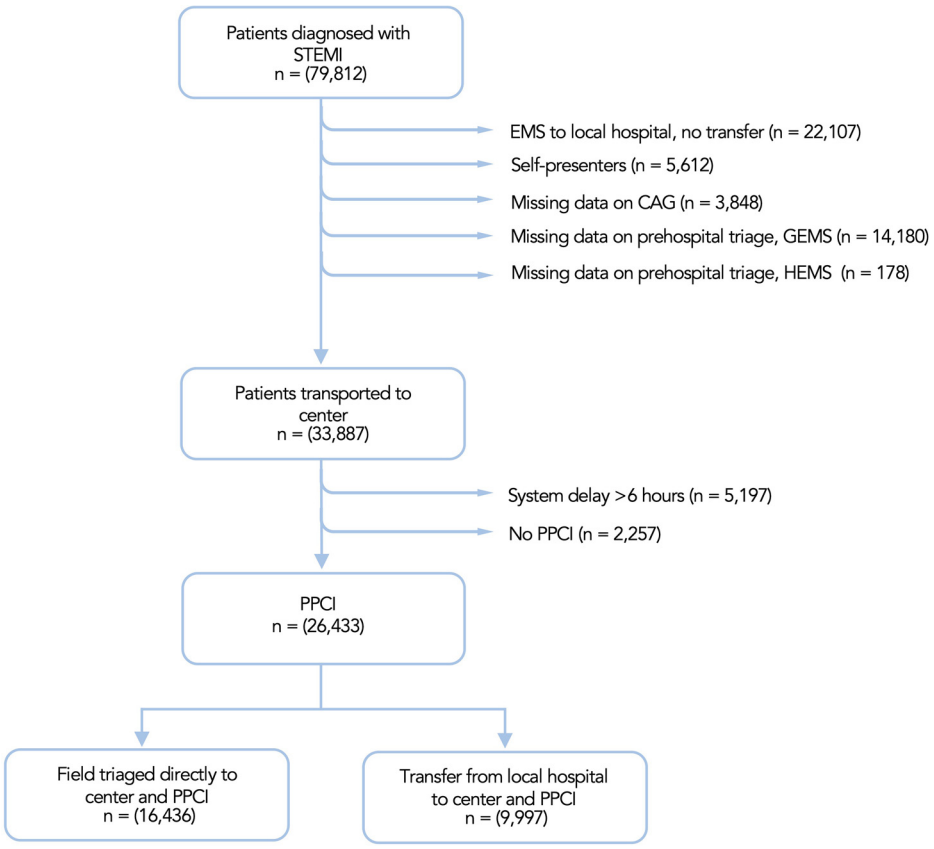

Figure 1. Flow-chart of study population from 1999 to 2016. CAG = coronary angiography.

(IQR 71 to 116) minutes at a distance of <25 km to 141 (IQR 127 to 157) minutes at a distance of 126 to 170 km from the PPCI center.

Results of the primary outcomes are shown in Figure 3. The proportion of patients with a system delay ≤120 minutes when field triaged and transported by GEMS contemporary were 65%, 39%, and 14% at a distance of 76 to 100 km, 101 to 125 km, and 126 to 170 km from the PPCI center, respectively. In patients transported by HEMS, the proportions were 84%, 71%, 49% at a distance of 76 to 100 km, 101 to 125 km, and 126 to 170 km from the PPCI center, respectively.

Regional differences are listed in Table 4. Some regions used HEMS less frequently (39 missions) than others (637 missions) during the study period. The proportion of patients with a system delay ≤120 minutes in the GEMS contemporary period varied from 24% to 71% between regions.

When only focusing on field triaged patients, and using second-order polynomial regression analysis, we found an association between transportation distance (x) to the PPCI center and system delay (Y) of: $Y = 100.66 + 0.2001x + 0.00071x^2$ in patients transported by GEMS contemporary and $Y = 89.18 + 0.189973x + 0.000398x^2$ in patients transported by HEMS (Figure 4). The estimated reduction in system delay when using HEMS instead of GEMS contemporary for patients who were field triaged was 14, 16, 20, 25, and 29 minutes at a transport distance of 75, 100, 125, 150, and 170 km from the PPCI center, respectively.

Discussion

This is the first nationwide multicenter study of patients with STEMI to describe the association between distance to PPCI center and healthcare system delay stratified by mode of transportation in Denmark. The present study confirmed that using HEMS in rural areas enables reperfusion therapy within 120 minutes in most patients living up to 170 km from an invasive center. The proportion of patients achieving timely reperfusion within 120 minutes when living 76 to 100 km, 101 to 125 km, and 126 to 170 km was 65%, 39%, and 14% when transported by GEMS contemporary compared with 84%, 71%, and 49% in patients transported by HEMS. In addition, a remarkable time reduction was achieved using HEMS rather than GEMS for distances >75 km.

In some countries, a growing number of cardiac catheterization laboratories have been established to surmount high regional rates of cardiovascular disease and optimize timely reperfusion for patients with STEMI.[10,11] In Denmark, the STEMI system of care differs from those of other countries as a centralized approach has prevailed.[3,4] However, centralization has caused longer transportation distances for patients living in rural areas with the risk of greater system delay. Conversely, according to our data,

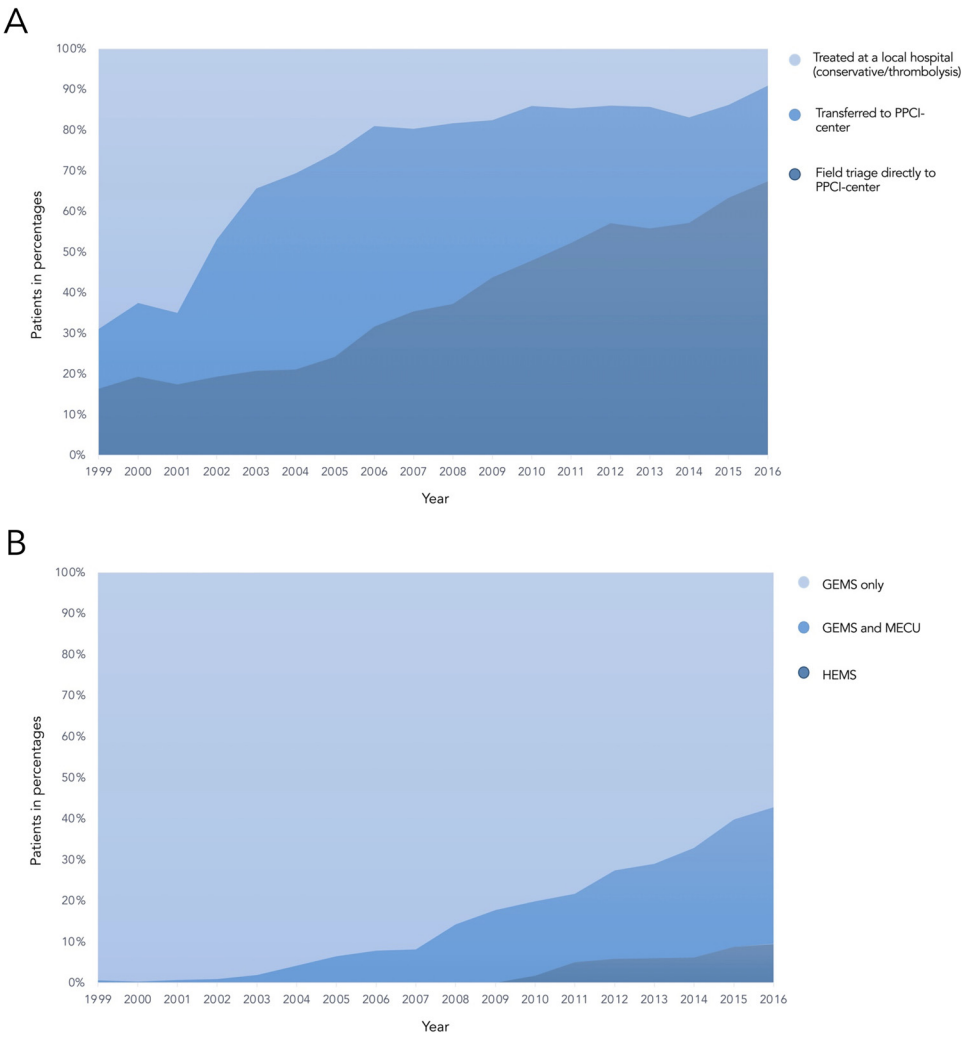

Figure 2. Triage and transport of patients with ST-elevation myocardial infarction. MECU = mobile emergency care unit.

the median system delay in patients living next door to the PPCI center, that is, with a transport distance of 0 to 25 km, was still 89 (72 to 121) minutes, and the benchmark first medical contact to device time of ≤120 minutes was achieved only for 75% in this urban population. Hence, even when living next door to the PPCI center, a system delay of ≤120 minutes for all patients cannot be achieved. Though our study reflects a dedicated focus on optimizing health care system delay over a 20-year period, our results still indicate that there is clearly room for improvement regionally and nationally in triage and rapid transport to the PPCI center.

Similarly, Moens et al[12] reported that 99% of HEMS patients living in rural and suburban areas were admitted directly to a percutaneous coronary intervention (PCI)-capable facility in <90 minutes after the dispatch call as opposed to only 17% with GEMS. In contrast, Hakim et al[13] showed that helicopter transportation of patients with STEMI was 5 times less efficient than ground transportation in admitting the patient within the 90-minutes window. However, most patients included in this study had transfer distances of ≤50 km, and only 2.5% had transport distances exceeding 75 km. In contrast, our study recognizes distance as an essential factor for activating HEMS for STEMI. Our results showed that for distances >75 km, HEMS allowed 64% of the patients to be treated within 120 minutes compared with only 41% of the patients transported by GEMS contemporary. The difference observed was even more prominent with longer distances. Considering the immense difference in transport distance in patients transported by GEMS and HEMS, that is, 47 versus 119 km, HEMS is evidently a prerequisite for achieving minimal system delay in rural areas within a system where PPCI therapy is centralized.

In the overall population of GEMS contemporary and HEMS, we observed a median system delay of 113 (88 to 154) minutes in patients field triaged, which was similar to the 112 minutes reported in the study by McMullan et al[14] and the 110 minutes from first medical contact to PPCI registered in the study by Hakim et al.[13] We have previously addressed the time-saving benefit of telemedicine with prehospital electrocardiogram (ECG) and direct referral for PPCI.[15] The present study confirms this relation, as a notable time-saving was observed by field triage in both

Table 1
Baseline characteristics and delays to reperfusion of patients with ST-elevation myocardial infarction receiving primary percutaneous coronary intervention. Stratified by transportation and time period

Parameter	GEMS historical (1999-Apr 2010) (n = 12,899)	GEMS contemporary (May 2010-2016) (n = 12,282)	HEMS (May 2010-2016) (n = 1,252)	GEMS and HEMS (May 2010-2016) (n = 13,534)
Age (years)	65 ± 13	65 ± 13	64 ± 13	65 ± 13
Men	9,305 (73%)	9,105 (74%)	937 (75%)	10,040 (74%)
Comorbidities				
Diabetes	907 (9%)	1,196 (11%)	141 (13%)	1,337 (11%)
Hypercholesterolemia	1,474 (19%)	2,873 (28%)	268 (26%)	3,141 (28%)
Hypertension	3,259 (33%)	4,227 (40%)	396 (37%)	4,623 (40%)
Previous PCI	706 (8%)	1,283 (12%)	108 (9%)	1,391 (12%)
Previous MI	1,037 (11%)	1,149 (11%)	108 (10%)	1,257 (11%)
Distance to centre (km)	53 [24-93]	47 [20-81]	119 [99-142]	52 [24-96]
Field triage direct to PCI centre	5,466 (42%)	9,935 (81%)	1,035 (83%)	10,970 (81%)
System delay (min)	138 [102-185]	112 [87-157]	116 [100-138]	113 [88-154]
System delay, field triage (min)	106 [81-140]	102 [82-133]	112 [97-130]	103 [84-132]
System delay, no field triage (min)	164 [129-211]	202 [155-261]	141 [120-188]	197 [151-256]
Patients treated within 120 min (field triaged)	3,383/5,466 (62%)	6,629/9,935 (67%)	661/1,035 (64%)	7,290/10,970 (67%)

Values are n (%); mean + SD or median (interquartile range, [IQR]).

System delay = time from first medical contact to PCI; GEMS = ground emergency medical service; HEMS = helicopter emergency service; PCI = percutaneous coronary intervention; MI = myocardial infarction.

transport methods. In the setting of interfacility HEMS transfer of patients with STEMI from a non-PCI hospital to a PCI-capable hospital, the potential benefit of HEMS may be lost because of the time spent on activation and prolonged on-scene delays.[13,14,16] Inter-facility transfer is not associated with timely reperfusion, and reperfusion may be delayed beyond recommendations.[16] Currently, no guidelines address the minimal distance or optimal reduction in system delay for using HEMS. In our study, patients living far from advanced care did achieve a time-saving gain by HEMS transport. Finding the right balance is challenging where time-to-treatment is minimized, and volume standards are maximized. However, achieving this balance is compulsory for continuous optimization of care in patients with STEMI.

The observational character of the study introduces some degree of residual confounding. We only aimed to include transfer patients and field triaged patients in whom STEMI was evident on admission. Accordingly, we excluded patients with extreme system delay >6 hours, who were considered to represent patients in whom STEMI had occurred after admission. In addition, some patients in our study with a long system delay of <6 hours might also belong to this group of patients. A total of 14,358 patients were excluded because of missing data on prehospital triage. This may introduce some degree of selection bias. Finally, the data used in this study were collected from 1999 to 2016. Advances have been made in prehospital triage during this period and beyond, and accordingly, the total system delay for GEMS may be overestimated. Differentiation between historical and contemporary cohort groups is believed to minimize this potential effect. Finally, it is important to stress that the guideline recommendations are to perform PPCI within 120 minutes from diagnosis (ECG acquired). In the present study, we measured time from EMS call to PPCI, and around 30 minutes elapse from

Table 2
Triage and various delays in patients with ST-elevation myocardial infarction by distance from the scene of the event to the invasive center in the whole cohort (n = 25,236)

Parameter	Distance from the scene of the event to the PPCI centre					
	0-25 km	26-50 km	51-75 km	76-100 km	101-125 km	126-170 km
Total cohort	(n = 6,370)	(n = 5,731)	(n = 4,335)	(n = 3,025)	(n = 2,698)	(n = 3,077)
Median transportation distance (km)	9 [5-17]	37 [31-44]	60 [55-68]	87 [80-93]	112 [106-119]	141 [134-160]
Field triage direct to PPCI centre	5,188 (81%)	3,808 (66%)	2,307 (53%)	1,400 (46%)	1,461 (54%)	1,443 (47%)
System delay when field triaged (min)	89 [72-121]	93 [78-120]	103 [89-133]	112 [99-130]	124 [110-145]	139 [123-157]
Field triaged and treated within 120 minutes	3,868/5,188 (75%)	2,864/3,808 (75%)	1,568/2,307 (68%)	895/1,400 (64%)	633 /1,461 (43%)	310/1,443 (22%)

Values are n, (%); or median (interquartile range, [IQR]).

System delay = time from first medical contact to intervention; PPCI = primary percutaneous coronary intervention; GEMS = ground-based emergency medical service; HEMS = helicopter emergency medical service.

Table 3
Triage and system delays in patients with ST-elevation myocardial infarction by distance from the scene of the event to the invasive center and time periods

	Distance from the scene of the event to the PPCI centre					
Parameter	0-25 km	26-50 km	51-75 km	76-100 km	101-125 km	126-170 km
Proportion of patients who were field triaged						
GEMS historical (1999-Apr 2010)	2,284/3,124 (73%)	1,430/2,951 (49%)	564/2,174 (26%)	377/1,638 (23%)	373/1,282 (29%)	384/1,540 (25%)
GEMS contemporary (May 2010-2016)	2,901/3,243 (90%)	2,367/2,765 (87%)	1,698/2,112 (80%)	823/1,166 (71%)	776/1,064 (73%)	668/1,042 (64%)
HEMS (May 2010-2016)	3/3 (100%)	11/15 (73%)	45/49 (92%)	200/221 (91%)	312/352 (89%)	391/495 (79%)
System delay in field triaged patients (min)						
GEMS historical (1999-Apr 2010)	93 [73-127]	95 [77-127]	106 [90-134]	119 [105-138]	133 [118-156]	152 [137-171]
GEMS contemporary (May 2010-2016)	86 [71-116]	92 [79-116]	102 [89-134]	112 [100-132]	127 [114-145]	141 [127-157]
HEMS (May 2010-2016)	113 [86-130]	117 [81-142]	99 [86-127]	100 [91-113]	109 [97-126]	121 [107-139]
System delay ≤ 120 minutes in field triaged patients						
GEMS historical (1999-Apr 2010)	1,640/2,284 (72%)	1,026/1,430 (72%)	367/564 (65%)	196/377 (52%)	112/373 (30%)	23/384 (6%)
GEMS contemporary (May 2010-2016)	2,226/2,907 (77%)	1,832/2,367 (77%)	1,169/1,698 (69%)	532/823 (65%)	300/776 (39%)	95/668 (14%)
HEMS (May 2010-2016)	N/A	N/A	32/45 (71%)	167/200 (84%)	221/312 (71%)	192/391 (49%)

Values are n, (%); or median (interquartile range, [IQR]).

System delay = time from first medical contact to intervention; PPCI = primary percutaneous coronary intervention; GEMS = ground-based emergency medical service; HEMS = helicopter emergency medical service.

EMS call to diagnosis (ECG) is established.[4] Accordingly, the current study underestimated the proportion of patients treated timely according to the guideline recommendations. The present study was not powered to document a mortality benefit when using HEMS, but previous data support that every hour of reduction in system delay translates into a 10% relative reduction in mortality.[17] The 30 minutes reduction in system delay achieved by HEMS in urban areas supports a potential mortality benefit using HEMS. Moreover, because establishing PCI-centers in all urban areas is not feasible, the modest difference in system delay observed in patients living in urban and rural areas justifies the centralized treatment strategy for patients with STEMI adopted in Denmark.

In conclusion, the present study confirmed that a centralized STEMI system of care using HEMS in rural areas

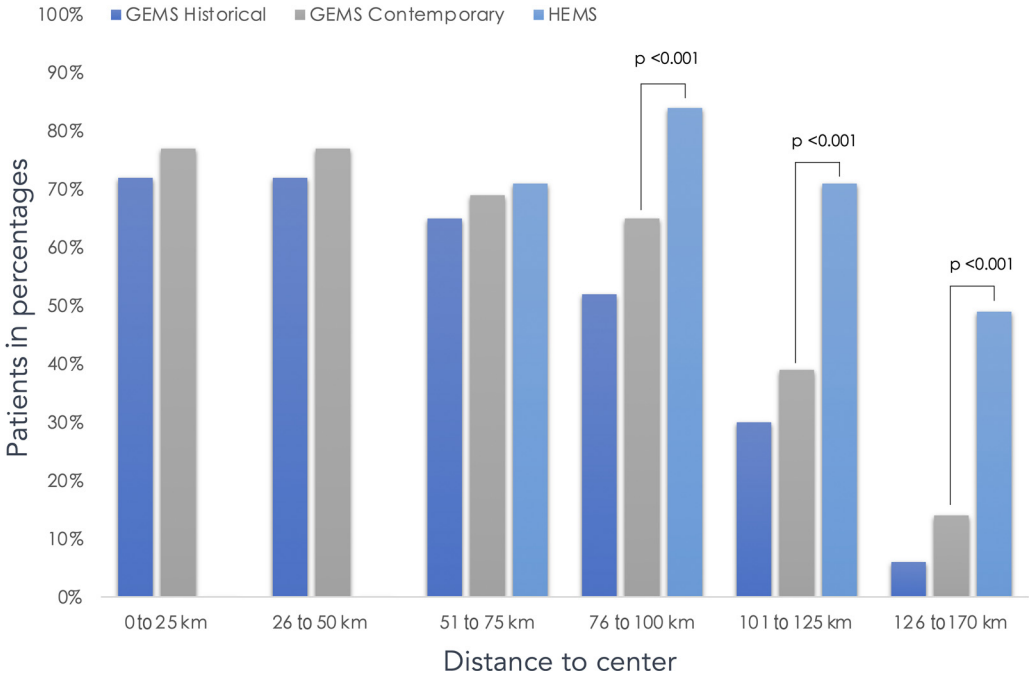

Figure 3. Proportion of patients treated with primary percutaneous coronary intervention within 120 minutes of emergency medical service call if field triaged. Stratified by time periods, mode of transportation and distance to invasive center. Contemporary period = May 2010 to 2016; Historical period = 1999 to April 2010.

Table 4
Regional differences in triage and delay to therapy in patients with ST-elevation myocardial infarction transported by ground emergency medical service or helicopter emergency medical service

Parameter	North Denmark Region	Central Denmark Region	Region of Southern Denmark	Capital Region of Denmark	Region Zealand
No. of inhabitants (mio)	0.6	1.3	1.2	1.9	0.8
Transportation distance (km)	46 [21-71]	52 [27-85]	81 [37-125]	25 [10-38]	97 [73-118]
No. of patients in various time periods (n)					
GEMS, 1999-Apr 2010	1,825	4,234	3,024	2,242	1,574
GEMS, May 2010-2016	1,541	3,062	3,032	2,983	1,664
HEMS, May 2010-2016	39	387	121	68	637
No. of patients field triaged and treated within 120 min					
GEMS, 1999-Apr 2010	470/1,825 (26%)	1,257/4,234 (30%)	536/3,024 (18%)	873/2,242 (39%)	247/1,574 (16%)
GEMS, May 2010-2016	366/1,541 (24%)	1,921/3,062 (63%)	1,451/3,032 (48%)	2,125/2,983 (71%)	766/1,664 (46%)
HEMS, May 2010-2016	11/39 (28%)	192/387 (50%)	49/121 (41%)	35/68 (52%)	374/637 (59%)
System delay in field triaged patients (min)					
GEMS, 1999-Apr 2010	128 [95-157]	92 [75-118]	121 [98-155]	84 [68-110]	127 [109-147]
GEMS, May 2010-2016	150 [118-192]	93 [76-117]	109 [89-135]	88 [76-105]	112 [95-130]
HEMS, May 2010-2016	158 [111-206]	111 [95-131]	120 [102-134]	108 [93-126]	112 [97-128]

Values are n (%); or median (interquartile range, [IQR]).

System delay = time from first medical contact to intervention; Historical period = 1999-Apr 2010; Contemporary period = May 2010-2016; GEMS = ground-based emergency medical service; HEMS = helicopter emergency medical service.

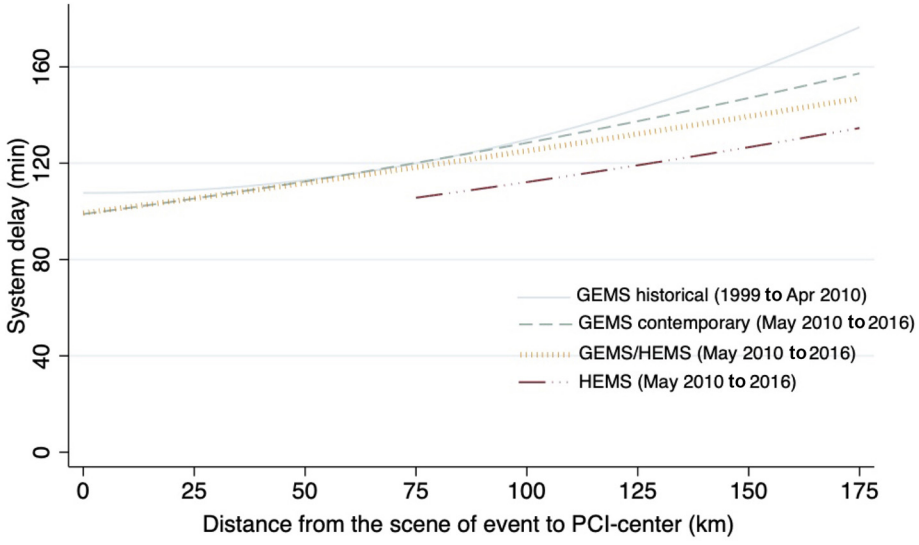

Figure 4. Association between distance from scene of the event to the invasive center and healthcare system delay (time from first medical contact to percutaneous coronary intervention in patients with ST-elevation myocardial infarction field triaged directly to the PPCI center and transported by ground emergency service or helicopter emergency service.) Plots are based on polynomial regression analysis. Apr = April.

ensures that most patients with STEMI are treated within 120 minutes of their EMS call. Field triage directly from the scene of the event to PPCI centers is mandatory to reduce system delay.

Disclosures

The authors have no conflicts of interest to declare.

Data Availability Statement

The data underlying this article were provided by the 5 emergency medical service organizations, the Danish Air Ambulance, and the Danish Health Data Authority, under the license of the Danish Data Protection Agency. Data will be shared on request to the corresponding author with permission from the previously mentioned authorities.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2022.01.042.

1. Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci C, Bueno H, Caforio ALP, Crea F, Goudevenos JA, Halvorsen S, Hindricks G, Kastrati A, Lenzen MJ, Prescott E, Roffi M, Valgimigli M, Varenhorst C, Vranckx P, Widimský P, ESC Scientific Document Group. 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: the Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). *Eur Heart J* 2018;39:119–177.
2. Andersen HR, Nielsen TT, Rasmussen K, Thuesen L, Kelbaek H, Thayssen P, Abildgaard U, Pedersen F, Madsen JK, Grande P, Villadsen AB, Krusell LR, Haghfelt T, Lomholt P, Husted SE, Vigholt E, Kjaergard HK, Mortensen LS, DANAMI-2 Investigators. A comparison of coronary angioplasty with fibrinolytic therapy in acute myocardial infarction. *N Engl J Med* 2003;349:733–742.
3. Terkelsen CJ, Jensen LO, Tilsted HH, Thaysen P, Ravkilde J, Johnsen SP, Trautner S, Andersen HR, Thuesen L, Lassen JF. Primary percutaneous coronary intervention as a national reperfusion strategy in patients with ST-segment elevation myocardial infarction. *Circ Cardiovasc Interv* 2011;4:570–576.
4. Rasmussen MB, Frost L, Stengaard C, Brorholt-Petersen JU, Dodt KK, Søndergaard HM, Terkelsen CJ. Diagnostic performance and system delay using telemedicine for prehospital diagnosis in triaging and treatment of STEMI. *Heart* 2014;100:711–715.
5. Christiansen T, Vrangbæk K. Hospital centralization and performance in Denmark-Ten years on. *Health Policy* 2018;122:321–328.
6. Andersen MS, Carlsen HP, Christensen EF. Criteria-based emergency medical dispatch of ambulances fulfils goals. *Dan Med Bull* 2011;58:A4336.
7. Lindskou TA, Mikkelsen S, Christensen EF, Hansen PA, Jørgensen G, Hendriksen OM, Kirkegaard H, Berlac PA, Søvsø MB. The Danish prehospital emergency healthcare system and research possibilities. *Scand J Trauma Resusc Emerg Med* 2019;27:100.
8. Andersen MS, Johnsen SP, Sørensen JN, Jepsen SB, Hansen JB, Christensen EF. Implementing a nationwide criteria-based emergency medical dispatch system: a register-based follow-up study. *Scand J Trauma Resusc Emerg Med* 2013;21:53.
9. Alstrup K, Møller TP, Knudsen L, Hansen TM, Petersen JAK, Rognås L, Barfod C. Characteristics of patients treated by the Danish Helicopter Emergency Medical Service from 2014−2018: a nationwide population-based study. *Scand J Trauma Resusc Emerg Med* 2019;27:102.
10. Langabeer JR, Henry TD, Kereiakes DJ, Dellifraine J, Emert J, Wang Z, Stuart L, King R, Segrest W, Moyer P, Jollis JG. Growth in percutaneous coronary intervention capacity relative to population and disease prevalence. *J Am Heart Assoc* 2013;2:e000370.
11. Garg S, Anderson SG, Oldroyd K, Berry C, Emdin CA, Peters SA, West NE, Kelly D, Balachandran K, McDonald J, Singh R, Devadathan S, Redwood S, Ludman PF, Rahimi K, Woodward M. British Cardiovascular Intervention Society. National Institute for Cardiovascular Outcomes Research. Outcomes of percutaneous coronary intervention performed at offsite versus onsite surgical centers in the United Kingdom. *J Am Coll Cardiol* 2015;66:363–372.
12. Moens D, Stipulante S, Donneau AF, Hartstein G, Pirotte O, D'Orio V, Ghuysen A. Air versus ground transport of patients with acute myocardial infarction: experience in a rural-based helicopter medical service. *Eur J Emerg Med* 2015;22:273–278.
13. Hakim R, Revue E, Saint Etienne C, Marcollet P, Chassaing S, Decomis MP, Yafi W, Laure C, Gautier S, Godillon L, Akkoyun-Farinez J, Angoulvant D, Koning R, Motreff P, Grammatico-Guillon L, Rangé G. Does helicopter transport delay prehospital transfer for STEMI patients in rural areas? Findings from the CRAC France PCI registry. *Eur Heart J Acute Cardiovasc Care* 2020;9:958–965.
14. McMullan JT, Hinckley W, Bentley J, Davis T, Fermann GJ, Gunderman M, Hart KW, Knight WA, Lindsell CJ, Miller C, Shackleford A, Gibler WB. Ground emergency medical services requests for helicopter transfer of ST-segment elevation myocardial infarction patients decrease medical contact to balloon times in rural and suburban settings. *Acad Emerg Med* 2012;19:153–160.
15. Sørensen JT, Terkelsen CJ, Nørgaard BL, Trautner S, Hansen TM, Bøtker HE, Lassen JF, Andersen HR. Urban and rural implementation of pre-hospital diagnosis and direct referral for primary percutaneous coronary intervention in patients with acute ST-elevation myocardial infarction. *Eur Heart J* 2011;32:430–436.
16. McMullan JT, Hinckley W, Bentley J, Davis T, Fermann GJ, Gunderman M, Hart KW, Knight WA, Lindsell CJ, Shackleford A, Gibler WB. Reperfusion is delayed beyond guideline recommendations in patients requiring interhospital helicopter transfer for treatment of ST-segment elevation myocardial infarction. *Ann Emerg Med* 2011;57:213–220. e1.
17. Terkelsen CJ, Sørensen JT, Maeng M, Jensen LO, Tilsted HH, Trautner S, Vach W, Johnsen SP, Thuesen L, Lassen JF. System delay and mortality among patients with STEMI treated with primary percutaneous coronary intervention. *JAMA* 2010;304:763–771.