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ORIGINAL RESEARCH

Impact of COVID-19 Pandemic on Cardiovascular Testing in Asia

The IAEA INCAPS-COVID Study

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ABSTRACT

BACKGROUND The coronavirus disease-2019 (COVID-19) pandemic significantly affected management of cardiovascular disease around the world. The effect of the pandemic on volume of cardiovascular diagnostic procedures is not known.

OBJECTIVES This study sought to evaluate the effects of the early phase of the COVID-19 pandemic on cardiovascular diagnostic procedures and safety practices in Asia.

METHODS The International Atomic Energy Agency conducted a worldwide survey to assess changes in cardiovascular procedure volume and safety practices caused by COVID-19. Testing volumes were reported for March 2020 and April 2020 and were compared to those from March 2019. Data from 180 centers across 33 Asian countries were grouped into 4 subregions for comparison.

RESULTS Procedure volumes decreased by 47% from March 2019 to March 2020, showing recovery from March 2020 to April 2020 in Eastern Asia, particularly in China. The majority of centers cancelled outpatient activities and increased time per study. Practice changes included implementing physical distancing and restricting visitors. Although COVID testing was not commonly performed, it was conducted in one-third of facilities in Eastern Asia. The most severe reductions in procedure volumes were observed in lower-income countries, where volumes decreased 81% from March 2019 to April 2020.

CONCLUSIONS The COVID-19 pandemic in Asia caused significant reductions in cardiovascular diagnostic procedures, particularly in low-income countries. Further studies on effects of COVID-19 on cardiovascular outcomes and changes in care delivery are warranted. (JACC: Asia 2021;1:187–199) © 2021 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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ABBREVIATIONS AND ACRONYMS

CMR = cardiac magnetic resonance

COVID-19 = coronavirus disease-19

CTA = computed tomographic angiography

ICA = invasive coronary angiography

PET = positron emission tomography

SARS-CoV-2 = severe acute respiratory syndrome-coronavirus-2

TTE = transthoracic echocardiography

The coronavirus disease-2019 (COVID-19), caused by the novel coronavirus severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2), was first identified in China in December 2019; it initially affected Eastern Asia and quickly spread to the rest of Asia and across the globe. The World Health Organization declared a COVID-19 pandemic on March 11, 2020 (1). COVID-19 is a contagious disease with highly variable clinical presentations and manifestations (2), and figures of COVID-19 cases, deaths, and mortality rates vary significantly from country to country (3). The pandemic has necessitated extraordinary actions by governments and the global medical community to maintain medical supplies and prevent rapid transmission. These responses have had an untoward impact on economies and fundamentally changed the practice of medicine and delivery of health care, including management of cardiovascular disease (CVD). CVD remains the leading cause of morbidity and mortality worldwide in all countries regardless of socioeconomic status (4,5). In recent decades, health care professionals have attempted to optimize the diagnosis and treatment of CVD (5,6), significantly reducing mortality and incidence of major cardiovascular events (7-10). The COVID-19 pandemic holds potential to halt that progress by delaying the application of advanced diagnostic procedures that guide detection and treatment of CVD.

SARS-CoV-2 can infect people of all ages. However, the virus poses a particular risk for people over the age of 60 years and those with pre-existing medical conditions. Development of severe disease is known to be higher in patients with CVD (11). Patients with COVID-19 and CVD have higher mortality than those without comorbidity (12). Moreover, efforts to prevent the spread of COVID-19 have redirected critical health care resources and changed conventional practice patterns for routine CVD care (13-16). With a global estimated 17.9 million annual deaths caused by CVD (17,18), the negative impact of the pandemic on patients treated for CVD cannot be overstated. Indeed, a recent study from Italy reported that inpatient cardiac deaths have increased during the COVID-19 pandemic (19).

A key objective of the International Atomic Energy Agency (IAEA) Division of Human Health is to support Member States' fight against cancer, CVDs, malnutrition, and other diseases using nuclear and nuclear-related techniques (20,21). Various diagnostic modalities employed by cardiologists rely upon the use of ionizing radiation. In efforts led by the IAEA Division of Human Health, the INCAPS (IAEA Non-invasive Cardiology Protocols Study) COVID Investigators Group (Supplemental Appendix) conducted a large-scale global survey to assess changes in noninvasive and invasive diagnostic procedure volumes and clinical safety practices caused by the COVID-19 pandemic, referred to as the INCAPS COVID study (22).

COVID-19 began to spread from Asia and affected other countries at different times. Mortality rates, infection rates, infection control methods, and response policies vary widely between countries and regions (23,24). Comparisons of the impact of COVID-19 on cardiovascular practices and health resource supplies across the globe will be informative

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TABLE 1 Characteristics of Participating Centers and Procedure Numbers

	Asian Region					Worldwide		
	Eastern	South-Eastern	Southern	Western and Central	*P* Value	Asia	RoW	*P* Value
Number of centers	81	36	38	25		180	729	
Number of countries	4	10	7	12		33	75	
Number of procedures								
March 2019	130,909	19,250	29,488	12,556		192,203	486,435	
March 2020	69,034	13,140	12,418	6,500		101,092	293,533	
April 2020	88,170	7,567	3,013	3,553		102,303	142,133	
Procedures per center								
March 2019	632 (219-1,233)	120 (19-795)	190 (73-810)	252 (115-507)	<0.01	367 (93-1,067)	248 (78-812)	0.09
March 2020	472 (150-935)	41 (11-418)	122 (52-390)	93 (26-233)	<0.01	188 (52-764)	126 (41-451)	0.03
April 2020	578 (227-1,055)	29 (1-81)	38 (0-173)	29 (2-118)	<0.01	139 (10-571)	57 (13-232)	<0.01
Hospital beds	914 (613-2,500)	673 (250-1,000)	350 (200-924)	600 (400-950)	<0.01	751 (350-1,368)	460 (200-800)	<0.01
Inpatient center	80 (99)	33 (92)	34 (89)	25 (100)	0.04	172 (96)	567 (78)	<0.01
Teaching institution	62 (77)	26 (72)	20 (53)	21 (84)	0.03	129 (72)	468 (64)	0.04
Economic level by center								
Low	–	–	2 (5)	–	<0.01	2 (1)	2 (0.3)	<0.01
Lower-middle	1 (1)	28 (78)	28 (74)	1 (4)		58 (32)	28 (4)	
Upper-middle	30 (37)	3 (8)	8 (21)	5 (20)		46 (26)	236 (32)	
Upper	50 (62)	5 (14)	–	19 (76)		74 (41)	463 (64)	

Values are n, median (interquartile range), or n (%). Procedure counts are for centers performing testing in March 2019.
RoW = rest of world.

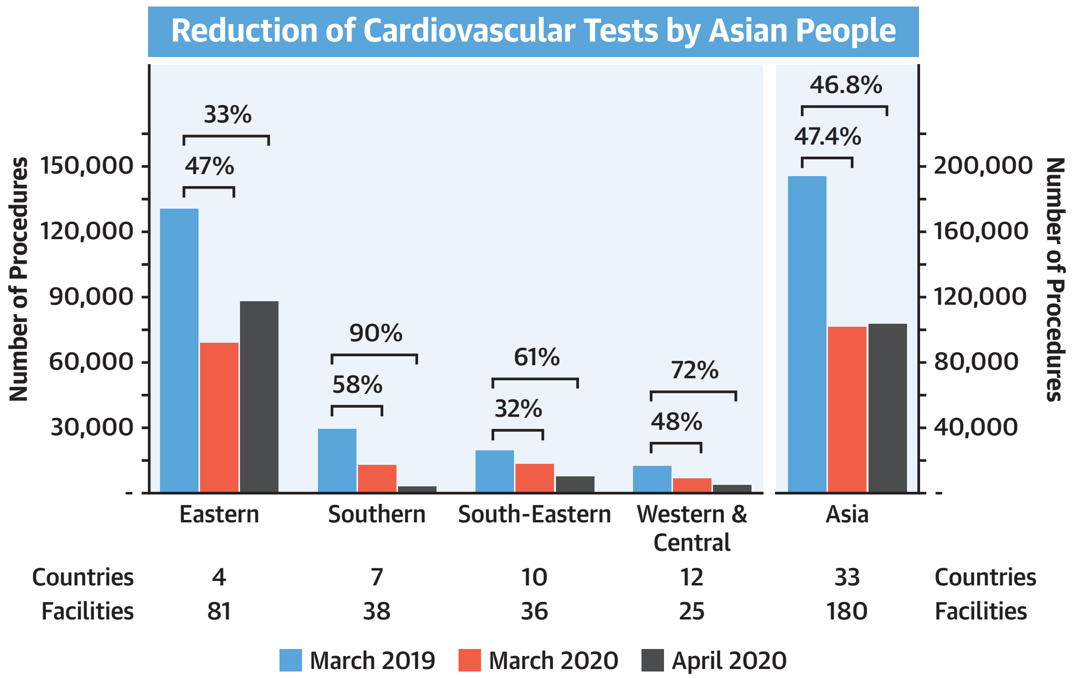
for identifying the requirements for recovery from the pandemic and the development of proper strategies for future outbreaks of emerging infectious diseases (25,26). The aim of this analysis was to identify differences in the impact of the COVID-19 pandemic on cardiovascular diagnostic procedure volumes and practices between Asia and the rest of the world, and among Asian subregions.

METHODS

STUDY DESIGN. The study was conducted under the IAEA INCAPS Group, which has conducted numerous studies on practice variations in cardiovascular diagnostic procedures (27-34). The study design has been described in detail elsewhere (22). A web-based survey questionnaire was performed to assess the impact of the COVID-19 pandemic on cardiovascular diagnostic care delivery. The questionnaire included the following subsections: 1) descriptors of participating health care facilities and health care professionals; 2) the use of personal protective equipment and strategic plans for reopening; and 3) changes in procedural volumes for a range of cardiovascular diagnostic procedures. The latter included transthoracic echocardiography (TTE) and transesophageal echocardiography, nonstress cardiac magnetic resonance (CMR), stress testing (stress electrocardiography, echocardiography, single-photon emission computed tomography, positron emission tomography [PET], and CMR), PET infection studies, coronary artery calcium scanning, coronary computed tomographic angiography (CTA), and invasive coronary angiography (ICA). Data were obtained from each participating site for March 2020 and April 2020 and were compared to March 2019, which served as a baseline. Data were aggregated by country and region. In this subanalysis, the Asian participating countries of the INCAPS COVID study were divided into 4 subregions (Eastern, Southeastern, Southern, and Central and Western) according to the United Nations' geoscheme (35), which is specified in the Supplemental Appendix. Countries were classified into 4 categories by income status (low, lower-middle, upper-middle, and high) in accordance with the World Bank classification (36).

DATA COLLECTION. Candidate facilities were invited to participate using various methods, including e-mails from the IAEA INCAPS COVID executive committee and national coordinators (37), e-mails from IAEA to cardiology and imaging societies (listed in the Supplemental Appendix), communications from professional societies to their members, and social media platforms (Twitter, LinkedIn, and Facebook). An electronic data entry system was devised to collect data on the impact of the COVID-19 pandemic on cardiovascular diagnostic procedures. The IAEA employs a secure software platform, the

CENTRAL ILLUSTRATION Reductions in Cardiovascular Disease Diagnostic Testing Volumes by Asian Region



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The numbers of included countries and facilities in each subregion are shown in the **bottom table**.

International Research Integration System (38), for questionnaire data collection. In INCAPS COVID, no patient-specific personal information or confidential data were collected, and all study sites participated voluntarily; therefore, review by an ethics committee was not required. The present study complied with the Declaration of Helsinki.

Throughout the enrollment period (May 11, 2020, to May 30, 2020), the Data Coordination Committee reviewed entries on a daily basis and reached out to participating health care personnel with questions regarding missing data or duplicate entries from the same institution. Only 1 entry from a given center was included in the final data set, and entries were excluded if data were missing or incomplete. Final database cleaning was completed on July 1, 2020.

STATISTICAL ANALYSIS. Nonparametric statistical analysis using the Kruskal-Wallis test with asymptotic 2-sided *P* values was conducted on differences in test volumes between 2019 and 2020 and on continuous variables between Asia and the rest of the world, and among Asian subregions. The chi-square test was used to compare center characteristics between world regions. Statistical analyses were performed using Stata version 16 (Stata Corporation, LLC) and Microsoft Excel (2016). Maps were created using rnaturalearth and tmap packages in R (R Foundation for Statistical Computing) (39,40).

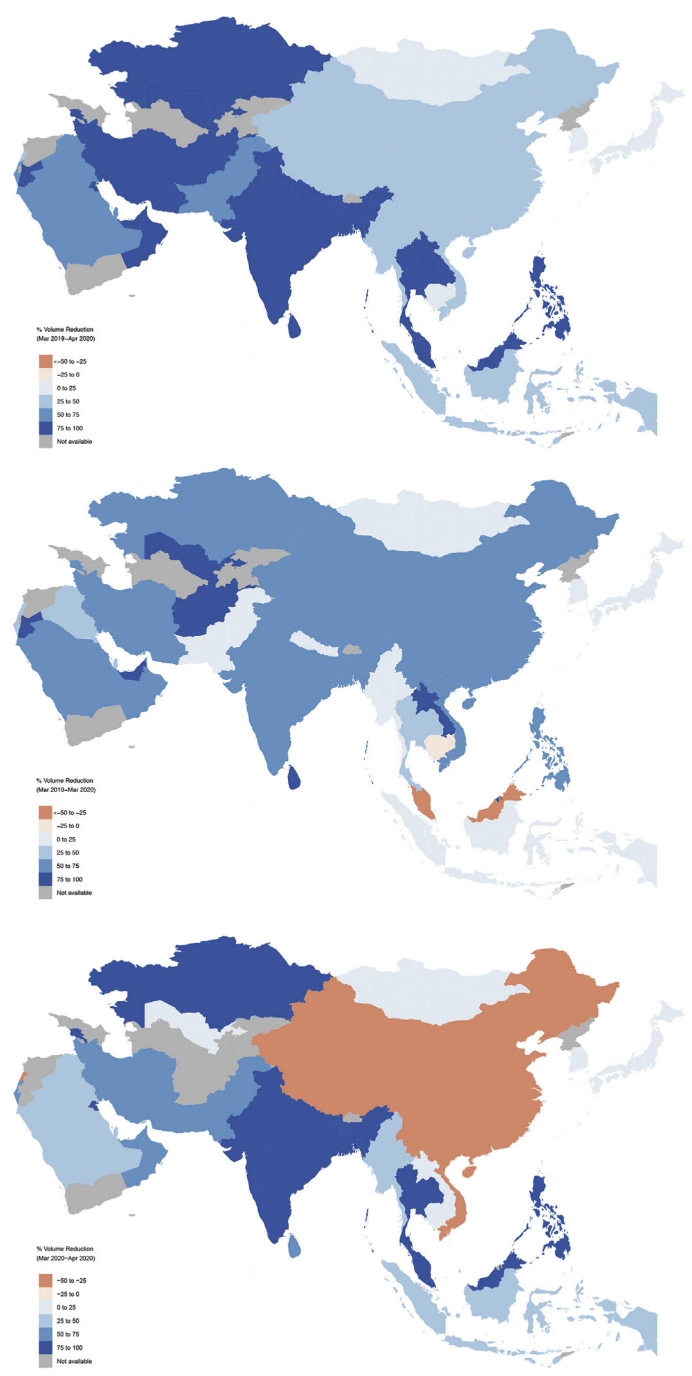
RESULTS

CENTER CHARACTERISTICS. Data from 180 centers in 33 Asian countries were obtained. According to the United Nations' geoscheme, Asian countries were separated into 4 subregions: Eastern Asia (4 countries, 81 facilities), Southeastern Asia (10 countries, 36 facilities), Southern Asia (7 countries, 38 facilities), and Western and Central Asia (12 countries, 25 facilities). A list of the countries in each subregion is shown in the Supplemental Appendix, and center characteristics are summarized in Table 1. A total of 395,598 cardiac diagnostic procedures were performed at participating centers in Asia during the 3 months (March 2019, March 2020, and April 2020) considered.

PROCEDURE REDUCTIONS. In Asia, cardiac diagnostic procedure volumes decreased by 47% in March 2020 compared with March 2019 (**Table 1, Central Illustration**). However, recovery by nearly 1% was noted between March 2020 and April 2020. This differed from the rest of the world, which showed a continuous decline (52%) between March 2020 and April 2020. At the subregion level, recovery was driven entirely by procedures performed in Eastern Asia, with the other 3 subregions (South-Eastern, Southern, and Western and Central) showing no recovery (**Central Illustration**). **Figure 1** shows maps of the total procedure reduction over the study period, with clear regional differences (top panel: March 2019 to April 2020, middle panel: March 2019 to March 2020, bottom panel: March 2020 to April 2020). In the Eastern Asian subregion, more than 95% of procedure volume data obtained came from China, Korea, and Japan; the trends among these 3 countries differed widely (Supplemental Table 1). In China, the number of examinations had already decreased in March 2020 (60% reduction), whereas recovery was observed in April 2020 from March 2020 (58% increase). In Korea, the number of examinations decreased in March 2020 (10% reduction), with no marked changes in the number of examinations performed in April 2020 (1% reduction). In Japan, the number of examinations conducted only slightly decreased in March 2020 (2% reduction), whereas a substantial decrease was observed in April 2020 (18% reduction). Therefore, the recovery observed in April 2020 was mainly driven by the recovery in China. This difference in procedure reduction was also visible on the map shown in **Figure 1**, with clear regional differences. In terms of the number of procedures analyzed per center, there was no recovery between March 2020 and April 2020, but the decline slowed. In April 2020, procedure numbers per center in Asia were significantly larger than those in the rest of the world (**Table 1**).

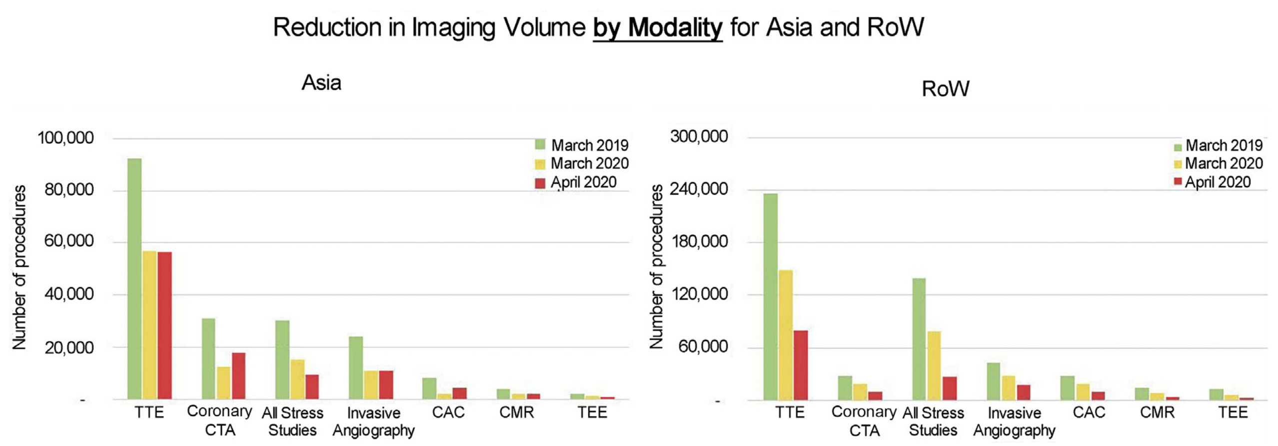
Decreases in procedure volume also varied between the various imaging modalities. As shown in **Figure 2**, the volume of all diagnostic modalities decreased between March 2019 and March 2020 in Asia. Total procedure volume across all imaging modalities fell by 47% from March 2019 to March 2020; the median number of procedures performed per participating center fell from 367 to 188 during this time period (**Table 1**). However, by April 2020, coronary CTA volume had recovered, whereas TTE and ICA volumes remained reduced. No such recovery was observed in the rest of the world, which saw

FIGURE 1 Asian Map Showing Reductions in Total Cardiovascular Procedural Volumes



(Top) Change from March 2019 to April 2020, indicating total change during this study period. **(Middle)** Change from March 2019 to March 2020, indicating the impact of the very early phase of the pandemic. **(Bottom)** Change from March 2020 to April 2020, indicating short-term trends during the very early phase of pandemic. Countries or territories of a country in **gray** did not have data available. **Darker blue** color indicates severe reduction. **Warmer color** indicates recovery.

FIGURE 2 Reductions in Each Cardiac Procedure Modality



The number of each procedure type in Asia **(left)** and in the rest of the world (ROW) **(right)** at March 2019, March 2020, and April 2020. All types of stress test modalities (exercise electrocardiography, stress echocardiography, nuclear stress imaging [single-photon emission computed tomography and positron emission tomography], and stress cardiac magnetic resonance [CMR]) are grouped together. Note the recovery of coronary computed tomography angiography (CTA) was observed in Asia but not in the rest of the world. CAC = coronary artery calcium; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography.

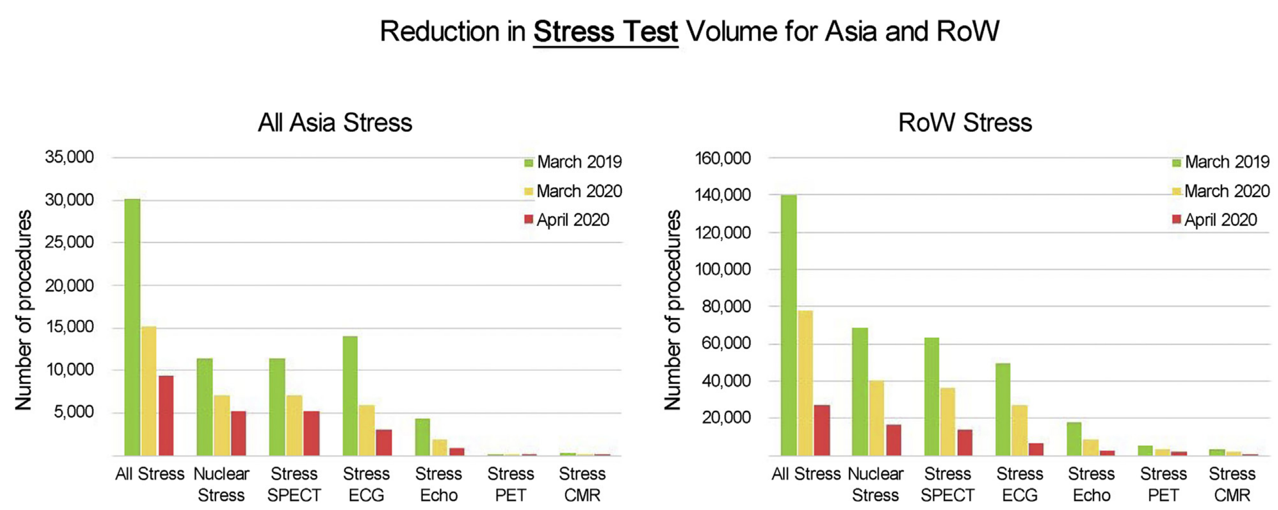
further reductions across all modalities from March 2020 to April 2020. In Asia, stress testing volume across all modalities saw a year-over-year decline from March 2019 to March 2020 and continued to decrease into April 2020 (Figure 3).

When divided into 4 subregions (Figures 4 and 5), recovery of several procedures (TTE, coronary CTA, ICA, nuclear stress test) was observed in Eastern Asia: 14%, 59%, 45%, and 17% increase from March 2020 to April 2020 in volume of TTE, coronary CTA, ICA, and nuclear stress test volumes, respectively. In contrast, all other subregions saw continued decline in volume of these procedures over the same period. Stress PET and stress CMR were performed in very low numbers in all 4 subregions compared with before the pandemic: only 106 stress PET and 316 stress CMR were reported in all of Asia in March 2019, which declined by 57% and 31%, respectively, by March 2020. Interestingly, compared with the other 3 subregions in Asia, the volume of stress echocardiography was very low both before and during the pandemic in Eastern Asia (Figure 5). In March 2019 as well as March 2020, just 3% of all reported stress TTE in Asia were performed in Eastern Asia.

CENTER CAPACITY AND PRACTICE. We questioned whether any changes in center capacity and practices occurred during the enrollment period compared with the pre-COVID period. Numerous changes were observed in Asian facilities (Table 2). “Some outpatient activity canceled” was experienced in the majority of centers (78%), although slightly less often than in the rest of the world (85%; $P = 0.038$). Although the majority of centers allowed increased time per study for cleaning and disinfection (57%) and eliminated protocols requiring close contact (51%), those changes were less common than in the rest of the world (77%; $P < 0.001$; 65%; $P = 0.001$, respectively). Indicators of additional workload for medical workers, such as extended hours (17%) and new weekend hours (13%), were not common, which was similar to the rest of the world.

Adoption of infection prevention and control measures, such as separate spaces for COVID-19-positive patients (81%), restricting visitors (89%), screening for symptoms (82%), and requiring masks (76%), were implemented in most centers in Asia as well as in the rest of the world. However, physical distancing (84%) and reducing wait room times (72%) were less often implemented, and checking temperatures (84%) was more often implemented compared with the rest of the world ($P = 0.014$, $P < 0.001$, and $P < 0.001$, respectively). COVID-19 testing was not commonly performed in Asia (23%), but its frequency was still significantly higher ($P = 0.001$) than in the rest of the world (13%). Similar results were observed among all 4 subregions of Asia, except for COVID-19 testing, which was performed most frequently in Eastern Asia (33% of centers) and less frequently elsewhere (Southeastern 8%, Southern 19%, Western and Central 16%; $P = 0.018$).

FIGURE 3 **Reductions in Stress Test Volumes**



The number of each stress procedure in Asia **(left)** and in the ROW **(right)** at March 2019, March 2020, and April 2020. ECG = electrocardiogram; Echo = echocardiography; PET = positron emission tomography; SPECT = single-photon emission computed tomography; other abbreviations as in Figure 2.

DIFFERENCES BETWEEN TYPES OF CENTERS. A pattern was observed in the types of facilities and changes in overall procedure volumes (Table 3). University-affiliated teaching facilities showed a smaller reduction (45%) to nonteaching centers (55%). Small hospitals showed greater reductions than larger hospitals (69% reduction in the lowest tertile of number of beds, 35% in the middle tertile, and 42% in the highest tertile). Similar results were obtained in the rest of the world, but reductions tended to be smaller in Asia compared with the rest of the world.

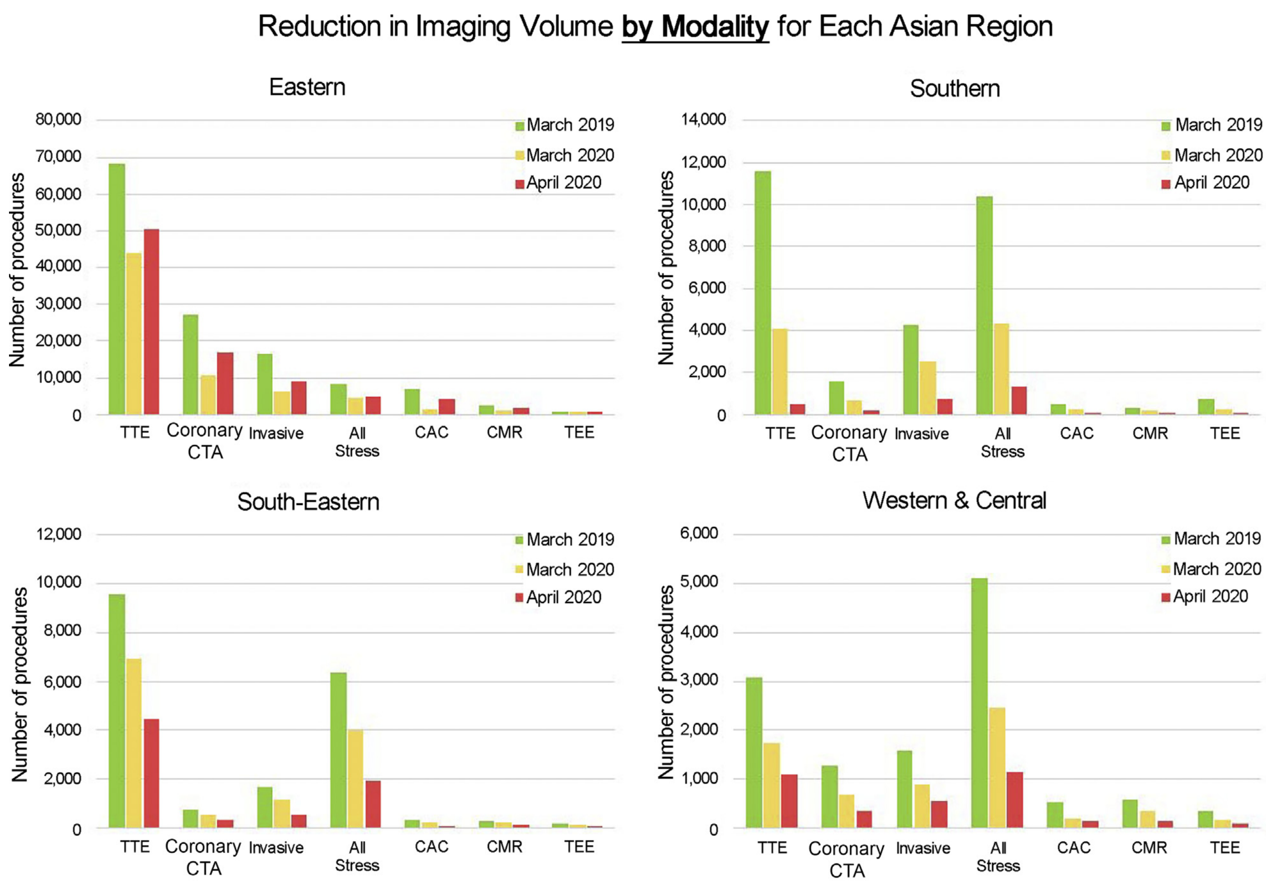
DISPARITIES BY INCOME LEVELS. Differences were observed in procedure reductions between countries in Asia based on the World Bank income groups (Table 1, Figure 6). COVID-19-associated reductions in cardiac diagnostic procedures were more prominent in countries with lower per capita income. Data for low-income countries were available for only 4 countries worldwide and 2 in Asia, and data for 1 Asian low-income country was incomplete, making it difficult to compare data between low-income countries in Asia and the rest of the world. However, in the 3 other categories—upper-middle income (9 countries), lower-middle income (12 countries), and high income (10 countries)—Asian countries with lower per capita income clearly experienced greater procedure reductions than high-income Asian countries across procedure types.

DISCUSSION

The rapid global spread of COVID-19 has changed the global economy and social environment and has had a negative impact on routine medical practice, particularly the diagnostic evaluation of CVD (13,41-43). The magnitude of COVID-19's impact on procedure volumes for evaluation of CVD has not yet been quantitatively evaluated. Led by the IAEA, INCAPS COVID is the first international survey conducted to assess this knowledge gap (22). The present study is a subanalysis of data collected in Asia, which was the first region to be affected by COVID-19. Although our subanalysis revealed that many effects of the COVID-19 pandemic were similar in Asia and the rest of the world, the following differences were noted: 1) early recovery in the number of examinations performed, which was specific to the Eastern Asia subregion; 2) important regional differences in the magnitude of the impact, with Eastern Asia experiencing a smaller impact; and 3) differences in procedure volume reduction observed based on economic status, with lower-income countries being more adversely affected.

The negative impact of the pandemic was reflected by a reduced number of diagnostic procedures and changes in capacities and clinical safety practices, such as physical distancing, temperature checking, and limiting patient volumes. Small centers and low-income countries were most negatively impacted by

FIGURE 4 Reductions in Individual Cardiac Procedure Modality in Each Subregion

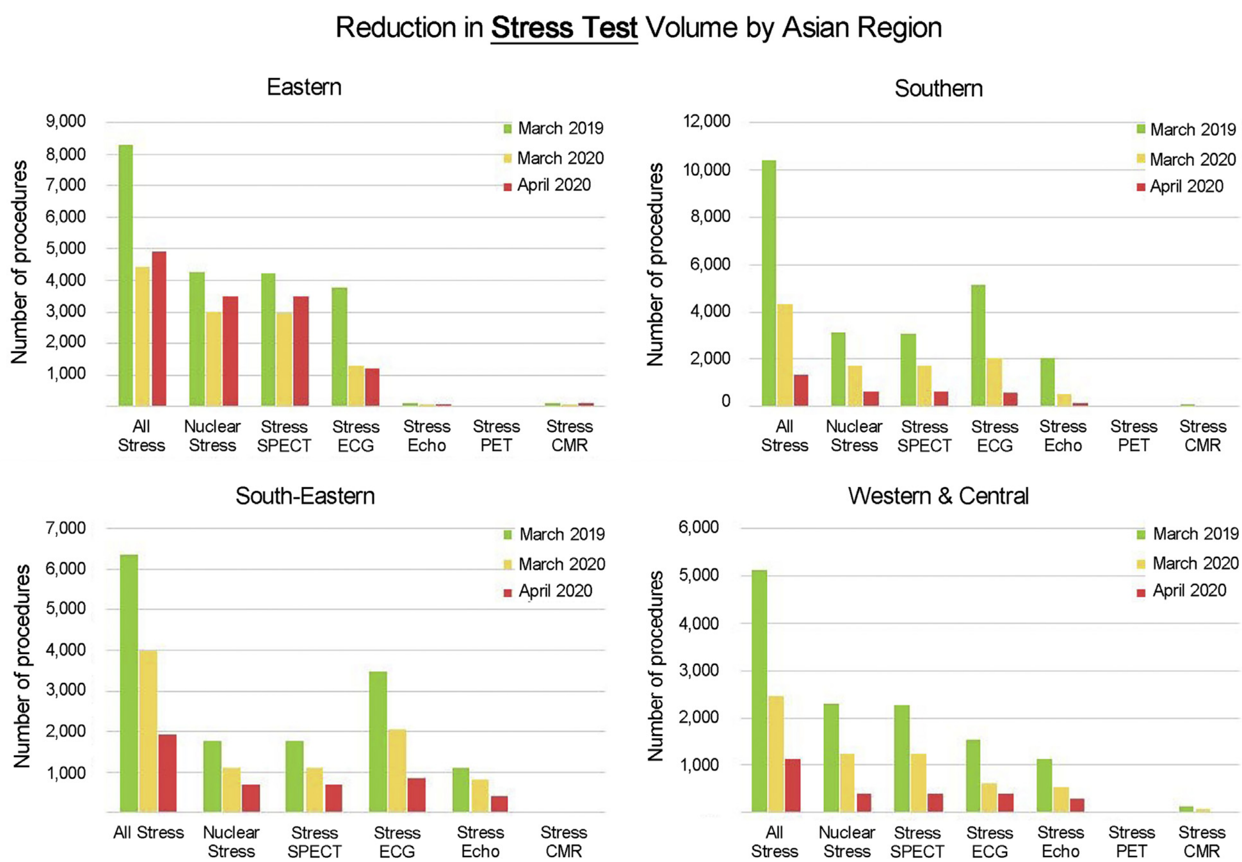


Reductions in the number of each procedure type in each Asian subregion. Note the different y-axis for each subregion. Abbreviations as in Figure 2.

the pandemic. Similar results were observed between Asia and the rest of the world. However, the Eastern Asian region experienced some recovery of procedure volume from March 2020 to April 2020. This observation may be attributable to the temporal spread of COVID-19 in Asia. In China, the number of examinations had already severely decreased by March 2020, whereas a recovery of diagnostic procedure volume was observed in April 2020. In Korea, the nadir occurred between March 2020 and April 2020. In Japan, the number of examinations had not yet decreased in March 2020, but then markedly declined in April 2020. This result corresponds to the differential arrival of the first wave of COVID-19 spread in these countries. The first wave peaked in February 2020 in China, March 2020 in Korea, and April 2020 in Japan, indicating a general coincidence in the order of peak infection rate and decline in the number of examinations (18,44,45). These observations suggest that decreases in cardiac examinations caused by COVID-19 will become more severe as the number of patients with COVID-19 increases, a pattern that may be attenuated with appropriate responses and countermeasures.

Interestingly, this relationship between the convergence of the first wave of COVID-19 and the stabilization of the cardiac procedure volume was not seen in all Asian subregions. Southern Asia, which includes India and Iran, showed the greatest reductions in procedure numbers among the 4 Asian subregions (Central Illustration, Table 1), whereas most of the countries in this region, except Iran, did not experience a first wave of the COVID-19 pandemic during the study period of March 2020 to April 2020 (18,44). The reasons for the large reductions in procedure volumes preceding an increase in COVID-19 patients in this subregion are not clear. It is possible that reduced volume reflects

FIGURE 5 Reductions in Stress Tests Volume in Each Subregion



Reductions in the number of each stress procedure in each Asian subregion. Note the different y-axis for each subregion. Abbreviations as in Figures 2 and 3.

a proactive measure as centers prepared for the arrival of the first wave, rather than a reactive one. In the unique case of Cambodia, which as of November 2020 has reported 308 cases and no COVID-19 deaths (18), almost no reduction in procedure volume was observed. Its apparent success in containing the coronavirus while simultaneously maintaining other health care services will surely be a topic of much investigation and discussion in the months and years to come.

The observed decrease in the number of procedures was similar when looking specifically at stress testing. However, stress testing procedures did not recover to the same extent as nonstress testing. This may be related to the potential risk of aerosolization during exercise stress testing. It is also possible that the response to COVID-19 caused a paradigm shift in cardiac testing, prompting a shift away from exercise testing. It is interesting to note that a recovery of nuclear stress tests was observed in Eastern Asia. Nuclear stress tests are generally performed with exercise or pharmacological agents, with a preference for pharmacological stress testing in recent years (9). This shift to pharmacological stress testing may have been accelerated in the process of responding to COVID-19. However, there is a lack of published comparisons between volume and types of examinations conducted before and after the COVID-19 era.

The relationship between income status and procedure volume markedly differed between Asia and the rest of the world. The initial INCAPS COVID survey showed greater procedure volume declines in low-income countries than in high-income countries, and it appears that much of this difference was driven by data from Asia. Indeed, when data from Asia are excluded, the relationship between economic status and procedure volume reductions in our survey becomes significantly less pronounced. The reasons for this relationship between income and reduction in

TABLE 2 Changes in Center Capacity and Practice

	Eastern	South-Eastern	Southern	Western and Central	*P* Value	Asia	RoW	*P* Value
Change in capacity								
Some outpatient activities cancelled	59 (73)	31 (86)	29 (81)	20 (80)	0.449	139 (78)	613 (85)	0.038
All outpatient activities cancelled	27 (34)	20 (56)	22 (61)	11 (46)	0.024	80 (45)	325 (45)	0.952
Phased reopening after peak pandemic	48 (59)	19 (53)	23 (66)	10 (40)	0.218	100 (56)	382 (53)	0.381
Extended hours	15 (19)	5 (14)	4 (11)	6 (24)	0.543	30 (17)	93 (13)	0.161
New weekend hours	11 (14)	5 (14)	4 (11)	3 (12)	0.977	23 (13)	63 (9)	0.085
Use of telehealth for patient care	45 (56)	19 (53)	21 (58)	12 (48)	0.855	97 (55)	406 (56)	0.731
Increased time per study for cleaning/disinfection	47 (58)	15 (42)	25 (66)	16 (64)	0.158	103 (57)	554 (77)	<0.001
Eliminate protocols requiring close contact	27 (33)	22 (61)	27 (71)	15 (60)	<0.001	91 (51)	466 (65)	0.001
Change in practice								
Physical distancing	67 (83)	32 (89)	30 (83)	21 (84)	<0.001	150 (84)	655 (91)	0.014
Separate spaces for COVID-19+/–	68 (84)	31 (86)	29 (81)	16 (64)	0.874	144 (81)	573 (80)	0.820
Reduced waiting room time	51 (63)	33 (92)	27 (75)	18 (72)	0.155	129 (72)	610 (84)	<0.001
Limit visitors	74 (91)	32 (89)	32 (89)	20 (80)	0.010	158 (89)	676 (93)	0.031
Temperature checks	72 (89)	30 (83)	29 (81)	18 (72)	0.445	149 (84)	462 (64)	<0.001
Symptom screening	72 (89)	31 (86)	27 (75)	15 (63)	0.212	145 (82)	562 (78)	0.247
COVID-19 testing	27 (33)	3 (8)	7 (19)	4 (16)	0.018	41 (23)	96 (13)	0.001
Require masks	63 (78)	26 (72)	28 (74)	19 (76)	0.016	136 (76)	544 (75)	0.840

Values are actual facility number (% to total facility number).
COVID-19 = coronavirus disease-2019.

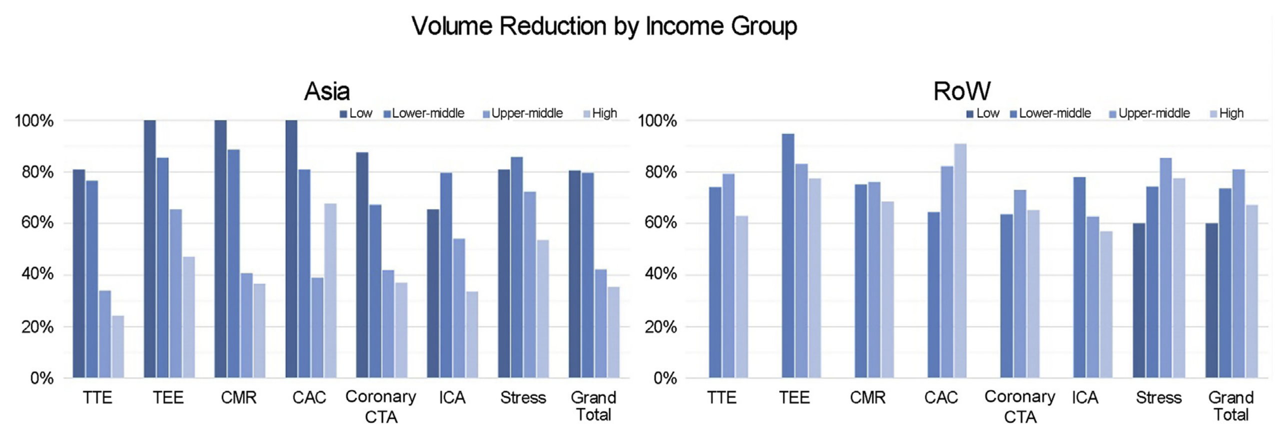
procedure volumes in Asia remain unclear. One possibility is that these differences may have emerged because Asia was the first region to be affected by COVID-19. It is also possible that the relationship between economic status and the reduction of cardiovascular procedures might be related to the source of health care funding (eg, government, socialized health support, private insurance, or personal out-of-pocket), which requires more detailed analysis. In any case, these results may contribute to the establishment of a common international understanding of how to allocate health care resource support. Countries with low economic status tend to have population centers that experience overcrowding and limited infrastructure, making it difficult to adhere to public health rules such as social distancing (46). They also tend to have fewer health care resources than developed countries, which may make them more susceptible to the impact of COVID-19 (47,48). The association we observed between a country's per capita income and reduction in cardiovascular diagnostic procedures may suggest a need to reallocate global health support to poorer countries. Further research on the long-term impact of COVID-19 on cardiovascular testing in low- and middle-income countries is needed.

TABLE 3 Overall Percent Reductions in Cardiovascular Diagnostic Procedures by the Type of Center

								Stress Tests					
	TTE	TEE	CMR	PET Infection	CAC	Coronary CTA	ICA	ECG	Echo	SPECT	PET	CMR	Total
Type of facility													
Inpatient	39/66	60/78	42/69	50/63	46/89	42/68	54/58	78/86	80/83	54/79	58/54	48/74	47/70
Outpatient	39/72	100/82	–/80	–/69	0/85	–15/62	56/52	70/85	100/85	58/74	–/62	–/73	48/75
Teaching center status													
Teaching	38/65	57/78	42/70	57/63	44/89	42/66	54/57	77/87	74/84	56/80	79/58	44/69	45/70
Nonteaching	43/71	74/78	49/74	29/63	74/87	41/69	55/62	80/84	87/80	49/75	23/53	60/82	55/74
Hospital beds													
Lowest Tertile	60/75	77/79	63/76	47/77	75/81	51/71	67/60	84/87	89/82	75/82	78/66	100/77	69/77
Middle Tertile	26/62	39/81	17/72	47/70	74/90	18/63	26/58	73/84	75/82	63/78	51/58	36/80	35/69
Highest Tertile	37/65	45/78	35/62	61/56	42/88	43/67	49/58	72/88	66/82	44/80	81/50	58/60	42/68

Numbers are presented as Asia/RoW.
CAC = coronary artery calcium; CMR = cardiac magnetic resonance; CTA = computed tomography angiography; ECG = electrocardiogram; Echo = echocardiography; ICA = invasive coronary angiography; PET = positron emission tomography; RoW = rest of the world; SPECT = single-photon emission computed tomography; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography.

FIGURE 6 **Reductions in Cardiac Diagnostic Procedures by Income Levels**



Reductions in the number of cardiac diagnostic procedures in low, lower-middle, upper-middle, and high-income countries between March 2019 and April 2020. ICA = invasive coronary angiography; other abbreviations as in Figure 2.

STUDY LIMITATIONS. A major limitation of the present study is the relatively narrow temporal range of data obtained. The data are limited to March 2020 and April 2020, whereas the peak of the first wave of COVID-19 occurred before March 2020 in China and after April 2020 in other countries. The COVID-19 pandemic is ongoing, and long-term changes in the use of cardiac testing are expected. Additionally, recognition of "long covid" (post-acute sequelae of SARS CoV-2) may lead to increased cardiac testing use. Continued data collection and analyses are needed to clarify those effects. The INCAPS COVID Investigators Group is planning to perform a second survey (INCAPS COVID 2) to evaluate those unanswered questions. Another limitation is that participation in the study was voluntary, and therefore the density of the data varied significantly between countries and may not be generalizable. In some countries, data were only available from a single facility, which is unlikely to be representative of the prevailing conditions across the country as a whole. To compensate for this limitation, the Asian region was divided into 4 subregions, each comprised of multiple countries, as comparison at the country level was not feasible. However, heterogeneity in the density of the data persisted even when countries were grouped together into 4 subregions; indeed, data from Eastern Asia accounted for approximately 70% of all Asian data. Because the data were based on a voluntary survey, the information cannot be validated for errors or inaccuracies. Despite these limitations, the data obtained provide important and timely insight on the impact of the ongoing global COVID-19 pandemic on cardiovascular diagnostic procedures.

CONCLUSIONS

COVID-19 caused a significant reduction of cardiovascular diagnostic procedures in Asia. Lower-income countries showed greater reductions than higher-income countries, and this trend was more prominent in Asia than in the rest of the world. Significant differences between Asian subregions were also observed. In Eastern Asia, a recovery of procedure volumes was observed as of April 2020, particularly in China, whereas a further decline was observed in other regions. Further study is warranted to determine the impact of the COVID-19 pandemic on CVD morbidity and mortality, as well as to develop strategies to maintain essential health care services like cardiac diagnostics in a resurgence of COVID-19 or in future pandemics.

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PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: The COVID-19 pandemic was associated with severe reductions in cardiovascular diagnostic procedural volumes in Asia, with a particularly pronounced impact on countries with lower socioeconomic status.

TRANSLATIONAL OUTLOOK: The effects of reduced procedural volume on CVD morbidity and mortality are not known at this point, and further study is warranted to address this gap in knowledge as well as to develop strategies for maintaining the availability of cardiac diagnostics in the event of a resurgence of COVID-19 or another pandemic.

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KEY WORDS cardiac testing, cardiovascular disease, coronavirus, COVID-19, global health

APPENDIX For the INCAPS COVID Investigators Group members, cooperating societies, and Asian countries included in the Asia substudy as well as a supplemental table, please see the online version of this paper.