Chapter

Regional Anesthesia in Times of COVID-19

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Abstract

The globalized coronavirus pandemic 2019 has kept us on our toes. Although confusion is widespread and there is a trend toward normalization of almost all human activities, outbreaks remain frequent. The majority of patients with COVID-19 have a trivial to moderate clinical course; a small group develops severe pneumonia and other life-threatening complications. Vaccination against this virus has contributed to better control of the pandemic, but there are no antiviral drugs that have demonstrated efficacy; therefore, the management of surgical patients confirmed or suspected of this disease is a challenge for health care workers, including the anesthesiologists, as well as the non-COVID-19 patients who at a given moment could become carriers or sick. General anesthesia produces aerosols and risks medical and technical personnel being infected, especially those who manage the airway. On the other hand, regional anesthesia has advantages over general anesthesia because the airway is not handled; however, its limited duration is the most important concern. It is reasonable that regional anesthesia occupies a preponderant place in the safe management of all patients, as long as the type of surgery allows it, the anesthesiologist has sufficient skills and patients accept the proposed technique. At this time of globalized crisis due to COVID-19, the intrapandemic anesthetic management of patients undergoing surgery continues to be a changing task, a challenge that has been solved as new data based on solid scientific evidence arise, besides the development of drugs, safer vaccines, equipment, and health prophylactic methods. There is a clear tendency to use regional anesthesia whenever this is possible.

Keywords: COVID-19, regional anesthesia, safety

1. Introduction

In early December 2019, the first cases of coronavirus disease 2019 (COVID-19) were reported in Wuhan, a city located in the Chinese province of Hubei. Most of these patients stated exposure to the Huanan seafood wholesale market selling several alive animals. On the eve of 2020, the WHO office in China was informed of cases of atypical pneumonia with mysterious etiology. Three days later, the first 44 patients with this new pathology were notified and a new member of enveloped RNA coronavirus was identified in bronchoalveolar lavage fluid from a patient in Wuhan and subsequently confirmed as the cause of this infection by the Chinese Center for Disease Control and Prevention. On January 7, 2020, the WHO named

this virus a 2019 novel coronavirus (2019-nCoV). On February 11, 2020, the WHO named the illness associated with 2019-nCoV the 2019 novel coronavirus disease (COVID-19). On January 23, 2020, the central government of China imposed a lockdown in Wuhan and other cities in Hubei in an effort to quarantine the center of an outbreak of COVID-19; this action is commonly referred to as the Wuhan lockdown. The Huanan seafood market became recognized worldwide as the "Ground Zero" site of COVID-19. Since then, the disease has spread rapidly to all countries and territories of the planet—with the exception of Turkmenistan, North Korea, Tuvalu, and Nauru, which have reported no cases—becoming a pandemic that has devastated the world in all its activities and collapsing all health systems [1–5].

Although the available global statistics are approximations, as December 31, 2021; 287,574,670 cases had been recorded, with 5,449,965 deaths and 253,516,625 people recovered [6]. These data are changing every moment in relation to the virulence of the new strains, the worldwide resources for the comprehensive care of the population, and the attitude of the people. As COVID-19 spreads across the planet, perioperative medical and surgical personnel must prepare for the challenges associated with the best care for the pandemic. Rapid suspicion, diagnosis and isolation, proper clinical management, and prevention of disease transmission are vital not only for COVID-19 patients but also for other patients and healthcare workers (HCWs) who are at risk of transmission.

Professionals in perioperative areas, such as other specialties, have been developing timely guidelines based on experiences acquired since the beginning of this pandemic in such a way that peri anesthetic care is the safest and most effective for patients and health personnel. Care policies must be endorsed by hospital administrators, medical societies involved, governments, and the third-party payer, to establish an adequate consensus that can adapt to the frequent changes that are necessary for such a way that the infrastructure and available supplies are optimized.

At this time of the COVID-19 pandemic, we must consider five large groups of patients [7]—people with active COVID-19, patients with a history of remission of SARS-CoV-2, potential carriers, vaccinated and unvaccinated patients, and patients without COVID-19. The pre-anesthetic evaluation and perioperative anesthesiological management are based on these groups according to the type of urgent or scheduled surgery, the available resources, and, of course, the experience of each anesthesiologist.

This chapter reviews the actual role of regional anesthesia in the era of COVID-19, considering the different clinical scenarios that this pandemic has generated. Nowadays, there is no information on how regional anesthesia could affect patients with active COVID-19, those with the post-COVID-19 syndrome, carriers, or recently vaccinated people. Practical recommendations that guarantee both the safety of each patient and also of HCWs are addressed, as well as the protection of the equipment. More research is needed to justify the design of management guidelines in regional anesthesia based solidly on global scientific evidence.

2. SARS-CoV-2 virus

COVID-19 or coronavirus disease is caused by the SARS-CoV-2 virus that belongs to the betacoronavirus genus and shares high homology to the severe acute respiratory syndrome coronavirus (SARS-CoV) that occurred in 2003. This virus is closely related to SARS-CoV-1 and possibly originated either from bats or pangolins. Pneumonia and acute respiratory distress syndrome are the primary complications, although there are other disorders such as cardiovascular, hematological with lethal thrombotic complications, renal, gastrointestinal, hepatic, endocrine,

and central nervous system diseases, just to mention a few. This sequence of events is due to the activation of immune responses that trigger uncontrolled massive inflammatory responses mediated by elevated serum levels of pro-inflammatory cytokines that can cause localized and systemic tissue damage. Eosinopenia and lymphopenia with reduction of CD4 + and CD8 + T cells, B cells, and natural killer (NK) cells have been identified in severe cases, severe disease suggests a reduction in NK cell number and function, resulting in decreased clearance of infected and activated cells. A higher ratio of neutrophils to lymphocytes has also been reported, being an indicator of inflammation and infection. COVID-19 patients display high levels of inflammatory cytokines and chemokines (IL-1, IP-10, MCP-1), with severe cases showing elevation in TNF alfa, IL-1, IL-6, IL-8, IL-10, MCP-1, and MIP-1A, leading to severe pulmonary damage and IL-1 has also been linked to the expression of thromboxane-A2 resulting in increased platelet activation and aggregation [8–11].

2.1 Variants

The evolution of the SARS-CoV-2 has been continuous with several variants emerging with unusual frequency. Although the clinical picture is similar, these genetic mutations have meant the prolongation of the pandemic with numerous unsolved effects and challenges. Omicron (B.1.1.529), the last variant that originated in South Africa in November 2021 has been classified as a concern variant, which, like the previous variants, has generated globalized uncertainty. These genetic mutations can affect the gene encoding the Spike (S) antigen with effects on preventive and therapeutic strategies known so far. The gold standard for the identification of variants is the sequencing of the entire genome, although recently real-time PCR techniques have been developed for the detection of specific mutations that can facilitate their identification.

Studying the variants could help assess risks and develop better treatment and prevention strategies [12–17]. An international classification system has been established to distinguish emerging variants of this virus into variants of concern (VOC) and variants of interest (VOI), which are listed in **Table 1**.

The under surveillance and de-escalated variants are also included in this classification. The classification of SARS-CoV-2 variants is continually modified

Variants of concern (VOCs)	**Date/Country**	**Mutations**
Alpha (B.1.1.7 lineage) Formerly GR/501Y.V1	UK Dec 2020	17
Beta (B.1.351 lineage) B.1.351 or Beta, or GH501Y.V2	South Africa Oct 2020	9
Gamma (P.1 lineage) Gamma or GR/501Y.V3	Brazil Dec 2020	10
Delta (B.1.617.2 lineage) Delta variant	India Dec 2020	10
Omicron	South Africa Nov 2021	> 30
Variants of interest (VOIs)		
Zeta (P.2)	Brazil April 2020	8
Epsilon (B.1.427 and B.1.429) CAL.20C/L452R	USA June 2020	5
Eta (B.1.525) and Iota (B.1.526)	USA Nov 2020	13
Lambda (C.37)	Peru Dec 2020	3
Kappa (B.1.617.1)	India Dec 2021	7

Table 1.
COVID-19 variants.

according to the genetic mutations of the virus and the WHO, CDC, and ESDC guidelines [16, 17, 18].

2.2 Clinical manifestations

COVID-19 is an infectious disease primarily of the respiratory system that is transmitted from animal to human and from human to human through air droplets, aerosols, and contaminated fomites. The most characterized symptoms are fever, cough, fatigue, dyspnea, sore throat, headache, myalgias, and arthralgias. Mild respiratory symptoms are the most frequent clinical manifestation; however, a broad plethora of signs and symptoms have been described, from asymptomatic patients to severe pneumonia, acute respiratory distress syndrome, respiratory failure, sepsis, and multi-organ failure. Even though the respiratory system is the most prominent target of SARS-CoV-2, the extrapulmonary damage is very extensive and devastating, contributing to its morbidity and lethality. Non-pulmonary manifestations are abundant and can affect systems, such as cardiovascular, central and peripheral nervous, hematological, digestive, hepatobiliary, renal, endocrine, olfactory, and taste disturbances, as well as skin signs [19–25]. **Table 2** lists the most frequent clinical manifestations of greatest clinical interest. The clinical picture varies according to its evolution, especially in seriously ill patients. These manifestations are usually modified with the various vaccination schemes.

2.2.1 Post-COVID-19 syndrome

The chronic post-COVID-19 syndrome is another aspect that is slightly known, as well as the psychological alterations secondary to the disease and the confinement that this pandemic has produced. SARS-CoV-2 fatality rates have been estimated between 1 and 7% [26], so there will be a large population recovered from COVID-19; patients who can acquire a multitude of long-term systemic disorders that are of paramount importance, especially when this group of patients undergoes

System	Associated manifestations/Lesions
Respiratory	Pneumonia, acute respiratory distress syndrome, respiratory failure, pulmonary microvascular thrombosis
Cardiovascular	Myocardial injury, acute coronary syndrome, myocarditis, Takotsubo cardiomyopathy, arrhythmias, heart failure, cardiogenic shock, and even sudden death
Hematological	Lymphopenia, neutrophilia, hyperferritinemia. Coagulopathy characterized by elevated D-dimer and an increased risk of VTE, PE, and DIC. Bleeding events
Neurology	Headache, dizziness, myalgia, anosmia, dysgeusia, encephalopathy, encephalitis, necrotizing hemorrhagic encephalopathy, spinal arachnoiditis, acute myelitis, stroke, seizures, rhabdomyolysis, Guillain-Barre, and Miller Fisher syndromes
Gastrointestinal, liver, and pancreas	Anorexia, nausea, vomiting, diarrhea, abdominal pain, gastrointestinal bleeding, hematochezia. Liver and pancreatic damage
Renal	Proteinuria, hematuria, acute kidney injury
Endocrine	Exacerbating hyperglycemia, euglycemic ketosis, and diabetic ketoacidosis
Skin	Acro-cutaneous (pernio or chilblain-like), maculopapular rash, vesicles, livedoid/necrotic lesions, exanthematous rashes, petechiae

VTE = Venous thromboembolism, PE = Pulmonary embolus, DIC = Disseminated intravascular coagulation.

Table 2.
Common disorders in patients with acute COVID-19.

System	Associated manifestations/Lesions
Respiratory	Restrictive abnormalities, reduced diffusion capacity, small airways obstruction, pulmonary fibrosis, reduced exercise capacity, pneumothorax, secondary infections, massive hemoptysis, pulmonary hypertension with or without evidence of thrombosis
Cardiovascular	Chest pain, dyspnea, palpitations, hypertension, myocarditis, pericarditis, postural orthostatic tachycardia syndrome, arrhythmias
Hematological	Prothrombotic state (deep vein thrombosis, venous thromboembolism), lymphocytopenia, thrombocytopenia, hemorrhage
Neurology	Headache, vertigo/dizziness, anosmia, ageusia, hypogeusia, dysgeusia, insomnia, memory impairment, inability to concentrate, global CNS dysfunction, encephalitis, ischemic stroke, intracranial hemorrhage, encephalopathy, seizures, peripheral neuropathies, autoimmune demyelinating encephalomyelitis, dysautonomia
Renal	Chronic renal failure, focal glomerulopathy, tubulo-reticular injury, proteinuria, hematuria
Endocrine	Post-COVID-19 primary type 2 diabetes mellitus, thyroiditis
Psychiatric, psychosocial manifestations	Chronic fatigue, cognitive dysfunction, sleep disturbances, memory impairment, burnout syndrome

Table 3.
Frequent clinical manifestations/lesions of the chronic post-COVID-19 syndrome.

surgical interventions. Post-COVID-19 chronic damage, to the cardiopulmonary, hematologic, renal, and neurological systems [26–30], is of special interest to the anesthesiologist. Of equal interest are the possible pharmacological interactions between the drugs that these patients have been taking during the acute and chronic phases and the drugs used in anesthesia. **Table 3** lists the most relevant alterations that should be detected in the pre-anesthetic evaluation. Laboratory tests that may persist altered in this syndrome and must be meticulously evaluated include hemoglobin level, erythrocyte sedimentation rate, white blood cell count, lymphocyte count, C-reactive protein, serum glutamic pyruvic transaminase, serum ferritin, prothrombin time, D-dimer, serum creatinine, as well as chest X-ray, CT or NMR.

2.3 Diagnosis

Clinical suspicion of infection with COVID-19 is the first step toward the diagnosis of this disease. However, the initial clinical picture can easily be mistaken with other viral diseases of the respiratory tract, and sometimes it can be totally asymptomatic. On the other hand, the available vaccines have modified the clinical manifestations. This makes it necessary to start a diagnostic approach with laboratory tests and thorax imaging (X-ray, CT, and NMR) at the slightest suspicion of COVID-19.

Although the gold standard test in the diagnosis of COVID-19 is PCR (polymerase chain reaction), it is also necessary to establish other techniques with high sensitivity and specificity that can be used on a large scale. Currently, there are three diagnostic tests used—nucleic acid detection tests (PCR), antigen detection tests (Ag), and antibody detection tests (Ab): IgM/A and IgG [31–33].

3. Risk of infection and death for the health personnel

Health personnel who work on the front lines caring for patients with COVID-19 have a high risk of contagion and death compared to those who work in non-COVID-19 areas, although physicians from all specialties may die from COVID-19. Lack of

personal protective equipment was cited as a common cause of death. Although there are no reliable statistics, the published data mention figures of contagion and death not previously seen among HCWs, being emergency physicians, internal medicine, anesthesiologists, intensivists, pulmonologists, infectious disease specialists, primary care physicians, and nurses being the most affected [34–36]. The study of Ing and coworkers [37] reported 278 physicians who died from COVID-19 infection—the average age of 63.7 years, 90% male (235/261). General practitioners and emergency room doctors (108/254), respirologists (5/254), internal medicine specialists (13/254), and anesthesiologists (6/254) comprised 52% of those dying. Two percent of the deceased were epidemiologists (5/254), 2% were infectious disease specialists (4/254), 6% were dentists (16/254), 4% were ENT (9/254), and 3% were ophthalmologists (8/254). The countries with the most reported physician deaths were Italy (121/278; 44%), Iran (43/278; 15%), Philippines (21/278; 8%), Indonesia (17/278; 6%), China (16/278; 6%), Spain (12/278; 4%), USA (12/278; 4%) and UK (11/278,4%). In Mexico, the Mexican Federation of Anesthesiology AC has registered 62 anesthesiologists who died from COVID-19 since the beginning of the pandemic (Hernandez CE. Personal communication), although this figure could be higher since this association has only 5100 members and there are around 15,000 anesthesiologists in this country.

After the first outbreak in China, anesthesiologists in that country were the first to establish safety measures and online education for optimal perioperative management of patients with COVID-19: airway management, oxygen therapy, ventilatory and hemodynamic support, sedation, and analgesia, as well as attention to mental health aspects for workers in surgical areas and intensive care units [38]. After this publication, multiple recommendations appeared with two main goals: the safe management of COVID-19 and non-COVID-19 patients and the protection of all HCWs.

As these management guidelines were developed, the hospitals were reconfigured to increase their capacity to care for COVID-19 patients. “Not necessary” surgeries were postponed, supplies and personal protective equipment were provided to the staff, drugs were investigated for the disease and/or its complications, and preoperative tests were made mandatory for COVID-19, a practice which has generated much controversy, especially in countries with limited resources [31, 39]. On the other hand, asymptomatic carriers among the health personnel have been considered a risk of transmission of COVID-19, especially personnel working in emergency departments. An Egyptian study [40] revealed the prevalence of COVID-19 in asymptomatic HCWs in the emergency department of a tertiary care facility is 14.3% by RT-PCR. The study of Mostafa et al. [41] also done in Egypt included 4040 HCWs from 12 hospitals; 170 (4.2%) were positive for (RT-PCR) and rapid serological tests for IgM and IgG. Most of the infected HCWs were asymptomatic (116/170, 68.2%). The proportion of infection among the asymptomatic (n = 116/3424) was 3.4% (95% CI: 2.8–4.0). These researchers recommended to extend universal testing to all HCWs as infections among them may reflect community rather than nosocomial transmission. In a similar way to emergency physicians, anesthesiologists run a high risk of contagion since they are the providers of care both in the ICU and the perioperative areas and are exposed to the virus every day.

4. Returning to quasi-normal activities after shutdown

- COVID-19 has been and will continue to be an unexpected and catastrophic nightmare for healthcare systems around the world.

- The immediate cessation of elective care ordered by the governments had severe negative effects.

- The resumption of elective surgery during the various outbreaks and remissions of the pandemic has required adjustments to pre-pandemic routines.

All health systems on the planet have collapsed since the beginning of this pandemic; the rapid increase in critically ill patients exceeded the capacity of the emergency and intensive care services, which is why hospitals were transformed into COVID-19 care centers, new non-hospital areas were created or adapted to take care for these patients, and drastic preventive measures such as the social distancing policies, mandatory lockdowns, large isolation periods, confinement at home, home office work, mandatory face masks, frequent hand washing, and sanitation measures. Elective surgeries and many urgent procedures, as well as non-surgical medical hospitalizations, outpatient and home consultation, and the training of students, residents, and new specialists, underwent substantial changes which resulted in a serious increase in non-COVID-19 patient's morbidity and mortality. A systematic review of patients with an acute abdomen during the initial phase of the pandemic proposed that every effort be made to assess the feasibility of postponing surgery until the patient is no longer considered potentially infectious or at risk of perioperative complications. When surgery is necessary, the anesthesiologist and the surgeon must minimize the risk of exposure to the virus by involving the minimum number of personnel and reducing the time in the operating room. When there are no safety measures that allow safe laparoscopy, open surgery should be considered to decrease aerosols [42].

During the different stages of the pandemic, government hospitals and private health care institutions have been designing health care programs for COVID-19 and non-COVID patients in such a way as to return to normal pre-pandemic health care, or what we now know as the new health care routines. The surgeries of all specialties that had been suspended have been resuming a course quite different from the previously established sequences. New care guidelines have been oriented based on the experiences acquired since the beginning of this global health crisis, with the primary goal being to avoid contagion from other patients and health personnel without deterioration of the quality of care [43–45]. As soon as it was possible to adopt new safety measures for non-COVID patients and medical personnel, postponed surgeries that had endangered the lives of thousands of patients with cancers, cardiovascular disease, or organ transplant patients were restarted. Gradually, other types of surgeries were performed until hospital centers and outpatient and short-stay surgery units returned to the new normality. Management guidelines have also been issued to resume surgery in various specialties, with special care in pediatric and obstetric anesthesia [46].

The psychological disorders that the HCWs have undergone [47–49] are also of paramount importance for a reliable return to professional activities in anesthesia. Although for many physicians, returning to their pre-pandemic professional practice has been relatively quick and easy, for anesthesiologists who have been on the front line of this health crisis, returning to the anesthetic consultation, operating rooms, recovery areas or the ICU conveys still a high risk. Not only is it necessary to adopt the new guidelines, but it is prudent to prevent, diagnose and treat these psychological pathologies such as exhaustion, fear, anger, anguish, and uncertainty that are factors that could interfere with our professional performance. This almost "*two-year race is now a marathon that passes between nuclear reactors, next to war zones, of many unusual dangers*" where medical errors can flourish at any moment. As anesthesiologists, we must have the courage, resilience, determination, and conviction to continue with this new goal of providing safe anesthesia to each one of our patients in this era of COVID-19 [50, 51].

With the measures and precautions properly implemented it is now feasible and extremely safe without increased risk for patients to resume all surgical activities.

The health personnel of the surgical and recovery areas has been adapting to the new care guidelines that still have unresolved controversies [52]. Unfortunately, outbreaks with the new variants, including the new strain Omicron [19], continue to perpetuate the risks of contagion for HCWs, especially for professionals who manipulate the airway, which favors the use of regional anesthesia.

5. Clinical scenarios in the era of COVID-19

The COVID-19 health crisis has been changing the way we practice medicine. Fortunately, the WHO vaccination programs in agreement with the governments of almost the entire planet have reduced infections and positively modified morbidity and mortality figures. Some clinical scenarios can be considered in this era [7]: patients with active COVID-19, patients recovered from SARS-CoV-2, potential carriers, vaccinated and unvaccinated patients, and a majority group of patients without COVID-19. The pre-anesthetic evaluation and perioperative anesthesiological management are now based on these assumed groups, as well as on the type of urgent or scheduled surgery, on the available resources, and, of course, on the experience of each anesthesiologist.

5.1 Patients with active COVID-19

Despite the enormous number of clinical trials and vaccines available, unfortunately, we still lack an effective cure for COVID-19. Therefore, the anesthesiologic approach to these patients must be safe and effective for both the patient and the medical team. Transporting patients with active COVID-19 from their bed to the operating room and vice versa is a critical maneuver that requires both the patient and the HCWs to be properly protected and to do so through a pre-established route. An interesting experimental study showed that the surgical smoke generated by the electric scalpel and ultrasonic scalpel is not a risk factor; the coronavirus present in the smoke was unable to induce plaque formation in cultured cells. In addition, filtration of surgical smoke through a surgical mask effectively reduces the amount of viral RNA by at least 99.80% [53].

5.2 COVID-19 survivors

People who got COVID-19 and survived can be divided into two groups; recovery ad-integrum and those who develop the long-term disease. Those in the first group do not represent a special risk for anesthesiological management, but patients in the second group should be carefully evaluated for long-term cardiac, pulmonary, kidney, hematological, and neurological conditions.

5.2.1 Long term COVID-19 patients

Two years after the start of this pandemic, more than 287 million cases and 5.4 million deaths had been reported worldwide [6, 54]; approximately 253 million people around the world have recovered from Covid-19, of which 10 to 40% continued with symptoms of this disease for a few weeks to months. This is a new disease that has been called post-COVID-19, Prolonged COVID-19, or Post-acute COVID-19 syndrome [55–57].

COVID-19 long-term sequelae are yet unknown, but they can situate these patients at high risk when they undergo anesthesia and surgery [56]. The chronic post-COVID-19 lesions of greatest interest to the anesthesiologist are cardiovascular, pulmonary, kidney, hematological, and metabolic.

5.2.1.1 Cardiovascular

Up to 20–30% of hospitalized patients with COVID-19 have evidence of myocardial involvement, including acute myocardial injury, arrhythmias, cardiogenic shock, and even sudden death. Acute coronary syndrome (ACS) can be one of the initial presentations of COVID-19 infection which may range from ST elevation and myocardial infarction to Takotsubo cardiomyopathy [57]. The incidence of myocardial injury as reported in China increases with the severity of illness, uprising to 22.2% of patients needing ICU care [58]. Additionally, drug interactions with COVID-19 therapies can put the patient at risk for arrhythmias, cardiomyopathy, and sudden death [22]. A comprehensive cardiovascular review has been recommended in patients who recovered from heart injury due to COVID-19 since they may have residual damage even in asymptomatic patients, especially in search of arrhythmias and myocarditis [59, 60].

5.2.1.2 Lung

Mild to severe dyspnea are frequent manifestations of the post-COVID-19 syndrome. The lungs are the most damaged organs in patients with moderate to severe COVID-19; an undetermined percentage of recovered persons will develop structural pulmonary abnormalities that usually last for several months. The prospective study of Sonnweber et al. [61] with 145 patients with COVID-19 showed that 41% had respiratory symptoms 100 days after the onset of the disease—dyspnea reduced diffusion capacity in 21% of the studied cohort. The CT scans with alterations in 63%, with bilateral ground-glass opacities and/or reticulation of lower lobes. Other studies have found residual ground-glass opacities, consolidations, reticular and linear opacities, residual crazy paving patterns, melted sugar signs, and parenchymal fibrotic bands [62, 63]. A decreased lung diffusing capacity for carbon monoxide possibly due to loss of alveolar units with alveolar membrane damage was reported recently [64].

Long-term hematologic damage is not accurately recognized. It is unknown whether pulmonary thromboembolism in COVID-19 resolves completely in survivors or presents with long-term sequelae of lung parenchymal or pulmonary vascular damage or pulmonary hypertension. It is prudent to determine if there is thrombocytopenia, D-dimer levels, prothrombin time (PT) prolongation, international normalized ratio (INR), thrombin time (TT), and activated partial thromboplastin time (aPTT) reduction.

5.2.1.3 Kidney

Acute renal failure is a frequent complication in COVID-19 that affects up to 36.6% of patients, of whom the majority of survivors recover, but the long-term effects on renal function and risk of death are unknown. Patients at greatest risk of chronic kidney damage are older adults, African Americans, or those with diabetes and/or hypertension. Kidney impairment may be found 6 months after discharge.

5.2.1.4 Metabolic and endocrine disorders

Viral damage to the islets of Langerhans can lead to transient diabetes mellitus. Thyroid follicular damage, thyroiditis, hypothyroidism, as well as transient pituitary lesions, and damage to the hypothalamus-pituitary–adrenal axis leading to hypocortisolism and secondary hypothyroidism have also been found [64, 65].

5.3 Potential COVID-19 carriers

There is enough evidence that many COVID-19 patients are asymptomatic or have only mild symptoms, but they can transmit the virus to other people. There are difficulties in the detection of these asymptomatic carriers, which hinders the prevention and control of this pandemic [66]. A systematic review and meta-analysis [67] found that the proportion of asymptomatic among COVID-19 positive people is high with a substantial transmission potential in communities, therefore, asymptomatic carriers occupy a decisive place in the management of this global crisis.

5.4 Vaccinated and unvaccinated patients

Morbidity and mortality have decreased in vaccinated people due to vaccine-induced immunity against SARS-CoV-2. On the other hand, it has been shown that vaccinated people can be asymptomatic carriers, especially of the Delta variant, and they constitute another transmission factor [68]. During the last two outbreaks of the pandemic, unvaccinated people tend to develop more clinical complications, and their death rate is higher. This last group represents a management and contagion challenge similar to the beginning of this pandemic. Unfortunately, anti-vaccine people represent an important group and continue to be a factor that favors the persistence of this disease and only a few countries have taken drastic measures against this group.

In vaccinated patients, it is important to consider two facts—1) complications secondary to vaccines, especially the rare possibility of myocarditis and pericarditis that has been described after the application of COVID-19 mRNA vaccines (i.e., Moderna and Pfizer-BioNTech). This potential complication has been seen mainly in men under 30 years of age, which makes surveillance in this group of vaccinated people necessary [69, 70]. COVID-19 viral vector vaccines (i.e., Johnson & Johnson/Janssen and Oxford/Astra-Zeneca) use a modified version of adenovirus, which expresses a stabilized spike protein on its surface but is incapable of replicating. Similar to the Astra-Zeneca vaccine, the Johnson & Johnson vaccine was temporarily paused because of reports of thrombotic events. 2) The second point regarding vaccine is the time of vaccination in relation to the time of surgery anesthesia. To date, there are no scientifically proven guidelines on when to apply the vaccine in relation to the surgical moment. Some medical groups have recommended vaccination programs in this clinical setting [71, 72]:

- Surgery or urgent medical procedures should not be postponed based on the vaccination status

- Knowing the vaccination status of the potential patient is mandatory. It is ideal for patients to have a complete vaccination schedule prior to surgery. In special cases, a single dose of vaccine as early as possible before surgery should be considered. The earlier the vaccine can be given preoperatively, the greater the protection.

- Elective surgery does not contraindicate COVID-19 vaccination

- Vaccination should be done 2 weeks before surgery. If there is an adverse event related to vaccination, it is prudent to postpone surgery until the patient has recovered or the patient's condition has stabilized

- After surgery, it is recommended to wait at least 2 weeks before vaccinating, or until complete recovery in patients complicated by the operation

- Vaccination is recommended for patients with prior COVID-19 infection
- It is vital that vaccination reactogenicity (secondary reactions to vaccines) has been resolved before surgery
- Patients who need elective surgery should have priority to be vaccinated before the general population.

These recommendations could be modified in the near future when there are data based on new scientific evidence obtained from prospective studies. It is worthy to remember that vaccinated people can get COVID-19 and be carriers or have mild to severe manifestations.

5.5 Patients without COVID-19

Fortunately, this is the largest group in the midst of this health crisis. Theoretically, all patients without COVID-19 scheduled for an anesthesiological procedure could be managed as before this pandemic. However, in this era of COVID-19, there are many controversies, because scientific advances change every day, health systems have not yet recovered 100%, and many patients and HCWs are still afraid of contagion and death. The most cautious conduct is to manage each patient as if they were a potential transmitter of SARS-CoV-2. As above mentioned, there is evidence that COVID-19 carriers are asymptomatic, but easily transmit the virus to other individuals. It is this group of carriers that have forced us to handle ALL of our patients with widely recommended preventive recommendations.

At Lotus Med Group outpatient and short-stay plastic surgery unit, we suspended all activity for 6 weeks at the beginning of the pandemic. Before we restart the consultation and the surgery, we elaborated a plan for approaching our patients:

1. Most of the consultations—as they were partially done before the pandemic—would be online.
2. Only the patient would attend the face-to-face consultation.
3. Mandatory N95 mask in the waiting room, during the consultation, in the patient room, in the operating room as well in the recovery area.
4. Questionnaire about COVID-19.
5. Rapid blood test for COVID-19.
6. All personnel were protected with a mask, healthy distance, frequent hand washing, and sanitation of work areas.
7. Anesthesiologist with personal protection equipment.

This regulation was modified according to the new information available and the availability of resources. The rapid IgM and IgG serological tests were substituted by the RT-PCR, which must be performed between 3 and 5 days prior to the consultation/surgery. Patients with a positive result are postponed for surgery or consultation and must have another PCR test with a negative result. All staff received a PCR test and when vaccinations became available, all staff were vaccinated immediately.

Most of the surgical procedures performed in our unit are done with subarachnoid anesthesia [73]. General anesthesia is used only in breast surgeries, chest liposuctions, some cases of combined or very prolonged surgical procedures, or when there is a contraindication to regional anesthesia. All facial surgery is performed with local anesthesia and intravenous sedation, administering nasal oxygen with flows of 0.5–1 Lt/min.

6. General versus regional anesthesia

Under the current information, the type of anesthesia that we should use during this pandemic in the various clinical settings described is still controversial. Although general anesthesia is now safer than at the beginning of this crisis, the current trend is to use regional anesthesia whenever possible, ensuring the possibility that conversion to general anesthesia is not necessary.

- When the type of surgery allows, always use regional anesthesia during the COVID-19 pandemic
- If the patient has COVID-19, it is not a formal contraindication to perform regional anesthesia
- The most experienced anesthesiologist in the hospital should perform the anesthesia procedures
- The least number of HCWs in the operating room is recommended
- Whenever possible, informed consent should be obtained digitally
- Avoiding the aerosols found in general anesthesia can further protect HCWs and other patients [74]

During this time of COVID-19, we have two major scenarios in the practice of anesthesia: 1) Hospitals where there are well-established care programs for COVID-19 patients and people without this infection. These hospitals have personnel resources and supplies that vary according to each country and geographic region of the planet. The surgery programs have been gradually normalized according to their capacity and the level of infections by SARS-Cov-2. 2) On the other hand, outpatient and short-stay surgery units suspended their activities for short periods of time, but quickly resumed their activities during the pandemic due to the high demand for surgical patients referred from hospitals that limited their usual operating capacity due to being collapsed by COVID-19 patients [75, 76].

General anesthesia leads to the generation of aerosols, increasing the risk of COVID-19 contamination in operating rooms and recovery areas, significantly exposing healthcare teams to COVID-19 infection during tracheal intubation, extubation, and in the immediate period of recovery from anesthesia. The risk of transmission of acute respiratory infections to HCWs during aerosol-generating procedures, such as tracheal intubation, has been reported to be high. On the other hand, it is well known that general anesthesia decreases the immune response which could negatively interfere with the evolution of COVID-19 patients [77, 78]. Furthermore, general anesthesia has a higher risk of perioperative lung complications than regional anesthesia.

7. Regional anesthesia

Although some researchers have suggested that general anesthesia is safe for anesthesiologists and other HCWs, at this time of COVID-19, there is a clear tendency to use–whenever possible–the various regional anesthesia techniques [79–83].

The information available has focused on patients with active COVID-19 and post-COVID-19 syndrome. There is not enough information on the use of regional anesthesia in asymptomatic carriers, recently vaccinated and non-COVID-19 patients requiring anesthesia for surgery or any other medical procedures during this time of the pandemic. However, it is prudent to favor its use as a safe way to avoid possible infections in health personnel and to avoid complications for patients. A Turkish study [84] with 126 specialists in anesthesiology and resuscitation found that 42.6% had an increase in the use of regional anesthesia, compared to 57.3% who had no change. 74% were neuraxial anesthesia. The distribution of peripheral nerve blocks (PNBs) showed that upper extremity blocks were used at a rate of 64.9%, lower extremity blocks at 30.38%, and trunk blocks at 15%. Up to 44% of anesthesiologists used ultrasound guidance and 50% used both neurostimulation and ultrasound. An email survey of members of the American Society for Regional Anesthesia and Pain Medicine, UK Regional Anesthesia, and the European Society for Regional Anesthesia and Pain Therapy involving 729 anesthesiologists from 73 countries found that the use of regional anesthesia increased or remained the same, arguing that its use does not produce aerosols and reduces the risk of possible complications to patients. Only 2% of those surveyed decreased the use of regional anesthesia compared to the pre-pandemic period, being the most common reason for the possibility of urgent conversion to general anesthesia [85].

The following practical considerations are derived from the information available, the possibilities in the various clinical settings described above, the opinions of experts, and our experience.

7.1 General recommendations in the operating room

Before starting regional anesthesia, it is recommended to plan the available resources (staff, drugs, and equipment), appropriate clinical environment, suitable personal protective equipment for each case (in patients with active COVID-19 or carriers use PPE, goggles and N95 mask should be used throughout the perioperative period. In the other clinical scenarios described above, it is prudent to use minimal protective equipment that include goggles, N95 mask, face shield, surgical gown, and gloves), and evaluate meticulously the best regional anesthesia technique, as well as post-anesthetic care, always protecting patients and HCWs. All patients must be clinically monitored, in addition to being properly monitored with noninvasive blood pressure, electrocardiogram, respiratory rate, and pulse oximetry. If possible, carbon dioxide (CO_2) monitoring is recommended. Intraoperative oxygen administration should be avoided, and only if pulse oximetry is 90% or less should be given at low flows (0.5 to 1 Lt/min). Oxygen must be administered with nasal prongs (cannula) with a surgical mask layered over it. It is advisable not to use sedatives during regional anesthesia. When the patient is restless, sedation should be minimal to avoid respiratory depression and the need to administer oxygen and thereby increasing aerosol production. Patients should always keep their N95 masks on to prevent droplet transmission, and preferably not speak during their surgery. The use of long-acting local anesthetic (bupivacaine, levobupivacaine, ropivacaine, and etidocaine) prolongs the anesthetic effect of regional anesthesia. In addition to a sufficient and safe dose, the addition of an additive such as dexmedetomidine, clonidine, morphine, or fentanyl prolongs its duration [86, 87]. Nerve blocks should

always be performed in the operating room, and preferably recover in the operating room to limit contamination and contagion. It is mandatory to limit the number of personnel to the minimum necessary. An HCW must be available to bring the necessary supplies to the operating room if required. It has also been recommended by various authors that regional anesthesia should be administered by the most experienced anesthesiologist. However, this negatively interferes with the learning of residents [88–90], which is why we consider it correct that an expert anesthesiologist support colleague in training as long as they follow the guidelines to avoid contagion and with the proper PPE [87].

7.2 Neuroaxial anesthesia

Epidural, subarachnoid, and combined spinal-epidural anesthesia can be used in all types of patients with maximum safety and efficacy during this pandemic [73, 78–84, 86, 87]. Major et al. found that during this pandemic laparoscopic gynecological surgery under general anesthesia is associated with higher mortality and pulmonary complications. These authors recommend the use of neuraxial anesthesia with low-pressure pneumoperitoneum ≤8 and in pelvic surgery, the Trendelenburg position of as much as 30–45° is essential [91].

Two years after the onset of the pandemic, there are many enigmas about the impact of the coronavirus 2019 on pregnant women, which have been considered at high risk due to the physiological changes of pregnancy and the effects on implantation, fetal growth and development, as well as the risk of infection in the newborn [92]. Anesthetic management guidelines for the mother-fetus-HCWs trinomial have been developed to reduce the possibility of contagion and complications of COVID-19 [93–95]. The available studies support the use of neuraxial anesthesia for labor, vaginal or cesarean delivery section, although the use of general anesthesia in urgent cesarean section continues to be the choice. Chen's retrospective study of 17 pregnant women found significant intraoperative arterial hypotension in 12 of 14 patients who received epidural anesthesia. Three patients were managed under general anesthesia. No newborns or HCWs were infected with COVID-19 [96]. Early epidural block minimizes the need for general anesthesia for urgent cesarean delivery. Depending on the hemodynamic status of each patient, a choice must be made between spinal, epidural, or combined spinal-epidural anesthesia, the latter with a very low spinal dose. Before doing a neuraxial procedure in these patients, it would be advisable to review the platelet count given that one-third of patients with COVID-19 infection have been reported to have thrombocytopenia compared with 7–12% of patients during pregnancy alone.

The possibility of neuroinfections (meningitis or encephalitis) after neuraxial analgesia/anesthesia is an unresolved topic, although it has been mentioned that this possibility is extremely low and there are no published cases with this complication [97]. At present, postdural puncture headache in patients with COVID-19, the epidural blood patch should be avoided [98], instead, regional analgesia can be used with peripheral blocks (greater occipital nerve block, lesser occipital nerve block, sphenopalatine ganglion block, and/or trigger point injections) [99, 100].

7.3 Peripheral nerve blocks

The introduction of ultrasound guidance has facilitated the development of new regional blocks with safe and effective results, for example, the erector spinae plane block, quadratus lumbar block, injection between the popliteal artery and the posterior knee capsule, pectoral nerve blocks, the transverse plane of the abdomen

and many more [101]. The use of ultrasound guidance in peripheral nerve blocks performed by an expert anesthesiologist reduces the incidence of failure and complications. The ultrasound machine and all the accessories used must be properly protected with disposable plastic and be sanitized at the end of each nerve block. Murata et al. published some recommendations when using ultrasound-guided regional anesthesia [102] since the gel, the transducer, as well as the ultrasound machine used, are vectors that can transmit pathogens, including SARS-CoV2. Devices that only have contact with intact patient skin are classified as non-critical and can be sanitized with 70–90% alcohol, aldehyde, phenolic and quaternary ammonium-based disinfectants, and be used in conjunction with a single-use sterile transducer cover during the procedure. Needle guidance aids that are affixed to the transducer must be sterilized if re-used, but sterile and disposable attachments may be better suited for use in a pandemic. At the end of each regional block, the gel residues must

Planning	Equipment/supplies	Regional anesthesia	Comments
COVID-19 positive patients or persons under investigation			
Check COVID-19 status Examine cardiopulmonary, renal, hematological, metabolic, and neurological status Chest CT or NMR	HCWs with full PPE Protect and sanitize equipment	Not contraindicated	RA is contraindicated in severe cases with multiorganic failure Postpone surgery if not urgent 7 weeks or longer after infection
Post-COVID-19 patients			
Test Cardiopulmonary, renal, hematological, metabolic, and neurological status Chest CT or NMR Negative PCR test	MPPE	Not contraindicated Peripheral nerve blocks if possible	Neuraxial anesthesia could be contraindicated in dysautonomia and cardiac injury
Asymptomatic carriers			
Positive PCR, Antigen detection test, Antibody detection test	HCWs with full PPE Protect and sanitize equipment	Not contraindicated	Non-urgent or necessary surgery should be postponed until there is a negative PCR. In urgent surgery RA is preferable, Use full PPE
Patients vaccinated against COVID-19			
Negative PCR test	MPPE	Better option	Postpone surgery if there is an adverse vaccine reaction Vaccination should be done 2 weeks before surgery Vaccinated patients may have COVID-19 or be carriers
Non-COVID-19 patients			
Negative PCR test	MPPE	Best selection	Use your anesthetic of choice technique It is prudent to use minimum protective equipment Make a reasonable follow up of your patient via telephone/ online in search for data from Covid-19

Patient with N95 mask at all times, nasal O2 only if necessary. RA = Regional anesthesia. PPE = Personal protective equipment. MPPE = Minimum personal protective equipment.

Table 4.
Recommendations for the management of regional anesthesia in the era of COVID-19.

be cleaned. If there are blood or body fluids on the transducer or its cable, they must also be decontaminated because they can be a vector for viral transmission.

A study to retrospectively analyze two cohorts of pre-pandemic vs. intrapandemic patients undergoing breast cancer surgery compared general anesthesia vs. paravertebral blocks and found that regional anesthesia significantly reduced hospital discharge time, the need for postoperative analgesics, time in the PACU, and the incidence of postoperative nausea and vomiting, concluding that this type of block offers safe anesthesia for patients and HCWs are not exposed to aerosols produced by general anesthesia, especially anesthesiologists [102].

Some nerve blocks can affect pulmonary function due to paralysis of the diaphragm or incidental pneumothorax. Brachial plexus block, stellate ganglion block, cervical epidural block, and thoracic subarachnoid anesthesia are procedures that could worsen borderline lung function in some patients with severe COVID-19 pneumonia, so these types of regional anesthesia should be avoided in these patients o meticulously adopt the recommendations to avoid these incidents.

There is always the possibility that regional anesthesia could fail. Before starting the surgery, it should be tested whether the dermatomes where the surgery will be performed have been adequately anesthetized. When the surgery is prolonged, conversion to general anesthesia is necessary. In both situations, the anesthesiologist must protect himself according to the established guidelines depending on whether it is a patient with active COVID-19 or one of the other scenarios described above, minimizing the production of aerosols. The possibility of systemic toxicity due to local anesthetics is remote, but if it develops it represents a true emergency that occasionally requires tracheal intubation. This emergency must be resolved in accordance with the established treatment protocols and the personnel must be properly protected to avoid becoming infected during the management of the airway [87].

Table 4 lists updated recommendations on the study, evaluation, and management of regional anesthesia in the various intrapandemic clinical scenarios. These are suggestions, which can be adapted to local needs and capabilities.

8. Conclusions

SARS-CoV-2 is the third coronavirus producing an outbreak of this century, and surely it will not be the last pandemic. The progressive appearance of variants, especially Delta and Omicron with a rapid transmission potential confirms that the pandemic is endless, with a greater negative impact which commits us to maintain prevention and management protocols in accordance with the recommendations dictated by experts. Perioperative SARS-CoV-2 infection increases postoperative mortality, which is why it has been determined that these patients should postpone elective surgery whenever possible. A prospective, multicenter, international study compared patients with and without COVID-19 undergoing urgent surgery, finding a 30-day adjusted primary mortality in patients without COVID-19 of 1.5% (95% CI: 1.4–1.5), while those affected by SARS-CoV-2 mortality was significantly increased in those who undertook surgery within 0–2 weeks, 3–4 weeks and 5–6 weeks of diagnosis (odds ratio (95% CI) 4.1 (3.3–4.8), 3.9 (2.6–5.1) and 3.6 (2.0–5.2), respectively). This study recommends that surgery should be postponed for at least 7 weeks after COVID-19 infection, and patients with ongoing symptoms ≥7 weeks from diagnosis may benefit from a longer delay [102]. Proper triage of urgent and non-urgent surgical patients is mandatory for the surgical team to minimize the exposure of HCWs and patients during this era. All patients with unknown COVID-19 status should be considered suspect and therefore essential precautions should be taken for their management.

Although a large number of patients affected by COVID-19 require urgent surgery under general anesthesia, an undetermined number of cases can be properly managed with regional anesthesia, especially those patients without severe respiratory failure, myocardial involvement, or coagulation disorders. Regarding the best anesthetic management of all types of patients in this era of COVID-19, we must identify all the available pieces and prudently put them together in a plan based on the evolutionary complexity of this pandemic puzzle, in such a way that patients, HCWs, and the use of supplies and medical equipment are optimized to the maximum. On the other hand, this goal should consider anesthetic management that reduces the possibility of perpetuating the global, regional and local spread of this virus. Regional anesthesia has come to reach a prominent place in the comprehensive management of these patients, and the various clinical environments must be considered, with obstetrics being a special group due to the particular physiological changes of pregnant women.

The coronavirus 2 pandemic will continue to change humanity and we as anesthesiologists will continue to run in this deadly marathon under new and changing health care modalities, whether in the perioperative areas, the emergency rooms, or the intensive care units. Undoubtedly, our professional practice will continue to be of very high risk, so the perioperative management of patients with COVID-19 and the various clinical scenarios that this health crisis has generated must keep us alert and in need of continuous updating.

Conflict of interest

There is no conflict of interest.

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