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Point-of-Care Diagnosis of Acute Myocardial Infarction in Central Vietnam

International Exchange, Needs Assessment, and Spatial Care Paths

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Objectives: Objectives were to (a) advance point-of-care (POC) education, international exchange, and culture; (b) report needs assessment survey results from Thua Thien Hue Province, Central Vietnam; (c) determine diagnostic capabilities in regional health care districts of the small-world network of Hue University Medical Center; and (d) recommend Spatial Care Paths that accelerate the care of acute myocardial infarction (AMI) patients.

Methods: We organized progressively focused, intensive, and interactive lectures, workshops, and investigative teamwork over a 2-year period. We surveyed hospital staff in person to determine the status of diagnostic testing at 15 hospitals in 7 districts. Questions focused on cardiac rapid response, prediabetes/diabetes, infectious diseases, and other serious challenges, including epidemic preparedness.

Results: Educational exchange revealed a nationwide shortage of POC coordinators. Throughout the province, ambulances transfer patients primarily between hospitals, rarely picking up from homes. No helicopter rescue was available. Ambulance travel times from distant sites to referral hospitals were excessive, longer in coastal and mountainous areas. Most hospitals (92.3%) used electrocardiogram and creatine phosphokinase-MB isoenzyme to diagnose AMI. Cardiac troponin I/T testing was performed only at large referral hospitals.

Conclusions: Central Vietnam must improve rapid diagnosis and treatment of AMI patients. Early upstream POC cardiac troponin testing on Spatial Care Paths will expedite transfers directly to hospitals capable of intervening, improving outcomes following coronary occlusion. Point-of-care coordinator certification and financial support will enhance standards of care cost-effectively. Training young physicians pivots on high-value evidence-based learning when POC cardiac troponin T/cardiac troponin I biomarkers are in place for rapid decision making, especially in emergency rooms.

Key Words: acute coronary syndrome (ACS), ambulance, cardiac troponin (cTn) I and T, district hospitals, evidence-based medicine (EBM), geographic information systems, hospital levels, Hue University of Medicine and Pharmacy (HUMP), needs assessment, point-of-care (POC) culture, prehospital diagnosis, primary care, small-world networks (SWNs), Thua Thien Hue Province (TTHP), value proposition

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The long-term collaborative goal is national development of point-of-care (POC) culture, professional practice, and evidence-based decision making in Vietnam. Specific objectives for this research were (a) to compare needs assessment survey results in Vietnam currently versus 1 decade ago, (b) to determine hospital POC instrument and diagnostic capabilities in the regional districts of Thua Thien Hue Province (TTHP), and (c) to recommend designs, technologies, systems logic, algorithms, and Spatial Care Paths (SCPs) that accelerate the care of patients suspected of having acute myocardial infarction (AMI) in the health care small-world network (SWN) of Hue University Medical Center.

NATIONAL DEVELOPMENT

Following countrywide education programs in 2016 and 2017 (Table 1), our collaborative strategy for advancing point-of-need decision making in Central Vietnam comprised (a) producing an international symposium (Table 2) presented by local and international speakers (Fig. 1) and free for all who wished to attend; (b) conducting full-time field research on site for 1 month; (c) performing POC testing (POCT) needs assessment throughout TTHP; and (d) accelerating diagnosis to improve the care of AMI patients by implementing POC cardiac biomarker testing while optimizing regional SWNs. Surveys also addressed POCT for other medical challenges, such as molecular technologies for infectious diseases, outbreaks, and sepsis; test clusters for diabetes mellitus; and laboratory support of critically ill patients in isolation and intensive care.

BACKGROUND

Historical Perspective

Over a decade ago, one author in collaboration with country colleagues in Cambodia and Vietnam performed surveys¹ of POCT sponsored by a Fulbright Scholar Award (to G.J.K.) for the development of POC culture in Association of Southeast Asian Nations (ASEAN) member states. The Fulbright was based out of Chulalongkorn University in Bangkok, Thailand. Upon surveying Cambodia at that time, we found no cardiac biomarker testing whatsoever. In Southern Vietnam, 33% of small hospitals surveyed¹ performed exclusively creatine phosphokinase (CK) or CK-MB isoenzyme (CK-MB) testing in small laboratories to diagnose AMI, whereas none offered cardiac troponin (cTn) testing; 33% of medium-sized hospital laboratories performed qualitative cardiac troponin I (cTnI), and 33%, quantitative cardiac troponin T (cTnT) testing; and 25% of large hospitals performed either qualitative or quantitative cTnI, and 25%, quantitative cTnT testing. None of the sites surveyed offered cardiac biomarker testing at points of care (see Tables 2 and 3 in Kost et al¹).

At the time of the previous survey, Vietnamese health systems lacked systematic means of quickly rescuing, diagnosing, and treating patients living in remote locations. No helicopter

TABLE 1. National Educational Program and POC Culture Development in Vietnam

Year	Event, Locations, and Topics
2016	Tricity educational tour—HCMC, Hue, and Hanoi Public lectures, staff training, and hands-on workshops Preliminary needs assessment and competency examinations HCMC: role of the laboratory in managing POCT and its safety Hue: the above, plus specialty focus on rule-in and rule-out AMI Hanoi: all of the above plus introduction to the POC coordinator
2017	Bicity symposia in Hanoi and HCMC—POC coordinator education Hanoi sponsor: Vietnam Association of Clinical Biochemists HCMC sponsor: Center for Standardization & Quality Control in the Medical Laboratory (CSQL)—held on site at the CSQL
2017	International symposium in Hue (Table 2) Sponsors: • POCT•CTR at the UC Davis • HUMP Field research in TTHP performed by collaborating faculty and student participation

transport was available, and ambulance service was inadequate. We concluded, “Cost-effectiveness should be assessed in the context of complete cycles of care from home to hospital and back, for which POCT offers unique advantages in the diagnosis, triage, acute care, intensive care, bedside testing, and after discharge, monitoring at the primary care and home levels.”¹ Further, “Critical care

testing and POCT must become prominent components of public health strategies and infrastructures in this low-income country to improve acute care and disaster preparedness.”¹ Now, cardiac deaths are increasing in Vietnam, in part attributed to late diagnosis,² and more fundamentally, to the surprising increase in, and burden of, ischemic heart disease.^{3,4}

TABLE 2. International Symposium Lectures—MƯC LƯC

- An overview of POCT
Prof Gerald J. Kost, MD, PhD, MS, FAACC; POCT•CTR
UC Davis
- Regulatory oversight and accreditation—the international perspective
Prof Gerald J. Kost, UC Davis
- The role of the POC coordinator
Dr Nguyen Thuy Loan Chi, French-Vietnamese Hospital, HCMC
- Innovative POC strategies for enhancing infectious disease diagnosis in the emergency department
Assoc Prof Nam Tran, PhD, Pathology and Laboratory Medicine, School of Medicine, UC Davis
- Instrument selection and validation
Prof Gerald J. Kost, UC Davis
- Instrument and clinical needs for rapid response testing and POCT at HUMP
Dr Duong Thi Bich Thuan, HUMP
- Quality control for POCT and insights from the Individualized Quality Control Plan approach
Prof Gerald J. Kost, UC Davis
- Applying of the hs-cTnT in the diagnosis, monitoring and predicting of cardiovascular disease in the Central of Vietnam
Prof Hoang Anh Tien, Hue University Hospital
- Clinical goals of rapid response and POCT for diabetes, ACSs, and critical care, including highly infectious diseases (eg, Ebola)
Prof Gerald J. Kost, UC Davis
- Conversion from contemporary troponin to next generation troponin T testing
Assoc Prof Nam Tran, PhD, UC Davis
- Clinical value of next generation troponin T and heart failure biomarker testing
Assoc Prof Nam Tran, PhD, UC Davis
- POC ECG and hemodynamic ambulatory monitoring from hospital to home
Jesse Lin, BS, MT(ASCP), EMBA, Taiwan National University, Taipei
- Using rapid response POC molecular diagnostics to improve patient outcomes
Amanullah Zadran, POCT•CTR, UC Davis
- Molecular diagnostic: resistance markers and syndromic diagnosis
Kelly Nguyen and Mykhaylo Sayenko, POCT•CTR, UC Davis
- POCT policy and guidelines (P & G)—status in Asian countries and global perspective
Prof Gerald J. Kost, UC Davis



FIGURE 1. International symposium speakers and research team in Hue. This figure can be viewed online in color at www.poctjournal.com.

New Mission

In 2014, the World Health Organization produced a Vietnam country profile of noncommunicable disease and associated mortality.⁵ Of approximately 91 million people, 33% of deaths were attributed to cardiovascular diseases alone. Thus, the current new mission for our joint program with Vietnam is (a) to improve the standard of care and outcomes for patients with AMI; (b) to do so with geographic and demographic equity, specifically targeting badly neglected rural regions in need; and (c) to direct diagnostic resources appropriately, efficiently, and cost-effectively.

EDUCATION AND TRAINING

Hypothesis

Our basic hypothesis is that education is fundamental to progress, progress is vital for social equity, and social equity is inherent in sustainable POC culture. We conducted a 2-year national POCT and acute coronary syndrome (ACS) lecture program in 2016 and 2017 comprising collaborative-cooperative instruction and shared experiences in the practice of point-of-need decision making and rapid response diagnostics.

We held lecture and training sessions in 3 key regions—Ho Chi Minh City (HCMC, the South), Hue (Central), and Hanoi (the North). These activities presaged our international exchange organized and supported by the Point-of-Care Testing Center for Teaching and Research (POCT•CTR) at the University of California, Davis (UC Davis), for TTHP, in collaboration with the Faculty of Hue University of Medicine and Pharmacy (HUMP).

International Symposium

Before the needs assessment field survey began, the POCT•CTR sponsored an International Symposium at HUMP with presentations given by (a) the leading Vietnamese POC coordinator, who works at French-Vietnam Hospital in HCMC, (b) guests invited from the United States and Taiwan, and (c) local HUMP expert speakers.

Three undergraduate students (K.N., M.V.S., and A.Z.) from UC Davis, received POCT•CTR travel-research funding, and one (A.Z.), a distinguished UC Davis Student Travel Award, to present at the symposium. Table 2 outlines the international symposium program, which provided a successful platform for launching collaborative regional research investigating the province health care SWN.

Shift to Primary Care

This long-term program was designed to progressively facilitate the implementation of POCT throughout Vietnam in line

with recent central government emphasis on redirecting substantial health care funding to smaller community hospitals and primary care sites of first patient contact where diagnostic testing is needed urgently on a daily basis, in order to practice evidence-based medicine.

METHODS

Survey Scope

To determine the status of POCT and other diagnostics at 15 hospitals in 7 districts in TTHP, we surveyed hospital staff on site in both the Vietnamese and English languages. For consistency, we used newly prepared formal survey questionnaires. The province has a tropical monsoon climate, making it rainy and humid throughout the year. It borders Laos to the west. Districts closest to the border are mountainous, with very limited medical resources and extremely constrained access to health care. People living in mountainous regions tend to be culturally distinct and not well integrated with urban styles. To the east is the Biển Đông Sea, also known as the South China Sea. The coastal peninsulas and other geographic features of the thin central region of Vietnam present their own challenges for north-south travel over high passes and expeditious cardiac care.

The province is made up of 9 district-level subdivisions comprising 6 districts (A Lúoi, Nam Đông, Phong Điền, Phú Lộc, Phú Vang, and Quảng Điền), 2 towns (Hương Thủy and Hương Trà), and 1 provincial city, Hue, the ninth most populous in Vietnam. Further subdivided administrative units comprise 8 commune-level towns, 105 communes, and 39 wards. We surveyed 6 districts in the time permitted during 1 month on site. This collaborative research was followed by e-mail correspondence, teleconferences, and limited select field visits conducted by Vietnamese students to expand the base of district sites and clarify factual details.

Hospital Levels

Vietnamese hospitals are classified by the government into “levels” (Table 3). The most common is level 4, 1 per commune, with more than 150 in TTHP. These sites, historically and typically the least well equipped and poorest funded, also are known as community health centers. Level 3 hospitals, 1 per district, are commonly known as district hospitals. They are better equipped and funded than level 4 hospitals.

There is 1 level 2 hospital per province, the provincial hospital, even better equipped and funded. Hue University Hospital is level 2. Hue Central Hospital is located in the provincial capitol and is one of the largest in Vietnam. It is 1 of only 3 level 1 hospitals, along with Bach Mai Hospital in Hanoi and Cho Ray Hospital in HCMC, in all of Vietnam. Administration of a level 1

TABLE 3. Hospital Levels in Vietnam

	Level 4	Level 3	Level 2	Level 1
Locations	Several per district, usually one per commune	One per district	One per province	Three in Vietnam: Hue, Hanoi, and HCMC
Labor room (LR)	An LR is usually present, but only for emergencies. Level 4 hospitals generally are not permitted to assist in childbirth and usually will transfer patients to a level 3	An LR is present and actively used to help with childbirth. Select hospitals can perform cesarean deliveries	An LR is present and actively used for performing cesarean deliveries	An LR is present and actively used for performing cesarean deliveries
Common reasons for visiting	Level 4 hospitals provide very basic health care, mostly medications. Select ones have POC glucose testing. Some focus on traditional medicine	Level 3 hospitals provide marginally more advanced health care and can treat minor wounds, perform surgeries, and perform basic laboratory tests	Level 2 hospitals perform advanced health care and perform major surgeries. Some have cardiac specialists and neonatal intensive care units and can treat most patients	Level 1 hospitals are the most advanced and well-equipped hospitals in Vietnam with all the features of a level 2 hospital plus specialty centers. For example, Hue Central Hospital centers comprise advanced technologies, infectious diseases, cancer, pediatrics, hematology and transfusion, burns/plastic surgery, and obstetrics/gynecology; this hospital covers 14 central and highlands provinces
Patient transfer	Patients transferred for any condition requiring more than minor care. Usually transfer to the nearest level 3 hospital, but when warranted, level 4 may bypass level 3 and transfer directly to level 2 or 1 with permission	Patients usually are transferred for more serious conditions that involve highly invasive surgeries or advanced/expensive equipment to treat	Transfer for specified infectious diseases when a level 1 hospital has specific units, procedures requiring advanced equipment, or extreme patient overflow	Generally, level 1 hospitals do not transfer patients
Beds	5–10	50–250	600–700	Hue Central Hospital 2400 Bach Mai Hospital 2400 (Hanoi) Cho Ray Hospital 1800 (HCMC)

hospital is tightly controlled by the central government. We did not survey the level 1 hospital. Our focus was on the regional health care SWN, mainly rural areas referring patients to higher-level hospitals.

Needs Assessment

We conducted POC needs assessment⁶ according to formal methods and statistical approaches developed during the course of our UC Davis Point-of-Care Testing Center funded by the National Institute of Biomedical Imaging and Bioengineering, National Institutes of Health, at the POCT•CTR. We published a series of articles summarized in the first chapter,⁷ “Needs Assessment for Rapid Decision Making in Pandemics, Complex Emergencies, and Disasters: A Global Perspective,” of *Global Point of Care: Strategies for Disasters, Emergencies, and Public Health Resilience (Global Point of Care)*.

In *Global Point of Care*,⁸ the first Appendix provides an English survey tool that readers can adapt to their own settings and interests. Working from this platform,⁹ we customized a survey for Central Vietnam. The World Health Organization recently emphasized the importance of needs assessment as a first step in relation to determining purpose in “A Guide to Aid the Selection of Diagnostic Tests.”¹⁰ Our new English survey was translated into Vietnamese (Appendix 2, Supplemental Digital Content 2, <http://links.lww.com/POC/A17>) by 1 coauthor (T.T.B.D.) and piloted

to improve fidelity of responses. Both this Vietnamese translation and the English version (Appendix 1, Supplemental Digital Content 1, <http://links.lww.com/POC/A16>) can be found in the appendices available online.

Geographic Information System, SWNs, and SCPs

Approaches to geographic and topographic analyses are described by Ferguson et al^{11,12} based on research conducted at the POCT•CTR. Small-world network theory and application are explained in “Using Small-World Networks to Optimize Preparedness, Response, and Resilience,” Chapter 49 in *Global Point of Care*.¹³ An SCP is defined as the most efficient route taken by the patient when receiving definitive care in an SWN.¹⁴ Background rationale, detailed explanation, SCP illustrations, and tabular summaries of impact can be found with free access at <http://www.ifcc.org/media/332055/eJIFCC2014Vol25No2pp134-153.pdf>.

POC Culture

The concept of POC culture (“the future of world medicine for individuals globally”) was created by 1 author (G.J.K.) in 2010 and summarized by Kost et al.¹⁵ Relevant survey questions regarding POC culture were based on Appendix 3¹⁶ of *Global Point of Care*⁸ and on previous surveys conducted in Cambodia,

Indonesia, the Philippines, Thailand, Vietnam, and other ASEAN member states.

Analysis and Statistics

Quantitative methods, associated publications, case illustrations, and needs assessment theory can be found in Chapter 1 of *Global Point of Care*.⁷ Briefly, survey respondents assigned ranks, R_j , with $j = [1, n_r]$, where n_r is the number of possible ranks for

each factor; F_i , where $i = [1, n_f]$; and n_f = the number of factors given for selection. Scores were calculated using the following equation: $S_j = (n_r + 1) - R_j$.

We determined the weighted scores by summing the product of each score and the corresponding frequency as follows:

$$WS_i = \sum_{j=1}^{n_r} S_j \times F_{ij}$$

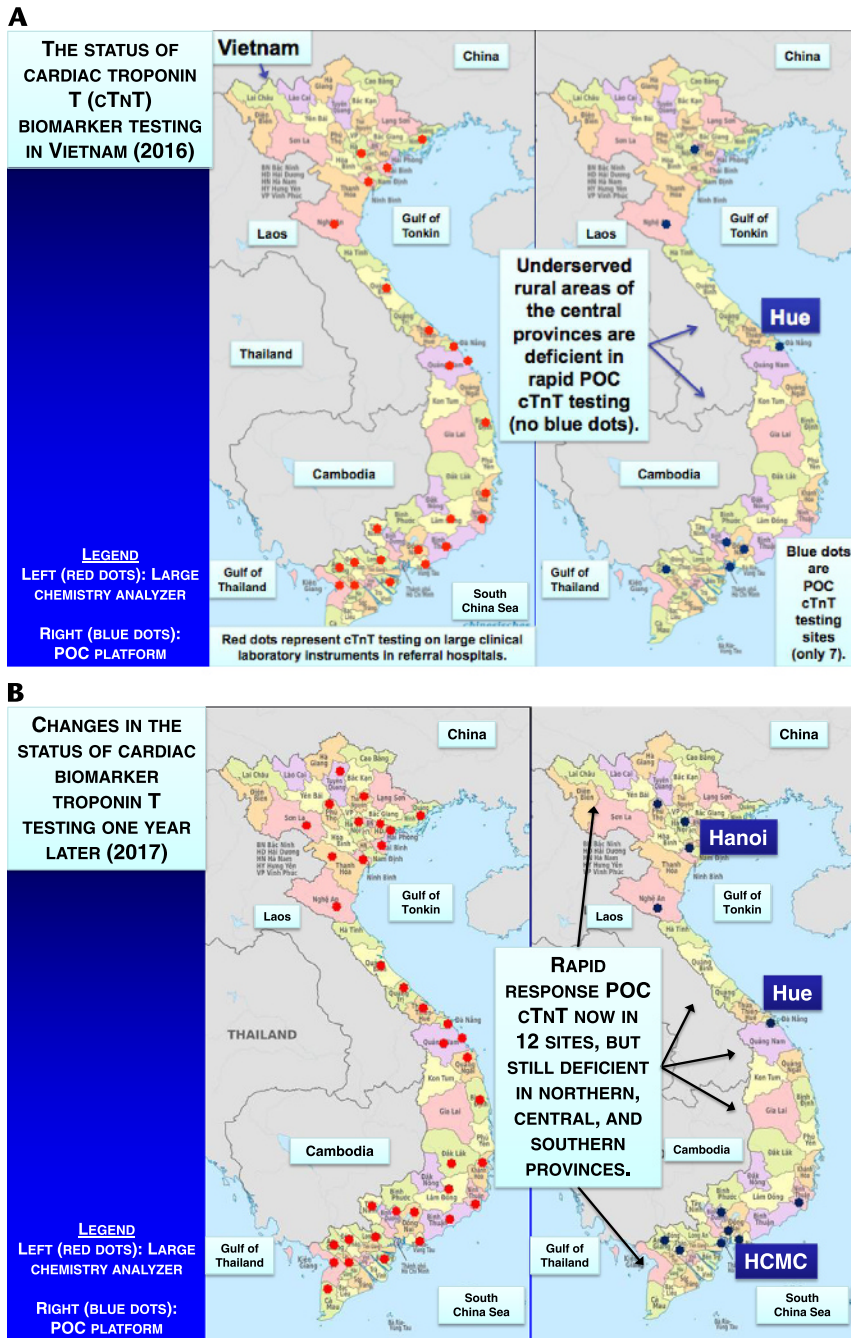


FIGURE 2. Status of POC and clinical laboratory cardiac biomarker testing in Vietnam. The left frame shows the status in 2016, whereas the right frame, 2017. This geographic information systems analysis of trends over the 2-year period of POCT national development shows that Central Vietnam remains deficient in both POC and clinical laboratory cTnT diagnostic resources. During the survey in TTHP, we found no POC cTnI testing, which generally was deficient in central and far north-south regions. This figure can be viewed online in color at www.poctjournal.com.

where the frequency, F_{ij} , is the number of times survey respondents assigned an individual factor a specific rank. When a respondent designated the same rank for 2 or more factors (a “tie”), an average rank was assigned to each factor, and positions of factors with lower ranks were adjusted accordingly. Statistical methods are described by Kost et al.⁷

RESULTS

Tables 1 and 2 present the 2-year educational programs conducted in North, Central, and South Vietnam during 2016 and 2017. In 2017, we focused on Central Vietnam, because the preceding broad diagnostics surveys documented deficiencies of cardiac biomarker testing in this region, both at points of care and in hospital laboratories (Fig. 2). Table 4 and subsequent Tables 5–11 present survey results.

Table 4 reports the results of basic needs assessment. Overall, respondents favored key diagnostic test clusters for urgent care. The Pareto plot (Fig. 3) illustrates the results and indicates statistically significant differences in rankings. Top priorities were attached to hematology, pulse oximetry, chemistry/electrolytes/ionized calcium (Ca^{2+}), blood gases, and rapid microbiology test clusters in the emergency room.

Despite the high prevalence of ACS in the province, cardiac biomarkers came in sixth. Coagulation tests and blood typing received the lowest overall weighted scores. However, cardiac biomarkers placed third after hematology and rapid microbiology tests at level 4 hospitals, which often provide the initial critical contact points for urgent cardiac care. Likewise, the level 2 hospital ranked cardiac biomarkers third, in this case after rapid microbiology and coagulation test clusters.

Table 5 summarizes demographics, critical care resources, and cardiac biomarker utilization in the hospitals surveyed. None of the sites reported vigorous POCT programs. The level 2 hospital offered both cTnT and cTnI testing. Neither cTn test was present in the other hospital levels, which depended mostly on electrocardiogram (ECG) for screening ACS patients. In the level 2 hospital, cTnT is performed on the Cobas 6000 system (Roche Diagnostics) and reimbursed by insurance. Emergency room staff in this hospital rarely ordered cTnI (none in the past year) because it was not covered by insurance. A cardiologist was available to

which the other hospitals could refer patients, but we found no POC coordinators.

Table 6 reports site-specific deployment of POCT in community health centers, district hospitals, and the provincial hospital. Prehospital diagnosis of AMI in ambulances could alleviate the problem of obligatory transport of patients through the government-defined chain of different hospitals levels, which causes adverse delays, but none was found. We did find glucose meters in use. Table 7 presents the POC tests emergency medical staff felt should be performed while transporting patients, in order to speed up treatment, along with their rationale for use.

Tables 8 and 9 focus on the challenges of providing rapid response for patients with chest pain, no matter where they are at the time. Table 8 reports responses to specific survey questions. For question 3.2 (see the Appendices, Supplemental Digital Content 1 [http://links.lww.com/POC/A16] and Supplemental Digital Content 2 [http://links.lww.com/POC/A17]), respondents stated that ambulances did not function to rescue patients directly from homes, in some cases because of a shortage of ambulance-type vehicles.

In severe cases, patients could go directly to levels 1 and 2 hospitals with financial support, but for less severe cases, tiered partial payments incentivize patients to engage levels 4 > 3 > 2 > 1. Recently, patients have been allowed to skip level 4 and go to level 3 without financial penalty, but only if within their province of residence. A patient deemed a less severe case is penalized when going directly to level 1 or 2, because in that instance, insurance payment will not cover the full hospital costs.

From a public health standpoint, Table 9 justifies additional funding and the implementation of POC resources for patients with ACS, stroke, and hypertension, which would also facilitate the care of patients who present to the emergency room as a result of motor vehicle accidents, which occur most commonly among the young and middle aged.

Table 10 reflects the community approaches to patients suspected of having an AMI. For example, survey results revealed that severity dictates where patients seek help, as noted previously. However, without reliable ambulance service, the pathway to rescue is chaotic, frustrating, and time consuming. Responding to question 5.5, AMI was identified as the most common condition requiring referral to the larger hospitals in Hue City. Indeed, respondents reported that often AMI was untreated or not treated

TABLE 4. Weighted Scores Identifying Needs Priorities for POC Diagnostic Tests*

Diagnostic Test Clusters	Level 2 Hospital (n = 1)	Level 3 Hospitals (n = 7)	Level 4 Hospitals (n = 7)	Sum of the Weighted Scores [†]	Test Cluster Location in Hospital [†]
Hematology (CBC, differential, platelet)	7	51	42	100	Mostly ER and Laboratory
Pulse oximeter (O ₂ saturation)	8	42	30	80	ER
Chemistry/electrolytes/ionized calcium	5	40	28	73	ER
Blood gases (pH, PO ₂ , PCO ₂)	6	29	31	66	ER
Rapid microbiology	1	21	36	58	Mostly ER and Laboratory
Cardiac biomarkers (cTnT, cTnI, others)	3	22	32	57	ER
Blood typing (A, B, O, Rh)	4	22	27	53	ER
Coagulation (PT, INR)	2	25	26	53	ER

See the Pareto plot, Figure 3.

*Survey question 2.6 asks to rank diagnostic tests from 1, “most needed,” to 8, “least needed.” Questions receiving rank of 1 were assigned a rank score of 8, whereas an 8, a rank score of 1; see Methods. The weighted scores generated above are for each diagnostic category (n = 15).

[†]The majority of respondents suggested locations where POC tests maximize utility.

CBC indicates complete blood count; ER, emergency room; INR, international normalized ratio; PCO₂, partial pressure of carbon dioxide; PO₂, partial pressure of oxygen; and PT, prothrombin time.

TABLE 5. Demographics, Critical Care Resources, and Cardiac Biomarker Utilization in Central Vietnam Hospitals

	Level 4 Hospitals (n = 7*)	Level 3 Hospitals (n = 7*)	Level 2 Hospital (n = 1*)
Demographics			
No. daily patient visits, mean (SD)	33 (18.4)	256 (206.5)	410
No. beds	7 (2.6)	128 (65.9)	605
Physicians	1 (0.49)	27 (9.9)	248
Nurses	1 (0.38)	40 [†] (19.8)	150
Diagnostic laboratory service			
Weekdays, mean (SD)	1 Site, [‡] 7 h 45 min	8 h (0.35)	8 h
On-call service provided	1 Site [‡]	6 Sites [‡]	Available
POCT program	No	No	No
POCT director	No	No	No
POC coordinator	No	No	No
Critical care resources			
No. SPO ₂ monitors, mean (SD)	Not available	3 (2.7)	9
Blood gases	Not available	Not available	PO ₂ , P _{CO2} , pH, H _{CO3} ⁻
Electrolytes	Not available	3 Sites [‡] ; Na ⁺ , Cl ⁻ , K ⁺ , Ca ²⁺	Na ⁺ , Cl ⁻ , K ⁺ , Ca ²⁺
Intervention and cardiac biomarkers			
Qualitative	Not available	Not available	cTnI
Quantitative	Not available	LDH (3), AST (7), CK-MB (1)	cTnT, CK, CK-MB, LDH, AST, NT-pro-BNP
Referral site for cardiac care [§]	DH (3), PH (4), RH (5)	RH (7), RH (6)	RH
Interventional cardiologist available	No	No	Yes
Tests used to diagnose AMI [¶]	ECG (4)	ECG (7), AST (3), cTnT (1), Ultrasound (1)	ECG, cTnT, CK, CK-MB

*The number of hospitals in each category.

[†]Six hospitals responded.

[‡]The number of hospitals that responded to the question in the given level.

[§]Patients presenting with cardiac conditions at this particular hospital type typically are referred to the corresponding hospitals for cardiac care; numbers in parentheses reflect the frequency of the hospital referral type.

^{||}The PH transports patients to the regional hospital when extreme complications are present.

[¶]Diagnostic tests frequently used to diagnose AMI when a patient arrives at this type of hospital, despite other qualitative and quantitative diagnostic tests available.

AST indicates aspartate aminotransferase; CK, creatine phosphokinase; DH, level 3 district hospitals; LDH, lactate dehydrogenase; NT-pro-BNP, N-terminal pro-B-type natriuretic peptide; PH, level 2 provincial hospital; RH, level 1 regional hospital; SPO₂, peripheral capillary oxygen saturation.

rapidly enough. For question 3.35, respondents wanted improved transportation systems, ambulances equipped with diagnostic technologies, enhanced screening, and training in resuscitation and cardiopulmonary resuscitation.

DISCUSSION

Past Versus Present Survey Results

Comparison of documented trends starting 12 years ago¹ through 2016–2017 (Fig. 2) with current survey results reveals relatively modest progress in POC cardiac biomarker use throughout Vietnam. Vietnamese health care delivery systems would benefit from improved fundamental resources for the diagnosis, rapid transport, and treatment of critically ill patients, especially those presenting with ACS, in which case POC cTnI or cTnT could help rule in the diagnosis of AMI.

Role of POC Cardiac Biomarkers

Ruling out the diagnosis of AMI is limited by the low sensitivity of POC cTn assays. Therefore, temporal trends in cTn¹⁷

should be followed closely, and as necessary, high-risk patients transferred promptly. In rural areas, Minh¹⁸ recommended, "...evidence-based health interventions for reducing the burden of the cardiovascular disease epidemic in Vietnam..." Further, "Interventions should be comprehensive and integrated, including both primary and secondary approaches, as well as policy-level involvement." In addition, biomarkers of heart failure, which are rising in importance in Asia, would facilitate differential diagnosis.^{19,20}

A recent Asia Pacific consensus statement²¹ endorsed cardiac biomarker testing broadly, including high-sensitivity (hs) cTn, and stated, "...where only POCT is available, patients with elevated readings should be considered at high risk, while patients with low/undetectable readings should be retested after 6 hours or sent for laboratory testing... and regular education on the appropriate use of troponin tests is essential." Contributors included 2 cardiology units in Vietnam, the Department of Cardiology at University Medical Center in HCMC and the National Cardiology Institute in Hanoi.

The consensus authors²¹ failed to point out, however, that current POC cTn tests cannot be used to rule out AMI because of low sensitivity. They focused on cTnI, whereas the POC cTn

TABLE 6. Site-Specific Deployment of POCT*

Department	POC Tests and Weighted Scores
Community health centers (n = 7)	
Emergency department	Urinalysis (27), ECG (25), ultrasound (23), BP (26), glucose meter (15), malaria Ag (8)
Labor room [†]	CTG (10), ultrasound (10), BP (10)
District hospitals (n = 7)	
Emergency department	ECG (50), SPO ₂ (26), glucose meter (19), vital signs monitor [‡] (9), CBC (17), BP (8), biochemistry tests (8), pregnancy test (7), lipid panel (7)
Intensive care unit	Glucose meter (26), ECG (18), CBC (17), vital sign monitor (10), SPO ₂ (9), urea creatinine (8), x-ray (6), ultrasound (5)
Operating room	ECG (16), glucose meter (15), vital signs monitor (10), CBC (10), SPO ₂ (10), respiratory rate monitor (9), BP (8), ultrasound (8), x-ray (7)
Neonatal intensive care unit	CTG (10)
Labor room	CTG (39), vital signs monitor (10), EMG (10), pH tests (10), BP (9)
Ward	ECG (20), vital signs monitor (10), SPO ₂ (9), respiratory rate monitor (9)
Ambulances	Glucose meter (10)
Provincial hospital (n = 1)	
Emergency department	SPO ₂ (10), glucose meter (9)
Intensive care unit	SPO ₂ (10), BP (9), EtCO ₂ (8), ECG (7), glucose meter (6)
Operating room	SPO ₂ (10), BP (9), EtCO ₂ (8), ECG (7), glucose meter (6)
Neonatal intensive care unit	SPO ₂ (10), glucose meter (9)
Labor room	CTG (10)
Ambulances	BP (10)

*Survey questions 2.8 through 2.15 present rank analysis and weighted scores of POC tests across a row. Departments are listed on the left for each group of hospital levels.

[†]Two responding community health centers offered labor room services.

[‡]Vital signs monitor is used for BP, HR, RR, and SPO₂ in real time.

BP indicates blood pressure; CBC, complete blood count; CTG, cardiocotography; EMG, electromyogram; EtCO₂, end-tidal CO₂; malaria Ag, malaria antigen test; RR, respiratory rate; SPO₂, peripheral capillary oxygen saturation.

used commonly throughout Southeast Asia is cTnT. They did not comment on how POC cTnT can be partnered with laboratory-based hs-cTnT. These shortcomings must be rectified by additional work toward agreed practice standards, including for hs-cTnT when it appears in the clinical laboratories of Vietnam.

Technological Progress

Improved cardiac biomarker assays, such as the 9-minute hs-cTnT assay,²² the first hs-cTn test introduced in the United States that meets the International Federation of Clinical Chemistry and Laboratory Medicine guidelines and precision requirements under the third universal definition of AMI,²³ should be implemented in Vietnamese hospital laboratories along with systematic approaches to rescuing rural patients with acute chest pain. Advances in assay speed enable faster therapeutic turnaround time, the time from ordering a test to treating the patient. Accelerated decision making fits one author's (G.J.K.) original vision 12 years ago²⁴ illustrated as a paradigm shift of progressively faster cardiac biomarkers assays driving consensus standards of cardiac care.

As respondents reported, critical care infrastructure in Central Vietnam needs strengthening by simultaneously implementing whole-blood analyzers—handheld, portable, or transportable formats—for patients arriving at smaller hospitals, especially multiplex whole-blood analyzers with test clusters that include free calcium (“ionized calcium,” Ca²⁺) needed when stabilizing critically ill cardiac patients. Eventually, hs-cTn tests will appear on POC devices²⁵ that allow both rule-in and rule-out of AMI, but for now POCT is best suited to ruling in the diagnosis when

accompanied by characteristic history, symptoms, and signs, including ECG findings.

Value Proposition

The total costs for performing POCT, quality control, and proficiency testing must be weighed against benefits and alternatives by means of value propositions, as illustrated in Figure 4. Financial assistance can empower physicians and nurses in problem solving, local ownership, and sustainable enterprise. Current human resources and economic constraints, however, will not permit rapid improvement in Central Vietnam without substantial help from the central government, Ministry of Health, and foreign donors. In the United States, emergency rooms are experimenting with direct rapid physician evaluation in lieu of time-consuming triage,²⁶ and in this regard, POC multiplex testing can be pivotal to rapid and efficient diagnosis in Central Vietnam.

Spatial Care Paths

Transport services, equipment, boats, and vehicles in the SWN of Hue University Hospital should be improved substantially, and in particular, coordinated SCPs must be designed and implemented so that the time to diagnosis and treatment is less than 1 hour. Spatial Care Paths help define the most efficient routes in TTHP for rescuing, diagnosing, and treating AMI patients rapidly. Figures 5 and 6 illustrate practical frameworks for solving the problem of limited access and prolonged time to treatment in challenging areas.

TABLE 7. POCT Emergency Medical Staff Should Perform While Transporting Patients in Order to Speed Up Treatment*

	Provincial Hospital (n = 1)	District Hospitals (n = 7)	Community Health Centers (n = 7)
Major results	SPO ₂ was ranked the highest, glucose meters second, CBC third, electrolytes fourth, and blood gases fifth, with weighted scores of 10, 9, 8, 7, and 6, respectively.	Glucose meters received a weighted score of 31, cardiac biomarkers 10, blood pressure cuffs 8, coagulation tests 6, ultrasound 5, and blood gases 4.	Blood gas testing received a weighted score of 16, cardiac biomarkers 13, rapid infectious disease testing 8, blood pressure cuff 7, and CBC 5.
Impact/value	SPO ₂ can provide value in several patient conditions, including pulmonary failure, cardiovascular compromise, and others. Glucose meters can help detect hypoglycemia/hyperglycemia. CBC is instrumental in determining WBC in cases of highly infectious diseases (eg Ebola virus disease) and assist in early decision making and isolation. RBC, Hgb/Hct, platelets, and other measurements are invaluable in assessing anemia, inflammation, bleeding disorders, leukemia, and others. Electrolyte testing is valuable in metabolic disorders. Arterial blood gas testing can be a preliminary step of assessing acid/base imbalances and alerting physicians upstream in the SCP.	Glucose meter tests can be useful for EMS teams in district hospitals by providing information in severe situations where a patient is suffering from hypoglycemia/hyperglycemia. Cardiac biomarkers tests are instrumental for ruling in AMI. Blood pressure cuffs are influential in identifying low blood pressures and can enhance clinical decision making. Coagulation tests can help assess blood clotting ability, especially in severe trauma. Portable ultrasound testing is noninvasive, ideally used for trauma. Arterial blood gas testing assesses acid/base imbalances. POC test utilization allows physicians upstream in the SCP to prepare and respond efficiently.	Arterial blood gas testing can be essential in assessing acid/base imbalances, facilitating physicians upstream in the SCP to prepare. Rapid infectious disease testing (eg, malaria) would allow patients to receive prompt treatment. Blood pressure cuff can help assess if a patient has dangerously low/high BP which can lead to stroke. Cardiac biomarkers tests are essential in ruling in AMI, providing time for earlier intervention. A CBC analyzer could prove useful in screening for extremely low/high WBC counts, which may indicate the presence of highly infectious diseases and other problems, such as dengue fever.

*The responses were provided for survey question 2.18. For survey question 2.24, the following responses were recorded: respondents requested glucose testing (4), complete blood count analyzers (3), blood gases (2), urinalysis (2), ECG (2), biochemistry tests (2), cTnT (1), β-human chorionic gonadotropin test (1), coagulation testing (1), electrolyte testing (1), blood typing (1), hemoglobin A_{1c} (1), HIV tests (1), ultrasound (1), microbiology tests (1), organ function tests (1) (eg liver, renal, pulmonary), and mucin clot test (1) to be additional POC test provided to their hospital. For survey question 2.25, the following responses were recorded: respondents requested glucose meter (8) and blood pressure cuff (6) as POC tests that should be provided to patients to perform themselves. For survey question 2.26, the following responses were recorded: respondents requested POC tests to be placed in the health care network at primary care sites close to patient homes and work (6), at patients' home, allowing them to perform self-testing (5) and at a hospital close to where the patients live, on average, roughly 3.75 km by travel distance (8), or at a regional hospital when a maximum distance of 5 to 10 km away (1).

BP indicates blood pressure; CBC, complete blood count; EMS, emergency medical services; Hct, hematocrit; Hgb, hemoglobin; SCP, SCP; SPO₂, peripheral capillary oxygen saturation; and WBC, white blood cell count.

TABLE 8. Characterization of Emergency Services

Survey Questions	Major Results
3.1 Do you have helicopter transport?	No sites have helicopter rescue or transportation.
3.2 How far can your ambulance travel to pick up a patient?	CHCs are not equipped with ambulances to transfer patients. CHCs are required to call 115 to have patients transferred.* Six DHs responded [†] and stated they can travel on average 41 [22.3 [‡]] km to pick up a patient. However, they are not responsible for patient pick-up from home; instead, they transport patients to level 1, 2 hospitals. PH transfers patients to central hospital when PH cannot treat them, but central hospital can. PH recommends patients go to Hanoi or HCMC for some specific diseases when patients cannot be treated at central hospital.
3.3 If patients were 5, 10, 25, or 50 km away, approximately how long would it take to reach them and bring them back?	CHCs are unable to pick up or drop off patients due to the lack of ambulances. DHs take 9 [2.3 [‡]] min to transfer patients to sites 5 km away, 20 [5.1 [‡]] min for a distance of 10 km, 38 [11.5 [‡]] min for 25 km, and 74 [32 [‡]] min to pick up/drop off a patient at a distance of 50 km away. The PH takes approximately 5 minutes to transport a patient to sites 5 km away, 15 minutes for 10 km, 25 minutes for 25 km, and 60 minutes for a distance of 50 km (31.1 mi) away.
3.4 How often does your EMS team transport patients using an ambulance?	CHCs do not have an EMS team to transport patients; they are required to call 115 to transfer patients.* The EMS team on-site at DHs, on average transports 3 [2.78 [‡]] patients per day and 53 [55.8 [‡]] patients per month. The PH's EMS team often transfers 2 patients per day and 61 patients per month.
3.5 Does your hospital provide local patients with a pick-up using an ambulance in case of emergencies or natural disasters (eg, floods, earthquakes, storms)?	CHCs are unable to provide transportation using an ambulance due to absence of ambulances. DHs can pick up patients using an ambulance during emergencies or natural disasters. The PH provides ambulance transportation only in special cases such as disasters and large festivals and rarely used to transport colleagues.
3.6 Do you need to transport critically ill patients to other hospitals? If yes, specify transport distance, referral site, and why. If no, specify why not.	CHCs directly transport patients to DHs (7) within a distance of 12 [9.5 [‡]] km, whereas some transport to PH (2) or RH (2) for severe trauma, AMI, cardiac disease, tumors, surgery, acute asthma, severe burn, or in cases where treatment cannot be provided due to the lack of instruments. DHs transfer to the PH (7) and RH (6) within a distance of 24 [15.8 [‡]] km and some DHs also transport critically ill patients to the tuberculosis specialization center (1) and psychiatric hospital (1).
3.7 If it is necessary to transfer patients to other hospitals, where do you transfer them and how long does it take?	CHCs transfer patients to DHs (7) in 16 [8 [‡]] min, whereas some CHCs transport patients in 19 [8.5 [‡]] min to the PH (4), and 15 [5 [‡]] min to RH (3). DHs transfer patients to the PH (7) in 29 [16.9 [‡]] min and to the RH (6) in 32 [16 [‡]] min. One DH transfers patients to the optometry hospital (1) in 35 min, the psychiatric hospital (1) in 30 min and tuberculosis specialization center (1) in 25 min. The PH transfers patients to the RH in approximately 10 min.
3.8 Identify the community hospital closest to your hospital. Specify the distance and the travel time.	The CHC closest to a neighboring CHC is within 3 [1.7 [‡]] km and a travel time of 6 [3.5 [‡]] min. The CHC closest to a DH is within 2 [0.79 [‡]] km and a travel time of 5 [2.67 [‡]] min. For the PH, the closest CHC is within a distance of 1 km and travel time of 5 min.
3.9 Identify the referral (or regional) hospital closest to your hospital. Specify the distance and the travel time.	The closest referral hospital to a CHC is within 10 [7.8 [‡]] km and 15 [§] [8 [‡]] min away. The closest referral hospital to a DH, on average is 23 [17.2 [‡]] km and 24 [16.9 [‡]] min. The closest referral hospital to the PH is at a distance of 0.5 km requiring 10 min travel time.
3.10 Please specify the number of primary care clinics, health-promoting hospitals, or primary care units that are your hospital's responsibility.	No CHCs responded. One DH is responsible for 10 CHCs, another is responsible for 11 CHCs. DHs are responsible for CHCs within their area for education and training.
3.11 Now describe ambulance sites covered from your hospital. State distances, transport times, and destinations.	No CHCs responded. No DHs responded. The PH service transport patients 0.5 km to the regional hospital.

*115 is the call number of the ambulatory response service.

[†]One district hospital stated they would travel any distance to pick up a patient.

[‡]SDs are provided in brackets.

[§]One CHC site reported referral to the regional hospital was 40 km away, which would approximately take 60 minutes to reach.

^{||}Five district hospitals did not respond.

CHC indicates community health center; DH, district hospital; EMS, emergency medical services; PH, provincial hospital; RH, regional hospital.

Point-of-care cTn placements in hospitals of different levels and on ambulances can be optimized based on SCP designs explored further by local nurses, physicians, and health care SWN

administrators. Table 11 summarizes ambulance services, which need to refocus efforts away from taxi-like functions and instead rescue patients with chest pain, particularly in rural inaccessible

TABLE 9. Strategic Diagnosis, POCT Availability, and Referral Patterns in Central Vietnam

A. Patients With Acute Chest Pain			
Survey Questions*	Level 2 Provincial Hospital (n = 1)	Level 3 District Hospitals (n = 7)	Level 4 Community Health Centers (n = 7)
Diagnostic tests performed [†]	ECG, cTnT, CK-MB, CK	ECG (7), AST (3), cTnT (1), ultrasound (1)	ECG (4), none [‡] (3)
POC tests available [§]	SPO ₂ , glucose meter, ECG, BP cuff, ultrasound, vital signs, CTG	ECG (6), ultrasound (1)	ECG (5), ultrasound (2), none (1)
Referral hospital	Regional hospital	Regional hospital (7), provincial hospital (6)	Regional hospital (5), provincial hospital (4), district hospital (3)
B. Patients With Stroke			
Survey Questions	Level 2 Provincial Hospital (n = 1)	Level 3 District Hospitals (n = 7)	Level 4 Community Health Centers (n = 7)
Diagnostic tests performed [†]	MRI, ECG, CT scan, ultrasound	None (5), CBC (1), BP cuff (1), lipid panel (1), ECG (1)	None (7)
POC tests available [§]	SPO ₂ , glucose meter	None (5), SPO ₂ (1), BP cuff (1), ECG (1), vital signs (1)	None (6), ultrasound (1)
Referral hospital	None	Regional hospital (4), provincial hospital (6)	Regional hospital (5), provincial hospital (4), district hospital (2)
C. Patients With Hypertension			
Survey Questions	Level 2 Provincial Hospital (n = 1)	Level 3 District Hospitals (n = 7)	Level 4 Community Health Centers (n = 7)
Diagnostic tests performed [†]	Electrolytes, urea/creatinine	BP cuff (6), ECG (1), lipid panel (2), urea/creatinine (1)	BP cuff (7), urinalysis (1), ECG (1)
POC tests available [§]	SPO ₂ , glucose meter	BP cuff (4), ECG (2), none (2), vital signs (1)	BP cuff (3), urinalysis (1), ECG (1), ultrasound (1), none (2)
Referral hospital	None	Regional hospital (3), provincial hospital (6), does not transfer (1)	Regional hospital (4), provincial hospital (3), district hospital (4)

Numbers in parentheses indicate number of sites reporting use of the test.

*Survey question 3.32 asked respondents “In the health network, if your hospital lacks diagnostic tests during emergencies or natural disasters, where do you normally seek for them?” Hospital respondents stated that the regional hospital (9), provincial hospital (7), district hospitals (4), medic hospital (1), HCMC (1), and Hanoi (1) were sites where diagnostic tests are sought in emergencies. One respondent clarified, in emergency situations, patients will likely go to the hospital nearest to their homes (1).

[†]Survey question 3.29.

[‡]One community health center has an ECG available but does not use it to diagnose AMI when the patient presents with symptoms; instead, the patient travels to the district hospital for diagnosis.

[§]Survey question 3.31.

^{||}Survey question 3.30.

[¶]Provincial hospital transports patients to the regional hospital when treatment is only available there and in the case of extreme complications.

AST indicates aspartate aminotransferase; BP, blood pressure; CK, creatine phosphokinase; CBC, complete blood count; CT, computed tomography; MRI, magnetic resonance imaging; SPO₂, peripheral capillary oxygen saturation.

TABLE 10. Acute Coronary Syndromes and Approaches to Patient Care in the Community

Survey Questions	Level 2 Provincial Hospital (n = 1)	Level 3 District Hospitals (n = 7)	Level 4 Community Health Centers (n = 7)
3.33 Which health facilities does your hospital support if serving as a referral hospital?	Serves as a referral site for all districts hospitals, community health centers, and even some neighboring provinces	Serves as a referral site for neighboring community health centers in the district, and in one case (Phu Yang Hospital), for more distant community health centers	None (7)
3.34 For which health facilities does your hospital need to seek specialized health care?	Regional hospital, Hanoi, or HCMC provide specialized care for patients where disease progression is not manageable	Provincial hospital (5), regional hospital (6), optometry (2), psychiatric hospital (1), tuberculosis center (1), and HIV provincial testing center (1)	Provincial hospital (4), district hospital (4), regional hospital (3), HIV provincial testing center (1), psychiatric hospital (1)
3.35 In your health care network, how would you improve access to care for cardiac arrest patients?	Provide POC diagnostic tools to community health centers	Specialize ambulances for cardiac arrest (3), POC biomarkers in ambulances (3), improve ER physician's knowledge (1), educate patients about sign and symptoms (1), medications become more available for cardiac arrest (1), ER should perform tests (1), hospital ambulances collaborate with 115 (1), ambulances be equipped with defibrillator, oxygen mask, and vital signs monitoring (2), ECG (1)	Improve transportation systems (3), provide community health centers with ambulances equipped with diagnostic technologies (1), screening examinations (1), resuscitators (1), education about risks and signs and symptoms (2), cardiopulmonary resuscitation training (1)
5.1 Please list and rank the most common medical problems in your community (1, top; 10, least important)*	Hypertension is the most common medical problem, receiving a weighted score of 5	Hypertension is ranked the most common medical problem, receiving a weighted score 62. Diabetes is ranked the second most common medical problems in the community, receiving a weighted score of 53	Hypertension is reported to be the most common medical problem among communities, receiving a weighted score of 51. Cardiac diseases were also a concern and received a weighted score of 8
5.2 Which medical problems are neglected?	Diabetes, COPD, heart failure, cancer	Diabetes (4), hypertension (3), disease prevention (1), metabolic disorders (1), hygiene (1), pollution (1), food safety (1), lipoedema (1)	Hypertension (3), stroke (1), diabetes (3), hepatitis (1), cancer (1)
5.3 What medical problems influence peoples' working performance the most?	Heart failure, COPD, arthritis, severe back pain	TB (1), stroke (1), asthma (2), COPD (3), bronchitis, hypertension (3), intestinal disorders (1), rashes (1), infections (1), diabetes (2), renal failure (1), psychological problems (2), epilepsy (1), stroke (1), arthritis (2), joint degeneration (1)	Hypertension (2), stroke (1), cardiac diseases (1), diabetes (2), cancer (1), rheumatoid arthritis (1), joint diseases (1)
5.4 In case of emergencies, where do the people turn to receive health care delivery?	Severity dictates where patients will go	District hospital (4), PH (2), regional hospital (2), hospital nearest to patient's home (2)	District hospital (4), PH (4), regional hospital (4)
5.5 What are the most common patient diagnoses that you cannot treat at your own hospital and therefore must refer to another hospital? List and rank: (1, top; 5, least important)*	Certain severe cases of AMI will transfer to regional hospital for more specialized care. This is less common, thus receiving a weighted score of 1	AMI is the most common diagnosis that must be referred, receiving a weighted score of 22. Stroke was the second most common, receiving a weighted score of 12	Cardiac conditions (eg AMI, cardiac diseases) are most commonly untreated and received the highest weighted score of 19. Hypertension received the second highest weighted score of 8. Stroke was also a concern at some CHCs receiving a weighted score of 3

*Parentheses indicate the number of hospitals that provided responses from a given type of hospital. COPD indicates chronic obstructive pulmonary disease.

TABLE 11. Ambulance Services in TTHP Province

	Level 4 Hospitals	Level 3 Hospitals	Level 2 Hospital
Does it have an ambulance?	No	Yes	Yes
How often is the ambulance used?	Not used at all	Varies depending on region's population. Can range from 1 or 10 patients a month to 50 to 1300 patients a month	60–62 patients use the ambulance per month
Are there any physicians or nurses on the ambulance?	N/A	No (83%), yes (16.7%), not common, but very few districts do have a physician or nurse on the ambulance	No
Are there any POCT devices or diagnostic tests available on the ambulance?	N/A	50% of ambulances will have oxygen masks or glucose meters, and 50% do not have any POCT devices or diagnostic tests	Blood pressure device, oxygen masks
Do ambulances pick up patients from their home?	N/A	No	No
Is the ambulance used to transport patients? If not, what is it used for?	N/A	Yes	Transports patients to the Hue Central Hospital
	N/A	N/A	Generally, ambulance are used only to take patients home
If there no ambulance is available for use, what type of transportation do patients rely on to get to the hospitals or to transfer up levels?	Motorbike, walking, sometimes taxi	Motorbikes, walking, and bikes are used to transport patients to district hospitals. People tend to rely on ambulances when transferring up levels	Patients do not use ambulances to go to hospitals and rely on own means of transportation such as taxis and motorbikes. When transferring from hospital to hospital, they will use an ambulance
Where are patients transferred?	Level 2 province hospital	Level 2 province hospital or level 1 central hospital	Either level 2 province hospital or level 3 district hospital
Reason of transfer?	No experience or little knowledge of certain fields, no devices or tests available, doctors are not allowed to perform certain tasks, do not have proper treatment available	No experience or little knowledge of certain fields, no devices or tests available, doctors are not allowed to perform certain tasks, do not have proper treatment available. Can transfer down levels if lower-level hospitals are able to perform or have the treatment available	Patients are usually transferred down when there is overcrowding or if the lower-level hospitals are able to perform or have the treatment available
Prehospital POC c In ambulances?	No	No	No

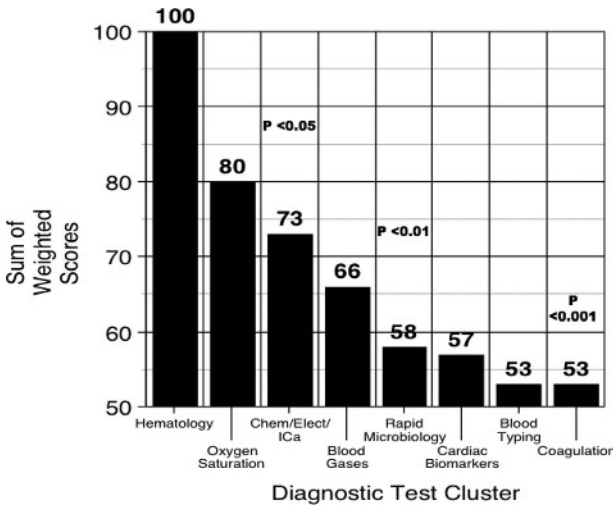


FIGURE 3. Pareto plot showing survey respondent priorities for diagnostic test clusters. The Pareto plot presents perceived priorities for diagnostic test clusters based on survey needs assessment. *P* values approximate levels of significant differences for the labeled test clusters versus hematology, the one ranked highest. Note that this graphic reflects what respondents stated is needed, not necessarily what is in place already. See Table 4 for additional details.

areas. Survey respondents stated that most (80%–90%) patients were transported by motorcycle or transported themselves to hospitals, obviously high risk.

Logistics prove as important as test characteristics, such as sensitivity, specificity, and predictive value, when ensuring high quality of diagnostic evidence at points of need in limited-resource settings. In conjunction with designing SCPs for the entire province, we recommend performing further SWN analysis, based on the principles established for limited-resource countries and their rural settings.²⁷ In view of the high prevalence of cardiac

disease in this province, rapid access to proven treatment via enhanced ambulance services combined with POC cTn testing will improve patient outcomes, cost-effectiveness, and equity of care for rural patients.

CONCLUSIONS

Needs Assessment

Based on demographic and geographic analyses of survey responses, resources for rapid diagnosis of AMI at points of care and in hospital laboratories performing cTn testing are lacking in Central Vietnam, similar to what appears to be the situation in the far north and far south (Fig. 2). All 3 regions have challenging topology subject to adverse weather encumbered by flooding and other natural disasters.

Lack of POC cardiac biomarker testing in the rural and mountainous areas of TTHP means that patient access and routing to swift interventional care for AMI are compromised even more so when transportation routes are blocked. Systems analysis provides strong indication for implementing POC cTn testing locally for diagnosis, triage, risk stratification, management, and prognosis of patients with suspected myocardial infarction.

International Exchange and Long-term Educational Impact

The 2-year education program was effective in highlighting the importance of cardiac biomarkers and their use at points of decision making. The second year saw direct interactive involvement of key opinion leaders and organizations, including the Center for Standardization & Quality Control in the Medical Laboratory in HCMC, the Vietnamese Association of Clinical Biochemists, and Hue University of Pharmacy and Medicine, where we held the 2017 International Symposium (Table 2). Participants learned how to use cTn assays to shorten visits to the emergency department, reduce the time to final diagnosis, manage non-ST-segment elevation myocardial infarction, and allow earlier safe discharge of low-risk subjects.²⁸

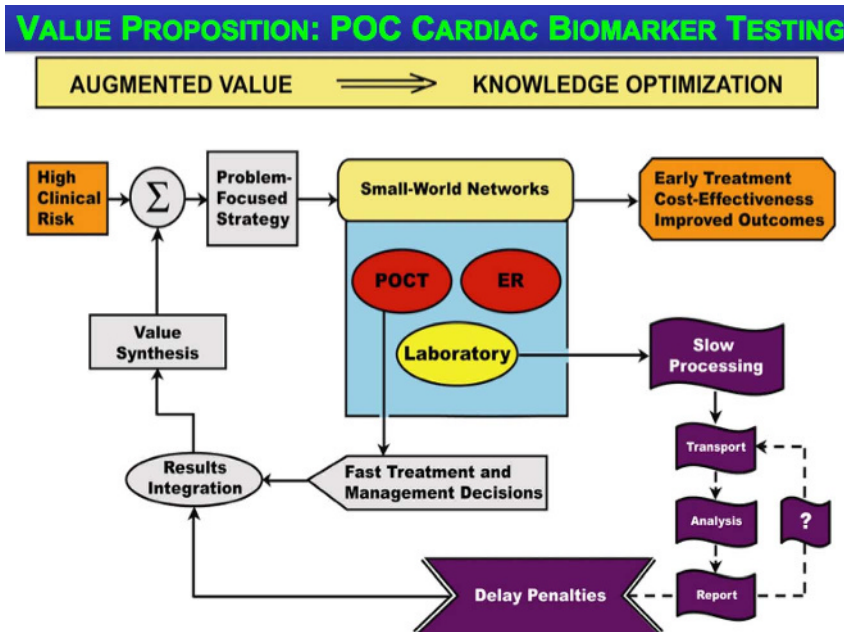


FIGURE 4. Risk reduction value proposition for rapid response and improved outcomes. This figure can be viewed online in color at www.pocjournal.com.

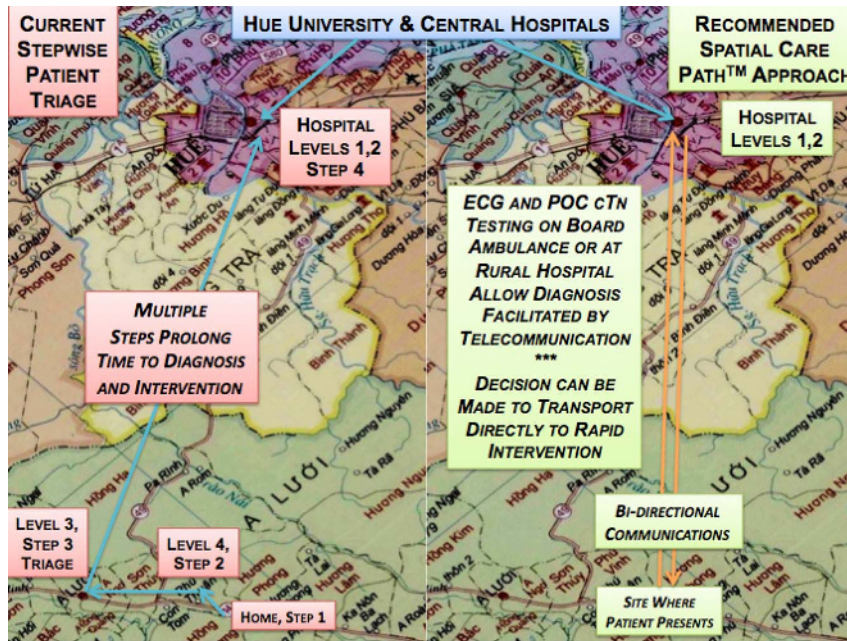


FIGURE 5. Spatial Care Path design for mountainous regions in TTHP. This figure can be viewed online in color at www.poctjournal.com.

POC Coordinators

Everyone recognized the critical need for training, deployment, and funding of POC coordinators throughout Vietnam, in order to implement POCT, ensure its quality, achieve accreditation (eg, ISO 22870), and facilitate future Ministry of Health policy, guidelines, and funding.

We suggest forming POC coordinator groups, similar to those that arose spontaneously during the early stages of the POC paradigm shift in the United States. These groups now meet regularly in person and/or via the Web (eg, see Internet-based lecture and audio POC coordinator programs at Whitehat Communications [<https://whitehatcom.com/>]).

Economic Burden and Cost-effectiveness

According to a recent (2017) report by American authors,²⁹ “The HEART (History, ECG, Age, Risk factors, and initial Troponin) Pathway^{29–34} can be successfully implemented in a community hospital setting and achieve a meaningful reduction in the rate of admissions to the hospital for patients presenting with chest pain. The use of a simple, clinically meaningful computerized decision support tool was essential for good compliance... use of the pathway was associated with minimal major adverse cardiac events.” Nguyen et al^{35–37} stated, “The cost of AMI per hospitalization in Vietnam is higher than GDP per capita... AMI prevention is needed to reduce the burden of disease as well as to avoid catastrophic expenditure and impoverishment problems in Vietnam,” especially among women, who “...experience higher case fatality rates than men.”

Protocol-Based Practice

Current literature offers an international perspective of POC practice. Studies in the United States have demonstrated increasing use of cTnI/T and the 99th percentile threshold for the diagnosis of AMI.³⁸ Others showed the practical utility of POC cTn for patients presenting to the emergency department.^{39,40} Japanese authors recently assessed the usefulness of POC cTn in the emergency department.⁴¹ A POC study conducted in an emergency department in

Taiwan demonstrated the advantages of using multiple cardiac biomarkers to improve diagnosis of elderly and female patients,⁴² challenging groups for diagnosis, who would benefit in Vietnam.

Therefore, if validated for specific settings in Vietnam, algorithmic protocols, such as the HEART Pathway, with adaptations to merge POC decision making, will prove cost-effective for AMI patients and justify countrywide implementation of hs-cTn in clinical laboratories in partnership with POC cTn in emergency rooms in Vietnam. However, a definitive consensus protocol, with consideration of community settings²⁹ and the potentially adverse impact of low-level cTn cutoffs on resource utilization,⁴³ needs to be established specifically for Vietnam.

Health Care Resources

Health technology advisors recommend POC troponin testing for patients presenting with symptoms of ACS in settings with no immediate access to central laboratory testing.^{44–46} Appropriate use of POC assays will prove valuable during any central government redistribution of health care resources and in fact can become one of the primary modalities used to address acute care needs.

Cardiac biomarker testing in smaller hospitals (eg, levels 3 and 4) will serve larger numbers of patients consistent with demography and geography. Point-of-care cTn testing will fill service gaps in mountainous and coastal topographies, while facilitating more equitable cardiac care for diverse rural populations in Vietnam. Elderly ACS patients burdened with higher prevalence of risk factors, such as hypertension and diabetes mellitus,⁴⁷ stand to benefit significantly.

Geographic Optimization

The analysis of travel times, ambulance routes, and telecommunication systems, ideally performed by means of POC geographic information system approaches,^{11,12} will reveal optimal sites for the placement of POC cardiac biomarker testing in emergency rooms with simultaneous consideration of routing of patients from homes and primary care sites to definitive intervention for coronary occlusion.

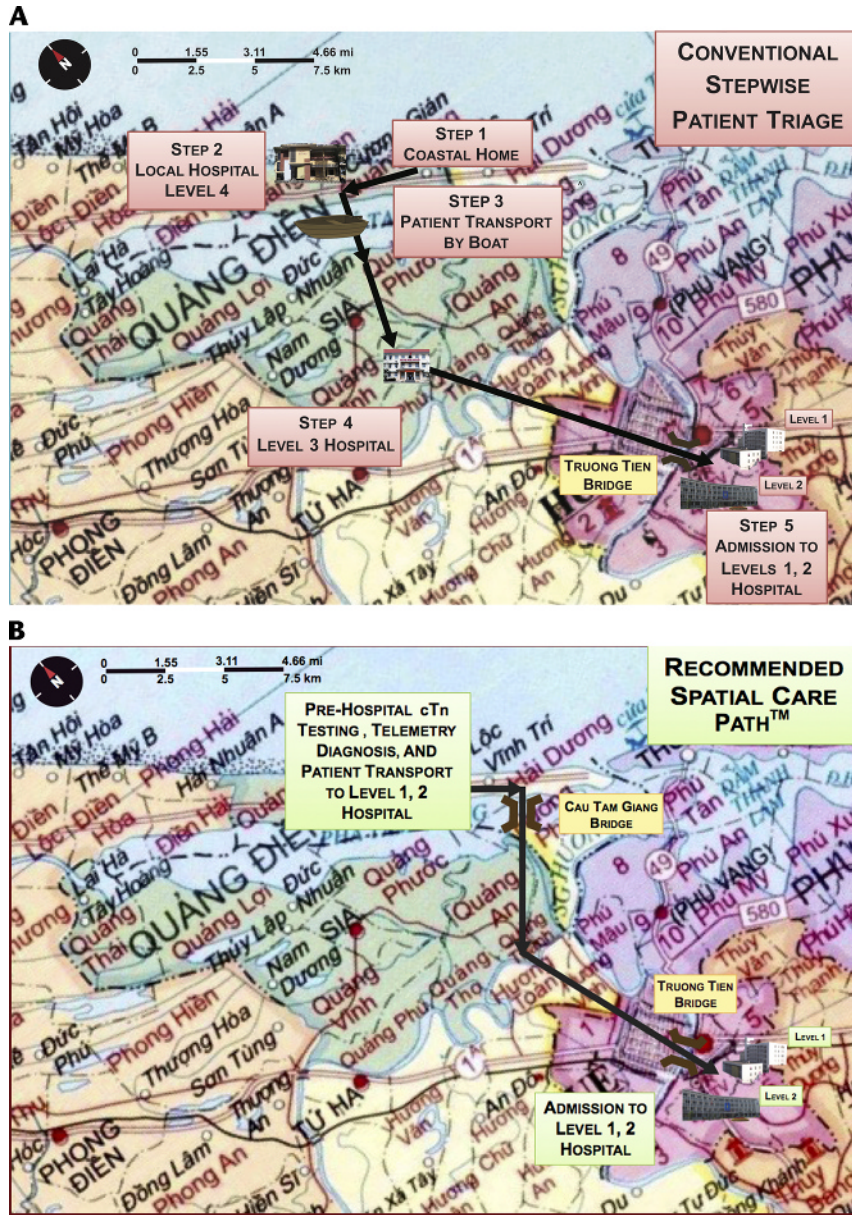


FIGURE 6. Sequence of AMI patient progress in the coastal region. A, Conventional multistep patient evaluation and serial referrals triage involves serial patient steps in the coastal region near Hue in Central Vietnam. First, the patient travels by motorcycle or taxi from home to the level 4 hospital, then subsequently via boat and taxi to the level 3 hospital. Next, if warranted following evaluation, the patient transfers from the level 3 hospital to level 1 or level 2 hospital via ambulance. The sequential referral process is time consuming. B, Accelerated SCP with prehospital POC cTn diagnosis to reduce the number of steps taken, we recommend an efficient SCP for the coastal region near Hue. Diagnosis by means of POC cTn testing near the home or POCT available on an ambulance, along with telehealth ECG and bidirectional radio communication by a cardiologist, would permit the confirmed patient to skip the sequential steps and be transported directly from home to interventional care in the level 1 or level 2 hospital. Therapeutic turnaround time could be optimized. This figure can be viewed online in color at www.pocjournal.com.

The coastal district represents a unique challenge for topographic analysis and SCP optimization. For example, a time-consuming leg of patient transport typically is by boat (Fig. 6). Helicopter transport would solve the problem. However, that resource generally is not available, so careful placement of POC cTn testing can be used to dynamically diagnose AMI, that is, follow trends in cTn over the course of the prolonged transport and appropriately redirect to immediate intervention.

Province cardiologists should consider using prehospital diagnosis with POC cTn testing onboard ambulances in conjunction

with telemetry of ECG and bidirectional telecommunication with cardiologists at referral sites.^{48,49} When relatively stable, patients could bypass intermediate levels 4 and 3 hospitals and be routed directly to levels 1 and 2 sites, where interventional cardiologists and adequate facilities, equipment, and medicinal supplies might be available.

Upstream SCP

Point-of-care testing embedded upstream closer to homes and sites of primary care and as mobile testing in ambulances allows

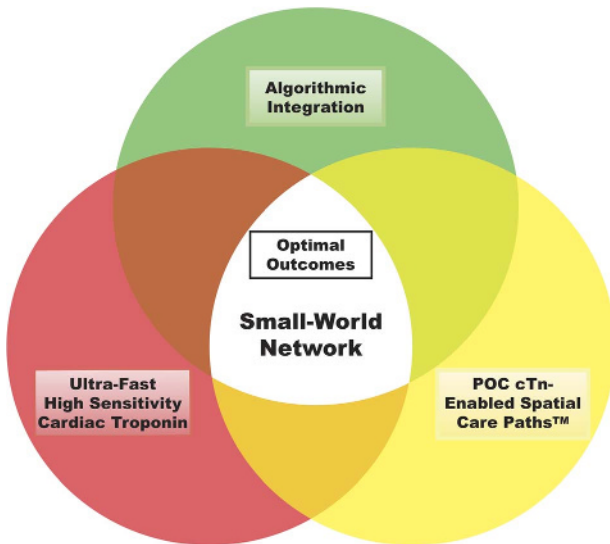


FIGURE 7. Future logic synthesis for rapid intervention for acute chest pain. This figure can be viewed online in color at www.poctjournal.com.

SCPs to shift timely diagnosis and accelerate critical decision making for patients presenting with chest pain. The same principles apply to highly infectious diseases^{50–52} and other emergencies at points of need. In conjunction with POC coordinator guidance and oversight, this paradigm shift in accessibility to diagnosis and faster therapeutic response to acute medical challenges improves preparedness, sustainability, and resilience in the community.

Value of Physician Training

In limited-resource settings throughout Asia, we have encountered nurses who demand POC cTn testing to enhance decision making by young physicians assigned to remote emergency rooms and small hospitals, usually for 2 years of payback for government support of their medical education.

Point-of-care cTn provides crucial training, because these young graduates, typically working late hours by themselves, can use actual diagnostic evidence to practice their medical art, rather than guessing what is wrong with patients or placing patients in emergency room holding areas while waiting, too late, for a fatal condition to fully manifest.

Heretofore, the high value of POC cardiac biomarker testing for postgraduate education in remote limited-resource settings has been totally absent from studies of POCT cost-effectiveness. Physician training, per se, represents a critical role for POCT, an indispensable value hidden in plain sight.

FUTURE VISION

POC Culture

The international symposium in Vietnam provided a change agent for POC practice. Now engaged, professional attendees likely will initiate the type of cultural transformation seen in other Southeast Asian nations, such as Thailand. Following initial demonstration projects and symposia,²⁷ POC cTnT was implemented in more than 500 Thai sites using 700 POC devices.

This innovation accelerated evidence-based diagnosis and therapeutic intervention for patients with AMI nationwide. Investigators in Vietnam can improve access, integrate algorithms, decrease overall costs, enhance education, and improve equity of care, especially in rural areas where geographic information systems analysis would prove highly beneficial for consistent deployment of resources.

Systems Logic

The Venn diagram (Fig. 7) captures the logic of future rapid chest pain evaluation by combining the upstream shift in POCT with state-of-the-art cTn assays integrated algorithmically (eg, using the HEART Pathway) to improve medical and economic outcomes in health care SWNs. With future technological progress (eg, see Florescu et al²⁵ and Sarangadharan et al⁵³), hs-cTn eventually will become available on handheld digital POC platforms.



FIGURE 8. National POCT policy and guidelines documents. A, Malaysia, 2012. B, Thailand, 2015. This figure can be viewed online in color at www.poctjournal.com.

The apparent discontinuity of the clinical laboratory (bottom left) versus points of need (bottom right) in Figure 7 will merge, advancing standards of care holistically throughout limited-resource communities. At the same time, mathematical models and geographic information systems can facilitate ambulance transport within the neglected areas of regional SWNs.⁵⁴

National POCT Policy and Guidelines

We recommend that Vietnam establish national policy and guidelines, not only for the use and deployment of cardiac biomarkers, but also for POCT in general. Near neighbors, first Malaysia in 2012⁵⁵ and then Thailand in 2015,⁵⁶ were successful in implementing suitable policy and guidelines (Figs. 8A, B).

One author (G.J.K.) has presented articles and been invited to speak in other countries, such as China, the Philippines, Singapore, South Africa, and Taiwan, to advance national guideline initiatives. Vietnamese government guidelines will provide a solid platform for funding, help harmonize POCT, facilitate collaboration, improve cooperation, and advance the standard of care for ACS patients.

Standards of Care

Policy should address regional cooperation among leading hospitals for cardiovascular care (eg, Ha Noi Heart Hospital, Cho Ray in HCMC, and Hue Central Hospital), satellite hospitals, and referral sites with linkages from home to intervention established through the design of efficient SCPs. Survey tools borrowed from the United States, for example, recently proposed by Hoa et al,⁵⁷ are not adapted for the geography, topography, or settings of limited-resource countries. Adding needs assessment of POC and key test clusters to such survey tools will advance standards of primary care, responsiveness for patients who present with chest pain, and critical care support in Central Vietnam.

ASEAN Leadership

Forming a “critical mass” of countries in Southeast Asia with harmonized POCT policy and guidelines⁵⁸ and avenues for bioinnovation⁵⁹ would help codify the practice of POC cardiac biomarker testing, as well as creative use of POC technologies throughout ASEAN member states, leading to broad assimilation of POC culture.

Resulting direct evidence-based diagnosis will transform the care of patients with AMI, infectious diseases, and other urgent medical problems. Analogous to cTn-initiated improvements in the differential diagnosis of ACS patients historically, POC cTn in Central Vietnam will improve geographic accessibility, fill point-of-service gaps, and propel the quality of equitable care to higher regional standards with added community resilience.⁶⁰

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