Original research

Electrocardiographic findings and prognostic values in patients hospitalised with COVID-19 in the World Heart Federation Global Study

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ABSTRACT

Background. COVID-19 affects the cardiovascular system and ECG abnormalities may be associated with worse prognosis. We evaluated the prognostic value of ECG abnormalities in individuals with COVID-19.

Methods. Multicentre cohort study with adults hospitalised with COVID-19 from 40 hospitals across 23 countries. Patients were followed-up from admission until 30 days. ECG were obtained at each participating site and coded according to the Minnesota coding criteria. The primary outcome was defined as death from any cause. Secondary outcomes were admission to the intensive care unit (ICU) and major adverse cardiovascular events (MACE). Multiple logistic regression was used to evaluate the association of ECG abnormalities with the outcomes.

Results. Among 5313 participants, 2451 had at least one ECG and were included in this analysis. The mean age (SD) was 58.0 (16.1) years, 60.7% were male and 61.1% from lower-income to middle-income countries. The prevalence of major ECG abnormalities was 21.3% (n=521), 447 (18.2%) patients died, 196 (8.0%) had MACE and 1115 (45.5%) were admitted to an ICU. After adjustment, the presence of any major ECG abnormality was associated with a higher risk of death (OR 1.39; 95% CI 1.09 to 1.78) and cardiovascular events (OR 1.81; 95% CI 1.30 to 2.51). Sinus tachycardia (>120 bpm) with an increased risk of death (OR 3.86; 95% CI 1.97 to 7.48), MACE (OR 2.68; 95% CI 1.10 to 5.85) and ICU admission OR 1.99; 95% CI 1.03 to 3.88) were associated with all-cause death (OR 1.39; 95% CI 1.09 to 1.78 and OR 3.86; 95% CI 1.97 to 7.48, respectively) and major cardiovascular outcomes (OR 1.81; 95% CI 1.30 to 2.51 and OR 2.68; 95% CI 1.10 to 5.85, respectively).

Conclusion. Major ECG abnormalities and a heart rate >120 bpm were prognostic markers in adults hospitalised with COVID-19.

INTRODUCTION

COVID-19 is a respiratory tract infection caused by SARS-CoV-2 that rapidly spread worldwide and a pandemic was declared by WHO in March 2020.1 Although the main clinical manifestations are respiratory, the cardiovascular system can be affected, especially in patients with SARS.2 Acute cardiac injury, inferred from elevations in cardiac troponin levels, is reported in 8%–62% of hospitalised patients and is associated with a worse prognosis.3 COVID-19 can also be associated with endothelitis, arrhythmias, acute coronary syndrome, venous
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thromboembolism and heart failure, the latter as a consequence of a deterioration of previous heart disease or induced by viral myocarditis. Indeed, underlying cardiovascular disease is associated with an increased risk of in-hospital death among patients hospitalised with COVID-19.5

COVID-19 is associated with a variety of ECG abnormalities, with up to 90% of critically ill patients demonstrating at least one abnormality.6 The ECG abnormalities in COVID-19 may be due to cytokine storm, hypoxic injury, electrolyte abnormalities, plaque rupture, coronary spasm, microthrombi or direct endothelial or myocardial injury.7 ECG alterations during hospitalisation have been associated with adverse outcomes and infection severity,8 as well as predictive of the risk of death,9–11 although most of these studies were retrospective, from single centres and with limited sample sizes.

Although COVID-19 impacted economic, political and social spheres worldwide, it also brought up the health disparity across the world.12 The pandemic opened wide overwhelmed healthcare centres, inequality in medical access, unavailability of treatment resources and lack of vaccines, especially in the low-income and middle-income countries (LMICs).13 Up to now, the current published data on COVID-19 are mainly from high-income countries (HICs), where the clinical scenario is widely different and does not represent the global reality. Therefore, our study aims to prospectively evaluate the prognostic value of major ECG abnormalities in patients hospitalised with COVID-19 in a comprehensive pancontinental study mostly including patients from low-income countries (LICs), LMICs and upper middle-income countries (UMICs).

METHODS

Design

This is a multicentric cohort study that included hospitalised adults due to COVID-19, as part of the World Heart Federation (WHF) Global Study on cardiovascular disease (CVD) and COVID-19 initiative.14 Participants were followed up from hospital admission until 30 days postdischarge (by telephone) for adverse event evaluation, as per protocol.15

Study participants

Participants were recruited from diverse countries in North and South America, Europe, Africa and Asia resulting in a sample mostly from LMICs. Bangladesh, India and Iran contributed with the majority of valid ECGs. All adult individuals hospitalised with a confirmed COVID-19 infection were eligible for recruitment. For this particular study, the subjects without a valid ECG were excluded. Figure 1 summarises the participating sites and their proportion in contribution to the sample size. Table 1 represents the disparity between participants’ recruitment and ECG availability for each site.

ECG evaluation

ECGs were obtained at each participating site, preferably at admission, or alternatively, as soon as possible if unable, for some reason, to perform it right at admission. Most ECGs (70%) were done at admission (online supplemental table 1). As a study mainly from LMICs, many challenges in propaedeutics have risen during its conduction. Not every centre had an ECG machine, not all centres had digital machines and expertise varied among centres. To overcome these barriers, remote training and a user’s manual were provided to achieve a maximal possible

Table 1 Baseline data of the participants, according to the presence or absence of an electrocardiographic major abnormality

<table>
<thead>
<tr>
<th></th>
<th>All n=2451</th>
<th>With major ECG abnormality n=521</th>
<th>Without major ECG abnormality n=1930</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>58.0 (16.1)</td>
<td>64.44 (14.9)</td>
<td>57.22 (15.1)</td>
<td>–</td>
</tr>
<tr>
<td>Male sex</td>
<td>1488 (60.7)</td>
<td>324 (62.2)</td>
<td>1164 (60.3)</td>
<td>0.44</td>
</tr>
<tr>
<td>Country</td>
<td></td>
<td></td>
<td></td>
<td>0.09</td>
</tr>
<tr>
<td>LIC</td>
<td>185 (7.5)</td>
<td>26 (5)</td>
<td>159 (8.2)</td>
<td></td>
</tr>
<tr>
<td>LMIC</td>
<td>1497 (61.1)</td>
<td>324 (62.2)</td>
<td>1173 (60.8)</td>
<td></td>
</tr>
<tr>
<td>UMIC</td>
<td>375 (15.3)</td>
<td>86 (16.5)</td>
<td>289 (15.0)</td>
<td></td>
</tr>
<tr>
<td>HIC</td>
<td>394 (16.1)</td>
<td>85 (16.3)</td>
<td>309 (16)</td>
<td></td>
</tr>
<tr>
<td>Non-HIC</td>
<td>2057 (83.9)</td>
<td>436 (83.7)</td>
<td>1621 (84)</td>
<td>0.87</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1189 (48.5)</td>
<td>320 (61.4)</td>
<td>869 (45)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Diabetes</td>
<td>895 (36.5)</td>
<td>223 (42.8)</td>
<td>672 (34.8)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>CVD</td>
<td>289 (11.8)</td>
<td>130 (25)</td>
<td>159 (8.2)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>CKD</td>
<td>195 (80)</td>
<td>62 (11.9)</td>
<td>133 (6.9)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Smoking</td>
<td>110 (4.5)</td>
<td>23 (4.4)</td>
<td>87 (4.5)</td>
<td>0.93</td>
</tr>
<tr>
<td>Asthma</td>
<td>88 (3.6)</td>
<td>18 (3.5)</td>
<td>70 (3.6)</td>
<td>0.85</td>
</tr>
<tr>
<td>Chronic immunodeficiency</td>
<td>80 (3.3)</td>
<td>26 (5)</td>
<td>54 (2.8)</td>
<td>0.01</td>
</tr>
<tr>
<td>Cancer</td>
<td>58 (2.4)</td>
<td>15 (2.9)</td>
<td>43 (2.2)</td>
<td>0.39</td>
</tr>
</tbody>
</table>

Data are present as mean (SD) or number (%). CKD, chronic kidney disease; CVD, cardiovascular disease; HIC, high-income countries; LIC, low-income countries; LMIC, lower middle-income countries; UMIC, upper middle-income countries.
standardisation. All ECGs were transmitted to an ECG reading centre at the ‘Centro de Telessaúde in Hospital das Clínicas Belo Horizonte/MG’ for standardised measurement, reporting and codification according to the Minnesota coding criteria (MC) in a validated ECG data management software. ECG acquisition in individuals during an acute case of COVID-19 is challenging due to isolation precautions. Added to resource limitations in some centres, having a digital ECG machine connected to a computer and to the internet was not always possible. Although our reading centre usually receives the exams as a .xml file, those were only a very small amount of ECG sources. The vast majority had to be sent as a picture or a PDF file. Integrating these tracings into our system, allowing measurement of ECG intervals in different formats and possibly different picture sizes, was another necessity. As a solution, we created an adaptation to calibrate the ECG measuring rule within the reading software according to the millimetric scale of the original paper photo (or to calibrate the ECG measuring rule within the reading software was another necessity. As a solution, we created an adaptation to calibrate the ECG measuring rule within the reading software according to the millimetric scale of the original paper photo (or PDF file) to have the correct values for every picture for amplitude and duration measurement (see online supplemental figure 1). An app was also created so that healthcare professionals or technicians who did the ECG could take the picture of the exam and transmit it to the reading centre directly from their smartphones (see online supplemental figure 2).

ECG findings were described according to standardised measurements (heart rate (HR), PR interval, QRS duration and axis, corrected QT interval (QTC)) and abnormalities (according to the MC system). Abnormalities used were grouped into ischaemic abnormalities (q waves and ST-T abnormalities MC groups 1, 4 and 5), atrial fibrillation (AF, MC group 8), prolonged QTc, sinus tachycardia (defined for the study as >120 bpm), right and left complete bundle branch block (MC group 7) and presence of any major abnormality according to MC.

**Covariables**

Participants’ clinical data were collected. Variables of interest for our study were demographics (age, sex, origin (LMIC and HIC)), cardiovascular risk factors (smoking status, hypertension, diabetes) and concomitant comorbidities (prevalently CVD: history of stroke, peripheral arterial disease, heart failure, coronary heart disease), asthma, chronic immunosuppression and chronic kidney disease.

**Outcomes**

The primary outcome was defined as death from any cause within 30 days. The secondary outcomes were ICU admission and cardiovascular events (myocarditis, pericarditis, myocardial infarction, acute heart failure, ischaemic and haemorrhagic stroke). Cardiovascular outcomes were defined by hospital records and electronic case report form by site investigators.

**Statistical analysis**

Continuous variables were described as medians and IQR and discrete variables by their frequency (%). Multivariate imputation by chained equation (MICE) was used to handle missing variables related to exposures and clinical characteristics of interest (listed in table 1). MICE assumes that the missing data are missing at random, this means that the probability of the missing value depends only on the observed value. The missing values are predicted by regression models, where a separate model imputes each incomplete variable. For the imputed variables, there were no more than 1.1% missing values, except for smoking (25.1%). Multiple logistic regression was used to evaluate the association of ECG abnormalities to the outcomes of interest. Adjustments were made in a step-by-step fashion including gender, age, country of residence, cardiovascular risk factors (diabetes, hypertension, tobacco use) and presence of comorbidities (CVD, asthma, cancer, immunosuppression and chronic kidney disease). Models were cumulative meaning the second model included the variables from the previous model and so on. The LMIC was tested in the models using an interaction with the ECG abnormalities. If non-significant, the model considered the variable country into two categories: HICs and non-HICs: LMICs, UMICs and LICs. We used the software R V4.1.1 for all performed analyses.

**Patient and public involvement**

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

**RESULTS**

A total of 5313 patients admitted with COVID-19 between June 2020 and September 2021 were recruited. However, only 2451 (46.1%) had at least one ECG performed and, therefore, were included in this study.

The participants had a mean age (SD) of 58.0 (16.1) years, 60.7% were male and the majority (61.1%) were recruited from LMICs. The most prevalent comorbidities were hypertension (48.5%), diabetes (36.5%), CVD (11.8%) and chronic kidney disease (8.0%), as shown in table 1. Patients with major ECG abnormalities were associated with a higher prevalence of diabetes, CVD, chronic kidney disease and chronic immunodeficiency. On the other hand, those without any major ECG abnormality had more hypertension and were more likely to be current smokers. The clinical characteristics of the entire cohort (those with and without a valid ECG) are fully described in online supplemental table 2.

Major ECG abnormalities were reported in 21.3% (521) of the patients. The presence of any major ECG abnormality, AF, bundle branch block, ischaemic abnormalities, prolonged QT interval and sinus tachycardia was more frequent in patients that experienced at least one adverse outcome (table 2).

A total of 447 (18.2%) patients died, 196 (8.0%) had cardiovascular events and 1115 (45.5%) were admitted to an ICU with minimal loss to follow-up (<2%). We tested the models using
an interaction for LMIC countries with ECG abnormalities and resulted in a non-significant variable. After multivariate adjustment for gender, age, country of residence, cardiovascular risk factors and presence of comorbidities, the presence of any major ECG abnormality was associated with a higher risk of death (OR 1.39; 95% CI 1.09 to 1.78) and adverse cardiovascular events (OR 1.81; 95% CI 1.30 to 2.51). AF, bundle branch block, ischaemic abnormalities and prolonged QT interval did not show an increased risk of outcomes. On the other hand, sinus tachycardia was associated with an increased risk of death (OR 3.86; 95% CI 1.97 to 7.48), cardiovascular events (OR 2.68; 95% CI 1.10 to 5.85) and ICU admission (OR 1.93; 95% CI 1.03 to 4.00) (table 3; figure 2). When we analysed the HR in four groups (HR <50 bpm, 80–99 bpm, 100–119 bpm and 120 bpm), only an HR >120 bpm was associated with adverse outcomes (online supplemental table 3). Online supplemental table 4 describes the OR of the individual components in the regression models.

**DISCUSSION**

We presented the results of the impact of major ECG abnormalities in a large cohort of individuals with confirmed COVID-19 disease from four different continents. In our study, after adjustment in multivariate analyses accounting for many potential confounders, the presence of an HR >120 bpm was a consistent predictor of all evaluated outcomes and the presence of any major abnormality of death and cardiovascular events. We can perceive however that, although not statistically significant (perhaps due to lack of statistical power), ischaemic abnormalities, AF and a prolonged QT interval demonstrated a tendency for harm when considering cardiovascular outcomes and death. For ICU admissions, the effect of ECG abnormalities other than HR >120 bpm was not evident. One of the hypotheses for this finding probably lies in the nature of ICU admissions in COVID-19, which are by far respiratory failure. These may not be so closely related to ECG abnormalities, but tachycardia. When looking from one side, a specifically cardiovascular end point, or at the other side a broader end point that might include more cardiovascular cases such as all-cause mortality, the relationship to ECG abnormalities becomes clearer.

Former studies have also reported on the association between ECG abnormalities and poor COVID-19 outcomes. ECG with

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Prognostic value of major electrocardiographic abnormalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR (95% CI)</td>
<td>Model 1 (unadjusted)</td>
</tr>
<tr>
<td>Any major ECG abnormality</td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>1.70 (1.37 to 2.18)</td>
</tr>
<tr>
<td>CV event</td>
<td>2.64 (1.94 to 3.56)</td>
</tr>
<tr>
<td>ICU admission</td>
<td>1.06 (0.87 to 1.30)</td>
</tr>
<tr>
<td>AF</td>
<td>0.80 (0.35 to 1.63)</td>
</tr>
<tr>
<td>CV event</td>
<td>2.54 (1.20 to 5.10)</td>
</tr>
<tr>
<td>ICU admission</td>
<td>1.04 (0.55 to 2.00)</td>
</tr>
<tr>
<td>BBB</td>
<td>1.44 (0.92 to 2.18)</td>
</tr>
<tr>
<td>CV event</td>
<td>1.67 (0.92 to 2.85)</td>
</tr>
<tr>
<td>ICU admission</td>
<td>1.03 (0.71 to 1.49)</td>
</tr>
<tr>
<td>Ischaemic abnormalities</td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>1.56 (1.16 to 2.08)</td>
</tr>
<tr>
<td>CV event</td>
<td>1.76 (1.18 to 2.57)</td>
</tr>
<tr>
<td>ICU admission</td>
<td>1.07 (0.84 to 1.40)</td>
</tr>
<tr>
<td>Prolonged QT</td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>1.46 (0.84 to 2.43)</td>
</tr>
<tr>
<td>CV event</td>
<td>2.62 (1.40 to 4.63)</td>
</tr>
<tr>
<td>ICU admission</td>
<td>1.17 (0.74 to 1.80)</td>
</tr>
<tr>
<td>Heart rate &gt;120 bpm</td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>3.95 (2.10 to 7.48)</td>
</tr>
<tr>
<td>CV event</td>
<td>3.04 (1.29 to 6.40)</td>
</tr>
<tr>
<td>ICU admission</td>
<td>1.93 (1.02 to 3.80)</td>
</tr>
</tbody>
</table>

*Diabetes, hypertension, tobacco use.
†Cardiovascular disease, asthma, cancer, immunosuppression and chronic kidney disease.
CV, cardiovascular; ICU, intensive care unit; AF, atrial fibrillation; BBB, bundle branch block.
prior myocardial infarction pattern or acute ST-T pathology at ICU admission was associated with death and the need for vasoactive treatment in a cohort of 80 patients admitted to an ICU in Sweden.\textsuperscript{20} Lanza \textit{et al}\textsuperscript{13} found that QRS duration, QRS duration $\geq$ 110 ms, left bundle branch block and presence of any ECG abnormality had a significant independent association with mortality in 324 consecutive patients admitted to one emergency department in Italy with a confirmed diagnosis of SARS-CoV-2 infection. Thakore \textit{et al}\textsuperscript{12} demonstrated a positive association between prolonged QT intervals and adverse outcomes in 662 patients with COVID-19 and baseline ECG.

Data of the above studies are derived mostly from single centres and smaller cohorts, and always from HICs, with higher age and prevalence of previous CVD. Reporting on ECG abnormalities and clinical outcomes also varied between studies and ECG evaluation was not always standardised. All this can account, at least in part, for some differences in results. We provide evidence from a multicentric study with one of the largest ECG databases, classification of the abnormalities according to the MC, a widely validated tool for ECG assessment.\textsuperscript{21}

CVD and adverse COVID-19 outcomes are intrinsically related.\textsuperscript{22} Although specific cardiovascular outcomes directly related to COVID-19 toxicity such as clinical myocarditis are not so common,\textsuperscript{23} they become more frequent when using a broader definition of cardiovascular outcomes like the ones reported in our study. How CVD and ECG abnormalities lie on the causal pathway of poor outcomes in COVID-19 (and the way around) needs to be better elucidated. Severe systemic conditions have been reported to cause cardiac injury\textsuperscript{24} and one could also argue that a poor cardiac reserve per se, due to pre-existing conditions, might suffice to explain an adverse outcome. Still, direct myocardial injury due to viral damage and cytokine storm and indirect injury due to endothelial damage, disruption of the renin-angiotensin system, thrombus inflammatory activity, hypoxia-induced injury and stress-induced arrhythmias are potential explanations for the relation between CVD and COVID-19.\textsuperscript{1,25} The ECG can be considered a marker of cardiovascular damage (either structural or in electrical pathways), hence, there is plausibility for a relation between and altered ECG and poor outcomes in COVID-19. Another point of concern is how a COVID-19 case might affect future cardiovascular risk since individuals that have had a COVID-19 infection (mild cases included) have been reported to be at increased risk for future cardiovascular adverse events.\textsuperscript{26} Finally, another angle from which COVID-19 can impact cardiovascular health is due to logistical difficulties in managing two major health issues in the health system, especially in the context of preventing intra-hospital transmission of COVID-19.\textsuperscript{27} During the pandemic, cardiovascular hospitalisations and procedures have decreased at a cost of increased cardiovascular mortality with greater disparities in LMICs.\textsuperscript{28} These are all striking pieces of information that, taken together, point to a direction in which COVID-19 and CVD are more intimately related than we have accounted for at the beginning of the pandemic. We can also notice a bidirectional effect of both COVID-19 causing CVD and being aggravated by it. In this sense, the ECG abnormalities can be seen as a marker of present cardiovascular damage and/or CVD.

Therefore, differentiating CVD or COVID-19 as the cause of poor outcomes in individuals presenting both conditions can be challenging. This can be illustrated by the findings of Brant \textit{et al}.\textsuperscript{29} They report on excess cardiovascular mortality during the COVID-19 pandemic in six large Brazilian cities. Among the cities with a more structured health system, a decline in specified cardiovascular death was reportedly accompanied by an increase in unspecified cardiovascular and home deaths. This translates to the difficulty in adjudicating deaths in COVID-19 associated with CVD.

Our study has important limitations. Most importantly, ECG data were available for only 2451 participants from 5313 of the whole cohort. Although some degree of selection bias might be present, data presented in online supplemental table 2 show that the clinical characteristics of these two groups were similar. The main reason some sites had a big number (or totality) of ECG missing was unavailability of an ECG machine at time mostly due to resource limitation. It is noticeable that when compared with the complete cohort, this population with a valid ECG had a higher rate of death (18.2\% vs 15.1\%) and ICU admission (45.5\% vs 31.4\%).\textsuperscript{14} One potential explanation for this lower risk profile regarding outcomes might be that individuals perceived as low risk could perhaps have had their ECG omitted in some sites. Another limitation is that we do not have a second ECG from the individuals to analyse ECG changes or incidence of abnormalities during the hospital stay. We also did not have a previous ‘baseline ECG’ from individuals which makes it impossible to differentiate if ECG abnormalities were relatively recent or related to COVID-19 index case of simply older prevalent abnormalities. We believe though that this is a minor issue since the aim of our study was not to evaluate the incidence of ECG abnormalities but rather evaluate if having that abnormality would impact future events after being hospitalised with COVID-19. A third limitation is that we had to use imputation techniques to account for missing data, although the frequency of missing data was small for the variables used. The very large sample size, the extent of geographical representation and standardisation in reporting on ECG abnormalities are relevant strengths of our study.

In conclusion, major ECG abnormalities were independent predictors of severe outcomes in COVID-19 hospitalisations. A low-cost and widely available clinical tool such as the ECG can be used to help prognosticate these individuals.

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Contributors MFM-F contributed to study design and drafted the manuscript. GMP contributed to study design and managed ECG acquisition, CPMS contributed to study design and performed the statistical analysis, KS contributed to study design, data management, and reviewed the manuscript; VAR contributed to data acquisition and reviewed the manuscript; FT contributed to data acquisition and reviewed the manuscript; CV contributed to data acquisition, figures elaboration and reviewed the manuscript; BM contributed to data acquisition and reviewed the manuscript; NS contributed to data acquisition and reviewed the manuscript; AWC contributed to data acquisition and reviewed the manuscript; NN contributed to data acquisition and reviewed the manuscript; SD contributed to data acquisition and reviewed the manuscript; PP contributed to study design, data management and reviewed the manuscript; DP contributed to study design, data management and reviewed the manuscript; KS-H contributed to study design, data management and reviewed the manuscript; ALPR contributed to study design, ECG data management, drafted the manuscript and is acting as guarantor.

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Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Institutional ethics approval for the project was obtained from the University of Cape Town, South Africa (ethics committee approval number 1600415161). Additionally, all participating sites investigators obtained ethical approval from their respective institutional ethics committees before patient recruitment in the study. Mandated national regulatory clearances were also obtained. Patients who voluntarily agreed to participate in the study gave informed consent.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information.

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REFERENCES
