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Response time of emergency vehicles may be predicted using ordinary GPS estimates

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ABSTRACT

INTRODUCTION: In a multiple-tier prehospital emergency system, knowing the response time of supplemental prehospital units may aid the ambulance personnel in deciding whether to remain at the scene and initiate treatment or to load the patient and head towards the hospital. We sought to correlate the actual to the predicted response time indicated at the GPS display in the vehicles of the supplemental prehospital resources.

METHODS: From December 2016 to February 2017, all emergency runs with lights and sirens performed by the mobile emergency care units in Odense were registered. For each emergency run, the physician registered the actual response time, the distance to the incident when travelling along the route suggested by the GPS and the predicted time to arrival. These registrations of time variables served as the basis for a linear regression analysis. A correlation between estimated and actual response time was calculated.

RESULTS: A total of 617 runs were registered. In all, 189 runs were excluded. Thus, a total of 428 runs were included. We found a linear correlation between the GPS-predicted response time and the actual response time, which may be described by the following equation: $y = 0.88 + 0.58x$ ($R^2 = 0.90$; $p < 0.0001$).

CONCLUSIONS: We found a linear correlation between the GPS-estimated transport time and the actual response time. We propose a practical model in which the actual transport times can be predicted by multiplying the GPS-estimated transport time by 0.6 and adding 1 min.

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A clear correlation between response time and patient outcome cannot consistently be established when investigating complete patient cohorts [1-7]. However, the intuitive notion is that - in selected cases - shorter response times lead to improved patient outcomes. Thus, ambulances, rapid response units and physician-manned mobile emergency care units (MECUs) are dispatched with lights and sirens when the medical dispatcher at the emergency medical dispatch centre suspects that a patient suffers from a life- or limb-threatening condition [8].

Presently, no system is available to Danish prehospital services that may predict the actual time of arrival at the prehospital scene when the units are dispatched with lights and sirens. Thus, it is not possible to forecast the actual response time in cases of emergency.

If a rapid response unit staffed with a paramedic or MECUs are dispatched together with an ambulance, these supplemental units most often have to drive for longer distances before reaching the scene. The supplemental prehospital units thus usually arrive later than the ambulance. If the arrival of the supplemental units at the scene can be predicted, this estimate may be taken into account in decisions made by the emergency medical technicians (EMTs). Should the ambulance leave the scene and head for the hospital or arrange a rendezvous with the supplemental units. The decision to load the patient into the ambulance and leave the scene usually results in a lowering of the treatment capacity within the ambulance as the ambulance driver is unable to assist the EMT in the cabin. The decision to leave the scene and head for the hospital or the rendez-vous point is thus a decision that should be based on the most accurate information available. We speculated that it would be possible to predict the arrival of the supplemental prehospital resource at the scene using the predicted arrival time indicated on the GPS display to calculate the actual arrival when initiating the emergency run.

METHODS

System setting

This prospective study was conducted at the MECU in Odense, Denmark, which services a mixed urban/rural population of 260,000 people and covers an area of 2,500 km^2. Approximately 68% of the covered population resides in the city of Odense. The MECU is a rapid response unit staffed with a prehospital emergency physician and an EMT. The MECU supplements the ambulance service 24/7/365 and responds to approximately 26% of all emergency calls with lights and sirens involving ambulances [6]. The MECU is equipped with a GPS-based navigation system based on map data. When the MECU is dispatched, the dispatcher automatically transfers the location of the incident to the GPS, which immediately displays the fastest route from the current position. Simultaneously, the GPS calculates the distance to the target and estimates the time of arrival at the scene provided the driver respects normal traffic rules and takes current traffic conditions into account.

Methods

From December 2016 to February 2017, we investigated all emergency runs with lights and sirens made by the MECU in Odense. When dispatched, the physician registered the time of departure, the distance to the incident when travelling along the route suggested by the GPS and the time of the GPS-predicted arrival in integers of minutes. Upon arrival at the scene, the MECU physician registered the actual time of arrival (in integers of minutes). Furthermore, the MECU physician registered if the route taken to the destination had been affected by complications due to extreme weather conditions, problems with the GPS reception or whether alterations of the route caused by roadwork had occurred. Finally, the MECU physician registered whether the route taken was predominantly by urban roads or rural roads and/or motorways. In Denmark, there is a general 50 km/h speed limit within urban areas, an 80 km/h speed limit in rural areas and a 110-130 km/h speed limit on motorways. The distinction between urban roads, rural roads and motorways was thus made according to the speed limits observed along the route.

Missions were excluded if the emergency run was cancelled during the transport to the scene; if the mission was re-prioritised; or if the urgency of the mission produced changes in the use of lights and sirens during transport to the scene. Missions in which the MECU physician stated that the route had been changed during the run because of roadwork or other external factors were also excluded.

Missions ordered without lights and sirens (typically administrative tasks) were not included.

All non-altered missions dispatched with lights and sirens were included.

Following this study, in ten cases, the GPS-calculated transport times were verified by comparing the estimated

GPS arrival times with actual arrival times when obeying normal traffic regulations.

Statistics

All data were entered into case record forms (CRF) by the attending MECU physicians. Data were then transferred from the CRFs to a spreadsheet. Linear regression was applied to describe the correlation between the GPS-estimated transport time and the actual transport time. The regression analysis was performed taking urban roads, rural roads or motorways into consideration.

Ethical considerations

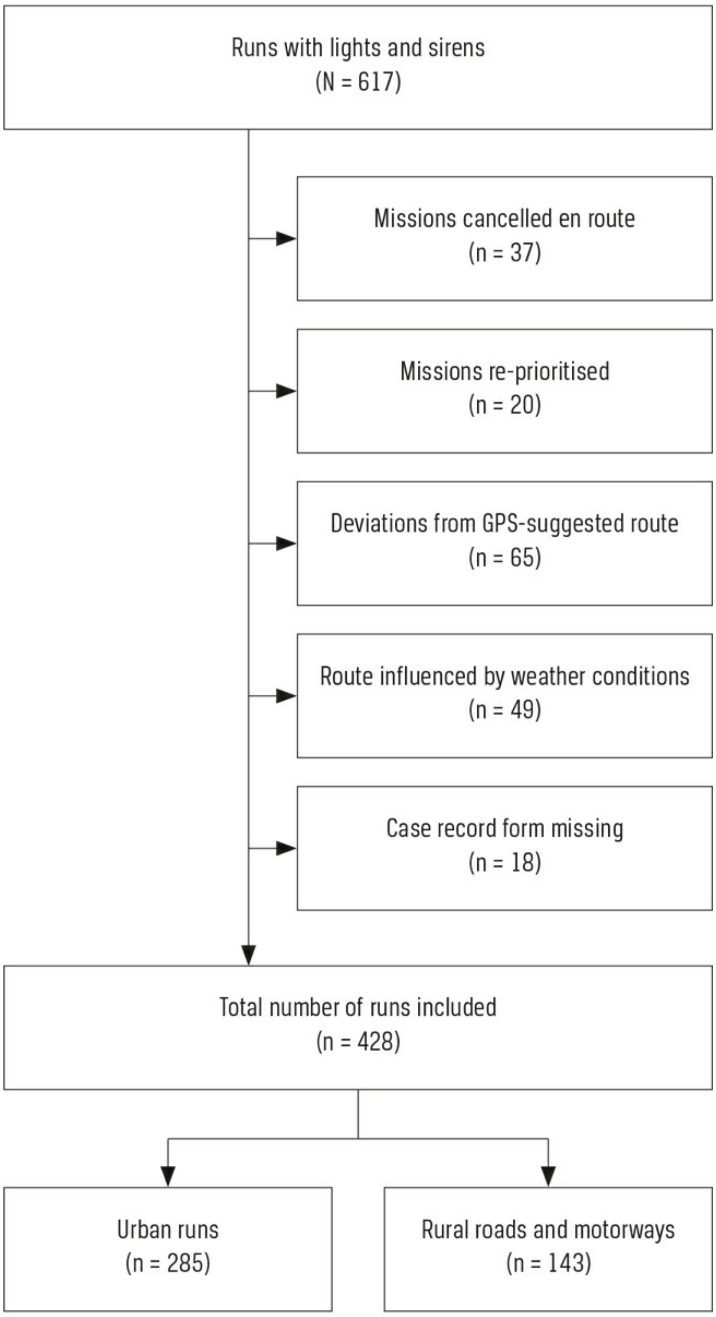
No patient- or personnel-identifiable variables were recorded in this study. Thus, under Danish law, no ethical approvals were required.

Trial registration: not relevant.

RESULTS

Twelve different EMTs and 14 anaesthesiologists served on the MECU during the study period. A total of 617 emergency runs were registered. Among all emergency runs with lights and sirens, 189 runs were excluded and a total of 428 runs thus included for analysis (see **Figure 1**). Among these, 285 emergency runs were predominantly carried out in urban areas, whereas 143 emergency runs occurred in predominantly rural areas or on motorways.

FIGURE 1 / Flow chart describing the missions.



For all emergency runs, the median distance travelled was 8 km (quartiles: 4-16.75 km). The GPS-predicted transport time was 10 min. (quartiles: 6-18 min.). The actual median response time was 7 min. (quartiles: 4-11 min.). The median distance travelled in the urban area was 6 km per emergency run. This distance increased to 20 km per rural/motorway run. The median response time within the urban area was 5 min., which increased to 13 min. beyond the urban area.

We found a linear correlation between the GPS-predicted time of transport and the actual time of transport. For all emergency runs, the correlation between the estimated time of transport (x) and the actual time of transport (y) could be described by the following equation:

$y = 0.88 + 0.58x$ ($R^2 = 0.90$; $p < 0.0001$)

The correlation between the predicted and the actual transport time in emergency runs was made predominantly within the city was:

$y = 0.60 + 0.62x$ ($R^2 = 0.89$; $p < 0.0001$)

For emergency runs occurring predominantly outside the city, the correlation was:

$y = 0.76 + 0.58x$ ($R^2 = 0.71$, $p < 0.0001$)

For a visual presentation of the correlation between predicted transport times and actual transport times, see **Figure 2**, **Figure 3** and **Figure 4**.

FIGURE 2 / Correlation between estimated transport times and actual transport times, all roads. Shaded areas represent 95% confidence intervals. $y = 0.88 + 0.58x$ ($R^2 = 0.90$; $p < 0.0001$).

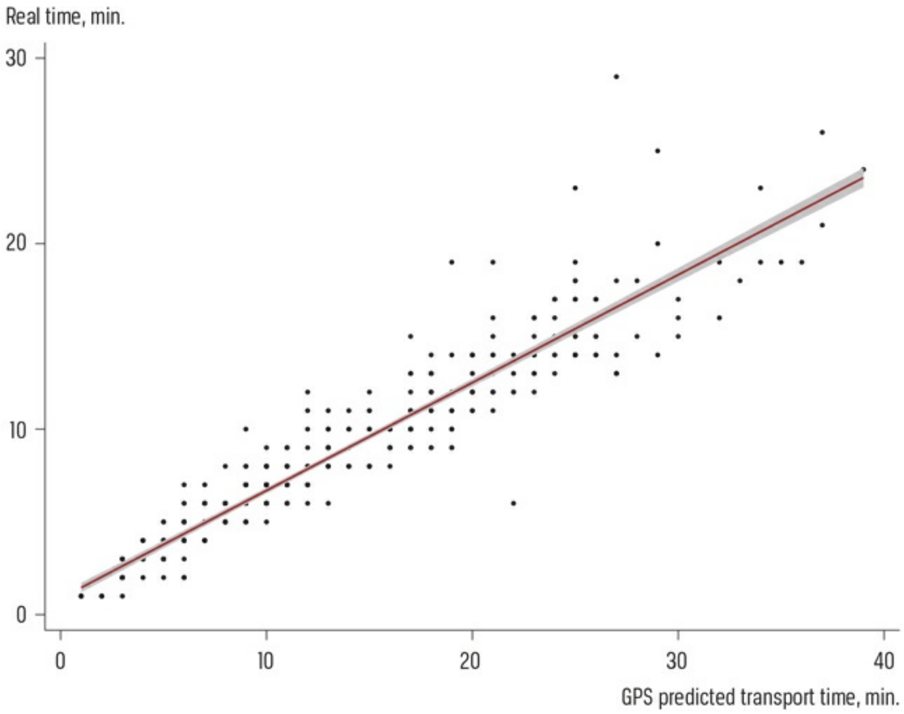


FIGURE 3 / Correlation between estimated transport time and actual transport time, urban roads. Shaded areas represent 95% confidence intervals. $y = 0.60 + 0.62x$ ($R^2 = 0.89$; $p < 0.0001$).

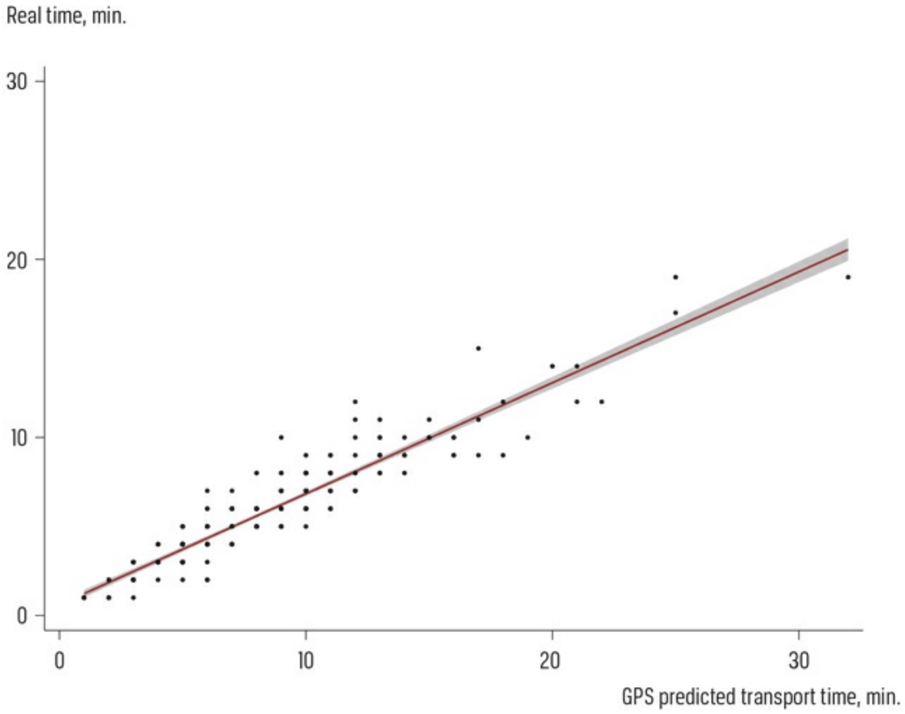
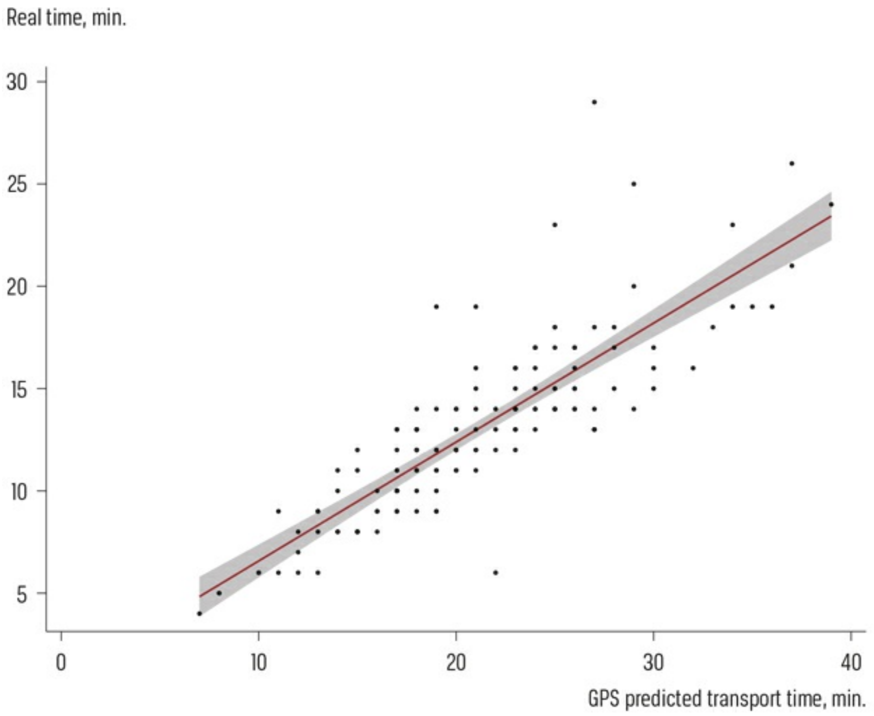


FIGURE 4 / Correlation between estimated transport times and actual transport times, rural roads and motorways. Shaded areas represent 95% confidence intervals. $y = 0.76 + 0.58x$ ($R^2 = 0.71$; $p < 0.0001$).



DISCUSSION

In this study, we found that it is possible to make very accurate predictions of the arrival of prehospital supplemental services dispatched with lights and sirens. Furthermore, these predictions can be calculated using the routine GPS- generated predictions of transport times.

The public notion is that the lower the response time of the emergency medical system (EMS) the better. This notion is not unambiguously supported in the general cohort of prehospital patients [1-6]. However, time to treatment is considered crucial in emergency conditions within the “first hour quintet” (cardiac arrest, respiratory failure, trauma, acute coronary syndromes and stroke) [9].

Although “response time” as a singular indicator for quality in the prehospital services is thus not sufficient, this parameter serves as one of several indicators of prehospital quality [10]. As such, the concept of “response time” is probably a parameter that should be taken into consideration when evaluating or planning prehospital services.

It has previously been demonstrated that lights and sirens reduce the response times of emergency vehicles [11]. This particular study found response times of 4.9 min. in 32 ambulance runs performed with lights and sirens. A subsequent “dry run” performed on the same route but without lights and sirens produced a 6.6-min. run duration. This corresponds to a 27% reduction in response time when applying lights and sirens. Ho & Lindquist investigated 67 ambulance runs within a rural setting by letting a similarly equipped “chase” ambulance duplicate the ambulance run by driving to the same destination via the same route without lights and sirens and obeying all traffic laws. A reduction in transport time of 30.9% was reported; shorter runs recording a higher time saving longer runs [12]. Hunt et al studied 50 ambulance runs and found a reduction in transport time of approximately 0.2 min. when comparing emergency runs with lights and sirens to comparable runs without lights and sirens [13].

Using data from 48,308 ambulance missions, Fleischman et al used GPS coordinates from an EMS system to derive and validate a model that accurately predicted ambulance time of arrival to the emergency department. The study reported that lights and sirens reduced the transport time of the ambulances from the scene of an incident to the hospital by an average of 3.1 min. for transports with a duration of less than 8.8 min., and 5.3 min. for longer transports [14].

Especially for critical patients, accurately predicting ambulance time of arrival to the emergency department is important for effective resource management [14]. These predictions cannot be made as “guesstimates”, as the prehospital provider’s estimate of the duration of the transport at its conclusion has been shown to be off by an average of 33% [15].

Response time as a concept is relevant in a Danish context where anaesthesiologist-manned MECUs are part of a three-tiered prehospital system. Supplemental units from other tiers of the prehospital system are not necessarily dispatched from the same ambulance station or at the same time as the basic prehospital unit is dispatched. Thus, it may aid the prehospital provider at the scene to know when a supplemental rapid response vehicle can be expected at the scene. Precise knowledge of the expected arrival time for supplemental prehospital providers may qualify decisions about two different treatment principles: load-and-go versus stay-and-treat. As the level of treatment offered by the ambulance will most probably be reduced while driving due to the simple fact that the ambulance driver cannot be present in the cabin while driving the ambulance, there is only one prehospital provider available to treat the patient should the decision to load-and-go be made. In contrast, knowing that a supplemental prehospital resource is on its way and may arrive at a specified time point may qualify a decision of the EMTs to stay at the scene, offer treatment by two prehospital care providers and thereby ensure that a third prehospital care provider with higher competences may aid the treatment during transportation.

We thus sought to establish a method to predict the actual arrival of supplemental emergency vehicles based on the somewhat arbitrary parameter “transport time of the vehicle given that all traffic regulations were respected”. We found that the correlation between the estimated and actual time of transport may be described by the following equation: $y = 0.88 + 0.58x$. In practice, we thus suggest that the actual transport time is calculated by taking the predicted transport time for the emergency vehicle multiplied by 0.6 and adding 1 min. This rather precise rule for calculation of transport times for supplemental rapid response vehicles in the emergency medical system may serve as a decision tool in the planning of future EMS-related decisions, like planning the locations of EMS bases according to locally accepted response times or aid prehospital providers in when deciding whether to stay-and-treat or load-and-go.

Strengths of the study: One strength of the study is that data were collected from consecutive ambulance runs. Furthermore, apart from the major study by Fleischman et al [14], our material is larger than those usually reported in studies of this kind.

Although the high R^2 values (range: 0.71-0.90) suggest that the model has an acceptable degree of fit, a significant weakness of the study is that the model may be too simple. It is highly possible that incorporating other factors into the equation, such as local transport infrastructure, variations in traffic volume in the course of the day, as well as ongoing road construction and repair, could have yielded a better fitting model. Furthermore, all registrations were performed using only one type of vehicle. Organisations using other vehicles may come to different conclusions.

We have not corrected for these weaknesses, and interpretations of our results should be made considering these potential confounders.

Another weakness is that the study is a single-centre study. This limits our conclusions to emergency runs performed within the city of Odense and surroundings. However, the correlations within urban roads and outside urban roads were almost identical: $y = 0.60 + 0.62x$ for urban emergency runs only and $y = 0.76 + 0.58x$ for emergency runs taking place predominantly outside the city. In practice, the only difference in the constant needed to add to the calculated result of actual transportation times during urban and rural emergency runs would be 0.16 min., the equivalent of 10 sec. This similarity leads us to believe that the results are applicable to other areas with a similarly developed infrastructure with asphalt roads and mixed urban and rural settlements.

CONCLUSIONS

We established a linear correlation between the GPS-estimated and the actual response time in emergency runs made with a physician-manned rapid response vehicle operating in and around Odense, Denmark. We propose a model in which the expected transport times can be predicted by multiplying the GPS-estimated transport time by 0.6 and adding 1 min. Information regarding the expected time of arrival may be forwarded by direct communication between the attending prehospital units.

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ABBREVIATIONS

CRF = case record form

EMS = emergency medical system

EMT = emergency medical technician

GPS = global positioning system

MECU = mobile emergency care unit

LITERATURE

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