Received: 17 October 2019 | Revised: 2 February 2020 | Accepted: 4 February 2020

DOI: 10.1002/jcla.23263

RESEARCH ARTICLE

WILEY

How to choose a point-of-care testing for troponin

Ya-hui Lin | Yang Zhang | Yu-tao Liu | Kai Cui | Jin-suo Kang | Zhou Zhou

Center of Laboratory Medicine, Beijing Key Laboratory for Molecular Diagnostics of Cardiovascular Diseases, State Key Laboratory of Cardiovascular Disease, National Center for Cardiovascular Diseases & Fuwai Hospital, Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing, China

Correspondence
Zhou Zhou and Ya-hui Lin, Center of Laboratory Medicine, Beijing Key Laboratory for Molecular Diagnostics of Cardiovascular Diseases, State Key Laboratory of Cardiovascular Disease, National Center for Cardiovascular Diseases & Fuwai Hospital, Chinese Academy of Medical Sciences & Peking Union Medical College, No.167 North Lishi Road, Xicheng District, Beijing 100037 China.
Emails: zhouzhou@fuwaihospital.org (ZZ); linyahui@fuwaihosptial.org (YHL)

Funding information
International S&T Cooperation Program of China, Grant/Award Number: 2014DFG32540; Peking Union medical college Young Foundation, Grant/Award Number: 3332015107

Abstract

Background: Point-of-care (POC) cTn assays are needed when the central laboratory is unable to provide timely results to the emergency department. Many POC devices are available. The prospect of choosing them is daunting. In order to provide a quick decision-making reference for POC cTn device selection comparing them to the central laboratory, seven POC devices commonly employed by emergency department were evaluated.

Methods: Firstly, we reviewed all devices package inserts. Secondly, we evaluated several POC cTn assays for imprecision, linearity, and correlation with central laboratory assays according to CLSI EP protocols. The linear regression analyses were performed only for the detectable concentrations. Five cTnI devices (Alere Triage, BioMerieux Vidas, Mitsubishi Pathfast, ReLIA TZ-301, and Radiometer AQT90) were evaluated against a contemporary cTnI assay (Beckman Access II Accu TnI). Two cTnT assays (Radiometer AQT90 and Roche Cobas h232) were compared to a high-sensitivity (hs) cTnT method (Roche Cobas e601).

Results: For cTn levels around the 99th percentile upper reference limits (URLs) of the comparator assays, imprecision could not be assessed for the Alere, BioMerieux, and Cobas h232 as they gave undetectable readings due to a lack of assay sensitivity. Imprecision (CV) was unacceptably high for the ReLIA (33.3%). On account of this precision metric, these four assays were deemed unsuitable. Regression analyses showed acceptable linearity for all the POC devices. The correlation coefficients for ReLIA, BioMerieux, Cobas h232, and Radiometer cTnT were >0.95. Unlike the cTnT devices, the cTnI assays employ different capture and detection antibodies leading to non-commutable results. The POC cTn results were concordant with their comparator—Radiometer cTnT 90%, Pathfast cTnI 85%, and Radiometer cTnI 75%.

Conclusion: Our study provides the procedure and essential data to guide selection of a POC cTn device. Of the point-of-care devices, methods evaluated Radiometer AQT90 (cTnI and cTnT) and Pathfast might be considered.

KEYWORDS

analytical evaluation, cardiac troponin, point-of-care testing

1 | INTRODUCTION

Measurements of cardiac troponin (cTn) are vital in the management and diagnosis of myocardial injury and are the preferred cardiac biomarker.[1,2] This is especially critical in the emergency department (ED) where rapid decision-making in chest pain patients improves outcome and decreases mortality.[3-5] The main focus in the ED is to discharge patients home as soon as possible or to admit them to the hospital ward. Laboratory tests are vital for making such decisions in the ED.[6] In fact, laboratory tests are requested in up to half of the patients presenting at the ED.[7] Clinical guidelines stipulate a maximum turnaround time of 60 minutes (preferably 30 minutes) from blood draw to results availability.[8] The central laboratory is often challenged to deliver such rapid test results.[9] This has given rise to the introduction of many point-of-care (POC) devices that can provide rapid troponin results.[10-13] However, different POC cTn assays exhibit variable analytical sensitivity and accuracy[14] and give results discordant with those of the central laboratory.[15] Laboratorians and clinicians need a handy information resource to decide on which POC cTn to adopt. While a sensitive POC cTn is preferred for rapid diagnosis of acute myocardial infarction,[16] expert committees of Cardiology societies concede that assays with imprecision of up to 20% may be used for diagnosis and risk stratification.[17] Thus, we undertook to evaluate the analytical performance of seven POC cTn assays (5 cTnI and 2 cTnT) against our central laboratory cTnI assay and a high-sensitivity cTnT (hs-cTnT) method according to Clinical and Laboratory Standards Institute (CLSI) protocols.

2 | MATERIALS AND METHODS

2.1 | Analyzers

Five POC cTnI assays—Alere Triage Cardio3TnI (Alere International), BioMerieux Vidas Troponin I Ultra (Biomerieux), Mitsubishi Pathfast cTnI (LSI Medience Corporation), ReLIA TZ-301 cTnI (Ruilai Biological Engineering), and Radiometer AQT90 TnI (Radiometer Medical), were evaluated against the central laboratory cTnI assay (Access II Accu TnI, Beckman Coulter). Two POC cTnT assays—Radiometer AQT90 cTnT (Radiometer Medical) and Roche Cobas h232 (Roche Diagnostics), were compared to a central laboratory hs-cTnT assay—Roche Cobas e601 (Roche Diagnostics).

2.2 | Sample preparation

Samples were collected into Greiner serum tubes (VACUETTE® 454204, Greiner Bio-One), centrifuged at 3000 *g* for 10 minutes, and immediately made into multiple aliquots. One aliquot was tested on the AccuTnI (Beckman Access II) and the results released to the ED, while the other aliquots were stored at −80°C until used. Before analysis, the samples were thawed at room temperature, centrifuged at 3000 *g* for 10 minutes, and the supernatant tested on the various cTn platforms.

TABLE 1 Analytical characteristics from nine quantitative devices

Company · platform · assay	LoD, (μg/L)	99th percentile upper reference limit, μg/L	Time, (min)	Volume, (μL)	Sample type	Amino acid residues of epitopes recognized by Antibodies	
						Capture antibodies	Detection antibodies
cTnI							
Beckman Access II Accu TnI	0.01	0.04	12	55	Plasma/Serum	41-49	24-40
Alere Triage cTnI	0.05	0.05	20	250	Plasma/Whole blood	27-39	83-93, 190-196
bioMerieux Vidas cTnI Ultra	0.01	0.01	20	200	Plasma/Whole blood	41-49, 22-29	87-91, 7B9
Mitsubishi Pathfast cTnI	0.02	0.029	17	100	Plasma/Serum	41-49	71-116, 163-209
ReLIA TZ-301 cTnI	0.02	0.039	8	70	Plasma/Serum/Whole blood	41-49, 83-93	24-40
Radiometer AQT90 cTnI	0.01	0.023	18	1500	Plasma/Serum/Whole blood	41-49, 190-196	137-149
cTnT							
Roche Cobas e601 hs-cTnT	0.005	0.014	9	50	Plasma/Serum	125-131	136-147
Radiometer AQT90 cTnT	0.01	0.017	12	1500	Plasma/Serum/Whole blood	125-131	136-147
Roche Cobas h232 Cardiac cTnT	0.05	NA	12	150	Whole blood	125-131	136-147

Abbreviations: cTnI, cardiac troponin I; cTnT, cardiac troponin T; LoD, limit of detection.

2.3 | Analytical performances

Imprecision studies were based on the CLSI EP15-A protocol (duplicate measurements twice per day on 3 levels for 5 consecutive days) using pooled human serum.[18] The cTn concentration of the low serum pool was within the respective assay's 99th percentile upper reference limits (URL), while the medium and high level pools were around fivefold and 10-fold of their respective URLs. Troponin values at the 99th percentile with good imprecision (CV ≤ 10%) are "guideline acceptable," intermediate imprecision (CV 10%-20%) is "clinically usable," and poor imprecision (CV > 20%) is not acceptable.[19]

To demonstrate the linearity of low cTn concentrations, we employed the CLSI EP06-A protocol by proportionally mixing high and low human serum pools.[20] Six concentrations were measured twice at each level.

Correlation studies between central laboratory assays and POC assays were performed on the same forty samples from consecutive patients admitted to Fuwai hospital according to the CLSI EP09-A3.[21] These samples covered the most frequent cTn concentration ranges (cTnI: 0.01-37 μg/L; cTnT: 0.005-10 μg/L) encountered in our chest pain patients.

The same reagent lots of each assay were used throughout the evaluation.

2.4 | Statistical analyses

All statistical analyses were performed on MedCalc Statistical Software version 15.2.2 (MedCalc Software). Least squares linear regression was employed for linearity assessment, and Passing-Bablok

TABLE 2 Imprecision summary

Assay platform	Mean concentration (μg/L)		%CV Within run	%CV Total	Judgment
cTnI					
Beckman Access II AccuTnI	Low	0.033	4.48	8.59	Guideline Acceptable
	Medium	0.382	2.69	5.26	
	High	1.587	5.03	9.59	
Alere Triage cTnI	Low	<0.05	NA	NA	Clinically Acceptable
	Medium	0.074	16.55	16.65	
	High	0.472	7.55	11.08	
BioMerieux Vidas cTnI Ultra	Low	<0.01	NA	NA	Guideline Acceptable
	Medium	0.430	2.77	4.15	
	High	1.017	1.17	2.18	
Mitsubishi Pathfast cTnI	Low	0.006	12.55	13.37	Clinically Acceptable
	Medium	0.104	7.76	8.58	
	High	0.361	14.77	15.02	
ReLIA TZ-301 cTnI	Low	0.044	33.24	32.32	Unacceptable
	Medium	0.407	17.08	15.74	
	High	1.400	6.58	8.89	
Radiometer AQT90 cTnI	Low	0.011	7.69	7.96	Guideline Acceptable
	Medium	0.144	3.71	3.35	
	High	0.304	3.83	4.40	
cTnT					
Roche Cobas e601 hs-cTnT	Low	0.013	3.44	5.90	Guideline Acceptable
	Medium	0.148	1.39	2.73	
	High	0.593	1.21	1.54	
Radiometer AQT90 cTnT	Low	0.014	6.76	9.53	Guideline Acceptable
	Medium	0.104	3.93	4.99	
	High	0.584	2.78	2.99	
Roche Cobas h232 Cardiac cTnT	Low	<0.05	NA	NA	Unacceptable
	Medium	0.05-0.10	NA	NA	
	High	0.415	5.750	10.587	

Abbreviations: CV, coefficient of variation; cTnI, cardiac troponin I; cTnT, cardiac troponin T; NA: not applicable.

TABLE 3 Linearity of seven quantitative POCT cTn devices with "in-house" prepared samples

Company · platform · assay	Slope	Intercept	R^2	Recovery (%)	
				At lower concentrations	At higher concentrations
cTnI					
Beckman · Access II · AccuTnI	0.999	−0.422	0.998	98.8	97.6
Alere · Triage · cTnI	0.987	−0.492	0.980	71.2	91.9
BioMerieux · Vidas · cTnI Ultra	0.994	0.067	0.999	128.7	102.3
Mitsubishi · Pathfast · cTnI	0.987	−0.223	0.981	90.9	80.9
ReLIA · TZ-301 · cTnI	1.004	−0.240	0.999	98.3	96.3
Radiometer · AQT90 · cTnI	1.002	−0.022	0.999	96.4	98.1
cTnT					
Roche · Cobas e601 · hs-cTnT	0.995	0.021	0.999	99.2	99.4
Radiometer · AQT90 · cTnT	0.998	−0.026	0.999	116.3	98.4
Roche · Cobas h232 · Cardiac cTnT	0.987	0.028	0.999	112.4	101.9

Abbreviations: cTnI, cardiac troponin I; cTnT, cardiac troponin T.

regression analysis was used for correlation studies. Values below the limit of detection were replaced with one half the limit of detection. A P value < .05 was considered statistically significant.

2.5 | Others

This study was conducted according to the Declaration of Helsinki and approved by the Institutional Review Board of Fuwai Hospital (IRB approval number 2016-809).

3 | RESULTS

3.1 | Review package inserts

Firstly, the analytical characteristics of the seven POC cTn assays and two central laboratory assays according to the manufacturer's claims were summarized in Table 1.

3.2 | Evaluate the possible candidates

The imprecision of all devices assessed is shown in Table 2. For the low-level serum pool, the central laboratory instruments showed a CV of 5.90% for the Roche hs-cTnT and 8.59% for the Beckman Accu TnI, respectively. At this cTn concentration, the imprecision of the Radiometer AQT90 cTnI and AQT90 cTnT (7.96% and 9.53%, respectively) was quite respectable while that for the Mitsubishi Pathfast cTnI (13.37%) was clinically acceptable. For the low-level serum pool, the Alere cTnI, BioMerieux cTnI, and Roche Cobas h232 cTnT gave undetectable readings, while the imprecision of the ReLIA cTnI was guideline unacceptable (>20%).[19] Imprecision for the medium and high serum pools was less than 10% for most of the methods except the Alere cTnI and ReLIA cTnI (CV between 15% and 20%).

Regression analyses showed that all devices have acceptable linearity. The average recovery at lower cTn concentrations (close to the 99th percentile URL) was uneven among different devices ranging from 71.2% to 128.7%. The recovery at higher cTn concentrations was satisfactory ranging from 80.9% to 102.3% (See Table 3). The recovery of Beckman · Access II · Accu TnI and Roche · Cobas e601 · hs-cTnT was 98.8% and 99.2% at lower cTn concentrations, and 97.6% and 99.4% at higher cTn concentrations, respectively.

As per CLSI document EP09-A3,[21] the correlation between devices and the comparator assays using Passing-Bablok regression is summarized in Table 4. The correlation coefficients for ReLIA TZ-301 and BioMerieux Vidas versus Beckman Accu TnI were surprisingly good (>0.95) while that between Radiometer AQT90 cTnI and Beckman Accu cTnI were slightly lower at 0.86.

The Mitsubishi Pathfast, BioMerieux Vidas, Alere Triage, and Radiometer AQT90 cTnI values were consistently lower than the Beckman Accu TnI (see Figure 1). For cTnT, the correlation coefficients for Roche Cobas h232 and Radiometer AQT90 results versus Roche Cobas e601 were 0.969 and 0.982, respectively.

3.3 | Analyze candidate POC cTn assays

For the three suitable candidate POC cTn assays, we performed a concordance analysis according to their cTn result categories—<LoD, LoD to 99th percentile URL (99P), and >99P (Table 5). Concordance between Roche Cobas hs-cTnT and Radiometer cTnT was 90% (36/40). For the Beckman Accu cTnI, the concordance was 85% (34/40) and 75% (30/40) with Mitsubishi Pathfast and Radiometer AQT90, respectively.

4 | DISCUSSION

The primary goal of cTn assays is to aid in the early assessment of acute myocardial infarction especially in hospital emergency departments. Therefore, the analytical imprecision at the decision limit (at the 99th percentile URL) of different cTn assays is vital for clinical decision-making. For this imprecision metric, the optimal imprecision (CV ≤ 10%) is considered "guideline acceptable." Intermediate imprecision (10%-20%) is "clinically usable",[17] but imprecision >20% is not acceptable.[19] Information on POC cTn assay imprecision is frequently obtained from manufacturer's package inserts[22] or published literature under ideal, non-routine laboratory conditions. In the current study, the total imprecision of POC cTn assays is compared to central laboratory assays by simultaneously measuring common pooled human sera containing cTn concentrations covering the clinical decision range—99th percentile URL, fivefold URL, and 10-fold URL. Although POCT devices are optimized for whole blood samples, we used serum in our investigations since no stable whole blood materials are available. Besides, manufacturers employ serum-based liquid controls and report precision data in their package inserts based on serum or plasma. It is noteworthy that two of the seven POC cTn assays (Radiometer AQT90 cTnI and cTnT) achieved precision that is guideline acceptable, while one other assay (Mitsubishi Pathfast cTnI) met the clinically usable designation. The Cobas h232 cTnT assay is semi-quantitative; cTnT values < 0.050 μg/L are reported as negative, while those between 0.050 and 0.100 μg/L are reported as positive; actual cTnT results are only reported for values above 0.100 μg/L. Roche has since improved the Cobas h232 to render it fully quantitative with a measuring range of 0.040-2.000 μg/L.[23]

TABLE 4 Regression analyses between POC cTn devices against Beckman Access II or Roche Cobas e601

	Passing-Bablok Regression		Correlation		% of undetectable values
	Linear model	Bias at 99th URL, μg/L	*R*	*P* value	
cTnI					
ReLIA TZ-301[a]	y = −0.021 + 0.931x	40%	0.969	<.0001	0
Mitsubishi Pathfast[a]	y = −0.001 + 4.033x	290%	0.934	<.0001	17.5
Alere Triage[a]	y = 0.001 + 1.734x	220%	0.875	<.0001	25
BioMerieux Vidas[a]	y = −0.009 + 2.033x	28%	0.959	<.0001	25
Radiometer AQT90[a]	y = −0.040 + 9.805x	465%	0.864	<.0001	30
cTnT					
Roche Cobas h232[b]	y = −0.021 + 0.456x	14%	0.969	<.0001	35
Radiometer AQT90[b]	y = 0.011 + 0.940x	193%	0.982	<.0001	25

Abbreviations: cTnT, cardiac troponin T; hs-cTnT; cTnI, cardiac troponin I.

[a]Linear regression analysis against Beckman Access II cTnI.

[b]Linear regression analysis against Roche Cobas e601.

TABLE 5 Concordance between result categories of POC devices against Beckman Access II or Roche Cobas e601

	Radiometer cTnI (μg/L)			Mitsubishi Pathfast (μg/L)		
Beckman · Access II · AccuTnI	<LoD	LoD–99P	>99 P	<LoD	LoD–99P	>99 P
<LoD (4)	0.004			0.003	0.001	
LoD – 99P (1)	0.001			0.001		
>LoD (35)	0.005	0.004	0.026	0.004		0.031
Sub-total (40)	0.01	0.004	0.026	0.008	0.001	0.031
	Radiometer cTnT					
Roche Cobas e601 hs-cTnT						
<LoD (2)	0.002					
LoD – 99P (6)		0.006				
>LoD (32)	0.003	0.001	0.028			
Sub-total (40)	0.005	0.007	0.028			

Abbreviations; 99P, 99th percentile URL; cTnI, cardiac troponin I; cTnT, cardiac troponin T; LoD, limit of detection.

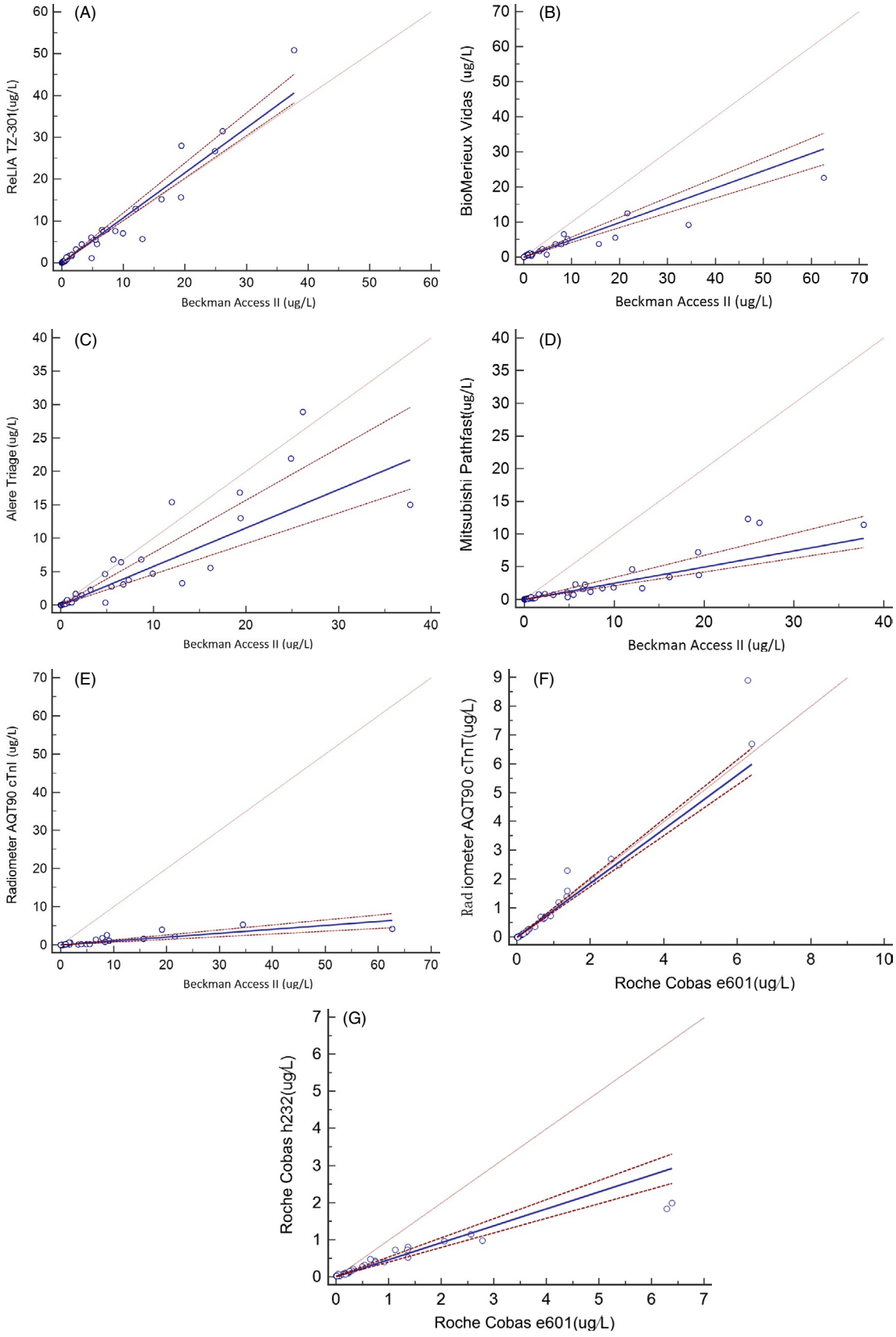

FIGURE 1 Passing-Bablok regression analysis of POC cTn assays. A, ReLIA TZ-301, (B) BioMerieux Vidas, (C) Alere Triage, (D) Mitsubishi Pathfast, (E)Radiometer AQT90 cTnI, (F) Radiometer AQT90 cTnT, and (G) Roche Cobas h232. Legend: Solid line is Passing and Bablok regression; dot line is identity; dash line is 95% CI bands

At the time, our evaluation was performed, the improved Cobas h232 was not available to us as it had not yet obtained regulatory approval for clinical use.

Our results confirm the discrepant cTn concentrations obtained between different POC devices and the central laboratory analyzers. Even on an aggregate level by categories (below LoD, LoD to 99P, and above 99P), the discordance is not insignificant—10% with the Radiometer cTnT, but 15%-25% with the suitable cTnI devices (Mitsubishi Pathfast and Radiometer). This discrepancy may be caused by a variety of reasons including the use of various capture and detection antibodies/labels, reacting conditions, detection principles, and calculation methods.[24] In addition, the available and unique cTn standard reference material, SRM 2921, is a trimeric I-T-C complex which is difficult to simulate accurate cTn levels in vivo. Besides, SRM 2921 appears to have poor stability due to factors such as time and temperature.[25] Besides, ALP-dependent and chemiluminescent immunoassays have been reported to show better total imprecision at the URL than cTn assays employing fluorophores or gold particles.[26] The difference in antibody specificities has been a key factor hindering the harmonization of POCT measurements, especially for the cTnI assays. It is noteworthy that the epitopes recognized by the capture and detection antibodies employed by the Beckman Access II as well as the ReLIA TZ-301 are located at the stable mid-region of cTnI.[27] However, the epitopes recognized by the detection antibodies of the Mitsubishi Pathfast, Alere Triage, and Radiometer AQT90 are close to the less stable C-terminus of cTnI at amino acids 163-209, 190-196, and 137-149, respectively.[28] Our results show that the measured values of these POC assays were significantly lower than Beckman Access II when the same samples were tested (see Figure 1). With regard to cTnT, the results of Radiometer AQT90 and Roche Cobas e601 are similar and with good correlation since identical capture and detection antibodies are employed. However, the correlation coefficients were only marginally dissimilar for Cobas h232 and AQT90-TnT versus Cobas e601. Thus even when antibodies employed recognize the same antigenic epitopes, cTnT concentrations from POCT devices are unlikely to equate to those of the central laboratory.[29]

Harmonization of POC cTn testing is sorely needed because cTn may be tested on both POC and central laboratory immunochemistry analyzers in the same patient with chest pain presenting to the emergency department. It is important that results from the POC cTn performed at the emergency department are comparable to those from the central laboratory. When choosing POC cTn assays, the analytical characteristics of the various POC devices especially their precision at around the 99th percentile URL should be carefully examined first. Instruments with high imprecision should be excluded. The package insert data (Table 1) reveal that the Cobas h232 has no statement on the 99th percentile URL and is unlikely to meet acceptability criteria. Moreover, identical limits of detection and the 99th percentile URLs are stated for the Alere cTnI and the Biomerieux cTnI; thus, a high imprecision at the URL can be expected. This view is confirmed by the poor CV at the low serum pool (Table 2) for Cobas h232, Alere cTnI, Biomerieux cTnI, and ReLia cTnI rendering them "not acceptable." Our study provides laboratories and emergency department personnel some objective data for choosing a suitable POC cTn assay as well as not to pursue unlikely candidates.

POC cTn has decreased time in the emergency department (ED) for patients with chest pain,[5] and the degree of benefit also depends on the setting in which it is used especially acceptance by ED personnel. In the pre-hospital phase, POC cTn has helped in the triage of chest pain patients to the appropriate hospital facility.[30] Beyond hospitals, POC cTn has reduced costs from unnecessary referrals in primary care settings but at the expense of some missed cases of small or early myocardial infarction due to the limitation of assay sensitivity.[31] However, higher sensitivity POC cTn platforms are looming on the horizon and promises to change the ED diagnostic landscape.[32-34]

Our study provided the step-by-step guide to choose POC for cTn and a head-head comparison of 7 POC troponin devices. It is aimed at providing a quick decision-making reference for POC cTn device selection comparing them to the central laboratory cTnI and hs-cTnT. This is the first POC cTn study conducted in the real-world conditions prevailing in the Asia-Pacific. Besides, there is paucity of peer-reviewed literature verifying manufacturers' analytical claims. The study has some limitations in that we did not conduct reference interval studies or clinical performance studies of the different POC cTn platforms. This information is already available in part in the published literature.[14,29,35-38] Further studies on larger population samples are needed.[39] In another hand, POC cTnI assays were compared against a contemporary assay, whereas cTnT assays were compared against a high-sensitivity assay. As we known, the imprecision or sensitivity of high-sensitivity troponin is better than contemporary troponin. It means that the standards of POC for troponin T were higher troponin I.

ACKNOWLEDGMENTS

The study was supported by the International S&T Cooperation Program of China (2014DFG32540 to Guangxin Xiang) and the Peking Union medical college Young Foundation (3332015107).

CONFLICT OF INTEREST

We have no conflicts of interest to declare.

AUTHOR CONTRIBUTIONS

All the authors have accepted responsibility for the entire content of this submitted the study and approved submission.

ORCID

Ya-hui Lin https://orcid.org/0000-0003-2868-4929
Zhou Zhou https://orcid.org/0000-0002-7674-9857

REFERENCES

1. Thygesen K, Alpert JS, Jaffe AS, et al. Third universal definition of myocardial infarction. *Eur Heart J*. 2012;33:2551-2567.
2. Roffi M, Patrono C, Collet JP, 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;37:267-315.
3. Diercks DB, Roe MT, Chen AY, et al. Prolonged emergency department stays of non-ST-segment elevation myocardial infarction patients are associated with worse adherence to the American College of Cardiology/American Heart Association guidelines for management and increased adverse events. *Ann Emerg Med*. 2007;50:489-496.
4. Pines JM, Pollack CV Jr, Diercks DB, Chang AM, Shofer FS, Hollander JE. The association between emergency department crowding and adverse cardiovascular outcomes in patients with chest pain. *Acad Emerg Med*. 2009;16:617-625.
5. Loten C, Attia J, Hullick C, Marley J, McElduff P. Point of care troponin decreases time in the emergency department for patients with possible acute coronary syndrome: a randomised controlled trial. *Emerg Med J*. 2010;27:194-198.
6. Janssens PM, van de Wijngaart DJ, van Dijk N. Sensible use of laboratory testing requires active laboratory involvement. *Clin Chem Lab Med*. 2014;52:e131-e132.
7. van der Horst A, van de Wijngaarta DJ, Scherrenburg J, van Dijk N, Janssens PMW. Practical motives are prominent in test-ordering in the emergency department. *Clin Chem Lab Med*. 2017;55:1523-1529.
8. Braunwald E, Antman EM, Beasley JW, et al. ACC/AHA guidelines for the management of patients with unstable angina and non-ST-segment elevation myocardial infarction. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on the Management of Patients With Unstable Angina). *J Am Coll Cardiol*. 2000;36:970-1062.
9. Christenson RH, Azzazy HM. Cardiac point of care testing: a focused review of current National Academy of Clinical Biochemistry guidelines and measurement platforms. *Clin Biochem*. 2008;42:150-157.
10. Yang Z, Zhou DM. Cardiac markers and their point-of-care testing for diagnosis of acute myocardial infarction. *Clin Biochem*. 2006;8:771-780.
11. McDonnell B, Hearty S, Leonard P, O'Kennedy R. Cardiac biomarkers and the case for point-of-care testing. *Clin Biochem*. 2009;42:549-561.
12. Storrow AB, Lyon JA, Porter MW, et al. A systematic review of emergency department point-of-care cardiac markers and efficiency measures. *Point of Care*. 2009;8:121-125.
13. Bingisser R, Cairns C, Christ M, et al. Cardiac troponin: a critical review of the case for point-of-care testing in the ED. *Am J Emerg Med*. 2012;30:1639-1649.
14. Palamalai V, Murakami MM, Apple FS. Diagnostic performance of four point of care cardiac troponin I assays to rule in and rule out acute myocardial infarction. *Clin Biochem*. 2013;46:1631-1635.
15. Apple FS, Ler R, Murakami MM. Determination of 19 cardiac troponin I and T assay 99th percentile values from a common presumably healthy population. *Clin Chem*. 2012;58:1574-1581.
16. Kavsak PA, Worster A. For a rapid diagnosis of acute myocardial infarction, a sensitive troponin assay is needed in the near-patient testing setting. *Expert Rev Cardiovasc Ther*. 2012;10:309-312.
17. Jaffe AS, Apple FS, Morrow DA, Lindahl B, Katus HA. Being rational about (im) precision: a statement from the Biochemistry Subcommittee of the Joint European Society of Cardiology/American College of Cardiology Foundation/American Heart Association/World Heart Federation Task Force for the definition of myocardial infarction. *Clin Chem*. 2010;56:941-943.
18. Clinical and Laboratory Standards Institute (CLSI). *User Verification of Precision and Estimation of Bias; approved Guideline*. CLSI document EP15-A. Wayne, PA: CLSI; 2001.
19. Apple FS. A new season for cardiac troponin assays: it's time to keep a scorecard. *Clin Chem*. 2009;55:1303-1306.
20. Clinical and Laboratory Standards Institute (CLSI). *Evaluation of the Linearity of Quantitative Measurement Procedures: a Statistical Approach; Approved Guideline*. CLSI document EP06-A. Wayne, PA: CLSI; 2003.
21. Clinical and Laboratory Standards Institute (CLSI). *Measurement Procedure Comparison and Bias Estimation Using Patient Samples; Approved Guideline—Third Edition*. CLSI document EP09-A3. Wayne, PA: CLSI; 2013.
22. Amundson BE, Apple FS. Cardiac troponin assays: a review of quantitative point-of-care devices and their efficacy in the diagnosis of myocardial infarction. *Clin Chem Lab Med*. 2015;53:665-676.
23. Roche Diagnostics. Roche cardiac POC troponin T [package insert] v 2.0 2017-06.
24. Jarolim P. High sensitivity cardiac troponin assays in the clinical laboratories. *Clin Chem Lab Med*. 2015;53:635-652.
25. Mingels AM, Cobbaert CM, de Jong N, van den Hof WF, van Dieijen-Visser MP. Time- and temperature-dependent stability of troponin standard reference material 2921 in serum and plasma. *Clin Chem Lab Med*. 2012;50:1681-1684.
26. Wu AH. A selected history and future of immunoassay development and applications in clinical chemistry. *Clin Chim Acta*. 2006;369:119-124.
27. Apple FS, Collinson PO. PO for the IFCC Task Force on clinical applications of cardiac biomarkers. Analytical characteristics of high-sensitivity cardiac troponin assays. *Clin Chem*. 2012;58:54-61.
28. Lippi G, Cervellin G. Degradation of troponin I in serum or plasma: mechanisms, and analytical and clinical implications. *Semin Thromb Hemost*. 2012;38:222-229.
29. Dupuy AM, Sebbane M, Roubille F, et al. Analytical evaluation of point of care cTnT and clinical performances in an unselected population as compared with central laboratory highly sensitive cTnT. *Clin Biochem*. 2015;48:334-339.
30. Stengaard C, Sorensen JT, Ladefoged SA, et al. Quantitative point-of-care troponin T measurement for diagnosis and prognosis in patients with a suspected acute myocardial infarction. *Am J Cardiol*. 2013;112:1361-1366.
31. Nilsson S, Andersson A, Janzon M, Karlsson J-E, Levin L-A. Cost consequences of point-of-care troponin T testing in a Swedish primary health care setting. *Scand J Prim Health Care*. 2014;32:241-247.
32. Venge P, van Lippen L, Blaschke S, et al. Equal clinical performance of a novel point-of-care cardiac troponin I (cTnI) assay with a commonly used high-sensitivity cTnI assay. *Clin Chim Acta*. 2017;469:119-125.
33. Lopez-Calle E, Espindola P, Spinke J, et al. A new immunochemistry platform for a guideline-compliant cardiac troponin T assay at the point of care: proof of principle. *Clin Chem Lab Med*. 2017;55:1798-1804.
34. Kemper DWM, Semjonow V, de Theije F, et al. Analytical evaluation of a new point of care system for measuring cardiac troponin I. *Clin Biochem*. 2017;50:174-180.
35. Asha SE, Cooke A, Walter E, Weaver J. Three-month outcome of patients with suspected acute coronary syndrome using point-of-care cardiac troponin-T testing compared with laboratory-based cardiac troponin-T testing: a randomised trial. *Emerg Med. J*. 2015;32:601-607.
36. ter Avest E, Visser A, Reitsma B, Breedveld R, Wolthuis A. Point-of-care troponin T is inferior to high-sensitivity troponin T for ruling out acute myocardial infarction in the emergency department. *Eur J Emerg Med*. 2016;23:95-101.
37. Mion MM, Bragato G, Casarotti A, et al. Clinical performance of cardiac troponin I: a comparison between the POCT AQT90 flex and the dimension vista analyzer in an emergency setting. *Clin Biochem*. 2017;50:763-767.

38. Slagman A, von Recum J, Möckel M, et al. Diagnostic performance of a high-sensitive troponin T assay and a troponin T point of care assay in the clinical routine of an emergency department: a clinical cohort study. *Int J Cardiol*. 2017;230:454-460.
39. Greiser A, Winter T, Mahfoud H, et al. The 99th percentile and imprecision of point-of-care cardiac troponin I in comparison to central laboratory tests in a large reference population. *Clin Biochem*. 2017;50:1198-1202.

How to cite this article: Lin Y-H, Zhang Y, Liu Y-T, Cui K, Kang J-S, Zhou Z. How to choose a point-of-care testing for troponin. *J Clin Lab Anal*. 2020;34:e23263. https://doi.org/10.1002/jcla.23263