

# Worldwide Disparities in Recovery of Cardiac Testing 1 Year Into COVID-19



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## ABSTRACT

**BACKGROUND** The extent to which health care systems have adapted to the COVID-19 pandemic to provide necessary cardiac diagnostic services is unknown.

**OBJECTIVES** The aim of this study was to determine the impact of the pandemic on cardiac testing practices, volumes and types of diagnostic services, and perceived psychological stress to health care providers worldwide.

**METHODS** The International Atomic Energy Agency conducted a worldwide survey assessing alterations from baseline in cardiovascular diagnostic care at the pandemic's onset and 1 year later. Multivariable regression was used to determine factors associated with procedure volume recovery.

**RESULTS** Surveys were submitted from 669 centers in 107 countries. Worldwide reduction in cardiac procedure volumes of 64% from March 2019 to April 2020 recovered by April 2021 in high- and upper middle-income countries (recovery rates of 108% and 99%) but remained depressed in lower middle- and low-income countries (46% and 30% recovery). Although stress testing was used 12% less frequently in 2021 than in 2019, coronary computed tomographic angiography was used 14% more, a trend also seen for other advanced cardiac imaging modalities (positron emission tomography and magnetic resonance; 22%-25% increases). Pandemic-related psychological stress was estimated to have affected nearly 40% of staff, impacting patient care at 78% of sites. In multivariable regression, only lower-income status and physicians' psychological stress were significant in predicting recovery of cardiac testing.

**CONCLUSIONS** Cardiac diagnostic testing has yet to recover to prepandemic levels in lower-income countries. Worldwide, the decrease in standard stress testing is offset by greater use of advanced cardiac imaging modalities. Pandemic-related psychological stress among providers is widespread and associated with poor recovery of cardiac testing. (J Am Coll Cardiol 2022;79:2001-2017) © 2022 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

**CT** = computed tomography

**CTA** = computed tomographic angiography

**IAEA** = International Atomic Energy Agency

**PET** = positron emission tomography

**SPECT** = single-photon emission computed tomography

**TEE** = transesophageal echocardiography

**TTE** = transthoracic echocardiography

The COVID-19 pandemic resulted in a sudden global disruption in the performance of diagnostic and therapeutic cardiovascular procedures in early 2020. The International Atomic Energy Agency (IAEA) Division of Human Health previously conducted a large-scale survey, INCAPS COVID (IAEA Noninvasive Cardiology Protocols COVID), to assess the initial impact of the COVID-19 pandemic on changes in noninvasive and invasive cardiovascular diagnostic procedural volumes, staff and patient exposure mitigation strategies, and plans for reopening. This initial study,<sup>1</sup> involving >900 sites from 108 countries, quantified the significant global decrease in cardiovascular diagnostic procedure volumes from March 2019 to April 2020 and noted a greater impact of COVID-19 on practices in poorer countries, raising concerns that long-term cardiovascular outcomes may be negatively affected by the decreased availability of timely cardiovascular diagnoses and treatments.

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Since the spring of 2020, health care systems have attempted to safely reopen and provide cardiovascular diagnostic testing, despite challenges related to the ongoing COVID-19 pandemic that include financial hardship, staff availability and burnout, and patient avoidance of health care contact because of fear of infection. Recovery of global cardiac testing procedural volumes since the early stages of the pandemic has not been evaluated and is of significant public health importance. Changes in cardiovascular diagnostic testing patterns and modality utilization related to the pandemic may have also occurred and have not been previously quantified. Finally, the prevalence of psychological stress related to COVID-19 on imaging staff members and its impact on subsequent patient care has not been well

documented. Therefore, the INCAPS COVID investigators performed a global, web-based survey to reevaluate noninvasive and invasive cardiovascular diagnostic procedural volumes, changes in testing practice, provider well-being, and patient and staff safety practices that occurred in the year following the initial COVID-19 outbreak. Quantifying the ongoing changes in global cardiovascular diagnostic testing practices will better inform future studies aimed at determining COVID-19's impact on long-term cardiovascular outcomes and shifts in diagnostic testing pathways in the postpandemic environment.

## METHODS

**STUDY DESIGN.** With the onset of the COVID-19 pandemic, the IAEA Nuclear Medicine and Diagnostic Imaging Section convened the INCAPS COVID executive committee, composed of experts in clinical cardiology and cardiac imaging from around the world, and conducted an initial study characterizing the impact of the pandemic's first 2 months on worldwide cardiovascular diagnostic care delivery. To characterize intermediate-term trends in the use and practice of cardiac diagnostic testing, the executive committee devised and conducted a follow-up survey, INCAPS COVID 2, 1 year after the first study. We studied the following tests: transthoracic echocardiography (TTE), transesophageal echocardiography (TEE), cardiac magnetic resonance (CMR), stress testing (stress electrocardiography, echocardiography, single-photon emission computed tomography [SPECT], positron emission tomography [PET], and CMR), positron emission tomographic infection studies, coronary artery calcium scanning, coronary computed tomographic angiography (CTA), and invasive coronary angiography. We designed a questionnaire to capture information on 4 domains: 1) descriptors of participating health care facilities and health care professionals; 2) supplies of

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materials, practices, and protocols; 3) perceptions of psychological stress to practitioners; and 4) changes in procedural volumes.

Data were obtained from each participating site at the pre-COVID-19 baseline in March 2019 and also in April 2020 and April 2021. We used IAEA-standard country coding for 8 world regions; participating countries in each region are specified in the [Supplemental Appendix](#). We categorized countries as low, lower middle, upper middle, and high income per World Bank classification.<sup>2</sup>

**DATA COLLECTION.** To improve the representativeness of our data, we made many efforts to be inclusive in site participation, as detailed in the [Supplemental Methods](#). A secure web-based platform, the International Research Integration System, was used for data collection. Only 1 entry from a given center was included in the final dataset. Entries were excluded for reasons such as missing or incomplete responses to the questionnaire. No patient-specific or confidential data were collected, and all participation by study sites was voluntary, therefore it was deemed that no external ethics committee review was required; the study complied with the Declaration of Helsinki. Moreover, the Columbia University Institutional Review Board determined that the work did not meet the criteria to be considered human-subjects research under 45 CFR 46, as there was no interaction with subjects; there was no intervention; and private, identifiable information was not collected.

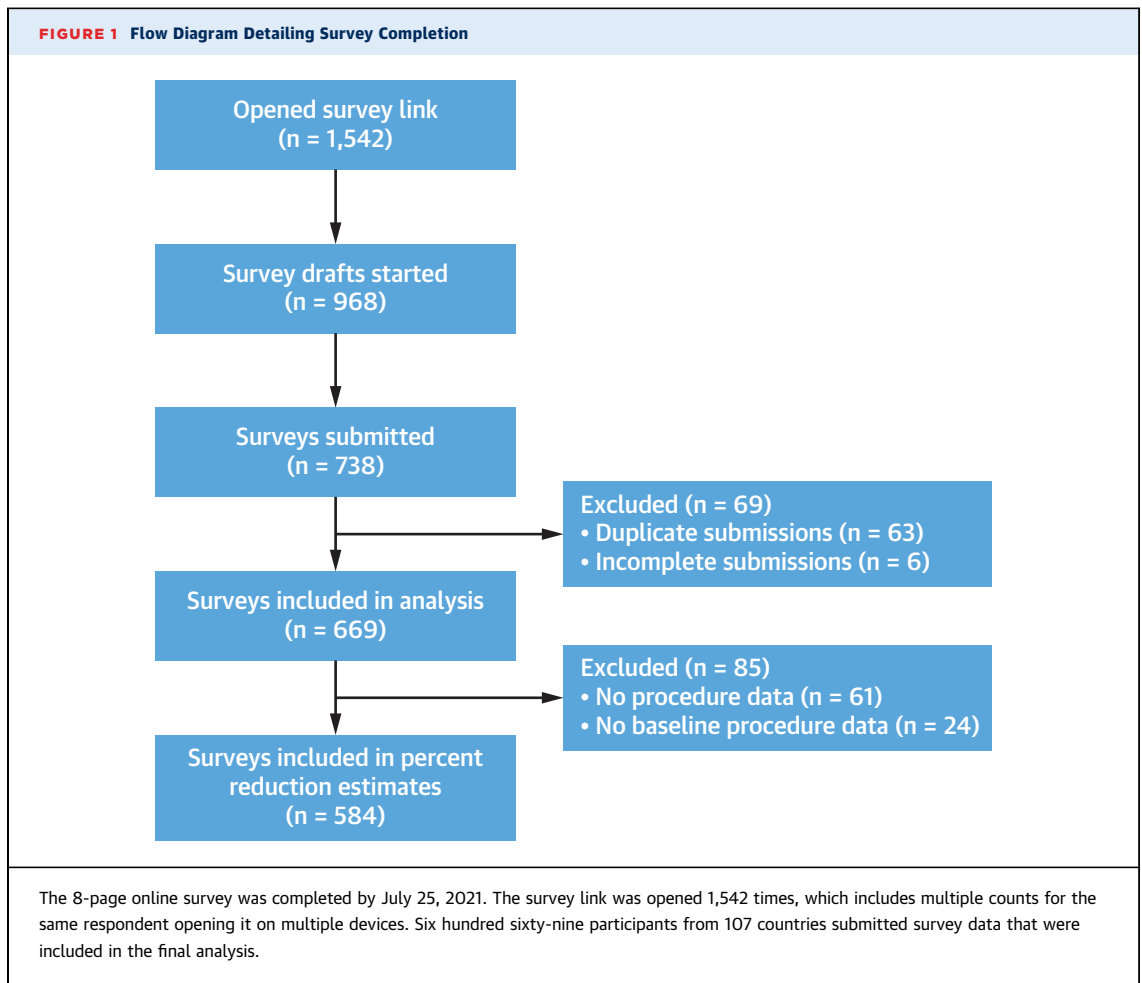
**STATISTICAL ANALYSIS.** Recovery rates from early-stage COVID-19-related decreases in procedure volumes were calculated as:  $100\% \times \{1 - [(March\ 2019\ volume - April\ 2021\ volume) / (March\ 2019\ volume - April\ 2020\ volume)]\}$ . Pearson chi-square and Fisher exact tests were performed to compare center characteristics among world regions. Nonparametric statistics using Wilcoxon rank sum and Kruskal-Wallis tests with asymptotic 2-sided *P* values were used to compare differences in test volumes between time points and differences in continuous variables between world regions. A robust regression model using Huber's M estimator to minimize the effect of influential outliers was used to determine factors associated with procedure volume recovery rate. Variables considered in the analysis were country income level (World Bank classification), March 2019 (baseline) procedure volume, teaching facility (vs nonteaching), hospital facility (vs nonhospital), and the rate of COVID-19 vaccinations in the country in which the facility operates (vaccinations per 100 people of the country population). Numbers of vaccinations were compiled from national governments and the World

Health Organization, while population estimates used to determine rates were based on United Nations World Population Prospects, all via Our World in Data.<sup>3</sup> Variables with *P* values  $\leq 0.25$  in univariable analyses were included in the multivariable model. Statistical analysis was performed using Stata/SE version 16.0 (StataCorp) and Excel 365 (Microsoft). Maps were created using the *rnaturalearth* and *tmap* packages in R version 4.0.1 (R Development Core Team).

## RESULTS

**CENTERS.** Data were obtained from 669 inpatient and outpatient centers in 107 countries, of which 584 centers in 97 countries provided suitable data on baseline 2019 procedure volumes. Of all centers, 448 (67%) were linked to sites that had participated in INCAPS COVID 1. [Figure 1](#) details the iterative exclusion criteria applied to select the final sample, and characteristics of these centers are summarized in [Table 1](#). A total of 1.2 million cardiac diagnostic procedures were performed at sites during the 1-month periods considered across the 3 years (March for 2019, April for 2020 and 2021). Stress SPECT was performed at the greatest proportion of responding centers worldwide (62%), followed by coronary CTA (48%), TTE (41%), and stress electrocardiography (41%), while stress CMR (17%), positron emission tomographic infection studies (13%), and stress PET (10%) were performed in the smallest proportions ([Supplemental Table 1](#)). Countries contributing data had a combined population of 6.8 billion and more than 147 million cases of COVID-19 as of April 30, 2021, constituting 97.4% of the world's reported cases, as of the end of the study period.

**CHANGES IN PROCEDURE VOLUMES.** At INCAPS COVID 2 sites worldwide, cardiac diagnostic procedure volumes decreased by 64% from March 2019 to April 2020, but 97% of this decrease had recovered by April 2021, when a 2% reduction from baseline persisted ([Central Illustration](#)). This recovery varied markedly among world regions ([Supplemental Table 2](#)) and countries ([Figure 2](#)). Modest (3%-13%) increases in procedure volumes from 2019 to 2021, associated with recovery rates of 105% to 119%, were observed in the Far East, Southeast Asia and the Pacific, United States and Canada, and Western Europe, and there was full recovery in Eastern Europe. In contrast, decreases persisted in Latin America (17% decrease from 2019, 79% recovery rate), Middle East and South Asia (33% decrease, 58% recovery), and Africa (42% decrease, 45% recovery). Changes in procedure volumes also varied



among specific procedure types. Compared with 2019 baselines, stress tests suffered a 77% decline in 2020 and were used 12% less frequently in 2021 (Figure 3), corresponding to a recovery rate of 84%. In contrast, cardiac computed tomography (CT) suffered a 61% decline in 2020 compared with 2019 and was used 15% more frequently in 2021 than at baseline, with a recovery rate of 125%. Recovery of cardiac CT exceeded that of stress testing in all regions except for Eastern Europe. In comparison with 2019 baseline, by 2021 TTE (3% decrease, 95% recovery) and invasive coronary angiography (0.2% decrease, 99.7% recovery) had returned close to pre-COVID-19 volumes, whereas TEE (recovery rate 129%), CMR (135%), and PET (139%) had all recovered to modestly surpass pre-COVID-19 use. These changes were significant ( $P < 0.001$ ) for all procedures. Country-wise changes in individual procedures are illustrated in Figures 4 and 5.

**CENTER CAPACITY, PRACTICE, AND PROTOCOLS.** Numerous changes in center capacity, practice, and protocols were observed between 2019 and 2021

(Table 2). These were broadly consistent worldwide, with modest differences among regions. A substantial minority of sites did at some point extend hours for cardiac diagnostic testing (32%) and add new weekend hours (23%) compared with before the pandemic, but in 2021 about one-half of these had reverted to prepandemic conditions. Nearly one-half of sites (48%) had reduced hours for cardiac diagnostic testing, but in 2021 this remained so at only 17%. Some sites had (34%) or currently have (42%) systematic approaches to rescheduling and testing patients whose studies were postponed because of the pandemic. The majority of cardiac diagnostic testing sites have used telehealth during the pandemic, including for registration and consent (58%), for remote reading or reporting of studies (50%), and/or review of studies with referring physicians (43%), and the majority of this use has persisted to the present.

Changes in practice aimed at social distancing, such as alterations in the waiting room, limiting family members, and spacing elevators, and efforts such as mandatory masking and temperature checks,

**TABLE 1** Characteristics of Participating Centers

	Africa	Eastern Europe	Far East	Latin America	Middle East and South Asia	United States and Canada	Southeast Asia and Pacific	Western Europe	Total	P Value
Number of centers	38	53	82	135	63	102	45	151	669	
Participated in INCAPS COVID 1	24 (65)	43 (81)	64 (78)	95 (70)	29 (46)	75 (74)	30 (67)	88 (58)	448 (67)	
Number of countries	14	21	7	19	15	2	9	20	107	
Number of procedures										
March 2019	17,206	33,021	100,864	85,450	40,064	117,085	21,384	94,376	509,450	
April 2020	4,151	12,246	57,144	18,867	8,557	37,366	10,407	34,733	183,471	
April 2021	10,057	33,088	107,682	71,326	26,694	132,047	22,187	96,924	500,005	
Procedures per center										
March 2019	100 (22-675)	147 (37-907)	625 (110-1,096)	139 (61-425)	330 (106-1,013)	893 (328-1,738)	133 (45-933)	253 (89-997)	281 (83-1,009)	<0.001
April 2020	24 (4-125)	17 (2-211)	367 (95-889)	31 (8-130)	85 (9-245)	327 (100-663)	88 (13-419)	112 (23-332)	98 (16-368)	<0.001
April 2021	90 (37-333)	217 (55-985)	784 (250-1,420)	148 (50-353)	240 (61-737)	964 (326-1,938)	168 (30-827)	258 (112-1,002)	296 (86-1,007)	<0.001
Teaching institution	25 (66)	38 (72)	63 (77)	74 (55)	48 (76)	74 (73)	33 (73)	120 (79)	475 (71)	0.001
Economic level by center										
Low	6 (16)	0 (0)	0 (0)	0 (0)	1 (2)	0 (0)	0 (0)	0 (0)	6 (1)	
Lower middle	19 (50)	3 (6)	14 (17)	4 (3)	37 (59)	0 (0)	4 (9)	0 (0)	81 (12)	
Upper middle	12 (32)	26 (49)	17 (21)	125 (93)	9 (14)	0 (0)	7 (16)	2 (1)	198 (30)	
Upper	1 (3)	24 (45)	51 (62)	6 (4)	16 (25)	102 (100)	34 (76)	149 (99)	383 (57)	<0.001

Values are n, n (%), or median (IQR). Procedure counts are for centers performing testing in March 2019. P values are from Kruskal-Wallis tests comparing procedures and hospital beds per center among world regions and chi-square tests comparing types of center, teaching institution status, and economic level among world regions.

have occurred, although not uniformly, at a strong majority of sites and remained in use at the time of the survey (Table 2). Shortages of personal protective equipment occurred at many sites worldwide, especially in low-income countries and especially for high-filtration (N95/KN95/KF94/FFP2) masks. Protective equipment shortages in general resulted in less availability in 2020 than in 2021 (Figure 6).

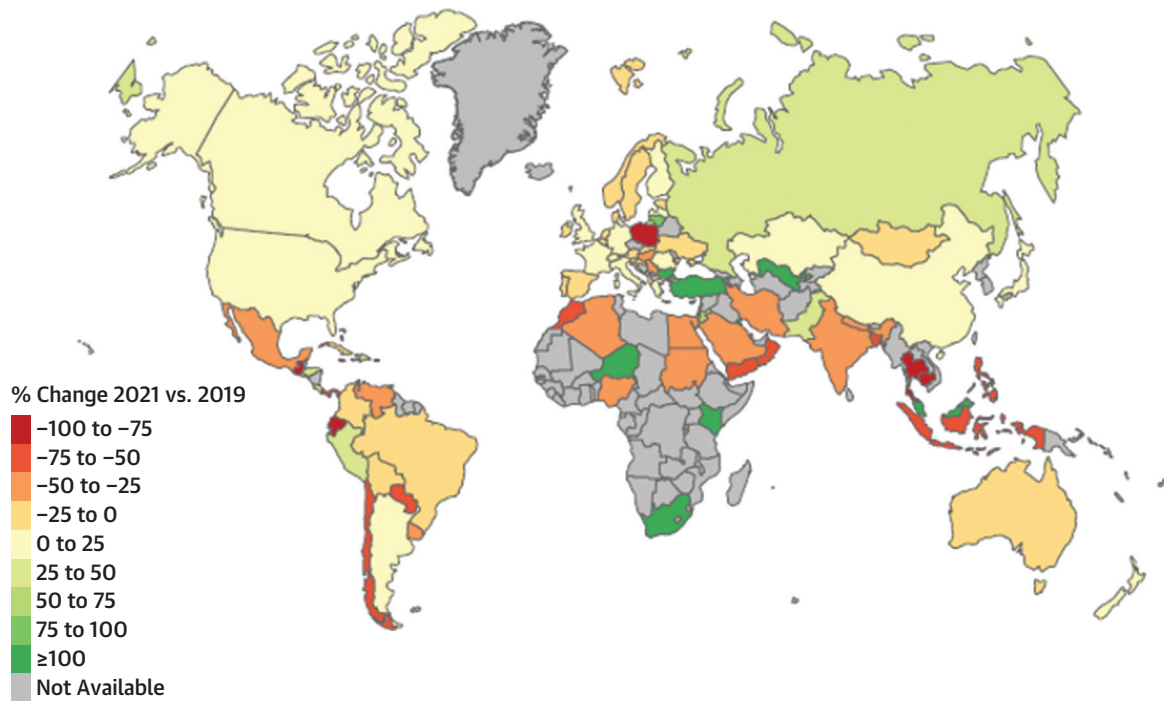
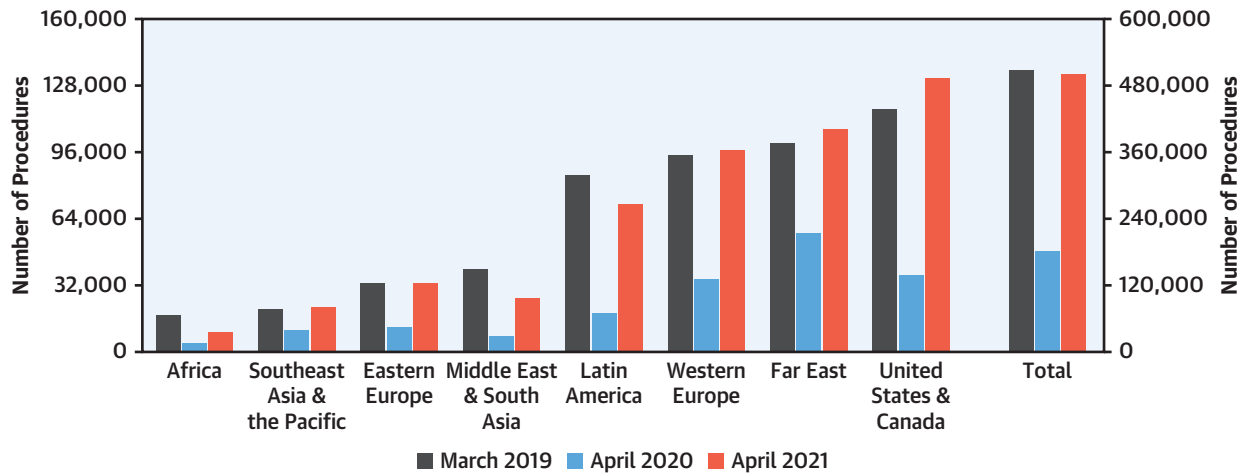
**TESTING PROTOCOLS.** Imaging and catheterization protocols have also changed because of the pandemic. For example, pharmacologic stress testing was preferred during the pandemic over exercise stress testing at 62% of sites in 2020, and that remained the case at 36% of sites in 2021. Expedited imaging protocols were used during the pandemic with varying rates across testing modalities, the highest rates being for TTE (eg, focused examination; 65%) and single-photon emission computed tomographic myocardial perfusion imaging (eg, stress-first or stress-only protocol; 63%). Most of these expedited protocols remained in place at the time of the survey. As of the end of April 2021, 20% of sites worldwide required COVID-19 testing prior to stress testing in all patients, and an additional 9% of sites required such testing for nonvaccinated patients (Supplemental

Table 3). Slightly lower rates of testing (16% for all, 7% for unvaccinated) were observed for noninvasive imaging, with higher rates observed for TEE (49% and 7%) and diagnostic cardiac catheterization (57% and 6%).

**STAFFING AND IMPACT OF THE PANDEMIC ON STAFF MEMBERS.** The economic crisis from COVID-19 has led to numerous changes in staffing. More than one-third of sites (n = 231 [35%]) fired or temporarily furloughed physicians or staff members or reduced salaries. These pandemic-related staffing changes occurred more frequently in 2020 (n = 200 [30%]) and had to a large degree decreased in frequency by 2021 (n = 72 [11%]). For example, while imaging staff members and physicians were furloughed at 4% and 3% of sites in 2021, an additional 17% and 12% of sites had undertaken such furloughs earlier in the pandemic.

On the basis of the estimates of survey respondents, close to 40% of cardiac diagnostic testing staff members had excess psychological stress because of the pandemic. These estimated rates were similar for physician and nonphysician staff members and across world regions (Table 3). This psychological stress was reported to affect patient care in 78% of

**CENTRAL ILLUSTRATION** Change in Worldwide Cardiovascular Disease Diagnostic Testing Volume From Baseline

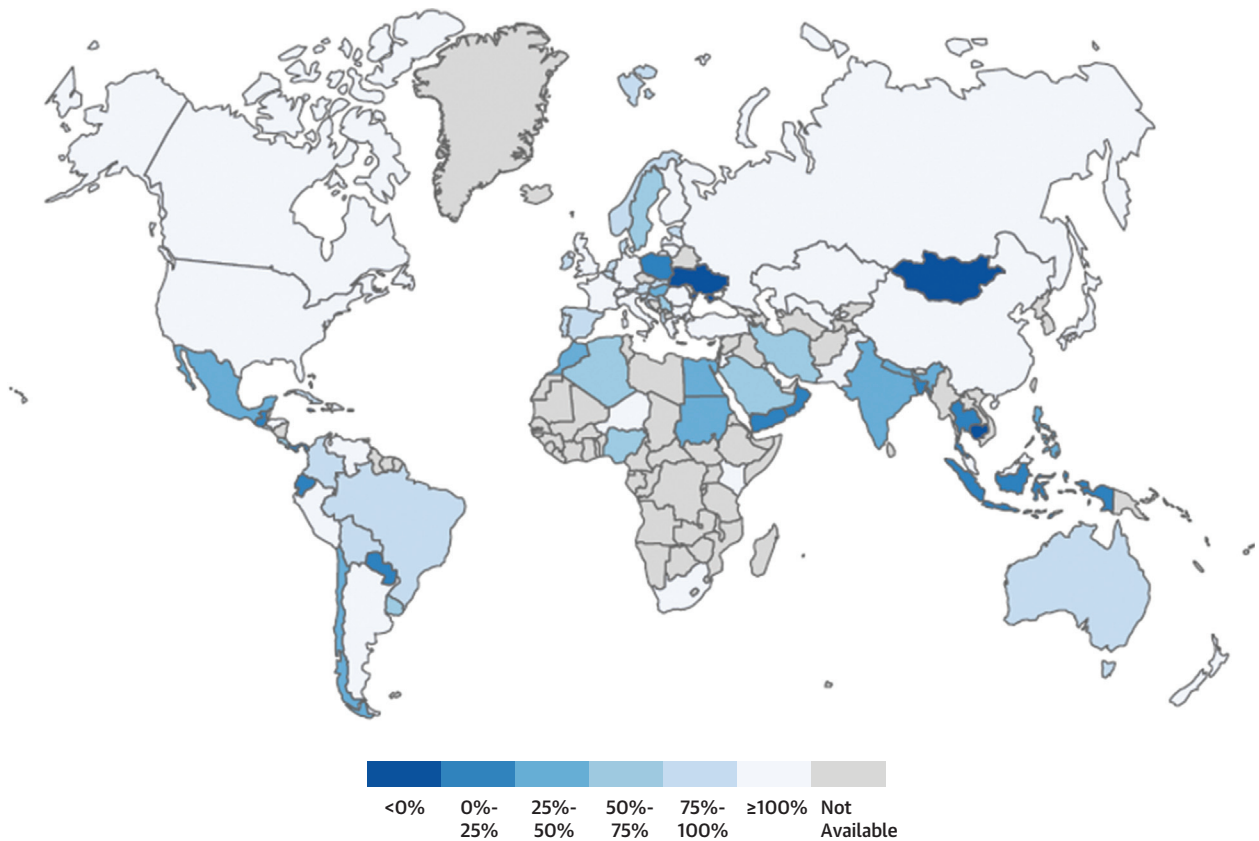


Einstein AJ, et al. *J Am Coll Cardiol.* 2022;79(20):2001-2017.

**(Top)** Bar chart of cardiovascular disease test volumes at the 669 participating centers, by International Atomic Energy Agency world regions, for 2019 baseline, the beginning of the pandemic (April 2020), and 1 year into the pandemic (April 2021). Note different y-axes for world regions and worldwide. Percentage reductions from 2019 are reported at the tops of the columns. **(Bottom)** World map demonstrating changes in total cardiovascular procedural volume from March 2019 to April 2021 across the 107 participating countries. Countries or territories of a country in gray did not have data available. Procedures recorded included morphologic and other types of rest imaging (transthoracic and transesophageal echocardiography, cardiac magnetic resonance [CMR], and positron emission tomography [PET] for infective endocarditis), coronary imaging (coronary computed tomographic angiography, coronary artery calcium scoring, and invasive coronary angiography), and stress testing (stress electrocardiography, stress echocardiography, nuclear stress imaging [single-photon emission computed tomography and PET], and stress CMR). For each numerical range specified by a color, the lower limit provided is inclusive whereas the upper limit is exclusive; for example, -100 to -75 reflects a % change that is  $\geq$ -100%, but  $<$ -75%, while 75 to 100 reflects a % change that is  $\geq$ 75%, but  $<$ 100%.



**FIGURE 2** Worldwide Recovery in Cardiac Diagnostic Testing



Recovery is defined as percentage return in 2021 to 2019 baseline, from 2020 volumes at the initial phase of the pandemic. **Lightest blue** reflects full recovery, and **darker shades of blue** reflect lower recovery. For each range specified by a shade of blue in the color bar, the lower limit provided is inclusive whereas the upper limit is exclusive; for example, 0%-25% reflects a percentage recovery that is  $\geq 0\%$ , but  $< 25\%$ .

sites, including a moderate impact at 23% of sites and a profound impact at 8% of sites. No significant difference was observed in the perceived impact of physician and other clinical staff psychological stress on patient care for facilities that perform advanced cardiac imaging modalities (ie, CT, magnetic resonance imaging, or PET) vs those that do not perform advanced imaging ( $P = 0.060$ ) (Supplemental Table 4).

**DIFFERENCES AMONG TYPES OF CENTERS.** Procedure change and recovery rates differed among types of centers (Supplemental Table 2). Of note, outpatient imaging-only centers remained hardest hit, with a 14% reduction in procedures from 2019 to 2021, compared with hospitals, which had a 2% reduction, and outpatient facilities with physician practices, which had a 36% increase. University-affiliated teaching sites experienced lower reductions in procedures than nonteaching facilities in 2020 (62% vs

70% overall), but both types of sites nearly recovered to baseline in 2021 (recovery rates of 96% and 100%, respectively). Changes from 2019 to 2021 procedure volume (8% higher for hospitals in the highest tertile of number of beds, 4% lower for the middle tertile, and 19% lower for the lowest tertile) and recovery rates (114%, 95%, and 74%, respectively) were higher at larger hospitals than smaller ones (Supplemental Figure 1). There were no differences in procedure volume recovery or percentage of staff members with excess psychological stress related to the pandemic between sites that reported furloughs or layoffs during the pandemic and those that did not (Supplemental Table 5).

**DISPARITIES BETWEEN LEVELS OF ECONOMIC DEVELOPMENT.** We observed significant differences in recovery of overall cardiac testing between economically challenged and wealthier countries. Although in 2020, volumes of cardiac diagnostic



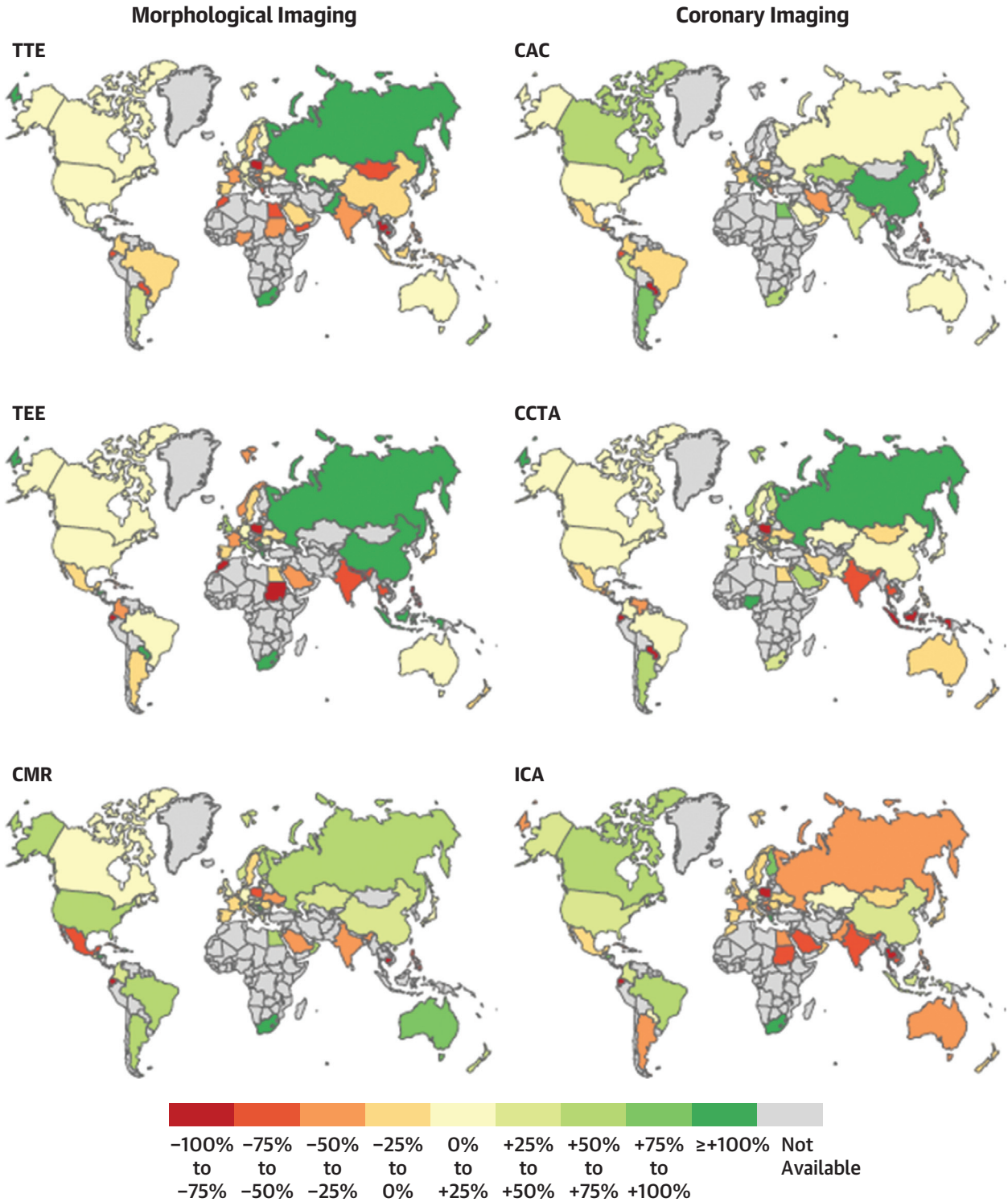
testing procedures decreased for all income levels, especially for low-income and lower middle-income countries, by 2021 overall diagnostic testing had recovered to pre-COVID-19 levels in high-income and upper middle-income countries, with recovery rates of 108% and 99%, respectively. However, cardiac testing remained depressed in 2021 in lower middle-income and low-income countries, at levels 58% and 48% of those before COVID-19 (Figure 7) and with recovery rates of 46% and 30%. However estimated excess pandemic-related psychological stress to providers was similar across levels of economic development: 38% of physicians and 39% of nonphysician providers in low-income and lower middle-income countries, compared with 37% of physicians and 41% of nonphysician providers in upper middle-income and high-income countries.

In multivariable regression, mean recovery of procedure volumes was 28% lower for facilities located in low-income or lower middle-income countries compared with facilities in upper middle- or high-income countries (95% CI: 11%-45%;  $P = 0.002$ ), 0.23% lower for every 1% increase in proportion of physicians with excess psychological stress (95% CI: 0.07%-0.38%;  $P = 0.004$ ), and 0.40% higher for every 1 vaccination per 100 people in the country (95% CI: 0.21%-0.60%;  $P < 0.001$ ). Baseline procedure volume, teaching facility status, and hospital facility status were not significant predictors of recovery in multivariable analysis (Supplemental Table 6).

This observation of better recovery in wealthier countries was generally observed across procedure types, with some variation. For example, growth in coronary CTA from 2019 to 2021 was limited to upper



**FIGURE 4** Worldwide Changes in Morphologic and Coronary Imaging Procedure Volumes



Maps displaying by-country estimated changes in procedure volume for common morphologic imaging (**left column**) and coronary imaging (**right column**) procedures, from prepandemic to 1 year into the pandemic. Changes as displayed are color coded on the basis of percentage change in volume from March 2019 to April 2021. For each range specified by a color in the color bar, the lower limit provided is inclusive whereas the upper limit is exclusive; for example, -100% to -75% reflects a % change that is  $\geq -100\%$ , but  $< -75\%$ , while +75% to +100% reflects a % change that is  $\geq 75\%$ , but  $< 100\%$ . ICA = invasive coronary angiography; other abbreviations as in [Figure 3](#).

**FIGURE 5** Worldwide Changes in Stress Testing Procedure Volumes

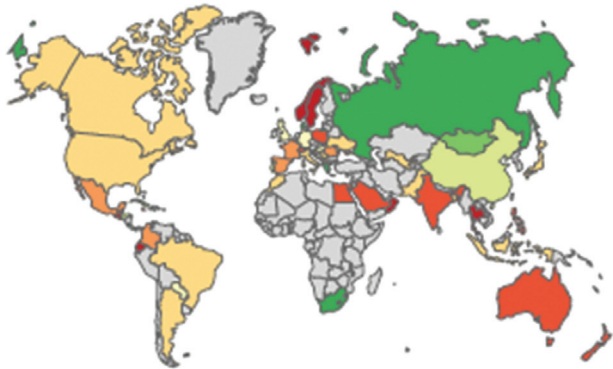
**ECG**



**Nuclear**



**Echocardiography**



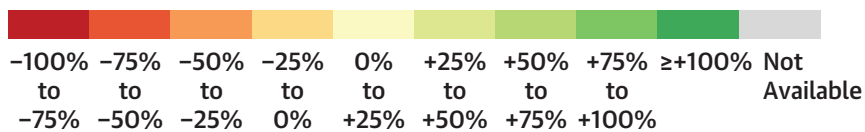
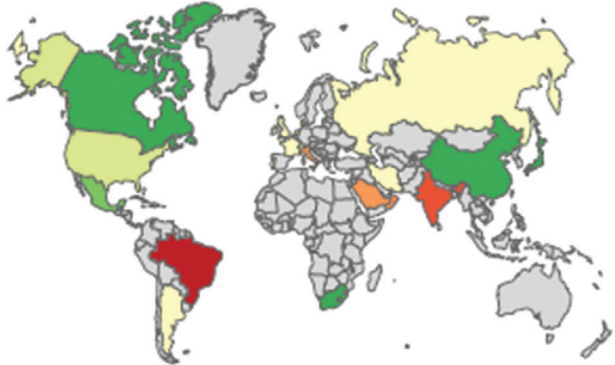
**SPECT**



**CMR**



**PET**



Maps displaying by-country estimated changes in procedure volume for common cardiac stress testing procedures, from prepandemic to 1 year into the pandemic. Changes are color coded on the basis of percentage change in volume from March 2019 to April 2021. For each range specified by a color in the color bar, the lower limit provided is inclusive whereas the upper limit is exclusive; for example, -100% to -75% reflects a % change that is  $\geq -100\%$ , but  $< -75\%$ , while +75% to +100% reflects a % change that is  $\geq 75\%$ , but  $< 100\%$ . Abbreviations as in [Figure 3](#).

**TABLE 2** Changes in Cardiovascular Testing Capacity, Practice, and Protocols During the COVID-19 Pandemic

	Prior Use During COVID-19 Pandemic (n = 669)	Current Use (n = 669)
Change in capacity		
Reduced hours compared with prepandemic	204 (31)	113 (17)
Systemic approach to rescheduling/testing patients whose studies were canceled/postponed because of pandemic	223 (34)	278 (42)
Use telehealth for patient interaction aspects (registration, consent)	114 (17)	269 (41)
Use remote reading/reporting of studies (telehealth)	92 (14)	239 (36)
Use telehealth for review of studies with referring providers	82 (12)	203 (31)
Change in practice		
Test for COVID-19 in patients prior to all diagnostic testing	143 (22)	112 (17)
Test for COVID-19 in patients prior to some diagnostic testing	134 (20)	304 (46)
Change in protocols		
Pharmacologic stress testing preferred over exercise to reduce risk for coronavirus transmission	172 (26)	233 (36)
Expedited imaging protocols		
SPECT myocardial perfusion imaging (eg, stress-first/stress-only)	60 (16)	177 (47)
PET myocardial perfusion imaging (eg, shorter protocols)	25 (7)	52 (15)
MRI (eg, single gadolinium injection)	41 (12)	92 (27)
CT (eg, modify rate-control protocols such as increased use of prescan oral beta-blocker)	32 (9)	142 (41)
Transthoracic echocardiography (eg, focused examination)	80 (23)	145 (42)
Transesophageal echocardiography (eg, focused examination)	69 (20)	112 (33)
Values are n (%). Current use reflects use at time of survey response. CT = computed tomography; MRI = magnetic resonance imaging; PET = positron emission tomographic; SPECT = single-photon emission computed tomographic.		

middle- and high-income countries, while coronary CTA procedure volumes decreased by 23% from pre-COVID-19 levels in lower middle-income countries. TTE levels recovered to baseline in upper middle- and high-income countries but remained decreased by 41% in lower middle-income countries and by 50% in low-income countries. Moreover, abbreviated transthoracic echocardiographic protocols (eg, with fewer views), which have been used at some time during the pandemic at a majority of sites across all income levels, remained abbreviated in 2021 in a higher proportion (56%) of low- and lower middle-income sites compared with upper middle-income (44%) and high-income (37%) sites. The decline in stress testing was more profound in poorer countries, whereas PET and CMR stress testing increased from pre-COVID-19 levels in upper middle- and high-income countries. Greater proportions of sites in low-income and lower middle-income countries currently have reduced hours for cardiac testing compared with prepandemic (57% low, 36% lower middle, 26% upper middle, and 8% high income) and have used reduced hours at some point during the pandemic (71%, 70%, 61%, and 37%, respectively).

## DISCUSSION

The COVID-19 pandemic has had an immeasurable impact on the health and well-being of populations

around the world, yet little is known regarding the impact of COVID-19 on diagnostic testing patterns for cardiovascular disease and other chronic diseases, during both peak and recovery phases of the pandemic. We present worldwide findings on cardiovascular diagnostic testing use from 669 inpatient and outpatient centers from 107 countries, with a combined population of 6.8 billion and nearly 98% of the world's reported cases of COVID-19. We previously reported a reduction of 64% in cardiac diagnostic procedure volumes during the early phase of the pandemic in 2020.<sup>1</sup> In our present report, we reveal marked recovery of most (97%) of the cardiovascular diagnostic testing procedure volume worldwide during 2021. However, patterns of recovery varied substantively across world regions and countries, with notably less robust recovery in economically challenged countries compared with wealthier countries. In 2021, recovery rates for cardiovascular diagnostic procedures continued to lag in low-income and lower middle-income countries, well behind the rest of the world, and remain depressed compared with prepandemic volumes. These important findings highlight the collateral impact of the pandemic on chronic conditions, such as cardiovascular disease, and how it has exacerbated disparities in health care for non-COVID-19 conditions worldwide. If these challenges are not assessed, the devastating effects of COVID-19 may threaten advances that have been

**TABLE 3 Psychological Impact of the Pandemic**

	Africa	Eastern Europe	Far East	Latin America	Middle East and South Asia	United States and Canada	Southeast Asia and the Pacific	Western Europe	Worldwide
Clinical staff estimated to have excess psychological stress related to pandemic									
Physician, %	36 ± 29	38 ± 36	35 ± 30	46 ± 33	40 ± 32	40 ± 31	28 ± 35	29 ± 29	37 ± 32
Nonphysician, %	38 ± 28	42 ± 34	38 ± 33	48 ± 29	43 ± 32	44 ± 31	35 ± 37	33 ± 30	40 ± 31
Impact of pandemic-related psychological stress on patient care									
None	7 (19)	17 (33)	19 (23)	18 (13)	14 (22)	16 (16)	11 (25)	41 (27)	143 (22)
Mild	18 (50)	23 (44)	38 (46)	62 (46)	28 (44)	51 (51)	22 (50)	74 (49)	316 (48)
Moderate	9 (25)	9 (17)	24 (29)	36 (27)	17 (27)	21 (21)	5 (11)	28 (19)	149 (23)
Profound	2 (6)	3 (6)	1 (1)	19 (14)	4 (6)	12 (12)	6 (14)	7 (5)	54 (8)

Values are mean ± SD or n (%). Percentages in the bottom half of the table may not sum to 100% because of rounding.

made toward the United Nations Sustainable Development Goals.<sup>4</sup>

**DISPARITIES OF DIAGNOSTIC TESTING IN LOWER-INCOME COUNTRIES.** Throughout the pandemic, higher COVID-19 positivity rates have been reported in lower- compared with higher-income areas, likely attributable to population density and health care systems ill equipped to handle high rates of transmission, along with limited availability of testing and vaccines.<sup>5,6</sup> The pandemic also created a worldwide financial crisis, with growing debt in lower-income countries and an expanded population entering poverty, intensifying issues regarding food insecurity as well as access to and funding for health care.<sup>7-9</sup> An estimated 77% of individuals living in low-income countries live in households that have lost income during the pandemic.<sup>7</sup> The INCAPS COVID 2 survey shows that COVID-19 has further exacerbated preexisting health inequalities in low-income and lower middle-income countries. The frequency of cardiac diagnostic testing in low-income and lower middle-income countries lagged behind upper middle- and high-income countries prior to the pandemic<sup>4</sup> and remains depressed compared with prepandemic levels. Our analysis revealed that procedure volume recovery was 31% lower at facilities located in low- and lower middle-income countries compared with centers in upper middle- or high-income countries ( $P = 0.001$ ). There is growing evidence of ongoing disruptions to essential health services in low-income and lower middle-income countries that have been caused by the ongoing pandemic, including essential health services<sup>10</sup> and maternal and child health.<sup>11</sup> The recent World Health Organization national pulse survey showed that

high-income countries reported fewer disruptions to essential health services in January to March 2021 compared with lower income countries.<sup>10</sup> Without mitigation of these effects, the COVID-19 pandemic will continue to exacerbate worldwide disparities in health care for noncommunicable disease, such as cardiovascular disease.

**PSYCHOLOGICAL IMPACT OF THE COVID-19 PANDEMIC ON HEALTH CARE WORKERS.** Early studies reported a variable psychological impact of the pandemic on health care workers; with more recent reports that symptoms related to post-traumatic stress are commonly occurring among medical staff members.<sup>12-14</sup> From this INCAPS COVID 2 study, respondents reported an alarming degree of excess psychological stress related to the pandemic among both physicians and nonphysician staff members, and the perceived proportion of staff members with increased stress was a significant predictor of decreased recovery of cardiac testing ( $P = 0.003$ ) in multivariable analysis. Both the acute psychological impact of the pandemic's early phases and the chronic impact of the ongoing pandemic on health care workers must be considered.<sup>15</sup> Several previous studies have identified high rates of depression, anxiety, post-traumatic stress disorder, and burnout among health care workers during the COVID-19 pandemic.<sup>16-20</sup> In our study, there were no major regional and economic level differences in the prevalence of psychological distress, suggesting that this is a universal feature facing health care systems worldwide. The long-term impact of the pandemic on health care workers is currently unknown, and clearly prioritizing near- and long-term mental well-being is of vital importance to the health care community.



**CHANGES IN TEST SELECTION AND PERFORMANCE: EMERGENCE OF ADVANCED IMAGING MODALITIES AND DECREASED EXERCISE STRESS.**

Beyond these findings, the worldwide growth in “advanced” cardiac imaging modalities—CT, magnetic resonance imaging, and PET—was an additional emerging pattern from our most recent survey that is as of yet unexplained. Recovery of cardiac CT exceeded that of stress testing in all regions, except for Eastern Europe. Specifically, cardiac CT suffered a 61% decline in 2020 and was used 15% more frequently in 2021 than at baseline, with a recovery rate of 125%. It remains plausible that the improved safety profile for health care providers and technologists during coronary CTA, related to decreased procedural times and lower rates of aerosolization during testing compared with stress testing,<sup>21</sup> may be driving this increase or that acute care needs for evaluation of suspected unstable angina among patients with COVID-19 may also be affecting this testing pattern. In addition, challenges in radiotracer supply chains may also have decreased the use of stress SPECT. Another factor potentially affecting use of stress testing and other noninvasive tests is that the documented increase in acute coronary syndromes<sup>22</sup> and delay in care during the pandemic may have led to bypassing cardiac imaging, with more patients proceeding directly to invasive procedures; however, we observed no change between 2019 and 2021 in the use of invasive angiography. Regardless, the shift to higher utilization of coronary CTA is consistent with increasing support from European and American clinical practice guidelines on management of coronary disease and chest pain.<sup>23-25</sup>

We also observed a significant and sustained decrease in the overall use of exercise stress testing. Among patients who underwent nuclear stress testing, there was a significant shift toward using pharmacologic stress following the onset of the COVID-19 pandemic. This practice, if persistent, may result in long-term decreases in the routine use of exercise stress electrocardiography, echocardiography, and SPECT. At the same time, notwithstanding decreases in stress electrocardiography (17%) and SPECT (16%) from 2019 to 2021, stress testing using PET and CMR, although at considerably lower volumes, increased by 25% over the same time period, closely matched by rest uses of these modalities. These findings are consistent with recent pre-COVID-19 trends in the U.S. Medicare population.<sup>26</sup> Whether the worldwide decline in procedure volumes of more traditional modalities and growth of advanced cardiac imaging persist, and how these trends vary geographically, is an important subject for further

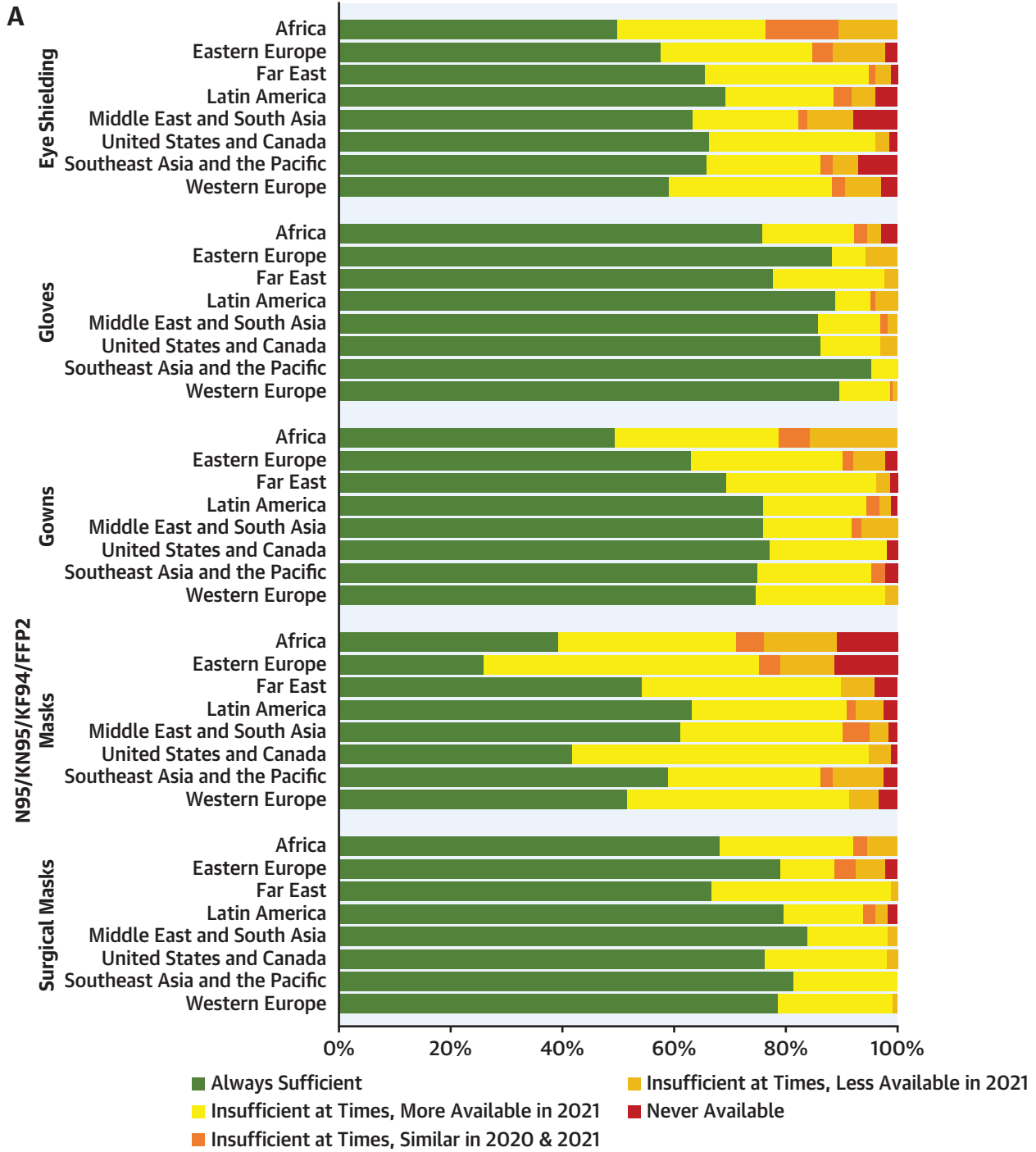
study. The economic impact of continued increased use of PET, CT, and CMR, which may be more expensive tests to perform compared with traditional stress testing, requires further study across health care systems and payment models. Although in an observational registry of patients with suspected coronary disease in 41 centers in the United States and Canada, advanced imaging with PET and coronary CTA led to higher 2-year costs than did SPECT,<sup>27</sup> driven largely by more subsequent invasive procedures, research is mixed, with PET, CT, and CMR found to be cost effective in several other studies in comparison with alternative testing pathways.<sup>28,29</sup>

**STUDY LIMITATIONS.** As with all self-reported surveys, there is the possibility of selection and nonresponse bias, recall bias, unverified answers, and incomplete data, thus making the data collected subject to multiple potential sources of inaccuracy. The findings from the 669 centers included in the analyses may not entirely reflect centers that were not part of the study. Although sites were instructed to report reasonably accurate estimates of procedural volumes, the potential for inaccurate reporting exists. Extensive attempts were made to include as many centers as possible. Nevertheless, some countries had more respondents than others. The number of responses from low-income countries was small, partly reflecting lack of access to many of these advanced diagnostic tests in low-income countries. The pandemic continues to affect countries and regions throughout the world differently, and our survey represented 1 month when countries may have been in different phases of the pandemic. Each site’s use of cardiac testing in April 2021 may reflect to some degree the local severity of the pandemic at that time, and this was not quantified. The data on the pandemic’s impact on psychological stress were estimates reflecting perceived excess stress among physicians and nonphysician testing staff members and their impact on patient care; the influence of referring providers’ stress on the use of testing requires further study.

**CONCLUSIONS**

Worldwide, there has been a 97% recovery in cardiac diagnostic testing procedure volumes. However, complete recovery was observed primarily in high-income and upper middle-income countries, whereas procedure volumes in low-income and lower middle-income countries have yet to fully recover. Greater recovery rates and even new growth was observed for advanced cardiac imaging modalities: CT, MRI, and PET. The permanency of lagging

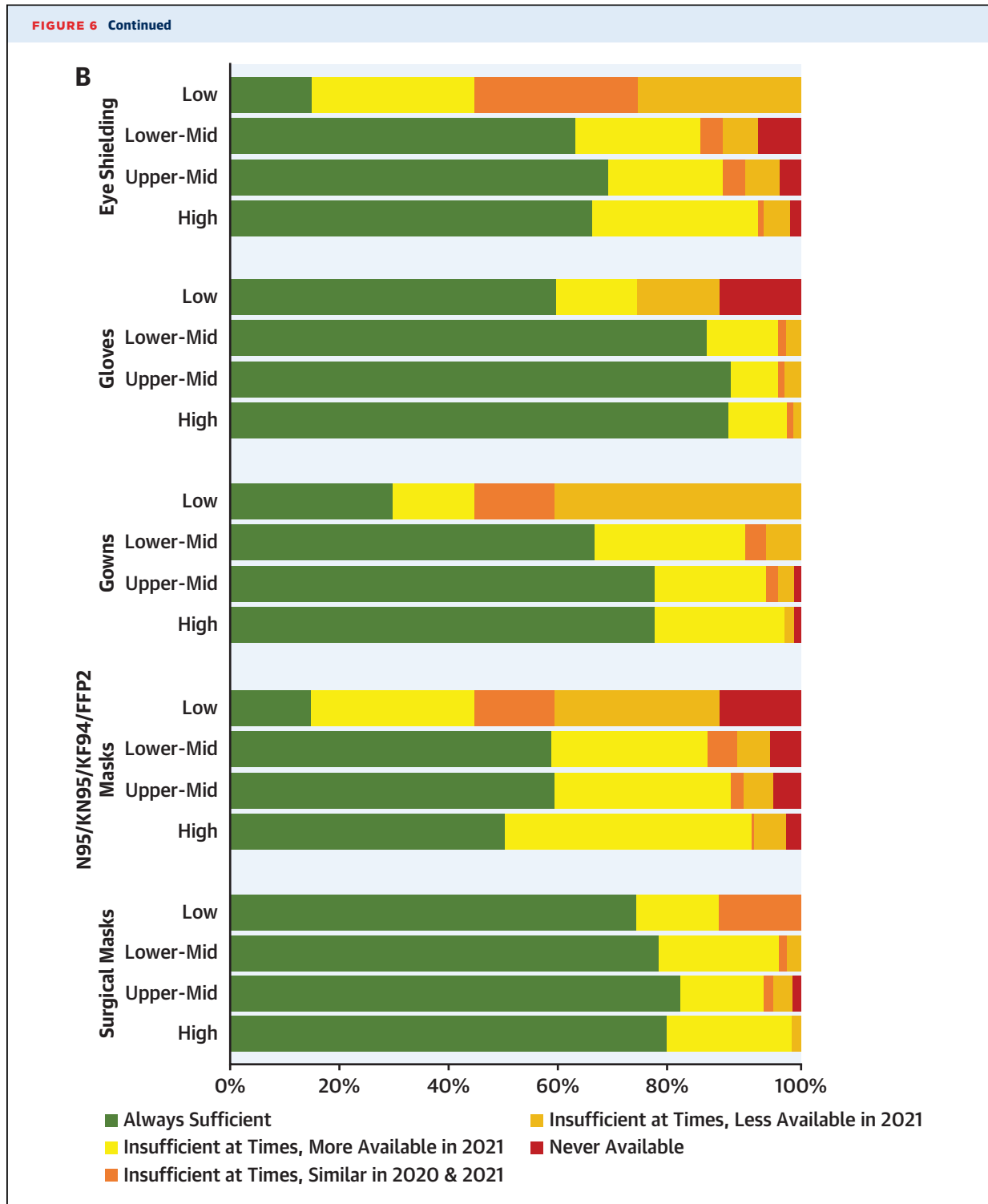
**FIGURE 6** Worldwide Shortages of Personal Protective Equipment



Percentage of centers reporting types of shortage of 5 important forms of personal protective equipment during the COVID-19 pandemic. **Green** denotes no shortage, **red** denotes lack of availability throughout the pandemic, and shades of **yellow/orange** denote shortage at some times, with specific shade specifying whether availability was greater in 2020 or 2021. **(A)** By world region. **(B)** By World Bank income level.

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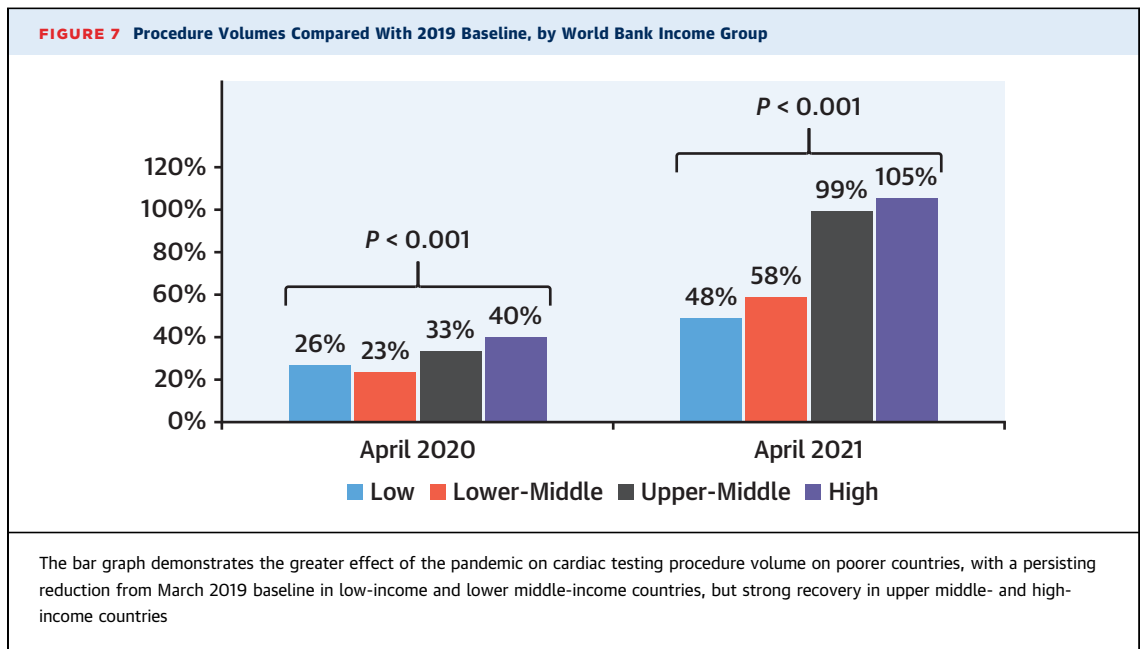




recovery for other modalities, such as stress SPECT, remains unknown. Psychological stress was prevalent across providers at surveyed health care facilities and significantly affected recovery in cardiac care, necessitating greater attention to the near- and

long-term impact of the COVID-19 pandemic for health care staff members around the world.

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**Supplemental Appendix**, thanks cardiology and imaging professional societies worldwide for their assistance in disseminating the survey to their memberships. These include, alphabetically and not limited to, the American Society of Nuclear Cardiology, the Arab Society of Nuclear Medicine, the Australasian Association of Nuclear Medicine Specialists, the Australia-New Zealand Society of Nuclear Medicine, the Belgian Society of Nuclear Medicine, the Brazilian Nuclear Medicine Society, the British Society of Cardiovascular Imaging, the Conjoint Committee for the Recognition of Training in CT Coronary Angiography, the Consortium of Universities and Institutions in Japan, Gruppo Italiano Cardiologia Nucleare, the Indonesian Society of Nuclear Medicine, the Japanese Society of Nuclear Cardiology, the Philippine Society of Nuclear Medicine, the Russian Society of Radiology, the Society of Cardiovascular Computed Tomography, the Society for Cardiovascular Magnetic Resonance, and the Thailand Society of Nuclear Medicine.

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#### PERSPECTIVES

##### COMPETENCY IN SYSTEMS-BASED PRACTICE:

The COVID-19 pandemic initially reduced diagnostic testing for heart disease, and a year after the first wave of the pandemic, the situation has not improved in lower-income countries. A high level of psychological stress among practitioners attributable to the pandemic has had a negative impact on the restoration of diagnostic services.

**TRANSLATIONAL OUTLOOK:** Efforts are needed to mitigate the deleterious effects of the pandemic on the psychological wellness of physicians and other caregivers and to ensure timely access to diagnostic cardiac testing, especially in lower income countries.

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

**APPENDIX** For a list of members of the INCAPS COVID 2 Investigators Group, supplemental methods, a supplemental figure, supplemental tables, country participation, and the data collection instrument, please see the online version of this paper.