Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Role of anaesthesiologists during the COVID-19 outbreak in China

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Brief title: Anaesthesiologists in COVID-19 care

Keywords: airway management; anaesthesiologist; China; critical care; coronavirus, COVID-19; infection control; rapid response team

From December 2019, a respiratory disease caused by the novel coronavirus SARS-CoV-2 was traced to Wuhan, China, and transmitted to over 143 countries. On 30 January 2020 the WHO designated the novel coronavirus pneumonia outbreak as a global health emergency and named it COVID-19. As of 15 March 2020, 81048 confirmed COVID-19 cases had been reported in China.[1] From 24 January, the traditional Chinese New Year eve, over 42,000 healthcare providers from all around China have gathered in Wuhan to support the local healthcare system (data from National Health Commission of China). Among them, over 1000 were anaesthesiologists (data from Chinese Society of Anaesthesiology, CSA). In the battle against COVID-19, Chinese anaesthesiologists explored new working models to improve patient outcomes and minimize the risk of contracting COVID-19.

Airway management team

COVID-19 can have similarities and differences compared to Severe Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS) in terms of infectious period, transmissibility, clinical severity, and extent of community spread (table 1). With the increasing knowledge of the clinical progress of COVID-19 cases, the timing of invasive ventilation changed. As indicated by computed tomography (CT) results,[2] 5-8 days after onset

of initial symptoms the infection rapidly aggravated and extended to a bilateral multi-lobar pulmonary effusion and consolidation. Although non-invasive ventilation temporarily improves oxygenation in COVID-19 patients, it may not necessarily change the natural course of the acute respiratory distress syndrome (ARDS).[3] On 18 February 2020, the state council of China issued *Question and answers of tracheal intubation for novel coronavirus pneumonia cases*, in which the criteria for tracheal intubation were defined as oxygenation index < 150 mmHg after at least 2 h of continuous positive airway pressure (CPAP) with 100% oxygen, and it was recommended that intubation be scheduled rather than emergent. According to the new criteria, patients would receive intubation and ventilation therapy earlier. As a result, more patients needed intubation. In many hospitals, airway management teams consisting of skilled anaesthesiologists were established to meet the need for intubation.

Depending on the anaesthesiologists available, airway management team size was 4-18 people. Airway management team members worked in rotation, with only 1-2 anaesthesiologists in the isolation ward at a time. The minimal size helps avoid unnecessary viral exposure. An intubation cart containing modular packs of medicines and materials was kept in the ward to minimise the traffic of people bringing materials into the room. Videolaryngoscopy with a replaceable blade was widely used to avoid placing the face of the anaesthesiologist close to the patient. Light wand, laryngeal mask airway (LMA), flexible bronchoscope and cricothyroid puncture kit were also available in the cart in case of difficult intubation. Protocols for unanticipated difficult airway were followed, highlighting the role of an intubating LMA.[4]

Any known or suspected COVID-19 patient must be regarded as ultra-high risk. Tracheal intubation of these patients is a high-risk aerosol-generating airway procedure requiring standard grade 3 personal protective equipment (PPE)[4] including an N95 mask, goggles, face shield, double gown, double gloves, protective overshoes, and a powered respirator (powered air purifying respirators).

The Airway Management group of the CSA issued *Expert Recommendations for Tracheal Intubation in Critically ill Patients with Novel Coronavirus Disease 2019* on 22

February, 2020.[4] According to these recommendations and current evidence, principles include minimizing generation of aerosols (see Supplemental Digital Content 1 for guidance for tracheal intubation of COVID-19 cases).[4 5] Bag-mask ventilation prior to intubation, patient coughing during laryngoscopy or intubation, and inadequate sedation putting the patient at risk of agitation can generate aerosols. With adequate pre-oxygenation, bag-mask ventilation can ideally be avoided. Continuous positive airway pressure (CPAP) with 100% oxygen for 5 min is recommended for pre-oxygenation. If available, high-flow nasal cannula (HFNC) delivery systems can be used for pre-oxygenation, though these can increase the risk of viral spread through aerosol generation.[6] To minimise this risk, the mouth and nose of the patient can be covered with normal saline saturated gauze during pre-oxygenation. To avoid agitation and cough, intubations are best done using a rapid sequence intubation technique.[4 5] Midazolam, propofol and etomidate can be used depending on the patient condition. After sedation, at least 0.9 mg kg^{-1} of rocuronium or 1 mg kg^{-1} of succinylcholine should be used. A hydrophobic filter should be attached to the resuscitation bag, between the mask or tracheal tube (TT) and the bag. When difficult airway is anticipated, flexible bronchoscopic intubation can be performed using a videobronchoscope. Awake fibreoptic intubation should be avoided to decrease exposure to aerosols.[5] If unanticipated difficult airway occurs, anintubating LMA and surgical airway can be considered.

Extubation with minimal agitation and coughing is important for both ICU patients and surgical patients. Careful suctioning with a closed sputum suction device before return of consciousness can be important.[7] A recent meta-analysis[8] reported that procedures (including dexmedetomidine, remifentanil, fentanyl, and lidocaine i.v., intracuff, tracheal or topical) were all better than placebo in reducing moderate to severe emergence cough, with dexmedetomidine ranked the most effective. Dexmedetomidine and lidocaine by various routes have been used in COVID-19 cases. Extubation before return of consciousness is recommended for patients without a difficult airway.[7] However, a device for reintubation should be available. Extubation without removal of the filter is important. [4]

Intensive care

Anaesthesiologists in surgical intensive care units (SICU) and anaesthesia intensive care units (AICU) contribute greatly to the management of COVID-19 cases. At Jinyintan Hospital in Wuhan,[9] of 17 patients who developed ARDS, 11 worsened in a short period of time. At Zhongnan Hospital in Wuhan,[10] 47.2% of patients in the ICU received invasive ventilation and four were switched to extracorporeal membrane oxygenation (ECMO). Preprint reports of deaths revealed that durations from initial symptoms to death were short (15 days, interquartile range 11-20 days).[11] Autopsy results of COVID-19 cases indicated much sticky mucus in the small airways.[12] A high percentage of patients in the ICU need 'active' invasive airway intervention, and critically ill patients may benefit from ECMO, two fields that anaesthesiologists are expert in.

During the outbreak, critical care services in China were confronted with a rapid increase in the demand on resources. All hospitals and other organizations were involved in the care for COVID-19 cases. In many hospitals airway team members took charge of ventilation management after tracheal intubation. Once intubated, classical ventilation strategies [6 13] have been effective in critically ill COVID-19 cases, including lung protective mechanical ventilation strategies and prone position ventilation. Lung protective mechanical ventilation strategies include low target tidal volume (6 mL kg^{-1} predicted body weight), plateau pressure $\leq$30 cm H_2O, target SaO_2 88–95%, pH $\geq$ 7.25, and intermittent recruitment maneuvers.[14]

Ultrasonography, another technique widely used in the field of anaesthesiology during the last decade in China, was very useful in the management of critically ill COVID-19 patients. Anaesthesiologists usually use ultrasound for nerve blocks, vascular puncture and emergency screenin, of the chest and abdomen. Given potential delay in obtaining examinations including chest radiography for patients under airborne isolation, portable ultrasonography is useful to quickly assist in the diagnosis of conditions such as pleural effusion and pneumothorax.[6] PPE, especially purifying respirators, can preclude procedures such as auscultation. Ultrasonography can also be used in airway evaluation and determination of TT depth.[15]

Fast response resuscitation team

Based on experience during the SARS outbreak,[6] fast response resuscitation teams were organised in some hospitals in Wuhan made up mostly of anaesthesiologists. Members of the resuscitation team stayed on call near the isolated area. During initial resuscitation efforts by the first responder, fast response resuscitation team members would don PPE and take charge of the resuscitation. Like the airway management cart, the resuscitation cart was equipped with modular medicine and equipment to avoid unnecessary traffic. The team size is typically minimized to four to avoid unnecessary viral exposure.

Clinical anaesthesia

During the outbreak of COVID-19, the most important consideration for clinical anaesthesia is infection control. By 10 February 2020, most hospitals in China accepted emergency cases only. However, recently elective surgeries have increased rapidly. Besides, Wuhan, many other areas could also have many infected people. Thus, anaesthesiologists play an essential and demanding role in the preoperative evaluation of COVID-19 infection risk (Supplemental Digital Content 2 shows a fast triage flow chart). Currently, suspicion for infection with COVID-19 requires two symptoms with an epidemiological link, or three without epidemiological link.[13] Epidemiological links include travel within 14 days to affected areas, or close contact within 14 days of illness onset with a confirmed patient, or close contact with a person having fever and respiratory symptoms and travel to an affected area within 14 days of illness onset.[13] Fever may not be present in all patients. The absence of fever in COVID-19 is more frequent than in SARS and MERS, so appropriate infectious control precautions should be in place even in those without typical symptoms.[16] With the spread of the virus to more areas and countries, anaesthesiologists all over the world may face the challenge of weighing the risk of infection and the need for medical care of patients.

Role of academic anaesthesiology organizations in China

Chinese academic anaesthesiology organizations immediately reacted to the COVID-19 outbreak, focusing on improving medical care and protecting anaesthesiologists.

Psychological support for front-line anaesthesiologists. In the care of COVID-19

patients, anaesthesiologists are vulnerable to both infection and mental health problems. They may experience depression by the situation, fear of contagion and spreading the virus to their family and others. The heavy workload and discomfort of wearing PPE for long durations can worsen the depression. Healthcare workers in high-risk clinical settings such as SARS units had substantially more post-traumatic stress symptoms.[17] On 13 February 2020, the CSA established a platform to provide psychological support for healthcare providers, especially for front-line anaesthesiologists and their families. Over 20 psychologists provided consultations for anaesthesiologists who took care of COVID-19 patients.

Continuous update of information on COVID-19. Clear communication with regular and accurate updates about the COVID-19 outbreak were provided to anaesthesiologists in order to improve quality of care and to address their sense of uncertainty and fear. The CSA and Chinese Association of Anaesthesiologists (CAA) issued and updated a series of practice recommendations and consensus guidelines, covering facility organization and anaesthetic care during the outbreak of COVID-19 pneumonia. One of the most recent was expert recommendations for anaesthesia and infection control in elective surgeries during recovery after outbreak[7]. The CSA also established a platform for information on COVID-19 patient care[18]. The most frequently asked questions about COVID-19 are continuously collected and answered.

Online discussion of anaesthesia care by experts and front-line anaesthesiologists. The CSA and CAA organised online discussions on topics including airway management, infection control and medical care of specific populations, such as the parturients, during the outbreak of COVID-19. Experts with experiences in H1N1, SARS and Ebola management and front-line anaesthesiologists were invited into the discussions.

In conclusion, Chinese anaesthesiologists were essential to various critical aspects of the response to the outbreak of COVID-19. Earlier invasive ventilation, establishment of airway management teams and fast response resuscitation teams, and use of point-of-care ultrasonography were major contributions. With the change in epidemiologic characteristics of COVID-19 patients, anaesthesiologists took on the responsibility of infection control as

well.

Authors' contributions

ZL: conception, data collection, revision, and final approval of the manuscript

HD: conception, revision, and final approval of the manuscript

MY: data collection, writing of the draft, and final approval of the manuscript

Declaration of interest

The authors declare that they have no conflict of interest.

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Table 1 Comparison of COVID-19, SARS and MERS

Characteristics	COVID-19	SARS	MERS
Clinical symptoms	Cough or not, sore throat, shortness of breath, fever, myalgia	Cough, dyspnea, fever, chill, malaise, headache, diarrhoea	Sore throat, dry cough, dyspnea, fever, chill, rigors
Epidemiology	R_0: 2.2-6.49, mean 3.28[19] Pre-symptomatic transmission exists	R_0: 2-5 Peak viral shedding occurs after patients were already quite ill	R_0<1
Mortality	5735/153517 (3.7%)[a1]	774/8096 (9.6%)[b20]	858/2494 (34.4%)[c 21]
Computed tomography results[2]	Multifocal patchy GGOs with subpleural distribution, progresses into diffuse heterogeneous consolidation with GGO	Subpleural GGO and consolidation, prominent lower lobe involvement, interlobular septal and intralobular septal thickening	Bilateral, basilar and subpleural airspace, extensive GGO and occasional septal thickening and pleural effusions
Pathology			
Lung	Early phase[22]: lung oedema, proteinaceous exudate with globules, patchy inflammatory cellular infiltration Late phase[23]: pulmonary oedema with hyaline membrane formation, interstitial mononuclear inflammatory infiltrates, viral cytopathic-like changes in the intra-alveolar spaces	Bilateral lung extensive consolidation, localized haemorrhage and necrosis, desquamative pulmonary alveolitis and bronchitis, proliferation and desquamation of alveolar epithelial cells Viral particles in	Necrotising pneumonia, pulmonary diffuse alveolar damage[24]

		lung tissue[24]	
Other organs	Mild interstitial mononuclear inflammatory infiltrates in the heart [23] Influence on other organs still not defined[12]	Massive necrosis of splenic lymphoid tissue; systemic vasculitis; thrombosis in small veins; degeneration and necrosis of parenchyma cells in the lung, liver, kidney, heart, and adrenal gland[24]	Acute kidney injury, portal and lobular hepatitis and myositis with muscle atrophic changes. Brain and heart were histologically unremarkable[24]

[a]Data as of March 15, 2020

[b]Data up to 2003

[c]Data up to November, 2019

COVID: coronavirus disease; ARDS: acute respiratory syndrome; MERS: Middle-east respiratory syndrome; GGO: ground-glass opacity; SARS: xxx