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Clinical paper

Response times in rural areas for emergency medical services, fire and rescue services and voluntary first responders during out-of-hospital cardiac arrests

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Abstract

Aim: To increase survival in out-of-hospital cardiac arrests (OHCA), great efforts are made to improve the number of voluntary first responders (VFR). However, evidence of the potential utility of such efforts is sparse, especially in rural areas. Therefore, the aim was to describe and compare response times for emergency medical services (EMS), fire and rescue services (FRS), and VFR during OHCA in relation to population density.

Methods: This observational and comparative study was based on data including positions and time stamps for VFR and response times for EMS and FRS in a region in southern Sweden.

Results: In total, 285 OHCAs between 1 July 2020 and 31 December 2021 were analysed. VFR had the shortest median response time in comparison to EMS and FRS in all studied population densities. The overall median (Q1–Q3) time gain for VFR was 03:07 (01:39–05:41) minutes. A small proportion (19.2%) of alerted VFR accepted the assignments. This is most problematic in rural and sub-rural areas, where there were low numbers of alerted VFR. Also, FRS had shorter response time than EMS in all studied population densities except in urban areas.

Conclusion: The differences found in median response times between rural and urban areas are worrisome from an equality perspective. More focus should be placed on recruiting VFR, especially in rural areas since VFR can potentially contribute to saving more lives. Also, since FRS has a shorter response time than EMS in rural, sub-rural, and sub-urban areas, FRS should be dispatched more frequently.

Keywords: Out-of-hospital cardiac arrest, Emergency medical services, Fire and rescue services, Voluntary first responders, Response times

Introduction

Out-of-hospital cardiac arrest (OHCA) is a leading cause of mortality worldwide. Annually, approximately 275,000 people suffer from OHCA treated by emergency medical services (EMS) in Europe, of which about 10% survive to hospital discharge.[1,2] Immediate initiation of cardiopulmonary resuscitation (CPR) and early defibrillation are crucial in improving the chance of survival.[3,4] Therefore, shortening EMS response times in OHCA is important.[5–8] Availability goals for EMS response times differ between countries, where, for example, the UK has a predetermined goal for OHCA call response independent of whether it occurs in urban or rural areas — in average not exceeding 7 minutes, and responding to 90% within 15 minutes.[9] Availability goals for EMS response times in Sweden differ considerably between regions.[10] As in other countries,[11] the most prolonged response times are seen for ambulance units stationed in rural areas.[12].

To shorten response time, great efforts have been made to involve fire and rescue service (FRS) as well as volunteer first responders (VFR). Consequently, FRS in most Swedish regions are dual-dispatched and/or dispatched to shorten the response time when it is assumed they will arrive before ambulance personnel to perform lifesaving interventions.[13–15] FRS integrated into EMS as first responders contribute substantially to decreased OHCA response times, especially in rural areas.[4,6,7] Also, implementing

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smartphone systems to alert VFR in case of OHCA increases the rate of early CPR and defibrillation and improves patient outcomes.[16,17] In some Nordic countries, VFR are most commonly alerted in urban OHCAs, resulting in shortened response times in comparison to EMS.[18–20] However, although European guidelines strongly encourage the implementation of technology to alert VFR,[21] such potential life-saving efforts have not been specifically evaluated in rural areas.

Aim

The aim of this study was to describe and compare response times in rural areas for emergency medical services, fire and rescue services, and voluntary first responders during out-of-hospital cardiac arrests in relation to population density.

Method

Study design and setting

This observational study was conducted in a region in southern Sweden over the course of 18 months between 1 July 2020 and 31 December 2021. The region has a population of 200,000 inhabitants and an area of 8,458 km^2, which is divided into eight municipalities including two cities: one with approximately 71,000 inhabitants and one with 16,000 inhabitants. Overall population density is 24/km^2 with a range between municipalities from 8.1 to 57.0 inhabitants/km^2. Ethical approval was received from the Swedish Ethical Review Authority (No. 2021–00563).

Emergency medical communication centre (EMCC)

In 2020, the regional EMCC had an availability goal of answering emergency calls not exceeding a mean of 8 seconds, ≥92% within 15 seconds, and all calls in less than 30 seconds.[22] In OHCA events, the EMCC dispatched two ambulances, and FRS were dispatched if only one ambulance was available or if FRS were assessed as being first on scene. The EMCC dispatcher determines the OHCA position according to the caller's description or global positioning system (GPS) coordinates.

Emergency medical services (EMS)

In 2020, the region had 8 ambulance stations (Fig. 1) including a total of 17 ambulances providing advanced life support. Six ambulances were active daytime on weekdays, and 11 ambulances were active 24/7. At least one active-around-the-clock ambulance was stationed in each municipality. The regional ambulance availability goal for acute assignments was to reach 60% of persons seeking help within 10 minutes.[10] When dispatched, ambulance personnel had a predetermined turnout time of ≤ 90 seconds (Fig. 2).

Fire and rescue services (FRS)

In 2020, the region had five FRS organisations operating in 37 fire stations (Fig. 1), staffed with firefighters trained in basic life support and equipped with automated external defibrillators. Full-time firefighters were stationed in both cities with a predetermined turnout time of ≤ 90 seconds, while part-time firefighters were stationed in rural areas with a turnout time of ≤ 5–7 minutes. In 22 rural fire stations, firefighters were paid and required to attend in the event of an alarm, while at 13 fire stations firefighters were volunteers and attended if they were available. To shorten response times in sparsely populated areas, some FRS also used a first incident person (FIP), whereby a part-time firefighter served as a first responder with a smaller emergency vehicle with a turnout time of ≤ 90 seconds, going directly to the scene.

Voluntary first responders (VFR)

In 2020, starting 1 July, VFR were alerted by a smartphone application to suspected OHCA in the region. The system complemented EMS dispatch with VFR alerts during daytime from 07:00–23:00. During the study period, the system identified up to 30 (1 July 2020 to 31 May 2021) or up to 40 (1 June to 31 December 2021) VFR within a maximum radius of 10 km linear distance. The VFR was designated to either proceed to the scene to perform CPR, or to pick up an automated external defibrillator on the way. At start-up, 1572 VFR were registered, while 2892 were registered at the end of the study period. VFR were not alerted to OHCA when it was deemed unfavourable.

Data collection

Data were collected using two data sources; information on positions and time stamps for VFR was obtained from Heartrunner Sweden AB (Heartrunner) while information on EMS and FRS event times (Fig. 2) was obtained from EMCC. Serial numbers from Heartrunner were matched with EMCC case numbers to combine datasets. During the study period, Heartrunner received 299 OHCA alerts from EMCC. Of those, 14 OHCA alerts were identified as duplicates, test alerts, or were cancelled before EMS was dispatched. In total, EMS was dispatched, and VFR was alerted in 285 OHCAs, and in 163 of these, FRS was also dispatched.

EMS and FRS confirmed start off travel and arrival at the scene, i.e., vehicle arriving at the OHCA location, by manually reporting time stamps to EMCC. In 13 OHCAs, FRS did not confirm arrival time resulting in a total of 150 FRS cases included in the analyses.

VFRs en route times were measured from the moment Heartrunner received the request from EMCC to the moment when the first VFR smartphone GPS arrived at the scene. A 50-meter radius buffer zone from the suspected OHCA was created to assess the first VFR on scene. In 94 OHCAs no VFR arrived within the zone, resulting in a total of 191 VFR cases included in the analyses.

To calculate population density in the surrounding area of each OHCA, open geodata was used with vector layers presenting the registered population into 1 km^2 grids.[23] The vector layer was converted into a raster layer. A polygon layer was then created by buffering the position of each OHCA with a radius buffer zone of 1800 meters. The population density within this zone was estimated by summing the number of inhabitants in each grid within the radius buffer zone. Each OHCA was then ranked from smallest to largest population density, and all OHCAs were categorised into four equally large groups based on population density, i.e., inhabitants in a radius of 1800 meters were divided into rural (7–660), sub-rural (674–2514), sub-urban (2515–12,456), and urban (12,750–29,599).

Data analysis

Since most of the time variables were highly skewed, they were described using non-parametric statistics. The Pearson chi-square test was used to compare the proportion of alerted VFR in relation to population density. The Pearson chi-square test was also used to compare who was first on scene, i.e., VFR vs. EMS or FRS. The Wilcoxon signed-rank test was used to compare the response

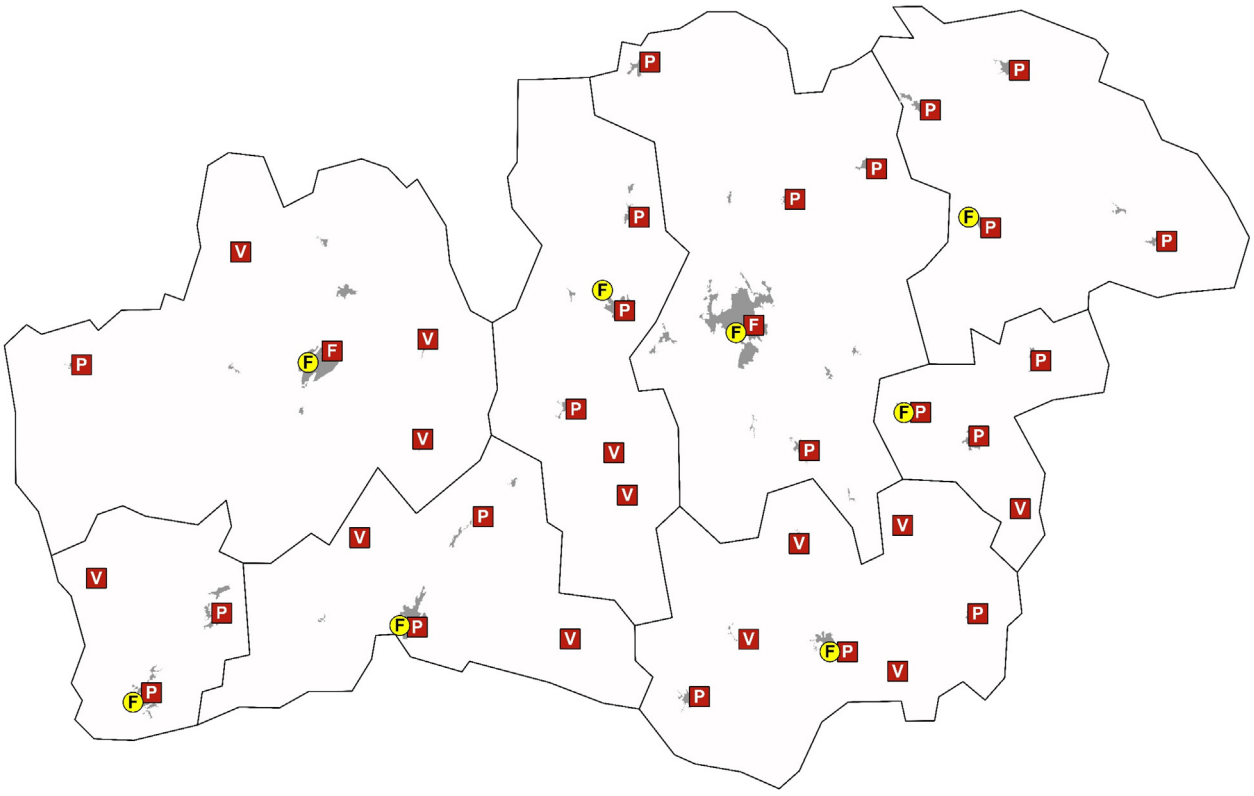

Fig. 1 – Map showing stations of emergency medical services (yellow box), fire and rescue service stations; full-time (red box marked F), part-time (red box marked P) and voluntary (red box marked V). Gray fields show the distribution of villages or cities with more than 200 inhabitants.

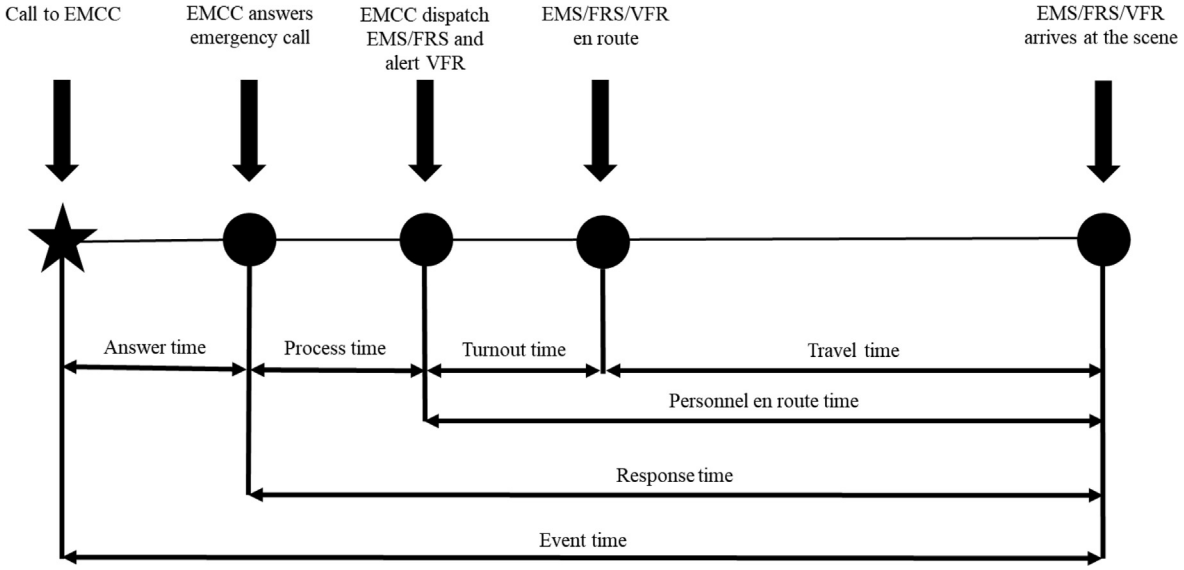

Fig. 2 – Sequence of events comprising the time frame from a received emergency call to emergency medical communication centre (EMCC) until the first of all involved actors; emergency medical services (EMS); fire and rescue services (FRS); and voluntary first responders (VFR), arrives at the scene.

time between EMS or FRS, dependent on which one was first on scene, and VFR. Cohen's r was used as an effect size measure, and interpreted as: 0.1–0.3 as small, 0.3–0.5 as medium, and 0.5–1.0 as large. Statistical significance was set at $p < 0.05$. Analyses were carried out in R 4.3.0 (R Foundation for Statistical Computing, Vienna, Austria) and Rstudio 2023.03.1 + 446 (PBC, Boston, MA) using the following packages: dplyr 2.3.2, rstatix 0.7.2, summarytools 1.0.1, and terra 1.7–29.

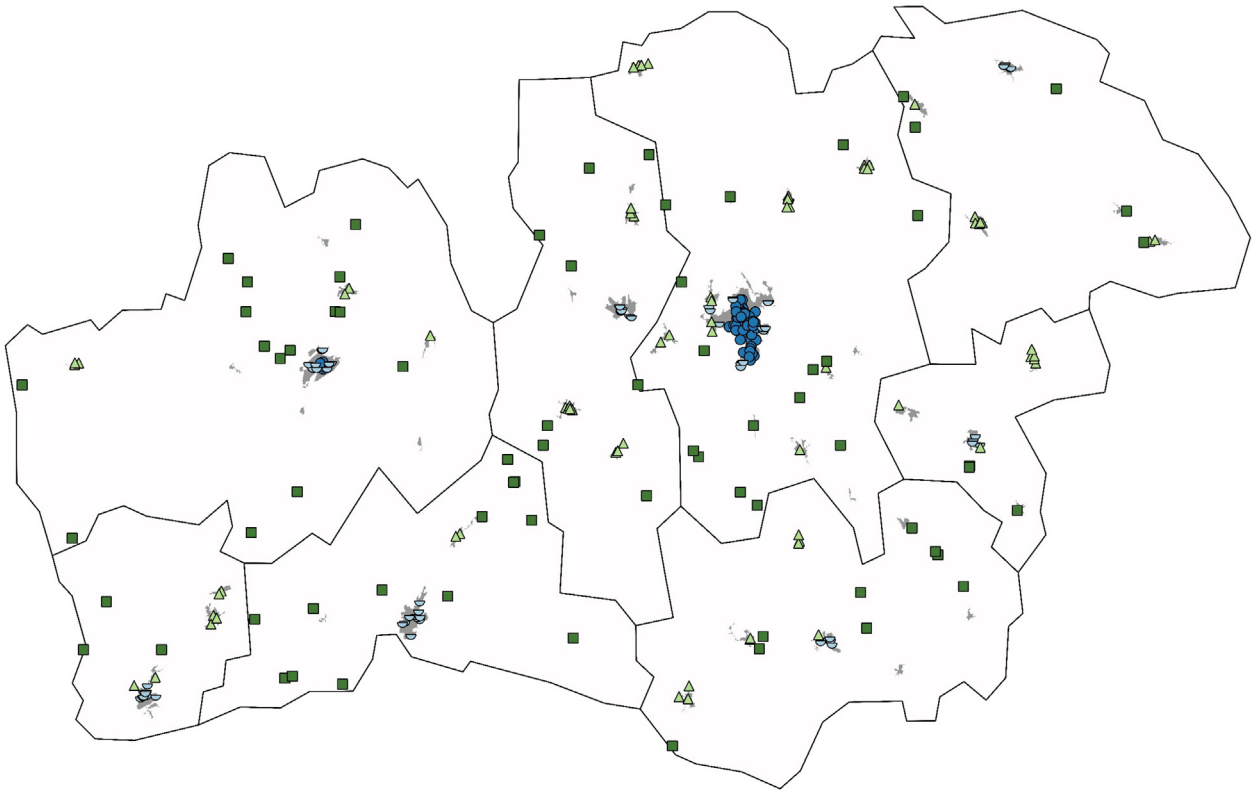

Fig. 3 – Map showing locations of out-of-hospital cardiac arrest (OHCA) according to population density; rural (dark-green box), sub-rural (light-green triangle), sub-urban (light-blue half circle) and urban (dark-blue circle). Gray fields show the distribution of villages or cities with more than 200 inhabitants.

Results

The results are presented for all OHCAs and divided by population density (Fig. 3), in accordance with total event time, i.e., from call to EMCC until the first of all the actors (EMS/FRS/VFR) arrived on scene (Table 1). Moreover, numbers of alerted VFR, accepted VFR, distance for the first VFR arriving at the scene (Table 2), and time gained (Table 3) are presented.

Answer time

In all cases (n = 285), the answer time for EMCC was in median 8 seconds (Q1–Q3 = 3–17, Min–Max = 1–126).

Process time

The EMCC process time in minutes and seconds was shortest for VFR (Mdn = 02:13, n = 285) followed by EMS (Mdn = 02:16, n = 285), and FRS (Mdn = 02:38, n = 163) (Table 1). In 190 of 285 (67%) OHCAs, VFR was alerted before EMS was dispatched (Mdn = 00:24).

Turnout time

The turnout time was shortest for VFR (Mdn = 00:37, n = 191) followed by EMS, (Mdn = 00:56, n = 285), and FRS (Mdn = 02:07, n = 163) (Table 1). In urban areas, the median for FRS exceeded the predetermined turnout time of $\leq$ 90 seconds (Mdn = 01:34, n = 24). During turnout time, there was differences in numbers of VFR alerted in relation to population density. In median, 30 VFR were alerted in urban and sub-urban areas whereas 11 and 14 were alerted in sub-rural and rural areas respectively. Also, there was differences in numbers of VFR accepting the alert. In urban areas, VFR accepted a median of 7 alerts versus 6 alerts in sub-urban, and 3 in sub-rural and rural areas, respectively (Table 2). In relation to the number of alerted VFR, the acceptance was highest in sub-rural areas (27%), followed by urban (23%), rural (21%), and sub-urban (20%) areas. However, these differences were not statistically significant ($\chi^2(3) = 1.08$, p = 0.783).

Travel time

The travel time was shortest for FRS (Mdn = 03:43, n = 150) followed by VFR (Mdn = 03:52, n = 191), and EMS (Mdn = 09:22, n = 285) (Table 1). The shortest travel time for EMS was seen in urban areas (Mdn = 04:46, n = 72), for FRS in sub-rural areas (Mdn = 02:51, n = 54), and for VFR in sub-rural areas (Mdn = 02:56, n = 41). The first VFR to reach the patient in an urban area was in median 515 meters (linear distance) away from the patient when accepting the alert, compared to 3747 meters in rural areas (Table 2).

Response time

The response time was shortest for VFR (Mdn = 07:12, n = 191) followed by FRS (Mdn = 10:03, n = 150), and EMS (Mdn = 12:51, n = 285). VFR had the shortest median response time in all studied population densities. FRS had shorter response times than EMS in all studied population densities except those in urban areas (Table 1). Comparisons between VFR and EMS or FRS, depending on which one was first on scene, showed that VFR had overall significantly shorter median response times (07:12 vs. 08:56, p < 0.001,

Table 1 – Event time comprising response times in rural areas for emergency medical communication centre (EMCC), emergency medical services (EMS), fire and rescue services (FRS), and voluntary first responders (VFR) during out-of-hospital cardiac arrests in relation to population density.

Characteristics		All (n = 285)			Rural (n = 71)			Sub-rural (n = 71)			Sub-urban (n = 71)			Urban (n = 72)		
		EMS	FRS	VFR	EMS	FRS	VFR	EMS	FRS	VFR	EMS	FRS	VFR	EMS	FRS	VFR
	n	285	163	285	71	47	71	71	57	71	71	35	71	72	24	72
EMCC process time	Mdn	00:02:16	00:02:38	00:02:13	00:02:22	00:02:49	00:02:27	00:02:14	00:02:55	00:02:18	00:02:16	00:02:29	00:02:05	00:02:04	00:02:22	00:02:14
	Q_1	00:01:49	00:02:03	00:01:39	00:02:02	00:02:08	00:01:50	00:01:51	00:02:10	00:01:38	00:01:42	00:01:44	00:01:29	00:01:43	00:01:50	00:01:37
	Q_3	00:02:57	00:03:49	00:03:22	00:03:22	00:03:44	00:03:51	00:02:49	00:04:19	00:03:40	00:02:54	00:03:21	00:02:46	00:02:54	00:03:21	00:03:19
	Min	00:00:41	00:01:05	00:00:42	00:01:29	00:01:31	00:01:06	00:00:52	00:01:05	00:00:42	00:01:07	00:01:12	00:00:43	00:00:41	00:01:31	00:00:46
	Max	00:10:20	00:26:59	00:26:35	00:06:47	00:26:59	00:26:35	00:06:28	00:18:42	00:20:29	00:06:50	00:06:44	00:20:48	00:10:20	00:11:29	00:11:24
	n	285	163	191	71	47	40	71	57	41	71	35	54	72	24	56
Turnout time	Mdn	00:00:56	00:02:07	00:00:37	00:01:02	00:02:43	00:00:47	00:00:52	00:02:57	00:00:36	00:00:57	00:01:46	00:00:28	00:00:50	00:01:34	00:00:39
	Q_1	00:00:27	00:01:30	00:00:24	00:00:26	00:01:39	00:00:29	00:00:25	00:01:55	00:00:24	00:00:27	00:01:03	00:00:22	00:00:28	00:01:19	00:00:26
	Q_3	00:01:12	00:03:53	00:00:56	00:01:18	00:04:33	00:01:01	00:01:17	00:04:22	00:00:55	00:01:11	00:03:01	00:00:46	00:01:07	00:01:53	00:00:56
	Min	00:00:06	00:00:09	00:00:11	00:00:07	00:00:23	00:00:12	00:00:07	00:00:52	00:00:13	00:00:07	00:00:09	00:00:11	00:00:06	00:00:46	00:00:12
	Max	00:04:11	00:10:12	00:08:49	00:03:25	00:10:12	00:03:21	00:04:11	00:10:03	00:08:49	00:04:03	00:05:22	00:01:36	00:02:15	00:03:03	00:02:48
	n	285	150	191	71	42	40	71	54	41	71	32	54	72	22	56
Travel time	Mdn	00:09:22	00:03:43	00:03:52	00:14:40	00:07:55	00:06:47	00:13:18	00:02:51	00:02:56	00:06:58	00:02:54	00:03:24	00:04:46	00:03:30	00:03:08
	Q_1	00:04:55	00:02:36	00:02:28	00:10:52	00:05:07	00:05:04	00:09:08	00:01:55	00:01:41	00:04:28	00:01:50	00:02:32	00:03:50	00:02:55	00:02:11
	Q_3	00:15:51	00:06:33	00:05:58	00:19:17	00:12:53	00:15:16	00:18:13	00:04:16	00:04:19	00:15:11	00:03:59	00:04:55	00:06:21	00:04:59	00:04:43
	Min	00:01:47	00:00:14	00:00:00	00:05:08	00:01:06	00:02:54	00:02:21	00:00:14	00:00:00	00:01:47	00:00:26	00:00:17	00:01:55	00:02:01	00:00:00
	Max	00:51:06	00:44:50	00:27:47	00:51:06	00:44:50	00:27:47	00:49:36	00:30:57	00:27:18	00:38:05	00:10:43	00:18:33	00:14:38	00:06:37	00:26:16
	n	285	150	191	71	42	40	71	54	41	71	32	54	72	22	56
Response time	Mdn	00:12:51	00:10:03	00:07:12	00:19:03	00:14:10	00:12:37	00:16:27	00:09:37	00:06:28	00:09:52	00:08:00	00:06:10	00:08:07	00:08:37	00:07:03
	Q_1	00:08:17	00:07:50	00:05:24	00:14:16	00:11:33	00:09:12	00:12:42	00:07:42	00:04:27	00:07:31	00:06:01	00:05:03	00:06:56	00:06:39	00:05:15
	Q_3	00:19:41	00:13:23	00:10:01	00:23:07	00:18:07	00:19:21	00:21:47	00:12:12	00:08:41	00:20:00	00:09:46	00:08:12	00:09:28	00:09:50	00:08:55
	Min	00:03:38	00:04:05	00:01:38	00:08:11	00:08:11	00:04:45	00:05:25	00:05:25	00:02:38	00:03:38	00:04:05	00:01:38	00:04:52	00:06:18	00:02:17
	Max	00:57:14	00:51:33	00:43:23	00:57:14	00:51:33	00:43:23	00:53:02	00:37:07	00:30:36	00:39:23	00:14:11	00:21:03	00:19:37	00:15:56	00:29:11

Table 2 – Number of alerted and accepted assignments to voluntary first responders (VFR) and linear distance for first VFR to arrive at the scene, in relation to population density.

Characteristics		All (n = 285)	Rural (n = 71)	Sub-rural (n = 71)	Sub-urban (n = 71)	Urban (n = 72)
Number of alerted VFR	Mdn	26	14	11	30	30
	Q1	11	5	7	21	30
	Q3	30	23	23	35	40
	Min	0	0	0	4	0
	Max	40	40	40	40	40
Number of VFR-accepted assignments	Mdn	5	3	3	6	7
	Q1	2	1	1	4	4
	Q3	7	5	5	8	9
	Min	0	0	0	0	0
	Max	16	11	13	15	16
Linear distance in metres for first VFR to arrive at the scene	Mdn	880	3747	604	887	515
	Q1	352	2046	261	406	216
	Q3	1988	5569	1327	1615	1136
	Min	26	346	28	60	26
	Max	9996	9744	9996	7524	2262

Table 3 – Time gain for fire and rescue services (FRS) before emergency medical services (EMS). Also, for voluntary first responders (VFR) before EMS or FRS first on scene, in relation to population density.

Characteristics			Rural (n = 71)	Sub-rural (n = 71)	Sub-urban (n = 71)	Urban (n = 72)
Time gain for FRS (before EMS)	n	125	35	47	25	18
	Mdn	00:06:34	00:06:26	00:10:01	00:10:24	00:00:57
	Q1	00:03:04	00:03:36	00:05:20	00:03:05	00:00:25
	Q3	00:12:54	00:09:59	00:15:11	00:16:32	00:02:55
	Min	00:00:07	00:01:18	00:00:22	00:00:32	00:00:07
	Max	00:44:19	00:24:58	00:44:19	00:27:48	00:05:31
Time gain for EMS (before EMS or FRS)	n	132	26	30	36	40
	Mdn	00:03:07	00:03:26	00:04:16	00:03:19	00:02:08
	Q1	00:01:39	00:01:59	00:02:11	00:01:35	00:01:14
	Q3	00:05:41	00:08:33	00:06:42	00:05:36	00:03:14
	Min	00:00:02	00:00:11	00:00:13	00:00:05	00:00:02
	Max	00:24:35	00:24:35	00:16:27	00:18:21	00:09:09

r = 0.38, n = 191). Except in the case of rural areas (12:37 vs. 14:26, p = 0.089, r = 0.27, n = 40), similar findings were also seen in sub-rural (06:28 vs. 09:24, p < 0.001, r = 0.52, n = 41), sub-urban (06:10 vs. 07:40, p = 0.015, r = 0.33, n = 54), and urban (07:04 vs. 07:52, p = 0.001, r = 0.44, n = 56) areas.

Overall, VFR was first on scene (n = 132) with a median time gain of 03:07. FRS was on scene before EMS in 125 OHCAs, with a median time gain of 06:34 (Table 3). For all OHCAs (n = 285), VFR was significantly ($\chi^2(2) = 32.5$, p < 0.001) more often first on scene (n = 132, 46.3%) compared to EMS (n = 78, 27.4%) and FRS (n = 75, 26.3%).

Discussion

To the best of our knowledge, this is one of the first studies describing and comparing response times for EMS, FRS, and VFR in a rural setting. VFR had the shortest median response time in comparison to EMS and FRS in all studied population densities. A small proportion of alerted VFR accepted the assignment. This is most problematic in rural and sub-rural areas, with few VFR available. Also, FRS had a shorter response time than EMS in all studied population densities except in urban areas.

The results show that the overall median response time for EMS, FRS, and VFR was between just over 7 minutes and almost 13 minutes. As a result, no one reaches the goal set by the Swedish Resuscitation Council's that out-of-hospital defibrillation should be performed within 5 minutes.[24] The great difference between rural and urban areas is in itself worrisome, and from an equality perspective even more problematic. While the median response time in urban areas fell between 7–9 minutes, it was between 13–19 minutes in rural areas, which in a worst-case scenario means that OHCA patients in rural areas in general must wait significant longer for life-saving interventions. By using Swedish registry data from 2018, a previous study predicted 30-day survival in relation to EMS response times nationwide. The results showed that the total number of OHCA

survivors was 846 if their EMS response time fell between 7 and 9 minutes, while the model predicted 577 survivors when EMS response time fell between 10 and 15 minutes. The total number of predicted survivors with an EMS response time $\geq$ 15 minutes was 504.[5] Extrapolating this to the results of the present study, the difference between rural and urban areas means that approximately 400 lives may be lost annually in Sweden due to delayed OHCA care.

VFR were most often first on scene and had a significantly shorter response time compared to EMS and FRS, regardless of population density. One important explanation is that VFR in general are likely to be closer to the OHCA than EMS or FRS. Another explanation could be that several VFR are alerted simultaneously, increasing the probability that someone will be close to the scene. A third explanation could be that two-thirds of the VFR were alerted before the EMS and FRS. The combination of these three factors has probably contributed to the difference. Since EMS response times in general are longer in rural areas,[12] recruiting more VFR in rural areas is crucial.

The vast majority of alerted VFR do not accept the assignment. Although the proportion of VFR accepting alerts are similar, the negative consequences of fewer VFR responding to alerts are likely to be more serious in rural and sub-rural areas. Engaging communities and implementing smartphone applications to alert VFR in OHCA is highly recommended in international guidelines.[21] However, according to our results, there is a need for more VFR, especially in non-urban areas. Hence, efforts to increase recruitment are important — and feasible, as VFR in rural areas are often first on scene, even with a long distance to the OHCA.

Despite VFR having a shorter median response time than FRS, as indicated in the present result, part-time firefighters in FRS are on-call 24/7 and will promptly respond to emergencies. In contrast, VFR are volunteers and have no obligation to accept alerts. This suggests that FRS bridges the gap between VFR and EMS, resulting in reduced waiting times for professional assistance. Hence, FRS is a crucial first line of response in sparsely populated areas and important for increasing safety in society.[25] Furthermore, firefighters undergo regular training in basic life support, ensuring quality of treatment in contrast to volunteers. FRS units are also spread across a greater number of stations compared to EMS, resulting in a wider geographical coverage. Consequently, FRS have a shorter response time — by several minutes — in rural and sub-rural areas.

Notably, the study highlights an interesting finding regarding actual turnout time for FRS. In urban areas, full-time firefighters are expected to turn out within 90 seconds, while part-time firefighters in rural areas have a predetermined turnout time of 5–7 minutes. The study shows that median FRS response time falls short of the 90-second requirement in urban areas, but they surpass the predetermined time in rural areas. The median turnout time for FRS in rural areas was 2 minutes and 43 seconds, significantly shorter than the specified requirement. This could partly be attributed to utilisation of the FIP concept, which dispatches a smaller vehicle directly to the scene within 90 seconds. Using this concept is common practice. Typically, a fire commander is designated as FIP for immediate dispatch to the emergency scene, aimed at reducing response time while awaiting the arrival of the remaining crew.[26,27] Moreover, the use of a dual-dispatch system for EMS and FRS in OHCA, i.e., both are dispatched simultaneously, is likely to contribute to even shorter FRS response times.

Limitations

During ongoing alerts, the VFR's smartphone position is frequently updated (median 11 seconds). However, in some cases, the updated interval from the latest known position until a VFR is assessed to have arrived at the scene is significantly longer. In 28 OHCAs, this update interval exceeded 60 seconds, and in one extreme case, it exceeded 25 minutes. This is likely due to technical limitations in smartphone positioning, which could have affected the results in a way that inaccurately extended VFR en route time.

The calculated 50-meter buffer zone might be considered a limitation. However, in contrast to earlier VFR studies that calculated with a 25-meter buffer zone. We argue that the 50-meter zone is more adequate as it is not certain that EMCC dispatchers have located the OCHA as precisely as within a 25-meter zone. Moreover, EMS and FRS confirmed arrival at the scene inside the vehicle when arriving at the OHCA location.

Another limitation is lacking information about the reason for FRS not confirming their arrival in 13 OHCAs.

Conclusions

The differences found in median response times between rural and urban areas are worrisome from an equality perspective. VFR had the shortest median response time to OHCA in comparison to EMS and FRS in all studied population densities. More focus should be put on recruiting VFR, especially in rural areas since they have the potential to contribute saving more lives. Also, since FRS had a shorter response time than EMS in rural, sub-rural, and sub-urban areas, part-time and volunteer fire fighters should be dispatched more frequently. Although VFR had the significantly shortest median response time to OHCA, in more than half of the cases (53.7%) EMS and/or FRS where first on the scene. Therefore, they complement each other in a favourable way, creating effective cooperation between professions and volunteers, assisting and providing emergency care to people in need.

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CRediT authorship contribution statement

Anders Svensson: Visualization, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Bengt Nilsson:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. **Emelie Lantz:** Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Anders Bremer:** Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Kristofer Årestedt:** Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. **Johan Israelsson:** Conceptualization, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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