## Title

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## Journal

Radiology: Cardiothoracic Imaging, 5(5)

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## Publication Date

2023-10-01

## DOI

10.1148/ryct.220288

Peer reviewed

Radiology: Cardiothoracic Imaging

ORIGINAL RESEARCH

# Cardiovascular Testing in the United States during the COVID-19 Pandemic: Volume Recovery and Worldwide Comparison

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Study supported by the International Atomic Energy Agency. M.C.W. supported by the British Heart Foundation (grant no. FS/ICRF/20/26002).

[1]Members of the INCAPS COVID 2 Investigators Group are listed in Appendix S1.

Conflicts of interest are listed at the end of this article.

*Radiology: Cardiothoracic Imaging* 2023; 5(5):e220288 • https://doi.org/10.1148/ryct.220288 • Content codes: CA CT MI VA

**Purpose:** To characterize the recovery of diagnostic cardiovascular procedure volumes in U.S. and non-U.S. facilities in the year following the initial COVID-19 outbreak.

**Materials and Methods:** The International Atomic Energy Agency (IAEA) coordinated a worldwide study called the IAEA Noninvasive Cardiology Protocols Study of COVID-19 2 (INCAPS COVID 2), collecting data from 669 facilities in 107 countries, including 93 facilities in 34 U.S. states, to determine the impact of the pandemic on diagnostic cardiovascular procedure volumes. Participants reported volumes for each diagnostic imaging modality used at their facility for March 2019 (baseline), April 2020, and April 2021. This secondary analysis of INCAPS COVID 2 evaluated differences in changes in procedure volume between U.S. and non-U.S. facilities and among U.S. regions. Factors associated with return to prepandemic volumes in the United States were also analyzed in a multivariable regression analysis.

**Results:** Reduction in procedure volumes in April 2020 compared with baseline was similar for U.S. and non-U.S. facilities (−66% vs −71%, $P = .27$). U.S. facilities reported greater return to baseline in April 2021 than did all non-U.S. facilities (4% vs −6%, $P = .008$), but there was no evidence of a difference when comparing U.S. facilities with non-U.S. high-income country (NUHIC) facilities (4% vs 0%, $P = .18$). U.S. regional differences in return to baseline were observed between the Midwest (11%), Northeast (9%), South (1%), and West (−7%, $P = .03$), but no studied factors were significant predictors of 2021 change from prepandemic baseline.

**Conclusion:** The reductions in cardiac testing during the early pandemic have recovered within a year to prepandemic baselines in the United States and NUHICs, while procedure volumes remain depressed in lower-income countries.

*Supplemental material is available for this article.*

### Abbreviations

CCTA = coronary CT angiography, CVD = cardiovascular disease, IAEA = International Atomic Energy Agency, INCAPS COVID = IAEA Noninvasive Cardiology Protocols Study of COVID-19, NUHIC = non-U.S. high-income country, ZCTA = Zip Code Tabulation Area


### Summary

Declines in cardiovascular procedure volumes observed early in the COVID-19 pandemic greatly recovered in 2021 in the United States and other high-income countries, but not in facilities in lower-income countries.


### Key Points

- U.S. facilities reported a 4% increase in cardiovascular testing volumes in April 2021 compared with prepandemic baseline volumes, while non-U.S. facilities reported a 6% decline in procedure volumes ($P$ = .008), attributable to markedly lower recovery in lower-middle- (−41%) and low- (−50%) income countries.
- Significant variations were observed among U.S. regions, with greater return of procedure volumes observed in the Midwest (11%) and Northeast (9%) compared with the South (1%) and West (−7%, $P$ = .03).
- No factors were independently associated with procedure volume recovery in U.S. facilities in a multivariable model.


### Keywords

SPECT, Cardiac, Epidemiology, Angiography, CT Angiography, CT, Echocardiography, SPECT/CT, MR Imaging, Radionuclide Studies, COVID-19, Cardiovascular Imaging, Diagnostic Cardiovascular Procedure, Cardiovascular Disease, Cardiac Testing


The COVID-19 pandemic has severely impacted the delivery of health care across the world. Declines in health care use were observed across nearly every specialty during the early pandemic, including cardiothoracic imaging, where worldwide procedure volumes decreased by 64% in April 2020 compared with March 2019 (1–5). Cardiovascular disease (CVD) remains the leading cause of death for both men and women worldwide, and diagnostic procedures are imperative for the timely diagnosis and risk stratification of patients with suspected CVD (6,7). The decline in procedure volumes during the early pandemic prompted concerns over the potential consequences of decreased cardiovascular testing on long-term CVD morbidity and mortality rates (8,9).

There is limited evidence regarding the association between decreased procedure volumes during the early pandemic and clinical outcomes. One study conducted during the initial wave of the COVID-19 pandemic noted a decrease in heart failure admissions, which has been an argument for potential overtesting of CVD; however, other studies have suggested that reduced testing during the pandemic may have led to missed diagnoses and delays in care for CVD, potentially resulting in poorer clinical outcomes (10–12). Many facilities have since reopened with new protocols and practices to enhance patient and staff safety during the pandemic. The extent to which these changes have resulted in a full restoration of cardiovascular testing and the degree of adaptation similarity across different regions, considering the heterogeneity of pandemic timing and local resources, are still under investigation.

To evaluate reductions in cardiovascular testing during the early pandemic, the International Atomic Energy Agency (IAEA; Vienna, Austria) established a research committee in April 2020 that coordinated an international study, called the IAEA Noninvasive Cardiology Protocols Study of COVID-19 (INCAPS COVID), to determine the impact of the pandemic on diagnostic cardiovascular procedure volumes around the world (8). More than a year into the pandemic, the INCAPS COVID investigators reconvened in early 2021 for a follow-up study, INCAPS COVID 2, to examine the extent of the return of worldwide cardiovascular testing (13). Here, we describe the change from prepandemic baseline volumes between U.S. and non-U.S. facilities and among U.S. regions, and we analyze factors associated with changes in cardiovascular testing in the United States 1 year into the COVID-19 pandemic.

## Materials and Methods

### Study Design

The INCAPS COVID 2 executive committee was established to study the impact of the COVID-19 pandemic on worldwide diagnostic cardiovascular procedure volumes. The study design has been previously described (13). A survey was designed in which facilities that perform diagnostic cardiovascular testing reported procedure volume data for March 2019 (considered to be the facility's prepandemic baseline volume), April 2020, and April 2021. A single survey was accepted for each participating site, which could be submitted by any practitioner qualified to answer the questions (eg, cardiologist, nuclear medicine physician, technologist). Participants were also asked to answer questions regarding the current impact of the pandemic on their facility's operating capacity, practices, protocols, and staffing, as well as its impact on the psychologic well-being of staff and the facility's current periprocedural COVID-19 testing policies.

In this secondary analysis of INCAPS COVID 2, we compare data between U.S. and non-U.S. facilities (all non-U.S. facilities, in addition to only non-U.S. high-income country [NUHIC] facilities), as well as among U.S. regions as defined by the U.S. Census Bureau: Midwest, Northeast, South, and West (Table S1) (14). No patient-specific or confidential data were collected, and all participation by study sites was voluntary, therefore no external ethics committee review was deemed required. The study also complies with the Declaration of Helsinki. Moreover, the Columbia University Institutional Review Board determined that the work does not meet the criteria to be considered human subjects research under the Code of Federal Regulations Title 45: Public Welfare, Part 46, as there was no interaction with participants, no intervention, and no collection of private, identifiable information.

### Data Collection

Survey data were collected using a secure software platform hosted by the IAEA, the International Research Integration System *(https://iris.iaea.org)*. Using a standardized data collection form, each site provided procedure volume data for the following test types: stress electrocardiography (without associated imaging), stress echocardiography, stress SPECT, stress PET, stress cardiac MRI, coronary artery calcium CT, coronary CT angiography (CCTA), transthoracic echocardiography, transesophageal echocardiography, PET cardiac infection studies (fluorine 18 fluorodeoxyglucose to assess for intracardiac infection), nonstress cardiac MRI, and invasive coronary angiography.

The U.S. regional analysis included data compiled from external sources, including COVID-19 prevalence data (15) and U.S. demographic and socioeconomic data from the 2010 U.S. census (16). County-level COVID-19 and census data were compiled based on the county Federal Information Processing System codes, which were assigned to each facility on the basis of the county in which the facility operates. While more granular COVID-19 data were not consistently available, census-level data were also aggregated at the ZIP Code Tabulation Area (ZCTA) level for each facility. ZCTAs were assigned to each facility using the zip code in which the facility operates.

### Statistical Analysis

Differences in frequency distributions were statistically compared using Pearson $\chi^2$ and Fisher exact tests, and differences in continuous variables were compared using Wilcoxon rank sum and Kruskal-Wallis tests. A robust regression model using Huber M-estimator to reduce the weight of influential outliers was used to determine factors associated with procedure volume change in the United States between March 2019 and April 2021 (17). Variables with a *P* value less than or equal to .20 in bivariate analyses were included in a full multivariable model. A second multivariable model was analyzed, in which final inclusion was based on stepwise elimination of variables exceeding a significance level of .10. Variables considered in the model were county COVID-19 prevalence (cases per 10 000) and death rate (deaths per 10 000) on April 30, 2021, teaching facility, inpatient facility, urban facility (defined as a facility located in a county in a metro area with population > 1 million), use of telehealth for patient care, baseline procedure volume in 2019, percentage of physician staff with increased psychologic stress related to the pandemic, political party affiliation of the state governor in April 2021, and ZCTA-level census demographics, including household income and percentage of the population with high school education, unemployed, Black race, and foreign born. A two-tailed *P* value less than .05 was considered statistically significant. Statistical analysis was conducted using Stata/SE (version 15.1; StataCorp). The authors had full access to and take full responsibility for the integrity of the data.

## Results

### Facility Characteristics

Characteristics for U.S. and non-U.S. imaging centers are summarized in Table 1. Worldwide data were analyzed from a final sample of 669 facilities (220 newly recruited and 449 returning participants from the first INCAPS COVID study) in 107 countries, including U.S. data from 93 facilities (26 new and 67 returning) located in 71 distinct counties in 34 U.S. states. Procedure volume data were submitted from 79 U.S. centers, totaling 262 691 studies (107 582 in March 2019, 33 858 in April 2020, and 121 251 in April 2021), and 505 non-U.S. centers, totaling 930 235 studies (401 868 in March 2019, 149 613 in April 2020, and 378 754 in April 2021) for a combined 1.2 million imaging studies. Baseline procedure volume per center was higher for U.S. facilities compared with all non-U.S. facilities (951 vs 222, *P* < .001) and NUHIC facilities (951 vs 300, *P* < .001). The proportion of surveys submitted by inpatient facilities in the United States was lower than that for non-U.S. centers (77% vs 88%, *P* = .006) and NUHIC centers (77% vs 95%, *P* < .001). Cardiologists submitted a greater proportion of surveys for U.S. facilities (76%) than for non-U.S. facilities (36%), whereas nuclear medicine physicians submitted more surveys for non-U.S. facilities (39%) compared with U.S. facilities (3%, Table S2).

### Procedure Volumes for U.S., Non-U.S., and NUHIC Centers

The median percentage change in procedure volumes from March 2019 to April 2020 and March 2019 to April 2021 are summarized in Table 2 and Figure 1. The median change in procedure volumes during the early pandemic (April 2020) was similar between U.S. and non-U.S. facilities (−66% vs −71%, *P* = .27) and U.S. and NUHIC facilities (−66% vs −62%, *P* = .221). U.S. facilities reported greater return to baseline from March 2019 to April 2021 compared with non-U.S. facilities (4% vs −6%, *P* = .008) but not compared with NUHIC facilities (4% vs 0%, *P* = .18). By April 2021, U.S. centers reported significantly greater return to baseline than did non-U.S. centers for stress electrocardiography, stress echocardiography, stress SPECT, stress cardiac MRI, coronary artery calcium CT, CCTA, transthoracic echocardiography, and transesophageal echocardiography. U.S. facilities also reported greater return to baseline than did NUHIC centers for most procedure types; however, the difference was significant only for stress electrocardiography and stress cardiac MRI. We also analyzed the change in aggregated total procedures (Fig 2), which showed that U.S. facilities reported greater return of total procedure volumes for most procedure types. Stress testing volumes remained depressed in non-U.S. facilities (−16%) compared with U.S. facilities (−2%) in April 2021, while coronary artery calcium CT, CCTA, and cardiac MRI volumes were higher in both U.S. (8%, 22%, and 55%, respectively) and non-U.S. (27%, 13%, and 35%, respectively) facilities.

Figure 3 compares the reduction and return to baseline of U.S. cardiac testing and non-U.S. facilities by income level. Significant differences were observed in April 2020 reductions, in which the median declines in low- (−70%), lower-middle- (−86%), and upper-middle- (−79%) income countries were of greater magnitude than for NUHICs (−62%) and the United States (−66%, *P* < .001). Significant differences were also observed in April 2021, where low- (−50%) and lower-middle- (−41%) income countries reported persistent and substantial declines compared with 2019,

**Table 1: Characteristics for U.S., Non-U.S., and U.S. Regional Imaging Facilities**

| | U.S. Regional Facilities | | | | | Worldwide Facilities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Midwest | Northeast | South | West | *P* Value | U.S. Facilities | All Non-U.S. Facilities | *P* Value | NUHIC Facilities | *P* Value |
| No. of centers | 18 | 30 | 30 | 15 | | 93 | 576 | | 290 | |
| No. of U.S. states or non-U.S. countries | 10 | 7 | 12 | 5 | | 34 | 106 | | 47 | |
| Participated in INCAPS COVID 1 | 15 (83) | 20 (67) | 23 (77) | 9 (60) | | 67 (72) | 382 (66) | | 191 (66) | |
| No. of procedures | | | | | | | | | | |
| March 2019 | 26 164 | 41 768 | 27 881 | 11 769 | | 107 582 | 401 868 | | 178 716 | |
| April 2020 | 7181 | 11 711 | 8893 | 6073 | | 33 858 | 149 613 | | 80 475 | |
| April 2021 | 28 747 | 48 307 | 32 017 | 12 180 | | 121 251 | 378 754 | | 179 608 | |
| Type of test* | | | | | | | | | | |
| Stress ECG | 12 (67) | 21 (70) | 18 (60) | 6 (40) | .28 | 57 (61) | 216 (38) | <.001 | 119 (41) | <.001 |
| Stress echo | 13 (72) | 21 (70) | 12 (40) | 6 (40) | .06 | 52 (56) | 168 (29) | <.001 | 96 (33) | <.001 |
| Stress SPECT | 14 (78) | 22 (73) | 22 (73) | 11 (73) | .82 | 69 (74) | 345 (60) | .001 | 195 (67) | .01 |
| Stress PET | 4 (22) | 9 (30) | 7 (23) | 5 (33) | .72 | 25 (27) | 40 (7) | <.001 | 21 (7) | <.001 |
| Stress cardiac MRI | 7 (39) | 6 (20) | 6 (20) | 4 (27) | .58 | 23 (25) | 94 (16) | .03 | 53 (18) | .09 |
| CAC CT | 14 (78) | 14 (47) | 12 (40) | 6 (40) | .15 | 46 (49) | 146 (25) | <.001 | 70 (24) | <.001 |
| CCTA | 14 (78) | 16 (53) | 15 (50) | 8 (53) | .49 | 53 (57) | 270 (47) | .02 | 160 (55) | .28 |
| TTE | 13 (72) | 21 (70) | 17 (57) | 7 (47) | .53 | 58 (62) | 216 (38) | <.001 | 133 (46) | <.001 |
| TEE | 12 (67) | 17 (57) | 11 (37) | 6 (40) | .33 | 46 (49) | 179 (31) | <.001 | 120 (41) | .04 |
| PET infection | 2 (11) | 2 (7) | 4 (13) | 1 (7) | .78 | 9 (10) | 77 (13) | .37 | 56 (19) | .05 |
| Cardiac MRI | 13 (72) | 17 (57) | 9 (30) | 8 (53) | .06 | 47 (51) | 210 (36) | .003 | 133 (46) | .15 |
| Invasive coronary angiography | 12 (67) | 13 (43) | 13 (43) | 7 (47) | .60 | 45 (48) | 186 (32) | .001 | 111 (38) | .18 |
| Baseline procedures per center† | 1081 (235–1849) | 1062 (429–1832) | 573 (318–1738) | 612 (408–1529) | .83 | 951 (323–1826) | 222 (74–885) | <.001 | 300 (87–975) | <.001 |
| Hospital beds | 638 (450–810) | 682 (294–882) | 430 (300–710) | 492 (400–800) | .49 | 560 (300–859) | 500 (242–928) | .67 | 600 (320–1000) | .16 |
| Inpatient center | 16 (89) | 24 (80) | 21 (70) | 11 (73) | .47 | 72 (77) | 506 (88) | .006 | 276 (95) | <.001 |
| Teaching institution | 13 (72) | 20 (67) | 21 (70) | 11 (73) | .96 | 65 (70) | 410 (71) | .80 | 223 (77) | .17 |

Note.—Values are numbers, with percentages in parentheses, or medians, with IQRs in parentheses. CAC = coronary artery calcium, CCTA = coronary CT angiography, ECG = electrocardiography, echo = echocardiography, INCAPS COVID 1 = International Atomic Energy Agency Noninvasive Cardiology Protocols Study of COVID-19, NUHIC = non-U.S. high income country, TEE = transesophageal echocardiography, TTE = transthoracic echocardiography.

* Percentages displayed in parentheses refer to the percentage of centers that reported procedure volume data for each specific test (*n* is the number of facilities reporting procedure volume data).

† March 2019 procedure volumes considered as baseline.

while upper-middle-income countries (−13%), NUHICs (0%), and the United States (4%) reported procedure volumes near or at prior 2019 baseline volumes ($P < .001$).

## Procedure Volumes for U.S. Centers by Region

The reduction and return to baseline of procedure volumes are summarized by U.S. region (Table 2 and Fig 4) and state (Fig S1). The median change in procedure volumes among U.S. regions differed, both early in the pandemic in April 2020 ($P = .01$) and in return to baseline of procedures in April 2021 ($P = .03$, Table 2). Facilities in the Midwest (−64%), Northeast (−70%), and South (−73%) reported greater declines than did facilities in the West (−46%) during the early pandemic ($P = .014$). However, facilities in the West also had the lowest return to baseline, with a median

**Table 2: Reduction and Return to Baseline of Cardiac Procedure Volumes by Diagnostic Test and Facility Characteristics**

| | U.S. Regional Facilities | | | | | Worldwide Facilities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Midwest | Northeast | South | West | *P* Value | United States | All Non-U.S. | *P* Value | NUHIC | *P* Value |
| Change in procedures | | | | | | | | | | |
| March 2019 to April 2020 | −64 | −70 | −73 | −46 | .01 | −66 | −71 | .27 | −62 | .22 |
| March 2019 to April 2021 | 11 | 9 | 1 | −7 | .03 | 4 | −6 | .008 | 0% | .18 |
| Change in procedures by test type | | | | | | | | | | |
| Reduction (2019 to 2020) | | | | | | | | | | |
| Stress ECG | −96 | −92 | −94 | −68 | .15 | −93 | −85 | .046 | −81 | .03 |
| Stress echocardiography | −95 | −92 | −87 | −81 | .67 | −91 | −89 | .51 | −90 | .60 |
| Stress SPECT | −84 | −89 | −80 | −63 | .01 | −80 | −80 | .31 | −71 | .14 |
| Stress PET | −56 | −75 | −62 | −58 | .46 | −63 | −88 | .03 | −75 | .60 |
| Stress cardiac MRI | −75 | −98 | −68 | −86 | .71 | −75 | −90 | .69 | −100 | .49 |
| CAC CT | −95 | −84 | −100 | −94 | .21 | −93 | −85 | .30 | −75 | .06 |
| CCTA | −57 | −67 | −64 | −58 | .91 | −65 | −64 | .94 | −50 | .27 |
| TTE | −58 | −62 | −67 | −40 | .14 | −60 | −59 | .09 | −50 | .07 |
| TEE | −93 | −79 | −71 | −71 | .19 | −78 | −84 | .28 | −75 | .79 |
| PET infection | −25 | −96 | −100 | −100 | .22 | −100 | −67 | .13 | −60 | .04 |
| Cardiac MRI | −83 | −80 | −67 | −60 | .77 | −72 | −73 | .42 | −67 | .12 |
| Invasive coronary angiography | −71 | −68 | −60 | −48 | .02 | −65 | −51 | .01 | −44 | <.001 |
| Return to baseline (2019 vs 2021) | | | | | | | | | | |
| Stress ECG | −5 | −13 | −20 | 0 | .91 | −13 | −35 | .001 | −33 | .002 |
| Stress echocardiography | 0 | −18 | −10 | −18 | .75 | −11 | −28 | .04 | −23 | .19 |
| Stress SPECT | −9 | −10 | 1 | 0 | .75 | −6 | −20 | .008 | −14 | .17 |
| Stress PET | 9 | 38 | 0 | −17 | .90 | 0 | −8 | .20 | 0 | .71 |
| Stress cardiac MRI | 38 | 81 | −13 | 63 | .86 | 14 | −20 | .02 | −20 | .04 |
| CAC CT | 2 | 2 | −23 | −12 | .27 | 0 | −14 | .03 | 0 | .31 |
| CCTA | 38 | 33 | 11 | 0 | .65 | 22 | 0 | .047 | 5 | .35 |
| TTE | 17 | 8 | 0 | 3 | .44 | 8 | −6 | <.001 | 0 | .08 |
| TEE | 21 | 1 | −32 | 12 | .06 | 10 | −12 | .045 | −3 | .35 |
| PET infection | −17 | −58 | 0 | −100 | .11 | −20 | 0 | .44 | 0 | .21 |
| Cardiac MRI | 30 | 14 | 20 | −9 | .45 | 16 | 0 | .22 | 6 | .28 |
| Invasive coronary angiography | −1 | 8 | −40 | −12 | .049 | −2 | −13 | .15 | −7 | .41 |
| Change in procedures by facility type | | | | | | | | | | |
| Reduction (2019 to 2020) | | | | | | | | | | |
| Outpatient | −77 | −57 | −76 | −19 | .14 | −55 | −79 | .08 | −74 | .11 |
| Inpatient | −64 | −71 | −73 | −51 | .08 | −66 | −69 | .69 | −61 | .38 |
| Return to baseline (2019 vs 2021) | | | | | | | | | | |
| Outpatient | 15 | 19 | 3 | 38 | .71 | 15 | 0 | .30 | −16 | .59 |

***(Table 2 continues)***

**Table 2 *(continued)*: Reduction and Return to Baseline of Cardiac Procedure Volumes by Diagnostic Test and Facility Characteristics**

| | U.S. Regional Facilities | | | | | Worldwide Facilities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Midwest | Northeast | South | West | *P* Value | United States | All Non-U.S. | *P* Value | NUHIC | *P* Value |
| Inpatient | 9 | 8 | 0 | −12 | .15 | 3 | −7 | .26 | 0 | .30 |
| Change in procedures by teaching status | | | | | | | | | | |
| Reduction (2019 to 2020) | | | | | | | | | | |
| Nonteaching | −64 | −56 | −72 | −21 | .20 | −64 | −73 | .29 | −61 | .54 |
| Teaching | −64 | −74 | −73 | −51 | .02 | −68 | −70 | .54 | −63 | .25 |
| Return to baseline (2019 vs 2021) | | | | | | | | | | |
| Nonteaching | 15 | 9 | 4 | 56 | .90 | 9 | −8 | .09 | 0 | .32 |
| Teaching | 8 | 9 | 0 | −8 | .17 | 3 | −6 | .045 | 0 | .37 |

Note.—Values are percentages. Percentage change is reported as the median of the percentage change of all individual facilities in each category. CAC = coronary artery calcium, CCTA = coronary CT angiography, ECG = electrocardiography, NUHIC = non-U.S. high-income countries, TEE = transesophageal echocardiography, TTE = transthoracic echocardiography.

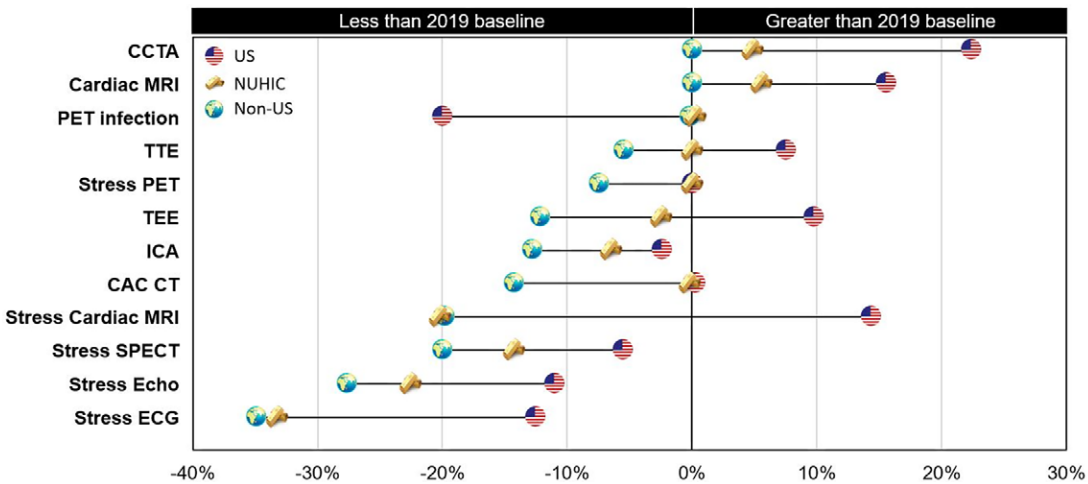


**Figure 1:** Change in diagnostic cardiovascular testing in 2021 compared with prepandemic procedure baseline volumes. Chart compares the median percentage change in procedure volumes of U.S. (represented by U.S. flag), NUHIC (represented by gold bars), and all non-U.S. (represented by world globe) facilities from March 2019 to April 2021. Percentage change represents the median of the percentage change values of all individual facilities in each category. Procedure types on the vertical axis are shown in descending order of percentage change for all non-U.S. facilities. CAC = coronary artery calcium, CCTA = coronary CT angiography, ECG = electrocardiography, Echo = echocardiography, ICA = invasive coronary angiography, NUHIC = non-U.S. high-income country, TEE = transesophageal echocardiography, TTE = transthoracic echocardiography.

change in procedure volume of −7% in April 2021 compared with baseline, whereas, the median volume change was greater than baseline in the Midwest (11%), Northeast (9%), and South (1%, $P = .03$). No studied factors were significantly associated with change in procedure volume from 2019 to 2021 in U.S. facilities in a multivariable regression analysis (Table S3).

## Operational Capacity, Safety Policies, and Staffing

Table 3 summarizes the number of facilities that reported current use of various operational, safety, and staffing policies at the time of survey completion. Rates of telehealth use for both patient care (61% vs 38%, $P < .001$) and nonpatient care activities, such as remote reading of studies (53% vs 34%, $P < .001$), were significantly higher in U.S. facilities compared with all non-U.S. facilities and nearly twofold greater compared with NUHIC facilities. Compared with all non-U.S. and NUHIC facilities, significantly more U.S. facilities reported requiring that patients complete symptom screening questionnaires and wear face masks, while fewer U.S. facilities reported limiting accompanying family mem-

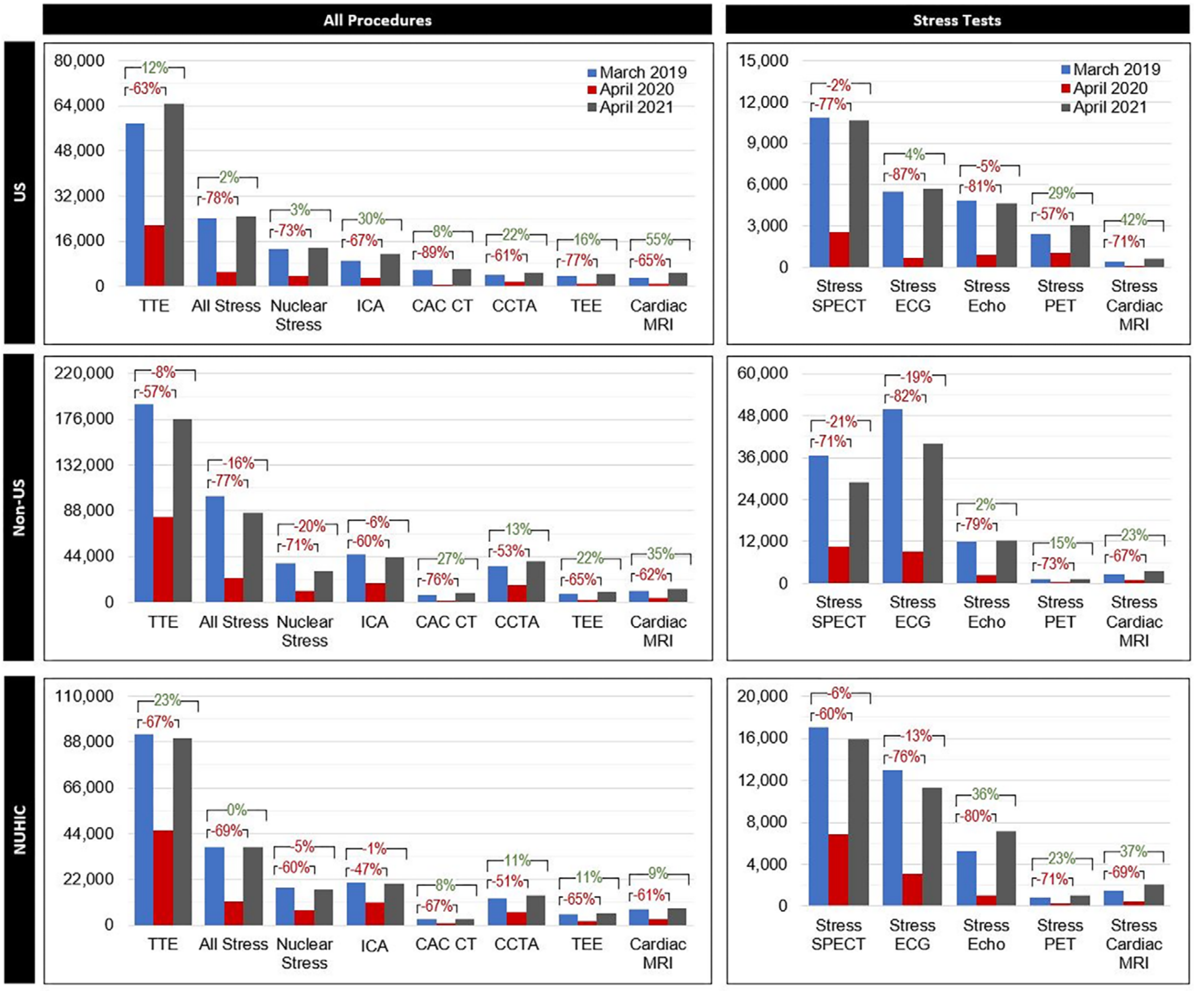


**Figure 2:** Change in total procedure volumes by procedure type. Clustered bar graphs show the total procedure volumes for March 2019 (blue), April 2020 (red), and April 2021 (gray) by procedure type for U.S., non-U.S., and NUHIC facilities. Percentage change values represent the change in total summed procedures of all individual facilities in each category (in contrast to the median of the individual percentage change values shown in the central illustration) from 2019 to 2020 (bottom bracket) and 2019 to 2021 (top bracket). Nuclear stress testing includes stress SPECT and stress PET. PET infection testing is not shown in the figure because of the small sample size. CAC = coronary artery calcium, CCTA = coronary CT angiography, ECG = electrocardiography, Echo = echocardiography, ICA = invasive coronary angiography, NUHIC = non-U.S. high-income country, TEE = transesophageal echocardiography, TTE = transthoracic echocardiography.

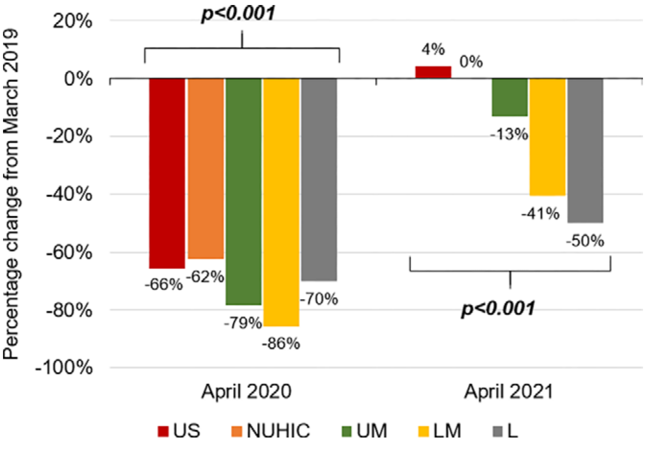


**Figure 3:** Median reduction and return to baseline of procedure volumes by country income level. Clustered bar chart shows the median percentage change in diagnostic cardiovascular procedure volumes in April 2020 (left) and April 2021 (right) compared with prepandemic baseline by country income level. Facilities in lower-middle-income countries (LM) and low-income countries (L) reported significantly lower recovery of procedure volumes in 2021 compared with facilities in upper-middle-income countries (UM), NUHIC, and the United States, which reported volumes near or at 2019 baselines. Percentage change was calculated as the median value of the percentage change of all individual facilities in each category. NUHIC = non-U.S. high income countries.

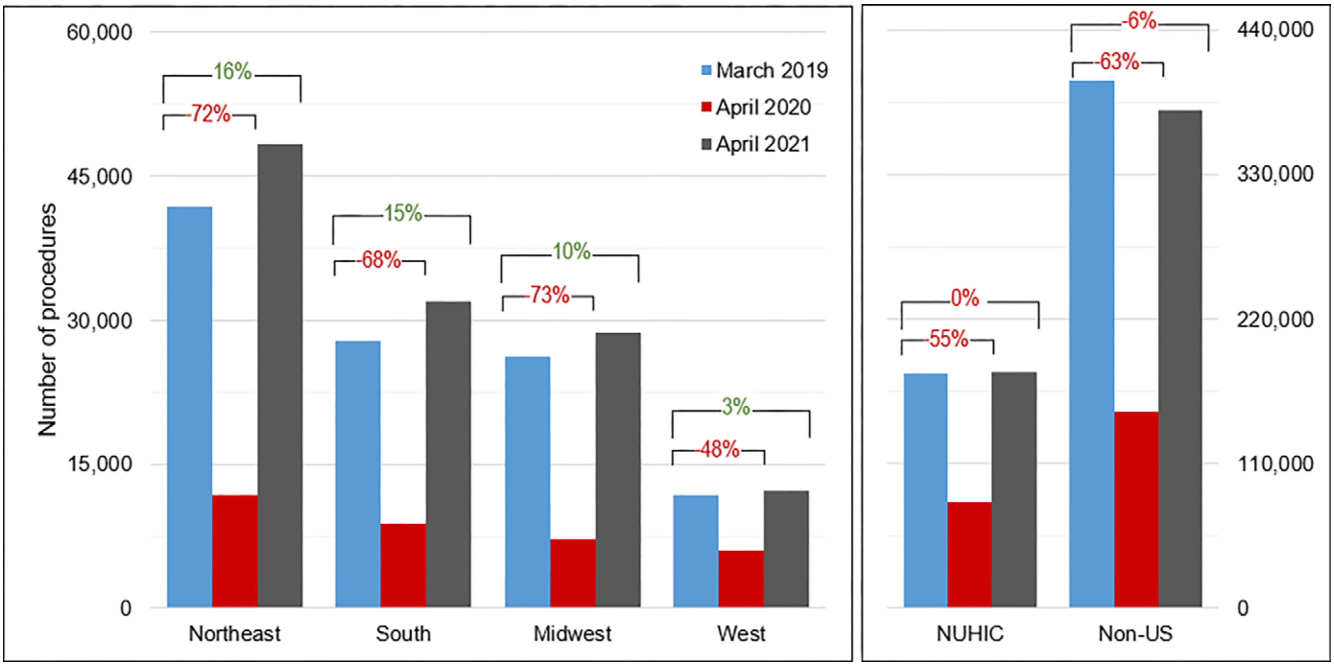


**Figure 4:** Change in total cardiovascular procedure volumes by U.S. region, NUHIC, and all non-U.S. centers. The percentage change values represent the change in total summed procedures of all individual facilities from 2019 to 2020 (bottom bracket) and 2019 to 2021 (top bracket). NUHIC = non-U.S. high income countries.

**Table 3: Changes in Capacity, Practices, Protocols, and Staffing Applied in April 2021**

| | U.S. Regional Facilities | | | | | Worldwide Facilities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Type of Change | Midwest ($n$ = 18) | Northeast ($n$ = 30) | South ($n$ = 30) | West ($n$ = 15) | $P$ Value | United States ($n$ = 93) | Non-U.S. ($n$ = 576) | $P$ Value | NUHIC ($n$ = 288) | $P$ Value |
| Change in capacity | | | | | | | | | | |
| Extended hours compared with prepandemic | 3 (19) | 6 (20) | 3 (10) | 6 (40) | .17 | 18 (20) | 96 (17) | .46 | 50 (17) | .57 |
| New weekend hours compared with prepandemic | 3 (19) | 5 (17) | … | 4 (27) | .02* | 12 (13) | 70 (12) | .73 | 30 (10) | .43 |
| Reduced hours compared with prepandemic | … | 2 (7) | 3 (10) | 1 (7) | .72 | 6 (7) | 107 (19) | .004* | 24 (8) | .60 |
| Systemic approach to reschedule studies postponed due to pandemic | 6 (38) | 10 (33) | 14 (48) | 6 (40) | .72 | 36 (40) | 242 (43) | .65 | 117 (41) | .90 |
| Use of telehealth for direct patient interactions | 11 (73) | 16 (53) | 17 (59) | 10 (67) | .60 | 54 (61) | 215 (38) | <.001* | 94 (33) | <.001* |
| Use of telehealth for remote reading/reporting of studies | 7 (44) | 16 (53) | 18 (62) | 7 (47) | .62 | 48 (53) | 191 (34) | .001* | 73 (25) | <.001* |
| Use of telehealth for review of studies with referring providers | 6 (33) | 12 (40) | 14 (47) | 9 (60) | .47 | 41 (44) | 162 (29) | .004* | 56 (20) | <.001* |
| Change in practice | | | | | | | | | | |
| Alteration in patient transport (eg, spacing use of elevators) | 12 (75) | 16 (53) | 15 (50) | 10 (67) | .35 | 53 (58) | 344 (61) | .73 | 167 (58) | .97 |
| Change in waiting areas to allow physical distancing | 15 (94) | 27 (90) | 27 (90) | 14 (93) | >.99 | 83 (91) | 492 (86) | .24 | 246 (85) | .16 |
| Separate spaces for patients with and without COVID-19 | 12 (75) | 23 (77) | 18 (60) | 10 (67) | .52 | 63 (69) | 449 (79) | .04* | 222 (77) | .12 |
| Reduced patient time in waiting room | 13 (81) | 22 (73) | 20 (67) | 11 (73) | .79 | 66 (73) | 407 (72) | .90 | 194 (67) | .36 |

***(Table 3 continues)***

**Table 3 (*continued*): Changes in Capacity, Practices, Protocols, and Staffing Applied in April 2021**

| Type of Change | U.S. Regional Facilities | | | | | Worldwide Facilities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Midwest (*n* = 18) | Northeast (*n* = 30) | South (*n* = 30) | West (*n* = 15) | *P* Value | United States (*n* = 93) | Non-U.S. (*n* = 576) | *P* Value | NUHIC (*n* = 288) | *P* Value |
| Limitation of accompanying family members and/or visitors | 12 (75) | 16 (53) | 25 (83) | 14 (100) | .004* | 67 (74) | 502 (89) | .001* | 247 (86) | .01* |
| Temperature measurements for all patients and visitors | 10 (63) | 14 (47) | 21 (70) | 8 (53) | .31 | 53 (58) | 388 (68) | .07 | 169 (59) | .91 |
| Screening questionnaire to all patients and visitors | 16 (89) | 26 (87) | 26 (87) | 13 (87) | >.99 | 81 (87) | 400 (70) | <.001* | 197 (68) | <.001* |
| Require cloth or surgical mask for all patients and visitors | 16 (89) | 29 (97) | 27 (90) | 14 (93) | .78 | 86 (92) | 462 (81) | .005* | 232 (80) | .005* |
| Change in staffing (for cardiac testing) | | | | | | | | | | |
| Temporarily furloughed physicians | … | 1 (3) | … | 1 (7) | | 2 (2) | 20 (4) | | 1 (0) | |
| Temporarily furloughed nonphysician staff | 1 (6) | 1 (3) | 1 (3) | 1 (7) | .32 | 4 (4) | 20 (4) | .76 | … | .08 |
| Reduced salaries of physicians | 1 (6) | 1 (3) | 1 (3) | … | .83 | 3 (3) | 43 (8) | .76 | 6 (2) | .003* |
| Reduced salaries of nonphysician staff | 2 (12) | 1 (3) | 1 (3) | … | >.99 | 4 (4) | 32 (6) | .18 | 3 (1) | .45 |
| Laid off physicians | 1 (6) | … | … | 1 (7) | .55 | 2 (2) | 7 (1) | .81 | … | .06 |
| Laid off nonphysician staff | … | … | 1 (3) | 1 (7) | .12 | 2 (2) | 14 (2) | .36 | 1 (0) | .06 |

Note.—Values are numbers, with percentages in parentheses. Table displays the proportion of facilities that reported current/ongoing use of these changes in April 2021. NUHIC = non-U.S. high income countries.
*Significant *P* value (<.05).

bers and/or visitors. The median reported percentage of staff with excess psychologic stress related to the pandemic was 33% higher in U.S. facilities compared with NUHIC facilities for both physician (*P* = .03) and nonphysician (*P* = .02) staff (Table S4).

### COVID-19 Testing Policies

Specific COVID-19 testing policies by procedure are summarized in Table 4. U.S. facilities reported significantly greater use of COVID-19 testing prior to stress tests, transesophageal echocardiography, and invasive coronary angiography compared with non-U.S. and NUHIC facilities. More than three-quarters of U.S. facilities reported testing all patients for COVID-19 prior to transesophageal echocardiography and invasive coronary angiography compared with 44% and 54%, respectively, of non-U.S. facilities and 46% and 54% of NUHIC facilities. There was no evidence of a difference in testing policies before noninvasive cardiac testing, with most worldwide sites testing no patients prior to such studies in April 2021. There was also no evidence of differences in periprocedural COVID-19 testing policies among U.S. regions.

## Discussion

We examined data from 669 facilities in 107 countries to determine the extent of diagnostic cardiovascular procedure volume recovery in the United States compared with the rest of the world 1 year into the COVID-19 pandemic and to identify factors associated with return to baseline in the United States. The INCAPS COVID Investigators Group convened in the early pandemic to examine the impact of the COVID-19 pandemic on diagnostic cardiovascular procedures and reported a 64% decline in procedure volumes from 108 countries in April 2020 compared with March 2019 (8). A subgroup analysis of U.S. centers showed that declines in the United States were similar to those in the rest of the world (68% vs 63%, *P* = .24) (9). In the present study, we showed that cardiovascular procedure volumes in the United States had recovered to a greater extent than those in the rest of the world in April 2021. The median change in procedure volumes among U.S. facilities in April 2021 was 4% above March 2019 baseline volumes, whereas the median change among non-U.S. facilities was 6% below 2019 baseline volumes (*P* = .008), driven by disproportionately lower return of cardiovascular testing in low- (−50%) and lower-middle- (−41%) income countries where 2021 procedure volumes remained significantly depressed.

We also observed differences between the practices and policies implemented in U.S. and NUHIC facilities in early 2021. First, U.S. facilities reported twofold greater use of telehealth services compared with NUHIC facilities. According to a report published by the U.S. Department of Health and Human Services, the number of telehealth visits for Medicare beneficiaries increased by 63-fold from 2019 to 2020, from approximately

**Table 4: COVID-19 Testing Policies Used in April 2021**

| | U.S. Regional Facilities | | | | | Worldwide Facilities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Midwest ($n$ = 18) | Northeast ($n$ = 30) | South ($n$ = 30) | West ($n$ = 15) | $P$ Value | United States ($n$ = 93) | Non-U.S. ($n$ = 576) | $P$ Value | NUHIC ($n$ = 285) | $P$ Value |
| Prior to stress testing | | | | | | | | | | |
| All patients | 6 (35) | 11 (37) | 6 (20) | 6 (40) | | 29 (32) | 102 (18) | | 43 (15) | |
| Unvaccinated only | 4 (24) | 5 (17) | 6 (20) | 2 (13) | | 17 (18) | 42 (7) | | 18 (6) | |
| No patients | 7 (41) | 14 (47) | 18 (60) | 7 (47) | .74 | 46 (50) | 417 (74) | <.001 | 224 (79) | <.001 |
| Prior to noninvasive cardiac imaging | | | | | | | | | | |
| All patients | 4 (24) | 6 (20) | 4 (13) | 3 (20) | | 17 (18) | 86 (15) | | 32 (11) | |
| Unvaccinated only | 3 (18) | 3 (10) | 2 (7) | 1 (7) | | 9 (10) | 38 (7) | | 17 (6) | |
| No patients | 10 (59) | 21 (70) | 24 (80) | 11 (73) | .82 | 66 (72) | 432 (78) | .42 | 234 (83) | .07 |
| Prior to transesophageal echocardiography | | | | | | | | | | |
| All patients | 12 (71) | 25 (83) | 21 (72) | 11 (79) | | 69 (77) | 217 (44) | | 114 (46) | |
| Unvaccinated only | 3 (18) | 3 (10) | 3 (10) | 1 (7) | | 10 (11) | 31 (6) | | 14 (6) | |
| No patients | 2 (12) | 2 (7) | 5 (17) | 2 (14) | .85 | 11 (12) | 245 (50) | <.001 | 121 (49) | <.001 |
| Prior to diagnostic cardiac catheterization | | | | | | | | | | |
| All patients | 12 (71) | 25 (83) | 20 (67) | 11 (79) | | 68 (75) | 269 (54) | | 137 (54) | |
| Unvaccinated only | 3 (18) | 3 (10) | 4 (13) | 1 (7) | | 11 (12) | 25 (5) | | 14 (5) | |
| No patients | 2 (12) | 2 (7) | 6 (20) | 2 (14) | .75 | 12 (13) | 206 (41) | <.001 | 105 (41) | <.001 |

Note.—Values are numbers, with percentages in parentheses. Table displays the proportion of facilities using each periprocedural COVID-19 testing policy in April 2021. NUHIC = non-U.S. high income countries.

840 000 to 52.7 million visits (18). The rapid transition from in-person to telehealth visits in the United States was largely facilitated by the Centers for Medicare & Medicaid Services, which amended regulations to increase telehealth reimbursements and removed geographic barriers to care (19). Indeed, telehealth use has also risen in other high-income countries, but, in many cases, to a lesser extent. A lack of developed telemedicine services and policies governing reimbursements in many NUHICs may have slowed widespread adoption (20,21). Though further studies are needed to gauge the long-term impact of increased telehealth use on patient outcomes, studies have already shown that telehealth is associated with increased patient satisfaction, improved patient retention, and improved access to care for a wide range of patient populations and communities (22–24).

We also found that recovery was not equal for all procedure types. Stress testing modalities had the poorest recovery worldwide. In contrast, CCTA had the greatest recovery, with volumes at or above prepandemic levels in U.S. (22%), non-U.S. (0%), and NUHIC (5%) facilities. Exercise stress testing is an aerosolizing procedure that can expose staff to respiratory droplets and was thus discouraged during the acute phase of the pandemic by some societal guidelines (25). On the other hand, CT offers shorter testing times and reduced contact between patients and staff, which may have been a factor in some facilities throughout the pandemic. Median change in cardiac MRI volumes (16%) was second behind CCTA in the United States, and stress cardiac MRI (14%) had the greatest return of all stress testing modalities, suggesting a general trend toward greater use of advanced imaging modalities in the United States. Further studies are needed to better characterize and understand the potential practice changes observed in U.S. facilities in the recovery phase of the COVID-19 pandemic.

Finally, we found that regional recovery in the United States was greatest in the Northeast and Midwest and lowest in the South and West. Though this difference was statistically significant, the source of the difference was not apparent, considering that significant variations among U.S. regions were not observed for most procedure types, and factors such as COVID-19 prevalence, facility type, practice setting, baseline procedure volume, telehealth use, and demographic characteristics of the surrounding community were not associated with return of U.S. procedure volumes in a multivariable regression model.

This study had several limitations. Information was obtained through an online survey, making data prone to potential biases (eg, selection bias or nonresponse bias) and inaccuracies through incomplete, erroneous, or unverified responses. To mitigate this, comprehensive efforts (as described in the Methods section) were undertaken to ensure broad and diverse participation in the survey, and we established a data coordination committee to scrutinize responses for potential errors during the data collection period and contacted individual sites for clarifications when necessary. U.S. regional response rates varied, and the extent to which the facilities in our study represent the distribution of cardiovascular imaging centers in the United States is unknown. Nevertheless, within the United States, there were no regional differences in the proportion of facilities performing each procedure type. Additionally, nearly half of facilities reported procedure volume data for the majority of procedure types, signifying inclusion of a diverse sample of imaging centers. We were not able to directly measure the clinical impact of the changes in cardiovascular diagnostic procedures that were observed, however, changes in health care use can have important clinical and public health implications, and our study provides a foundation for future research to examine broader changes in health care use during the COVID-19 pandemic. The IAEA also plans to lead the implementation of INCAPS 4 in late 2023, which will provide updated data on global cardiovascular procedure volumes, in addition to technology, protocols, and radiation dosing trends. Finally, our ability to detect factors associated with change in procedure volumes in a multivariable analysis was likely limited by the sample size of U.S. facilities. Furthermore, the potential impact of confounding variables, such as shifting clinical practice and evolving guidelines, may have influenced the observed changes in procedures volumes. Still, participation from 93 centers across 34 states makes this one of the largest analyses of diagnostic cardiovascular procedures reported in the United States published to date.

In conclusion, we observed significantly greater return of diagnostic cardiovascular procedure volumes in the United States compared with the rest of the world 1 year into the COVID-19 pandemic. This difference was attributable to incomplete recovery reported by facilities in lower-income countries, given that recovery was generally similar between facilities in the United States and other high-income countries. The recovery phase of the pandemic has also resulted in a uniform trend toward increased use of advanced imaging modalities, such as CCTA and cardiac MRI, in U.S. and non-U.S. facilities, which requires further evaluation. Finally, return of U.S. procedure volumes was greatest in the Northeast and Midwest, but no additional factors were predictive of changes in U.S. procedure volumes in a multivariable model. As the COVID-19 pandemic remains a global threat, U.S. and NUHIC institutions have managed to return to cardiovascular procedure volumes at or above prepandemic levels, while recovery still lags in lower-income countries. To address potential excess morbidity and mortality rates from CVD in economically disadvantaged regions, a multifaceted approach is necessary, which may include strategies such as increasing telehealth infrastructure, leveraging mobile clinics, and improving health care worker training to augment recovery of cardiovascular diagnostic procedures.

**Acknowledgments:** The INCAPS COVID Investigators Group, listed by name in Appendix S1, thanks cardiology and imaging professional societies worldwide for their assistance in disseminating the survey to their memberships. These include, alphabetically, but are not limited to, American Society of Nuclear Cardiology, Arab Society of Nuclear Medicine, Australasian Association of Nuclear Medicine Specialists, Australia-New Zealand Society of Nuclear Medicine, Belgian Society of Nuclear Medicine, Brazilian Nuclear Medicine Society, British Society of Cardiovascular Imaging, Conjoint Committee for the Recognition of Training in CT Coronary Angiography Australia and New Zealand, Consortium of Universities and Institutions in Japan, Danish Society of Cardiology, Gruppo Italiano Cardiologia Nucleare, Indonesian Society of Nuclear Medicine, Japanese Society of Nuclear Cardiology, Moscow Regional Department of Russian Nuclear Medicine Society, Philippine Society of Nuclear Medicine, Russian Society of Radiology, Sociedad Española de Medicina Nuclear e Imagen Molecular, Society of Cardiovascular Computed Tomography, and Thailand Society of Nuclear Medicine.

**Author contributions:** Guarantors of integrity of entire study, **C.B.H., A.J.E.**; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; agrees to ensure any questions related to the work are appropriately resolved, all authors; literature research, **C.B.H., L.J.S., A.D.C., N.B., J.V.V., M.C.W., M.A.M., R.P.B.P., D.W., M.J.R., T.N.B.P., D.P., A.J.E.**; clinical studies, **T.C.V., A.D.C., N.B., J.V.V., M.A.M., M.J.B., M.Y.C., V.L.M., R.C.T., D.W., Y.A.C., M.J.R., Y.P., M.Y.C.**; statistical analysis, **C.B.H., L.J.S., T.C.V., G.K., M.C.W., Y.P., A.J.E.**; and manuscript editing, **C.B.H., S.D., L.J.S., T.C.V., A.D.C., N.B., R.J.C., G.K., J.V.V., M.C.W., M.A.M., D.S.B., A.B., P.E.B., M.J.B., R.P.B.P., M.Y.C., M.P.D., R.D., M.F., J.B.G., F.G.H., R.C.H., L.K., V.L.M., J.N., P.F.R.L., N.R.S., A.S., P.S., R.C.T., D.W., Y.A.C., E.M., M.J.R., J.L.M., P.P., M.S., T.N.B.P., M.D., D.P., A.J.E.**

**Disclosures of conflicts of interest:** **C.B.H.** No relevant relationships. **S.D.** Research grants to author's institution from Pfizer, GE HealthCare, Attralus, Siemens, and Philips; consulting fees from AstraZeneca and Novo Nordisk; support from Novo Nordisk for travel to an advisory board meeting. **L.J.S.** No relevant relationships. **T.C.V.** No relevant relationships. **A.D.C.** Grant support from GW Heart and Vascular Institute; consultant for Siemens Healthineers; equity in Cleerly. **N.B.** No relevant relationships. **R.J.C.** No relevant relationships. **G.K.** No relevant relationships. **J.V.V.** No relevant relationships. **M.C.W.** Support from the British Heart Foundation (FS/ICRF/20/26002); payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing, or education events from Canon Medical Systems, Siemens Healthineers, and Novartis; member of the *Radiology: Cardiothoracic Imaging* editorial board. **M.A.M.** Research support from Siemens; consulting fees from Jubilant and Philips; payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing, or educational events from Jubilant. **D.S.B.** Receives software royalties from Cedars-Sinai Medical Center; consultant for General Electric and Bayer. **A.B.** No relevant relationships. **R.W.B.** No relevant relationships. **P.E.B.** No relevant relationships. **M.J.B.** Grant support from General Electric. **R.P.B.P.** Women as One grant ($25 000), paid to author's institution; Knowledge to Practice honoraria ($500) for being a panelist during a virtual educational event; honoraria ($1000, $2500) from American College of Radiology for CME education products; member of American Society of Nuclear Cardiology board of directors, Intersocietal Accreditation Commission CT board of directors, and American College of Cardiology board of governors. **M.Y.C.** No relevant relationships. **M.P.D.** Salary support from Genentech for COVID-19 research. **R.D.** No relevant relationships. **M.F.** Grants or contracts from the National Institutes of Health (NIH) and the American Heart Association (AHA); consulting fees from Biography, Elucid, HeartFlow, and Siemens Healthineers; vice-president of the Society of Cardiovascular Computed Tomography; stock or stock options in Elucid. **J.B.G.** No relevant relationships. **F.G.H.** Grant support from GE HealthCare. **R.C.H.** No relevant relationships. **L.K.** Member of the *Radiology: Cardiothoracic Imaging* editorial board. **V.L.M.** Grants or contracts from the NIH, AHA, and Siemens; consulting fees from Siemens, INVIA Medical Imaging Solutions, and Ionetix; member of AHA Cardiovascular Radiology and Interventions Council Leadership Committee and the American Society of Nuclear Cardiology Program Committee; stock in General Electric, Ionetix, and Cardinal Health; scientific advisor to Ionetix; received software from INVIA Medical Imaging Solutions. **J.N.** No relevant relationships. **P.F.R.L.** Grants or contracts from iTHRIV Scholar, which is supported in part by the National Center for Advancing Translational Sciences of the NIH (award nos. UL1TR003015 and KL2TR003016); patent planned, issued, or pending number 3062/140PCT/US for "Methods, systems, and computer-readable media for utilizing US device to perform MV decalcification." **N.R.S.** Grant support from Pfizer; stock in General Electric. **A.S.** No relevant relationships. **P.S.** Grant funding from Pfizer to author's institution and from Astellas; royalties from UpToDate; personal consulting fees from Bridgebio (Eidos), Spectrum Dynamics, Pfizer, and Alnylam; member of the American Society of Nuclear Cardiology board of directors. **R.C.T.** No relevant relationships. **D.W.** Consultant for Astellas, BridgeBio, Pfizer, and Alnylam advisory boards; payment for speakers bureaus work from Astellas and Pfizer; chair of ASNC Health Policy Committee; member of advisory boards of Bridge Bio and Alynylam, and grant interviewer for Ionis. **Y.A.C.** No relevant relationships. **E.M.** No relevant relationships. **M.J.R.** No relevant relationships. **J.L.M.** No relevant relationships. **P.P.** Consulting fees from Medtronic and AstraZeneca. **M.S.** No relevant relationships. **T.N.B.P.** No relevant relationships. **Y.P.** No relevant relationships. **M.D.** No relevant relationships. **D.P.** No relevant relationships. **A.J.E.** Support from the International Atomic Energy Agency to Columbia University; grants from GE HealthCare, Canon Medical Systems, W.L. Gore & Associates, Eidos Therapeutics, Attralus, Pfizer, Roche Medical Systems, and Neovasc to Columbia University; speaker's fees from Ionetix; consulting fees from W. L. Gore & Associates; support from the Society of Nuclear Medicine and Molecular Imaging for attending meetings and/or travel; patents planned, issued, or pending for Columbia Technology Ventures; leadership or fiduciary role in the American College of Cardiology, American Society of Nuclear Cardiology, and the Society of Nuclear Medicine and Molecular Imaging; and authorship fees from Wolters Kluwer Healthcare–UpToDate.

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