The impact of prehospital blood sampling on the emergency department process of patients with chest pain

a pragmatic non-randomized controlled trial

Van Nieuwkerk, Johan L.; Van Der Linden, M. Christien; Verheul, Rolf J.; Van Loon-Van Gaalen, Merel; Janmaat, Marije; Van Der Linden, Naomi

DOI
10.5847/wjem.j.1920-8642.2023.054

Publication date
2023

Document Version
Final published version

Published in
World Journal of Emergency Medicine

Citation (APA)
Van Nieuwkerk, J. L., Van Der Linden, M. C., Verheul, R. J., Van Loon-Van Gaalen, M., Janmaat, M., & Van Der Linden, N. (2023). The impact of prehospital blood sampling on the emergency department process of patients with chest pain: a pragmatic non-randomized controlled trial. *World Journal of Emergency Medicine*, *14*(4), 136-143. https://doi.org/10.5847/wjem.j.1920-8642.2023.054

Original Article

The impact of prehospital blood sampling on the emergency department process of patients with chest pain: a pragmatic non-randomized controlled trial

Johan L. van Nieuwkerk[1], M. Christien van der Linden[2], Rolf J. Verheul[3], Merel van Loon-van Gaalen[4], Marije Janmaat[5], Naomi van der Linden[6]

[1] *Emergency Department, Haaglanden Medical Centre & Emergency Medical Services Haaglanden, the Hague 2501 CB, the Netherlands*
[2] *Research and Development, Haaglanden Medical Centre, the Hague 2501 CK, the Netherlands*
[3] *Laboratory Services, Haaglanden Medical Centre, the Hague 2501 CK, the Netherlands*
[4] *Emergency Department, Haaglanden Medical Centre, the Hague 2501 CK, the Netherlands*
[5] *Faculty of Health, University of Applied Sciences Leiden, Leiden 2300 AJ, the Netherlands*
[6] *Faculty of Technology, Policy and Management, Delft University of Technology, Delft 2628 BX, the Netherlands*

Corresponding Author: *Christien van der Linden, Email: c.van.der.linden@haaglandenmc.nl*

BACKGROUND: In patients with chest pain who arrive at the emergency department (ED) by ambulance, venous access is frequently established prehospital, and could be utilized to sample blood. Prehospital blood sampling may save time in the diagnostic process. In this study, the association of prehospital blood draw with blood sample arrival times, troponin turnaround times, and ED length of stay (LOS), number of blood sample mix-ups and blood sample quality were assessed.

METHODS: The study was conducted from October 1, 2019 to February 29, 2020. In patients who were transported to the ED with acute chest pain with low suspicion for acute coronary syndrome (ACS), outcomes were compared between cases, in whom prehospital blood draw was performed, and controls, in whom blood was drawn at the ED. Regression analyses were used to assess the association of prehospital blood draw with the time intervals.

RESULTS: Prehospital blood draw was performed in 100 patients. In 406 patients, blood draw was performed at the ED. Prehospital blood draw was independently associated with shorter blood sample arrival times, shorter troponin turnaround times and decreased LOS (P<0.001). No differences in the number of blood sample mix-ups and quality were observed (P>0.05).

CONCLUSION: For patients with acute chest pain with low suspicion for ACS, prehospital blood sampling is associated with shorter time intervals, while there were no significant differences between the two groups in the validity of the blood samples.

KEYWORDS: Blood specimen collection; Crowding; Emergency medical services; Emergency services, Hospital; Troponin

World J Emerg Med 2023;14(4):000–000
DOI: 10.5847/wjem.j.1920–8642.2023.054

Introduction

Patients with acute chest pain often arrive at the emergency department (ED) by ambulance and are being cared for by emergency medical services (EMS). The EMS routinely performs a 12-lead electrocardiogram (ECG) and establishes a peripheral intravenous cannula (PIVC) for the intravenous administration of medication.[1, 2]

The diagnosis of an acute myocardial infarction (AMI) is based on clinical features, specific findings on the 12-lead ECG and elevation of cardiac biomarkers in the blood, specifically troponin values.[3] Chest pain patients with ST-segment elevation MI (STEMI) are

brought to a Cath Lab immediately, without awaiting lab results. Patients with chest pain and no abnormalities at their prehospital ECG are assessed at the ED, awaiting blood sample results and further diagnostic work-up.

In the latter patient group, prehospital blood sampling may save time in the diagnostic process by accelerating the availability of troponin results and thereby more rapidly identifying the patients who need to be admitted to the hospital.[4] This may shorten the time to disposition and decrease patients' ED length of stay (EDLOS). Other benefits of drawing blood from the PIVC include less pain and anxiety for the patient due to an additional venepuncture, and decreased ED staff workload.[5] Disadvantages of withdrawing blood from a PIVC may include risk of hemolysis, risk of infection, and undue blood exposure to EMS staff.[5-7]

In this study, we assessed blood sample arrival times (BSATs), troponin turnaround times (TTTs), EDLOS, and blood sample quality in patients who were transported to the ED with chest pain and no abnormalities at their prehospital ECG. Outcomes were compared between cases, in whom prehospital blood draw was performed, and controls, in whom blood draw was performed at the ED. Our hypothesis was that there would be no differences in blood sample quality and shorter time intervals, potentially expediting care for chest pain patients with no abnormalities on their prehospital ECG.

METHODS

Study design and setting

We conducted a prospective non-randomized controlled trial, comparing chest pain patients with no abnormalities on their prehospital ECG who underwent prehospital blood sampling with similar patients, in whom blood was drawn in the ED.

A pragmatic design was adopted, to assess whether our intervention would work under usual conditions.[8] Primary outcomes were BSAT at the laboratory, TTT, and EDLOS. Secondary outcomes were the number of blood sample mix-ups, and blood sample quality (hemolysis and insufficient amount of blood).

The study took place in an inner-city hospital and an EMS in the Hague, the Netherlands, from October 1, 2019 to February 29, 2020. The 30-bed ED serves as a regional level 1 trauma centre with 54,000 patient visits annually and a 24% admission rate. The EMS has several emergency dispatch centres in an area of 405 km^2 with a population of 1.2 million inhabitants. The EMS receives approximately 90,000 calls annually, of which 50,000 calls are transported to an ED, and 17,000 calls are transported to the ED of the study setting. After telephone triage, ambulance care can be dispatched with urgency levels A1 (arrival < 15 min), A2 (arrival <30 min), and B (ordered ambulance transportation). In the Netherlands, ambulances are staffed by a registered ambulance nurse with extensive in-hospital and prehospital training, accompanied by an ambulance driver. Ambulance nurses work autonomously using a national protocol.

Patients for cardiology are brought to the chest pain unit (CPU) during day and evening shifts and to the general ED during the night shift, unless all CPU beds are occupied. Then patients will be brought to the general ED regardless of the time. Patients with chest pain are treated according to local protocols, based on the European guidelines for the management of acute coronary syndromes (ACS).[9] In all chest pain patients with no abnormalities at their prehospital ECG, a rapid rule out strategy is initiated. If troponin values are normal, but obtained less than 6 h after the onset of the complaints, a new blood sample is obtained after 3 h to determine troponin kinetics.

Selection of participants

Patients were eligible for inclusion when they had chest pain, were 18 years or older, and were brought to our ED for cardiac assessment by ambulance with urgency level A2. Patients who died at the ED, patients who left the ED against medical advice, and patients who were transferred to another facility were excluded. Patients who had STEMI or other abnormalities on the prehospital ECG were excluded from this study, since these are level A1 patients. Patients who fulfilled the inclusion criteria and who underwent prehospital blood sampling were the cases. Patients who fulfilled the inclusion criteria and in whom blood sampling was performed at the ED were the controls. Sample size calculation showed the need to include 350 patients (70 cases vs. 280 controls) to detect a 15-minute decrease in TTT for the prehospital blood draw group versus the ED blood draw group, based on 80% power and $P<0.05$ significance.

Procedures

Twenty-five of the 106 ambulance nurses, selected by convenience sampling, were informed about the study and trained in the blood draw procedure of the hospital. The standard operating procedures of the hospital were used, as were the procedures for patient and sample identification. Participating ambulance nurses approached the patients who fulfilled the inclusion criteria for informed consent during EMS care, before or while the patient was in the ambulance. After

the patients' consent, blood sampling was performed by the ambulance nurse, in combination with the insertion of a PIVC. No changes were made in the procedure for obtaining blood specimens in the ED: the blood sample was obtained through venepuncture or by drawing blood through a previously inserted PIVC. All blood samples were collected in a BD Vacutainer® PST™ heparin gel tube (BD, UK), labelled, classified as 'urgent' and sent to the central laboratory by pneumatic tubes with the corresponding lab form. The laboratory procedures for processing blood samples remained unchanged. After centrifugation of the blood sample to obtain plasma, troponin T was measured with a highly sensitive STAT assay on a Cobas (Roche, Germany) analyser with a reported assay time of 9 min. After checking the sample integrity and confirming of the analytical validity by a lab technician, values were digitally reported and available to the ED. Doctors were actively informed by lab technicians about elevated troponin values according to the hospital protocol within 30 min. The troponin value was defined according to the HEART score as normal (below 0.014 μg/L), high (1 to 3 times the reference value), or extremely high (>3 times the reference value).[10] Laboratory personnel were blinded to the study groups.

Study procedures were reviewed with EMS staff and ED management and laboratory services. The study was approved by the regional medical research committee Leiden Den Haag Delft (nr.19-024).

Data measurements and definition

Data collected from the electronic medical records database included patient demographics, medical history and risk factors for cardiac ischemic events, arrival times, troponin values, radiology tests, disposition, the need for a second troponin test during the patient's ED stay, and time intervals. BSAT at the laboratory was defined as the duration between patient arrival at the ED and blood sample arrival at the laboratory. TTT was defined as the time between patient arrival at the ED and the availability of the troponin result. EDLOS was defined as the time between patient arrival and the time the patient left the ED to be admitted or discharged home, and was only calculated for the patients who were assessed at the general ED. Whether the patient arrived during extreme busyness at the ED was measured with the National ED OverCrowding Score (NEDOCS), a multidimensional scale to measure crowding.[11] The NEDOCS correlates well with perceived crowding in this ED.[12] Extreme busyness is defined as a NEDOCS of 61 and higher. We obtained data on the presence of insufficient quantity of the sample and the number of hemolyzed specimens from the laboratory database, looking at laboratory tests that are sensitive to hemolysis (e.g. potassium, lactate dehydrogenase). We assessed the numbers of blood sample mix-ups from the Safety Incident Reporting System.

Statistical analysis

Differences between the two groups were analysed using Chi-square tests and the Mann-Whitney *U* test. To identify risk factors independently associated with lengthier time frames, we performed linear regression analyses with a backward stepwise selection. In three separate models, we used BSAT, TTT, and EDLOS as the dependent variables. For EDLOS, only patients who were assessed at the general ED were included in the model. We included blood draw case or control, patient demographics, medical history, and ED visit characteristics, which were all entered into the model as independent variables. We eliminated the variable that explained the least variance and reran the model. We continued this process until the last variable we considered eliminating explained a statistically significant ($P \leq 0.05$) proportion of the variance. We present the first and the final model. Prior to running the regression models, skewed data were $\log_{10}$ transformed to achieve a more suitable distribution for linear regression. We considered a *P*-value ≤0.05 as indicative of a significant difference. We used the statistical package for the social sciences (IBM Corp., USA) for analysis.

RESULTS

During the study period, there were 34,540 ED visits, of which 29,355 were by adult patients. A total of 4,214 ED visits were registered for cardiology, of which 2,034 were transported to the ED by ambulance. In 643 of these 2,034 ED visits, patients had chest pain with low suspicion for ACS and no abnormalities on their ECG. Of these 643 ED visits, 136 ED visits were excluded because these were subsequent visits by the same patients. The remaining 507 unique patients were included in this study. Prehospital blood draw was performed in 101 of these patients, of whom one patient withdrew her informed consent, leaving 100 patients as cases. The other 406 patients were included as controls (Figure 1).

Cases and controls were similar with regard to patient demographics, troponin results, and number of patients arriving during extremely busy circumstances at the ED. Cases less often had a medical history of cardiovascular disease, and arrived at the ED more often in the evening compared to control patients (Table 1).

Subanalyses of the patient group who were assessed

at the general ED (*n*=244) showed no differences between cases and controls, except for a prior cardiovascular disease, which was less common in cases, and the need to draw a second troponin measurement during their ED stay, which was more common in cases (Supplementary Table 1).

BSATs and TTTs were 13 min and 11 min per patient, respectively, shorter in the cases than in the controls (P<0.001). We calculated total EDLOS in the patients who were assessed at the general ED and found no significant difference between cases and controls (Table 2).

We found no statistically significant differences in the number of blood sample mix-ups and blood sample quality between the groups.

In the multiple linear regression model with log-transformed BSAT as the dependent variable, none of the patient and visit characteristics were independently associated except for prehospital blood draw (P<0.001). This means that after adjustment for the other variables, prehospital blood draw remained independently associated with shorter BSAT (Supplementary Table 2).

The multiple linear regression model with log-transformed TTT as the dependent variable showed that prehospital blood draw and needing hospital admission significantly shortened the TTT. Arriving during the evening shift and a higher troponin result were associated with increased TTT (Table 3).

Prehospital blood draw was also independently associated with a shorter EDLOS. A higher age, the execution of one or more radiology tests, and the need to draw a second troponin sample during the patient's ED stay significantly increased EDLOS (Table 4).

DISCUSSION

The unadjusted results of our study show that prehospital blood sampling compared with blood draw at the ED markedly shortened both BSAT and TTT, but EDLOS remained unchanged. However, the study groups were not identical in their baseline characteristics. Therefore, multivariable regression analyses were used to adjust for confounding factors. These analyses showed that prehospital blood draw was independently associated with shorter BSAT and that the lab results were more quickly available to the physicians at the ED, potentially speeding up the patients' treatment. Also, prehospital blood draw significantly decreased EDLOS when corrected for the other variables, while a higher age, the need for a second troponin blood draw during the patient's ED stay, and one or more radiology requests were associated with an increase in LOS.

Few studies have been performed on the impact of

Table 1. Patient demographics, medical history, risk factors and ED visit characteristics of the total study population (*n*=506)

Variables	Cases (*n*=100)	Controls (*n*=406)	Odds ratio	95% *CI*	*P*[a]
Assessment at general ED, *n* (%)	42 (42.0)	202 (49.8)	0.73	0.47–1.14	0.17
Assessment at chest pain unit, *n* (%)	58 (58.0)	204 (50.2)			
Age, years, median (IQR)	64 (50–77)	64 (53–75)			0.98
Gender, male, *n* (%)	40 (40.0)	196 (48.3)	1.40	0.90–2.19	0.14
Medical history, *n*/total known (%)					
Diabetes[b]	28/98 (28.6)	49/207 (23.7)	0.78	0.45–1.33	0.36
Hypertension[c]	45/98 (45.9)	75/205 (36.6)	0.68	0.42–1.11	0.12
Dyslipidemia[d]	31/88 (35.2)	88/201 (43.8)	1.43	0.85–2.41	0.17
Prior cardiovascular disease[e]	36/98 (36.7)	101/104 (49.5)	1.69	1.03–2.77	0.04
Family history of cardiac events[f]	24/47 (51.1)	47/98 (48.0)	0.88	0.44–1.77	0.73
Smoking history[g], *n*/total known (%)					0.19
Current	17/53 (32.1)	44/119 (37.0)			
Former	19/53 (35.8)	27/119 (22.7)			
Never	17/53 (32.1)	48/119 (40.3)			
Arrival time, *n* (%)					0.04
Day shift (8 am to 4 pm)	21 (21.0)	111 (27.3)			
Evening shift (4 pm to midnight)	47 (47.0)	135 (33.3)			
Night shift (midnight to 8 am)	32 (32.0)	160 (39.4)			
Arrival during extreme busyness[h]	22 (22.0)	99 (24.4)	0.88	0.52–1.48	0.62
Troponin result, *n* (%)					0.14
Normal	62 (62.0)	273 (67.4)			
Elevated	29 (29.0)	82 (20.2)			
Strongly elevated	9 (9.0)	50 (12.3)			
Radiology requests, *n* (%)			0.73	0.42–1.26	0.25
None	81 (81.0)	307 (75.6)			
One or two	19 (19.0)	99 (24.4)			
Hospital admission, *n* (%)	65 (65.0)	258 (63.5)	1.07	0.67–1.68	0.79

[a] All variables were analyzed with the Chi-squre test, except age, which was analyzed with the Mann-Whitney *U* test; [b] Tested on 305 patients, due to missing information in 201 patients; [c] Tested on 303 patients, due to missing information in 203 patients; [d] Tested on 289 patients, due to missing information in 217 patients; [e] Tested on 302 patients, due to missing information in 204 patients; [f] Tested on 145 patients, due to missing information in 361 patients; [g] Tested on 172 patients, due to missing information in 334 patients; [h] Measured with the NEDOCS, level 61 and higher. *CI*: confidence interval; CT: computed tomography; ED: emergency department; IQR: interquartile range; NEDOCS: National Emergency Department OverCrowding Score.

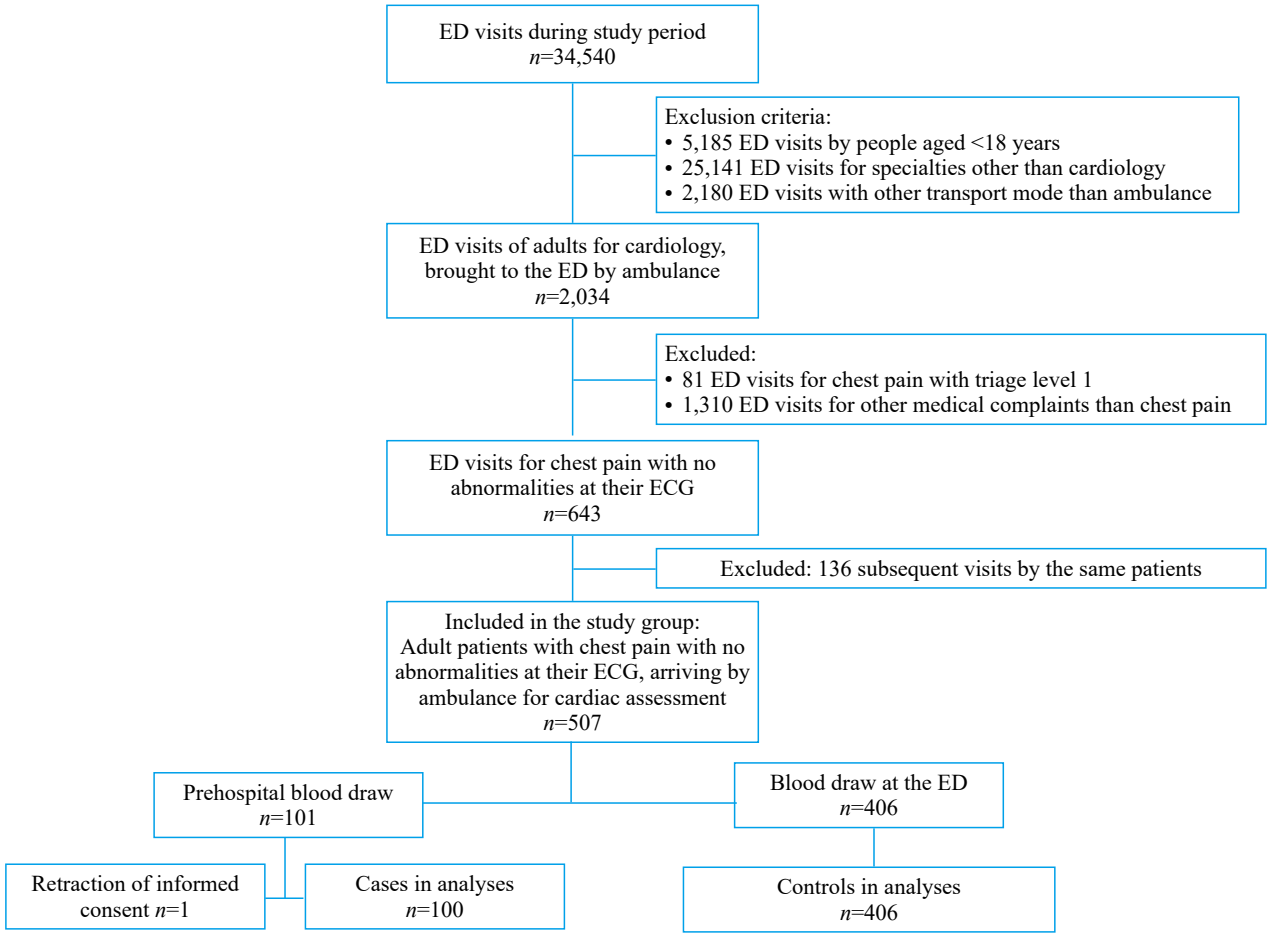

Figure 1. Flow chart of the study participants. ACS: acute coronary syndrome; ECG: electrocardiogram; ED: emergency department.

Table 2. Univariate analyses of time intervals

Time intervals	Cases (*n*=100)	Controls (*n*=406)	*P*-value
Total study population			
Blood sample arrival time, min, median (IQR) [a]	13 (8.3–18.8)	26 (19.0–34.0)	<0.001
Troponin turnaround time, min, median (IQR) [a]	53 (42.3–66.0)	64 (53.0–81.0)	<0.001
Patients who were assessed at the general ED	Cases (*n*=42)	Controls (*n*=202)	
EDLOS, min, median (IQR)[a]	180 (126–222)	181 (134–227)	0.26

[a] Analyzed with the Mann-Whitney *U* test. EDLOS: emergency department length of stay; IQR: interquartile range.

prehospital blood draw versus ED blood draw. A study analysing 101 patients demonstrated door-to-result times for serum chemistry studies in cases being 28 min faster than controls (P<0.02).[13] A 29-minute decrease in LOS was observed which did not reach statistical significance. In a study including 400 patients, the authors concluded that the practice of prehospital blood draws by EMS in the field should be supported, based on no differences in redraw rates and a non-significant decrease in median LOS.[6] In both studies, patients were included regardless of their presenting complaint or type of blood work. Differences between the study groups in patient characteristics are not described. DuCharme et al[14] included 41 patients with chest pain in two groups that were similar in patient demographics, medical history, and disposition. Patients were excluded if they had STEMI on their prehospital ECG. The median time from ED arrival to laboratory results was significantly shorter for the prehospital group than for the in-hospital group, and an 18-minute decrease was found in the turnaround time of cardiac biomarkers. There were no differences in the number of hemolysis events or no effect on EDLOS. In our study, similar results were found, but including confounding variables such as the need for a second troponin draw during the patient's ED stay in the regression models showed that prehospital blood draw significantly decreased EDLOS as well.

Prehospital blood sampling allows ED staff to send the blood to the laboratory immediately at the patients' arrival. Shortening TTT may expedite patients' treatment and improve outcomes. The similar admission percentages in cases and controls suggest similar health

outcomes, but more research is needed to assess the effect of prehospital blood sampling on patient outcome.

Untimely laboratory services have a major impact on the efficiency of diagnosis and initiation of treatments in the ED.[15,16] Waiting for laboratory results is frequently described as a cause for increased EDLOS and crowding.[13,17,18] In our study, the improvement in the efficiency of laboratory testing was reflected in a shorter EDLOS when adjusted for other factors. In our regression model concerning EDLOS, 26% of the variation was explained by prehospital blood draw, age, a second troponin draw, and a radiology request, suggesting that other, possibly important, contributors to EDLOS were not measured in this study. Prehospital blood sampling is a typical ED throughput intervention. Interventions that address input and throughput factors are only successful if the outflow of patients is also addressed. Since EDLOS and crowding are affected by factors beyond the ED process, multimodal interventions are needed to further reduce EDLOS and crowding.[19]

Arrival during the evening shift was independently associated with a longer TTT. In our ED, the highest number of patients present from noon until late evening. As ED volume increases, the number of blood tests also increases under conditions of fixed resources such as laboratory staffing,[20] leading to a backlog of blood samples on which tests must be run, and the associated increase in turnaround time. Longer turnaround times

Table 3. Factors independently associated with log-transformed troponin turnaround time

Factors	Initial model			Final model		
	B	95% *CI*	*P*-value[a]	B	95% *CI*	*P*-value[a]
Constant	1.50	1.24– 1.77	<0.001	1.73	1.70– 1.75	<0.001
Prehospital blood draw	-0.08	-0.17– -0.04	0.06	-0.10	-0.13– -0.07	<0.001
Age	-0.001	-0.003– 0.002	0.62			
Gender, male	-0.04	-0.10– 0.03	0.27			
Smoking history	0.02	-0.02– 0.06	0.26			
Diabetes mellitus	0.05	-0.04– 0.14	0.29			
Hypertension	0.005	-0.07– 0.08	0.90			
Dyslipidemia	0.06	-0.04– 0.15	0.23			
Prior cardiovascular disease	-0.003	-0.09– 0.09	0.94			
Family history of coronary disease	0.001	-0.06– 0.06	0.799			
Arrival at day shift	-0.03	-0.10– 0.05	0.48			
Arrival at evening shift	0.08	-0.03– 0.19	0.17	0.09	0.07– 0.12	<0.001
Busyness at arrival	0.001	-0.001– 0.002	0.47			
Troponin result	0.09	0.02– 0.17	0.02	0.06	0.04– 0.07	<0.001
Second troponin draw	-0.02	-0.10– 0.05	0.56			
Radiology request	-0.03	-0.09– 0.04	0.45			
Hospital admission	0.001	-0.10– 0.10	0.99	-0.03	-0.06– 0.00	0.046

B: beta-coefficient; *CI*: confidence interval; NEDOCS: National Emergency Department OverCrowding Score, levels 61 and higher.
[a] *P*-values were calculated using multivariate linear regression analyses using log-transformed troponin turnaround time as a dependent variable, adjusted for patient groups (prehospital blood draw and ED blood draw group), patient demographics, medical history and visit characteristics. For the final model, the variables with the largest *P*-values were sequentially removed until all *P*-values were smaller than 0.05. The R^2 for the final model was 0.20, indicating that 20% of the variance of troponin turnaround time is explained by prehospital blood draw, arrival in the evening shift, troponin result, and hospital admission.

Table 4. Factors independently associated with log-transformed ED length of stay*

Factors	Initial model			Final model		
	B	95% *CI*	*P*-value[a]	B[b]	95% *CI*	*P*-value[a]
Constant	2.25	1.99– 2.51	<0.001	2.09	2.01–2.17	<0.001
Prehospital blood draw	-0.02	-0.10– 0.06	0.59	-0.10	-0.16– -0.04	0.001
Age	0.003	0.001– 0.005	<0.001	0.002	0.001– 0.003	0.02
Gender, male	-0.03	-0.06– 0.06	0.93			
Smoking history	0.009	-0.03– 0.04	0.61			
Diabetes mellitus	-0.04	-0.12– 0.05	0.41			
Hypertension	-0.02	-0.10– 0.05	0.53			
Dyslipidemia	0.04	-0.05– 0.13	0.41			
Prior cardiovascular disease	-0.08	-0.16– 0.007	0.07			
Family history of coronary disease	0.02	-0.05– 0.08	0.64			
Arrival at day shift	-0.008	-0.08– 0.07	0.82			
Arrival at evening shift	-0.06	-0.17– 0.05	0.27			
Busyness at arrival	0.000	-0.001– 0.002	0.76			
Troponin result	-0.11	-0.18– -0.03	0.004			
Second troponin draw	0.16	0.09– 0.23	<0.001	0.20	0.15– 0.25	<0.001
Radiology request	0.06	-0.001– 0.13	0.06	0.05	0.003– 0.09	0.04
Hospital admission	0.02	-0.08– 0.12	0.70			

B: beta-coefficient; *CI*: confidence interval; CT: computed tomography; ED: emergency department.
*Calculated using information on patients who were assessed at the general ED, *n*=244.
[a] *P*-values were calculated using multivariate linear regression analyses using log-transformed EDLOS as a dependent variable, adjusted for patient groups (prehospital blood draw group and ED blood draw group), all patient demographics, medical history and visit characteristics.
[b] For the final model, the variables with the largest *P*-values were sequentially removed until all *P*-values were smaller than 0.05. R^2 was 0.26, indicating that 26% of the variation is explained by prehospital blood draw, age, a second troponin draw, and a radiology request.

may delay clinician decision-making and initiation of treatment,[20] causing ED crowding. Patient-per-nursing staff ratios in the ED setting are known to vary across time of day, with increased ratios during the evening shift[21] and increased workload. [22] A future study may help to better understand the effect of prehospital blood sampling on ED crowding and workload.

Our findings concerning errors such as hemolysis, which did not differ between the groups, are congruent with the literature.[6,13] Prehospital blood draw is safe with no statistically significant differences in haemolysis and redraw rates and no increased risk of blood exposure incidents.[6] Additionally, the high preanalytical stability and validity support the practice of prehospital blood draw.[4]

Strengths and limitations

This is one of the few studies assessing the association of prehospital blood sampling with time intervals, number of blood sample mixups and sample quality. The rigorous study procedures and the inclusion of potential effect modifiers are strengths of this study.

There are however, also some limitations. Since this was a non-randomized trial, there is a risk of bias. Using the ROBINS-I tool,[23] we rated our outcomes as having a moderate risk of bias, except for the outcome LOS, which was rated as critical risk for the first bias domain (i.e. bias due to confounding). Factors such as hospital occupancy were not controlled for in our models, but may affect time to hospital admission and increase EDLOS. Further research is required to assess the effect of prehospital blood sampling on EDLOS using a larger sample and including additional confounding factors in the model.

Only a quarter of the EMS staff were participating and data concerning which patients they did not include, if any, are lacking. Therefore, we cannot rule out confounding by indication. However, the dispatcher who allocated the ambulance was blinded to which EMS nurse participated in our study. While the groups were similar with respect to patient demographics, there were differences in the number of patients with a medical history of cardiovascular disease, as well as differences in the number of patients needing a second troponin sample during their ED stay. We lacked information on the medical history and smoking history of the patients in half of our sample. However, by performing multivariate regression analyses we were able to control for differences between the groups.

Cases were more often treated at the CPU than at the general ED (42% vs. 58%), while in the controls, this was 50% in each location. Since the CPU is located at our ED and blood samples of both departments are sent to the laboratory via the same pneumatic tube station, the effect on BSAT and TTT is negligible.

Finally, our study took place in an inner-city setting with short driving distances and short (i.e., <20 min) transportation times. We did not collect data on prehospital time delay, an interesting subject for future studies. We also did not collect data on external circumstances such as variations in temperature. Although we did not find any differences in blood sample quality between our study groups, this finding may be different in other settings or environmental circumstances. However, blood sampling from a prehospital environment has been found to be valid.[4]

Implications for emergency clinical care

The prehospital blood draw procedure could be expanded to other patient groups. Approximately 60% of the patients who arrive by ambulance meet EMS protocols for intravenous entrance.[6] Future studies are recommended for other prehospital sampling tests in which time sensitive processing could make a difference in ED treatment or processes. For example, ABO blood type and screening would get the right product to the patient sooner, saving scarce O negative transfusion units.

Based on the findings of our study, we propose implementing a dedicated chest pain pathway including prehospital blood draw by EMS for patients presenting with low suspicion for ACS. This may increase patient throughput at the ED, ultimately decrease ED crowding and improve patient outcomes.

CONCLUSIONS

This study shows that prehospital blood sampling significantly shortens the time to blood results and EDLOS for patients with acute chest pain and no abnormalities at their prehospital ECG, while maintaining similar blood sample quality.

ACKNOWLEDGEMENTS

The authors thank Rob Ong from the University of Applied Sciences Leiden, EMS policy officer Martijn Jochem, librarian Thomas Vissers, emergency physician Maartje de Kort, clinical chemist Elske Kusters, and cardiologist Pranobe Oemrawsingh, for their invaluable help during this study. Most importantly, we thank the ambulance nurses who participated in this project.

Funding: None.

Ethical approval: This study was retrospectively registered in the

ISRCTN registry with study ID ISRCTN80335325 on 09/01/2022. The trial registration was updated on 03/05/2022. All procedures performed in this study were in accordance with the 1964 *Helsinki Declaration* and its later amendments or comparable ethical standards. The ethical review committee of Southwest Holland (nr.19-024) granted approval and exemption. Patient consent was not needed.

Conflicts of interest: The authors declare that they have no competing interests.

Author contributions: JLVN and MCVDL contributed equally. JLVN: Conceptualization, Formal analysis, Writing- Original draft preparation. MCVDL: Conceptualization, Formal analysis, Writing – Original draft preparation, Writing- Review & Editing, Supervision. RJV: Conceptualization, Writing- Review & Editing. MVLVG: Writing- Review & Editing. MJ: Conceptualization, Writing- Review & Editing. NVDL: Conceptualization, Formal analysis, Writing- Review & Editing, Supervision. All authors have participated in the research as well as contributed to the drafting and approval of the final version of the manuscript.

All the supplementary files in this paper are available at http://wjem.com.cn.

REFERENCES

1 Cotton BA, Jerome R, Collier BR, Khetarpal S, Holevar M, Tucker B, et al. Guidelines for prehospital fluid resuscitation in the injured patient. J Trauma. 2009;67(2): 389-402.
2 van Schuppen H, Bierens J. Understanding the prehospital physician controversy. Step 1: comparing competencies of ambulance nurses and prehospital physicians. Eur J Emerg Med. 2011;18(6): 322-7.
3 Thygesen K, Alpert JS, Jaffe AS, Chaitman BR, Bax JJ, Morrow DA, et al. Fourth universal definition of myocardial infarction (2018). J Am Coll Cardiol. 2018;72(18): 2231-64.
4 Prottengeier J, Jess N, Harig F, Gall C, Schmidt J, Birkholz T. Can we rely on out-of-hospital blood samples? A prospective interventional study on the pre-analytical stability of blood samples under prehospital emergency medicine conditions. Scand J Trauma Resusc Emerg Med. 2017;25(1): 24.
5 Coventry LL, Jacob AM, Davies HT, Stoneman L, Keogh S, Jacob ER. Drawing blood from peripheral intravenous cannula compared with venepuncture: a systematic review and meta-analysis. J Adv Nurs. 2019;75(11): 2313-39.
6 Harrison G, Speroni KG, Dugan LS, Daniel MG. A comparison of the quality of blood specimens drawn in the field by EMS versus specimens obtained in the emergency department. J Emerg Nurs. 2010;36(1): 16-20.
7 Zhang L, Cao SY, Marsh N, Ray-Barruel G, Flynn J, Larsen E, et al. Infection risks associated with peripheral vascular catheters. J Infect Prev. 2016;17(5): 207-13.
8 Dal-Ré R, Janiaud P, Ioannidis JPA. Real-world evidence: how pragmatic are randomized controlled trials labeled as pragmatic? BMC Med. 2018;16(1): 49.
9 Roffi M, Patrono C, Collet JP, Mueller C, Valgimigli M, Andreotti F, et al. 2015 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation. Task Force for the Management of Acute Coronary Syndromes in Patients Presenting without Persistent ST-Segment Elevation of the European Society of Cardiology (ESC). Eur Heart J. 2016;37(3):267-315.
10 Six AJ, Cullen L, Backus BE, Greenslade J, Parsonage W, Aldous S, et al. The HEART score for the assessment of patients with chest pain in the emergency department: a multinational validation study. Crit Pathw Cardiol. 2013;12(3): 121-6.
11 Weiss SJ, Derlet R, Arndahl J, Ernst AA, Richards J, Fernández-Frackelton M, et al. Estimating the degree of emergency department overcrowding in academic medical centers: results of the National ED Overcrowding Study (NEDOCS). Acad Emerg Med. 2004;11(1): 38-50.
12 van der Linden MC, van Loon M, Gaakeer MI, Richards JR, Derlet RW, van der Linden N. A different crowd, a different crowding level? The predefined thresholds of crowding scales may not be optimal for all emergency departments. Int Emerg Nurs. 2018;41: 25-30.
13 Lindner H, Schmedel W, Martin M, Heidt M, McMahon C, Romans J. The impact of prehospital blood collection on time to laboratory test results and emergency department length of stay. Adv Emerg Nurs J. 2010;32(4): 354-9.
14 DuCharme B, Macci Bires A, Montanye E, Khan M, DuCharme S, Linse M, et al. Effect of prehospital blood draws on length of stay for chest pain patients in the emergency department: a pilot study. Crit Care Nurs Q. 2019;42(2): 208-14.
15 Lee-Lewandrowski E, Corboy D, Lewandrowski K, Sinclair J, McDermot S, Benzer TI. Implementation of a point-of-care satellite laboratory in the emergency department of an academic medical center. Impact on test turnaround time and patient emergency department length of stay. Arch Pathol Lab Med. 2003;127(4): 456-60.
16 Holland LL, Smith LL, Blick KE. Reducing laboratory turnaround time outliers can reduce emergency department patient length of stay: an 11-hospital study. Am J Clin Pathol. 2005;124(5): 672-4.
17 van der Linden C, Reijnen R, Derlet RW, Lindeboom R, van der Linden N, Lucas C, et al. Emergency department crowding in The Netherlands: managers' experiences. Int J Emerg Med. 2013;6(1): 41.
18 Kawano T, Nishiyama K, Hayashi H. Execution of diagnostic testing has a stronger effect on emergency department crowding than other common factors: a cross-sectional study. PLoS One. 2014;9(10): e108447.
19 van der Linden MC, Quarles van Ufford HM, Projectgroup Medical Specialists, van der Linden N. The impact of a multimodal intervention on emergency department crowding and patient flow. Int J Emerg Med. 2019;12(1): 21.
20 Hwang U, Baumlin K, Berman J, Chawla NK, Handel DA, Heard K, et al. Emergency department patient volume and troponin laboratory turnaround time. Acad Emerg Med. 2010;17(5): 501-7.
21 Amritzer MA, Muntlin Å, Berg LM, Göransson KE. Nursing staff ratio and skill mix in Swedish emergency departments: a national cross-sectional benchmark study. J Nurs Manag. 2021;29(8): 2594-602.
22 Ball JE, Murrells T, Rafferty AM, Morrow E, Griffiths P. 'Care left undone' during nursing shifts: associations with workload and perceived quality of care. BMJ Qual Saf. 2014;23(2): 116-25.
23 Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016;355: i4919.

Received September 29, 2022
Accepted after revision Feburary 1, 2023