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Cardiovascular testing recovery in Latin America one year into the COVID-19 pandemic: An analysis of data from an international longitudinal survey

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ABSTRACT

Background: The COVID-19 pandemic disproportionately impacted Latin America (LATAM), significantly disrupting cardiovascular testing. This study evaluated cardiac procedure recovery in LATAM one year after the outbreak.

Methods: The International Atomic Energy Agency (IAEA) surveyed 669 centers in 107 countries worldwide, including 135 facilities in 19 LATAM countries, to assess cardiovascular procedure volumes in March 2019, April 2020, and April 2021, and changes in center practices and staffing conditions one year into the COVID-19 pandemic.

Findings: LATAM centers reported a 21 % decrease in procedure volumes in April 2021 from pre-pandemic-baseline, vs. a 0 % change in the rest of the world (RoW), and greater volume reductions for almost all procedure types. Centers in Central America and Mexico reported the largest procedure reductions (47 % reduction) compared to the Caribbean (15 %), and South America (14 %, $p = 0.01$), and this LATAM region was a significant predictor of lower procedure recovery in multivariable regression. More LATAM centers reported reduced salaries and increased layoffs of clinical staff compared to RoW, and LATAM respondents estimated that half of physician and non-physician staff experienced excess psychological stress related to the pandemic, compared to 25 % and 30 % in RoW ($p < 0.001$).

Conclusions: Cardiovascular testing recovery in LATAM trailed behind RoW for most procedure types, with centers in Central America and Mexico reporting the greatest volume reductions. This study found lasting impacts of COVID-19 on cardiovascular care in LATAM and the need for mental health support for LATAM healthcare workers in current and future pandemics.

1. Introduction

In the latter half of the 20th century, Latin America experienced a transition from communicable to noncommunicable disease burden [1,2]. Improvements in clinical management of cardiovascular diseases, including greater access to cardiovascular diagnostic imaging, which is currently essential for early detection and appropriate treatment, [3,4] has led to significant reductions in cardiovascular mortality in Latin American countries. However, in early 2020, the COVID-19 pandemic spread around the world, placing enormous strain on Latin American hospital systems as resources were diverted to the care of the increasing number of patients infected with the virus. The international medical community soon became concerned that these disruptions could compromise the improvements in cardiovascular care made in the past decades in Latin America.

In early 2020, the International Atomic Energy Agency (IAEA) Noninvasive Cardiology Protocols Study (INCAPS) group surveyed 909 healthcare facilities in 108 countries to assess cardiovascular diagnostic imaging volumes following COVID-19-related healthcare disruptions. The INCAPS COVID 1 study found that worldwide implementation of cardiovascular testing decreased by 64 % from March 2019 to April 2020, one month after the onset of the pandemic [5]. Of note, disruptions in cardiovascular testing were greatest in low-income countries, which experienced disproportionate COVID-19 cases and infection fatality rates [6] and decreased access to tests and vaccines throughout the pandemic [7–10].

Starting in early 2021, healthcare systems attempted to adapt to the ongoing pandemic and resumed routine care of noncommunicable diseases. To assess the extent to which cardiac testing had resumed around the world, the INCAPS COVID group conducted a follow-up study in which 669 centers in 107 countries were surveyed one year after the onset of the pandemic. Initial analysis of the data showed a 97 % worldwide recovery of cardiac testing by April 2021 [11]. However, this recovery in procedure volumes was unequally distributed across world regions and by level of economic development. These disparities raised concerns about how the COVID-19 pandemic could have further exacerbated existing health disparities in lower income countries [12,13].

Since the onset of the pandemic, COVID-19 has disproportionately impacted Latin America, where 13 % of world cases and 25 % of deaths have been reported, while the region accounts for only 8 % of the world population [14,15]. Data from the first INCAPS COVID study showed that Latin America experienced one of the largest reductions in cardiac testing across the eight IAEA world regions, associated in part with strict quarantine measures and decreases in population mobility in the region [16]. Similarly, recent data from the INCAPS COVID 2 survey [11] has shown that disruptions in cardiac testing persisted in Latin America one year after the onset of the pandemic. The present study aims to further characterize the recovery of cardiac testing in Latin America, examining changes in procedure volumes, center practices, and testing protocols in April 2021 across 19 countries in the region, evaluating potential disparities in recovery of cardiac testing both within Latin America and compared to the rest of the world.

2. Methods

2.1. Study design

As previously described, [11] this study analyzed data collected by the INCAPS COVID 2 investigator group in a worldwide survey designed to assess recovery of cardiac diagnostic testing one year after the onset of the COVID-19 pandemic. The survey asked participating centers to provide information regarding testing facility characteristics changes in laboratory practices and testing protocols staffing conditions, supply of protective equipment, and estimated psychological stress of practitioners and estimated number of testing procedures performed in March 2019, April 2020, and April 2021. The cardiovascular tests included in this study are listed in Table 1. In this study, survey data was compared between Latin American (LATAM) facilities and centers from the rest of the world (RoW), and between centers in different Latin American regions and countries.

2.2. Data collection

Survey participants were asked to complete a secure questionnaire through IRIS, the International Research Integration System [17]. Efforts were taken to maximize the number and diversity of participating centers through professional outreach, social media campaigns, and recruitment by Latin American regional coordinators. After excluding duplicate and incomplete submissions, 669 survey entries were collected. Of these, 135 entries were collected from healthcare centers in Latin America (defined by IAEA-standard country coding), representing 19 countries: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Mexico, Panama, Paraguay, Peru, Uruguay, and Venezuela. Centers in these countries were further subdivided into the macro-regions of South America, Central America and Mexico, and the

Caribbean, according to standard United Nations designation [18]. The Columbia University Institutional Review Board determined that the study did not meet the criteria for human subjects research under 45 CFR 46.

2.3. Statistical analysis

Percentage changes in procedure volumes from March 2019 to April 2020 and April 2021 were calculated for each testing modality. Recovery rates of cardiac testing, defined as the change in procedure volumes in April 2021 from March 2019 baseline, relative to April 2020 decreases in testing volumes, were calculated as follows:

100 %*{1-[(March 2019 vol-April 2021 vol)/(March 2019 vol-April 2020 vol)]}, as previously described [11]. Differences in continuous variables were compared with non-parametric Wilcoxon rank sum and Kruskal-Wallis tests. Differences in frequency distributions of survey answers were compared using Fisher's exact tests.

A robust regression model that eliminates influential outliers and regresses iteratively using Huber weights and biweights [19] was constructed to identify factors associated with procedure recovery, defined above. Predictor variables tested in univariable analysis and considered for inclusion in the multivariable model include country income level (low-, lower middle-, upper-middle, high-income as defined by the World Bank), geographical region, estimated pandemic-related psychological stress of testing staff, hospital (vs. non-hospital) facility, teaching (vs. non-teaching) facility, number of hospital beds, baseline (March 2019) procedure volumes, COVID-19 cases, and COVID-19 vaccination rates. Variables with P-values ≤ 0.25 in univariable analysis were included in multivariable analysis. Maps displaying changes in testing volume and recovery rates across the Latin American region were generated with the rnaturalearth and tmap packages in R, while statistical analysis was performed using Stata/SE (version 15.1 StataCorp) and Microsoft Excel (version 16.80). A 2-tailed P-value < 0.05 was considered statistically significant.

3. Results

3.1. Characteristics of participating centers

As detailed in Table 1, survey responses were collected from a total of 669 facilities in 107 countries, of which 135 centers, representing 19 countries, were in Latin America. Centers in Latin America reported a total of 175,643 cardiovascular diagnostic procedures in the three one-month periods considered in this study – 85,450 in March 2019, 18,867 in April 2020, and 71,326 in April 2021, compared to 1,017,283 procedures performed in the rest of the world (RoW). Most testing modalities were performed by a smaller percentage of centers in Latin America compared to RoW. Baseline procedures per center were significantly lower in Latin America compared to RoW (139 vs. 390, $p < 0.001$), as were the number of hospital beds per center. Inpatient centers and teaching institutions comprised a significantly smaller proportion of survey respondents in Latin America, compared to RoW. Center characteristics between the regions differed solely in the number of hospital beds per center (213 in Central America and Mexico, 83 in the Caribbean, and 250 in South America, $p = 0.02$).

3.2. Changes in procedure volumes in Latin America vs. RoW

Latin American facilities reported a larger median decline in cardiovascular procedure volumes during the early stages of the pandemic: −79 % change from March 2019 to April 2020, compared to −70 % change for RoW, $p < 0.001$ (Table 2). This decline was greater for almost all imaging modalities. Lower procedure volumes persisted one year into the pandemic, with facilities in Latin America experiencing a 21 % median decline, compared to a 0 % change in RoW, $p < 0.001$ (Table 2, Supplementary Figure 1). Furthermore, mean procedure recovery in April 2021 was 14.4 % lower in Latin America compared to RoW ($p = 0.006$) in a multivariable regression model accounting for facility characteristics, national vaccination rate, and COVID-19 prevalence (Supplementary Table 1). Percent change from March 2019 to April 2021 was significantly lower in Latin America compared to RoW for stress SPECT, CAC, and CCTA. Of note, median percent changes from

Table 1
Characteristics of Participating Centers. Values are n, n(%), or median(interquartile range). P-values calculated by Fisher's exact test comparing the proportion of centers performing each test type and the proportion of inpatient and teaching centers, and by Wilcoxon rank sum and Kruskal-Wallis tests comparing baseline (March 2019) procedures per center and number of hospital beds per center between Latin America (LATAM) and the rest of the world (RoW), and between the three Latin American regions. March 2019 procedure volumes are considered baseline. Number of hospital beds and types of tests performed refer to April 2021 counts.

	LATAM Regions				Worldwide		
	Central America and Mexico	The Caribbean	South America	*P*	LATAM Facilities	RoW	*P*
Number of centers	29	5	101		135	534	
Number of countries	6	3	10		19	88	
Participated in INCAPS COVID 1	20 (69)	3 (60)	72 (71)		95 (71)	353 (66)	
Number of Procedures							
March 2019	8,683	3,982	72,785		85,450	424,000	
April 2020	2,791	390	15,686		18,867	164,604	
April 2021	5,691	3,221	62,414		71,326	428,679	
Type of Test							
Stress ECG	11 (38)	4 (80)	35 (35)	0.20	50 (37)	223 (42)	0.13
Stress Echocardiography	10 (34)	3 (60)	21 (21)	0.06	34 (25)	186 (35)	**0.009**
Stress SPECT	17 (59)	5 (100)	64 (63)	0.45	86 (64)	328 (61)	0.66
Stress PET	5 (17)	0 (0)	2 (2)	**0.007**	7 (5)	58 (11)	**0.04**
Stress CMR	6 (21)	0 (0)	26 (26)	0.45	32 (24)	85 (16)	0.08
CT coronary calcium	15 (52)	1 (20)	28 (28)	**0.03**	44 (33)	148 (28)	0.52
CT coronary angiography	15 (52)	1 (20)	40 (40)	0.25	56 (41)	267 (50)	**0.01**
TTE	9 (31)	2 (40)	25 (25)	0.59	36 (27)	238 (45)	**<0.001**
TEE	7 (24)	2 (40)	17 (17)	0.25	26 (19)	199 (37)	**<0.001**
PET infection	2 (7)	0 (0)	11 (11)	0.85	13 (10)	73 (14)	0.15
CMR	10 (34)	2 (40)	30 (30)	0.71	42 (31)	215 (40)	**0.01**
Invasive coronary angiography	9 (31)	2 (40)	19 (19)	0.20	30 (22)	201 (38)	**<0.001**
Baseline procedures per center	87 (38, 310)	147 (130, 601)	150 (72, 440)	0.28	139 (61, 425)	390 (95, 1091)	**<0.001**
Hospital Beds	213 (150, 300)	83 (15, 143)	250 (150, 450)	**0.02**	232 (143, 400)	582 (300, 1000)	**<0.001**
Inpatient center	20 (69)	3 (60)	67 (66)	1.0	90 (67)	488 (91)	**<0.001**
Teaching institution	19 (66)	3 (60)	52 (51)	0.41	74 (55)	401 (75)	**<0.001**

Table 2
Median changes in cardiovascular procedure volumes in 2020 and 2021 by diagnostic test. P-values comparing median percent change in procedure volumes calculated by Wilcoxon rank sum test for differences between Latin America (LATAM) and rest of the world (RoW), and Kruskal-Wallis test for differences between Latin American regions. ECG = electrocardiography, SPECT = single photon-emission computed tomography, PET = positron emission tomography, CMR = cardiac magnetic resonance, TTE = transthoracic echocardiography, TEE = transesophageal echocardiography, PET infection = positron emission tomography for infectious endocarditis.

	LATAM Regions				Worldwide		
	Central America and Mexico	The Caribbean	South America	*P*	LATAM laboratories	RoW	*P*
Change in procedures							
March 2019 to April 2020	−82 %	−96 %	−79 %	0.49	−79 %	−70 %	**<0.001**
March 2019 to April 2021	−47 %	−15 %	−14 %	**0.01**	−21 %	0 %	**<0.001**
Change in procedures by test type							
Reduction (2019 to 2020)							
Stress ECG	−85 %	−80 %	−93 %	0.96	−90 %	−87 %	0.28
Stress echocardiography	−69 %	−100 %	−89 %	0.29	−89 %	−90 %	0.42
Stress SPECT	−90 %	−100 %	−89 %	0.08	−91 %	−79 %	**0.007**
Stress PET	−100 %	–	−100 %	0.33	−87 %	−73 %	**0.006**
Stress CMR	−72 %	–	−76 %	0.51	−75 %	−100 %	0.07
CT coronary calcium	−98 %	−100 %	−90 %	0.33	−93 %	−85 %	0.16
CT coronary angiography	−87 %	−94 %	−73 %	0.09	−77 %	−59 %	**0.007**
TTE	−75 %	−74 %	−70 %	0.82	−71 %	−58 %	**0.05**
TEE	−100 %	−86 %	−90 %	0.61	−90 %	−80 %	**0.04**
PET infection	−100 %	–	−100 %	0.53	−100 %	−60 %	**0.002**
CMR	−89 %	−100 %	−81 %	0.13	−83 %	−67 %	**0.009**
Invasive coronary angiography	−79 %	−69 %	−65 %	0.51	−66 %	−54 %	**0.03**
Change in procedures by test type							
Return to baseline (2019 vs 2021)							
Stress ECG	−45 %	−18 %	–33 %	0.27	−34 %	−25 %	0.31
Stress echocardiography	−29 %	−52 %	−39 %	0.92	−66 %	–23 %	0.39
Stress SPECT	−55 %	−17 %	−29 %	**0.03**	–33 %	−15 %	**0.006**
Stress PET	25 %	–	−40 %	0.25	0 %	0 %	0.93
Stress CMR	−47 %	–	−5%	0.16	−20 %	−2%	0.53
CT coronary calcium	−50 %	−16 %	−31 %	0.68	–33 %	0 %	**0.01**
CT coronary angiography	−50 %	115 %	−8%	**0.04**	−18 %	5 %	**0.003**
TTE	8 %	−48 %	−19 %	0.07	−13 %	0 %	0.20
TEE	–32 %	−81 %	−19 %	0.21	−26 %	−1%	0.19
PET infection	200 %	–	−50 %	0.11	−50 %	0 %	0.35
CMR	−28 %	83 %	16 %	0.32	0 %	6 %	0.77
Invasive coronary angiography	–22 %	−51 %	−25 %	0.59	−27 %	−9%	0.64

March 2019 to April 2020 and 2021 were significantly lower in Latin American inpatient and outpatient centers, as well as teaching and non-teaching facilities, compared to facilities in RoW (Supplementary Table 2). Changes in total procedure volumes in Latin America and RoW are summarized in Fig. 1. Aggregate procedure volume reductions in Latin America from pre-pandemic baseline were greater for almost all imaging modalities in April 2020, with the exception of ICA, and in April 2021, except for CMR and stress PET. TEE, CMR, stress PET, and stress CMR were the only procedure types that increased from pre-pandemic baseline in Latin America.

3.3. Changes in procedure volumes across Latin American regions

Median procedure volume changes from March 2019 across Latin American regions did not differ significantly during the early pandemic but did reach a significant difference in April 2021 (Supplementary Figure 2, Table 2). By April 2021, the Caribbean and South America had largely recovered testing volumes to pre-pandemic levels, with procedure volume reductions from 2019 baseline of 15 % and 14 %, respectively, while Central America and Mexico still reported a significant median procedure volume reduction per center of 47 % ($p = 0.01$). Furthermore, mean procedure volume recovery was 27.2 % lower in Central America and Mexico compared to the rest of Latin America ($p = 0.04$) in multivariable regression analysis accounting for facility characteristics and COVID-19 statistics (Supplementary Table 3). Recovery in this region was lowest for most procedure test types, with stress SPECT and CCTA reaching statistical significance. Percent recovery and change in procedure volumes in 2021 from pre-pandemic baseline for each participating Latin American country are displayed in Supplementary Figures 3–5, highlighting these regional differences.

3.4. Changes in procedure volumes by country income level

During the early stages of the pandemic, cardiovascular procedure volume reductions appeared to correlate with country income level in both Latin America and RoW, with lower middle- and upper middle-income countries reporting greater declines in testing compared to high-income countries (Supplementary Figure 6). By April 2021, procedure volume recovery in high- and upper-middle income countries in RoW had largely recovered (98 % and 84 %, respectively), while centers in lower middle-income countries still reported a low recovery of 46 % compared to March 2019 ($p = 0.0001$, Fig. 2). In Latin America, procedure volume recovery followed the opposite trend, with centers in lower middle-income countries reporting a 97 % recovery compared to a 67 % and 20 % recovery in upper middle- and high-income countries, respectively ($p = 0.08$).

3.5. Changes in facility Operations, testing Protocols, and safety policies

A greater proportion of Latin American centers reported changes in facility operations one year into the COVID-19 pandemic, including reduced hours compared to pre-pandemic and use of telehealth for remote reading (Supplementary Table 4). Significantly more Latin American centers also reported the implementation of policies aimed at transmission control. However, COVID-19 testing prior to cardiovascular imaging was implemented less frequently in Latin America (Supplementary Table 5). Facility operations and testing policies in April 2021 did not vary notably across the three Latin American regions.

Shortages in personal protective equipment (PPE), including surgical and high-filtration (N95/KN95/KF94/FFP2) masks, gloves, gowns, and eye shielding, persisted in Latin America one year into the COVID-19

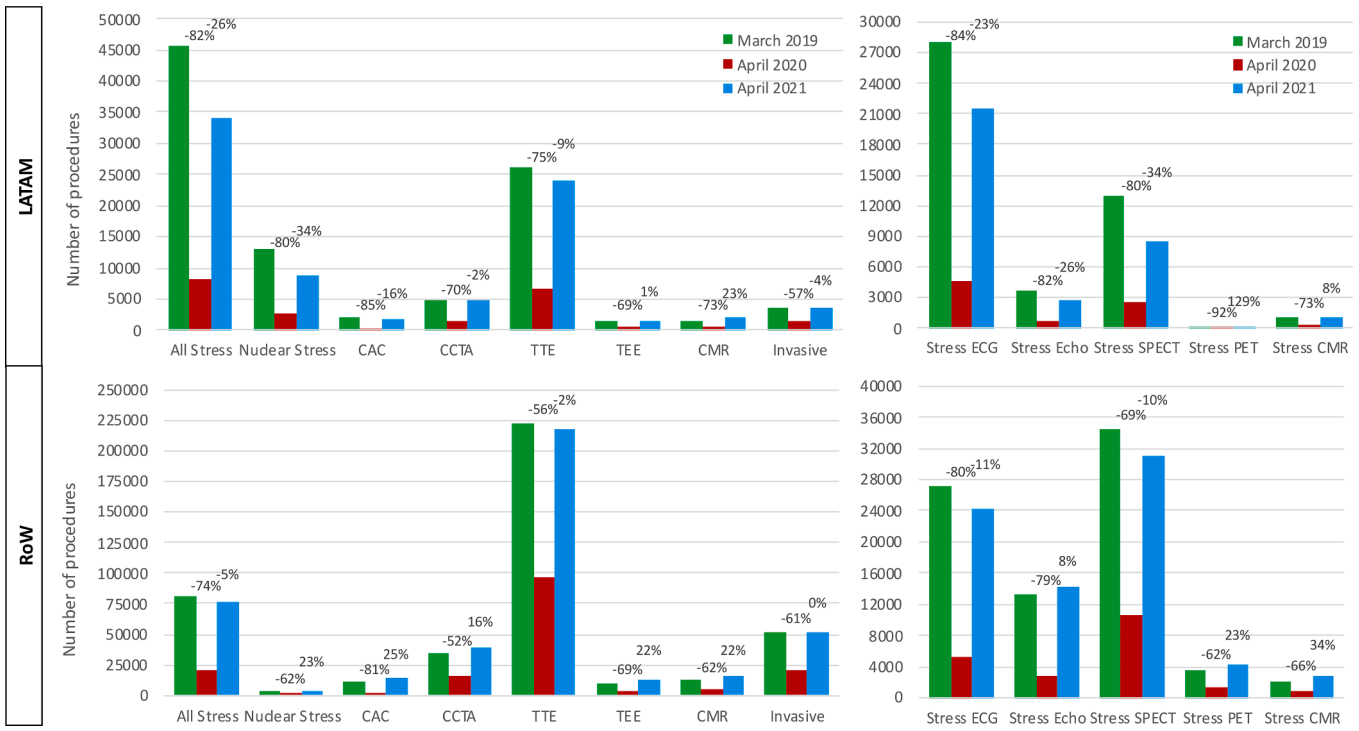

Fig. 1. Changes in total cardiovascular procedure volumes in Latin America vs. RoW. Total procedure volumes performed in March 2019 (green), April 2020 (red), and April 2021 (blue), displaying percent changes from March 2019 to April 2020 (left) and March 2019 to April 2021 (right) for each procedure type in Latin America (LATAM, top panel) and the rest of the world (RoW, bottom panel). ECG = electrocardiogram; Echo = echocardiography; SPECT = single-photon emission computed tomography; PET = positron emission tomography; CMR = cardiac magnetic resonance; CAC = coronary artery calcium; CCTA = coronary computed tomography angiography; TTE = transthoracic echocardiography; TEE = transesophageal echocardiography; Invasive = invasive coronary angiography. All stress includes stress ECG, stress Echo, stress SPECT, stress PET, and stress CMR, and nuclear stress incudes stress SPECT and stress PET. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

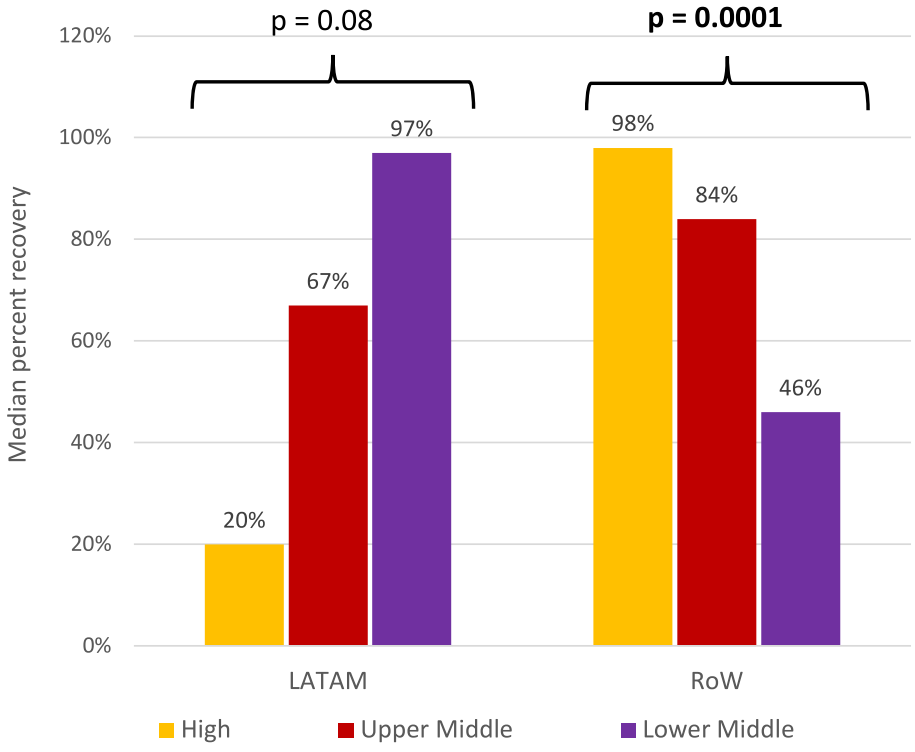

Fig. 2. Median recovery of procedure volumes in April 2021 by country income level. Figure displays median percent recovery in April 2021 to March 2019 procedure volumes, from early 2020 reductions, for centers in high- (yellow), upper middle- (red), and lower middle-income (purple) countries in Latin America (LATAM, left) and the rest of the world (RoW, right). P-values calculated by Kruskal-Wallis test. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

pandemic, although to a lesser extent than in centers in RoW (Supplementary Figure 7). However, within Latin America, there were notable differences in PPE availability between countries of different economic level, with a greater proportion of centers in high-income countries reporting always sufficient quantities of all types of PPE than centers in upper middle- and lower middle-income countries (Supplementary Figure 8). Of note, such stark differences in PPE availability by economic level were not observed in RoW.

3.6. Impact of the pandemic on clinical staff

The COVID-19 pandemic appears to have disproportionately affected clinical staff in Latin American centers compared to RoW. Economically, a greater proportion of Latin American centers reported reduced salaries for physicians (17 % vs. 4 % in RoW, $p < 0.001$) and non-physician staff (16 % vs. 3 % in RoW, $p < 0.001$), as well as layoffs for physicians (4 % vs. 1 % in RoW, $p = 0.02$) and non-physician staff (8 % vs. 1 % in RoW, $p < 0.001$. Supplementary Table 4). The pandemic also appears to have had a significant psychological impact on clinical staff in Latin America. Survey respondents in Latin American centers estimated that half of their clinical and non-clinical staff experienced excess psychological stress related to the pandemic (Supplementary Table 6), compared to 25 % of physician staff and 30 % of non-physician staff in RoW ($p < 0.001$). The psychological impact of the pandemic in Latin America may have ultimately affected patient care, with 14 % of Latin American centers reporting a profound impact of pandemic-related psychological stress on care, compared to 7 % in RoW ($p = 0.003$).

4. Discussion

Previous studies have documented the impact of COVID-19 on cardiovascular testing worldwide [3] and in Latin America [16] in early 2020. Here, data from the INCAPS COVID 2 survey [11] were analyzed to characterize the recovery of cardiovascular testing across Latin America in April 2021, one year after the onset of COVID-19. Our major findings were that: 1) cardiovascular procedure volume reductions persisted in Latin America one year into the pandemic, with Latin American centers reporting greater procedure volume reductions for almost all testing modalities compared to RoW: 2) unlike in worldwide centers, where cardiac CT had returned to or exceeded pre-pandemic baseline volumes, coronary artery calcium and coronary CT angiography remained notably depressed in Latin America; 3) centers in Central America and Mexico were disproportionately impacted by COVID-19 and reported the greatest reductions in testing in April 2021 within Latin America, raising important concerns regarding future cardiovascular outcomes in this region; and 4) the COVID-19 pandemic has had a lasting economic and psychological impact on Latin American clinical staff, to a significantly greater degree than in the rest of the world, underscoring the need for greater support for healthcare workers in Latin America.

Due to under-funding, hospital systems in Latin America were ill equipped to manage the rapid spread of COVID-19 [20]. In order to curtail the effects of the emerging pandemic on Latin American health systems, strict restrictions were set in place, including lockdowns in Argentina, Brazil, Colombia, Chile, and Peru, and quarantine measures in other Latin American countries, [21] which likely contributed to some of the greatest reductions in cardiovascular testing in 2020 worldwide [16,22–24].

This study found that cardiovascular testing volumes in Latin America in April 2021 trailed behind worldwide recoveries, as centers in Latin America reported greater volume reductions for all procedure types, except for CMR and stress PET. As in centers worldwide, stress testing remained depressed in Latin America, possibly because of the increased risk of viral transmission associated with these procedures. However, unlike in RoW, where cardiac CT had largely recovered by April 2021, coronary CTA and CAC were still used 18 % and 33 % less frequently than in March 2019, compared to a 5 % increase and 0 % change in RoW ($p = 0.003$ and $p = 0.01$). This reflects lasting reductions even in imaging modalities that were generally considered to pose less of a contagion risk between patients and testing staff, [25] and that were not vulnerable to disruptions in radiopharmaceutical supply chains, [26] as with SPECT and PET.

Lower rates of cardiovascular procedure recovery in Latin America could have resulted from the greater strain on hospital systems that persisted into early 2021. Our survey found that 27 % of Latin American centers held reduced hours compared to pre-pandemic times, as opposed to 15 % in RoW ($p = 0.001$), and a greater proportion of Latin American centers maintained policies to control transmission of the virus, such as screening protocols and restricting accompanying visitors and family, into 2021. These operational disruptions, coupled with persistent patient hesitancy to undergo diagnostic testing in hospitals for fear of contracting the virus, [27] may have significantly hampered recovery of cardiac imaging in Latin America.

While reductions in cardiac testing during the early stages of the pandemic were not significantly different across Latin America, procedure recovery in 2021 was found to be unequally distributed across the region. Centers in Central America and Mexico reported the greatest reduction, by 47 %, in procedure volumes in April 2021 compared to March 2019, falling significantly behind the recovery of South America (14 % reduction) and the Caribbean (15 %, $p = 0.01$). Countries in this region were among the hardest hit throughout the COVID-19 pandemic [28]. The disproportionate impact of the pandemic in this region may have resulted from the compounding effects of: 1. Slower and less stringent implementations of transmission control and contact tracing policies, [29,30] and 2. The highest prevalence of COVID-19 risk factors, such as diabetes and obesity, [31–34] in Latin America. The growing number of severely ill patients infected with SARS-CoV-2 forced hospital systems in the region to reallocate resources [20]. This pronounced impact of the pandemic in Central America and Mexico could have ultimately contributed to lower rates of cardiovascular testing recovery in the region.

Procedure volume recovery was also analyzed by World Bank income classification. While in RoW, cardiac testing recovery increased as a function of country income, the opposite trend appeared in Latin America: a 97 % recovery reported in lower middle-income countries, compared to 67 % and 20 % in upper middle- and high-income countries ($p = 0.08$). Such low testing recovery in this latter economic region, significantly less than in countries of similar economic level in RoW ($p = 0.03$), is attributable to reduced testing in three countries: Uruguay (26 % reduction in April 2021 from March 2019), Panama (59 % reduction), and Chile (67 % reduction, Supplementary Figure 3). Chile, in particular, was facing a surge of viral transmission in March and April 2021 [35,36]. In response, the Chilean government instituted strict new lockdown policies at the end of March 2021, [37] which could ultimately account for the low cardiovascular procedure volumes in April 2021. We did find concerning evidence of persisting disparities in PPE availability between Latin American countries of different economic level, with more centers in high-income countries reporting “always sufficient” quantities of all types of surveyed PPE than upper middle- and lower middle-income countries. PPE shortages in lower-income countries could have further exacerbated existing vulnerabilities to the COVID-19 pandemic, [38] and raise important concerns about these countries’ preparedness for future health emergencies.

Lastly, this study found concerning evidence of persistent detrimental impacts of the pandemic on clinical testing staff. A greater percentage of centers in Latin America reported reduced salaries and increased layoffs for physician and non-physician staff compared to RoW, likely reflecting the unprecedented economic toll of the pandemic in the region [39]. Survey respondents in Latin America also estimated that half of their testing staff experienced excess psychological stress related to the pandemic, at levels significantly higher than RoW. Previous studies have found alarming rates of mental health burden in Latin

American healthcare workers, associated with lack of PPE, chronic exposure to death, and discrimination by the population due to fears that they may be carriers of the disease [40,41]. Our findings underscore the greater need for mental health policy interventions targeting healthcare workers in the region, such as those instituted in Chile under the COVID-19 Mental Health Action Plan and the SaludableMente (Healthy Mind) Initiative [42].

4.1. Limitations

Due to the nature of the self-reported survey, this study is subject to several limitations, including potential selection and recall biases and incomplete data. While efforts were taken to maximize the quantity and diversity of participating centers, the number of surveys received was unequally distributed across Latin America, both by economic level, as described above, and by geographical region. For example, only 5 surveys were collected from the Caribbean, potentially reflecting scarcity of cardiovascular imaging centers in the region, which could impact the generalizability of our findings. Indeed, a recent survey found that Cuba, the only Caribbean country included in the study, had fewer than five CT scanners per million inhabitants in 2022, and less than one MRI scanner, PET scanner, and cyclotron per million, [43] and as of 2020, Haiti, the most populous country in the region, had only four CT scanners serving over 11 million people, according to IAEA/Pan American Health Organization estimates, [44] and to the best of our knowledge none of these are used to perform coronary CTA. These statistics highlight the urgent need for international initiatives aimed at improving access to medical imaging in the Caribbean, such as those headed by the American College of Radiology Foundation and RAD-AID in Haiti [45,46]. Nonetheless, this study was able to identify significant differences between centers in Latin America and the rest of the world, and between different Latin American regions and reported findings that have important implications for cardiovascular care and health policy in Latin America. This survey was also designed to collect procedure volume data during discrete one-month time frames in 2019, 2020, and 2021, during which times Latin American countries may have been in different stages of the pandemic in terms of case rates and public health policies. However, some of these factors were accounted for in regression analysis, and did not appear to significantly predict testing recovery.

5. Conclusions

This study found greater April 2021 reductions in almost all cardiovascular procedure modalities in Latin American centers than in RoW, with centers in Central America and Mexico reporting the lowest degree of recovery compared to South America and the Caribbean. We also report a startling degree of economic hardship and psychological stress experienced by Latin American healthcare workers one year into the COVID-19 pandemic. These findings support the growing body of literature documenting the unprecedented impact of the pandemic on Latin American healthcare and highlight the need for further investigation into the extent of cardiovascular testing recovery in post-pandemic Latin America, and the effects of diagnostic procedure reductions on cardiovascular outcomes in Latin American patients in the coming years. Maintaining healthcare infrastructure, providing regular training for healthcare workers, ensuring an adequate stockpile of PPE, engaging in community outreach and facilitating patient transportation to imaging centers, and increasing domestic and international investment into imaging technology and telehealth services will all be vital in mitigating the impact of future pandemics on preventative and diagnostic imaging in Latin America.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [Dr. Massardo has been supported by Pfizer for educational activities related to ATTR amyloidosis and has participated in two multicenter research projects supported by Pfizer. Dr. Williams has given talks for Canon Medical Systems, Siemens Healthineers and Novartis and is supported by the British Heart Foundation (FS/ICRF/20/26002). Dr. Villines is a current employee of Elucid Biomining, Inc that is unrelated to this work. Dr. Dorbala has received honoraria from Pfizer and GE Healthcare; and has received grants to her institution from Pfizer and GE Healthcare. Dr. Einstein has received fees for speaking from Ionetix, consulting from W. L. Gore & Associates, serving on a scientific advisory committee for Canon Medical Systems USA, and authorship from Wolters Kluwer Healthcare – UpToDate; has grants/grants pending from Attralus, Canon Medical Systems USA, Eidos Therapeutics, GE Healthcare, Pfizer, Roche Medical Systems, W. L. Gore & Associates, XyloCor Therapeutics, Neovasc, Intellia Therapeutics, Ionis Pharmaceuticals, the National Institutes of Health, and the IAEA. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose].

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Appendix A. Supplementary data

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