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Review article

Impact of COVID-19 on aortic operations

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ABSTRACT

The coronavirus disease 2019 (COVID-19) outbreak has profoundly affected all aspects of medicine and surgery. Vascular surgery practice and interventions were also forced to change in order to deal with new COVID-19–related priorities and emergencies. In this setting, difficulties in aortic disease management were two-fold: new vascular complications related to COVID-19 infection and the need to guarantee prompt and correct treatment for the general "non-COVID-19" population. Furthermore, discomfort deriving from precautions to minimize the risk of virus transmission among patients and among health care professionals, the need to separate COVID-19–positive from COVID-19–negative patients, and the high incidence of postoperative complications in COVID-19 cases created a challenging scenario for cardiac operations. The aim of this review was to provide evidence derived from the published literature (case reports, case series, multicenter experience, and expert opinion) on the impact of the COVID-19 outbreak on aortic vascular surgery services and interventions, describing COVID-19–related findings, intraoperative and postoperative outcomes, as well as the impact of the COVID-19 outbreak on noninfectious aortic patients.

1. Introduction

The coronavirus disease 2019 (COVID-19) outbreak is responsible for 114,315,846 confirmed cases, including 2,539,427 deaths worldwide, as reported in the World Health Organization Bulletin on March 3, 2021 [1]. Its catastrophic consequences on health has impacted all aspects of medical practice—from the availability of, and accessibility to, health services, to patients' disease management, to outpatients' cures, to the ease of invasive treatments, among others. Regarding vascular surgery services and procedures, all types of surgical or endovascular interventions are in a mutable

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state, dictated by COVID-19–related priorities [2–5]. Patients with COVID-19, both young and old, experience vascular complications, such as arterial and venous thromboembolic disease, which are increased by infectious and multiorgan failure status [6]. Furthermore, paradoxically, several negative aspects also arise for COVID-19–negative vascular patients. This population is subjected to an impairment of cures and examinations caused by filling of hospitals and, in particular, operating rooms. This leads to more serious vascular complications at first presentation [7].

In this scenario, management and treatment of aortic diseases maintain a role of primary importance because of the severity and complexity of these complications. In fact, although in the majority of cases surgical activities were minimized—particularly elective or nonurgent treatments—aortic services must remain open and offer 24/7 emergency availability.

The aim of this review was to describe and quantify the impact of the COVID-19 outbreak on aortic interventions, analyzing clinical and instrumental aortic findings in COVID-19–positive patients, types of interventions, impacts on vascular aortic services, practical recommendations, and evidence from the published literature.

2. Methods

For the purpose of this review, the Scale for the Assessment of Narrative Review Articles, a six-item scale developed for the quality assessment of narrative review articles was also adopted as an optimal presentation of selected studies [8,9]. Although the Scale for the Assessment of Narrative Review Articles is usually used during the peer-review process, we tried to obtain the maximum score possible (12 points) in order to improve the quality of the article. Furthermore, recommendations from Green et al [10] were adopted. Therefore, results are presented in a narrative form.

2.1. *Search strategy*

The research was conducted using PubMed, Scopus and Web of Science databases between January 31, 2020 and January 31, 2021, among articles in the English language. The National Center for Biotechnology Information's SARS-CoV-2 Resources database was also interrogated to find other relevant articles and trials. There were no limitations on study type applied to the search. Keywords were selected using Medical Subject Headings for PubMed and Medical Subject Headings/EMTREE for Scopus. The Boolean operators "AND" and "OR" were used to connect terms with each other. Keywords such as *COVID-19*, *coronavirus*, and *SARS-CoV-2* were combined with *aorta*, *aortic disease*, *acute aortic syndrome*, *aortic dissection*, and *aortic thrombosis*, and *aortic aneurysm* to obtain the first publication cluster. The peer-reviewed journals *Annals of Vascular Surgery, European Journal of Endovascular and Vascular Surgery, Journal of Vascular Surgery, The Journal of Thoracic and Cardiovascular Surgery, European Journal of Cardio-Thoracic Surgery*, *Seminars in Vascular Surgery* and *Circulation* were interrogated on February 15, 2021 in order to find articles published "ahead of print" and not yet indexed.

All titles and abstracts of potentially useful articles were selected. Two researchers (D.B. and M.F.) screened titles, abstracts, and full text independently. In case of discrepancies in article or data extraction, a third researcher (S.T.) was consulted to give the final judgment. Data from all included studies were then independently extracted. References of all identified relevant studies were used to perform a recursive search of the literature. The only inclusion criterion was the adherence to the topic "aorta and COVID-19 outbreak."

3. Results

Although the results and outcomes of the literature search were very heterogeneous and potentially limited, the following three central themes of patient management during COVID-19 outbreak period were apparent: patients' presentation, perioperative management, and COVID-19 effects on aortic pathology.

3.1. *In-hospital admission and consequences of COVID-19 outbreak*

In most of the countries involved in the COVID-19 pandemic, an extensive rearrangement of health care services was performed [11]. First, in most cases, all screening and surveillance programs were suspended or reduced. This means that in a densely populated area like South London, there are 271 on 667 patients with medium-sized abdominal aneurysms that had postponed their evaluation since the beginning of the COVID-19 pandemic [12].

Second, the surgical treatment of aortic disease has been restricted by the global COVID-19 outbreak both for health care–side and patient-side reasons. In fact, the analysis of reports from centers all over the world demonstrated a general trend centered on reducing elective procedures [13]. Notably, many national societies recommended limiting procedures to emergencies only. Among others, it is worth mentioning the indications given by the UK Aortic Surgery group and the Society of Cardiothoracic Surgery for Great Britain and Ireland [14], which divided patients into the following three groups based on emergency level:

- Level 1: Asymptomatic patients with indication to elective surgery;
- Level 2: Urgent status in patients with large aneurysm (>6 cm for root, ascending, and arch, or >5.5 cm with genetic aortic disease; >6.5 cm for descending thoracic aorta, >7 cm for abdominal aorta), with aneurysm and persistent chest/back pain, pseudoaneurysms, mycotic aneurysms, and aortic graft infections; and
- Level 3: Emergency status in acute aortic syndromes and ruptured aortic aneurysms.

More restrictively, the French Vascular Surgical Society based its policy on the 3Ss (save Staff, Space, and Stuff) principle, limiting surgical activity to acute aortic syndromes only, with endovascular techniques favored over open repair [15]. These choices were made mainly to relocate resources and maximize the response to the COVID-19 outbreak [16].

An alternative approach was proposed by, among others, the Lombardy Region in Italy [17–20]. In fact, with the aim of increasing the number of hospital and intensive care unit beds, Regional Authorities identified "hub" hospitals with highly specialized medical activities. These centers were designated as destinations for patients with acute diseases whose treatment could not be postponed. For that reason, during the COVID-19 outbreak, indication for hospital admission and surgery were restricted to symptomatic, urgent, or emergent disease only. The primary disadvantage of the hub/spoke system is the need for a widespread organization for diagnosis and patient transport. In addition, the severity of the clinical onset can affect the patient's portability. However, these disadvantages are balanced by better results offered to critical patients by a third-level surgical center. Mascia et al [21] reported a Lombard hub, single-center experience in March 2020. Notably, the authors observed a significant reduction in the number of ruptured and symptomatic aortic aneurysms. These results are in line with those of most Authors, who reported a substantial and precipitous drop in in the monthly surgical case emergency volumes [22]. El-Hamamsy et al [23] declared a 76.5% reduction (12.8 ± 4.6 cases/month before COVID-19 to 3.0 ± 1.0 cases/month after COVID-19; $P = .007$) in hospitalizations for type A dissection in New York during March and April 2020. Although the authors were unable to provide an explanation supported by robust data, they advanced several hypotheses, including patient fear of contracting COVID-19 at the emergency department (ED), overstretched first responders causing undue delays, or overburdened EDs causing delayed or missed diagnoses. As a consequence, the authors hypothesized that the increase in at-home deaths observed during the same period could be related to this trend. Mascia et al agree with this observation. On the contrary, Khot et al [24] reviewed data from New York City and Bergamo (Lombardy) and disagree with this hypothesis. As shrewdly observed by Mori et al [25], the few patients who presented at EDs were the sickest and had the worst presentation. More interestingly, Selway et al [12] reported how 42.5% of patients affected by aortic aneurysm and interviewed by telephone in South London were more afraid of death from COVID-19 than from ruptured aneurysm.

Idhrees et al [13] have tried to answer the question that every surgeon is asking, that is, "what are the consequences of temporary elective procedures being shut down during the COVID-19 era?" First, patients will be exposed to an increased risk of death pending surgery. Second, as soon as order is restored, hospitals will be crowded with the backlog patients. However, biased data continue to present a problem in evaluating the situation and defining reliable endorsements.

3.2. *Perioperative period and decision-making*

Some authors stressed the evidence that there are asymptomatic patients (or with mild symptoms) who are infected with COVID-19 that will not be detected by the current screening process [26]. In addition, surgeons must be mindful of the COVID-19 test processing time, which can vary significantly among institutions [27,28]. Accordingly, it is mandatory to protect the patients, workers, and public from the risk of infection. This is even more crucial in an urgent/emergency setting, where authors suggested treating all patients as potentially positive [28]. After the analysis on the habits of 23 surgeons from 18 countries, all of the participants agreed to use maximum personal protection equipment for every patient without regard to the patient's COVID-19 status [13]. McGuinness et al [29] showed that health care providers older than 50 years have ≥0.5% chance of mortality if they contract COVID-19. It is noteworthy how this mortality rate is greater than the survival benefit in a 3-month time horizon for aneurysms.

Considering the high mortality associated with nonoperative management, time-related mortality associated with acute aortic syndrome, given the lack of existing data regarding outcomes of patients with concurrent COVID-19 infection, the decision to delay treatment waiting for COVID-19 diagnoses is questionable [27,30]. In fact, the feasibility of aortic surgery with proven COVID-19 disease has been demonstrated [31]. The postoperative course is often unpredictable and burdened with pulmonary complications. Overall, the literature reported 24% perioperative mortality among cases that took place during the pandemic [32]. Preliminary results from a UK registry showed that 74.1% of patients surgically treated in emergency did not have any COVID-19 test preoperatively [11].

Fukuhara et al [27] reported a case report on a patient with type A aortic dissection complicated by acute respiratory distress syndrome in a patient initially not suspected for but later diagnosed with COVID-19. This brief report emphasized several aspects, considerations, and suggestions of emergent cardiac operation during the current COVID-19 [27]. For these complicated acute patients, the authors suggested a nonoperative management only in those with severe comorbidities, advanced age, malperfusion syndrome, and daily heavy smoking. In fact, in the case of a positive COVID-19 swab, mortality rate would be close to 100%. Lopez-Marco et al [11], reporting the experience of a multicentric survey in 19 centers in the United Kingdom over 81 days, noted 60% mortality in patients who presented at the ED for acute type A dissection and not treated surgically.

The attitude toward elective treatment of aortic pathologies is completely different. According to American College of Surgeons and Society of Vascular Surgery recommendations, during the COVID-19 outbreak, the treatment of abdominal aortic aneurysm repair should always be postponed if <6.5 cm in size and whenever possible if >6.5 cm [33,34]. Nevertheless, an approach centered on aneurysm dimension alone was criticized by some authors. In fact, it took into account neither regional prevalence of COVID-19 nor patients' symptoms and characteristics. Considering the elective nature of surgery, the literature provides confusing data regarding the hospitalization of those patients more vulnerable in case of infection. A cautious approach is reasonable in consideration of the risk of in-hospital infection, particularly in patients without sign and/or symptoms of urgent or mandatory aneurysm treatment. Otherwise, delaying elective surgery in young patients would be associated with an increased risk of aneurysm rupture not justified by the risk of death for COVID. However, regional incidence of COVID-19 and health care system status may modify these recommendations. According to McGuinness et al [29], a 60-year-old patient has a risk of death associated with COVID-19 of about 0.6%. On the contrary, the same patient with a relatively small (5.5 to 5.9 cm)

aneurysm would be exposed to a higher time-related risk of death (0.8% at 3 months and 1.9% at 6 months). Nonetheless, if operative risk increases (open surgery instead of endovascular repair), there is less risk associated with postponing repair. Finally, as resources become more limited, their model admits that a greater risk to patient survival may be tolerated.

A recent large-scale publication by COVIDSurg Collaborative and GlobalSurg Collaborative group, including 140,231 surgery patients, found that risks of postoperative morbidity and mortality are greatest if patients are operated within 6 weeks of diagnosis of COVID-19 infection, and recommended surgery be delayed for at least 7 weeks after COVID-19 infection [35]. The study included patients undergoing elective or emergency surgery for any indication (benign, trauma, obstetrics, and cancer). Although an ad-hoc analysis on vascular patients is not provided, this study is the largest and with the best evidence proposed to date, so it can also be adopted in case of vascular nonurgent patients with previous COVID-19 infection.

3.3. *Treatment quality: endovascular procedures versus traditional open surgery*

Inspired more by common sense than by scientific data, some authors advise reductions of all additional nonessential procedures with the purpose of preserving lifesaving health care resources. In fact, the more complex the procedure, the longer the hospital stay. It is worth noting that this would have a major impact on the risk of intrahospital infection [29]. Along the same lines, the COVID-19 outbreak limited intensive care accessibility to patients undergoing major surgery. This problem, in association with lack of anesthesiologists and hospital beds, has limited the chance for elective surgery in cases of chronic aortic disease. In a survey of 23 centers from 18 countries, 91.7% of participants admitted having stopped their surgical activities on elective patients during the outbreak [11].

In this scenario, some authors stressed the primacy of endovascular technique over traditional open surgery in terms of shortened procedure time, reduced need for intensive care, reduced impact on the respiratory system in patients already compromised, and shortened overall in-hospital stay [36–38]. These benefits would be even more pronounced in cases of ruptured aortic aneurysms, as endorsed by international guidelines [39]. By extension, some authors argued that the advantages would be even more significant for patients with concomitant COVID-19 pneumonia [36].

With reference to patients undergoing thoracic surgery, it is noteworthy how authors agree with endovascular intervention as the first-line choice whenever feasible. This is even more relevant for patients with COVID-19 if traditional surgical alternatives were to include cardiopulmonary bypass. In fact, they advise of the possible amplification of pulmonary inflammation [27].

Although the data are few and literature mainly anecdotal, a two-fold consideration must be done. First, some authors preferred endovascular techniques for the treatment of pathologies compared to before the COVID-19 outbreak, when they mostly adopted traditional open surgery [40,41]. Second, advanced endovascular techniques were preferred over open surgery in the case of extensive aortic repair involving the origin of mesenteric or renal arteries in an emergency (eg, fenestrated, branched endografts, or parallel grafting) [42]. These approaches have evoked some criticism. In fact, other authors suggested reconsideration of an “at all costs” use of endovascular techniques at this juncture [43].

3.4. *Relationship between COVID-19 and aortic disease*

Although there is evidence that COVID-19 could be considered a systemic inflammatory disease resulting in multiorgan failure, strong data have not yet been collected on aortic pathologies as possible expressions of this infection. In the same way, any worsening of previous pathologies already known and in follow-up have not been demonstrated. Even considering the thromboembolic complications associated with this pathology [44–46], almost nothing has been described in the literature on aortic disease.

Despite this, a possible relationship between COVID-19 infection and aortic disease has been suggested by several authors, based on the following considerations: association of COVID-19 infection and the downregulation of the angiotensin-converting enzyme 2 and activation of the renin–angiotensin–aldosterone system, with a consequent hypertensive status [47,48] and responsibility of activated macrophages in collagenase production and consequent vessel wall damage [49,50]. This process had been proposed elsewhere to explain the increased frequency of acute coronary syndrome seen in patients with COVID-19 [51]. Moreover, other authors presented suggestive experiences of vascular damage concomitant to COVID-19. For example, Akgul et al [52,53] reported a case of surgical treatment of aortic type A dissection in a patient affected by COVID-19. In the article, the authors reported only a macroscopic description of the aortic wall that they refer to as an aortitis: aortic wall thickness and rigidity, suture line bleeding. However, with our current knowledge, there is no clear evidence of COVID-19’s direct role in aortic wall damage. Yammine et al [54] presented a case of inflammatory abdominal aortic aneurysm concomitant to COVID-19 infection, without, however, support of the result by any ultrastructural or molecular investigation. Giacomelli et al [45] reported a case of acute thrombosis of an aortic prosthetic graft in a patient with severe COVID-19–related pneumonia. It should be noted that, in this case, the correlation between thrombosis and the COVID-19 infection was made by excluding technical defects at the anastomosis site or significant peripheral outflow obstructions. Unfortunately, evidence on this topic in the literature is mostly anecdotal, and surprisingly no microscopic or biochemical research has been performed.

4. Conclusions

Unless a larger cohort on aortic operations will be able to clarify a correlation between aortic disease and a potential COVID-19–correlated underlying aortitis process, surgical practice will not change to organize different treatment patterns. Therefore, especially in urgent scenarios, emergency surgery remains crucial regardless of the pandemic. With adequate preparation and the provision of appropriate

equipment, satisfactory outcomes can be achieved for such patients while best protecting the operators from contamination. Currently, aortic operations should be carried out straightforward, especially in urgent settings, by accepting the same constraints posed by any patient with COVID-19. Reasonably, cardiovascular specialists should pursue the minimally invasive approach as possible, therefore favoring an endovascular approach whenever possible in order to limit the sequelae determined by the possible underlying COVID-19–related pneumonia. Both international and regional registries and collaboration among cardiovascular societies will be the most effective and prompt way to pile up large amount of intraoperative and postoperative outcomes data to provide guidelines and general precautions to be adopted regarding aortic disease during the pandemic period, in cases of both COVID-19–positive and COVID-19–negative patients.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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