Cardiovascular Topics

Impact of COVID-19 on cardiac surgery outcomes

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Abstract

Aim: This study aimed to assess the impact of COVID-19 infection on cardiac surgery outcomes in patients who contracted COVID-19 peri-operatively or had recently recovered from COVID-19.

Methods: The study prospectively enrolled 95 patients scheduled for cardiac surgery who had recently recovered from COVID-19. This formed the post-COVID-19 group. The other group consisted of 25 patients who contracted COVID-19 peri-operatively. Patients were followed for all-cause mortality as the primary endpoint and postoperative course complications as the secondary endpoint. Data were compared to a historical cohort of 280 non-COVID-19 patients.

Results: The peri-operative COVID-19 group exhibited a significantly higher prevalence of primary outcome all-cause mortality (28%), compared with 4.3% in the controls ($p < 0.01$), as well as the secondary composite endpoint (stroke, peri-operative myocardial infarction and pneumonia) (52 vs 13.9%, $p < 0.01$). The post-COVID-19 group had a higher incidence of acute pulmonary embolism (3.2 vs 0%, $p < 0.01$) and atrial fibrillation (23.4 vs 11.4%, $p < 0.01$).

Conclusion: Patients who contracted COVID-19 peri-operatively had an increased rate of mortality and postoperative complications, while cardiac surgery in the recently recovered COVID-19 group was associated with a higher incidence of pulmonary embolism and atrial fibrillation.

Keywords: Coronavirus disease 2019 (COVID-19), cardiac surgery, outcomes, mortality, complications

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The first cluster of pneumonia cases caused by the novel coronavirus was detected in 2019.[1] Since then there has been a growing body of evidence that patients with cardiovascular diseases are susceptible to unfavourable outcomes after contracting coronavirus disease (COVID-19).[2] Recently Nguyen *et al*. reported a dramatic decrease in cardiac surgery volumes, with a concurrent increase in mortality rate during the pandemic.[3] At the same time, a parallel pandemic of post-COVID is occurring in millions of people after COVID-19 infection, and they are living with lingering symptoms and complications.

Little is known about the potential implications of COVID-19 in patients undergoing cardiac surgery. The data are mainly based on case reports or small series.[3,4] Some evidence shows that patients with acute COVID-19 had poor outcomes after cardiac surgery.[4,5] The data on post-COVID-19 patients who are more susceptible to postoperative cardiac surgery complications are even more scarce.[6]

Active SARS-CoV-2 infection represents a potentially serious risk factor for causing morbidity and mortality, especially in patients with pre-existing cardiovascular diseases.[7] As there are many unknowns on postoperative course and outcomes of these patients, new studies are needed.[8]

Our study's primary aim was to assess the impact of acute COVID-19 infection on cardiac surgery outcomes. The secondary aim was to assess cardiac surgery outcomes in patients with a history of recent COVID-19 infection.

Methods

We performed a prospective study that included patients hospitalised for scheduled cardiac surgery over the course of a period from 20 March 2020 to 1 January 2022 at the Institute of Cardiovascular Diseases of Vojvodina, a tertiary-care university centre in Serbia (Fig. 1).

All patients in the predefined time frame were prospectively evaluated for COVID-19 status. They were all screened and tested for SARS-CoV-2 virus using a real-time polymerase chain reaction (RT-PCR) test of nasopharyngeal swab samples on hospital admission. Patients scheduled for elective cardiac surgery who tested SARS-CoV-2 positive on admission were excluded from the study and rescheduled for cardiac surgery.

The study prospectively included two groups. Patients who were SARS-CoV-2 negative on admission but had proof of past

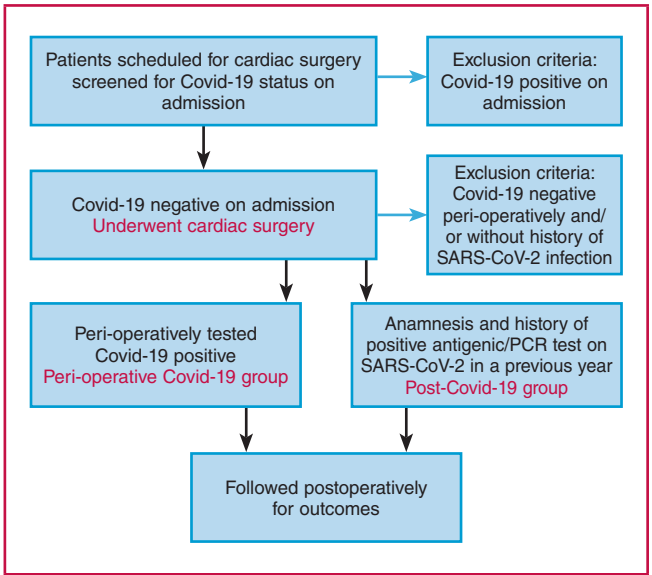

Fig. 1. Study flow chart.

COVID-19, using either RT-PCR or antigenic SARS-CoV-2 testing up to 360 days prior to cardiac surgery, were included and classified as the post-COVID-19 group. If patients had symptoms of infection during the hospital stay after cardiac surgery, they were tested at least once. Those who tested PCR SARS-CoV-2 positive during hospitalisation in the peri-operative period were included in a peri-operative COVID-19 group. Patients who underwent cardiac surgery and remained SARS-CoV-2 PCR negative during hospitalisation without proof of previous COVID-19 infection were excluded.

The rationale behind excluding patients who underwent cardiac surgery and remained COVID-19 negative as controls is the possibility that they might have been asymptomatic carriers or had previously recovered from COVID-19 without being aware of it. This could have been due to a lack of positive test results or a failure to recall any previous infection. Serology was not sampled for these patients.

The historical cohort control group comprised 280 patients who underwent cardiac surgery from 1 January 2020 to 1 March 2020. We chose to include these patients as controls because they underwent cardiac surgery before the COVID-19 era in Serbia.

Patients underwent a COVID-19 screening protocol using nasopharyngeal swab samples for SARS-CoV-2 detection via PCR on admission, a day before surgery, and after they were tested if they had signs and symptoms of infection (fever, cough, fatigue, or any other clinical or laboratory signs of infection). Those with symptoms and/or signs of infection, if proven SARS-CoV-2 positive, were included in peri-operative COVID-19 group.

These two groups of patients were followed for all-cause mortality as the primary endpoint. The secondary endpoint in this study was a composite measure of postoperative cardiopulmonary complications, which included incidents of stroke, peri-operative myocardial infarction and pneumonia. The patients were followed up during their postoperative hospital stay.

We collected and analysed the data on patients' demographics, previous co-morbidities, echocardiographic parameters, New York Heart Association (NYHA) class, surgery type [valvular, coronary artery bypass grafting (CABG)] and other (aortic dissection, pericardial surgery, tumours), urgency of surgery, time from surgery to COVID-19-positive test, number of hospital days, time spent in the intensive care unit (ICU), time on extracorporeal circulation, postoperative course and intrahospital mortality. Data were withdrawn from electronic records and compared with a historical cohort. Data were finally checked for missing or contradictory entries and values out of the normal range by one investigator.

The study was conducted according to the Declaration of Helsinki. The study was approved by the ethics commmitee of the ICVDV (1189-1/1/20).

Statistical analysis

To test the normal distribution, the Kolmogorov–Smirnov test was used. Continuous variables are presented as median with interquartile range (IQR) or mean with standard deviation (SD). Categorical variables are presented as absolute numbers and percentages. As appropriate, differences between the groups were tested via ANOVA, Mann–Whitney *U*-test, or chi-squared test. Univariable binary logistic regression was used to test predictors of mortality, and these are expressed as estimated odds ratios (OR) with their corresponding 95% confidence intervals (CI); *p*-values lower than 0.05 were considered statistically significant. The statistical software TIBCO Statistica™ (Statistica 14.0.0, The Ultimate Academic Bundle, StatSoft Europe GmbH, Hamburg, Germany; university license for the University of Novi Sad) and IBM SPSS Statistics, trial version were used for all analyses.

Results

The study included 400 patients, 280 non-COVID-19 controls, 95 patients in a post-COVID-19 group, and 25 patients in the peri-operative COVID-19 group. In the peri-operative COVID-19 group, the median time from surgery to COVID-19-positive test was 6 (10.5) (0–28) days, while in the post-COVID-19 group, the median time from COVID-19-positive test to surgery was 90 (73) (6–360) days.

Basic patient characteristics are presented in Table 1. The patients were predominantly males (76%) in the peri-operative COVID-19 group versus 63.2% in the post-COVID-19 and 68.2% in non-COVID-19 group ($p = 0.43$). The mean age was 66 (11) years in the non-COVID-19 group, 68 (13) in the post-COVID-19 group, and 67 (15) years in the peri-operative COVID-19 group ($p = 0.35$).

Patients with peri-operative COVID-19 had a significantly higher prevalence of NYHA class III on admission (40%) versus 14.6% in the non-COVID-19 group ($p < 0.01$). The post-COVID-19 group had significantly higher mean right ventricular systolic pressure when compared to the non-COVID-19 group [45.1 (15.5) vs 35.5 (18.8), respectively, $p < 0.01$]. There were no significant differences between the groups with regard to previous co-morbidities, except the peri-operative COVID-19 group had a higher incidence of prior CABG surgery (8 vs 0%, $p < 0.01$).

In the group with peri-operative COVID-19, the most prevalent symptoms of infection were fever (92%), cough (36%) and fatigue (44%). There were no significant differences between the groups in terms of surgery type and urgency, and most surgeries were elective (Tables 2, 3).

Table 1. Patients' characteristics on admission

Parameters	*Non-COVID-19* (n = *280*)	*Post COVID-19* (n = *95*)	*Peri-operative COVID-19* (n = *25*)	p-*value*
Gender (M), *n* (%)	191 (68.2)	60 (63.2)	19 (76)	NS
Age (years), median (IQR)	66 (11)	68 (13)	67 (15)	NS
NYHA class I, *n* (%)	9 (3.2)	4 (4.3)	2 (8)	NS
NYHA class II, *n* (%)	226 (80.7)	65 (70.7)	13 (52)	< 0.01**
NYHA class III, *n* (%)	41 (14.6)	22 (23.9)	10 (40)	0.04* < 0.01**
NYHA class IV, *n* (%)	4 (1.4)	1 (1.1)	0	NS
Hospitalised with acute MI, *n* (%)	24 (8.7)	6 (6.3)	2 (8)	NS
BMI (kg/m^2), median (IQR)	25.8 (4.6)	28.7 (6.6)	26.7 (6.3)	NS
EuroSCORE II, median (IQR)	1.2 (1.1)	1.6 (2.3)	3 (1.5)	NS
LVEF (%), median (IQR)	58 (12)	58 (26)	39.5 (27.3)	NS
RVSP (mmHg), mean (SD)	35.5 ± 18.8	45.1 ± 15.5	39 ± 16.5	< 0.01*
Mitral E/e′ ratio, median (IQR)	10.1 (5.9)	12.8 (9.3)	16.3 (15.3)	NS
History of hypertension, *n* (%)	242 (86.4)	80 (84.2)	19 (76)	NS
History of diabetes mellitus, *n* (%)	82 (29.3)	30 (31.6)	10 (40)	NS
History of hyperlipidaemia, *n* (%)	175 (62.5)	64 (67.4)	15 (60)	NS
History of chronic kidney disease, *n* (%)	11 (3.9)	8 (8.4)	1 (4)	NS
Family history of CVD, *n* (%)	158 (56.4)	50 (52.6)	13 (52)	NS
Smoking history, *n* (%)	78 (27.9)	30 (31.9)	12 (48)	NS
COPD, *n* (%)	25 (8.9)	10 (10.5)	3 (12)	NS
Malignancy, *n* (%)	14 (5.0)	7 (7.4)	1 (4)	NS
Peptic ulcer disease, *n* (%)	10 (3.6)	2 (2.1)	1 (4)	NS
Prior stroke, *n* (%)	11 (3.9)	3 (3.2)	3 (12)	NS
Prior MI, *n* (%)	73 (26.1)	23 (24.2)	10 (40)	NS
Prior PCI, *n* (%)	31 (11.1)	13 (13.7)	1 (4)	NS
Prior CABG, *n* (%)	0	0	2 (8)	< 0.01*

BMI: body mass index, CABG: coronary artery bypass grafting, COPD: chronic obstructive pulmonary disease, CVD: cardiovascular diseases, LVEF: left ventricular ejection fraction, IQR: interquartile range, MI: myocardial infarction, NYHA: New York Heart Association, PCI: percutaneous coronary intervention, RVSP: right ventricular systolic pressure, SD: standard deviation.
**p*-value computed as comparison of non-COVID-19 vs post-COVID-19.
***p*-value computed as comparison of non-COVID-19 vs peri-operative COVID-19.

No significant differences were observed for the primary and secondary endpoints between the post-COVID-19 group and the control group (Table 4). However, when comparing the post-COVID-19 group to the control group, there was a significantly higher prevalence of acute pulmonary embolism (3.2 vs 0%, $p < 0.01$) and atrial fibrillation (23.1 vs 11.8%, $p < 0.01$). In the postoperative course, post-COVID-19 patients more often needed red blood cell transfusion (73.6 vs 38.6%, $p < 0.01$), the use of noradrenalin (67.3 vs 45.7%, $p < 0.01$), and they stayed longer in the ICU [27.6 (29.9) vs 24.3 (5.9) hours, $p < 0.01$], with a shorter total hospital stay [10 (5) vs 12 (6) days, $p = 0.01$] as well

Table 2. Surgical characteristics of the non-COVID-19 compared to post-COVID-19 group

Variables	*Non-COVID-19* (n = *280*)	*Post COVID-19* (n = *95*)	χ^2	p-*value*
Surgery type, *n* (%)				
CABG	118 (42.1)	31 (32.6)	2.7	NS
Valvular surgery	94 (33.6)	35 (36.8)	0.3	NS
CABG/valve	57 (20.4)	24 (25.3)	1	NS
Other	11 (3.9)	5 (5.3)	0.3	NS
Operation urgency, *n* (%)				
Urgent/emergency	23 (8.2)	2 (3.2)	2.8	NS
Elective	257 (91.8)	92 (96.8)	2.7	NS

CABG: coronary artery bypass grafting.

Table 3. Surgical characteristics of the non-COVID-19 compared to peri-operative COVID-19 group

Variables	*Non-COVID-19* (n = *280*)	*Peri-operative COVID-19* (n = *25*)	χ^2	p-*value*
Surgery type, *n* (%)				
CABG	118 (42.1)	12 (48.0)	0.3	NS
Valvular surgery	94 (33.6)	9 (36.0)	0.06	NS
CABG/valve	57 (20.4)	4 (16.0)	0.3	NS
Other	11 (3.9)	0	1	NS
Operation urgency, *n* (%)				
Urgent/Emergency	23 (8.2)	1 (4)	0.6	NS
Elective	257 (91.8)	24 (96)	0.6	NS

as a shorter time from surgery to discharge [7 (1) vs 8 (3) days, $p = 0.02$]. There were no significant differences in mortality rate [2 (2.1) vs 12 (4.3%), $p = 0.34$].

Two patients died in the post-COVID-19 group, both after very complex combined CABG/valve surgery due to haemodynamic instability. One patient at the age of 83 years had a positive test 60 days before surgery, with an ejection fraction (EF) of 20% and EuroSCORE of 20.6. The other had surgery at the age of 70 years, 71 days after a COVID-19-positive test, with an EF of 35% and a EuroSCORE of 5.5.

All-cause mortality as the primary endpoint was met in 28% of patients in the peri-operative COVID-19 group compared to 4.3% in the controls ($p < 0.01$). The median time from surgery to death in the peri-operative COVID-19 group was 28 (22) days. The composite secondary endpoint was also significantly prevalent in the peri-operative COVID-19 group (52 vs 13.9%, $p < 0.01$).

Table 4. Postoperative course and outcomes of the non-COVID-19 compared to post-COVID-19 group

Variables	*Non-COVID-19* (n = *280*)	*Post-COVID-19* (n = *95*)	χ^2 *or* z	p-*value*
All-cause mortality, *n* (%)	12 (4.3)	2 (2.1)	0.9	NS
Composite secondary endpoint, *n* (%)	39 (13.9)	12 (12.6)	0.1	NS
Stroke, *n* (%)	25 (8.9)	3 (3.1)	0.1	NS
Pneumonia, *n* (%)	13 (6.1)	4 (4.2)	0.02	NS
PE, *n* (%)	0 (0)	3 (3.2)	9	< 0.01
Re-surgery, *n* (%)	4 (1.4)	1 (1.1)	0.05	NS
Sepsis, *n* (%)	7 (2.5)	1 (1.1)	0.7	NS
Shock, *n* (%)	9 (3.2)	2 (2.1)	0.3	NS
Acute kidney failure, *n* (%)	4 (1.4)	2 (2.1)	0.2	NS
Peri-operative MI, *n* (%)	5 (1.8)	1 (1.1)	0.2	NS
Paroxysms of atrial fibrillation, *n* (%)	33 (11.8)	22 (23.1)	7.2	< 0.01
Red blood cell transfusion, *n* (%)	108 (38.6)	70 (73.6)	34.7	< 0.01
Dobutamine, *n* (%)	43 (15.4)	21 (22.1)	2.2	NS
Adrenalin, *n* (%)	225 (80.4)	79 (83.1)	0.3	NS
Noradrenalin, *n* (%)	128 (45.7)	64 (67.3)	13.2	< 0.01
ECC (min), median (IQR)	73 (33)	74.5 (35.8)	–0.4	NS
Intubation time (hours), median (IQR)	11 (7)	12 (7.5)	–0.4	NS
ICU stay (hours), median (IQR)	24.3 (5.9)	27.6 (29.9)	1.7	< 0.01
Time from surgery to discharge (days), median (IQR)	8 (3)	7 (1)	2.4	0.02
Total hospital stay (days), median (IQR)	12 (6)	10 (5)	3.3	0.01

ECC: extracorporeal circulation, ICU: intensive care unit, MI: myocardial infarction, PE: pulmonary embolism, IQR: interquartile range.

Table 5. Postoperative course and outcomes of the non-COVID-19 compared to the peri-operative COVID-19 group

Variable	*Non-COVID-19* (n = *280*)	*Peri-operative COVID-19* (n = *25*)	χ^2 *or* z	p-*value*
All-cause mortality, *n* (%)	12 (4.3)	7 (28)	21.9	< 0.01
Composite secondary endpoint, *n* (%)	39 (13.9)	13 (52)	23.5	< 0.01
Stroke, *n* (%)	25 (8.9)	3 (12)	0.3	NS
Pneumonia, *n* (%)	13 (6.1)	9 (36)	26.1	< 0.01
PE, *n* (%)	0	0		
Red blood cell transfusion, *n* (%)	108 (38.6)	18 (72)	10.5	0.02
Re-surgery, *n* (%)	4 (1.4)	2 (8)	5.2	0.03
Sepsis, *n* (%)	7 (2.5)	4 (16)	11.9	0.01
Shock,	9 (3.2)	2 (8)	1.5	NS
Acute kidney failure, *n* (%)	4 (1.4)	0 (0.0)	0.3	NS
Peri-operative MI, *n* (%)	5 (1.8)	1 (4)	0.6	NS
Paroxysms of atrial fibrillation, *n* (%)	33 (11.8)	7 (28)	5.3	0.03
Dobutamine, *n* (%)	43 (15.4)	7 (28)	2.6	NS
Adrenalin, *n* (%)	225 (80.4)	19 (76)	0.3	NS
Noradrenalin, *n* (%)	128 (45.7)	14 (56)	0.9	NS
ECC, median (IQR)	74 (33)	67 (43.3)	–0.4	NS
Intubation time (hours), median (IQR)	11 (7)	11 (10)	–0.2	NS
ICU stay (hours), median (IQR)	24.3 (5.9)	61.4 (105.9)	5.9	< 0.01
Time from surgery to discharge (days), median (IQR)	8 (3)	9 (13)	2.5	NS
Total hospital stay (days), median (IQR)	12 (6)	16 (13)	3.3	0.01

ECC: extracorporeal circulation, ICU: intensive care unit, MI: myocardial infarction, PE: pulmonary embolism, IQR: interquartile range.

Patients with peri-operative COVID-19 compared to non-COVID-19 had a significantly higher prevalence of pneumonia (36 vs 6.1%, $p < 0.01$), red blood cell transfusion (72 vs 38.6%, $p < 0.01$), re-surgery (8 vs 1.4%, $p < 0.01$), sepsis (16 vs 2.5%, $p < 0.01$) and paroxysmal atrial fibrillation (28 vs 11.8%, $p < 0.01$). The median hospital stay was significantly prolonged in the peri-operative COVID-19 group compared to the non-COVID-19 group [16 (13) vs 12 (6) days, $p < 0.01$], as was the ICU stay [61.4 (105.9) vs 24.3 (5.9) hours, $p < 0.01$] (Table 5).

Univariant logistic regression analysis identified postoperative pneumonia (OR 9.4, 95% CI: 1.3–67.6, $p = 0.03$), sepsis (OR 13.5, 95% CI: 1.098–165.9, $p = 0.04$) and creatinine levels (OR 1.009, 95% CI: 1.001–1.018, $p = 0.04$) as significant predictors of mortality in the peri-operative COVID-19 group.

Discussion

Acute SARS-CoV-2 infection in the early peri-operative period was associated with an increased rate of postoperative complications, a high mortality rate of 28%, and prolonged ICU stay and hospitalisation time. Patients in the post-COVID-19 group had similar outcomes to those in the non-COVID-19 group, except for a higher prevalence of transfusion, pulmonary embolism and atrial fibrillation.

Our study results are comparable with other studies. In a retrospective review with nine United Kingdom centres involved, Sanders *et al.* reported that 53 patients with peri-operative COVID-19 had increased mortality rates (24.5 vs 3.5%, $p < 0.0001$) and longer postoperative stay (11 vs 6 days, $p = 0.001$).[5] In this study, patients diagnosed with COVID-19 before surgery had similar outcomes to non-COVID-19 patients. However, those who contracted COVID-19 after surgery had a significantly higher mortality rate (37.1 vs 0.0%, $p = 0.005$) and remained in hospital for an additional five days.

A meta-analysis published in March 2022 identified 18 studies reporting outcomes on COVID-19-positive patients undergoing cardiac surgery from 1 January 2019 to 24 February 2022.[8] In the 44 patients with peri-operatively diagnosed COVID-19, 63.6% experienced postoperative complications, with an overall in-hospital and 30-day mortality rate of 27.3%. The authors concluded that these patients had a longer ICU and postoperative length of stay and overall poor outcomes with high morbidity and mortality rates.

Mortality prevalence in cardiac surgery patients affected with COVID-19 is consistently higher compared to non-COVID-19 patients in the reported data, but poorer outcomes were reported even when COVID-19 was diagnosed after cardiac surgery. Barkhodari *et al.*,[3] in a study published in 2020 on 25 asymptomatic COVID-19 patients who underwent urgent or emergency cardiac surgery, reported a higher mortality rate (16%) and length of ICU stay compared to patients in the pre-COVID era. In a case series of 18 patients with early onset of COVID-19 after cardiac surgery, the overall mortality rate was 15%.[9] In the early months of the pandemic, in a case series on nine patients who underwent cardiac surgery and contracted COVID-19, the authors reported extremely poor outcomes, with a mortality rate of 44% and a significant length of hospital stay.[10]

Half of the patients with peri-operative SARS-CoV-2 infection experienced postoperative pulmonary complications associated with high mortality rates.[11] Generally, better outcomes are reported if cardiac surgery was performed after COVID-19 infection. In a case series of three patients who underwent urgent cardiac surgery after recent COVID-19 infection, the authors reported an uneventful postoperative course.[12] Likewise, a case report of successful CABG surgery in a patient with asymptomatic SARS-CoV-2 infection presenting with acute coronary syndrome and with severe multi-vessel coronary artery disease requiring urgent surgery was reported.[13]

Additionally, cases of a successful recovery were reported in patients with mild symptoms of COVID-19 who underwent emergency cardiac surgery.[14,15] The pre- and postoperative treatment with heparin and corticosteroids might have been crucial in reducing the incidence of pulmonary impairment, mortality rate and other adverse outcomes frequently observed in COVID-19 patients who underwent surgery. Ishmail *et al.* postulated that cardiac surgery could be performed safely in patients with pre-operative COVID-19 infection after a period of recovery, especially in the asymptomatic to mild category of infection.[16]

In our study, patients in the peri-operative COVID-19 group who tested positive after cardiac surgery had a significantly higher incidence of pneumonia, blood transfusion, re-surgery, sepsis and paroxysmal atrial fibrillation. Statistically significant predictors of mortality in the peri-operative COVID-19 group were pneumonia, sepsis and creatinine levels.

Angiotensin converting enzyme 2 receptors as the host receptors for SARS-CoV-2, are mostly expressed in respiratory epithelial cells and vascular endothelium.[17] Excessive inflammatory response, massive cytokine chemokine release and impaired immune defense may lead to tissue damage at the site

of virus entry and at a systemic level. As the early postoperative period is also a pro-inflammatory state, all responses can be doubly aggravated in the case of acute infection early after surgery. That could explain why patients diagnosed with COVID-19 early after surgery in our study and in other studies had the worst outcomes. If COVID-19 was diagnosed and treated prior to undergoing cardiac surgery, there was a higher likelihood of avoiding complications.

While most cases of acute COVID-19 in reported patients showed mild pre-operative symptoms, it is certain that critically ill COVID-19 patients face a significantly elevated risk of post-surgical morbidity and mortality. However, such data are seldom documented. Cardiac arrhythmias, such as atrial fibrillation, occur in patients infected, recovering and recovered from COVID-19.[18] New-onset atrial fibrillation was common among patients hospitalised with COVID-19.[19]

In a cohort of 62 patients diagnosed with COVID-19 infection before surgery, the case group exhibited significantly higher rates of postoperative complications, including stroke (25.8%), atrial fibrillation, pleural effusion, blood transfusion and inotrope use. Furthermore, the mortality rate was 11.3% among COVID-19-positive patients and 8.3% among those without COVID-19 infection.[20] The post-COVID-19 group exhibited a higher prevalence of red blood cell transfusion and pulmonary embolism.

SARS-CoV-2 has been recognised as a risk factor for deep-vein thrombosis and pulmonary embolism.[21] A recently published article underlined that SARS-CoV-2 infection was independently associated with an increased incidence of postoperative venous thromboembolism in patients with peri-operative and recent SARS-CoV-2 infection.[22] In a review, Lechuga *et al*.[23] highlighted that long COVID-19 is associated with different haematological variations, including alterations in red and white blood cells, impaired coagulation and increased inflammation. These changes may contribute to an increased bleeding risk and a higher likelihood of needing transfusion after cardiac surgery.

Our findings underscore the significance of implementing preventative measures and specific protocols to reduce complications and mortality. It is imperative to establish stringent screening protocols during the peri-operative phase, with a particular focus on the pre-operative and early postoperative period, for the early detection of SARS-CoV-2 infection in patients, enabling prompt initiation of treatment. Additionally, implementing extra caution to prevent infection within the hospital environment during this initial vulnerable period is of utmost importance.

Equally critical is vigilant monitoring during the postoperative phase to identify any signs of infection. When feasible, initiating treatment for COVID-19-positive patients, as well as considering the postponement of cardiac surgery until recovery, could mitigate complications. Furthermore, the effectiveness and safety of potential specific treatments involving antiviral and immunomodulatory therapies must be evaluated during this vulnerable period in future studies.

Limitations

Several limitations should be considered in this study. In an observational and non-randomised single-centre study, the outcomes could have been influenced by both identified and unidentified confounders. Another study limitation is potential selection bias. The study compared outcomes to a historical cohort, but using different controls might have led to different conclusions. Certain risk factors that influenced outcomes in the historical cohort might have differed from those in the post-COVID and COVID cases included in the study. Additionally, various factors impacting on postoperative care during the COVID-19 pandemic might have contributed to unfavourable outcomes in the peri-operative COVID-19 group. Patients in the peri-operative COVID-19 group had a higher prevalence of NYHA class III at baseline. Initially higher stages of heart failure might also have affected the postoperative outcomes.

Serology on SARS-CoV-2 was not sampled for the patients, and this could potentially be a confounder. These patients may be prone to complications. The number of patients in the peri-operative COVID-19 group was small, which could have limited the number of identified independent predictors of mortality and the consistency of the results. Follow up was short. Despite these limitations, the high statistical significance of the results can help us draw preliminary conclusions.

Conclusion

COVID-19 infection during the peri-operative phase has been linked to a higher incidence of postoperative complications, extended hospital stay and unfavourable outcomes, while cardiac surgery scheduled post-COVID did not increase the mortality rate. Recently recovered COVID-19 patients could be prone to atrial fibrillation and pulmonary embolism post cardiac surgery.

Our research emphasises the necessity for well-defined testing and monitoring protocols for cardiac surgery patients during the peri-operative period. We suggest strict and repeated SARS-CoV-2 testing pre-operatively and in the early postoperative period to discover infection on time and prevent complications.

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