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The Perioperative Management of Subarachnoid Hemorrhage During the Coronavirus Disease 2019 Pandemic in China

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Key words
- Coronavirus disease 2019
- Perioperative management
- Subarachnoid hemorrhage

Abbreviations and Acronyms
COVID-19: Coronavirus disease 2019
OR: Operating room
SAH: Subarachnoid hemorrhage

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■ BACKGROUND: **For most of the international community outside the epicenter, coronavirus disease 2019 (COVID-19) containment is normalizing, and daily medical practice runs parallel to preventing and treating COVID-19. This experience of simultaneously conducting emergent surgery and infection control for COVID-19 disease is useful outside the epicenter during the pandemic.**

■ CASE DESCRIPTION: **In this single-center retrospective observational study, we enrolled patients with subarachnoid hemorrhage (SAH) who were emergently admitted from January 23 to April 8, 2020. Based on the COVID-19 triage, patients with SAH were divided into 3 categories: positive, negative, and under investigation. During 77 days, 90 patients with SAH were admitted at the center. The median age was 55 years (range, 18–80 years) and 40 patients (44.4%) were male. None was positive, 42 patients were negative, and 48 patients were under investigation for COVID-19 before surgery. During the same period, 9 patients were diagnosed with COVID-19 without nosocomial infection.**

■ CONCLUSIONS: **Rescuing patients with SAH and containment of COVID-19 benefit from joint prevention and control, a centralized system of equipment distribution and personnel assignment, and quick workflow establishment.**

INTRODUCTION

The outbreak of a novel coronavirus has led to a public health emergency of international concern. Despite rigorous global containment and quarantine efforts, the total number of coronavirus disease 2019 (COVID-19) cases worldwide continues to increase. At the time of writing, the cases of COVID-19 had increased to 7,690,708, with 427,630 deaths (mortality 5.6%).[1] In China, 83,181 cases had been confirmed, and 4634 individuals had died (mortality 5.6%).

During the ongoing COVID-19 pandemic, most hospitals have postponed or even canceled elective surgery to divert medical resources to patients with COVID-19. However, some emergent surgery is inevitable for life-threatening conditions. Subarachnoid hemorrhage (SAH) is a prevalent emergent disease of the central nervous system.[2] Early and aggressive surgery or intervention reduces morbidity and mortality.[3] In addition, SAH is also complicated with fever and pulmonary changes,[4,5] which need to be differentiated from COVID-19.

Increasingly more medical institutions outside the epicenter face the dilemma of launching routine clinical practice and preventing COVID-19.[6] Therefore, the report of SAH cases from Beijing, China might be helpful during the pandemic.

METHODS

This report of a case series was approved by the ethics committee of Beijing Tiantan Hospital, Capital Medical University (reference number KY 2020-036-02) on May 20, 2020. Written informed consent was waived. We retrospectively observed patients with SAH admitted at Beijing Tiantan Hospital, Capital Medical University between January 23, 2020 and April 8, 2020.

All materials and data were retrieved from the database of electronic medical record systems, including demographics, baseline characteristics, COVID-19 triage, perioperative treatment, medical cost, and prognosis. American Society of Anesthesiologists physical status, Hunt-Hess classification,[7] World Federation of Neurosurgical Societies scale,[8] and Fisher computed tomography classification[9] were used to evaluate general condition and severity of SAH (**Supplementary Table 1**). COVID-19 triage included traveling history to Wuhan, body temperature, chest radiography or pulmonary computed tomography, complete blood count, and 2 consecutive nucleic acid tests. The nucleic acid test was added to the triage on February 28, 2020. A positive screening result was made according to the Chinese guidelines for COVID-19 diagnosis and treatment.[10,11] Based on the preoperative COVID-19 triage, patients were classified into 3 categories: positive, negative, and under investigation. Patients with a positive result on the COVID-19 nucleic acid test were classified as positive. Patients with all negative results in COVID-19

Table 1. Demographics and Baseline Information

Variable	All Patients (n = 90)	Under-Investigation Group (n = 48)	Negative Group (n = 42)	*P* Value*
Characteristics				
Age (years), median (range)	55 (18–80)	56 (18–80)	55 (23–67)	0.411
Male sex, n (%)	40 (44.4)	18 (37.5)	22 (52.4)	0.156
Body mass index (kg/m^2) (range)	24.0 (15.6–32.1)	24.0 (17.7–31.3)	25.0 (15.6–32.1)	0.123
Comorbidity, n (%)				
Hypertension	44 (48.9)	24 (50.0)	20 (47.6)	0.822
Cardiovascular disease	10 (11.1)	7 (14.6)	3 (7.1)	0.262
Respiratory disease	28 (31.1)	16 (33.3)	12 (28.6)	0.626
Endocrine system disease	11 (12.2)	7 (14.6)	4 (9.5)	0.465
American Society of Anesthesiologists physical status				0.453
III	61 (67.8)	30 (62.5)	31 (73.8)	
IV	25 (27.8)	16 (33.3)	9 (21.4)	
V	4 (4.4)	2 (4.2)	2 (4.8)	
Hunt-Hess grade, n (%)				0.835
1	25 (27.8)	12/48 (25.0)	14/41 (33.3)	
2	52 (58.9)	39/48 (60.4)	22/42 (52.4)	
3	7 (7.8)	4/48 (8.3)	3/42 (7.1)	
4	6 (6.7)	3/48 (6.3)	3/42 (7.1)	
Fisher computed tomography grade, n (%)				0.124
1	22 (24.4)	7 (14.6)	15 (35.7)	
2	38 (42.2)	22 (45.8)	16 (38.1)	
3	15 (16.7)	9 (18.8)	6 (14.3)	
4	15 (16.7)	10 (20.8)	5 (11.9)	
World Federation of Neurosurgical Societies scale grade, n (%)				0.754
1	56 (62.2)	28 (58.3)	28 (66.7)	
2	11 (12.2)	6 (12.5)	5 (11.9)	
3	5 (5.6)	2 (4.2)	3 (7.1)	
4	12 (13.3)	8 (16.7)	4 (9.5)	
5	6 (6.7)	4 (8.3)	2 (4.8)	
Diagnosis, n (%)				0.638
Aneurysm	87 (96.7)	46 (95.8)	41 (97.6)	
Arteriovenous malformation	3 (3.3)	2 (4.2)	1 (2.4)	
Treatment, n (%)				0.265
Craniotomy	37 (41.1)	20 (41.7)	17 (40.5)	
Endovascular therapy	39 (43.3)	18 (37.5)	21 (50.0)	
Angiography	14 (15.6)	10 (20.8)	4 (9.5)	

**P* value reflects the statistical comparison between 2 groups.

Table 2. Surgical and Anesthetic Information and Outcomes

Variable	All Patients (n = 90)	Under-Investigation Group (n = 48)	Negative Group (n = 42)	P Value*
Operation site, n (%)				0.254
Regular OR	44 (48.9)	24 (50.0)	20 (47.6)	
Isolation OR	40 (44.4)	19 (39.6)	21 (50.0)	
Negative-pressure OR	6 (6.7)	5 (10.4)	1 (2.4)	
Type of anesthesia, n (%)				0.073
General anesthesia	72 (80.0)	35 (72.9)	37 (88.1)	
Tracheal intubation	47 (52.2)	28 (80.0)	19 (51.4)	
Laryngeal mask	25 (27.8)	7 (20.0)	18 (48.6)	
Monitored anesthesia care	18 (18.9)	13 (27.1)	5 (11.9)	
Duration (minutes), mean (SD)				
Surgery	151.6 (78.9)	155.9 (88.0)	146.7 (67.6)	0.579
Anesthesia	192.4 (90.3)	196.9 (101.2)	187.4 (76.8)	0.616
Delayed tracheal extubation, n (%)	27 (30.0)	15 (31.2)	12 (28.6)	0.782
Length of hospital stay (days), mean (SD)	14.5 (10.6)	16.2 (10.4)	12.5 (10.6)	0.097
Hospital costs (RMB $\times 10^3$), mean (SD)	127.6 (78.5)	129.7 (86.0)	125.3 (69.9)	0.790
Prognosis, n (%)				0.480
Discharge	87 (96.7)	47 (97.9)	40 (95.2)	
Death	3 (3.3)	1 (2.1)	2 (4.8)	

OR, operating room; SD, standard deviation.
**P* value reflects the statistical comparison between 2 groups.

triage were classified as negative. Patients with a positive result in any one of the screening tests or whose testing was uncompleted were classified as under investigation.

Statistical Analysis

Normally distributed variables were described as means with standard deviation and compared by using independent t tests. Nonnormally distributed variables were summarized as medians with interquartile range and compared by using Mann-Whitney U tests. Categorical variables were described as count and percentage and compared by using χ^2 or Fisher exact tests. The level of significance was set at $P < 0.05$. Analysis was performed with SPSS version 24.0 (IBM Corp., Armonk, New York, USA).

RESULTS

During these 77 days, a total of 90 patients with SAH were consecutively admitted at the emergency. The median age was 55 years (range, 18–80 years) and 40 patients (44.4%) were male. Most patients had comorbidities, including hypertension ($n = 44$, 48.9%), cardiovascular disease ($n = 10$, 11.1%), respiratory disease ($n = 28$, 31.1%), and endocrine disease ($n = 11$, 12.2%) (Table 1).

According to the preoperative evaluation, most patients had mild to moderate SAH. Treatment involved craniotomy clipping ($n = 37$, 41.1%), endovascular therapy ($n = 39$, 43.3%), and conservative treatment after endovascular angiography ($n = 14$, 15.6%). The mean length of hospital stay was 14.5 days and mean cost was 127 thousand RMB. Three patients (3.3%) died and the remaining 87 were discharged from hospital (Table 2).

In the bundle of COVID-19 triage, 45 patients (50.0%) were local to Beijing and none had a history of travel to Wuhan. Abnormal preoperative results for temperature, lymphocyte count, and pulmonary presentation on chest radiography or pulmonary computed tomography were observed in 6 (6.7%), 30 (33.3%), and 26 (28.9%) patients, respectively. Based on the screening for COVID-19, none was positive, 48 patients were under investigation, and 42 had negative results. Thirty-nine patients (43.3%) completed the first pharyngeal sampling before surgery (Table 3).

The demographics, baseline characteristics, diagnosis, SAH severity and comorbidity, and surgical approach were similar between patients from the negative and under-investigation group (Table 1). More patients under investigation received surgery in a negative-pressure operating room (OR) (5 vs. 1), controlled ventilation through tracheal intubation (28 vs. 19), and delayed extubation (15 vs. 12) than did negative patients. The mean length of hospital stay was 4 days more in patients under investigation than in negative patients. During the same period, 9 patients were diagnosed with COVID-19 in the same institution without infection of health workers.

DISCUSSION

To contain the development of the COVID-19 pandemic, travel restrictions were imposed in Wuhan, China from January 23, 2020 to April 8, 2020. During these 77 days, 9 patients confirmed to have COVID-19, 90 patients with SAH and another 1632 patients underwent surgeries; no medical staff were infected in the center. The experience might be closely associated with the early establishment of a workflow (Figure 1) of infection control for emergent surgical patients. This workflow was created based on Chinese expert consensus for anesthesia management of surgical cases during the COVID-19 pandemic.[11,12]

The abnormal body temperature and white blood cell counts in patients with SAH should be differentiated from those with COVID-19. Fever is the primary sign (88.7%) of COVID-19 and a progressive

Table 3. Preoperative Screening Test of COVID-19

	Under-Investigation Group (n = 48), n (%)	Negative Group (n = 42), n (%)
Fever (≥37.3°C)	6 (12.5)	0
Low lymphocyte count	30 (62.5)	0
Abnormal in chest radiography	26 (54.2)	0
History of travel to Hubei	0 (0.0)	0
Negative in COVID-19 nucleic acid	17 (35.4)	22 (52.4)
Abnormality in 1 item	33 (68.8)	0
Abnormality in 2 items	15 (31.3)	0

decrease in peripheral blood lymphocyte levels was present in 83.2% of patients.[13,14] Fever after SAH is common as a result of systemic inflammatory reaction, basal cistern irritation, and loss of central temperature control.[15,16] Pneumonia is the most common reason for infectious fever.[5,17] Lung injuries were exacerbated by increased intracranial pressure through the brain–lung cross talk mechanism.[18]

To control the spread of COVID-19, multiple measures were imposed along with an emergent public health policy. First, comprehensive and effective preoperative evaluation and preparation were completed in a limited time frame. A standard protocol of screening was established as the COVID-19 pandemic developed and was completed on February 28, 2020, when the severe acute respiratory syndrome coronavirus 2 nucleic acid test was introduced to the screening. Two consecutive negative nucleic acid test results with intervals of 24–48 hours were required. However, only 43.3% of patients completed the first pharyngeal sampling before surgery, considering the urgency of the intervention.

Second, patients with SAH were treated in a designated area and transferred through a specific route before COVID-19 infection was clearly ruled out. After the first nucleic acid test, patients with SAH were admitted to the transition ward or directly transferred to the OR. For patients under investigation, most surgeries were performed in the negative-pressure OR and isolation OR. The negative-pressure OR and isolation OR were located at the outpatient OR and far away from the inpatient building, with isolated ventilation as well as sewage disposal systems. After surgery, patients with SAH were transferred to the isolated intensive care unit until COVID-19 was ruled out. Because of the gradual establishment of the workflow, half of the patients under investigation received surgery in the general OR at an early stage.

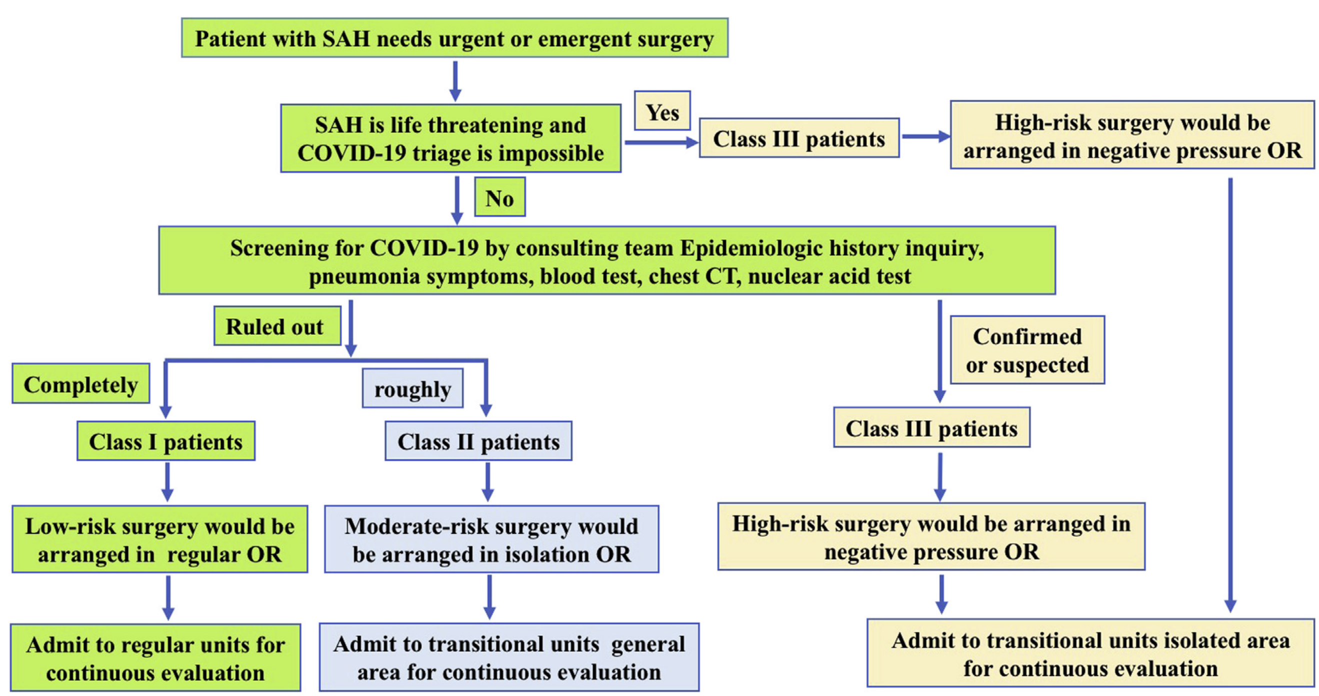

Figure 1. The workflow of the surgery procedure during the pandemic. Class III patients are those with suspected COVID-19, those with confirmed COVID-19, or those who cannot be screened. Class II patients are those in whom the possibility of COVID-19 has basically been ruled out by the emergency department or expert group but who have not completed 2 nucleic acid tests. Class I patients are those in whom the possibility of COVID-19 has basically been ruled out by the emergency department or expert group and who have completed 2 nucleic acid tests. CT, computed tomography; OR, operating room; SAH, subarachnoid hemorrhage.

Third, emergent surgical patients were generally divided into different classes according to both medical conditions and the screening test. Low-risk patients were those in whom COVID-19 was ruled out and who underwent emergency surgery in the general OR. Moderate-risk patients were those who did not complete the screening test for COVID-19 and underwent life-saving emergency surgery in the dedicated OR. High-risk patients were those with confirmed or suspected COVID-19 who received life-saving emergency surgery in the negative-pressure OR. In the report, no patient with SAH was transferred to the designated hospital for COVID-19. Because of anesthesia practices, including endotracheal intubation, anesthesiologists have the highest risk for infection by COVID-19.[19] Anesthesiologists were provided with level-3 protection for high-risk surgical patients.[20]

Joint prevention and control were well embodied in our clinical practice from the beginning of the pandemic. We established a special task force to conduct the nucleic acid test for COVID-19. Physicians from the diverse departments were allocated to pharyngeal swab sampling. Researchers from the laboratory were diverted to performing the clinical nucleic acid test. The overall management was focused on prevention resources and preferentially allocated to health care staff with a high risk of infection. The prevention and control office rapidly formulated the prevention and control workflow and updated it. At the time of writing, 62 documents had been released, ensuring a safe and well-organized medical service during the pandemic.

The successful experience of treating patients with SAH and containment of COVID-19 helps to overcome this difficult period outside the epicenter and will it is hoped provide references for other national areas.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Min Zeng: Writing - original draft. **Shu Li:** Methodology. **Muhan Li:** Visualization. **Xiang Yan:** Data curation. **Ruowen Li:** Data curation. **Jia Dong:** Formal analysis. **Yuewei Zhang:** Writing - review & editing. **Zhongrong Miao:** Writing - review & editing. **Shuo Wang:** Writing - review & editing. **Yuming Peng:** Funding acquisition, Conceptualization. **Ruquan Han:** Funding acquisition, Supervision.

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SUPPLEMENTARY DATA

Supplementary Table 1. Subarachnoid Hemorrhage Severity Clinical Grading Scale: Hunt and Hess, World Federation of Neurosurgical Societies Scale, and Fisher Computed Tomography Scale

Hunt and Hess Grade	World Federation of Neurosurgical Societies Scale	Fisher Computed Tomography Scale
1		
Asymptomatic or mild headache and slight nuchal rigidity	GCS score 15	No subarachnoid hemorrhage or intraventricular hemorrhage
2		
Moderate to severe headache, nuchal rigidity, no focal neurologic deficit other than cranial nerve palsy	GCS score 14—13 without major focal deficit (aphasia or hemiparesis/ hemiplegia)	Diffuse deposition of thin layer with all vertical layers of blood (interhemispheric fissure, insular cistern, ambient cistern) <1 mm thick
3		
Confusion, lethargy, or mild focal neurologic deficit other than cranial nerve palsy	GCS score 14—13 with major focal deficit	Vertical layers of blood ≥ 1 mm thick or localized clots (clots defined as $>3 \times 5$ mm)
4		
Stupor or moderate to severe hemiparesis	GCS score 7—12 with or without major focal deficit	Diffuse or no subarachnoid blood, but with intracerebral or intraventricular clots
5		
Coma, extensor posturing, moribund appearance	GCS score 3—6 with or without major focal deficit	

GCS, Glasgow Coma Scale.