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ORIGINAL ARTICLE

Recovery of cardiovascular diagnostic testing in Italy 1 year after coronavirus disease-2019 outbreak compared with other countries in Europe and worldwide: results from the International Atomic Energy Agency INCAPS COVID 2 survey

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Abstract

Aims

Recovery of cardiovascular diagnostic testing in Italy after the coronavirus disease-2019 (COVID-19) pandemic has not been quantified. The study aims to describe cardiac diagnostic procedure volumes, centres practice and protocols, and staff members' well-being 1 year after COVID-19 outbreak in Italy.

Methods and results

A global survey was conducted by the International Atomic Energy Agency to evaluate changes in cardiac diagnostic procedure volumes in April 2021. Evaluated procedures were transoesophageal echocardiogram, coronary computed tomography angiography, coronary artery calcium scanning, nuclear medicine infection studies, invasive coronary angiography, rest and stress transthoracic echocardiogram, cardiac magnetic resonance, single-photon emission computed tomography and positron emission tomography, and stress electrocardiogram. Data were compared with April 2020 and March 2019. Forty-two Italian centres took part in the survey. In April 2020, there was a 72% decrease of median volumes of cardiac diagnostic procedures compared with March 2019. In April 2021, volumes of cardiac diagnostic procedures remained decreased by 3% when compared with March 2019. Stress electrocardiogram, coronary computed tomography angiography, and stress cardiac magnetic resonance volumes increased in April 2021 compared with baseline (29%, 6%, and 16%, respectively). The majority of centres had adopted physical distancing measures (93%), COVID-19 screening through questionnaires (76%), or temperature checks (93%). Twenty-five per cent of physicians at Italian responding sites reported excessive levels of psychological stress.

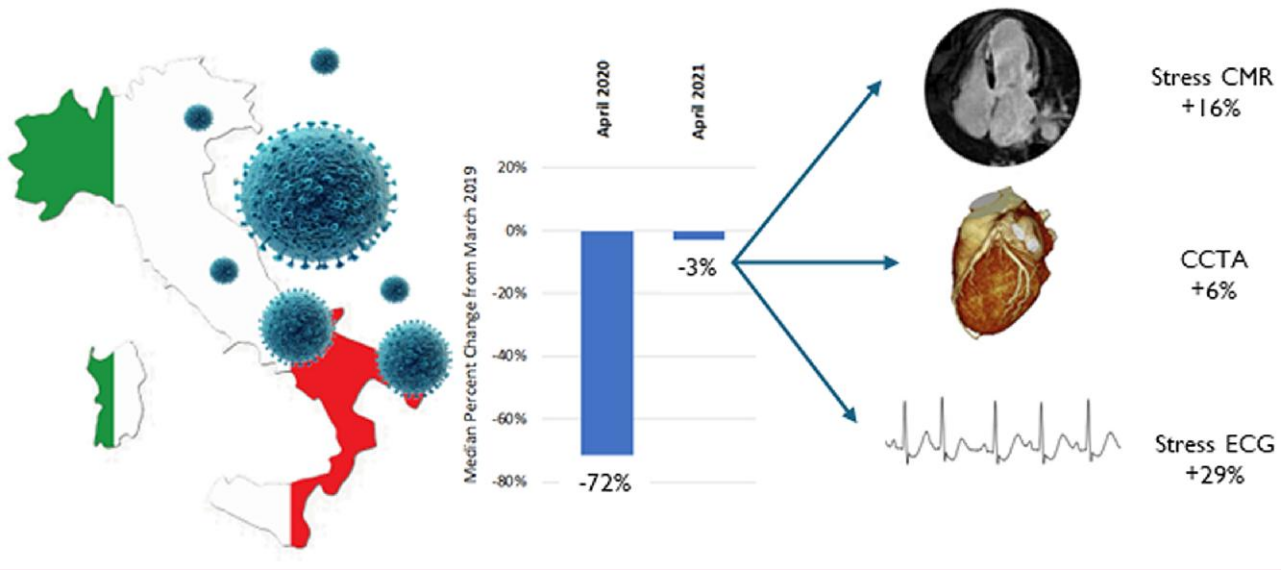
Conclusion

In April 2021, volumes of cardiac diagnostic procedures at Italian responding sites were still recovering. Centres had implemented several adaptations to ensure the provision of care to their patients. Even 1 year after the pandemic, a substantial minority of Italian healthcare providers were still experiencing excessive psychological stress.

Lay summary

The coronavirus disease-2019 pandemic has had an impact on cardiovascular care provision, leading to a decrease in the number of diagnostic procedures performed. As of April 2021, volumes of cardiovascular diagnostic procedures in Italy were still recovering, despite the implementation of several adaptations by healthcare centres to deal with the pandemic.

Graphical Abstract



Keywords cardiac diagnostic procedure volumes • COVID-19 • recovery • Italy

Introduction

The coronavirus disease-2019 (COVID-19) pandemic has disrupted healthcare services worldwide, resulting in fewer in-person visits, postponed elective procedures, and increased telehealth usage.[1,2] Consequently, emergency room visits, outpatient diagnostic procedures, and hospitalizations for non-COVID-19 medical conditions have decreased,[3-5] creating concerns regarding missed diagnoses during the pandemic and their potential adverse health effects.

Patients with cardiovascular disease, the leading global cause of death,[6] faced particular challenges due to disrupted medical care, as the pandemic resulted in reductions, delays, or cancellations of diagnostic cardiovascular procedures.[7,8] Studies indicate a significant decline in cardiovascular testing volumes and invasive cardiac procedures during the pandemic's early phase.[9-13]

To comprehensively evaluate the pandemic's impact on diagnostic cardiovascular procedures, the Nuclear Medicine and Diagnostic Imaging Section of the International Atomic Energy Agency (IAEA) launched a global study called IAEA Non-invasive CArdiology Protocols Study (INCAPS) COVID, involving facilities worldwide. Initial findings revealed a substantial reduction in cardiovascular diagnostic procedure volumes during the early pandemic phase, with greater effects observed in economically disadvantaged countries.[14,15] Subsequently, efforts have been made to resume cardiovascular testing amidst ongoing pandemic challenges, but the recovery process and changes in testing patterns remain underexplored.

A global survey was therefore conducted to reassess procedural volumes, testing practices, staff well-being, and patient safety in April 2021.[16] As with the reduction in procedure volumes caused by the pandemic, the recovery phase had significant regional differences. The global IAEA INCAPS COVID 2 survey showed a complete recovery in cardiac diagnostic testing by April 2021 in high- and upper middle-income countries, while the recovery process remained incomplete in lower middle- and low-income countries. Differences between diagnostic modalities also emerged, with a reduced utilization of stress testing in favour of an increase in advanced imaging modalities [coronary computed tomographic angiography, positron emission tomography (PET), and magnetic resonance]. Pandemic-related psychological stress was highly prevalent among responding physicians and predicted recovery of cardiac testing.[16]

Subsequent analyses focused on regional results of the survey. In the USA, a significant recovery in cardiovascular diagnostic testing had occurred in April 2021, similar to that observed in other high-income countries.[17] In Latin America, cardiac diagnostic testing volumes remained significantly reduced in April 2021, particularly in Central America and Mexico. Moreover, Latin American centres reported more frequently reduced salaries, increased layoffs, and excess psychological stress of clinical staff compared with the rest of the world (RoW).[18] Finally, Oceania saw a complete recovery of cardiac diagnostic volumes 1 year into the pandemic, with a poorer recovery in anatomical coronary testing compared with the RoW.[19]

This research aims to provide insights into the pandemic's long-term impact on cardiovascular outcomes and diagnostic pathways in the post-pandemic era in Italy.

Methods

In response to the COVID-19 pandemic, the IAEA Nuclear Medicine and Diagnostic Imaging Section established the INCAPS COVID executive committee, comprising international clinical cardiology and cardiac imaging experts. The initial study aimed to assess the impact of the pandemic on global cardiovascular diagnostic care delivery during the first 2 months. Subsequently, the executive committee conducted a follow-up survey named INCAPS COVID 2, 1 year after the first study, to analyse medium-term trends in the utilization and methodology of cardiac diagnostic testing.

The assessment encompassed various diagnostic tests, including transthoracic echocardiography (TTE), transoesophageal echocardiography (TEE), cardiac magnetic resonance (CMR), stress testing [involving stress electrocardiography, echocardiography, single-photon emission computed tomography (SPECT), PET, and CMR], PET infection studies, coronary

Table 1 Participating centres characteristics

	Italian facilities				Worldwide facilities				
	North	Centre	South	*P*	Italy	RoE	*P*	RoW	*P*
Number of centres	21	12	9		42	162		465	
Participated in INCAPS COVID 1	17 (81)	10 (83)	6 (67)		33 (79)	98 (60)		318 (68)	
Number of procedures									
March 2019	12 441	11 660	1447		25 548	101 849		382 053	
April 2020	4959	3349	884		9192	37 787		136 492	
April 2021	11 463	12 735	1820		26 018	103 994		369 993	
Type of test									
Stress ECG				0.77	18 (43)	61 (38)	0.89	194 (42)	0.62
Stress echocardiography	6 (29)	9 (75)	1 (11)	0.21	16 (38)	49 (30)	0.58	155 (33)	1.00
Stress SPECT	16 (76)	8 (67)	7 (78)	0.64	31 (74)	87 (54)	0.07	296 (64)	1.00
Stress PET	2 (10)	0 (0)	2 (22)	0.16	4 (10)	12 (7)	0.75	49 (11)	0.80
Stress CMR	4 (19)	2 (17)	1 (11)	1.00	7 (17)	36 (22)	0.40	74 (16)	1.00
CT coronary calcium	1 (5)	3 (25)	1 (11)	0.15	5 (12)	46 (28)	**0.02**	141 (30)	**<0.01**
CT coronary angiography	7 (33)	7 (58)	2 (22)	0.33	16 (38)	83 (51)	**0.05**	224 (48)	**0.05**
TTE	9 (43)	6 (50)	3 (33)	0.84	18 (43)	70 (43)	0.73	186 (40)	0.75
TEE	8 (38)	6 (50)	2 (22)	0.58	16 (38)	61 (38)	0.86	148 (32)	0.87
PET infection	7 (33)	4 (33)	3 (33)	1.00	14 (33)	32 (20)	0.15	40 (9)	**<0.01**
CMR	8 (38)	9 (75)	2 (22)	0.06	19 (45)	68 (42)	1.00	170 (37)	0.74
ICA	7 (33)	6 (50)	2 (22)	0.52	15 (36)	51 (31)	0.85	165 (35)	0.62
Baseline procedures per centre	158 (83, 869)	520 (230, 1222)	143 (63, 162)	0.08	215 (88, 720)	327 (71, 1000)	0.83	323 (87, 1022)	0.52
Hospital beds	810 (280, 1321)	925 (150, 1400)	800 (200, 1000)	0.71	850 (250, 1200)	520 (225, 1000)	0.16	450 (250, 850)	0.09
Inpatient centre	18 (86)	12 (100)	9 (100)	0.30	39 (93)	155 (96)	0.34	384 (83)	0.13
Teaching institution	15 (71)	8 (67)	8 (89)	0.53	31 (74)	127 (78)	0.54	317 (68)	0.49

Values are *n*, *n* (%), or median(interquartile range). Table displays the number of centres, baseline centre characteristics, and proportion of centres performing each test type for Italy, RoE, RoW, and the three Italian macro-regions. *P*-values calculated by Fisher's exact test for comparisons of frequency distributions or by Wilcoxon rank sum or Kruskal–Wallis tests for comparisons of continuous variables. *P*-values ≤ 0.05 are in bold.

Table 2 Median procedure volume changes from pre-pandemic baseline

	Italian facilities				Worldwide facilities					
	Italian facilities				Worldwide facilities					
	North	Centre	South	*P*	Italy	RoE	*P*	RoW	*P*	*P**
Change in procedures										
March 2019 to April 2020	−72%	−74%	−62%	0.79	−72%	−74%	0.53	−69%	0.91	0.43
March 2019 to April 2021	−6%	0%	17%	0.63	−3%	2%	0.20	−8%	0.52	**<0.01**
Change in procedures by test type										
Reduction (2019–20)										
Stress ECG	−90%	−99%	−38%	0.31	−90%	−87%	0.56	−88%	0.55	0.83
Stress echocardiography	−67%	−100%	0%	0.10	−83%	−91%	0.53	−89%	0.81	0.73
Stress SPECT	−83%	−84%	−75%	0.26	−80%	−84%	0.21	−80%	0.99	0.15
Stress PET	−88%		−94%	0.70	−94%	−87%	0.45	−74%	0.08	0.21
Stress CMR	−95%	−100%	−100%	0.60	−100%	−91%	0.12	−81%	**0.05**	0.12
CT coronary calcium	−100%	−92%	400%	0.28	−92%	−80%	0.95	−90%	1.00	0.97
CT coronary angiography	−75%	−82%	175%	0.19	−73%	−75%	0.83	−60%	0.25	0.07
TTE	−68%	−59%	−40%	0.17	−64%	−56%	0.87	−60%	0.69	0.86
TEE	−89%	−83%	63%	0.25	−81%	−85%	0.94	−80%	0.51	0.62
PET infection	−83%	−100%	−95%	0.08	−85%	−60%	0.07	−100%	0.75	0.06
CMR	−80%	−95%	−46%	**0.01**	−88%	−76%	0.08	−90%	**0.01**	**0.02**
ICA	−48%	−61%	−7%	0.12	−55%	−55%	0.84	−57%	0.74	0.95
Change in procedures by test type										
Return to baseline (2019 vs. 2021)										
Stress ECG	−12%	−38%	−31%	0.61	−29%	−25%	0.80	−27%	0.64	0.90
Stress echocardiography	−32%	3%	0%	0.36	−14%	−25%	0.72	−24%	0.72	0.92
Stress SPECT	−15%	−18%	−25%	0.85	−20%	−12%	0.85	−19%	0.89	0.77
Stress PET	−13%		667%	1.00	−13%	10%	0.54	0%	0.81	0.33
Stress CMR	0%	−51%	−50%	0.11	−20%	−17%	0.75	−3%	0.84	0.78
CT coronary calcium	0%	−80%	500%	0.34	0%	−15%	0.89	0%	0.81	0.58
CT coronary angiography	100%	−38%	225%	**0.05**	27%	8%	0.88	0%	0.35	**0.05**
TTE	−33%	18%	20%	**0.01**	−18%	0%	0.61	−2%	0.96	0.68
TEE	−18%	31%	100%	0.17	−4%	0%	0.42	−9%	0.07	0.10
PET infection	0%	53%	−40%	0.47	0%	0%	0.92	−46%	**0.03**	**0.01**
CMR	5%	−20%	8%	0.79	−11%	5%	0.39	7%	0.53	0.77
ICA	−33%	−5%	133%	0.13	−9%	−5%	0.60	−14%	0.83	0.43

Table displays the median procedure volume changes in April 2020 and April 2021 from March 2019 for each test type for centres in Italy, RoE, RoW, and the three Italian macro-regions. PET infection, positron emission tomography for infective endocarditis; Invasive, invasive coronary angiography.
P-values by Wilcoxon rank sum or Kruskal–Wallis tests. *P** indicates a *P*-value comparing procedure volume changes between Italy, RoE, and RoW by Kruskal–Wallis test. *P*-values ≤ 0.05 are in bold.

artery calcium scanning, coronary computed tomographic angiography (CCTA), and invasive coronary angiography (ICA). A comprehensive questionnaire was devised to gather data across four key domains: (i) characteristics of participating healthcare facilities; (ii) availability of resources, methodologies, and protocols; (iii) psychological stress experienced by practitioners; and (iv) alterations in procedural volumes.

Data were collected from each participating site at baseline in March 2019, as well as in April 2020 and April 2021. Efforts were undertaken to ensure the inclusivity of site participation. Data collection was facilitated through a secure web-based platform called the International Research Integration System. The data set comprised only one entry from each centre, with exclusions made for incomplete or missing questionnaire responses.

Statistical analysis

The Italian regions from which data from participating centres were collected were grouped into three macro-regions: Northern Italy (including Emilia Romagna, Liguria, Lombardia, Piemonte, Trentino Alto Adige, and Veneto regions), Central Italy (Abruzzo, Lazio, Marche, and Toscana regions), and Southern Italy (Campania, Puglia, and Sicilia regions). Changes in procedure volumes from March 2019 to April 2020 and 2021 were compared between centres in Italy, the rest of Europe (RoE), as defined by standard IAEA designation, and the RoW. Procedure volume changes in Italy were also compared with centres in non-Italy high-income countries (NIHIC), upper middle-, lower middle-, and low-income countries in Europe, and worldwide. Country income level was defined by the World Bank classification.[20]

Procedure volume recovery was calculated as 100% * {1 − [(March 2019 volume to April 2021 volume)/(March 2019 volume to April 2020 volume)]}, as previously described.[16] Differences in continuous variables that were not normally distributed, such as changes in procedure volumes and volume recovery, were compared using non-parametric Wilcoxon rank sum and Kruskal–Wallis tests, while differences in frequency distributions of survey answers were compared using Fisher's exact tests. Maps showing differences in procedure volumes across Italy were generated using the

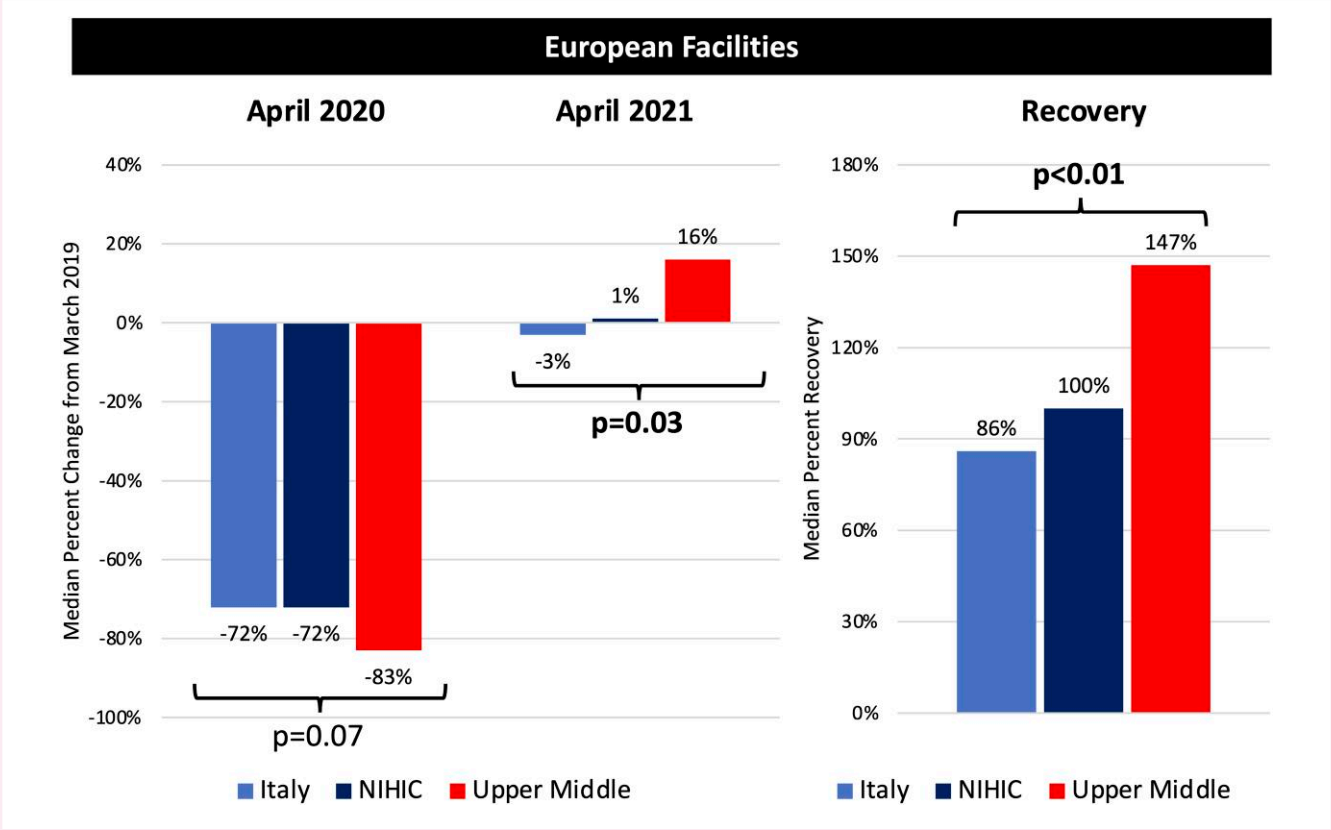


Figure 1 Changes in procedure volumes by country income level in European facilities. Bar charts displaying the median per cent change in procedure volumes in April 2020 and April 2021 from March 2019 and per cent recovery in April 2021 for Italian centres (first bar, light blue), European NIHIC (second bar, dark blue), and European upper middle-income countries (third bar, red). *P*-values calculated by Kruskal–Wallis test, with bold indicating statistical significance.

rnaturalearth and tmap packages in R, while statistical analysis was performed using Stata/SE and Microsoft Excel. A two-tailed *P*-value ≤ 0.05 was considered statistically significant.

Results

Characteristics of participating centres

Data were collected from 669 centres in 107 countries worldwide, with 42 Italian inpatient or outpatient centres responding to the survey. Seventy-nine per cent of Italian responding centres had participated in INCAPS COVID 1. A summary of participating centres characteristics can be found in *Table 1*. During the studied 1-month periods (March 2019, April 2020, and April 2021), a total of 60 000 cardiac diagnostic procedures were performed at Italian centres. The majority of Italian responding centres performed stress SPECT (74%), followed by CMR (45%), TTE, and stress electrocardiogram (ECG; 43% each). Stress CMR (17%), computed tomography (CT) calcium score (12%), and stress PET (10%) were less commonly available. Ninety-three per cent of responses from Italian centres came from inpatient centres, with a median number of 850 beds, and 74% of them were teaching institutions.

Table 1 also compares the characteristics of the participating centres in Italy with those in the RoE and the RoW. Italian responding centres had less availability of CCTA and CT calcium score compared with RoE and RoW centres and greater availability of PET for infective endocarditis compared with RoW centres.

Out of all the Italian responding centres, 21 were in Northern Italy, 12 in Central Italy, and 9 in Southern Italy. Due to the lower participation of centres in Southern Italy, the total number of baseline procedures was lower, despite a similar median baseline volume of cardiovascular diagnostic procedures per centre (*Table 1*).

Changes in procedure volumes

At the Italian responding sites, there was a 72% decrease in median volumes of cardiac diagnostic procedures from March 2019 to April 2020. However, much of this decrease had recovered by April 2021, with a 3% reduction from baseline persisting (*Table 2*). The changes in median procedure volumes did not significantly differ between Italy and the RoE, but recovery in Italy was significantly greater than in the RoW (*Table 2*).

Further considerations can be drawn by stratifying European and world nations according to their income levels. In April 2020, the total volume of cardiac diagnostic procedures decreased at similar rates in Italy, European NIHIC, and European upper middle-income countries. Conversely, recovery rates in April 2021 varied significantly. In Italy, the recovery process was not yet complete, and the total number of cardiac diagnostic procedures remained 3% below the baseline level, whereas NIHIC had a full recovery. It is also noteworthy that there was a 16% increase in the number of procedures in upper middle-income countries compared with the baseline (*Figure 1*). Moreover, when considering responding centres globally, the rates of cardiac procedure reduction in 2020 and subsequent recovery in 2021 varied significantly with income (*Figure 2*).

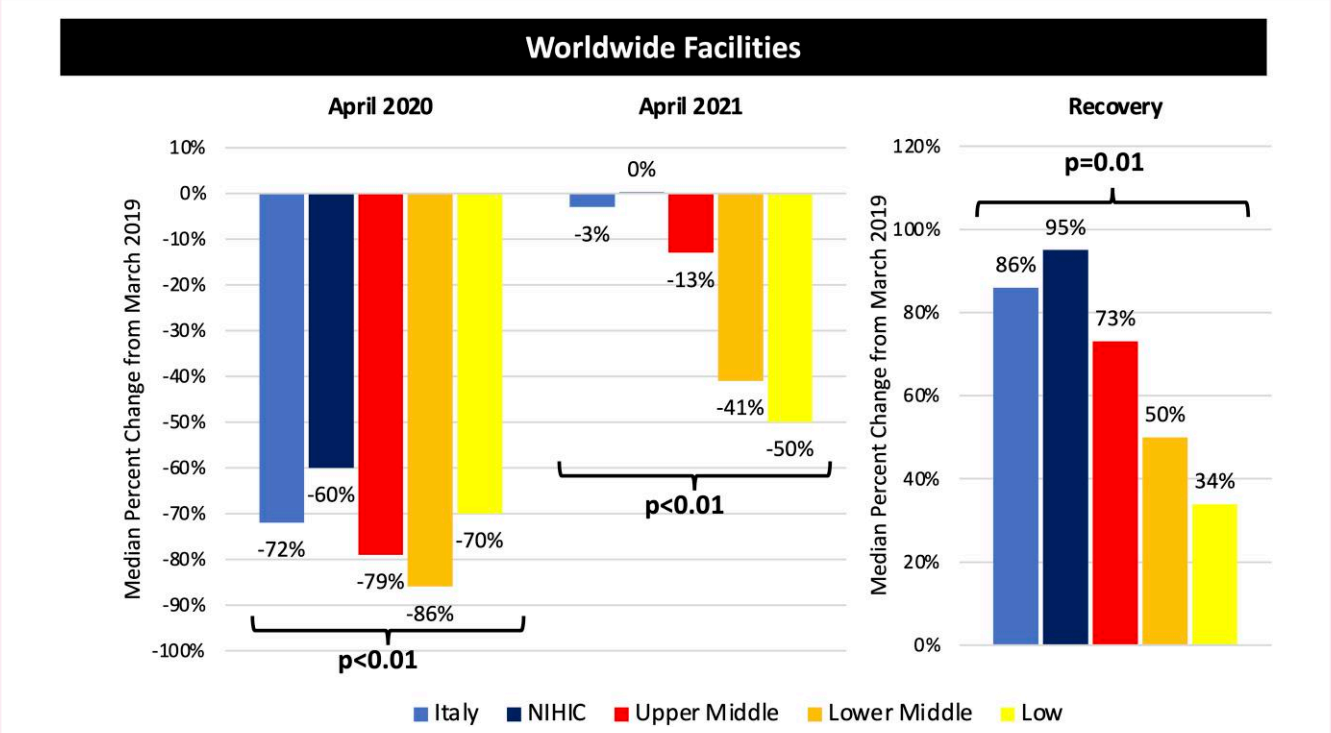


Figure 2 Changes in procedure volumes by country income level in worldwide facilities. Bar charts displaying the median per cent change in procedure volumes in April 2020 and April 2021 from March 2019 and per cent recovery in April 2021 for Italian centres (light blue), all NIHIC (dark blue), upper middle- (red), lower middle- (orange), and low-income countries (yellow) worldwide. *P*-values calculated by Kruskal–Wallis test, with bold indicating statistical significance.

The decrease and subsequent recovery in total procedures volumes varied among the three Italian macro-regions (*Figure 3*). In April 2020, Northern and Central Italian regions registered similar decreases in total procedures when compared with March 2019 (−60% and −71%, respectively), while total cardiovascular diagnostic procedures decreased by 39% in Southern Italy. In April 2021, full recovery had not yet been achieved in Northern Italy, as the total number of procedures still showed an 8% decline when compared with March 2019. Conversely, Central and Southern Italy centres experienced an increase in the total volume of procedures (9% and 26%, respectively; *Figure 3*).

At Italian responding sites, compared with 2019 baseline, TTE suffered a 58% reduction in 2020, and then procedure volumes settled back to the baseline (+1%; *Figure 4*). Stress tests showed a substantial reduction in 2020 (−76%), and this reduction improved although slightly persisted in 2021 (−3%). However, when considered individually, stress ECG and stress CMR showed a sharp increase in April 2021 (29% and 16%, respectively, when compared with March 2019), whereas other stress testing modalities remained underutilized in April 2021. CCTA saw a 60% reduction in 2020 then increased and stood in 2021 at a 6% increase over baseline. ICA procedures were reduced by 51% in 2020 and persisted at significantly reduced volumes (−11%) in 2021. The median changes in different procedures at Italian centres in 2020 and 2021 showed no significant difference from those observed at other European centres (*Table 2*).

Compared with 2019, the median changes of specific procedure volumes in 2021 across the three macro-regions tended to be similar, with the notable exceptions of CCTA (not yet fully recovered in Central Italy while significantly increased in Northern and Southern Italy) and TTE (still not fully recovered in Northern Italy and increased in the rest of Italy; *Table 2*).

Centre capacity, practice, and protocols

As with the other world centres that participated in the INCAPS COVID study, the Italian responding centres implemented several organizational changes between 2019 and 2021 in response to the pandemic (*Table 3*). A considerable number of Italian responding centres offered extended hours (24%) and employed telemedicine, particularly for direct patient interactions (27%). The majority of centres modified their waiting areas to enable physical distancing (93%), allocated separate spaces for patients with and without COVID-19 (90%), and implemented COVID-19 screening through questionnaires (76%) or temperature checks (93%). Cloth or surgical masks were required in 93% of centres.

Compared with participating centres in other countries, the use of telehealth services in Italian centres was significantly lower. On the other hand, Italian centres frequently adopted stricter measures compared with RoE and RoW centres, namely for physically separating patients with and without COVID-19, using temperature checks and requiring face masks (*Table 3*).

Among the three Italian macro-regions, centres in Northern Italy employed fewer weekend hours and telehealth services than those in Central and Southern Italy. Other adjustments in centre capacity, practice, and protocols were adopted in a similar proportion of centres across the three macro-regions (*Table 3*).

During the COVID-19 pandemic, shortages of personal protective equipment (PPE) were reported worldwide and in Italy. In particular, responding Italian centres reported substantial shortages of N95/KN95/KF94/FFP2 masks, gowns, and eye shields. As of April 2021, most Italian centres experiencing shortages had improved, with some differences in the availability of PPE in the three Italian macro-regions (*Figure 5*).

In April 2021, only a small minority of Italian responding sites required patients to undergo COVID-19 testing before undergoing non-

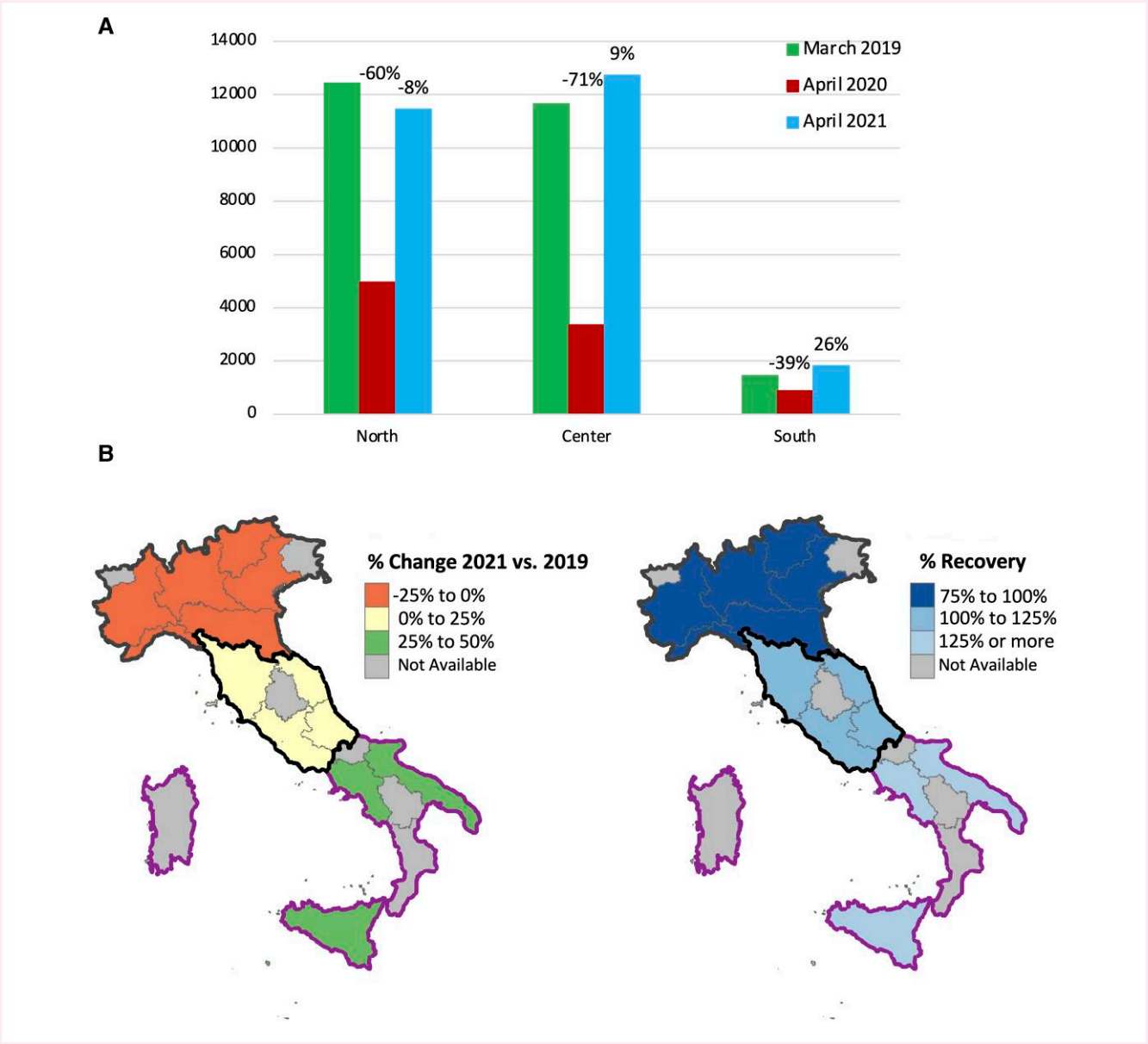


Figure 3 Procedure volume changes across Italian regions. (*A*) Bar charts displaying total procedure volumes in March 2019 (green), April 2020 (red), and April 2021 (blue) and per cent change in April 2020 (left) and April 2021 (right) from March 2019 for the three Italian macro-regions. (*B*) Maps displaying the per cent change in total procedure volumes in April 2021 from pre-pandemic baseline (left) and per cent recovery in April 2021 (right) for the three Italian macro-regions: Northern Italy (dark grey outline), Central Italy (black outline), and Southern Italy (purple outline). Grey represents regions for which no data were collected.

invasive cardiac imaging (14%), while patient screening was more commonly required prior to stress testing (21%), TEE (50%), and ICA (71%) procedures. When compared with RoE and RoW centres, there was no significant difference in patient screening practices at Italian centres. There were regional differences in screening practices for COVID-19, with centres in Southern Italy requiring testing before non-invasive cardiac imaging and stress testing significantly more frequently (*Table 4*).

Staff members' well-being

At Italian responding sites, changes in staffing were negligible, involving only temporary use of furlough for physicians (2%). However, workers at Italian centres showed comparable levels of psychological stress to RoE and RoW sites, with 25% of physicians and 20% of non-physician staff reporting it to be excessive. This excess stress had a noteworthy impact on patient care, with 74% of Italian centres noting some level of influence and 5% reporting a profound impact (*Table 5*).

Discussion

The present study provides valuable insights into how the COVID-19 pandemic affected cardiac diagnostic procedures, healthcare centres, and staff, globally and in Italy, highlighting regional differences and recovery efforts. Italian participating facilities observed a substantial decline in the median volumes of cardiac diagnostic procedures from March 2019

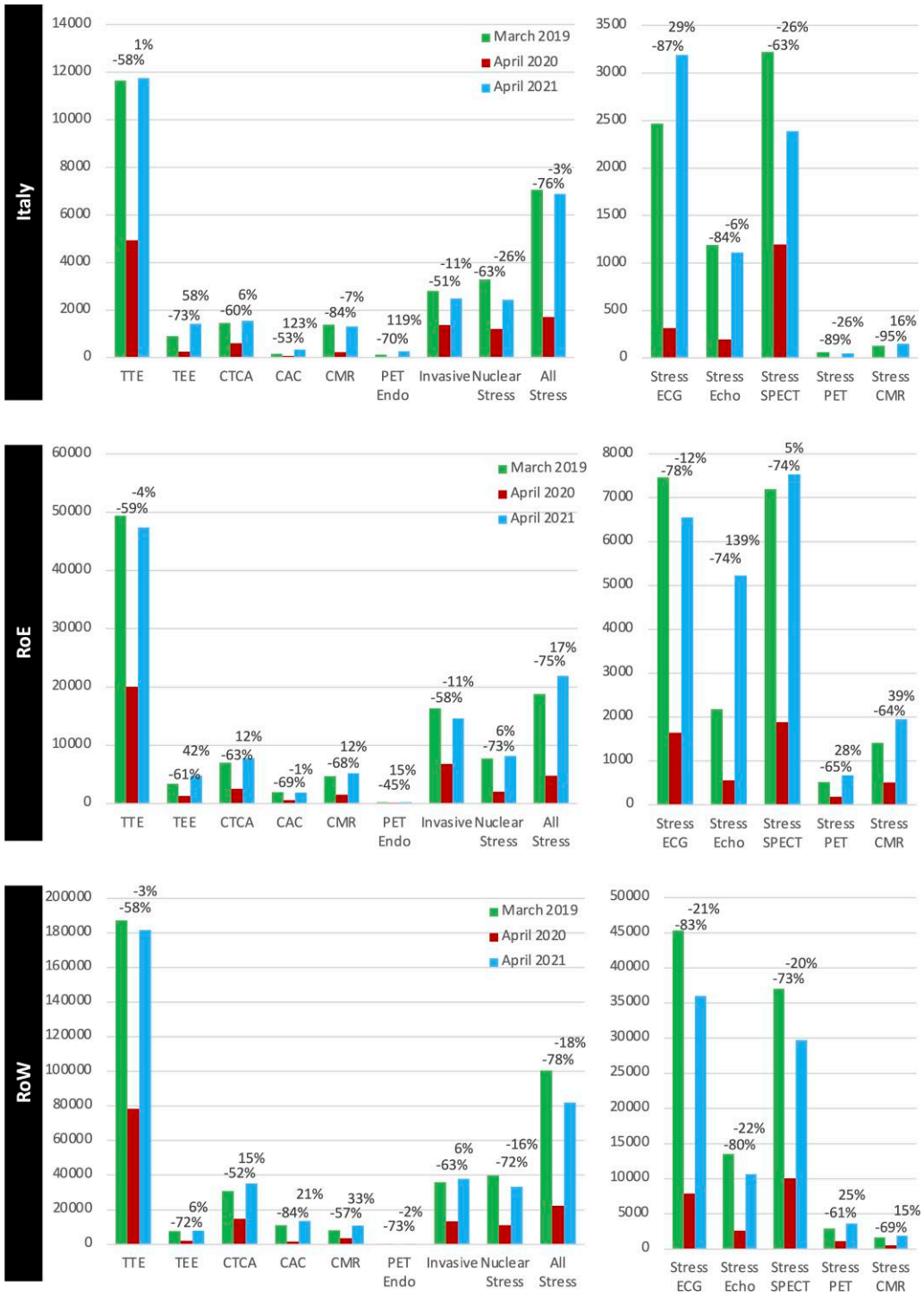


Figure 4 Total procedure volumes in Italy, RoE, and RoW. Bar charts displaying total procedure volumes in March 2019 (green), April 2020 (red), and April 2021 (blue) and per cent change in April 2020 (left) and April 2021 (right) from March 2019 for centres in Italy (top), RoE (centre), and RoW (bottom). Abbreviations as in *Figure 1*. 'All stress' includes stress ECG, stress echocardiography, stress SPECT, stress PET, and stress CMR, and 'nuclear stress' incudes stress SPECT and stress PET.

to April 2020 (72% reduction) but had largely recovered from this decline by April 2021 (−3% reduction from baseline). A significant influence of income on recovery rates has already been described across countries globally.[16] The present study confirms this association and shows that recovery rates at Italian responding sites are comparable with those at centres in the RoE and other high-income states.

Italian centres were classified into the Northern, Central, and Southern macro-regions of Italy, and differences in the recovery rates

Table 3 Changes in facility operations in April 2021 from pre-pandemic baseline

	Italian facilities				Worldwide facilities				
	North $n = 21$	Centre $n = 12$	South $n = 9$	*P*	Italy $n = 42$	RoE $n = 162$	*P*	RoW $n = 465$	*P*
Change in capacity									
Extended hours compared with pre-pandemic	2 (10)	5 (42)	3 (33)	0.09	10 (24)	39 (24)	1	65 (14)	0.12
New weekend hours compared with pre-pandemic	0 (0)	3 (25)	1 (11)	**0.05**	4 (10)	23 (15)	0.61	55 (12)	0.81
Reduced hours compared with pre-pandemic	3 (14)	1 (8)	0 (0)	0.78	4 (10)	6 (4)	0.22	103 (23)	**0.05**
Systemic approach to reschedule studies postponed due to pandemic	11 (52)	6 (50)	6 (67)	0.78	23 (55)	74 (47)	0.39	181 (40)	0.07
Use of telehealth for direct patient interactions	5 (25)	3 (25)	3 (33)	0.9	11 (27)	70 (44)	**0.05**	188 (41)	0.1
Use of telehealth for remote reading/reporting of studies	1 (5)	5 (42)	2 (22)	**0.02**	8 (19)	46 (29)	0.24	185 (41)	**<0.01**
Use of telehealth for review of studies with referring providers	1 (5)	3 (25)	3 (33)	0.08	7 (17)	38 (24)	0.41	158 (34)	**0.03**
Change in practice									
Alteration in patient transport, e.g. spacing use of elevators	16 (76)	5 (42)	4 (44)	0.08	25 (60)	95 (60)	1	277 (61)	0.87
Change in waiting areas to allow physical distancing	20 (95)	11 (92)	8 (89)	0.78	39 (93)	141 (88)	0.58	395 (86)	0.34
Separate spaces for patients with and without COVID-19	20 (95)	10 (83)	8 (89)	0.53	38 (90)	119 (75)	**0.04**	355 (77)	**0.05**
Reduced patient time in waiting room	18 (86)	10 (83)	6 (67)	0.51	34 (81)	116 (73)	0.33	323 (71)	0.21
Limitation of accompanying family members and/or visitors	20 (95)	11 (92)	8 (89)	0.78	39 (93)	140 (88)	0.58	390 (86)	0.25
Temperature measurements for all patients/visitors	19 (90)	11 (92)	9 (100)	1	39 (93)	78 (49)	**<0.01**	324 (71)	**<0.01**
Screening questionnaire to all patients/visitors	14 (67)	10 (83)	8 (89)	0.44	32 (76)	106 (66)	0.27	343 (74)	0.86
Require cloth/surgical mask for all patients/visitors	19 (90)	11 (92)	9 (100)	1	39 (93)	145 (90)	0.77	364 (79)	**0.03**
Change in staffing (for cardiac testing)									
Temporarily furloughed physicians	0 (0)	0 (0)	1 (11)	0.21	1 (2)	1 (1)	0.37	20 (4)	1
Temporarily furloughed non-physician staff	0 (0)	0 (0)	0 (0)		0 (0)	1 (1)	1	23 (5)	0.25
Reduced salaries of physicians	0 (0)	0 (0)	0 (0)		0 (0)	4 (3)	0.58	42 (9)	**0.04**
Reduced salaries of non-physician staff	0 (0)	0 (0)	0 (0)		0 (0)	0 (0)		36 (8)	0.06
Laid off physicians	0 (0)	0 (0)	0 (0)		0 (0)	0 (0)		9 (2)	1
Laid off non-physician staff	0 (0)	0 (0)	0 (0)		0 (0)	1 (1)	1	15 (3)	0.63

Values are *n* (%). Table displays the proportion of centres reporting the use of each practice in April 2021 for centres in Italy, RoE, RoW, and the three Italian macro-regions. *P*-values calculated by Fisher's exact test for comparisons of frequency distributions. *P*-values ≤ 0.05 are in bold.

were observed. While Central and Southern Italy had increases in their procedure volumes in April 2021, the recovery rate in Northern region lagged behind. However, a spurious result due to fewer participating centres in Southern Italy cannot be completely ruled out.

Recovery rates also varied across different cardiac diagnostic procedures in Italy. Stress tests and ICA volumes remained lower in April 2021 when compared with the 2019 baseline. CCTA experienced a similar significant reduction in April 2020 but had since recovered, surpassing the 2019 baseline by 6% in April 2021. These findings corroborate those of the global survey, which previously indicated a shift from stress testing to CCTA for diagnosing ischaemic heart disease.[16] This trend, already in place before COVID-19 pandemic[21,22] and increasingly supported by recent European and American guidelines,[23,24] has probably been reinforced during the pandemic by the improved safety profile for healthcare providers, shorter procedure times, lower rates of aerosolization (owing to the absence of exercise stress testing), and easier decontamination due to the absence of strong magnetic fields or radioactive material. When examining stress testing in Italian responding sites, however, it is noteworthy that while stress echocardiography, stress SPECT, and stress PET volumes remained reduced in April 2021 compared with March 2019, stress ECG and stress CMR showed a steep increase in 2021 (albeit on a smaller scale for stress CMR). The observed increase in stress ECG may be due to its wide availability, simplicity, ease of use, and accessibility, even though it has a significantly lower diagnostic accuracy.[25] On the other hand, the rise in stress CMR, an imaging technique with high diagnostic accuracy,[26] aligns with the upward trend of advanced cardiac imaging utilization, which was only temporarily halted during the COVID-19 pandemic.

In April 2021, the majority of Italian centres continued to implement several measures including physical distancing, separate areas for COVID-19 patients, mask mandates, and temperature checks. As other worldwide centres,[27,28] Italian centres reported shortages of PPE during the pandemic, but by April 2021, most had improved their PPE availability. The pandemic has resulted in staffing changes worldwide, with centres across the globe reporting worker layoffs and furloughs.[29] By contrast, at Italian responding sites, changes in staffing were minimal, with only brief furloughs for physicians. However, a substantial minority of staff reported excessive levels of psychological stress, which was also perceived to negatively affect patient care in most cases. These findings align with those of other studies, highlighting a significant psychological toll on healthcare workers amidst the pandemic.[30]

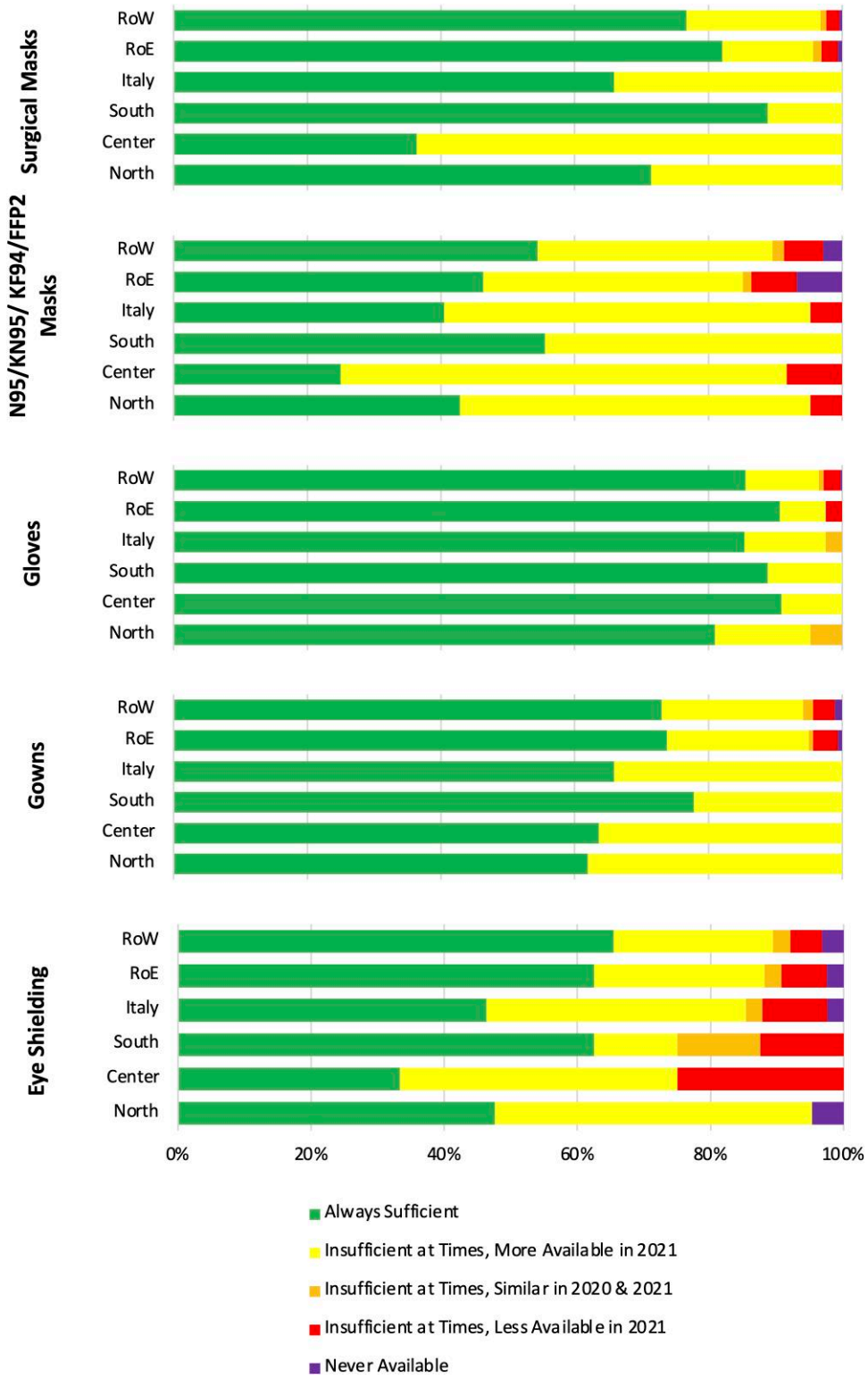


Figure 5 PPE availability in Italian, European, and worldwide centres. Stacked bar charts displaying PPE availability in April 2021 in centres in Italy, RoE, RoW, and the three Italian macro-regions. The scale ranges from 'Always Sufficient' (green) to 'Never Available (purple).

Study limitations

As with any survey, the collected data may be affected by a number of biases, including response and non-response biases and recall bias, possibly resulting in inaccuracies. Furthermore, participation in the study by Italian centres varied geographically, with a lower number of participating centres in Southern Italy, which may make comparisons

Table 4 COVID-19 testing practices in April 2021

	Italian facilities				Worldwide facilities				
	North $n = 21$	Centre $n = 12$	South $n = 9$	*P*	Italy $n = 42$	RoE $n = 162$	*P*	RoW $n = 465$	*P*
Prior to stress testing									
All patients	2 (10)	1 (8)	6 (67)		9 (21)	33 (21)		89 (20)	
Non-vaccinated only	1 (5)	1 (8)	1 (11)		3 (7)	13 (8)		43 (9)	
No patients	18 (86)	10 (83)	2 (22)	**<0.01**	30 (71)	110 (71)	1	323 (71)	0.93
Prior to non-invasive cardiac imaging									
All patients	1 (5)	0 (0)	5 (56)		6 (14)	29 (18)		68 (15)	
Non-vaccinated only	1 (5)	1 (8)	2 (22)		4 (10)	10 (6)		33 (7)	
No patients	19 (90)	11 (92)	2 (22)	**<0.01**	32 (76)	118 (75)	0.61	348 (78)	0.8
Prior to transoesophageal echocardiography									
All patients	8 (47)	6 (50)	4 (57)		18 (50)	80 (60)		188 (46)	
Non-vaccinated only	1 (6)	2 (17)	1 (14)		4 (11)	8 (6)		29 (7)	
No patients	8 (47)	4 (33)	2 (29)	0.83	14 (39)	46 (34)	0.38	196 (47)	0.41
Prior to diagnostic cardiac catheterization									
All patients	14 (74)	8 (67)	5 (71)		27 (71)	92 (66)		218 (53)	
Non-vaccinated only	1 (5)	2 (17)	1 (14)		4 (11)	9 (6)		23 (6)	
No patients	4 (21)	2 (17)	1 (14)	0.85	7 (18)	38 (27)	0.41	173 (42)	**<0.01**

Values are *n* (%). Table displays the proportion of centres in Italy, RoE, RoW, and the three Italian macro-regions reporting testing all patients, non-vaccinated patients only, and no patients for COVID-19 prior to different cardiovascular procedures in April 2021. *P*-values calculated by Fisher's exact test for comparisons of frequency distributions. *P*-values <0.05 are in bold.

Table 5 Psychological impact of the pandemic on testing staff

	Italian facilities				Worldwide facilities				
	North $n = 21$	Centre $n = 12$	South $n = 9$	*P*	Italy $n = 42$	RoE $n = 162$	*P*	RoW $n = 465$	*P*
Clinical staff with excess psychological stress related to pandemic, %*									
Physician	14	25	30	0.86	25	20	0.74	30	**0.04**
Non-physician	20	35	15	0.87	20	30	0.61	40	**0.04**
Impact of pandemic-related psychological stress on patient care, *n* (%)									
None	2 (10)	6 (50)	3 (33)		11 (26)	47 (29)		85 (18)	
Mild	14 (67)	4 (33)	3 (33)		21 (50)	76 (48)		219 (48)	
Moderate	4 (19)	2 (17)	2 (22)		8 (19)	29 (18)		112 (24)	
Profound	1 (5)	0 (0)	1 (11)	0.12	2 (5)	8 (5)	0.97	44 (10)	0.5

Values are median (%*) or *n* (%). Table displays the median percentage of clinical staff with excess psychological stress related to the pandemic estimated by centres in Italy, RoE, RoW, and the three Italian macro-regions and the proportion of centres reporting no, mild, moderate, and profound impact of psychological stress on patient care in April 2021. *P*-values calculated by Fisher's exact test for comparisons of frequency distributions or by Wilcoxon rank sum or Kruskal–Wallis tests for comparisons of continuous variables. *P*-values ≤ 0.05 are in bold.

between the three Italian macro-regions less accurate. Finally, psychological stress levels among healthcare providers were not measured using validated scores but were derived from self-reported data of perceived stress.

Conclusion

As of April 2021, the recovery in cardiac diagnostic procedure volumes in Italy was incomplete, with varying degrees across the three Italian macro-regions. Advanced cardiac imaging techniques, such as CCTA and stress CMR, were more commonly used in April 2021 compared with the 2019 baseline. Excessive levels of stress persisted among a significant minority of healthcare providers, 1 year into the pandemic. Continued monitoring and support are necessary to ensure that cardiac care facilities are able to recover fully from the pandemic and effectively provide care to their patients. Further research is needed to determine the impact of these findings on cardiovascular outcomes of patients.

Consent

The study did not collect patient-specific or confidential data, and participation by study sites was voluntary, obviating the need for external ethics committee review. Furthermore, the study complied with the

Declaration of Helsinki. The Columbia University Institutional Review Board determined that the study did not qualify as human subject research under 45 CFR 46, due to the absence of subject interaction, intervention, or collection of private identifiable information; therefore, obtaining informed consent from patients was not considered necessary.

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Conflict of interest: None declared.

Data availability

The data underlying this article will be shared upon reasonable request to the corresponding author.

Lead author biography

Professor Gianluca Pontone graduated with honours in medicine in 1997 followed by post-graduate degree in cardiology and radiology and PhD in Clinical Methodology in 2001, 2006, and 2014 at University of Milan, Italy. He is currently the director of Perioperative Cardiology and Cardiovascular Imaging Department and Co-director of Sport Cardiology Unit of Centro Cardiologico Monzino, a fully dedicated research hospital to cardiovascular disease and Professor of Cardiology at University of Milan. He is an author of more than 500 indexed articles on international journal, and he is currently the vice president of European Association Cardiovascular Imaging (EACVI) and chairman of working group of cardiovascular imaging of Italian Society of Cardiology (SIC).

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