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## Adult cardiovascular surgery and the coronavirus disease 2019 (COVID-19) pandemic: the Italian experience

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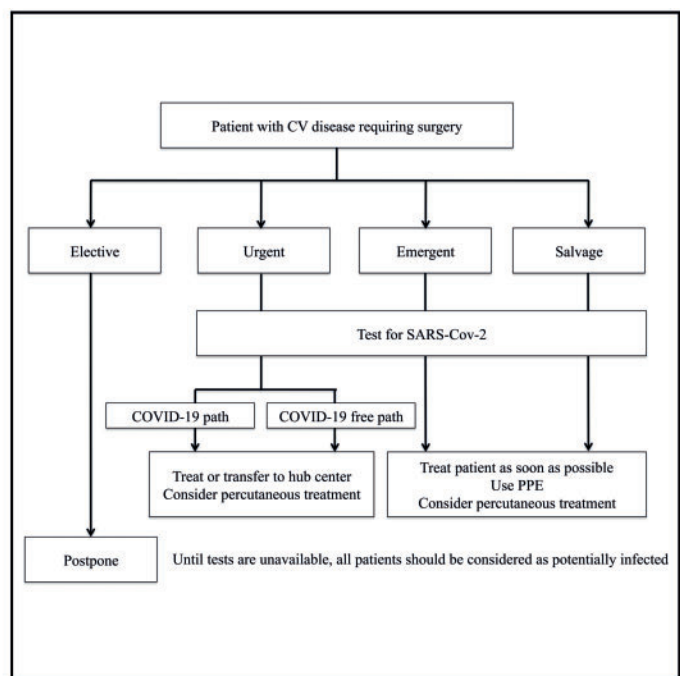
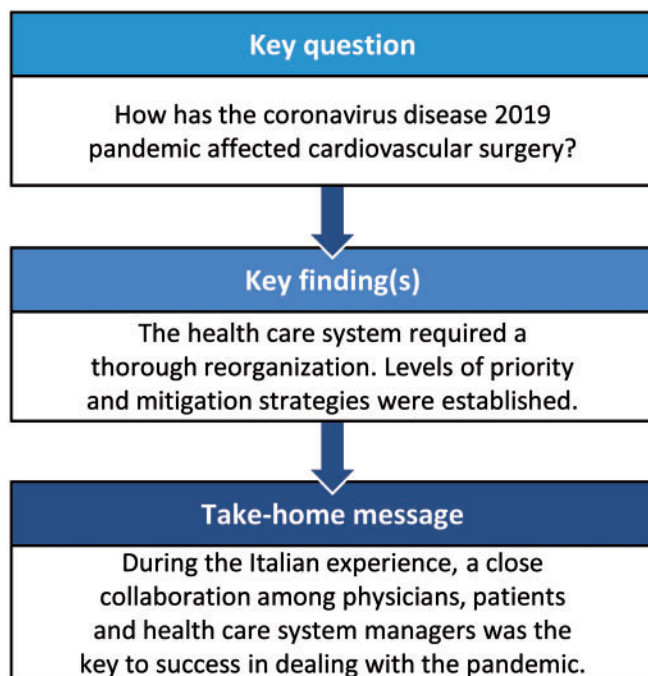
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### Abstract

The coronavirus disease 2019 (COVID-19) pandemic has profoundly affected all health care professionals. The outbreak required a thorough reorganization of the Italian regional local health care system to preserve resources such as ventilators, beds in intensive care units and surgical and anaesthesiological staff. Levels of priority were created, together with a rigorous triage procedure for patients with COVID-19, which led to postponement of all elective procedures. Urgent cases were discussed with the local heart team and percutaneous approaches were selected as the first treatment option to reduce hospital stay. COVID-19 and COVID-19-free pathways were created, including adequate preparation of the operating room, management of anaesthesiological procedures, transportation of patients and disinfection. It was determined that patients with chronic diseases were at increased risk of adverse outcomes. Systemic inflammation, cytokine

storm and hypercoagulability associated with COVID-19 increased the risk of heart failure and cardiac death. In this regard, the early use of extracorporeal membrane oxygenation could be life-saving in patients with severe forms of acute respiratory distress syndrome or refractory heart failure. The goal of this paper was to report the Italian experience during the COVID-19 pandemic in the setting of cardiovascular surgery.

**Keywords:** Coronavirus disease 2019 • Cardiac surgery • Extracorporeal membrane oxygenation • Vascular Surgery • Personal protective equipment

## ABBREVIATIONS

|            |   |
|------------|---|
| AGP        | Aerosol-generating procedure                      |
| ARDS       | Acute respiratory distress syndrome               |
| COVID-19   | Coronavirus disease 2019                          |
| DVT        | Deep venous thrombosis                            |
| ECMO       | Extracorporeal membrane oxygenation               |
| HF         | Heart failure                                     |
| ICU        | Intensive care unit                               |
| OR         | Operating room                                    |
| PPE        | Personal protective equipment                     |
| SARS-CoV-2 | Severe acute respiratory syndrome coronavirus 2   |
| VA-ECMO    | Veno-arterial extracorporeal membrane oxygenation |

## INTRODUCTION

Coronavirus disease 2019 (COVID-19) is a new pandemic infectious disease caused by a novel beta-coronavirus known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1]. It was first described in Wuhan, China in December 2019 and spread rapidly to most other countries. This novel single-stranded RNA virus is a zoonotic infection that moved from bats (natural reservoir) to intermediate species and then to humans. It is the third known beta-coronavirus that infects humans, causing severe respiratory illness; the others are the Middle East respiratory syndrome beta-coronavirus and severe acute respiratory syndrome beta-coronavirus [2].

SARS-CoV-2 represents a serious threat to public health because its infection leads to a wide spectrum of clinical manifestations, which include fever, chills, fatigue, myalgia, headache, sore throat, ageusia, anosmia and diarrhoea, up to the development of respiratory symptoms for pneumonia, which may progress to acute respiratory distress syndrome (ARDS), multiorgan failure and death. As of 18 May, more than 4.6 million people have been affected, with 315 000 deaths [3]. Race (Latino, Black and Asian), advanced age, gender (male), socioeconomic deprivation and pre-existing comorbidities such as diabetes, hypertension, renal disease, chronic obstructive pulmonary disease and coronary artery disease are associated with worse clinical outcomes [2]. Among these patients, those with end-stage heart failure (HF) represent the most vulnerable population at risk for COVID-19-related mortality and morbidity. The COVID-19 pandemic has led to the extensive modification of our national and regional health system because of the need to preserve caregivers, save resources and maintain the availability of beds for intensive care units (ICUs) while simultaneously preventing the risk of infection with SARS-CoV-2. The COVID-19 working environment is challenging, and the whole personal protection set-up makes

everything more difficult and discomfoting. The fear on the part of health care workers of becoming infected and of infecting their families has added a high degree of stress, suggesting that psychological support for professionals is necessary to prevent burnout during the pandemic. Our goal was to report how we have been and still are dealing with the COVID-19 outbreak in the setting of cardiovascular surgery.

## METHODS

The authors performed a systematic review by searching the literature in PubMed, Embase and the Cochrane Library from inception to 18 May 2020. In addition, public databases such as those of the World Health Organization and the Centers for Disease Control and Prevention were utilized. The key words were 'COVID-19', 'SARS-CoV2', 'Coronavirus', 'pandemic', 'cardiac surgery' and 'vascular surgery', searched individually or combined.

## Coronavirus disease 2019 pandemic: effects on end-stage heart failure

End-stage HF accounts for 5% of the HF population and includes patients with refractory HF requiring advanced treatment such as mechanical circulatory support, continuous inotropic support or a heart transplant [4]. There is increasing evidence that SARS-CoV-2 affects the heart causing myocardial infarction, myocarditis and HF, especially in patients with underlying cardiovascular disease [5, 6]. Among these, patients with HF are at increased risk of acute events, leading to death. Dong *et al.* [7] described 4 cases of end-stage HF in patients infected with COVID-19 and reported a mortality of 50%. Singh *et al.* [8] reported the first case of COVID-19 in a patient on a left ventricular assist device as destination therapy who developed ARDS and right ventricular dysfunction. This deterioration was related to the patient's 'functional' immunocompromised state, because it is known that long-term ventricular support induces a continuous inflammatory state with allosensitization [9]. Heart-transplant recipients represent the category at highest risk for severe illness. The prognosis of COVID-19 in patients with a heart transplant is unknown, and few data have been reported. Immunosuppression related to a transplant has an inflammatory effect, which alters the clinical presentation. Li *et al.* [10] reported 2 surviving heart-transplant recipients who presented with different diseases: 1 had mild symptoms and the other had more severe disease that required oxygen supplement, cessation of immunosuppression and intravenous immunoglobulin treatment. Interestingly, a survey of 87 heart-transplant recipients did not find a higher risk of infection with SARS-COV-2 [11]. It is unclear whether this damage is related to systemic/local and/or ischaemic/inflammatory

**Table 1:** Mitigation strategies and pharmacological prevention of thrombosis

- Practice social distancing
- Stop elective cases and create hub/spoke cardiothoracic centres
- Support telehealth medicine
- Create levels of priority
- Treat patients as COVID-19 positive (false negative and asymptomatic)
- Perform CT scans in patients with negative test results from nasal swab
- Use PPE (N95, ffp3, ffp3) and provide protocols for donning and doffing
- Complete tests as close as possible to the planned operative date
- Provide dedicated team(s) for COVID-19 OR and ICU
- Limit the number of health care providers in the OR
- Have the most experienced doctors perform anaesthesia and operative procedures
- Minimize the potential exposure of OR staff to AGP
- Stop positive pressure ventilation before disconnecting the patient from the ventilator
- Provide adults with COVID-19 with venous thromboembolism prophylaxis. Anticoagulant or antiplatelet therapy should not be used to prevent arterial thrombosis outside of the usual standard of care for patients without COVID-19. Low-molecular-weight heparin or unfractionated heparin may be preferred in hospitalized patients in the ICU because of their shorter half-lives, ability to be administered intravenously or subcutaneously and fewer drug–drug interactions compared with other oral drugs
- Treat patients with COVID-19 who require extracorporeal membrane oxygenation or renal replacement therapy or who have thrombosis of catheters with antithrombotic therapy
- Perform deep vein ultrasound examination

COVID-19: coronavirus disease 2019; CT: computed tomography; PPE: personal protective equipment; OR: operating room; ICU: intensive care unit; AGP: aerosol-generating procedure.

processes. Different potential pathophysiological mechanisms have been proposed: direct damage through virus invasion of cardiomyocytes, indirect damage due to the immune inflammatory response (vasculitis) and the cytokine storm, which favours a prothrombotic state, and oxidative stress related to severe hypoxia from oxygen supply/demand mismatch [6]. The different outcomes of patients with HF raise the hypothesis of different SARS-COV-2 HF phenotypes, ranging from classical HF due to myocardial injury related to oxygen supply/demand imbalance to severe acute HF related to the cytokine storm and direct myocardial damage [12].

### Infection mitigation strategies in cardiac surgery recovery

Mitigation strategies are required to reduce the risk of exposure of surgical and perioperative staff to aerosol-generating procedures (AGPs) as well as to protect all surgical patients and persons in the hospital environment from exposure to COVID-19 (Table 1). Nevertheless, all individuals should be considered as potentially infected until a negative result from a nasal swab is provided, and they should be treated with precautions similar to those used with patients who are confirmed to have COVID-19. Despite a strict surveillance procedure, patients and health care workers may still be at risk for infection in case of (i) poor compliance with the personal protective equipment (PPE) policy; (ii) asymptomatic patient visitors; (iii) false-negative swab test results (Table 2). It has been recommended that all elective cases be reduced or stopped and that tiered patient triage be

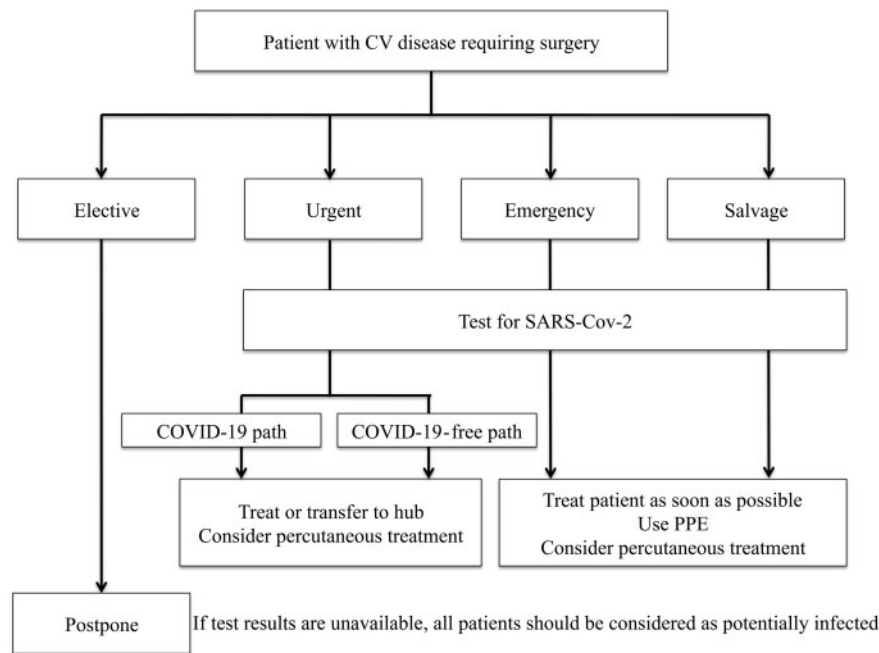
**Table 2:** Donning and doffing procedures

- Donning
    - Practice hand hygiene and do not wear any jewellery
    - Put on inner gloves
    - Put on shoe cover
    - Put on surgical cap covering both ears
    - Put on a protective mask (N95, ffp2, ffp3)
    - Put on gowns
    - Put on goggles and facial shield
    - Put on outer gloves
  - The sequence may be changed according to health provider preferences
    - Doffing
    - Remove outer gloves
    - Put on clean outer gloves
    - Remove facial shield
    - Remove gowns along with remaining outer gloves
    - Remove goggles and mask
    - Remove cap
    - Remove shoe covers
- It is mandatory to put on clean outer gloves and to wash hands with alcohol solutions at each step

implemented [13]. In Italy, the exponential increase of COVID-19 infections and the dramatic need for ICU beds led to a complete reorganization of the health care system: All elective surgical procedures were stopped, and cardiothoracic hubs were created for urgent and emergency operations [14]. According to Haft *et al.* [15], reducing the number of cardiac surgical procedures will result in the preservation of resources such as ventilators, beds, PPE and health care workers with advanced skills to deal with the COVID-19 surge. With the lockdown, outpatient clinics and day services have been suspended, thus reducing assistance for chronic patients.

In some countries, telemedicine programmes have been developed to allow virtual visits instead of in-person care [16]. Physicians have maintained continuous care and services using commonly available technologies (phones, smartphones, laptops and apps) for voice and video calls, chats or videoconferences. Salzano *et al.* [17] reported the utility of telemedicine during the COVID-19 lockdown. Interestingly, patients with HF monitored with telemedicine experienced fewer hospitalizations than those with similar characteristics during the same period in 2019.

The role of the heart team (cardiac surgeon, cardiac anaesthesiologist and cardiologist) is useful in the decision-making process, balancing the risk of delaying the procedure, the risk of exposure to patients infected with SARS-Cov-2 and the utilization of limited hospital resources. We needed to set different priority levels, which were defined according to the EuroSCORE II definition (Fig. 1; Table 3) [18, 19]. All patients should be discussed with the in-hospital heart team to determine the timing for the surgical procedure and to balance the benefits of the surgical procedure with the risk of exposure to SARS-Cov-2. To reduce the length of the hospital stay, all urgent and emergency cases should be evaluated for percutaneous treatment. However, this requirement raises some ethical considerations regarding the balance between long-term efficacy of percutaneous treatment and



**Figure 1:** Flow chart for levels of priority. CV: cardiovascular; COVID-19: coronavirus disease 2019; PPE: personal protective equipment; SARS-Cov-2: severe acute respiratory syndrome coronavirus 2.

the risk of delaying a surgical procedure, which might result in reduced survival after the pandemic [13, 20].

In Lombardy (Italy), the regional system introduced the hub-and-spoke model: They identified 4 primary centres (hubs) out of 20 cardiothoracic departments (spokes), serving more than 10 million people. The following criteria were considered for the choice of the hubs: the presence of at least 3 simultaneously dedicated 24/7 operating rooms (ORs) and the presence of a COVID-19-free postoperative ICU. In addition, a hub should guarantee patient access/hospitalization by providing multiple available medical teams (with at least 1 team on active duty 24/7), activate a 'fast-track' for non-COVID emergency/urgent patients, collaborate with spoke teams in their respective hubs and ensure that patient transport was managed by the forwarding hospital [21]. Once the patient was admitted, a nasal swab was performed as soon as possible. Repeated nasal swabs were performed in the persistence of fever and other symptoms.

A careful description of symptoms and a computed tomography scan of the chest might help to identify potential COVID-19 patients. Because all patients should be considered suspect, health care personnel should wear advanced PPE (N95 masks, eye protection, gown, facial shields and double long gloves) to minimize the risk of COVID-19 infection [22]. Complete testing should be performed as close as possible to the planned operative date (preferably <48 h) while waiting for surgery. Finally, health care providers should be taught a complete workflow process for infection prevention practices and for donning and doffing procedures.

### Effects of coronavirus disease 2019 pandemic on operating rooms and intensive care units

Protecting oneself first is always the top priority before helping patients. Cardiac surgery requires a relatively small dedicated

team of individuals [15]. It is mandatory to have a dedicated COVID-19 OR and ICU, while guaranteeing a COVID-19-free pathway. Nevertheless, because 10–30% of test results are false-negative, the American Society of Anesthesiology recommends that all anaesthesia teams wear PPE during all perioperative surgical procedures [24]. COVID-19 ORs and ICUs should be marked with warning signs and located away from COVID-19-free ORs. Patients should be transferred directly to the OR without stopping in preanaesthesia and postanaesthesia areas. The OR doors must be kept closed and maintain a positive pressure, with negative pressure ventilation in the anteroom. It is mandatory to limit entry and exit of OR personnel and limit the number of circulating staff but guaranteeing a minimum of 1 person for anaesthesia induction and maintenance during surgery. The most experienced doctors should perform all anaesthesia and surgical procedures to avoid complications and minimize the potential exposure of OR staff to AGP [23]. All equipment for intubation and drugs should be ready in the OR before the patient is transferred. Muscle relaxants and high-dose narcotics should be administered before airway manipulation to minimize the risk of coughing and vomiting. Before intubation, preoxygenation with 100% inspired oxygen is recommended to avoid bag-mask ventilation, and video laryngoscopy is advised. Transoesophageal echocardiography is considered an AGP. At the end of the procedure, the patient is transported to the ICU; ventilation is performed with a disposable Ambu bag, paying attention to stopping positive pressure ventilation before disconnecting the ventilator. Finally, the OR should be closed at least for 30 min to achieve 99.9% aerosol clearance (depending on the size of the OR, operative time and air change per h), and the floor and walls should be cleaned with a chlorine-containing disinfection solution [13, 18]. Patients transferred to the ICU should follow the COVID-19 infection prevention measures. In the event of cardiac arrest or other medical emergency, no procedures should be performed unless full PPE is



**Table 3:** Levels of priority in cardiac surgery [26]

- Elective cases (reschedule)
  - Chronic stable angina
  - Chronic valve disease
  - Aortic aneurysm <6 cm
  - Adult congenital defects
  - Procedure for isolated arrhythmia
- Urgent (perform as soon as possible)
  - ACS (LM disease, 3-vessels disease with proximal LAD)
  - Severe CHD with large area at risk or with depressed LVEF not suitable for PCI
  - Acute valvular disease
  - Aortic aneurysm >6 cm or rapid growth in 1 year
  - Active endocarditis
  - Prosthetic valve thrombosis
  - Cardiac tumours
  - Heart failure requiring ventricular assistance device
- Emergency/salvage (do not postpone)
  - Mechanical complications of MI
  - Acute heart failure for valve disorders (endocarditis)
  - Type A aortic dissection
  - Pericardial tamponade
- Salvage (cardiopulmonary resuscitation)
  - Cardiogenic shock requiring VA-ECMO

ACS: acute coronary syndrome; CHD: coronary heart disease; LAD: left anterior descending; LM: left main; LVEF: left ventricular ejection fraction; MI: myocardial infarction; PCI: percutaneous coronary intervention; VA-ECMO: veno-arterial extracorporeal membrane oxygenation.

donned. Furthermore, it is recommended that only 1 provider performs cardiopulmonary resuscitation.

### Vascular surgery in the coronavirus disease 2019 pandemic

Similar to the situation with cardiac surgery, COVID-19 disease has profoundly changed vascular surgery activities, the intention being to preserve resources, staff and availability of beds for patients affected by SARS-Cov2 [24–28]. All involved staff must follow a high-standard infection protection protocol, including wearing an N95 mask, gown, goggles and a face shield [28, 29]. A level of priority (Table 4) was established, and all elective cases have been deferred. All outpatient visits have been cancelled, except for patients with wound-healing issues or those requiring suture removal, and telemedicine has been implemented. A ruptured aneurysm should ideally be treated with an endovascular treatment unless contraindicated. In the case of critical leg ischaemia, percutaneous treatment is the first option. In the case of advanced disease, which requires complex revascularization and multiple debridements, amputation might be more appropriate to avoid a prolonged hospital stay [24]. An international survey conducted of 77 vascular surgeons indicated that 89.6% suspended or scaled down outpatient services; 79.2% suspended or scaled down inpatient services; 90.9% cancelled elective cases; and 92.2% still performed emergency vascular operations [29]. Interestingly, after applying local guidelines for triaging patients, Hemingway *et al.* [30] observed a dramatic reduction in weekly clinical and surgical volume of 96.5% (from 43.1 patients to 1.5 per week) and 71.7% (from 14 patients to 5.25 per week).

**Table 4:** Levels of priority in vascular surgery [26]

- Elective cases (reschedule)
  - Asymptomatic carotid surgery
  - Surgery for claudication (chronic limb ischaemia with rest pain or tissue lost, bypass/stent restenosis)
  - Descending thoracic or abdominal aortic aneurysm <6.5 cm
  - Venous surgery
- Access for haemodialysis
- Urgent (perform as soon as possible)
  - Symptomatic carotids
  - Critical leg ischaemia
  - Descending thoracic or abdominal aortic aneurysm >6.5 cm or rapid growth progression
  - Pseudoaneurysms
  - Amputation for infection necrosis
  - Symptomatic mesenteric ischaemia
  - Infected/thrombosed/not functional access for haemodialysis
- Emergency/salvage (do not postpone)
  - Ruptured aneurysm
  - Complicated type B dissection
  - Severe grade blunt aortic injuries
  - Wet gangrene
  - Acute limb ischaemia and fasciotomy

### Extracorporeal membrane oxygenation for patients with coronavirus disease 2019 and with severe cardiopulmonary failure on a waiting list for a transplant

Veno-venous extracorporeal membrane oxygenation can be a life-saving therapy for selected patients with COVID-19 pneumonia associated with ARDS. In this regard, an early implant of veno-venous extracorporeal membrane oxygenation, thereby avoiding prolonged mechanical ventilation, could be life-saving, whereas veno-arterial ECMO (VA-ECMO) seems to be mandatory in patients with advanced HF on the waiting list for a heart transplant [31, 32]. The World Health Organization clinical guidance for COVID-19 indicated that in regions with access to ECMO expertise, patients with refractory hypoxaemia, despite lung-protective ventilation strategies, should be treated in an ECMO centre [33]. However, ECMO is not often widely distributed in ICUs compared to conventional critical care units, and regional coordination is lacking. Therefore, ECMO availability should be carefully allocated in relation to other modalities for artificial support in accordance with the guidelines of the Extracorporeal Life Support Organization [34]. The role of ECMO and ECMO centres during the COVID-19 pandemic was recently investigated [35]. Moreover, the Society of Critical Care Medicine guidelines for the management of COVID-19 patients recommend the use of ECMO when conventional management fails [36]. Unfortunately, common clinical practice indicated that ECMO for patients with a combination of advanced age, multiple comorbidities or multiorgan failure is difficult to manage. Furthermore, centres that are inexperienced with ECMO should evaluate carefully whether to continue these programmes during resource-limited times. Overall, younger patients with minor or no comorbidities are the highest clinical priority. If resources change, priorities should also shift based on what can be safely done. Standard contraindications are terminal disease, severe damage to the central nervous system or advanced directives refusing ECMO. Patients on mechanical ventilation for more than 7 days should be

excluded; renal failure is not an exclusion criterion. However, not all eligible patients improve with ECMO support, and maintenance with such treatment should be evaluated if no lung or cardiac recovery occurs after 21 days (be returned to conventional management?).

Refractory HF is defined as sustained hypotension despite other treatments. Physiological and echocardiographic parameters may be further altered in patients with COVID-19. VA access is indicated, perhaps in the form of V-VA. In the presence of cardiac dysfunction and signs of circulatory impairment, continuous echocardiographic assessment is required [37]. Again, mechanical circulatory support is the only way to save the life of a heart transplant candidate and to decrease wait-list mortality [37]. Many epigenetic-sensitive mechanisms may predispose patients with advanced HF to progress until they can be added to the waiting list for a transplant [38, 39]. The choice between short- or long-term pretransplant supports depends on the type and severity of HF, which can be associated with pneumothorax in patients with COVID-19 [40]. VA-ECMO support is frequently provided before an orthotopic heart transplant. Peripheral VA-ECMO is a useful tool for the treatment of patients with INTERMACS profile 1/2. An orthotopic heart transplant for recipients bridged with VA-ECMO is less successful than for recipients without pretransplant mechanical support [41]. VA-ECMO is considered as a direct bridge to an orthotopic heart transplant when the availability of donor hearts is limited. Indeed, during the COVID-19 pandemic, the availability of hearts for an orthotopic transplant was extremely limited [37].

### Prevention of both arterial and deep venous thrombosis during the coronavirus disease 2019 pandemic

Advanced stages of COVID-19 may induce intravascular pulmonary thrombosis and systemic inflammation with elevation of both D-dimer and fibrinogen levels [42]. Specifically, increased levels of D-dimer at hospital admission correlate with more severe disease (0.5 mg/l) or occurrence of death (1 mg/l) [43]. The prothrombotic action of SARS-CoV-2 is supported by the topographical involvement of specific lung regions with a preference for the lower lobe (bilaterally) with peripheral involvement [44]. This situation supported the benefit of using low-molecular-weight heparin and the need to identify drugs that would reduce the inflammatory cytokine storm to protect the vascular wall [45]. In a retrospective study of 449 patients with severe COVID-19, the 28-day mortality of heparin users was lower than that of non-users in patients with D-dimer levels more than 6-fold the upper limit of normal [46]. Heparin has been implicated in binding to COVID-19 spike proteins and in down-regulating interleukin-6, the level of which is elevated in patients with COVID-19. Thus, unfractionated heparin or low-molecular-weight heparin remains the best choice of anticoagulant for patients admitted to the hospital [47] (Table 1). Some adjustments of the coagulation agent need to be performed during ECMO [48].

Tissue factor is exposed to damaged alveolar endothelial cells and on the surface of leukocytes promoting fibrin deposition, whereas significantly elevated levels of plasminogen activator inhibitor 1 from both lung epithelium and endothelial cells induce a hypofibrinolytic state [49]. To date, treatment with low-molecular-weight heparin is needed to limit coagulopathy. However, to degrade pre-existing fibrin in the lung, it is crucial to

induce local fibrinolysis. Tissue-type plasminogen activator is an approved intravenous thrombolytic treatment, and the nebulizer form is currently in a phase II clinical trial [50]. Plasminogen activators may degrade fibrin, thus improving oxygenation in critically ill patients with COVID-19. This process was recently proposed as a powerful function of neutrophils. In addition, the ability to form neutrophil extracellular traps may contribute to organ damage in patients with COVID-19 [51]. Neutrophil infiltration of the lungs and aberrant neutrophil extracellular trap formation could promote thrombosis, mucous secretions in the airways and cytokine production. Thus, drugs targeting neutrophil extracellular traps directly or indirectly could reduce these clinical events. Moreover, deep venous thrombosis (DVT) occurs in the upper limbs in patients with COVID-19, requiring continuous positive airway pressure [52, 53]. A relationship was found between DVT and ARDS in influenza A H1N1, in which there is enhanced leucocyte adhesion to the vein walls due to the production of proinflammatory molecules [54]. Such a proinflammatory condition may be influenced by genetic as well as epigenetic factors [55]. Overwhelming the production of D-dimer and tissue factor can contribute to DVT, as seen in other types of pneumonia, although no causal relationship with DVT has been established [56]. From an iatrogenic point of view, the use of a continuous positive airway pressure ventilator may compress the superficial or deep vessels of the upper limbs, thus damaging the microcirculation. In fact, in the clinical setting of cardiac surgery, during retardation of elective by-pass aortocoronary surgery, there is also an increased risk of failed fibrinolytic therapy and stent thrombosis in patients with ST-segment elevation myocardial infarction [57]. These events may induce ethical concerns about reducing the number of elective surgical procedures in high-risk patients during the COVID-19 pandemic [58, 59].

### Unique reflection on the Italian experience

The pandemic has thoroughly modified our Italian lifestyle and health care system, especially in the northern part of the country, but also in central and southern Italy. Most hospitals have become COVID-19 centres, and surgeons and doctors, regardless of specialty, have started to take care of patients with COVID-19 [60]. The availability of hospital beds has become saturated, and ICUs have collapsed because of the number of patients with severe pulmonary disease. In the presence of limited resources, the Italian Society of Intensive Care reported clinical ethical recommendations for the allocation of intensive care treatment, based on the principle of distributive justice [14]. Age, comorbidities and functional status of any critically ill patient should carefully be evaluated, favouring those with a higher chance of survival and those with a greater life expectancy. In this regard, ECMO is considered one of the most resource-consuming treatments and is therefore reserved only for selected patients. The visiting policy was revised for both COVID-19 and non-COVID-19 patients. No visits to patients were allowed, even in case of death. Communication with families was allowed only through social networks and video calls, using tablets.

The COVID-19 pandemic will leave a permanent mark on health care workers, because they are exposed to an unprecedented level of physical and psychological stress on a daily basis. The fear of being infected and of infecting others, isolation from family and friends for long periods, changes in daily work practices and procedures and physical strain from wearing PPE are

surely promoting stress and anxiety. To reduce this risk, the Istituto Superiore di Sanità recommends providing psychological support to protect the physical and mental health of health care workers [61].

## CONCLUSIONS

The COVID-19 pandemic has deeply challenged our lifestyle and our doctors' tasks. The pandemic forced us to reorganize our national, regional and local health systems to preserve care givers, resources and beds. Elective surgery was stopped, allowing only urgent or emergency cases. Mitigation strategies, guidelines and workflows provide the basis of success for dealing with the COVID-19 outbreak. Patients who survive COVID-19 infection will require careful monitoring, because the long-term effects of this disease on the lungs (fibrosis after pneumonia), heart and brain are still unknown. A 'tsunami' of rehabilitation needs is expected in Italy because many patients, after long stays in the ICU and the hospital, have to deal with muscle wastage, sleep disorders, depression and post-traumatic stress disorder. Lack of appropriate treatments is related not only to the occurrence of COVID-19 itself, but also to social constraints, transportation restrictions, difficulties in accessing drugs and supplies and psycho-social stress. We are now living and working with the COVID-19 pandemic, but it is also time to develop a roadmap with several possible routes for resuming our normal activities and lives, especially in the setting of cardiovascular surgery. Sharing of scientific data and political cooperation among nations will help us find the right way out of this pandemic.

**Conflict of interest:** none declared.

## Author contributions

**Francesco Donatelli:** Conceptualization; Methodology; Validation; Writing—review & editing. **Antonio Miceli:** Conceptualization; Validation; Visualization; Writing—original draft. **Mattia Glauber:** Conceptualization; Validation; Writing—review & editing. **Silvia Cirri:** Conceptualization; Methodology; Supervision; Writing—review & editing. **Ciro Maiello:** Conceptualization; Validation; Writing—original draft. **Enrico Coscioni:** Conceptualization; Validation; Writing—original draft. **Claudio Napoli:** Conceptualization; Methodology; Supervision; Validation; Writing—original draft; Writing—review & editing.

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