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EMS blood collection from patients with acute chest pain reduces emergency department length of stay

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Abstract

Background: Expediting the measurement of serum troponin by leveraging EMS blood collection could reduce the diagnostic time for patients with acute chest pain and help address Emergency Department (ED) overcrowding. However, this practice has not been examined among an ED chest pain patient population in the United States.

Methods: A prospective observational cohort study of adults with non-traumatic chest pain without ST-segment elevation myocardial infarction was conducted in three EMS agencies between 12/2016–4/2018. During transport, paramedics obtained a patient blood sample that was sent directly to the hospital core lab for troponin measurement. On ED arrival HEART Pathway assessments were completed by ED providers as part of standard care. ED providers were blinded to troponin results from EMS blood samples. To evaluate the potential impact on length of stay (LOS), the time difference between EMS blood draw and first clinical ED draw was calculated. To determine the safety of using troponin measures from EMS blood samples, the diagnostic performance of the HEART Pathway for 30-day major adverse cardiac events (MACE: composite of cardiac death, myocardial infarction (MI), coronary revascularization) was determined using EMS troponin plus arrival ED troponin and EMS troponin plus a serial 3-h ED troponin.

Results: The use of EMS blood samples for troponin measures among 401 patients presenting with acute chest pain resulted in a mean potential reduction in LOS of 72.5 ± SD 35.7 min. MACE at 30 days occurred in 21.0% (84/401), with 1 cardiac death, 78 MIs, and 5 revascularizations without MI. Use of the HEART Pathway with EMS and ED arrival troponin measures yielded a NPV of 98.0% (95% CI: 89.6–100). NPV improved to 100% (95% CI: 92.9–100) when using the EMS and 3-h ED troponin measures.

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Declaration of Competing Interest

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Conclusions: EMS blood collection used for core lab ED troponin measures could significantly reduce ED LOS and appears safe when integrated into the HEART Pathway.

Keywords

Chest pain; Prehospital; EMS; Troponin; Acute coronary syndrome

1. Introduction

Emergency Department (ED) overcrowding is increasingly common and widely recognized as a major threat to public health [1,2]. EDs often experience episodes of overcapacity resulting in the boarding of admitted patients and delays in care throughout the healthcare system [3]. Overcrowding strains health system resources and negatively impacts patient safety, patient satisfaction, access to and quality of care, as well as health system financial margins [4,5]. Operational efforts typically focus on potential solutions directed toward a specific work flow, complaint, or condition [6]. Acute chest pain is a leading cause of ED visits, accounting for nearly 7 million ED visits in the US each year [7]. Historically, most ED patients with chest pain undergo prolonged diagnostic evaluations, which often increase their ED length of stay (LOS) [8,9]. Safely expediting the ED evaluation of this large group of patients has the potential to reduce overcrowding, enhance access to care, improve patient satisfaction, and improve outcomes [10].

Accelerated diagnostic protocols (ADP), like the HEART Pathway, significantly increase the proportion of patients with chest pain that are discharged directly from the ED and reduce LOS and cost [11,12]. While serial troponin testing is a key safety feature of ADPs, it is the rate limiting step in patient disposition time. Average ED LOS for patients with chest pain is >4 h, even among low-risk patients who are ultimately discharged from the ED [12]. In fact, a prior analysis suggests that serial troponin testing is a stronger predictor of ED LOS than patient age or Emergency Severity Index [13]. Partnerships between emergency medical services (EMS) and the ED have the potential to expedite care by analyzing blood samples obtained by EMS prior to ED arrival in the hospital core lab. This process stands to decrease time to results, time to decision-making, and overall LOS. Analysis of EMS blood samples is uncommon and often prohibited by hospital policies. There is a lack of robust literature assessing the feasibility, validity, and safety of EMS blood samples for use in a hospital core laboratory. Few studies have explored the potential reduction in ED LOS from EMS-obtained blood samples and none have evaluated their diagnostic performance when used in the context of an ED chest pain ADP.

To address this evidence gap, we evaluate a novel approach of partnering with EMS to acquire early blood samples for troponin measurement. The primary objective of this analysis is to determine the potential impact of integrating these EMS blood samples into a health system's ED and laboratory operations in order to expedite the evaluation of patients with chest pain and thereby decrease LOS. A secondary objective is to determine the safety and diagnostic performance of integrating troponin measures from EMS blood samples into the HEART Pathway.

2. Methods

2.1. Study design

We conducted a prospective observational cohort study within 3 EMS systems from December 2016 to April 2018. Paramedics collected blood samples as part of their usual scope of practice on patients with non-traumatic chest pain. This study was performed under a waiver of informed consent obtained from the Wake Forest University School of Medicine Health Sciences Institutional Review Board and was registered with clinicaltrials.gov (NCT02709135) prior to patient accrual. The study de-sign and methods have been previously described [14].

2.2. Study setting

Three third service, county-based EMS agencies located in the central region of North Carolina participated in this study. Stokes County EMS is a rural agency that completes 6000 transports annually with 34 medics and 5 trans-port units. Surry County EMS is also a rural agency with 73 medics and 7 transport units and completes 17,000 transports annually. Forsyth County EMS is an urban agency with approximately 80 medics and 16 transport units and completes 35,000 transports each year. For this study, EMS included only patients transported to a single clinical site, the Wake Forest Baptist Health ED. The clinical site is both an adult and pediatric level 1 academic trauma/burn center with 24-h cardiac catheterization laboratory availability. The ED has an annual volume of 105,000 and is staffed with board certified or eligible emergency physicians who care for and oversee care provided by residents and advanced practice providers. The HEART Pathway is the ADP embedded within the electronic health record at WFBH.

2.3. Study population

The target population was a convenience sample of adult patients ≥ 21 years old calling 911 with acute, non-traumatic chest pain without evidence of ST-segment elevation myocardial infarction (STEMI) who were transported by EMS to WFBH. Exclusion criteria included: patients with concomitant non-cardiac medical, surgical, or psychiatric emer-gencies; those receiving hospice care; and patients with unstable vital signs, defined as hypotension (systolic < 90 mmHg), tachycardia (heart rate > 120), bradycardia (heart rate < 40), and hypoxemia (<90% pulse-oximetry on room air or usual home oxygen flow rate).

2.4. Study protocol

Protocol-driven routine chest pain care was provided, including obtaining intravenous access, an ECG, and the potential administration of aspirin, nitroglycerin, and supplemental oxygen. Upon ED arrival, transition of care was performed in the usual fashion and EMS blood samples were given to nursing staff. EMS[249] blood samples were then sent to the core lab for troponin measurement, with the results used for research purposes only (treating providers were blinded to results). While in the ED, participants received a standard chest pain evaluation using HEART Pathway risk stratification, which included an ECG and serial troponin measures at 0 and 3 h after ED arrival. [11,12] The EMS and clinical blood samples were measured on the same instruments in the medical center's core lab [AccuTnI+3 assay

(Beckman Coulter, California); 0.025 ng/ml 99th percentile upper reference limit (URL) from 4/3/17 to 12/12/17 or TnI-Ultra assay (Siemens, Munich, Germany); 0.040 ng/ml URL before 4/3/17 and after 12/12/17].

To determine the diagnostic performance of troponin measures from EMS blood samples, the EMS troponin result was incorporated into HEART Pathway risk assessment. To accomplish this, EMS troponin results were combined with the HEAR score (history of present illness elements, ECG, age, and risk factors) calculated by the treating provider and the subsequent troponin measures from blood collected after ED arrival in two separate ways. First, the HEART Pathway assessment was calculated using the EMS blood sample troponin and first ED blood sample troponin. Next, it was calculated using the EMS troponin and the 3-h ED troponin.

2.5. Outcomes

The primary objective of this analysis was to evaluate the potential LOS impact of integrating EMS blood samples into a health system's ED and laboratory workflow in the evaluation of adult patients with atraumatic chest pain. Predicted total ED LOS savings was calculated by determining the length of time the EMS blood was drawn before the initial ED clinical draw. The secondary objective was to determine the safety and diagnostic performance of integrating troponin measures from EMS blood samples into the HEART Pathway for 30-day major adverse cardiac events (MACE: composite of cardiac death, myocardial infarction (MI), coronary revascularization). Cardiac death was based on the modified Action to Control Cardiovascular Risk in Diabetes (ACCORD) trial definition [15]. MI was defined using the Joint European Society of Cardiology/American College of Cardiology Foundation/American Heart Association/World Health Federation Task Force universal definition [16]. All components of the primary MACE composite were adjudicated by three cardiovascular experts (two primary reviewers and one secondary reviewer). Any discrepancies among the two primary reviewers were resolved by the third reviewer. Participants without follow up data were searched for in the North Carolina Death Index (NCDI). Those not found in the NCDI were considered free from adverse events.

2.6. Data analysis

Descriptive statistics including mean, standard deviation (SD), median, and interquartile range (IQR) were used to characterize each of the time metrics of interest. Predicted LOS benefit was calculated by determining the time between the EMS blood draw and first clinical ED blood draw. Actual LOS was also reported for those patients with available disposition times (n = 315). Test characteristics (sensitivity, specificity, positive and negative predictive values (PPV and NPV), and positive and negative likelihood ratios (+LR and −LR)) for MACE at 30 days were determined for two separate HEART Pathway assessments. The first used the ED provider's HEAR score, EMS troponin as the first troponin and the initial clinical ED troponin as the serial troponin. The second was calculated using the ED provider's HEAR score, EMS troponin and the 3-h ED troponin. Analyses were performed using SAS 9.4 (SAS Institute, Cary, North Carolina) or R 3.5.1 (www.R-project.org).

3. Results

From December 2016 to April 2018, 79 paramedics from 3 EMS agencies accrued 506 eligible patients, of which 401 had both EMS and ED troponin measurements with draw time recorded. The study flow diagram is presented in Fig. 1 and patient characteristics are described in Table 1. MACE at 30 days occurred in 21.0% (84/401) of patients, with 1 cardiac death, 78 MI's, and 5 revascularizations without MI. Loss to follow-up occurred in 3.0% (12/401) of patients, none of which were found in the North Carolina Death Index.

Among the 401 patients in this cohort, EMS blood samples provided a 72.5 min (SD ± 35.7 min) reduction in predicted LOS. Fig. 2 represents the potential 72.5-min benefit of using the EMS blood samples to measure initial troponin. EMS blood samples were collected an average of 20.3 min (SD ± 12.3 min) prior to EMS arriving at the ED. Time metrics including means and medians calculated for blood samples drawn by EMS and ED are presented in Table 2.

The HEART Pathway assessments were evaluated on the 233 patients who had complete HEAR scores as well as EMS and ED troponin values available. The HEART Pathway score using the EMS troponin blood samples in the core lab plus arrival clinical ED blood identified 21.9% (51/233) of patients as low risk. Sensitivity for the detection of 30-day MACE was 98.4% (95% CI: 91.6%–100%) with a specificity of 29.6% (95% CI: 22.8%–37.1%). One patient stratified as low-risk by this method (HEAR Score = 3) was diagnosed with a type-II MI. He was a 47-year-old male with history of hypertension and cocaine use with a heart rate of 117, an initial ED troponin of 0.039 ng/ml (approximately 100 min after symptom onset) and 3-h troponin of 0.052 ng/ml that signed out of the ED against medical advice shortly after his serial troponin test. The provider HEART Pathway score using the EMS troponin blood samples in the core lab and the serial 3-h clinical ED blood identified 21.5% (50/233) of patients as low risk. Sensitivity for the detection of 30-day MACE was 100% (95% CI: 94.4%–100%) with a specificity of 29.6% (95% CI: 22.8%–37.1%). A summary of the test characteristics for the detection of MACE at 30 days are presented in Table 3. A receiver operating characteristic curve is presented in Fig. 3.

4. Discussion

This analysis is the first to demonstrate that blood drawn by paramedics prior to hospital arrival can be used as part of an ADP to potentially shorten ED LOS substantively. Implementation of this care pathway has the potential to dramatically reduce ED overcrowding by facilitating an earlier safe disposition decision time, which could translate into improved ED patient flow and bed availability. In addition, using prehospital blood collection with a 0/1-h high sensitivity troponin protocol could result in even shorter ED stays. We hypothesize that this would likely improve patient satisfaction as ED wait times and overall time spent in the ED are key determinants of the patient experience. [17,18] In addition, we suspect that patients with extended transport times, such as those from rural areas, will have an even greater reduction in ED LOS as EMS blood samples would be measured much earlier in their overall clinical course.

The use of EMS obtained blood samples is not standard practice and has historically been prohibited by hospital policies. There is not a great deal of literature assessing the feasibility, validity, and reliability of EMS blood samples for use in a hospital core laboratory, yet this avenue provides the earliest moment in the course of an acute illness or injury prior to intervention [19]. Few studies have compared EMS obtained blood samples to ED obtained blood samples, though most have demonstrated good reliability of the samples. In fact, one study found a decreased need for redraw with EMS obtained blood samples compared to ED obtained blood samples, with the ED obtained blood samples having higher hemolysis rates [20].

The use of EMS blood collection has been shown to decrease the time to laboratory result availability [21,22]. This early “diagnosis” in patients with an elevated first troponin can thereby facilitate more rapid cardiology consultation, treatment for Non-ST elevation myocardial infarction, and admission. In addition, implementation of this project represents an important use case for enhancing ED efficiency across multiple conditions beyond chest pain. This may be a scalable model for how health systems can collaborate with EMS organizations to improve the quality and value of patient care [22,23]. A novel combination of EMS blood collection with triage protocol orders have the potential to provide additional opportunities to streamline diagnosis where nursing and phlebotomy resources may be limited.

In addition to reducing ED LOS, our data suggest that the integration of an EMS blood sample troponin measure into an ADP is safe. The single patient with a low-risk HEART Pathway assessment openly admitted to cocaine use, improved during his ED stay, and signed out against medical advice. The HEART Pathway using EMS troponin plus the serial 3-h clinical ED troponin had a 100% NPV. There is a time interval between the first and second clinical draw that can be identified, which can provide a serial troponin measurement that will also produce this same acceptable level of safety for early discharge recommendation. As ADPs incorporate high sensitivity-troponin, blood drawn by EMS has the potential to cut patient LOS even shorter, which will likely translate to even greater ED bed turnover and efficiency. Using EMS blood shifts troponin measurement closer to the onset of symptoms and may increase the proportion of hyper-acute presenters. In these patients, deltas rather than cutoffs may be more helpful. Thus, a future version of this should use hsTn and deltas.

This study has limitations. Patients were accrued from 3 EMS agencies who were transported to a single academic medical center. Although we suspect there are many similarities between our EMS agencies, medical centers, and patients to those across the US, our results may not be generalizable to all agencies, centers, and patients. In addition, because our cohort was accrued by treating paramedics as a convenience sample, this design may have resulted in a selection bias. However, the demographics and prevalence of risk factors among our cohort are similar to other EMS cohorts with acute chest pain [22,24]. Although our 30-day MACE rate of 21.0% is higher than most ED cohorts, it is similar to other studies focused on EMS chest pain care [25–27]. The time of patient’s chest pain onset relative to calling 911 and paramedic patient contact was not collected. This prevented the ability to differentiate early presenters from late presenters. Previous

studies have demonstrated that troponin measurement is less sensitive for the detection of MI among early presenters compared to late presenters, [28,29] thus the proportion of early presenters in this cohort may have impacted troponin results and ADP assessments. This study used a contemporary, rather than high sensitivity troponin assay. Furthermore, the contemporary assay used at the medical center changed within the study period. Finally, this analysis calculated a potential reduction in ED LOS. Our analysis may have overestimated the magnitude of LOS reduction that will be realized from a clinical implementation since ED care is susceptible to unpredictable delays.

5. Conclusion

This innovative study demonstrates that EMS blood samples used for troponin analysis in the hospital core lab has the potential to significantly reduce ED LOS in patients with acute chest pain. These findings, in conjunction with more widespread adoption of high sensitivity troponin, have significant implications for reducing ED overcrowding and augmenting patient care. Given the high volume of patients with chest pain seen in US EDs, use of EMS blood samples to expedite troponin measurement could enhance ED throughput and improve healthcare outcomes. A prospective clinical implementation study of the use of EMS blood samples for troponin analysis is needed.

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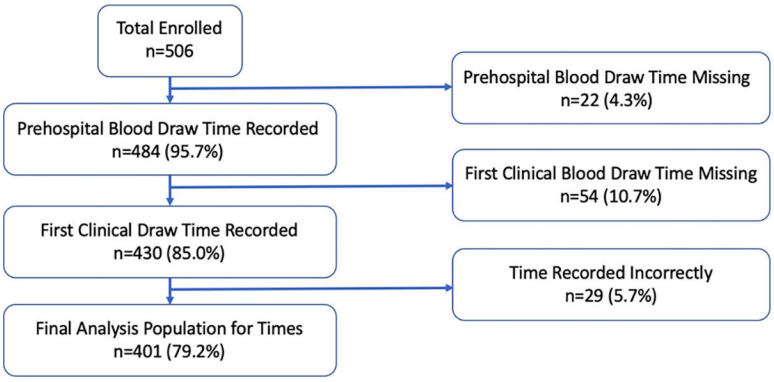

Fig. 1.
Study flow diagram.

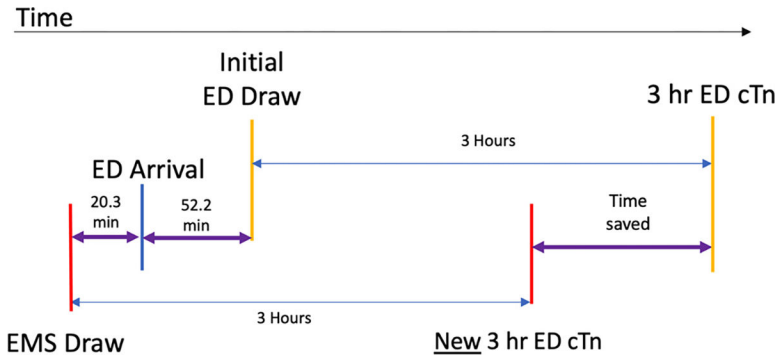

Fig. 2.
Conceptual benefit of EMS blood used to measure first troponin.

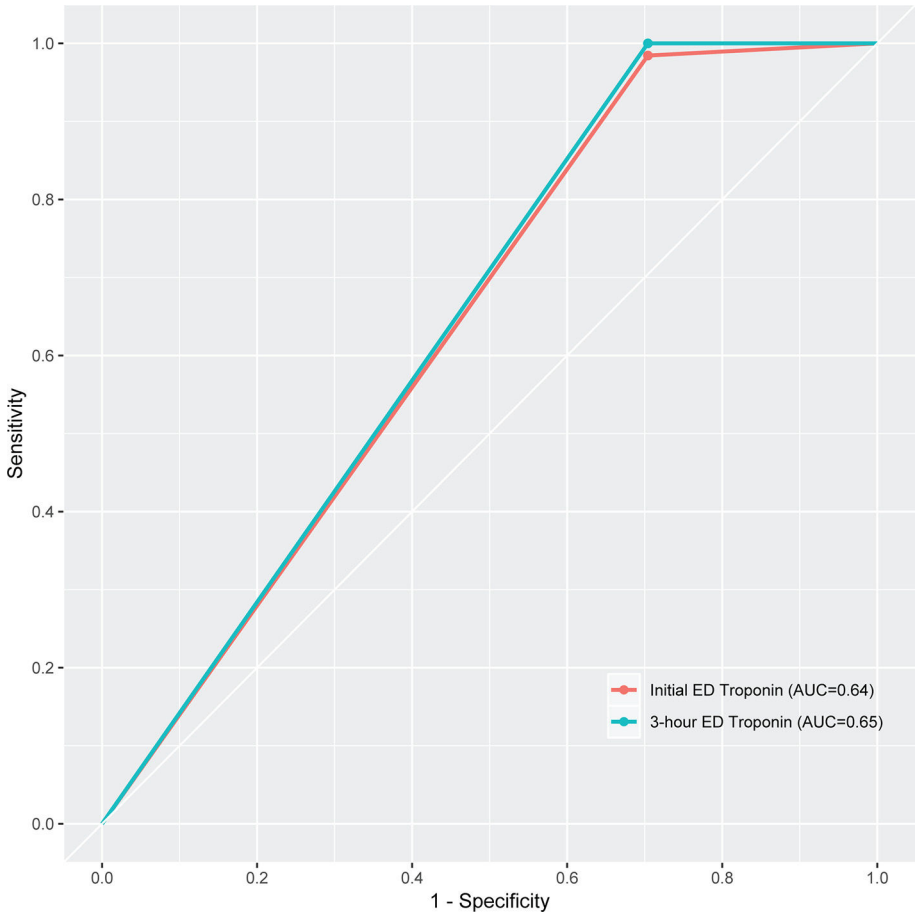

Fig. 3.

Receiver operating characteristic curve 30-day MACE using Emergency Department provider HEAR risk assessment with EMS blood draw run in the hospital core lab for troponin measurement and either initial ED troponin or 3-h ED troponin.

Table 1

Patient characteristics.

Patient characteristic	30-Day MACE (*N* = 84)	No 30-Day MACE (*N* = 317)	Total (*N* = 401)
Age years – mean ± SD	64.6 ± 13.4	58.9 ± 15.1	60.1 ± 14.9
Sex (female)	33 (39.3%)	176 (55.5%)	209 (52.1%)
Race			
Caucasian	39 (46.4%)	166 (52.4%)	205 (51.1%)
African American	38 (45.2%)	134 (42.3%)	172 (42.9%)
Asian	3 (3.6%)	1 (0.3%)	4 (1.0%)
Native American	0	1 (0.3%)	1 (0.2%)
Other	4 (4.8%)	15 (4.7%)	19 (4.7%)
Ethnicity (Hispanic)	2 (2.4%)	13 (4.1%)	15 (3.7%)
Risk factors			
Current smoking	19 (22.6%)	77 (24.3%)	96 (23.9%)
Hypertension	64 (76.2%)	215 (67.8%)	279 (69.6%)
Hyperlipidemia	29 (34.5%)	89 (28.1%)	118 (29.4%)
Diabetes	32 (38.1%)	99 (31.2%)	131 (32.7%)
Family history of CAD	19 (22.6%)	78 (24.6%)	97 (24.2%)
Obesity	23 (27.4%)	101 (31.9%)	124 (30.9%)
Prior coronary disease	30 (35.7%)	73 (23.0%)	103 (25.7%)
Prior MI	31 (36.9%)	52 (16.4%)	83 (20.7%)
Prior PCI	21 (25.0%)	39 (12.3%)	60 (15.0%)
Prior CABG	9 (10.7%)	33 (10.4%)	42 (10.5%)
Prior CHF	17 (20.2%)	42 (13.3%)	59 (14.8%)
Prior PVD	6 (7.1%)	14 (4.4%)	20 (5.0%)
Prior stroke	7 (8.3%)	34 (10.7%)	41 (10.2%)

SD – standard deviation, CAD – coronary artery disease, PVD – peripheral vascular disease, BMI – body mass index, MI – myocardial infarction, PCI – percutaneous coronary intervention, CABG – coronary artery bypass grafting, CHF – congestive heart failure.

Table 2

Time metrics calculated for total and low risk cohorts.

Time metric	Total minutes (*n* = 401); mean ± SD; median (IQR)
EMS blood draw to ED arrival time	20.3 ± 12.3; 20 (13–26)
ED arrival to ED blood draw time	52.2 ± 34.9; 44 (28–64)
EMS blood draw to ED blood draw time	72.5 ± 35.7; 65 (48–86)
Actual LOS (*n* = 315)	297.2 ± 120.3; 285 (200–386)

Table 3

Test characteristics for 30-day MACE using Emergency Department provider HEAR risk assessment with EMS blood draw run in the hospital core lab for troponin measurement and either initial ED troponin or 3-h ED troponin HEART Pathway (n = 233).

	HEAR with EMS and initial ED troponin	HEAR with EMS and 3-h ED troponin
Sensitivity (95% CI)	98.4% (91.6%–100%)	100% (94.4%–100%)
Specificity (95% CI)	29.6% (22.8%–37.1%)	29.6% (22.8%–37.1%)
NPV (95% CI)	98.0% (89.6%–100%)	100% (92.9%–100%)
PPV (95% CI)	34.6% (27.7%–42.0%)	35.0% (28.1%–42.4%)
−LR (95% CI)	0.053 (0.007–0.374)	0 (NA)
+LR (95% CI)	1.398 (1.262–1.549)	1.420 (1.288–1.566)

NPV – negative predictive value, PPV – positive predictive value, −LR – negative likelihood ratio, +LR positive likelihood ratio.