

Impact of COVID-19 on the imaging diagnosis of cardiac disease in Europe

(NCAPS COVID Investigators Group) Williams, Michelle Claire; Shaw, Leslee; Hirschfeld, Cole B; Maurovich-Horvat, Pal; Nørgaard, Bjarne L; Pontone, Gianluca; Jimenez-Heffernan, Amelia; Sinitsyn, Valentin; Sergienko, Vladimir; Ansheles, Alexey; ...

Source / Izvornik: **Open Heart**, 2021, 8

Journal article, Published version

Rad u časopisu, Objavljena verzija rada (izdavačev PDF)

<https://doi.org/10.1136/openhrt-2021-001681>

Permanent link / Trajna poveznica: <https://urn.nsk.hr/urn:nbn:hr:184:794440>

Rights / Prava: [Attribution-NonCommercial-NoDerivatives 4.0 International/Imenovanje-Nekomercijalno-Bez prerada 4.0 međunarodna](#)

Download date / Datum preuzimanja: **2025-03-12**







Repository / Repozitorij:

[Repository of the University of Rijeka, Faculty of Medicine - FMRI Repository](#)



openheart Impact of COVID-19 on the imaging diagnosis of cardiac disease in Europe

Michelle Claire Williams ¹, Leslee Shaw,² Cole B Hirschfeld,³ Pal Maurovich-Horvat ⁴, Bjarne L Nørgaard,⁵ Gianluca Pontone,⁶ Amelia Jimenez-Heffernan,⁷ Valentin Sinitsyn,⁸ Vladimir Sergienko,⁹ Alexey Ansheles,⁹ Jeroen J Bax,¹⁰ Ronny Buechel,¹¹ Elisa Milan,¹² Riemer H J A Slart,¹³ Edward Nicol,¹⁴ Chiara Bucciarelli-Ducci ^{15,16}, Yaroslav Pynda,¹⁷ Nathan Better,¹⁸ Rodrigo Cerci,¹⁹ Sharmila Dorbala,²⁰ Paolo Raggi,²¹ Todd C Villines,²² Joao Vitola,¹⁹ Eli Malkovskiy ³, Benjamin Goebel,²³ Yosef Cohen,²⁴ Michael Randazzo,³ Thomas N B Pascual,²⁵ Maurizio Dondi,¹⁷ Diana Paez,¹⁷ Andrew J Einstein,²⁶ On behalf of INCAPS COVID Investigators Group

► Additional supplemental material is published online only. To view, please visit the journal online (<http://dx.doi.org/10.1136/openhrt-2021-001681>).

To cite: Williams MC, Shaw L, Hirschfeld CB, *et al.* Impact of COVID-19 on the imaging diagnosis of cardiac disease in Europe. *Open Heart* 2021;**8**:e001681. doi:10.1136/openhrt-2021-001681

Received 6 April 2021
Accepted 12 July 2021



© Author(s) (or their employer(s)) 2021. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

For numbered affiliations see end of article.

Correspondence to

Dr Michelle Claire Williams;
michelle.williams@ed.ac.uk

ABSTRACT

Objectives We aimed to explore the impact of the COVID-19 pandemic on cardiac diagnostic testing and practice and to assess its impact in different regions in Europe.

Methods The online survey organised by the International Atomic Energy Agency Division of Human Health collected information on changes in cardiac imaging procedural volumes between March 2019 and March/April 2020. Data were collected from 909 centres in 108 countries.

Results Centres in Northern and Southern Europe were more likely to cancel all outpatient activities compared with Western and Eastern Europe. There was a greater reduction in total procedure volumes in Europe compared with the rest of the world in March 2020 (45% vs 41%, $p=0.003$), with a more marked reduction in Southern Europe (58%), but by April 2020 this was similar in Europe and the rest of the world (69% vs 63%, $p=0.261$). Regional variations were apparent between imaging modalities, but the largest reductions were in Southern Europe for nearly all modalities. In March 2020, location in Southern Europe was the only independent predictor of the reduction in procedure volume. However, in April 2020, lower gross domestic product and higher COVID-19 deaths were the only independent predictors.

Conclusion The first wave of the COVID-19 pandemic had a significant impact on care of patients with cardiac disease, with substantial regional variations in Europe. This has potential long-term implications for patients and plans are required to enable the diagnosis of non-COVID-19 conditions during the ongoing pandemic.

INTRODUCTION

Non-communicable diseases, including cardiovascular disease, remain the leading cause of mortality around the world. However, during the COVID-19 pandemic, there has been a dramatic disruption in healthcare provision around the world. Accurate diagnosis

Key questions

What is already known about this subject?

► Worldwide COVID-19 has had a dramatic impact on care of patients with cardiovascular disease. However, the impact on cardiac diagnostic testing in Europe has not been studied.

What does this study add?

► The COVID-19 pandemic resulted in a reduction in cardiac imaging in Europe of 45% in March 2020 and 69% in April 2020 compared with 2019, with the largest reduction in Southern Europe. In April 2020, lower gross domestic product and higher COVID-19 deaths were independent predictors of the reduction in cardiac imaging.

How might this impact on clinical practice?

► The considerable variability in the response to the pandemic has important implications for patient care. It is important to identify patients who have missed out on diagnostic testing. In addition, preparation for future waves of the pandemic should address these issues.

is central to the treatment of cardiac disease and delayed or missed diagnoses have the potential to impact long-term morbidity and mortality. After China and some countries in Southeast Asia, Europe became the epicentre of COVID-19 in March 2020. This paper focuses on the impact of the first peak of the COVID-19 pandemic on the management of cardiac disease in Europe compared with the rest of the world, in order to provide important learning opportunities for impending waves of the COVID-19 pandemic and for future pandemics.

Established guidelines have been developed which place non-invasive imaging at

the centre of the diagnosis and management of coronary artery disease. However, during the COVID-19 pandemic, both guidelines¹⁻⁵ and local practices have changed. We have recently shown in an international survey that the COVID-19 pandemic was associated with a significant reduction in cardiac imaging around the world, with a 64% reduction in cardiac imaging between March 2019 and April 2020.⁶ Several studies have shown that during the March/April 2020 COVID-19 peak, there was a reduction in hospital admissions for acute coronary syndromes,⁷⁻⁹ and an increase in out-of-hospital cardiac arrests¹⁰ with excess cardiovascular mortality around the world.¹¹ Furthermore, COVID-19 is itself potentially associated with myocardial injury, arrhythmia, and venous and arterial thrombosis.^{12 13} It is therefore essential that the diagnosis and management of cardiac disease is optimised during the COVID-19 pandemic.

The International Atomic Energy Agency (IAEA) Division of Human Health aims to support member states to combat cardiovascular diseases, cancer, malnutrition and other diseases through the use of appropriate prevention, diagnostic testing and treatment. In this light, the IAEA coordinated a worldwide survey of cardiac imaging laboratories (the IAEA Noninvasive Cardiology Protocols Study of COVID-19, INCAPS COVID Survey), to assess the impact of the pandemic on the diagnosis of cardiac disease. This analysis of the INCAPS COVID Survey aims to assess the impact of the COVID-19 pandemic on the diagnosis of cardiac diseases in Europe during the first peak of the pandemic, in order to inform future strategies.

METHODS

Study design

Data for this study were collected as part of the IAEA survey on the impact of COVID-19 on cardiac imaging (INCAPS COVID). An online survey was developed by a steering committee which included experts in cardiology and cardiovascular imaging. The survey included questions regarding the healthcare facility, healthcare professionals, personal protective equipment, strategic plans for reopening and changes in procedural volumes for a range of cardiac imaging procedures.

Data collection

Survey data were collected using a secure software platform used by the IAEA, the International Research Integration System (<https://iris.iaea.org>). Participation was encouraged using email and social media activity, from the IAEA, national and international cardiology and imaging societies and from national coordinators. No patient-specific or confidential data were collected. Patients or the public were not involved in the design, conduct, reporting or dissemination plans of this publication. During data collection, the Data Coordination Committee reviewed entries and reached out to survey participants with questions regarding missing, implausible, duplicate or inconsistent data. Participants were

provided the opportunity to clarify and correct response as needed. For each centre, only one entry was included in the final dataset. Final database cleaning was completed on 1 July 2020. Entries were excluded for reasons such as missing or incomplete responses to the questionnaire. As data were provided in confidence to the IAEA by survey respondents, sharing of the underlying data is not possible.

Population data were based on data obtained from World Bank from 2019.¹⁴ Data on COVID-19 cases and deaths in March and April 2020 were obtained from the WHO COVID-19 dashboard.¹⁵ Territories were not included in per country COVID-19 case numbers. Information on gross domestic product (GDP) was obtained from the World Bank for 2019.¹⁴ Income group was defined using the World Bank classification of high, upper-middle, lower-middle and low.¹⁶

Cardiac imaging procedure volumes

Participants were asked to provide estimates of procedure volumes from March 2019, March 2020 and April 2020, including both anatomical and functional imaging. Anatomical imaging included transthoracic echocardiography (TTE), transoesophageal echocardiography (TOE), cardiac magnetic resonance (CMR, non-stress), positron emission tomography (PET) infection studies, coronary artery calcium scanning, coronary CT angiography (CCTA) and invasive coronary angiography (ICA). Functional imaging included stress ECG, stress echocardiography, stress single-photon emission CT (SPECT), stress PET and stress CMR. Stress nuclear imaging included combined data from stress SPECT and stress PET. Data were aggregated on a regional level. Countries in Europe were defined using the United Nations geoscheme.¹⁷ European countries were divided into Northern, Southern, Eastern and Western regions, with Turkey and Cyprus included in the Eastern region.

Statistical analysis

In total, 936 questionnaires were submitted, and 27 duplicates were excluded from the results. Statistical analysis was performed using R (V.4.0.1, R Development Core Team, Vienna, Austria). Survey question responses are presented as number and percentage. Continuous data that are not normally distributed are presented as median and interquartile interval. Percentage change in procedure volume was compared between March 2019 and March or April 2020. A linear regression model was constructed to assess the impact of European region, population, GDP and COVID-19 deaths at a country level, on procedure volume reduction at a centre level in March and April 2020 compared with March 2019. COVID-19 cases and COVID-19 deaths were strongly correlated on a per country basis, but as the availability of COVID-19 testing was variable across countries, particularly in the early stages of the pandemic, COVID-19 deaths were chosen for inclusion in the linear regression

Table 1 Information on centres providing data for the survey in different European regions and comparisons between Europe and the rest of the world

	European region				P value	Europe	World	P value
	Western	Southern	Eastern	Northern				
Centres	38	95	38	70	–	241	605	–
Number of countries	8	12	11	9		40	66	–
Centre type								
Inpatient	92% (35)	97% (92)	87% (33)	97% (68)	0.080	95% (228)	76% (457)	<0.001
Outpatient	8% (3)	3% (3)	13% (5)	3% (2)		5% (13)	25% (148)	
Teaching facility	74% (28)	78% (74)	76% (29)	87% (61)	0.295	80% (192)	61% (369)	<0.001
Number of beds	900 [615–1110]	700 [290–999]	480 [225–1000]	633 [358–878]	0.034	700 [345–999]	450 [200–800]	<0.001
COVID-19 cases*	423 337	462 863	286 308	233 676	–	1 406 184	1 560 392	–
COVID-19 deaths*	45 053	54 289	6478	31 003	–	136 823	83 368	–

Numbers indicate absolute percentage and absolute values in parentheses. IQRs are shown in square brackets.

Bold text indicates a p value of <0.05.

*Per country providing procedure volume data and summed per region. COVID-19 cases and deaths in March and April 2020 from the WHO COVID-19 dashboard.¹⁵

model. Population, GDP and COVID-19 deaths were log transformed for analysis.

RESULTS

Centres

Around the world data were collected from 909 centres in 108 countries, and of these 845 centres in 106 countries provided data on procedure volumes. In Europe, data were collected from 241 centres in 40 countries, including 38 (16%) centres in Western Europe, 95 (39%) in Southern Europe, 38 (16%) in Eastern Europe and 70 (29%) in Northern Europe (table 1). Compared with the rest of the world, European centres were more likely to have inpatient facilities (95% vs 76%, $p<0.001$), teaching facilities (80% vs 61%, $p<0.001$) and had more hospital beds (700 (IQR 345–999) vs 450 (IQR 200–800), $p<0.001$; table 1). The number of hospital beds per centre was largest in Western Europe (table 1, $p=0.034$), but there were no other differences in facility type between European regions.

Changes to imaging procedure volumes

In surveyed European centres, a total of 142 463 procedures were performed in March 2019. There was a 45% reduction in total procedure volume in March 2020 ($n=78 969$) and a 69% reduction in April 2020 ($n=44 469$). For functional imaging in Europe in April 2020, the largest reductions in procedure volume compared with March 2019 were identified in stress echocardiography (84%), followed by stress ECG (83%), stress SPECT (79%), stress CMR (68%) and stress PET (42%, table 2). For anatomical imaging in Europe in April 2020 compared with March 2019, reductions in procedures by modality were identified

in CT calcium score (78%), followed by TEE (74%), CMR (non-stress, 72%), CCTA (69%), TTE (67%), PET studies for infection (53%) and ICA (51%, table 2). In April 2020, procedure volume reductions were similar in Europe compared with the rest of the world for all modalities, except for larger reductions in stress SPECT (79% vs 73%, $p=0.002$), stress nuclear (77% vs 72%, $p=0.012$) and CCTA (69% vs 50%, $p=0.003$, table 2).

There were regional and country variations in the reduction in total procedures (figure 1). In March 2020, there was a larger reduction in total procedures in Europe compared with the rest of the world (45% vs 41%, $p=0.003$), with the largest reductions in Southern Europe (58%, $p<0.001$, table 2). In April 2020, the reduction in total procedures was similar in Europe and the rest of the world (69% vs 63%, $p=0.261$), and Southern Europe remained the region with the highest total procedure reduction (78%, $p<0.001$).

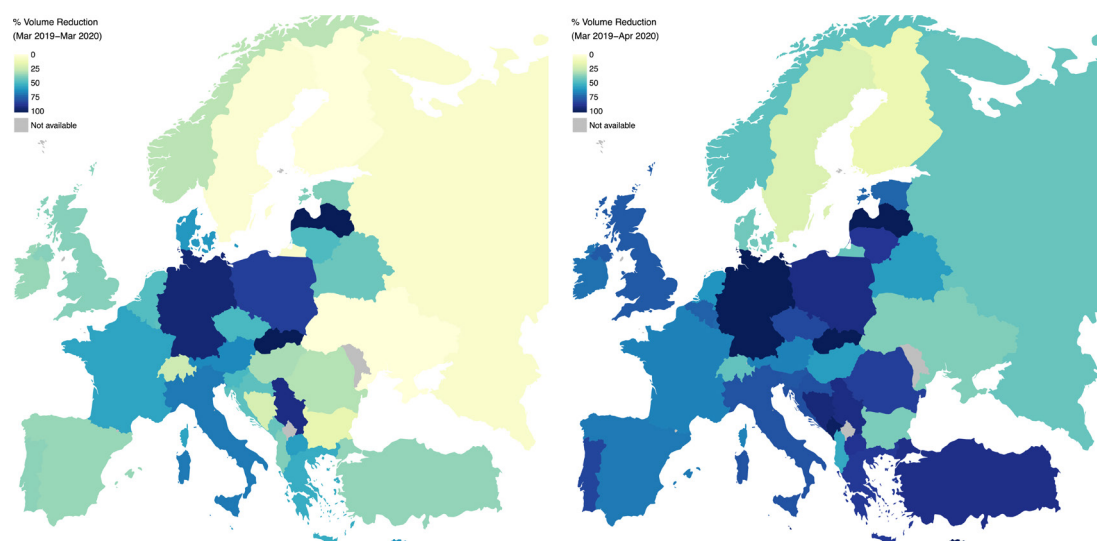
For all modalities, the reduction in procedure volume was higher in April 2020 compared with March 2020 (figures 2 and 3). Regional variations were apparent with the largest reductions in Southern Europe in both March and April 2020 for all modalities apart from CT calcium score, stress echocardiography and PET infection studies. In April 2020, procedure volume reductions were highest in Southern Europe for stress PET (94% reduction, $p=0.006$), stress nuclear (84% reduction, $p=0.014$), CMR (non-stress, 78% reduction, $p=0.010$) and invasive coronary angiography (63% reduction, $p=0.009$, table 2). Reduction in PET infection studies was highest in Eastern Europe (71% and 92%, respectively, $p<0.001$). Reductions in stress CMR and non-stress CMR were highest in Southern and Northern Europe (table 2).

Table 2 Reduction in procedure volumes across European regions compared with the rest of the world

	European region				P value	Europe	World	P value
	Western	Southern	Eastern	Northern				
Centres	38	95	38	70	–	241	605	–
Total procedure volume								
March 2019	24 018	48 340	13 149	56 956	–	142 463	536 175	–
March 2020	13 433	20 517	10 343	34 676	–	78 969	315 656	–
April 2020	9060	10 865	5819	18 725	–	44 469	199 967	–
Reduction in total procedures								
March 2019–March 2020	44%	58%	21%	39%	<0.001	45%	41%	0.003
March 2019–April 2020	62%	78%	56%	67%	<0.001	69%	63%	0.261
Reduction in procedures by modality (March 2019–April 2020)—functional imaging								
Stress ECG	76%	93%	49%	82%	0.115	83%	85%	0.923
Stress echocardiography	86%	89%	51%	93%	0.160	84%	82%	0.428
Stress SPECT	73%	83%	76%	77%	0.112	79%	73%	0.002
Stress PET	0	94%	88%	13%	0.006	42%	59%	0.739
Stress nuclear (SPECT and PET)	67%	84%	78%	72%	0.014	77%	72%	0.012
Stress CMR	45%	89%	40%	76%	0.081	68%	75%	0.948
Reduction in procedures by modality (March 2019–April 2020)—anatomical imaging								
CT calcium score	88%	77%	45%	93%	0.552	78%	70%	0.534
CCTA	58%	75%	68%	68%	0.896	69%	50%	0.003
TTE	67%	73%	50%	66%	0.174	67%	57%	0.331
TEE	65%	84%	54%	72%	0.139	74%	76%	0.070
PET infection	27%	71%	92%	13%	<0.001	53%	71%	0.714
CMR (non-stress)	45%	78%	55%	78%	0.010	72%	59%	0.067
Invasive coronary angiography	34%	63%	45%	50%	0.009	51%	59%	0.951

Bold text indicates a p value of <0.05.

CCTA, coronary CT angiography; CMR, cardiac magnetic resonance; PET, positron emission tomography; SPECT, single-photon emission CT; TEE, transoesophageal echocardiography; TTE, transthoracic echocardiography.

**Figure 1** Reduction in total cardiac imaging procedure volume (March 2019–March 2020 and March 2019–April 2020).

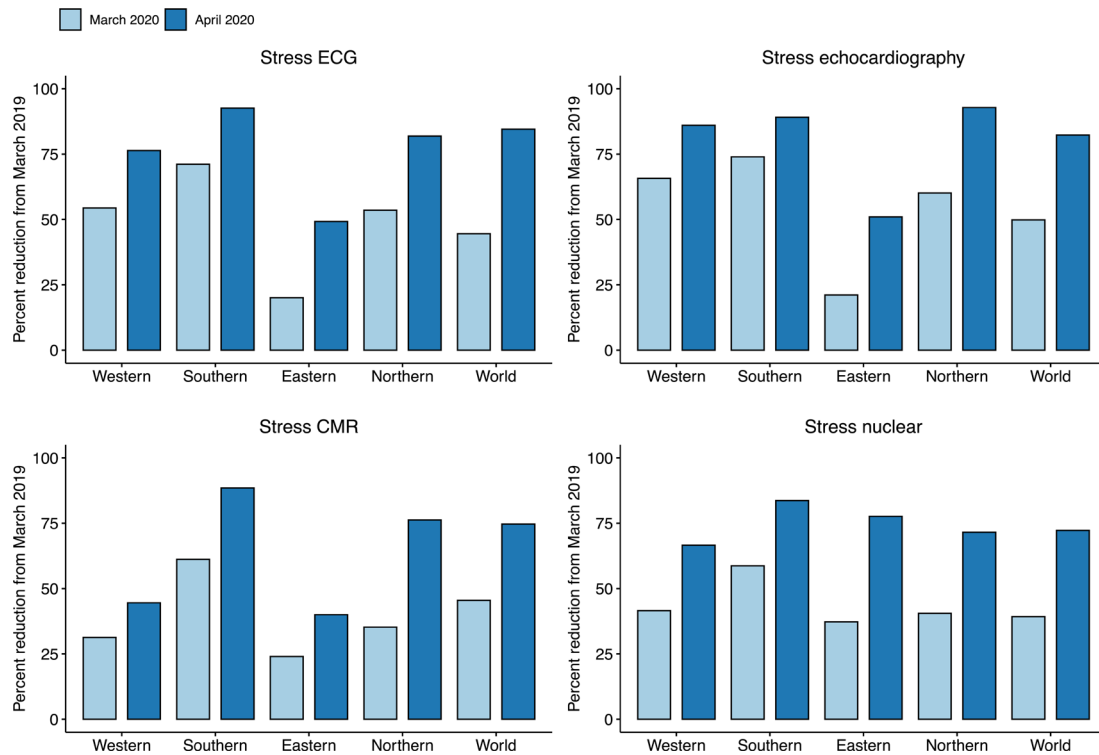


Figure 2 Reduction in procedure volume for functional imaging in different regions of Europe from March 2019 to March 2020 and April 2020. CMR, cardiac magnetic resonance.

During March and April 2020, there were 1 406 184 COVID-19 cases recorded in European countries represented in the survey, with more occurring in Western and Southern Europe compared with Northern or Eastern Europe (table 1). When centres providing information were stratified by World Bank income group, there were 210 European centres located in high-income countries, 29 in upper middle-income countries and 2 in low/middle-income countries. In April 2020, the European reduction in procedure volumes was highest in Europe in upper middle-income countries (77%), compared with high-income countries (68%) and lower middle-income countries (36%, $p=0.017$). Multivariable analysis showed that in March 2020, location in Southern Europe was the only independent predictor of a reduction in cardiac imaging procedure volume (figure 4). However, in April 2020, multivariable analysis showed that lower GDP and higher COVID-19 deaths were the only independent predictors of a reduction in imaging procedure volume (figure 4).

Changes in practice, imaging protocols and staffing

In Europe, 85% of centres reduced outpatient activities during March/April 2020, while 44% of centres cancelled all outpatient activities, similar to the rest of the world (table 3). Among European regions, the proportion of centres cancelling all outpatient activities was lower in Eastern and Western Europe compared with the other regions. European centres were also more likely to be planning phased reopening compared with the rest of the world (58% vs 51%, $p=0.003$), and this was particularly common in Western Europe (85%, $p=0.001$).

European centres were more likely to use extended working hours but less likely to use telehealth and remote reporting, compared with the rest of the world (table 2). Within Europe, the use of remote reporting was more common in Western and Northern Europe. European centres were less likely to perform temperature measurements, symptom screening and COVID-19 testing in imaging centres compared with the rest of the world. There were regional variations in the planning of patient arrivals, physical distancing in waiting areas, separate spaces for patients with COVID-19, limiting visitors, use of temperature measurements, masks for patients/visitors and increasing time for cleaning. European centres were less likely to change imaging protocols compared with the rest of the world (table 4), with regional variations in the use of exercise stress and modifications to cardiac nuclear and CT protocols. Redeployment of imaging staff was less frequent in Europe compared with the rest of the world (15% vs 22%, $p=0.011$). Use of furlough, reducing salaries or laying off staff was less frequent in Europe compared with the rest of the world (table 4).

DISCUSSION

The COVID-19 pandemic has had a dramatic impact on the provision of healthcare around the world. In this international survey of 108 countries, we have shown the substantial impact of the COVID-19 pandemic on the care of patients with cardiac disease. Responses to the COVID-19 pandemic varied throughout European countries and European regions, with a 45% reduction

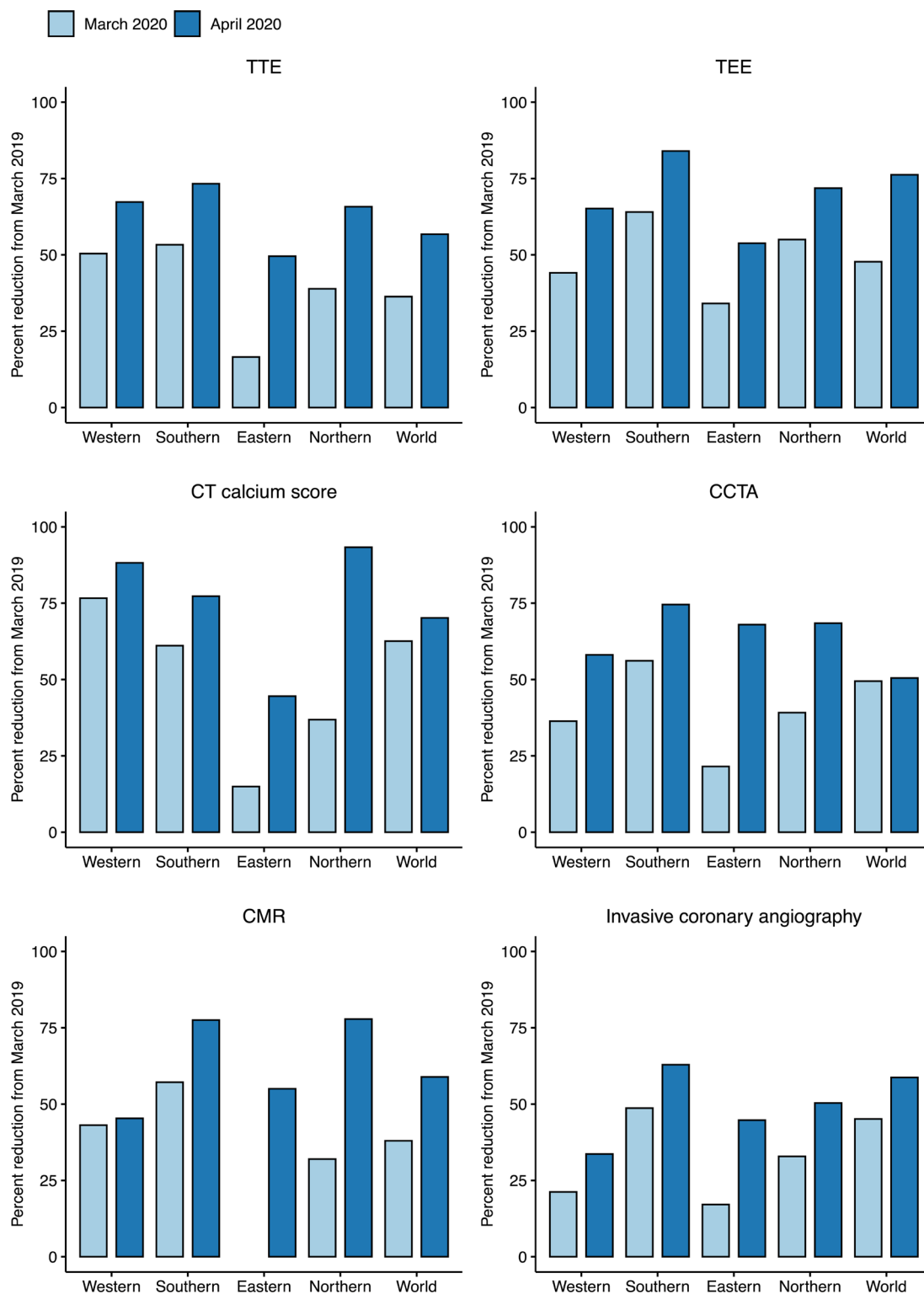


Figure 3 Reduction in procedure volume for anatomical imaging in different regions of Europe from March 2019 to March 2020 and April 2020. CCTA, coronary CT angiography; CMR, cardiac magnetic resonance (non-stress); TEE, transoesophageal echocardiography; TTE, transthoracic echocardiography.

in total cardiac imaging in March 2020 and a 69% reduction in April 2020. Reductions in cardiac imaging and changes to practices were greater in Europe compared with the rest of the world, particularly in Southern Europe, reflecting the trajectory of the pandemic at the time of the survey. Only location in Southern Europe was

a predictor of the reduction of cardiac imaging in March 2020, whereas lower GDP and higher COVID-19 deaths were independent predictors in April 2020. This highlights the considerable variability in the response to the pandemic, which has important implications for patient care.

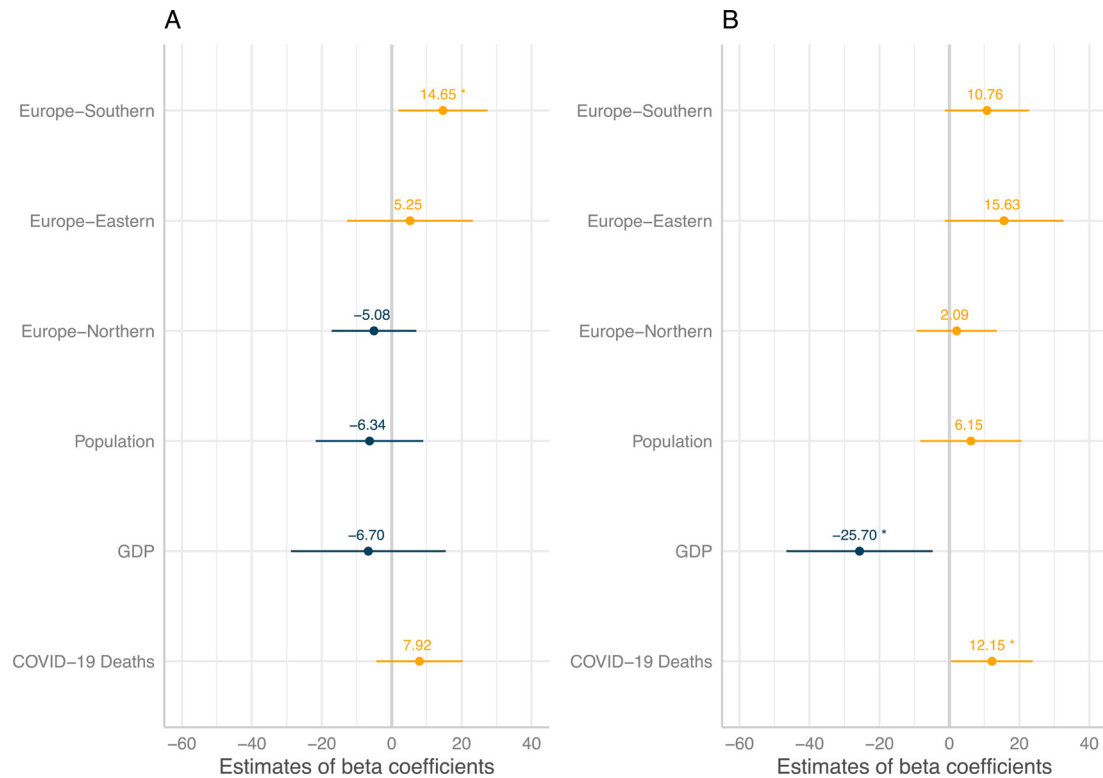


Figure 4 Multivariable models for the reduction in procedure volume at centres from March 2019 to (A) March 2020 and (B) April 2020. Population, GDP and COVID-19 deaths were log transformed for analysis (log10). Graphs show estimate of the beta coefficients and SE. * indicates a p value of <0.05. European regions were compared with Western Europe as the baseline. GDP, gross domestic product.

Cardiac imaging is central to the diagnostic pathway for many patients, with both acute and chronic conditions. Without accurate diagnoses, appropriate treatment cannot be provided. The COVID-19 pandemic has caused both delay and complete inability to obtain a diagnosis for many patients with cardiac conditions around the world. In Europe, in particular, only half the usual number of procedures were performed in March 2020, and one-third in April 2020. This may have important short-term and long-term health implications. In addition, patients with underlying cardiovascular disease are at an increased risk of poor outcomes following COVID-19 infection.^{18–21}

During the COVID-19 pandemic, several studies have reported an increase in out-of-hospital cardiac arrests^{10 22} and excess cardiovascular mortality.¹¹ In March 2020, there was a 48% reduction in admissions with acute myocardial infarction to Italian coronary care units²³ and in April 2020, there was a 52% increase in out-of-hospital cardiac arrests in some regions in Italy.²² Similarly, in England in March 2020, there was a 40% reduction in hospital admissions for acute coronary syndromes compared with the previous year.⁷ The worldwide reduction in hospital admissions with acute coronary syndromes^{7–9 23–25} is particularly concerning, as rapid diagnosis and treatment of this condition has been responsible for significant improvements in morbidity and mortality in recent years. Delays in cardiac diagnostic imaging may also impact other cardiovascular

treatments such as transcatheter aortic valve implantation²⁶ and cardiac surgery.²⁷

The long-term implications of delays in making an accurate diagnosis of cardiac diseases are currently uncertain, but our survey shows that there are many thousands of patients who have had their diagnosis delayed or prevented. It is possible that we may see later presentations or more severe presentations of cardiac conditions. Over the longer term, these patients may not be receiving appropriate preventative treatments because of their delayed diagnosis, and this may have downstream implications on cardiac morbidity and mortality. Guidelines have been developed to aid with the restarting of cardiac imaging services.^{1 2 5 28 29} Addressing this issue in a timely manner will be an important issue for health policymakers as countries deal with future waves of the COVID-19 pandemic and subsequent recovery.

Responses to the COVID-19 pandemic have varied between and within countries throughout Europe, influenced by a variety of factors including COVID-19 case numbers, the underlying healthcare system and political factors. We have shown that there were patterns in the application of these policies for healthcare in different regions in Europe, which initially reflected regional location but by April 2020 reflected COVID-19 deaths and GDP. Countries with a lower GDP were more likely to reduce cardiac imaging procedures in April 2020, likely in an attempt to prevent their healthcare

Table 3 Imaging departments' change in capacity and practice

	European region				P value	Europe	World	P value
	Western	Southern	Eastern	Northern				
	41	96	42	72	–	251	658	–
Change in capacity								
Some outpatient activities cancelled	98%	79%	81%	88%	0.217	85%	82%	0.076
All outpatient activities cancelled	37%	48%	33%	50%	0.009	44%	45%	0.512
Phased reopening	85%	51%	50%	53%	0.001	58%	51%	0.003
Extended hours	24%	23%	12%	17%	0.104	20%	11%	0.003
New weekend hours	17%	12%	10%	8%	0.237	11%	9%	0.735
Use telehealth for patient care	46%	45%	33%	53%	0.133	45%	59%	<0.001
Remote reporting	49%	28%	38%	57%	0.013	41%	51%	0.018
Change in practice								
Alterations in patient arrival	73%	61%	55%	81%	0.006	68%	73%	0.454
Physical distancing in waiting areas	95%	83%	79%	93%	0.007	87%	89%	0.383
Separate spaces for patients with COVID-19	90%	82%	62%	82%	0.016	80%	78%	0.847
Reducing patient time in waiting rooms	78%	91%	69%	81%	0.081	82%	81%	0.775
Limit accompanying family members and/or visitors	95%	95%	79%	94%	0.014	92%	92%	0.877
Temperature measurements	44%	74%	88%	18%	<0.001	55%	72%	<0.001
Symptom screening	73%	62%	71%	69%	0.357	68%	82%	<0.001
COVID-19 testing	10%	7%	12%	10%	0.330	9%	17%	0.003
Require masks for patients/visitors	68%	90%	88%	42%	<0.001	72%	76%	0.013
Increase time for cleaning	63%	75%	71%	76%	0.012	73%	72%	0.177

Light grey, <50%; dark grey, ≥50%; bold, p<0.05.

systems becoming overwhelmed. In addition to policies cancelling non-urgent investigations, other important factors may have driven the decline in performance of

imaging procedures, such as patient's inability or reluctance to seek healthcare advice during the COVID-19 pandemic. This includes factors such as fear, a desire

Table 4 Imaging departments' change in imaging protocols and staffing

	European region				P value	Europe	World	P value
	Western	Southern	Eastern	Northern				
	41	96	42	72	–	251	658	–
Changes to imaging protocols								
Limiting staff proximity to patients	90%	83%	76%	83%	0.166	83%	83%	0.830
Mandate personal protective equipment	93%	89%	88%	88%	0.151	88%	86%	0.611
Eliminate protocols requiring close contact	52%	51%	48%	65%	0.100	55%	64%	0.026
Avoid exercise stress testing	34%	51%	31%	39%	0.025	41%	51%	0.018
Modify cardiac nuclear imaging protocols	7%	31%	12%	10%	<0.001	18%	28%	0.009
Modify cardiac CT protocols	2%	15%	2%	14%	<0.001	10%	15%	0.139
Changes to staffing								
Redeployment	10%	16%	17%	15%	0.799	15%	23%	0.011
Rotating staff work shifts	54%	69%	62%	69%	0.091	66%	68%	0.451
Furloughed imaging physicians	7%	9%	10%	4%	1	8%	17%	<0.001
Furloughed non-physician imaging staff	10%	8%	12%	3%	0.288	8%	23%	<0.001
Reduced salaries of imaging physicians	7%	5%	12%	4%	0.638	6%	24%	<0.001
Reduced salaries of non-physician imaging staff	7%	3%	12%	4%	0.289	6%	22%	<0.001
Laid off imaging physicians	2%	0	5%	1%	0.374	2%	2%	0.038
Laid off non-physician imaging staff	2%	1%	2%	1%	0.660	2%	7%	<0.001

Light grey, <50%; dark grey, ≥50%; bold, p<0.05.

to avoid potential infection, access to public transport and other essential axillary services. This appears to be part of a general pattern of reduced healthcare utility for non-COVID-19 conditions during the pandemic. For example, emergency department visits decreased 41%–64% in the USA³⁰ and delayed cancer diagnoses are predicted to result in a significant increase in mortality over the next 5 years.³¹ It is therefore essential that we optimise healthcare access for patients with non-COVID-19 conditions during the pandemic.

This was a self-reported survey and thus has some limitations. Efforts were made to distribute this survey widely, but we cannot exclude that the included sites represent outliers in each country. Sampling and response bias are a potential issue with these data, as with any survey. This analysis was not based on national reporting of procedure numbers which may have been more thorough in some countries, but is not available or is inconsistent in many countries around the world. Country-level data for income and COVID-19 cases and deaths were used rather than centre-level data. Information for this survey was obtained during March and April 2020, which represented the initial peak of the COVID-19 pandemic in some countries. However, for some countries around the world, the peak came later, and for China the peak came earlier. We plan further surveys to assess further changes in practice. We found that in Europe, the reduction in procedure volumes was highest in upper middle-income countries compared with high or lower middle-income countries, which is different from the pattern observed worldwide.⁶ This may reflect the small number of lower middle-income European countries included in this survey and the distribution of countries of different income groups relative to the geographical epicentres of the early pandemic. In addition, country-based variations in the recording of COVID-19 cases and deaths may impact results.

In conclusion, we have shown the significant impact of the COVID-19 pandemic on the performance of diagnostic imaging for cardiac disease in Europe. This survey provides important information, as we now need to learn how to deal with an ongoing viral pandemic at the same time as managing patients with cardiac diseases.

Author affiliations

¹Centre for Cardiovascular Science, University of Edinburgh, Edinburgh, UK

²Presbyterian Hospital/Weill Cornell Medical Center, New York, New York, USA

³Columbia University Irving Medical Center, New York, New York, USA

⁴MTA-SE Cardiovascular Imaging Research Group, Semmelweis University, Heart and Vascular Center, Budapest, Hungary

⁵Cardiology, Aarhus University Hospital, Aarhus, Denmark

⁶Department of Cardiovascular Imaging, Centro Cardiologico Monzino IRCCS, Milan, Italy

⁷Hospital Juan Ramón Jiménez, Huelva, Spain

⁸Lomonosov Moscow State University, Moscow, Russian Federation

⁹National Medical Research Center of Cardiology of Healthcare Ministry, Moscow, Russian Federation

¹⁰Department of Cardiology, Leiden University Medical Center, Leiden, The Netherlands

¹¹Department of Nuclear Medicine, University Hospital Zurich, Zurich, Switzerland

¹²UOC Nuclear Medicine- Ospedale Cà Foncello, Treviso, Italy

¹³Department of Nuclear Medicine and Molecular Imaging, University of Groningen, Groningen, The Netherlands

¹⁴Department of Imaging, Royal Brompton Hospital, London, UK

¹⁵Royal Brompton and Harefield Hospitals, London, UK

¹⁶Guys and St Thomas NHS Trust and King's College London, London, UK

¹⁷International Atomic Energy Agency, Vienna, Austria

¹⁸Royal Melbourne Hospital and University of Melbourne, Melbourne, Victoria, Australia

¹⁹Quanta Diagnostico, Curitiba, Brazil

²⁰Brigham and Women's Hospital, Boston, Massachusetts, USA

²¹Division of Cardiology, University of Alberta, Edmonton, Alberta, Canada

²²Medicine (Cardiology), Walter Reed National Military Medical Center, Bethesda, Maryland, USA

²³Weill Cornell Medical College, New York, New York, USA

²⁴Technion Israel Institute of Technology, Haifa, Israel

²⁵Philippine Nuclear Research Institute, Quezon City, Philippines

²⁶Columbia University Medical Center, New York, New York, USA

Twitter Michelle Claire Williams @imagingmedsci and Chiara Bucciarelli-Ducci @ chiarabd

Acknowledgements The INCAPS COVID Investigators Group, listed by name in the online supplemental information, thank 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, Gruppo Italiano Cardiologia Nucleare, The Danish Society of Cardiology, Sociedad Española de Medicina Nuclear e Imagen Molecular, Indonesian Society of Nuclear Medicine, Japanese Society of Nuclear Cardiology, Philippine Society of Nuclear Medicine, Russian Society of Radiology, Moscow Regional Department of Russian Nuclear Medicine Society, Society of Cardiovascular Computed Tomography, and Thailand Society of Nuclear Medicine. MCW (FS/ICRF/20/26002) is supported by the British Heart Foundation.

Collaborators INCAPS COVID Investigators Group: Mohammad Nawaz Nasery; Artan Goda; Eryna Shirka; Rabie Benlabgaa; Salah Bouyoucef; Abdelkader Medjahedi; Qais Nailli; Mariela Agolti; Roberto Nicolas Agüero; Maria del Carmen Alak; Lucia Graciela Alberguina; Guillermo Arrofiada; Andrea Astesiano; Alfredo Astesiano; Carolina Bas Norton; Pablo Benteo; Juan Blanco; Juan Manuel Bonelli; Jose Javier Bustos; Raul Cabrejas; Jorge Cachero; Roxana Campisi; Alejandro Canderoli; Silvia Carames; Patricia Carrascosa; Ricardo Castro; Oscar Cendoya; Luciano Martin Cognigni; Carlos Collaud; Carlos Collaud; Claudia Cortes; Javier Curtis; Daniel Cragolino; Mariana Daicz; Alejandro De La Vega; Silvia Teresa De Maria; Horacio Del Riego; Fernando Dettori; Alejandro Deviggiano; Laura Dragonetti; Mario Embon; Ruben Emilio Enriquez; Jorge Ensinas; Fernando Faccio; Adolfo Facello; Diego Garofalo; Ricardo Geronazzo; Natalia Gonza; Lucas Gutierrez; Miguel Angel Guzzo; Miguel Angel Guzzo; Victor Hasbani; Melina Huerin; Victor Jäger; Julio Manuel Lewkowicz; Maria Nieves A López De Munain; Jose Maria Lotti; Alejandra Marquez; Osvaldo Masoli; Osvaldo Horacio Masoli; Edgardo Mastrovito; Matias Mayoraz; Graciela Eva Melado; Anibal Mele; Maria Fernanda Merani; Alejandro Horacio Meretta; Susana Molteni; Marcos Montecinos; Eduardo Noguera; Carlos Novoa; Claudio Pereyra Sueldo; Sebastian Perez Ascani; Pablo Pollono; Maria Paula Pujol; Alejandro Radzinski; Gustavo Raimondi; Marcela Redruello; Marina Rodríguez; Matías Rodríguez; Romina Lorena Romero; Arturo Romero Acuña; Federico Rovalletti; Lucas San Miguel; Lucrecia Solari; Bruno Strada; Sonia Traverso; Sonia Simona Traverso; Maria del Huerto Velazquez Espeche; Juan Sebastian Weihmuller; Juan Wolcan; Susana Zeffiro; Mari Sakanyan; Scott Beuzeville; Raef Boktor; Patrick Butler; Jennifer Calcott; Loretta Carr; Virgil Chan; Charles Chao; Woon Chong; Mark Dobson; D'Arne Downie; Girish Dwivedi; Barry Elison; Jean Engela; Roslyn Francis; Anand Gaikwad; Ashok Gangasandra Basavaraj; Bruce Goodwin; Robert Greenough; Christian Hamilton-Craig; Victor Hsieh; Subodh Joshi; Karin Lederer; Kenneth Lee; Joseph Lee; John Magnussen; Nghi Mai; Gordon Mander; Fiona Murton; Dee Nandurkar; Johanne Neill; Edward O'Rourke; Patricia O'Sullivan; George Pandos; Kunthi Pathmaraj; Alexander Pitman; Rohan Poulter; Manuja Premaratne; David Prior; Lloyd Ridley; Natalie Rutherford; Hamid Salehi; Connor Saunders; Luke Scarlett; Sujith Seneviratne; Deepa Shetty; Ganesh Shrestha; Jonathan Shulman; Vijay Solanki; Tony Stanton; Murch Stuart; Michael Stubbs; Ian Swainson; Kim Taubman; Andrew Taylor; Paul Thomas; Steven Unger; Anthony Upton; Shankar Vamadevan; William Van Gaal; Johan Verjans;

Demetrius Voutnis; Victor Wayne; Peter Wilson; David Wong; Kirby Wong; John Younger; Gudrun Feuchtnet; Siros Mirzaei; Konrad Weiss; Natalia Maroz-Vadalazhskaya; Olivier Gheysens; Filip Homans; Rodrigo Moreno-Reyes; Agnès Pasquet; Veronique Roelants; Caroline M. Van De Heyning; Raúl Araujo Ríos; Valentina Soldat-Stankovic; Sinisa Stankovic; Maria Helena Albernaz Siqueira; Augusto Almeida; Paulo Henrique Alves Togni; Jose Henrique Andrade; Luciana Andrade; Carlos Anselmi; Roberta Araújo; Guilherme Azevedo; Sabbrina Bezerra; Rodrigo Biancardi; Gabriel Blacher Grossman; Simone Brandão; Diego Bromfman Pianta; Lara Carreira; Bruno Castro; Tien Chang; Fernando Cunalí Jr.; Roberto Cury; Roberto Dantas; Fernando de Amorim Fernandes; Andrea De Lorenzo; Robson De Macedo Filho; Fernanda Erthal; Fabio Fernandes; Juliano Fernandes; Fabio Fernandes; Thiago Ferreira De Souza; Wilson Furlan Alves; Bruno Ghini; Luiz Gonçalves; Ilan Gottlieb; Marcelo Hadlich; Vinicius Kameoka; Ronaldo Lima; Adna Lima; Rafael Willain Lopes; Ricardo Machado e Silva; Tiago Magalhães; Fábio Martins Silva; Luiz Eduardo Mastrocola; Fábio Medeiros; José Claudio Meneghetti; Vania Naue; Danilo Neves; Roberto Nolasco; Cesar Nomura; Joao Bruno Oliveira; Eduardo Paixao; Filipe Penna De Carvalho; Ibraim Pinto; Priscila Possetti; Mayra Quinta; Rodrigo Rizzo Nogueira Ramos; Ricardo Rocha; Alfredo Rodrigues; Carlos Rodrigues; Leila Romantini; Adelina Sanches; Sara Santana; Leonardo Sara da Silva; Paulo Schwartzman; Cristina Sebastião Matushita; Tiago Senra; Afonso Shiozaki; Maria Eduarda Menezes de Siqueira; Cristiano Siqueira; Paola Smanio; Carlos Eduardo Soares; José Soares Junior; Marcio Sommer Bittencourt; Bernardo Spiro; Cláudio Tinoco Mesquita; Jorge Torrealo; Rafael Torres; Marly Uellendahl; Guilherme Urpia Monte; Otávia Verissimo; Estevan Vieira Cabeda; Felipe Villela Pedras; Roberto Waltrick; Marcello Zapparoli; Hamid Naseer; Marina Garcheva-Tsacheva; Irena Kostadinova; Youdaline Theng; Gad Abikhzer; Rene Barette; Benjamin Chow; Dominique Dabreo; Matthias Friedrich; Ria Garg; Mohammed Nassoh Hafez; Chris Johnson; Marla Kiess; Jonathon Leipsic; Eugene Leung; Robert Miller; Anastasia Oikononou; Stephan Probst; Idan Roifman; Gary Small; Vikas Tandon; Adwait Trivedi; James White; Katherine Zukotynski; Jose Canessa; Gabriel Castro Muñoz; Carmen Concha; Pablo Hidalgo; Cesar Lovera; Teresa Massardo; Luis Salazar Vargas; Pedro Abad; Harold Arturo; Sandra Ayala; Luis Benítez; Alberto Cadena; Carlos Caicedo; Antonio Calderón Moncayo; Antonio Calderón Moncayo; Sharon Gomez; Claudia T. Gutierrez Villamil; Claudia Jaimes; Juan Londoño; Juan Luis Londoño Blair; Luz Pabon; Mauricio Pineda; Juan Carlos Rojas; Diego Ruiz; Manuel Valencia Escobar; Andres Vasquez; Damiana Vergel; Alejandro Zuluaga; Isabel Berrocal Gamboa; Gabriel Castro; Ulises González; Ana Baric; Tonci Batinic; Maja Franceschi; Maja Hrabak Paar; Mladen Jukic; Petar Medakovic; Viktor Persic; Marina Pripic; Ante Punda; Juan Felipe Batista; Juan Manuel Gómez Lauchy; Yamile Marcos Gutierrez; Yamile Marcos Gutierrez; Rayner Menéndez; Amalia Peix; Luis Rochela; Christoforos Panagidis; Ioannis Petrou; Vaclav Engelmann; Milan Kaminek; Vladimir Kincl; Otto Lang; Milan Simanek; Jawdat Abdullah; Morten Bøttcher; Mette Christensen; Lars Christian Gormsen; Phillip Hasbak; Søren Hess; Paw Holdgaard; Allan Johansen; Kasper Kyhl; Bjarne Linde Norgaard; Kristian Altern Øvrehus; Niels Peter Rønnow Sand; Rolf Steffensen; Anders Thomassen; Bo Zerahn; Alfredo Perez; Giovanni Alejandro Escorza Velez; Mayra Sanchez Velez; Islam Shawky Abdel Aziz; Mahasen Abougabal; Taghreed Ahmed; Adel Allam; Ahmed Asfour; Mona Hassan; Alia Hassan; Ahmed Ibrahim; Sameh Kaffas; Ahmed Kandeel; Mohamed Mandour Ali; Ahmad Mansy; Hany Maurice; Sherif Nabil; Mahmoud Shaaban; Ana Camila Flores; Anne Poksi; Juhani Knuuti; Velipekka Kokkonen; Martti Larikka; Valtteri Uusitalo; Matthieu Bailly; Samuel Burg; Jean-François Deux; Vincent Habouzit; Fabien Hyafil; Olivier Lairez; Franck Proffit; Hamza Regaieg; Laure Sarda-Mantel; Vania Tacher; Roman P. Schneider; Harold Ayetey; George Angelidis; Aikaterini Archontaki; Sofia Chatziioannou; Ioannis Datseris; Christina Fragkaki; Panagiotis Georgoulas; Sophia Koukouraki; Maria Koutelou; Eleni Kyrozi; Evangelos Repasos; Petros Stavrou; Pipitsa Valsamaki; Carla Gonzalez; Goleat Gutierrez; Alejandro Maldonado; Klara Buga; Ildiko Garai; Pál Maurovich-Horvat; Erzsébet Schmidt; Balint Szilveszter; Edit Várady; Nilesh Banthia; Jinendra Kumar Bhagat; Rishi Bhargava; Vivek Bhat; Mona Bhatia; Partha Choudhury; Vijay Sai Chowdekar; Aparna Irodi; Shashank Jain; Elizabeth Joseph; Sukriti Kumar; Prof Dr Girijanandan Mahapatra; Deepanjan Mitra; Bhagwant Rai Mittal; Ahmad Ozair; Chetan Patel; Tapan Patel; Ravi Patel; Shivani Patel; Sudhir Saxena; Shantanu Sengupta; Santosh Singh; Bhanupriya Singh; Ashwani Sood; Atul Verma; Erwin Affandi; Padma Savenadia Alam; Edison Edison; Gani Gunawan; Habusari Hapkido; Basuki Hidayat; Aulia Huda; Anggoro Praja Mukti; Djoko Prawiro; Erwin Affandi Soeradi; Hilman Syawaluddin; Amjed Albadr; Majid Assadi; Farshad Emami; Golnaz Houshmand; Majid Maleki; Maryam Tajik Rostami; Seyed Rasoul Zakavi; Eed Abu Zaid; Svetlana Agranovich; Yoav Arnson; Rachel Bar-Shalom; Alex Frenkel; Galit Knafo; Rachel Lugassi; Israel Shlomo Maor Moalem; Maya Mor; Noam Muskal; Sara Ranser; Aryeh Shalev; Domenico Albano; Pierpaolo Alongi; Gaspare Arnone; Elisa Bagatin; Sergio Baldari; Matteo Bauckneht; Paolo Bertelli; Francesco Bianco; Rachele Bonfiglioli; Roberto Boni; Andrea Bruno;

Isabella Bruno; Elena Busnardo; Elena Califaretti; Luca Camoni; Aldo Carnevale; Roberta Casoni; Armando Ugo Cavallo; Giorgio Cavenaghi; Franca Chierichetti; Marcello Chiocchi; Corrado Cittanti; Mauro Colletta; Umberto Conti; Alberto Cossu; Alberto Cuocolo; Marco Cuzzocrea; Maria Luisa De Rimini; Giuseppe De Vincentis; Eleonora Del Giudice; Alberico Del Torto; Veronica Della Tommasina; Rexhep Durmo; Paola Anna Erba; Laura Evangelista; Riccardo Faletti; Evelina Faragasso; Mohsen Farsad; Paola Ferro; Luigia Florimonte; Viviana Frantellizzi; Fabio Massimo Fringuelli; Marco Gatti; Angela Gaudio; Alessia Gimelli; Raffaele Giubbini; Francesca Giuffrida; Salvatore Ialuna; Riccardo Laudicella; Lucia Leccisotti; Lucia Leva; Riccardo Liga; Carlo Liguori; Giampiero Longo; Margherita Maffione; Maria Elisabetta Mancini; Claudio Marcassa; Elisa Milan; Barbara Nardi; Sara Pacella; Giovanna Pepe; Gianluca Pontone; Sabina Pulizzi; Natale Quartuccio; Lucia Rampin; Fabrizio Ricci; Pierluigi Rossini; Giuseppe Rubini; Vincenzo Russo; Gian Mauro Sacchetti; Gianmario Sambuceti; Massimo Scarano; Roberto Sciagrà; Massimiliano Sperandio; Antonella Stefanelli; Guido Ventroni; Stefania Zoboli; Dainia Baugh; Duane Chambers; Ernest Madu; Felix Nunura; Hiroshi Asano; Chimura Misato; Chimura; Shinichiro Fujimoto; Koichiro Fujisue; Tomohisa Fukunaga; Yoshimitsu Fukushima; Kae Fukuyama; Jun Hashimoto; Yasutaka Ichikawa; Nobuo Iguchi; Masamichi Imai; Anri Inaki; Hayato Ishimura; Satoshi Isobe; Toshiaki Kadokami; Takao Kato; Takashi Kudo; Shinichiro Kumita; Hirota Maruno; Hiroyuki Matak; Masao Miyagawa; Ryota Morimoto; Masao Moroi; Shigeki Nagamachi; Kenichi Nakajima; Tomoaki Nakata; Ryo Nakazato; Mamoru Nanasato; Masanao Naya; Takashi Norikane; Yasutoshi Ohta; Satoshi Okayama; Atsuta Okazaki; Yoichi Otomi; Hideki Otsuka; Masaki Saito; Sakata Yasushi Sakata; Masayoshi Sarai; Daisuke Sato; Shinya Shiraishi; Yoshinobu Suwa; Kentaro Takanami; Kazuya Takehana; Junichi Taki; Nagara Tamaki; Yasuyo Taniguchi; Hiroki Teragawa; Nobuo Tomizawa; Kenichi Tsujita; Kyoko Umeji; Yasushi Wakabayashi; Shinichiro Yamada; Shinya Yamazaki; Tatsuya Yoneyama; Mohammad Rawashdeh; Daultai Batyrkhanov; Tairkhan Dautov; Khalid Makhdumi; Kevin Ombati; Faridah Alkandari; Masoud Garashi; Tchoyoson Lim Coie; Sonexay Rajvong; Artem Kalinin; Marika Kalnina; Mohamad Haidar; Renata Komiagiene; Giedre Kvieciškiene; Mindaugas Mataciunas; Donatas Vajauskas; Christian Picard; Noor Khairiah A. Karim; Luise Reichmuth; Anthony Samuel; Mohammad Aaftaab Allarakha; Ambedhkar Shantaram Naooje; Erick Alexanderson-Rosas; Erika Barragan; Alejandro Becerril González-Montecinos; Manuel Cabada; Daniel Calderon Rodriguez; Isabel Carvajal-Juarez; Violeta Cortés; Filiberto Cortés; Erasmo De La Peña; Manlio Gama-Moreno; Luis González; Nelsy Gonzalez Ramirez; Moisés Jiménez-Santos; Luis Matos; Edgar Monroy; Martha Morelos; Mario Ornelas; Jose Alberto Ortega Ramirez; Andrés Preciado-Anaya; Óscar Ulises Preciado-Gutiérrez; Adriana Puente Barragan; Sandra Graciela Rosales Uvera; Sigelinda Sandoval; Miguel Santaularia Tomas; Lilia M. Sierra-Galan; Lilia M. Sierra-Galan; Silvia Siu; Enrique Vallejo; Mario Valles; Marc Faraggi; Erdenechimeg Sereegotov; Srđja Ilic; Nozha Ben-Rais; Nadia Ismaili Alaoui; Sara Taleb; Khin Pa Pa Myo; Phyo Si Thu; Ram Kumar Ghimire; Bijoy Rajbanshi; Peter Barneveld; Andor Glaudemans; Jesse Habets; Klaas Pieter Koopmans; Jeroen Manders; Stefan Pool; Arthur Scholte; Asbjørn Scholtens; Riemer Slart; Paul Thimister; Erik-Jan Van Asperen; Niels Veltman; Derk Verschure; Nils Wagenaar; John Edmond; Chris Ellis; Kerryanne Johnson; Ross Keenan; Shaw Hua (Anthony) Kueh; Christopher Occlshaw; Alexander Sasse; Andrew To; Niels Van Pelt; Calum Young; Theresa Cuadra; Hector Bladimir Roque Vanegas; Idrissa Adamou Soli; Djibrillou Moussa Issoufou; Tolulope Ayodele; Chibuzo Madu; Yetunde Onimode; Elen Efron-Monsen; Signe Helene Forsdahl; Jenni-Mari Hildre Dimmen; Arve Jørgensen; Isabel Krohn; Pål Løvhaugen; Anders Tjellaug Bråten; Humoud Al Dhuhli; Faiza Al Kindi; Naeema Al-Bulushi; Zabab Jawa; Naima Tag; Muhammad Shehzad Afzal; Shazia Fatima; Muhammad Numair Younis; Musab Riaz; Mohammad Saadullah; Yariela Herrera; Dora Lenturur-Katal; Manuel Castillo Vázquez; José Ortellado; Afroza Akhter; Dianbo Cao; Stephen Cheung; Xu Dai; Lianggeng Gong; Dan Han; Yang Hou; Caiying Li; Tao Li; Dong Li; Sijin Li; Jinkang Liu; Hui Liu; Bin Lu; Ming Yen Ng; Kai Sun; Gongshun Tang; Jian Wang; Ximing Wang; Zhao-Qian Wang; Yining Wang; Yifan Wang; Jiang Wu; Zhifang Wu; Liming Xia; Jiangxi Xiao; Lei Xu; Youyou Yang; Wu Yin; Jianqun Yu; Li Yuan; Tong Zhang; Longjiang Zhang; Yong-Gao Zhang; Xiaoli Zhang; Li Zhu; Ana Alfaro; Paz Abrihan; Asela Barroso; Eric Cruz; Marie Rhiamar Gomez; Vincent Peter Magbow; John Michael Medina; Jerry Obaldo; Davidson Pastrana; Christian Michael Pawhay; Alvin Quinlan; Jeanelle Margaret Tang; Bettina Tecson; Kristine Joy Uson; Mila Uy; Magdalena Kostkiewicz; Jolanta Kunikowska; Nuno Bettencourt; Guilhermina Cantinho; Antonio Ferreira; Ghulam Syed; Samer Arnous; Said Atyani; Angela Byrne; Tadhg Gleeson; David Kerins; Conor Meehan; David Murphy; Mark Murphy; John Murray; Julie O'Brien; Ji-In Bang; Henry Bom; Sang-Geon Cho; Chae Moon Hong; Su Jin Jang; Young Hyu Jeong; Won Jun Kang; Ji-Young Kim; Jaetae Lee; Chang Kyeong Namgung; Young So; Kyoung Sook Won; Venjamin Majstorov; Marija Vavlukis; Barbara Gužic Salobir; Monika Štalč; Theodora Benedek; Imre Benedek; Raluca Mititelu; Claudiu Adrian Stan; Alexey Ansheles; Olga Darij; Olga Drozdova; Nina Gagarina; Vsevolod

Milyevich Gulyaev; Irina Itskovich; Anatoly Karalkin; Alexander Kokov; Ekaterina Migunova; Viktor Pospelov; Laria Ryzhkova; Guzaliya Saifullina; Svetlana Sazonova; Vladimir Sergienko; Irina Shurupova; Tatjana Trifonova; Vladimir Yurievich Ussov; Margarita Vakhromeeva; Nailya Valiullina; Konstantin Zavadovsky; Kirill Zhuravlev; Mirvat Alasnag; Subhani Okarvi; Dragana Sobic Saranovic; Felix Keng; Jia Hao Jason See; Ramkumar Sekar; Min Sen Yew; Andrej Vondrak; Shereen Bejai; George Bennie; Ria Bester; Gerrit Engelbrecht; Osayande Evbuomwan; Harlem Gongxeka; Magritha Jv Vuuren; Mitchell Kaplan; Purbhoo Khushica; Hoosen Lakhji; Lizette Louw; Nico Malan; Katarina Milos; Moshe Modiselle; Stuart More; Mathava Naidoo; Leonie Scholtz; Mboyo Vangu; Santiago Aguadé-Bruix; Isabel Blanco; Antonio Cabrera; Alicia Camarero; Irene Casás-Tormo; Hug Cuellar-Calabria; Albert Flotats; María Eugenia Fuentes Cañamero; María Elia García; Amelia Jimenez-Heffernan; Rubén Leta; Javier Lopez Diaz; Luis Lumberras; Juan Javier Marquez-Cabeza; Francisco Martin; Anxo Martine de Alegria; Francisco Medina; María Pedrera Canal; Virginia Peiro; Virginia Pubul-Nuñez; Juan Ignacio Rayo Madrid; Cristina Rodríguez Rey; Ricardo Ruano Perez; Joaquín Ruiz; Gertrudis Sabatel Hernández; Ana Sevilla; Nahla Zeidán; Damayanthi Nanayakkara; Chandraguptha Udugama; Magnus Simonsson; Hatem Alkadhi; Ronny Ralf Buechel; Peter Burger; Luca Ceriani; Bart De Boeck; Christoph Gräni; Alix Juillet de Saint Lager Lucas; Christel H. Kamani; Nadine Kawel-Boehm; Robert Manka; John O. Prior; Axel Rominger; Jean-Paul Vallée; Benjapa Khiewwan; Teerapon Premprabha; Tanyaluck Thientunyakit; Ali Sellem; Kemal Metin Kir; Haluk Sayman; Mugisha Julius Sebikali; Zerida Muyinda; Yaroslav Kmetyuk; Pavlo Korol; Olena Mykhalchenko; Volodymyr Pliatsek; Maryna Satyr; Batool Albaloshi; Mohamed Ismail Ahmed Hassan; Jill Anderson; Punit Bedi; Thomas Biggans; Anda Bularga; Russell Bull; Rajesh Burgul; John-Paul Carpenter; Duncan Coles; David Cusack; Aparna Deshpande; John Dougan; Timothy Fairbairn; Alexia Farrugia; Deepa Gopalan; Alistair Gummow; Prasad Guntur Ramkumar; Mark Hamilton; Mark Harbinson; Thomas Hartley; Benjamin Hudson; Nikhil Joshi; Michael Kay; Andrew Kelion; Azhar Khokhar; Jamie Kitt; Ken Lee; Chen Low; Sze Mun Mak; Ntouskou Marousa; Jon Martin; Elisa Mcalindon; Leon Menezes; Gareth Morgan-Hughes; Alastair Moss; Anthony Murray; Edward Nicol; Dilip Patel; Charles Peebles; Francesca Pugliese; Jonathan Carl Luis Rodrigues; Christopher Rofe; Nikant Sabharwal; Rebecca Schofield; Thomas Semple; Naveen Sharma; Peter Strouhal; Deepak Subedi; William Topping; Katharine Tweed; Jonathan Weir-Mccall; Suhny Abbara; Taimur Abbasi; Brian Abbott; Shady Abohashem; Sandra Abramson; Tarek Al-Abboud; Mouaz Al-Mallah; Omar Almousalli; Karthikeyan Ananthasubramaniam; Mohan Ashok Kumar; Jeffrey Askew; Lea Attanasio; Mallory Balmer-Swain; Richard R. Bayer; Adam Bernheim; Sabha Bhatti; Erik Bieging; Ron Blankstein; Stephen Bloom; Sean Blue; David Bluemke; Andressa Borges; Kelley Branch; Paco Bravo; Jessica Brothers; Matthew Budoff; Renée Bullock-Palmer; Angela Burandt; Floyd W. Burke; Kelvin Bush; Candace Candela; Elizabeth Capasso; Joao Cavalcante; Donald Chang; Saurav Chatterjee; Yiannis Chatzizisis; Michael Cheezum; Tiffany Chen; Jennifer Chen; Marcus Chen; Andrew Choi; James Clarck; Ayreen Cordero; Matthew Crim; Sorin Danciu; Bruce Decter; Nimish Dhruva; Neil Doherty; Rami Doukky; Anjori Dunbar; William Duvall; Rachael Edwards; Kerry Esquitin; Husam Farah; Emilio Fentanes; Maros Ferencik; Daniel Fisher; Daniel Fitzpatrick; Cameron Foster; Tony Fuisz; Michael Gannon; Lori Gastner; Myron Gerson; Brian Ghoshhajra; Alan Goldberg; Brian Goldner; Jorge Gonzalez; Rosco Gore; Sandra Gracia-López; Fadi Hage; Agha Haider; Sofia Haider; Yasmin Hamirani; Karen Hassen; Mallory Hatfield; Carolyn Hawkins; Katie Hawthorne; Nicholas Heath; Robert Hendel; Phillip Hernandez; Gregory Hill; Stephen Horgan; Jeff Huffman; Lynne Hurwitz; Ami Iskandrian; Rajesh Janardhanan; Christine Jellis; Scott Jerome; Dinesh Kalra; Sumanther Kaviratne; Fernando Kay; Faith Kelly; Omar Khaliq; Mona Kinkhabwala; George Kinzfolg Iii; Jacqueline Kircher; Rachael Kirkbride; Michael Kontos; Anupama Kottam; Joseph Krepp; Jay Layer; Steven H Lee; Jeffrey Leppo; John Lesser; Steve Leung; Howard Lewin; Diana Litmanovich; Yiyan Liu; Juan Lopez-Mattei; Kathleen Magurany; Jeremy Markowitz; Amanda Mar; Stephen E Matis; Michael Mckenna; Tony Mcrae; Fernando Mendoza; Michael Merhige; David Min; Chanan Moffitt; Karen Moncher; Warren Moore; Shamil Morayati; Michael Morris; Mahmud Mossa-Basha; Zorana Mrcsic; Venkatesh Murthy; Prashant Nagpal; Kyle Napier; Jagat Narula; Katarina Nelson; Prabhat Nijjar; Medhat Osman; Purvi Parwani; Edward Passen; Amit Patel; Pravin Patel; Ryan Paul; Lawrence Phillips; Venkateshwar Polsani; Rajaram Poludasu; Brian Pomerantz; Thomas Porter; Ryan Prentice; Amit Pursnani; Mark Rabbat; Suresh Ramamurti; Florence Rich; Hiram Rivera Luna; Austin Robinson; Kim Robles; Cesar Rodríguez; Mark Rorie; John Rumberger; Raymond Russell; Philip Sabra; Diego Sadler; Mary Schemmer; U. Joseph Schoepf; Samir Shah; Nishant Shah; Sujata Shanbhag; Gaurav Sharma; Steven Shayani; Jamshid Shirani; Pushpa Shivaram; Steven Sigman; Mitch Simon; Ahmad Slim; David Smith; Alexandra Smith; Prem Soman; Aditya Sood; Monvadi Barbara Srichai-Parsia; James Streeter; Albert T; Ahmed Tawakol; Dustin Thomas; Randall Thompson; Tara Torbet; Desiree Trinidad; Shawn Ullery; Samuel Unzek; Seth Uretsky; Srikanth

Vallurupalli; Vikas Verma; Alfonso Waller; Ellen Wang; Parker Ward; Gaby Weissman; George Wesbey; Kelly White; David Winchester; David Wolinsky; Sandra Yost; Michael Zgaljardic; Omar Alonso; Mario Beretta; Rodolfo Ferrando; Miguel Kapitan; Fernando Mut; Omoa Djuraev; Gulnora Rozikhodjaeva; Ha Le Ngoc; Son Hong Mai; Xuan Canh Nguyen.

Contributors The study was designed by AJE, MCW, LS, YP, NB, RC, SD, PR, TCV, JV, TNBP, MD and DP. Data were provided by members of the INCAPS COVID Investigators Group. Data were curated by YP, CH, EM, BG and MR. Statistical analysis was performed by MCW and CH. MCW drafted the manuscript. All authors reviewed and edited the manuscript. AJE is the guarantor of the study.

Funding This study is supported by the International Atomic Energy Agency.

Disclaimer The views expressed in this publication are those of the author(s) and not necessarily those of the NHS, the National Institute for Health Research, or the Department of Health and Social Care.

Map disclaimer The inclusion of any map (including the depiction of any boundaries therein), or of any geographic or locational reference, does not imply the expression of any opinion whatsoever on the part of BMJ concerning the legal status of any country, territory, jurisdiction or area or of its authorities. Any such expression remains solely that of the relevant source and is not endorsed by BMJ. Maps are provided without any warranty of any kind, either express or implied.

Competing interests PM-H is a shareholder of Neumann Medical. No other authors report conflicts of interest.

Patient consent for publication Not required.

Ethics approval All participation by study sites was voluntary and no patient-level data were provided, therefore it was deemed that no external ethics committee review was required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement No data are available. As data were provided in confidence to the IAEA by survey respondents, sharing of the underlying data is not possible.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

ORCID iDs

Michelle Claire Williams <http://orcid.org/0000-0003-3556-2428>

Pal Maurovich-Horvat <http://orcid.org/0000-0003-0885-736X>

Chiara Bucciarelli-Ducci <http://orcid.org/0000-0002-2515-0852>

Eli Malkovskiy <http://orcid.org/0000-0002-9027-7497>

REFERENCES

- ESC. ESC guidance for the diagnosis and management of CV disease during the COVID-19 pandemic. Available: <https://www.escardio.org/Education/COVID-19-and-Cardiology/ESC-COVID-19-Guidance>
- Choi AD, Abbara S, Branch KR, *et al.* Society of cardiovascular computed tomography guidance for use of cardiac computed tomography amidst the COVID-19 pandemic endorsed by the American College of cardiology. *J Cardiovasc Comput Tomogr* 2020;14:101–4.
- Skulstad H, Cosyns B, Popescu BA, *et al.* COVID-19 pandemic and cardiac imaging: EACVI recommendations on precautions, indications, prioritization, and protection for patients and healthcare personnel. *Eur Heart J Cardiovasc Imaging* 2020;21:592–8.
- Han Y, Chen T, Bryant J, *et al.* Society for cardiovascular magnetic resonance (SCMR) guidance for the practice of cardiovascular magnetic resonance during the COVID-19 pandemic. *J Cardiovasc Magn Reson* 2020;22:26.
- Skali H, Murthy VL, Paez D, *et al.* Guidance and best practices for reestablishment of non-emergent care in nuclear cardiology laboratories during the coronavirus disease 2019 (COVID-19) pandemic: An information statement from ASNC, IAEA, and SNMMI : Endorsed by the Infectious Diseases Society of America. *J Nucl Cardiol* 2020;27:1855–62.
- Einstein AJ, Shaw LJ, Hirschfeld C, *et al.* International impact of COVID-19 on the diagnosis of heart disease. *J Am Coll Cardiol* 2021;77:173–85.

- 7 Mafham MM, Spata E, Goldacre R, *et al*. COVID-19 pandemic and admission rates for and management of acute coronary syndromes in England. *Lancet* 2020;396:381–9.
- 8 De Filippo O, D'Ascenzo F, Angelini F, *et al*. Reduced rate of hospital admissions for ACS during Covid-19 outbreak in northern Italy. *N Engl J Med* 2020;383:88–9.
- 9 Kessler T, Graf T, Hilgendorf I, *et al*. Hospital admissions with acute coronary syndromes during the COVID-19 pandemic in German cardiac care units. *Cardiovasc Res* 2020;116:1800–1.
- 10 Lai PH, Lancet EA, Weiden MD, *et al*. Characteristics associated with out-of-hospital cardiac arrests and resuscitations during the novel coronavirus disease 2019 pandemic in New York City. *JAMA Cardiol* 2020;5:1154–63.
- 11 Wu J, Mamas MA, Mohamed MO, *et al*. Place and causes of acute cardiovascular mortality during the COVID-19 pandemic. *Heart* 2021;107:113–9.
- 12 Nishiga M, Wang DW, Han Y, *et al*. COVID-19 and cardiovascular disease: from basic mechanisms to clinical perspectives. *Nat Rev Cardiol* 2020;17:543–58.
- 13 Rudski L, Januzzi JL, Rigolin VH, *et al*. Multimodality imaging in evaluation of cardiovascular complications in patients with COVID-19: JACC scientific expert panel. *J Am Coll Cardiol* 2020;76:1345–57.
- 14 WorldBank. DataBank. Available: <https://databank.worldbank.org/home.aspx> [Accessed 2 Oct 2020].
- 15 WHO. World health organisation coronavirus disease (COVID-19) dashboard. Available: <https://covid19.who.int> [Accessed 2 Oct 2020].
- 16 WorldBank. World bank country and lending groups. Available: <http://databank.worldbank.org/data/download/site-content/OGHIST.xls> [Accessed 2 Oct 2020].
- 17 The United Nations Statistics Division. Standard country or area codes for statistical use M49. Available: <https://unstats.un.org/unsd/methodology/m49> [Accessed 2 Oct 2020].
- 18 Li X, Guan B, Su T, *et al*. Impact of cardiovascular disease and cardiac injury on in-hospital mortality in patients with COVID-19: a systematic review and meta-analysis. *Heart* 2020;106:1142–7.
- 19 Williamson EJ, Walker AJ, Bhaskaran K, *et al*. Factors associated with COVID-19-related death using OpenSAFELY. *Nature* 2020;584:430–6.
- 20 Petrilli CM, Jones SA, Yang J, *et al*. Factors associated with hospital admission and critical illness among 5279 people with coronavirus disease 2019 in New York City: prospective cohort study. *BMJ* 2020;369:m1966.
- 21 Hewitt J, Carter B, Vilches-Moraga A, *et al*. The effect of frailty on survival in patients with COVID-19 (COPE): a multicentre, European, observational cohort study. *Lancet Public Health* 2020;5:e444–51.
- 22 Baldi E, Sechi GM, Mare C, *et al*. COVID-19 kills at home: the close relationship between the epidemic and the increase of out-of-hospital cardiac arrests. *Eur Heart J* 2020;41:3045–54.
- 23 De Rosa S, Spaccarotella C, Basso C, *et al*. Reduction of hospitalizations for myocardial infarction in Italy in the COVID-19 era. *Eur Heart J* 2020;41:2083–8.
- 24 Bhatt AS, Moscone A, McElrath EE, *et al*. Fewer hospitalizations for acute cardiovascular conditions during the COVID-19 pandemic. *J Am Coll Cardiol* 2020;76:280–8.
- 25 Solomon MD, McNulty EJ, Rana JS, *et al*. The Covid-19 pandemic and the incidence of acute myocardial infarction. *N Engl J Med* 2020;383:691–3.
- 26 Khialani B, MacCarthy P. Transcatheter management of severe aortic stenosis during the COVID-19 pandemic. *Heart* 2020;106:1183–90.
- 27 Mohamed Abdel Shafi A, Hewage S, Harky A. The impact of COVID-19 on the provision of cardiac surgical services. *J Card Surg* 2020;35:1295–7.
- 28 Allen BD, Wong TC, Bucciarelli-Ducci C, *et al*. Society for cardiovascular magnetic resonance (SCMR) guidance for re-activation of cardiovascular magnetic resonance practice after peak phase of the COVID-19 pandemic. *J Cardiovasc Magn Reson* 2020;22:58.
- 29 Hung J, Abraham TP, Cohen MS, *et al*. ASE statement on the reintroduction of echocardiographic services during the COVID-19 pandemic. *J Am Soc Echocardiogr* 2020;33:1034–9.
- 30 Jeffery MM, D'Onofrio G, Paek H, *et al*. Trends in emergency department visits and hospital admissions in health care systems in 5 states in the first months of the COVID-19 pandemic in the US. *JAMA Intern Med* 2020;180:1328–33.
- 31 Maringe C, Spicer J, Morris M, *et al*. The impact of the COVID-19 pandemic on cancer deaths due to delays in diagnosis in England, UK: a national, population-based, modelling study. *Lancet Oncol* 2020;21:1023–34.