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Elective cardiac surgery during the COVID-19 pandemic: Proceed or postpone?

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During this coronavirus disease 2019 (COVID-19) pandemic, there is an international call to postpone all elective surgeries. Cardiac surgery carries a combined risk for cardiac patients, who are at risk for higher complications of COVID-19, and healthcare workers. In response to the COVID-19 pandemic, the American College of Surgeons and the American Society of Anesthesiologists recommended a sustained reduction in the rate of new COVID-19 cases for 14 days before the resumption of the elective surgery, but postponing surgery may impact patients' daily activities and increase the risk the of deterioration of their cardiac condition. We will discuss the risks and benefits of the decision whether to postpone or proceed with elective cardiac surgical procedures during the escalating COVID-19 pandemic considering the specific

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risk of the cardiac patients, the unique characteristics of the surgery, and the international health system capacity.

Introduction

The pandemic spread curve of coronavirus disease 2019 (COVID-19) follows an exponential trend [1]. Mitigation efforts to flatten the curve of the outbreak are critical in order to buy time, so that healthcare systems are not overwhelmed. Therefore, there is an international call to postpone all elective surgeries. Also, healthcare providers and anesthesiologists, in particular, are at high risk of contracting the COVID-19 infection, especially during aerosol-generating procedures such as endotracheal intubation [2]. However, cardiac patients who are scheduled for elective cardiac surgery are considered a special group of patients due to the impact of the disease on their daily activities and the risk of deterioration of their cardiac condition. In this manuscript, we discuss the risks and benefits of the decision to postpone or proceed with elective cardiac surgical procedures during the escalating COVID-19 pandemic considering the specific risk of the cardiac patients, the unique characteristics of the surgery, and the international health system capacity.

Pathophysiology

Since the emergence of the COVID-19 in China, it has rapidly spread, becoming a public health emergency of international concern [3]. The novel virus is more transmissible than the coronavirus that caused severe acute respiratory syndrome (SARS) and has infected more than ten times the number of SARS patients [4]. The doorway through which the coronaviruses infect human tissues is via the attachment of virus spike proteins (which give it a crown-like appearance) and angiotensin-converting enzyme 2 (ACE2) [5]. The binding of the novel coronavirus to this receptor is ten times stronger than that of other SARS viruses. Moreover, the genomic analysis of the novel coronavirus has revealed that the attachment being facilitated by a host-cell enzyme called Furin [6]. Furin, the activation site, is found in different human tissues, including the lungs, heart, liver, and small intestines, which explains the multi-organ failure associated with COVID-19 [7].

Transmission of the virus

Human-to-human transmission has been established, and the reproductive number (R_0; the number of secondary cases expected in a completely susceptible population) was estimated to be around 2.2 (95% CI, 1.4–3.9), which indicates high transmissibility [8]. The transmission from patients of mild disease can occur, but no evidence negates the possibility of transmission during the incubation period [9]. Therefore, it is imperative to understand that COVID-19 infection is highly contagious, and it is not unexpected that cardiac anesthesiologists will encounter patients scheduled for cardiac surgery who are either silent carriers or actual COVID-19 patients. A clear understanding of the impact of this disease and its interaction with cardiac surgery will help the cardiac surgeon and anesthesiologist take the proper decision whether to proceed with or postpone elective cardiac surgeries during the current COVID-19 pandemic.

COVID-19 infection in cardiac patients

A retrospective cohort study of 201 patients with confirmed COVID-19 showed that 31.2% had hypertension, 10.1% had diabetes mellitus (both are common comorbidities in cardiac patients), and 14.5% had cardiovascular diseases (CVD) [10]. Moreover, patients with underlying CVD have an aggravated course of pneumonia, which necessitates admission to the intensive care unit (ICU) and increases the mortality [11]. Zheng et al. attributed the cause to increased ACE2 expression from the use

of renin–angiotensin–aldosterone system inhibitors, which are a mainstay of treatment of the cardiac patients [12].

However, no guidelines recommend discontinuation of these drugs in cardiac patients who are at risk for or diagnosed with COVID-19 infection until further clinical trials confirm the effects of these drugs in COVID-19 infection [13]. Zheng et al. concluded that the patients of COVID-19 with underlying CVD have an adverse prognosis due to acute myocardial injury and chronic damage to the cardiovascular system. Indeed, this should make the healthcare workers thoroughly adherent to all principles of infection prevention and control to save these futile patients.

Hospital length of stay and nosocomial transmission

The hospital length of stay (LOS) for 53% of 496,797 isolated coronary artery bypass graft (CABG) procedures was 5 days, according to a study by Peterson et al. [14]. Wang et al. suspected the nosocomial transmission at 41% of the patients with COVID-19 Zhongnan Hospital of Wuhan University in Wuhan, China [10].

A case of nosocomial transmission of Middle East respiratory syndrome coronavirus from one patient to another was reported in hospital in northern France in 2013 [15]. Another issue to be considered is the silent carriers who do not present with clinical symptoms, but they are contagious to others [16].

In light of the abovementioned, cardiac patients are at higher risk of developing COVID-19 in the perioperative course especially if being hospitalized at the uncontrolled communicable period. However, escalating the infection control measures has been proved to prevent nosocomial transmission of COVID-19 [17]. Moreover, it would seem that being hospitalized in a segregated non-COVID unit (which most hospitals have done), with healthcare providers who are constantly self-monitored for symptoms and are instructed to use personal protective equipment (PPE) and hand hygiene for every patient contact, would be far safer than being in the community with high numbers of asymptomatic carriers and transmission.

Preoperative screening

A retrospective cohort study of 34 patients who underwent elective surgeries during the incubation period of COVID-19 showed a higher risk for ICU admission (44.1%) and mortality (20.5%) [18]. Another international cohort study revealed that perioperative COVID-19 (7 days before and 30 days after surgery) is associated with high mortality [19].

Therefore, preoperative screening should help to diagnose the asymptomatic carrier and the COVID-19 patients. However, the diagnosis of COVID-19 is quite challenging due to the inconsistent correlation between laboratory findings, radiological imaging, and the clinical picture and contact history of the patient [20]. Reverse transcriptase polymerase chain reaction and serological methods (enzyme-linked immunoassay) are widely used to diagnose the COVID-19 [21]. However, the window period, false sampling, cross-contamination of samples, and the inconsistence of sample collections and preparations are considerable limitations, which could lead to false-negative results. Moreover, mass screening of suspected cardiac patients and healthcare providers is an economic burden in developing countries. Therefore, that may cause the admission of cardiac patients who may develop COVID-19 in the perioperative period, which endangers both the patients and the healthcare providers.

Perioperative anxiety

A prospective and consecutive study involving 200 patients scheduled for cardiac surgery, showed that 28% of cardiac patients scheduled for cardiac surgery, especially CABG surgery, developed high preoperative anxiety [22]. Moreover, the COVID-19 pandemic triggered a wide range of public psychiatric problems, such as panic disorder, anxiety, and depression [23]. Both depression and anxiety are independent risks for mortality and morbidity (especially delirium) after CABG surgery [24].

Another perspective is the relation between anxiety disorders and immune system dysregulation, which has been proven since the term psychoneuroimmunology emerged in the 1970s [25]. Many

studies that have been summarized in a review article by Coughlin indicated an important link between anxiety disorders and vulnerability to viral infections in patients with known psychiatric diagnoses of anxiety [26]. Therefore, we should understand this added risk to make clinical decisions about postponing or proceeding with cardiac surgery.

Effect of cardiopulmonary bypass

Cardiac surgery involves a unique concern in contrast to other elective surgeries, which is the use of cardiopulmonary bypass (CPB). The exposure of blood to the non-endothelial surfaces during CPB triggers an inflammatory response by activation of coagulation pathways, complement system, and increasing the level of tumor necrosis factor α (TNF-α) and interleukin 10 (IL-10) [27].

The leading cause of mortality in COVID-19 patients is acute respiratory distress syndrome (ARDS) [28]. Growing evidence attributed the cause of ARDS in COVID-19 to cytokine storm syndrome, especially that high levels of proinflammatory cytokines (TNF-α and IL-10) were measured in patients with COVID-19 and this has also been correlated with the severity of the disease [29]. Therefore, it is clear that CBP in on-pump cardiac surgery has a deleterious effect in those high-risk patients for COVID-19 infection, especially if they are silent carriers. Alternative approaches to cardiac surgeries precluding the use of CPB, such as off-pump and catheter-based procedures, might be suitable in this patient's population. Moreover, the use of cytokine filter and cell-saver with processing the blood through minimal invasive extracorporeal circulation significantly decreases the inflammatory response [30].

In addition, the occurrence of pulmonary dysfunction after CPB is not uncommon. It can range from a temporary and clinically insignificant reduction in arterial oxygenation to a life-threatening injury manifested as ARDS [31]. The clinical presentation of COVID-19 has involved fever in 83%–98% of patients, dry cough in 76%–82%, and chest radiographs characterized by bilateral patchy infiltrates [32]. This may be confused with the pulmonary complications following CPB in cardiac surgery. A retrospective analysis of 34 patients scheduled for elective surgeries during the incubation period showed that all of them developed pneumonia after surgery, with a mortality rate of 20.5% [18]. This warrants attention to expand the preoperative testing and postoperative follow-up.

Impact of postponing cardiac surgery

A PubMed search of original, observational studies reporting complications while awaiting CABG or percutaneous coronary intervention (PCI) revealed that mortality, non-fatal myocardial infarction, and urgent revascularization are higher in patients with severe angina and left ventricular dysfunction [33]. Among cardiac deaths in patients with severe aortic stenosis, sudden death is the second cardiac cause of death [34]. This should clarify the clinical implications of the actual delay of these procedures. Moreover, this can guide the triage of patients by identifying the risk factors (impaired left ventricular function) and making the priority for fragile patients. The type of surgery should also be considered to determine the level of priority for the planned cardiac interventions. A prospective cohort analysis of death rates while waiting for cardiac surgery revealed that patients waiting for valve surgery have a higher risk of mortality than patients waiting for isolated CABG [35].

Health capacity

As the number of COVID-19 patients grows, the shortage of ventilators and PPE for medical staff is reported [36]. Considering this internationally limited ICU beds, ventilators, and shortage of healthcare providers, the relatively long postoperative period of cardiac surgery consumes the healthcare capacity. Even high-performing health systems might not be resilient against this unprecedented challenge [37].

Here, fast-track cardiac recovery for both coronary and valvular surgery might provide a safe, efficient, and cost-beneficial alternative [38]. Implementation of the enhanced recovery protocols after cardiac surgery (ERAS) has been proven to achieve early recovery and decrease the LOS in the ICU [39]. A retrospective study showed that robotic CABG surgery was associated with a decrease in the operative time and hospital LOS [40]. Regarding valvular surgery, a retrospective analysis of 227 minimally

invasive mitral valve replacement surgeries showed shorter hospital LOS [41]. A systematic review and meta-analysis of randomized trials revealed that transcatheter aortic valve replacement (TAVR) is associated with comparable clinical outcomes to surgical aortic valve replacement (SAVR) but with a reduced hospital LOS [42]. Moreover, TAVR is no longer confined to patients with a high risk of death. TAVR has been established as a treatment for low-risk patients with reduced risk of mortality, adverse events, and rehospitalization at 1 year in comparison with SAVR [43]. Indeed, reduction of the hospital LOS in minimally invasive cardiac surgeries will preserve the supply of ventilators and hospital beds. This will free the healthcare system and increase the capacity to cope with the anticipated increase of COVID-19 patients. However, the additional cost and the need for well-trained surgeons and cardiac anesthesiologists to perform such minimally invasive procedures might make these options unattainable in some developing countries. Therefore, it could be preserved for patients with preoperative risk factors for a prolonged ICU stay following cardiac surgery [44].

Risk for the cardiac team

Traffic in the operating room during cardiac surgery is a major concern. The cardiac surgery necessitates cardiac surgeons, anesthetists with their assistants, nurse, and perfusion physician. This level of traffic is a risk factor for surgical site infection and human errors [45]. Additionally, this increases the number of exposed physicians and makes transmission of COVID-19 feasible if either physicians or patients are asymptomatic carriers. Among a total of 44,672 confirmed cases recorded in China, 1716 (3.8%) were healthcare providers [10]. Therefore, there is a dual responsibility toward the patients and the healthcare personnel. However, a retrospective multicenter clinical study comprising 37 patients (5 confirmed and 32 suspected COVID-19) scheduled for emergency procedures, including cardiac procedures, showed that strict adherence to the guidelines of infection control could effectively decrease cross-infection in the operating room [46]. A case report of 41 healthcare providers who were in direct contact with confirmed COVID-19 patients and had exposure to an aerosol-generating procedure showed that none of them developed an infection with COVID-19 [47]. This emphasizes how effective the use of PPE is for healthcare workers who take care of patients infected with COVID-19. Therefore, these measures should be applied more readily in elective cardiac surgeries to ensure the safety of healthcare providers. Healthcare providers who have comorbidities (old age, immunosuppressed, or have a chronic illness), that increase the risk of COVID-19 infection, might be redeployed away from the frontline and assigned to tasks with lower risk such as helping in research or telemedicine services [48].

Decision

In response to the COVID-19 pandemic, the American College of Surgeons and the American Society of Anesthesiologists recommended a sustained reduction in the rate of new COVID-19 cases for 14 days before the resumption of the elective surgery [49]. The joint statement advised the health facilities to ensure an appropriate number of ICU beds, PPE, ventilators, and trained staff to the planned surgeries. In addition, the facility should have available preoperative screening for suspected cardiac patients and a valid strategy for periodic screening of the healthcare providers to protect both of them. A health status checklist should be implemented to confirm that every single member in the medical team is either COVID-19-negative or recovered from symptomatic COVID-19 with negative reverse transcriptase polymerase chain reaction tests (2 negative results separated by 48 h may be ideal) [50].

The surgical decision should be made by consensus of the cardiac surgeon, anesthetist, critical care physicians, and the patient to discuss timing the surgery during COVID-19 pandemic. The medical consensus should develop a priority list for elective cardiac surgery, considering the comorbidity of the patient and type of surgery, which related to more complications during the waiting period. An objective scoring system to decide when to proceed or postpone might be very helpful in this regard.

Conclusion

Cardiac surgery during the COVID-19 era carries a combined risk for cardiac patients who are at greater risk for the complications of COVID-19, and healthcare workers who are at higher risk for

infection. The decision to postpone or proceed with elective cardiac surgery should be made after weighing the risk of transmitting the infection to the fragile patient with the risk of morbidity and mortality incurred by delaying surgery.

Thoughtful decision-making remains the responsibility of healthcare delivery systems to preserve the health capacity, which is under escalating pressure of the COVID-19 pandemic and to protect both cardiac patients and healthcare providers.

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Practice points

- American College of Surgeons and the American Society of Anesthesiologists recommended a sustained reduction in the rate of new coronavirus disease 2019 (COVID-19) cases for 14 days before the resumption of the elective surgery
- Ideally, health status checklist should be implemented to each medical team member. COVID-19-negative or recovered from symptomatic COVID-19 with two negative reverse transcriptase polymerase chain reaction tests separated 48 h apart
- Surgical decision should be made by consensus of the surgeon, anesthetist, critical care physician, and the patient

Research agenda

- Research should be done to clarify the clinical implications of delay of elective cardiac surgery. A guideline would be ideal to triage patients.

Declaration of competing interest

The authors have no conflicts of interest to disclose.

References

*[1] Callaway E. Time to use the p-word? Coronavirus enter dangerous new phase. Nature 2020;579:12.
*[2] Cheung JC, Ho LT, Cheng JV, et al. Staff safety during emergency airway management for COVID-19 in Hong Kong. Lancet Respiratory Medicine 2020 Apr;8(4):e19.
[3] World Health Organization. Statement on the second meeting of the International Health Regulations (2005) Emergency Committee regarding the outbreak of novel coronavirus (2019-nCoV). Geneva, Switzerland. 2005.
*[4] Liu Y, Gayle AA, Wilder-Smith A, et al. The reproductive number of COVID-19 is higher compared to SARS coronavirus. Journal of Travel Medicine 2020 Mar 13;27(2):taaa021.
[5] Turner AJ, Hiscox JA, Hooper NM. ACE2: from vasopeptidase to SARS virus receptor. Trends in Pharmacological Sciences 2004 Jun 1;25(6):291–4.
*[6] Mallapaty S. Why does the coronavirus spread so easily between people? Nature 2020 Mar;579(7798):183.
*[7] Chen N, Zhou M, Dong X, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. Lancet 2020 Feb 15;395(10223):507–13.
*[8] Poon LL, Peiris M. Emergence of a novel human coronavirus threatening human health. Nature Medicine 2020 Feb 27:1–2.
[9] Chan JF, Yuan S, Kok KH, et al. A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster. Lancet 2020 Feb 15;395(10223):514–23.

[10] Wang D, Hu B, Hu C, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus–infected pneumonia in Wuhan, China. Jama 2020 Mar 17;323(11):1061–9.
*[11] Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet 2020 Feb 15;395(10223):497–506.
[12] Zheng YY, Ma YT, Zhang JY, et al. COVID-19 and the cardiovascular system. Nature Reviews Cardiology 2020 Mar 5:1–2.
[13] Vaduganathan M, Vardeny O, Michel T, et al. Renin–angiotensin–aldosterone system inhibitors in patients with Covid-19. New England Journal of Medicine 2020 Apr 23;382(17):1653–9.
[14] Peterson ED, Coombs LP, Ferguson TB, et al. STS national cardiac database investigators. Hospital variability in length of stay after coronary artery bypass surgery: results from the society of thoracic surgeon's national cardiac database. Annals of Thoracic Surgery 2002 Aug 1;74(2):464–73.
[15] Guery B, Poissy J, El Mansouf L, et al. Clinical features and viral diagnosis of two cases of infection with Middle East Respiratory Syndrome coronavirus: a report of nosocomial transmission. Lancet 2013 Jun 29;381(9885):2265–72.
*[16] Aguilar JB, Faust JS, Westafer LM, et al. Investigating the impact of asymptomatic carriers on COVID-19 transmission. medRxiv 2020 Jan 1. 2020.03.18.20037994.
*[17] Cheng VC, Wong SC, Chen JH, et al. Escalating infection control response to the rapidly evolving epidemiology of the Coronavirus disease 2019 (COVID-19) due to SARS-CoV-2 in Hong Kong. Infection Control Hospital Epidemiology 2020 Mar 5:1–6.
[18] Lei S, Jiang F, Su W, et al. Clinical characteristics and outcomes of patients undergoing surgeries during the incubation period of COVID-19 infection. EClinicalMedicine 2020 Apr 5:100331.
[19] Nepogodiev D, Glasbey JC, Li E, et al. Mortality and pulmonary complications in patients undergoing surgery with perioperative SARS-CoV-2 infection: an international cohort study. Lancet 2020 July 4-10;396(10243):27–38.
[20] Fang Y, Zhang H, Xie J, et al. Sensitivity of chest CT for COVID-19: comparison to RT-PCR. Radiology 2020 Feb 19:200432.
*[21] Chu DK, Pan Y, Cheng SM, et al. Molecular diagnosis of a novel coronavirus (2019-nCoV) causing an outbreak of pneumonia. Clinical Chemistry 2020 Apr 1;66(4):549–55.
[22] Hernández-Palazón J, Fuentes-García D, Falcón-Araña L, et al. Assessment of preoperative anxiety in cardiac surgery patients lacking a history of anxiety: contributing factors and postoperative morbidity. Journal of Cardiothoracic and Vascular Anesthesia 2018 Feb 1;32(1):236–44.
[23] Qiu J, Shen B, Zhao M, et al. A nationwide survey of psychological distress among Chinese people in the COVID-19 epidemic: implications and policy recommendations. General Psychiatry 2020;33(2).
[24] Tully PJ, Baker RA. Depression, anxiety, and cardiac morbidity outcomes after coronary artery bypass surgery: a contemporary and practical review. Journal of Geriatr Cardiology: JGC 2012 Jun;9(2):197.
[25] Dinan TG, Cryan JF. Microbes, immunity, and behavior: psychoneuroimmunology meets the microbiome. Neuropsychopharmacology 2017 Jan;42(1):178–92.
[26] Coughlin SS. Anxiety and depression: linkages with viral diseases. Public Health Reviews 2012 Dec;34(2):7.
[27] Gaudriot B, Uhel F, Gregoire M, et al. Immune dysfunction after cardiac surgery with cardiopulmonary bypass: beneficial effects of maintaining mechanical ventilation. Shock 2015 Sep 1;44(3):228–33.
[28] Ruan Q, Yang K, Wang W, et al. Clinical predictors of mortality due to COVID-19 based on an analysis of data of 150 patients from Wuhan, China. Intensive Care Medicine 2020 Mar 3:1–3.
[29] Chen C, Zhang XR, Ju ZY, et al. Advances in the research of cytokine storm mechanism induced by Corona Virus Disease 2019 and the corresponding immunotherapies. Zhonghua shao shang Za zhi= Zhonghua shaoshang zazhi= Chin Journal of Burns 2020 Mar 1;36:E005.
[30] Bauer A, Hausmann H, Schaarschmidt J, et al. Shed-blood-separation and cell-saver: an integral part of MiECC? Shed-blood-separation and its influence on the perioperative inflammatory response during coronary revascularization with minimal invasive extracorporeal circulation systems–a randomized controlled trial. Perfusion 2018 Mar;33(2):136–47.
[31] Huffmyer JL, Groves DS. Pulmonary complications of cardiopulmonary bypass. Best Practice Research Clinical Anaesthesiology 2015 Jun 1;29(2):163–75.
[32] del Rio C, Malani PN. COVID-19—new insights on a rapidly changing epidemic. Jama 2020 Feb 28. https://doi.org/10.1001/jama.2020.3072.
[33] Head SJ, da Costa BR, Beumer B, et al. Adverse events while awaiting myocardial revascularization: a systematic review and meta-analysis. European Journal of Cardio-Thoracic Surgery 2017 Aug 1;52(2):206–17.
[34] Minamino-Muta E, Kato T, Morimoto T, et al. Causes of death in patients with severe aortic stenosis: an observational study. Scientific reports 2017 Nov 7;7(1):1–6.
[35] Morgan CD, Sykora K, Naylor CD. Steering Committee of the Cardiac Care Network of Ontario. Analysis of deaths while waiting for cardiac surgery among 29 293 consecutive patients in Ontario, Canada. Heart 1998 Apr 1;79(4):345–9.
[36] Ranney ML, Griffeth V, Jha AK. Critical supply shortages—the need for ventilators and personal protective equipment during the Covid-19 Pandemic. New England Journal of Medicine 2020 Apr 30;382(18):e41.
[37] Legido-Quigley H, Asgari N, Teo YY, et al. Are high-performing health systems resilient against the COVID-19 epidemic? Lancet 2020 Mar 14;395(10227):848–50.
[38] Bainbridge D, Cheng D. Current evidence on fast track cardiac recovery management. European Heart Journal Supplements 2017 Jan 1;19(suppl_A):A3–7.
[39] Tatsuishi W, Nakano K, Kubota S, et al. Enhanced recovery (Fast-Track) after cardiac and vascular surgery. In enhanced recovery after surgery. Singapore: Springer; 2018. p. 135–49.
[40] Leyvi G, Schechter CB, Sehgal S, et al. Comparison of index hospitalization costs between robotic CABG and conventional CABG: implications for hybrid coronary revascularization. Journal of Cardiothoracic and Vascular Anesthesia 2016 Jan 1;30(1):12–8.
[41] Olds A, Bashjawish B, Saadat S, et al. Minimally invasive mitral valve surgery: the new gold standard? Journal of Am College of Cardiology 2018 Mar 10;71(11 Supplement):A1978.
[42] Burrage M, Moore P, Cole C, et al. Transcatheter aortic valve replacement is associated with comparable clinical outcomes to open aortic valve surgery but with a reduced length of in-patient hospital stay: a systematic review and meta-analysis of randomised trials. Heart, Lung and Circulation 2017 Mar 1;26(3):285–95.

[43] Mack MJ, Leon MB, Thourani VH, et al. Transcatheter aortic-valve replacement with a balloon-expandable valve in low-risk patients. New England Journal of Medicine 2019 May 2;380(18):1695–705.
[44] De Cocker J, Messaoudi N, Stockman BA, et al. Preoperative prediction of intensive care unit stay following cardiac surgery. European journal of cardio-thoracic surgery 2011 Jan 1;39(1):60–7.
[45] Young RS, O'Regan DJ. Cardiac surgical theatre traffic: time for traffic calming measures? Interactive cardiovascular and thoracic surgery 2010 Apr 1;10(4):526–9.
[46] Zhao S, Ling K, Yan H, et al. Anesthetic management of patients with suspected 2019 novel coronavirus infection during emergency procedures. Journal of Cardiothoracic and Vascular Anesthesia 2020 Feb 28.
[47] Ng K, Poon BH, Puar TH, et al. COVID-19 and the risk to health care workers: a case report. Annals of Internal Medicine 2020 Jun 2;172(11):766–7.
[48] Adams JG, Walls RM. Supporting the health care workforce during the COVID-19 global epidemic. JAMA 2020 Mar 12. https://doi.org/10.1001/jama.2020.3972.
[49] Home A. Joint statement: roadmap for resuming elective surgery after COVID-19 pandemic. 2020. p. 1–4. https://www.asahq.org/about-asa/newsroom/news-releases/2020/04/joint-statement-on-elective-surgery-after-covid-19-pandemic.
[50] Mayol J, Pérez CF. Elective surgery after the Pandemic: waves beyond the horizon. British Journal of Surgery 2020 May 8.