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


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 independent predictors of the reduction in cardiac imaging.

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 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 guidelines 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. Several studies have shown that during the March/April 2020 COVID-19 peak, there was a reduction in hospital admissions for acute coronary syndromes, and an increase in out-of-hospital cardiac arrests with excess cardiovascular mortality around the world. Furthermore, COVID-19 is itself potentially associated with myocardial injury, arrhythmia, and venous and arterial thrombosis. 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. Data on COVID-19 cases and deaths in March and April 2020 were obtained from the WHO COVID-19 dashboard. 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. Income group was defined using the World Bank classification of high, upper-middle, lower-middle and low.

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

<table>
<thead>
<tr>
<th>European region</th>
<th>Western</th>
<th>Southern</th>
<th>Eastern</th>
<th>Northern</th>
<th>P value</th>
<th>Europe</th>
<th>World</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centres</td>
<td>38</td>
<td>95</td>
<td>38</td>
<td>70</td>
<td>–</td>
<td>241</td>
<td>605</td>
<td>–</td>
</tr>
<tr>
<td>Number of countries</td>
<td>8</td>
<td>12</td>
<td>11</td>
<td>9</td>
<td>–</td>
<td>40</td>
<td>66</td>
<td>–</td>
</tr>
<tr>
<td>Centre type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inpatient</td>
<td>92%</td>
<td>97%</td>
<td>87%</td>
<td>97%</td>
<td>0.080</td>
<td>95%</td>
<td>76%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>(35)</td>
<td>(92)</td>
<td>(33)</td>
<td>(68)</td>
<td>(68)</td>
<td></td>
<td>(228)</td>
<td>(457)</td>
<td></td>
</tr>
<tr>
<td>Outpatient</td>
<td>8%</td>
<td>3%</td>
<td>13%</td>
<td>3%</td>
<td>0.295</td>
<td>80%</td>
<td>61%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>(3)</td>
<td>(3)</td>
<td>(5)</td>
<td>(2)</td>
<td>(2)</td>
<td></td>
<td>(13)</td>
<td>(148)</td>
<td></td>
</tr>
<tr>
<td>Teaching facility</td>
<td>74%</td>
<td>78%</td>
<td>76%</td>
<td>87%</td>
<td>0.034</td>
<td>700</td>
<td>450</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>(28)</td>
<td>(28)</td>
<td>(29)</td>
<td>(61)</td>
<td>(61)</td>
<td></td>
<td>(345–999)</td>
<td>(200–800)</td>
<td></td>
</tr>
<tr>
<td>Number of beds</td>
<td>900</td>
<td>700</td>
<td>480</td>
<td>633</td>
<td>0.034</td>
<td>700</td>
<td>450</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>[615–1110]</td>
<td>[290–999]</td>
<td>[225–1000]</td>
<td>[358–878]</td>
<td>[358–878]</td>
<td></td>
<td>[345–999]</td>
<td>[200–800]</td>
<td></td>
</tr>
<tr>
<td>COVID-19 cases*</td>
<td>423337</td>
<td>462863</td>
<td>286308</td>
<td>233676</td>
<td>–</td>
<td>1406184</td>
<td>1560392</td>
<td>–</td>
</tr>
<tr>
<td>COVID-19 deaths*</td>
<td>45053</td>
<td>54289</td>
<td>6478</td>
<td>31003</td>
<td>–</td>
<td>136823</td>
<td>83368</td>
<td>–</td>
</tr>
</tbody>
</table>

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.

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=78969) and a 69% reduction in April 2020 (n=44469). 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 (55%) 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=0.005), 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).

model. Population, GDP and COVID-19 deaths were log transformed for analysis.
## Table 2  Reduction in procedure volumes across European regions compared with the rest of the world

<table>
<thead>
<tr>
<th>European region</th>
<th>Western</th>
<th>Southern</th>
<th>Eastern</th>
<th>Northern</th>
<th>P value</th>
<th>Europe</th>
<th>World</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centres</td>
<td>38</td>
<td>95</td>
<td>38</td>
<td>70</td>
<td>–</td>
<td>241</td>
<td>605</td>
<td>–</td>
</tr>
<tr>
<td>Total procedure volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>March 2019</td>
<td>24,018</td>
<td>48,340</td>
<td>13,149</td>
<td>56,956</td>
<td>–</td>
<td>142,463</td>
<td>536,175</td>
<td>–</td>
</tr>
<tr>
<td>March 2020</td>
<td>13,433</td>
<td>20,517</td>
<td>10,343</td>
<td>34,676</td>
<td>–</td>
<td>78,969</td>
<td>315,656</td>
<td>–</td>
</tr>
<tr>
<td>April 2020</td>
<td>9,060</td>
<td>10,865</td>
<td>5,819</td>
<td>18,725</td>
<td>–</td>
<td>44,469</td>
<td>199,967</td>
<td>–</td>
</tr>
<tr>
<td>Reduction in total procedures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>March 2019–March 2020</td>
<td>44%</td>
<td>58%</td>
<td>21%</td>
<td>39%</td>
<td>&lt;0.001</td>
<td>45%</td>
<td>41%</td>
<td>0.003</td>
</tr>
<tr>
<td>March 2019–April 2020</td>
<td>62%</td>
<td>78%</td>
<td>56%</td>
<td>67%</td>
<td>&lt;0.001</td>
<td>69%</td>
<td>63%</td>
<td>0.261</td>
</tr>
<tr>
<td>Reduction in procedures by modality (March 2019–April 2020)—functional imaging</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stress ECG</td>
<td>76%</td>
<td>93%</td>
<td>49%</td>
<td>82%</td>
<td>0.115</td>
<td>83%</td>
<td>85%</td>
<td>0.923</td>
</tr>
<tr>
<td>Stress echocardiography</td>
<td>86%</td>
<td>89%</td>
<td>51%</td>
<td>93%</td>
<td>0.160</td>
<td>84%</td>
<td>82%</td>
<td>0.428</td>
</tr>
<tr>
<td>Stress SPECT</td>
<td>73%</td>
<td>83%</td>
<td>76%</td>
<td>77%</td>
<td>0.112</td>
<td>79%</td>
<td>73%</td>
<td>0.002</td>
</tr>
<tr>
<td>Stress PET</td>
<td>0</td>
<td>94%</td>
<td>88%</td>
<td>13%</td>
<td>0.006</td>
<td>42%</td>
<td>59%</td>
<td>0.739</td>
</tr>
<tr>
<td>Stress nuclear (SPECT and PET)</td>
<td>67%</td>
<td>84%</td>
<td>78%</td>
<td>72%</td>
<td>0.014</td>
<td>77%</td>
<td>72%</td>
<td>0.012</td>
</tr>
<tr>
<td>Stress CMR</td>
<td>45%</td>
<td>89%</td>
<td>40%</td>
<td>76%</td>
<td>0.081</td>
<td>68%</td>
<td>75%</td>
<td>0.948</td>
</tr>
<tr>
<td>Reduction in procedures by modality (March 2019–April 2020)—anatomical imaging</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT calcium score</td>
<td>88%</td>
<td>77%</td>
<td>45%</td>
<td>93%</td>
<td>0.552</td>
<td>78%</td>
<td>70%</td>
<td>0.534</td>
</tr>
<tr>
<td>CCTA</td>
<td>58%</td>
<td>75%</td>
<td>68%</td>
<td>68%</td>
<td>0.896</td>
<td>69%</td>
<td>50%</td>
<td>0.003</td>
</tr>
<tr>
<td>TTE</td>
<td>67%</td>
<td>73%</td>
<td>50%</td>
<td>66%</td>
<td>0.174</td>
<td>67%</td>
<td>57%</td>
<td>0.331</td>
</tr>
<tr>
<td>TEE</td>
<td>65%</td>
<td>84%</td>
<td>54%</td>
<td>72%</td>
<td>0.139</td>
<td>74%</td>
<td>76%</td>
<td>0.070</td>
</tr>
<tr>
<td>PET infection</td>
<td>27%</td>
<td>71%</td>
<td>92%</td>
<td>13%</td>
<td>&lt;0.001</td>
<td>53%</td>
<td>71%</td>
<td>0.714</td>
</tr>
<tr>
<td>CMR (non-stress)</td>
<td>45%</td>
<td>78%</td>
<td>55%</td>
<td>78%</td>
<td>0.010</td>
<td>72%</td>
<td>59%</td>
<td>0.067</td>
</tr>
<tr>
<td>Invasive coronary angiography</td>
<td>34%</td>
<td>63%</td>
<td>45%</td>
<td>50%</td>
<td>0.009</td>
<td>51%</td>
<td>59%</td>
<td>0.951</td>
</tr>
</tbody>
</table>

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).
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...
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 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.
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 arrests10 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 syndromes2 5–9 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

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.
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 3  Imaging departments’ change in capacity and practice

<table>
<thead>
<tr>
<th>European region</th>
<th>Western</th>
<th>Southern</th>
<th>Eastern</th>
<th>Northern</th>
<th>P value</th>
<th>Europe</th>
<th>World</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in capacity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Some outpatient activities cancelled</td>
<td>98%</td>
<td>79%</td>
<td>81%</td>
<td>88%</td>
<td>0.217</td>
<td>85%</td>
<td>82%</td>
<td>0.076</td>
</tr>
<tr>
<td>All outpatient activities cancelled</td>
<td>37%</td>
<td>48%</td>
<td>33%</td>
<td>50%</td>
<td>0.009</td>
<td>44%</td>
<td>45%</td>
<td>0.512</td>
</tr>
<tr>
<td>Phased reopening</td>
<td>85%</td>
<td>51%</td>
<td>50%</td>
<td>53%</td>
<td>0.001</td>
<td>58%</td>
<td>51%</td>
<td>0.003</td>
</tr>
<tr>
<td>Extended hours</td>
<td>24%</td>
<td>23%</td>
<td>12%</td>
<td>17%</td>
<td>0.104</td>
<td>20%</td>
<td>11%</td>
<td>0.003</td>
</tr>
<tr>
<td>New weekend hours</td>
<td>17%</td>
<td>12%</td>
<td>10%</td>
<td>8%</td>
<td>0.237</td>
<td>11%</td>
<td>9%</td>
<td>0.735</td>
</tr>
<tr>
<td>Use telehealth for patient care</td>
<td>46%</td>
<td>45%</td>
<td>33%</td>
<td>53%</td>
<td>0.133</td>
<td>45%</td>
<td>59%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Remote reporting</td>
<td>49%</td>
<td>28%</td>
<td>38%</td>
<td>57%</td>
<td>0.013</td>
<td>41%</td>
<td>51%</td>
<td>0.018</td>
</tr>
<tr>
<td>Change in practice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alterations in patient arrival</td>
<td>73%</td>
<td>61%</td>
<td>55%</td>
<td>81%</td>
<td>0.006</td>
<td>68%</td>
<td>73%</td>
<td>0.454</td>
</tr>
<tr>
<td>Physical distancing in waiting areas</td>
<td>95%</td>
<td>83%</td>
<td>79%</td>
<td>93%</td>
<td>0.007</td>
<td>87%</td>
<td>89%</td>
<td>0.383</td>
</tr>
<tr>
<td>Separate spaces for patients with COVID-19</td>
<td>90%</td>
<td>82%</td>
<td>62%</td>
<td>82%</td>
<td>0.016</td>
<td>80%</td>
<td>78%</td>
<td>0.847</td>
</tr>
<tr>
<td>Reducing patient time in waiting rooms</td>
<td>78%</td>
<td>91%</td>
<td>69%</td>
<td>81%</td>
<td>0.081</td>
<td>82%</td>
<td>81%</td>
<td>0.775</td>
</tr>
<tr>
<td>Limit accompanying family members and/or visitors</td>
<td>95%</td>
<td>95%</td>
<td>79%</td>
<td>94%</td>
<td>0.014</td>
<td>92%</td>
<td>92%</td>
<td>0.877</td>
</tr>
<tr>
<td>Temperature measurements</td>
<td>44%</td>
<td>74%</td>
<td>88%</td>
<td>18%</td>
<td>&lt;0.001</td>
<td>55%</td>
<td>72%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Symptom screening</td>
<td>73%</td>
<td>62%</td>
<td>71%</td>
<td>69%</td>
<td>0.357</td>
<td>68%</td>
<td>82%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>COVID-19 testing</td>
<td>10%</td>
<td>7%</td>
<td>12%</td>
<td>10%</td>
<td>0.330</td>
<td>9%</td>
<td>17%</td>
<td>0.003</td>
</tr>
<tr>
<td>Require masks for patients/visitors</td>
<td>68%</td>
<td>90%</td>
<td>88%</td>
<td>42%</td>
<td>&lt;0.001</td>
<td>72%</td>
<td>76%</td>
<td>0.013</td>
</tr>
<tr>
<td>Increase time for cleaning</td>
<td>63%</td>
<td>75%</td>
<td>71%</td>
<td>76%</td>
<td>0.012</td>
<td>73%</td>
<td>72%</td>
<td>0.177</td>
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Light grey, <50%; dark grey, ≥50%; bold, p<0.05.

Table 4  Imaging departments’ change in imaging protocols and staffing

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

Light grey, <50%; dark grey, ≥50%; bold, p<0.05.
to avoid potential infection, access to public transport and other essential auxillary 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 USA\textsuperscript{30} and delayed cancer diagnoses are predicted to result in a significant increase in mortality over the next 5 years.\textsuperscript{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.\textsuperscript{5} 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
\textsuperscript{1}Centre for Cardiovascular Science, University of Edinburgh, Edinburgh, UK
\textsuperscript{2}Presbyterian Hospital/Weill Cornell Medical Center, New York, New York, USA
\textsuperscript{3}Columbia University Irving Medical Center, New York, New York, USA
\textsuperscript{4}MTA-SE Cardiovascular Imaging Research Group, Semmelweis University, Heart and Vascular Center, Budapest, Hungary
\textsuperscript{5}Cardiology, Aarhus University Hospital, Aarhus, Denmark
\textsuperscript{6}Department of Cardiovascular Imaging, Centro Cardiologico Monzino IRCCS, Milan, Italy
\textsuperscript{7}Hospital Juan Ramón Jiménez, Huelva, Spain
\textsuperscript{8}Lomonosov Moscow State University, Moscow, Russian Federation
\textsuperscript{9}National Medical Research Center of Cardiology of Healthcare Ministry, Moscow, Russian Federation
\textsuperscript{10}Department of Cardiology, Leiden University Medical Center, Leiden, The Netherlands
\textsuperscript{11}Department of Nuclear Medicine, University Hospital Zurich, Zurich, Switzerland
\textsuperscript{12}UCR Nuclear Medicine–Osprellea Cà Foncello, Treviso, Italy
\textsuperscript{13}Department of Nuclear Medicine and Molecular Imaging, University of Groningen, Groningen, The Netherlands

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Collaborators INCAPS COVID Investigators Group: Mohammad Nawaz Nasery; Aratan Goda; Ervina Shirkia; Rabia Benlabagas; Salah Bouyoucef; Abdelkader Medjahedi; Qais Nailli; Mariel Agoli; Roberto Nicolas Aguero; Maria del Carmen Alca; Lucia Graciela Alberghiuna; Guillermo Arrofada; Andrea Astesiano; Alfredo Astesiano; Carolina Bas Norton; Pablo Benteo; Juan Blanco; Juan Manuel Bonell; Jose Javier Bustos; Raul Cabrejas; Jorge Carcher; Roxana Campisi; Alejandro Canderoli; Silvia Carames; Patricia Carrascosa; Ricardo Castro; Oscar Cendoya; Luciano Martín Cognighini; Carlos Collaud; Carlos Collaud; Claudia Cortes; Javier Courtis; Daniel Cragnolino; Mariana Daiz; Alejandro De La Vega; Silvia Teresa De Maria; Horacio Del Rio; Fernando Dettori; Alejandro Deviggianno; Laura Dragonnetti; Mario Embo; Ruben Emilio Enriquez; Jorge Ensinas; Fernando Faccio; Adolfo Facello; Diego Garofalo; Ricardo Geranzzio; Natalia Gonza; Luis Gutierrez; Miguel Angel Guzzo; Miguel Angel Guzzo; Victor Hashani; Melina Huerin; Victor Jager; Julio Manuel Lewkwitz; Maria Nieves A Lopez De Munain; Jose Maria Lotti; Alejandra Marquez; Osvaldo Masoli; Osvaldo Horacio Masoli; Edgardo Mastroroli; Matias Mayorza; Graciela Eva Melado; Anibal Mele; Maria Fernandez Merani; Alejandro Horacio Meretta; Susanna Molteni; Marcos Montecinos; Eduardo Noguera; Carlos Novoa; Claudia Pereyra Suelio; Sebastian Perez Ascani; Pablo Ponnlo; Maria Paula Pujo; Alejandro Radzinschi; Gustavo Raimondi; Marcela Redruello; Marina Rodriguez; Matias Rodriguez; Romina Lorena Romero; Arturo Romero Acuña; Federico Robetelli; Lucas San Miguel; Lucrecia Solar; Bruno Strada; Sonia Traverso; Sonia Simona Traverso; Maria del Huerto Velazquez Espeche; Juan Sebastian Weinhultzer; Juan Wolcan; Susana Zefiro; Mari Sakanyan; Scott Bezuelle; Rael Boktor; Patrick Butler; Jennifer Calcott; Loretta Carr; Virgil Chan; Charles Chan; Woon Chong; Mark Dobson; D’Arme Downie; Gishe Dwivedi; Barry Elison; Jean Engela; Roxlyn Francis; Anand Gavai; Ashok Gangasandra; Basavara; Bruce Goodwin; Robert Greengan; Christian Hamilton-Craig; Victor Hsieh; Subodh Joshi; Karin Lederer; Kenneth Lee; Joseph Lee; John Magnusson; Ngi Ma; Gordon Mander; Fiona Murton; Dee Nandurkar; Johanne Neill; Edward Novoa; Claudia Pereyra Suelio; Sebastian Perez Ascani; Pablo Ponnlo; Maria Paula Pujo; Alejandro Radzinschi; Gustavo Raimondi; Marcela Redruello; Marina Rodriguez; Matias Rodriguez; Romina Lorena Romero; Arturo Romero Acuña; Federico Robetelli; Lucas San Miguel; Lucrecia Solar; Bruno Strada; Sonia Traverso; Sonia Simona Traverso; Maria del Huerto Velazquez Espeche; Juan Sebastian Weinhultzer; Juan Wolcan; Susana Zefiro; Mari Sakanyan; Scott Bezuelle; Rael Boktor; Patrick Butler; Jennifer Calcott; Loretta Carr; Virgil Chan; Charles Chan; Woon Chong; Mark Dobson; D’Arme Downie; Gishe Dwivedi; Barry Elison; Jean Engela; Roxlyn Francis; Anand Gavai; Ashok Gangasandra; Basavara; Bruce Goodwin; Robert Greengan; Christian Hamilton-Craig; Victor Hsieh; Subodh Joshi; Karin Lederer; Kenneth Lee; Joseph Lee; John Magnusson; Ngi Ma; Gordon Mander; Fiona Murton; Dee Nandurkar; Johanne Neill; Edward O’Rourke; Patricia O’Sullivan; George Pandos; Kunthi Pathmarah; 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 Gaat; Johan Verjans;
Health care delivery, economics and global health care

Millerová Gulyaev, Irina Itskovich, Anatoly Karkinik, Alexander Kogan, Ekaterina Migunova, Viktor Pospelov, Darja Ryzhkova, Guzalia Saifullina, Svetlana Sazonova, Vladimir Sergienko, Irina Shurupova, Tatjana Trifonova, Vladimir Yurievich Usov, Margarita Vakhromeeva, Naiya Valullina, Konstantin Zavadovsky, Kirill Zhuravlev, Mirvat Alasnag, Shereen Bejai, George Wessey, Kelly White, David Winchester, David Wolinsky, Sandra Yost, Michael Zgajarcic, Omar Alonso, Mario Beretta, Rodolfo Ferrando, Miguel Kapitant, Fernando Mut, Omoa Djurajev, Gulnora Rozikhodzajeva; Ha Le Ngoc; Son Hong Mai; Xuan Chan 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.

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

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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 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.

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References


## INCAPS COVID


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INCAPS COVID Investigators Group

Executive Committee: Andrew J. Einstein (chair), Diana Paez (IAEA section head), Maurizio Dondi (IAEA project lead); (alphabetically) Nathan Better, Rodrigo Cerci, Sharmila Dorbala, Thomas N. B. Pascual, Paolo Raggi, Leslee J. Shaw, Todd C. Villines, Joao V. Vitola, Michelle C. Williams

Information Technology and Statistics Committee: Yaroslav Pynda (chair); (alphabetically): Gerd Hinterleitner, Yao Lu, Olga Morozova, Zhuoran Xu

Data Coordination Committee: Cole B. Hirschfeld (chair); (alphabetically): Yosef Cohen, Benjamin Goebel, Eli Malkovskiy, Michael Randazzo

Communications Committee: Andrew Choi (chair); (alphabetically): Juan Lopez-Mattei, Purvi Parwani

Members (alphabetically by country and last name)

Afghanistan: Mohammad Nawaz Nasery

Albania: Artan Goda, Ervina Shirka

Algeria: Rabie Benlabgaa, Salah Bouyoucef, Abdelkader Medjahedi, Qais Nailll

Argentina: Mariela Agolti, Roberto Nicolas Aguero, Maria del Carmen Alak, Lucia Graciela Alberguina, Guillermo Arroñada, 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 Courtis, Daniel Cragonlino, Mariana Daicz, Alejandro De La Vega, Silvia Teresa

2
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 Radzinschi, Gustavo Raimondi, Marcela Redrueillo, Marina Rodriguez, Matias Rodriguez, Romina Lorena Romero, Arturo Romero Acuña, Federico Rovaletti, Lucas San Miguel, Lucrecia Solari, Bruno Strada, Sonia Traverso, Sonia Simona Traverzo, Maria del Huerto Velazquez Espeche, Juan Sebastian Weihmuller, Juan Wolcan, Susana Zeffiro

**Armenia:** Mari Sakanyan

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

**Austria:** Gudrun Feuchtner, Siroos Mirzaei, Konrad Weiss

**Belarus:** Natallia Maroz-Vadalazhskaya

**Belgium:** Olivier Gheysens, Filip Homans, Rodrigo Moreno-Reyes, Agnès Pasquet, Veronique Roelants, Caroline M. Van De Heyning

**Bolivia:** Raúl Araujo Ríos

**Bosnia - Herzegovina:** Valentina Soldat-Stankovic, Sinisa Stankovic

Cristiano Siqueira, Paola Smanio, Carlos Eduardo Soares, José Soares Junior, Marcio Sommer Bittencourt, Bernardo Spiro, Cláudio Tinoco Mesquita, Jorge Torreao, Rafael Torres, Marly Uellendahl, Guilherme Urpia Monte, Otávia Veríssimo, Estevan Vieira Cabeda, Felipe Villela Pedras, Roberto Waltrick, Marcello Zapparoli

Brunei Darussalam: Hamid Naseer

Bulgaria: Marina Garcheva-Tsacheva, Irena Kostadinova

Cambodia: Youdaline Theng

Canada: 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 Oikonomou, Stephan Probst, Idan Roifman, Gary Small, Vikas Tandon, Adwait Trivedi, James White, Katherine Zukotynski

Chile: Jose Canessa, Gabriel Castro Muñoz, Carmen Concha, Pablo Hidalgo, Cesar Lovera, Teresa Massardo, Luis Salazar Vargas

Colombia: Pedro Abad, Harold Arturo, Sandra Ayala, Luis Benitez, 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

Costa Rica: Isabel Berrocal Gamboa, Gabriel Castro, Ulises González

Croatia: Ana Baric, Tonci Batinic, Maja Franceschi, Maja Hrabak Paar, Mladen Jukic, Petar Medakovic, Viktor Persic, Marina Prpic, Ante Punda

Cuba: Juan Felipe Batista, Juan Manuel Gómez Lauchy, Yamile Marcos Gutierrez, Yamile Marcos Gutierrez, Rayner Menéndez, Amalia Peix, Luis Rochela
Cyprus: Christoforos Panagidis, Ioannis Petrou

Czech Republic: Vaclav Engelmann, Milan Kaminek, Vladimír Kincl, Otto Lang, Milan Simanek

Denmark: Jawdat Abdulla, Morten Böttcher, Mette Christensen, Lars Christian Gormsen, Philip Hasbak, Søren Hess, Paw Holdgaard, Allan Johansen, Kasper Kyhl, Bjarne Linde Norgaard, Kristian Altern Øvrehus, Niels Peter Rønnow Sand, Rolf Steffensen, Anders Thomassen, Bo Zerahm

Dominican Republic: Alfredo Perez

Ecuador: Giovanni Alejandro Escorza Velez, Mayra Sanchez Velez


El Salvador: Ana Camila Flores

Estonia: Anne Poksi

Finland: Juhani Knuuti, Velipekka Kokkonen, Martti Larikka, Valtteri Uusitalo

France: Matthieu Bailly, Samuel Burg, Jean-François Deux, Vincent Habouzit, Fabien Hyafil, Olivier Lairez, Franck Proffit, Hamza Regaieeg, Laure Sarda-Mantel, Vania Tacher

Germany: Roman P. Schneider

Ghana: Harold Ayetey

Greece: George Angelidis, Aikaterini Archontaki, Sofia Chatziioannou, Ioannis Datseris, Christina Fragkaki, Panagiotis Georgoulas, Sophia Kourouraki, Maria Koutelou, Eleni Kyrozi, Evangelos Repasos, Petros Stavrou, Pipitsa Valsamaki

Guatemala: Carla Gonzalez, Goleat Gutierrez
**Honduras**: Alejandro Maldonado

**Hungary**: Klara Buga, Ildiko Garai, Pál Maurovich-Horvat, Erzsébet Schmidt, Balint Szilveszter, Edit Várady


**Indonesia**: Erwin Affandi, Padma Savenadia Alam, Edison Edison, Gani Gunawan, Habusari Hapkido, Basuki Hidayat, Aulia Huda, Anggoro Praja Mukti, Djoko Prawiro, Erwin Affandi Soeriadi, Hilman Syawaluddin

**Iraq**: Amjed Albadr

**Islamic Republic of Iran**: Majid Assadi, Farshad Emami, Golnaz Houshmand, Majid Maleki, Maryam Tajik Rostami, Seyed Rasoul Zakavi

**Israel**: 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

**Italy**: 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,

**Jamaica:** Dainia Baugh, Duane Chambers, Ernest Madu, Felix Nunura

**Japan:** 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, Hirotaka Maruno, Hiroyuki Mataka, Masao Miyagawa, Ryota Morimoto, Masao Moroi, Shigeki Nagamachi, Kenichi Nakajima, Tomoaki Nakata, Ryo Nakazato, Mamoru Nanasato, Masanao Naya, Takashi Norikane, Yasutoshi Ohta, Satoshi Okayama, Atsutaka Okizaki, 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

**Jordan:** Mohammad Rawashdeh
Kazakhstan: Daultai Batyrkhanov, Taïrkhan Dautov

Kenya: Khalid Makhdomi, Kevin Ombati

Kuwait: Faridah Alkandari, Masoud Garashi

Lao People's Democratic Republic: Tchoyoson Lim Coie, Sonexay Rajvong

Latvia: Artem Kalinin, Marika Kalnina

Lebanon: Mohamad Haidar

Lithuania: Renata Komiaziene, Giedre Kviecinskaite, Mindaugas Mataciunas, Donatas Vajauskas

Luxembourg: Christian Picard

Malaysia: Noor Khairiah A. Karim

Malta: Luise Reichmuth, Anthony Samuel

Mauritius: Mohammad Aaftaab Allarakha, Ambedhkar Shantaram Naoyee


Monaco: Marc Faraggi

Mongolia: Erdenechimeg Sereegotov

Montenegro: Srdja Ilic

Morocco: Nozha Ben-Rais, Nadia Ismaili Alaoui, Sara Taleb
Myanmar: Khin Pa Pa Myo, Phyo Si Thu

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Nicaragua: Teresa Cuadra, Hector Bladimir Roque Vanegas

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Nigeria: Tolulope Ayodele, Chibuzo Madu, Yetunde Onimode


Oman: Humoud Al Dhuhli, Faiza Al Kindi, Naeema Al-Bulushi, Zabah Jawa, Naima Tag

Pakistan: Muhammad Shehzad Afzal, Shazia Fatima, Muhammad Numair Younis, Musab Riaz, Mohammad Saadullah

Panama: Yariela Herrera

Papua New Guinea: Dora Lenturut-Katal

Paraguay: Manuel Castillo Vázquez, José Ortellado

People's Republic of Bangladesh: Afroza Akhter

People's Republic of China: 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

**Peru:** Ana Alfaro

**Philippines:** Paz Abrihan, Asela Barroso, Eric Cruz, Marie Rhiamar Gomez, Vincent Peter Magboo, John Michael Medina, Jerry Obaldo, Davidson Pastrana, Christian Michael Pawhay, Alvin Quinon, Jeanelle Margareth Tang, Bettina Tecson, Kristine Joy Uson, Mila Uy

**Poland:** Magdalena Kostkiewicz, Jolanta Kunikowska

**Portugal:** Nuno Bettencourt, Guilhermina Cantinho, Antonio Ferreira

**Qatar:** Ghulam Syed

**Republic of Ireland:** Samer Arnous, Said Atyani, Angela Byrne, Tadhg Gleeson, David Kerins, Conor Meehan, David Murphy, Mark Murphy, John Murray, Julie O'Brien

**Republic of Korea:** Ji-In Bang, Henry Bom, Sang-Geon Cho, Chae Moon Hong, Su Jin Jang, Yong Hyu Jeong, Won Jun Kang, Ji-Young Kim, Jaetae Lee, Chang Kyeong Namgung, Young So, Kyoung Sook Won

**Republic of North Macedonia:** Venjamin Majstorov, Marija Vavlukis

**Republic of Slovenia:** Barbara Gužic Salobir, Monika Štalc

**Romania:** Theodora Benedek, Imre Benedek, Raluca Mititelu, Claudiu Adrian Stan

**Russian Federation:** Alexey Ansheles, Olga Dariy, Olga Drozdova, Nina Gagarina, Vsevolod Milyevich Gulyaev, Irina Itskovich, Anatoly Karalkin, Alexander Kokov, Ekaterina Migunova, Viktor Pospelov, Daria Ryzhkova, Guzaliya Saifullina, Svetlana Sazonova, Vladimir Sergienko, Irina Shurupova, Tatjana Trifonova, Wladimir Yurievich Ussov, Margarita Vakhromeeva, Nailya Valiullina, Konstantin Zavadovsky, Kirill Zhuravlev

**Saudi Arabia:** Mirvat Alasnag, Subhani Okarvi
Serbia: Dragana Sobic Saranovic

Singapore: Felix Keng, Jia Hao Jason See, Ramkumar Sekar, Min Sen Yew

Slovak Republic: Andrej Vondrak

South Africa: Shereen Bejai, George Bennie, Ria Bester, Gerrit Engelbrecht, Osayande Evbuomwan, Harlem Gongxeka, Magritha Jv Vuuren, Mitchell Kaplan, Purbhoo Khushica,
Hoosen Lakhi, Lizette Louw, Nico Malan, Katarina Milos, Moshe Modiselle, Stuart More,
Mathava Naidoo, Leonie Scholtz, Mboyo Vangu

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Nahla Zeidán

Sri Lanka: Damayanthi Nanayakkara, Chandraguptha Udugama

Sweden: Magnus Simonsson

Switzerland: 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

Thailand: Benjapa Khiewvan, Teerapon Premprabha, Tanyaluck Thientunyakit

Tunisia: Ali Selleh

Turkey: Kemal Metin Kir, Haluk Sayman

Uganda: Mugisha Julius Sebikali, Zerida Muyinda
Ukraine: Yaroslav Kmetyuk, Pavlo Korol, Olena Mykhalchenko, Volodymyr Pliatsek, Maryna Satyr

United Arab Emirates: Batool Albalooshi, Mohamed Ismail Ahmed Hassan


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

**Uruguay:** Omar Alonso, Mario Beretta, Rodolfo Ferrando, Miguel Kapitan, Fernando Mut

**Uzbekistan:** Omoa Djuraev, Gulnora Rozikhodjaeva

**Vietnam:** Ha Le Ngoc, Son Hong Mai, Xuan Canh Nguyen
Supplementary methods

Choropleth maps were constructed in R using tmap[1] and rnaturalearth[2] packages.

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