

# Management Protocol for Emergency Aneurysm Craniotomy Clipping in Non-Major COVID-19 Epidemic Areas in Beijing, China

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## Research

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# Abstract

**Background:** An epidemic of COVID-19 outbreaked in Wuhan, China since December 2019. The ordinary medical service were hindered, however, the emergency cases including aneurysmal subarachnoid hemorrhage (aSAH) still required timely intervention and provoked challenges to the management protocol. In this study, we summarized our experience in the emergency management of aSAH (Beijing Tiantan Protocol, BTP) in Beijing, China.

**Methods:** Demographic, clinical and imaging data of consecutive emergency aSAH patients who underwent craniotomy clipping during the COVID-19 epidemic season were reviewed and compared with the retrospective period last year. Subgroup analysis was further performed to assess the outcomes of different screening results and different detail protocols. Neurological outcome was assessed with the modified Rankin Scale (mRS).

**Results:** A total of 127 aSAH referred to our emergency department and 42 (33.1%) underwent craniotomy clipping between January 20, 2020 and March 25, 2020. Compared with the retrospective period last year, the incidence of preoperative hospitalized adverse events and postoperative outcomes were similar (0.1, 95% CI 1.0 to 0.8,  $P=0.779$ ). In the subgroup analysis, 8 (19.0%) were initially screened as preliminary undetermined COVID-19 and 2 of them underwent craniotomy clipping in the negative pressure operating room (OR), the prognosis of patients with varied COVID-19 screening results was similar ( $F(2, 39) = 0.393$ ,  $P=0.678$ ). Since February 28, 12 cases (28.6%) received COVID-19 nucleic acid testing (NAT) upon admission and all showed negative, the false negative rate was 0.0%. The preoperative hospitalized adverse events and postoperative prognosis were still similar between patients with and without COVID-19 NAT (-0.3, 95% CI -1.4 to 0.9,  $P=0.653$ ).

**Conclusions:** Our emergency surgery management protocol (BTP) is reliable for scheduling emergency aneurysm craniotomy clipping in non-major epidemic areas.

## Introductions

In December 2019, an outbreak of pneumonia with unknown causes broke out in Wuhan, China. On January 7, 2020, Chinese scientists isolated a new type of coronavirus from the virus-infected pneumonia patients (1), which was later designated as coronavirus disease 2019 (COVID-19) by World Health Organization (WHO) in February 2020 (2). As of March 28, 2020, more than 500,000 cases of COVID-19 pneumonia have been confirmed globally, with a mortality rate of 4.3%.

On January 20, 2020, the first confirmed case of COVID-19 in Beijing (China) was confirmed in our hospital. During the past 65 days, a total of 416 confirmed cases have been reported in Beijing. Beijing has a permanent population of 21.53 million according to statistics from the Beijing Municipal Bureau of Statistics in 2019, and aneurysmal subarachnoid hemorrhage (aSAH) has an approximate incidence of 9 per 100,000 and a mortality rate of about 60% within 6 months (3), which means that a large number of aSAH patients are diagnosed every day. Beijing Tiantan Hospital is the biggest neurosurgery center in

China, and most of aneurysmal SAH patients in Beijing were treated in our hospital during this special period. To our knowledge, no previous studies have proposed a standardized and highly reliable emergency aSAH surgical treatment protocol in non-major COVID-19 epidemic areas. Based on the published incident management system by our hospital (4), we summed up our experience in the safe and effective protocol (Beijing Tiantan Protocol, BTP) of emergency admissions, transfer, surgery, and ward management for aSAH in non-major COVID-19 epidemic areas (416 to 21.53 million), which can provide references for most non-major epidemic cities in the world.

## Materials And Methods

### Study Design and Participants

This retrospective study included a single-center consecutive cohort of emergency aSAH inpatients from Beijing Tiantan Hospital (Beijing, China) between January 20, 2020 and March 25, 2020. The inclusion criteria were as follows: (1) Patients' preoperative CTA or digital subtraction angiography (DSA) indicated that the responsible lesion for SAH was cerebral aneurysms. (2) Patients undergoing emergency craniotomy clipping for the responsible aneurysms. (3) The duration between emergency admission and craniotomy was less than 72 hours. Written informed consent for collecting clinical information was obtained from each patient at admission. This study was performed according to the guidelines of the Declaration of Helsinki and was approved by the Institutional Review Board at Beijing Tiantan Hospital.

Finally, a total of 42 aSAH patients were enrolled in this study. In order to assess whether the BTP increased the risk of preoperative hospitalized adverse events and poor postoperative prognosis, we collected the baseline characteristics and prognostic data of emergency aSAH patients during the retrospective period last year (18 cases).

### Data Collection and Definition

Epidemiological, demographic, clinical, laboratory, treatment, and outcome data were extracted from electronic medical records using a standardized data collection form. Fever was defined as axillary temperature of at least 37.3°C (5). Positive epidemiological history, laboratory test and imaging findings were defined according to the Chinese management guideline for COVID-19 (version 5.0) (6). Fisher scale, modified Fisher scale, Hunt-Hess scale, World Federation of Neurological Surgeons (WFNS) scale, Glasgow Coma Scale (GCS) was used to evaluate the categories of severity (7-10). DCI was defined as new cerebral infarction identified on CT or magnetic resonance imaging (MRI) or proven at autopsy after excluding procedure-related infarction, or a new focal neurologic deficit and a persistent clinical deterioration after excluding other potential causes (11, 12). The mRS score was obtained when discharge. All data were checked by two physicians (YC and XLC) and a third researcher (LM) adjudicated any difference in interpretation between the two primary reviewers.

# Beijing Tiantan Protocol

After the patient came to the emergency department, the emergency physicians prescribed CT/CTA and clinical presentations to confirm the diagnosis of aSAH. Emergency physicians protect themselves according to the second-level protection standards: work clothing, shoe covers, disposable working caps, N95 masks (replace every 4 hours or when it is wet or at any time if there is pollution), goggles, protective clothing or isolation clothes, latex gloves (6, 13). Preliminary screening for COVID-19 in the emergency department included epidemiological history, admission axillary temperature, routine blood test, and lung CT (6). And then, the consultation team of COVID-19 prevention and control experts (consist of directors of emergency department, respiratory department and nosocomial infection department) in our hospital would evaluate the preliminary screening results and divided them into five groups: negative, preliminary undetermined (1), preliminary undetermined (2), suspected, and confirmed (**Figure 1**).

Since February 28, COVID-19 NAT was added to the screening protocol. The first COVID-19 NAT (pharyngeal swab, result waiting time: 6 hours) and routine preoperative preparation would be performed immediately in the transition ward (the standard of protection is the same as COVID-19 isolation ward: third-level protection standards). If the consultation result was “suspected or confirmed patient”, we do not recommend delaying surgery if the hospital has adequate protective equipment. We have dedicated patients transport channels, dedicated surgical teams and dedicated negative pressure OR. The surgical team should protect themselves according to the third-levels of protection standards: work clothing, protective boot covers, disposable working caps, N95 masks, goggles, medical protective masks (or positive pressure head covers), protective clothing, double-layer latex gloves (6, 13). After the surgery, the patients would be sent to the COVID-19 isolation negative pressure ICU. For the “preliminary undetermined” patients, if any 2 items of epidemiological history and clinical presentation were positive, the management protocol would be similar as the “suspected and confirmed” cases. If any 1 item of epidemiological history and clinical presentation was positive, the treatment protocol would be similar as the screening “negative” cases. For the screening “negative” patient, emergency craniotomy for clipping aneurysms would be arranged in the conventional OR. Both of the screening “negative and preliminary undetermined (1)” patients would be sent to the ordinary ICU after the surgery. The second COVID-19 NAT would be performed 24 hours after the first NAT for all emergency aSAH patients. According to the second COVID-19 NAT, it would be determined whether the patient be transferred to the Ordinary Ward / Ordinary Ward (single bed) / Transition Ward (refer to ordinary ward 14 days later if confirmed negative) / Isolation Ward (refer to designated hospital for COVID-19 when suitable).

Perioperative management of aSAH was the same as that recommended in previous guidelines (3, 14). Besides, the above screening procedures were performed again in patients with postoperative fever of unknown causes and in preoperative undetermined suspected cases. If the COVID-19 NAT was positive, the patients would be transferred to the COVID-19 designated hospital for further treatment after the intracranial condition stabilized. For screening negative, preliminary undetermined (1) and preliminary undetermined (2)/suspected/confirmed patients, paramedic adopts first-level protection standards (first-layer work clothes [eg, scrubs], disposable working caps, surgical masks), second-level protection

standards and third-level protection standards after operation, respectively (6, 13). Family members of the patient are not allowed to accompany the patient in the ward during the hospitalization. Visitors need to pass the preliminary screening of epidemiological history and temperature measurement.

## Statistical analysis

Continuous and categorical variables were presented as mean  $\pm$  standard deviations (SD) and counts (with percentages). Two-tailed t tests were used otherwise for continuous variable with Gaussian distribution. The Mann-Whitney U (Wilcoxon) test was used to compare non-normal distribution continuous variables. For categorical variables, either the Fisher exact test or the Pearson chi-square test was used. Statistical analysis was performed using SPSS (Version 25.0, IBM). The significance threshold was set at a 2-sided *P* value less than 0.05.

## Results

### Baseline characteristics

From January 20, 2020 to March 25, 2020, there were 9 patients diagnosed of COVID-19 with positive nucleic acid testing (NAT) in our hospital for all kinds of emergency patients. A total of 127 aSAH patients referred to our emergency department and 42 (33.1%) of them underwent craniotomy clipping (**Figure 2**). The patients' mean age was  $54.9 \pm 8.6$  years (range 35-74 years) (**Table 1**). 8 cases (19.0%) were initially screened as preliminary undetermined COVID-19 cases and 2 of them underwent craniotomy clipping surgery in the negative pressure operating room (OR). Since February 28, 12 cases (28.6%) received COVID-19 NAT upon admission and showed negative results, and the false negative rate was 0.0%. The location of responsible aneurysms were mostly located in the anterior communicating artery (ACoA, 31.0%), posterior communicating artery (PCoA, 35.7%), middle cerebral artery (MCA, 26.2%). The modified Fisher grade and Hunt-Hess grade was  $3.0 \pm 1.1$  and  $1.9 \pm 0.5$ , respectively. The duration between admission and craniotomy was  $34.8 \pm 18.5$  hours. 2 patients (4.8%) occurred generalized epilepsy during hospitalization before craniotomy.

Characteristics	Current	Last year	P value <sup>a</sup>
No. of patients	42	18	
No. of aneurysms	45	19	
Sex (male)	24 (57.1)	8 (44.4)	0.366
Age, years	54.9±8.6	49.4±10.7	0.039*
Admission stratification			
Normal patient	34 (81.0)		
Mild suspected patient	8 (19.0)		
Suspected patient	0 (0.0)		
Confirmed patient	0 (0.0)		
COVID-19 NAT (n=12) (negative)	12 (100.0)		
False negative COVID-19 NAT	0 (0.0)		
Location of responsible aneurysm			
ACoA	13 (31.0)	7 (38.9)	0.585
PCoA	15 (35.7)	5 (27.8)	
ACA	2 (4.8)	0 (0.0)	
MCA	11 (26.2)	6 (33.3)	
others	1 (2.4)	0 (0.0)	
Fisher grade	3.1±1.1	2.9±1.0	0.555
Modified Fisher grade	3.0±1.1	3.1±1.1	0.835
Hunt-Hess grade	1.9±0.5	2.4±0.6	0.003*
WFNS grade	2.7±0.9	2.8±1.1	0.690
GCS	12.9±1.2	12.0±2.3	0.367
Duration between rupture and craniotomy, hours	71.1±55.2	40.7±45.6	0.044*
Duration between admission and craniotomy, hours	37.1±16.8	28.7±11.7	0.058
Preoperative adverse events during hospitalization			
Rebleeding	0 (0.0)	0 (0.0)	>0.99
Infarction	0 (0.0)	0 (0.0)	>0.99

Epilepsy	2 (4.8)	1 (5.6)	>0.99
Duration of surgery, hours	3.5±1.0	4.1±2.3	0.277
Intraoperative blood loss, ml	260.7±238.0	258.3±152.7	0.969
Mean hospital LOS, days	14.9±8.8	17.4±6.9	0.298
Hospitalization cost, dollars <sup>b</sup>	13385.6±6973.4	14006.1±5640.4	0.740
Postoperative complications			
Postoperative hemorrhage	0 (0.0)	1 (5.6)	0.660
Postoperative DCI	13 (31.0)	8 (44.4)	0.315
Postoperative DVT	10 (23.8)	1 (5.6)	0.190
Postoperative intracranial infection	5 (11.9)	4 (22.2)	0.528
Discharge mRS score			
Mean	1.9±1.6	2.1±1.6	0.779
0-2	29 (69.0)	12 (66.7)	0.856
3-6	13 (31.0)	6 (33.3)	
<p>ACA = anterior cerebral artery; ACoA = anterior communicating aneurysm; aSAH = aneurysmal subarachnoid hemorrhage; COVID-19 = coronavirus disease 2019; CT = computed tomography; DCI = delayed cerebral ischemia; DVT = deep vein thrombosis; GCS = Glasgow Coma Scale; LOS = length of stay; MCA = middle cerebral artery; mRS = modified Rankin Scale; NAT = nucleic acid testing; PCA = posterior cerebral artery; WFNS = World Federation of Neurological Surgeons;</p> <p><sup>a</sup> P values indicate differences between the current period and the respective time period, and P less than 0.05 was considered statistically significant.</p> <p><sup>b</sup> The exchange rate between RMB and USD is 1 USD = 7.0942 RMB.</p> <p>Values are numbers of cases (%) unless otherwise indicated. Mean values are presented with SDs.</p>			

Table 1

Comparison of emergency aSAH patients between the current period and the respective time period last year.

## Comparison between current and retrospective period last year

There were 18 emergency aSAH patients underwent craniotomy clipping in our hospital during the retrospective period last year (**Table 1**). Compared with them, the patients who received BTP were older (5.5, 95% confidence intervals [CI] 0.3 to 10.7,  $P=0.039$ ) and had lower Hunt-Hess grades (0.5, 95% CI 0.2

to 0.8,  $P=0.003$ ). The duration between admission and craniotomy have no statistical differences ( $37.1\pm 16.8$  vs  $28.7\pm 11.7$ ; 8.4, 95% CI -0.3 to 17.1,  $P=0.058$ ), indicating that BTP may not prolong the duration of preoperative hospitalization. Finally, the incidence of preoperative hospitalized adverse events and postoperative neurofunctional outcomes ( $-0.1$ , 95% CI -1.0 to 0.8,  $P=0.779$ ) were similar in both groups. 13 cases (31.0%) in the BTP group and 8 cases (44.4%) in the control group occurred postoperative delayed cerebral ischemia (DCI) (0.6, 95% CI 0.2 to 1.7,  $P=0.315$ ).

## Subgroup analysis

There were no statistical difference in prognosis between the negative cases and preliminary undetermined COVID-19 cases (1) / (2) ( $F(2, 39)=0.393$ ,  $P=0.678$ ) (**Table 2**). Besides, although patients undergoing COVID-19 NAT took slightly longer from admission to craniotomy ( $35.9\pm 15.3$  vs  $40.2\pm 20.4$  hours; 4.4, 95% CI -7.3 to 16.0,  $P=0.453$ ), there were still no differences in preoperative hospitalized adverse events and postoperative prognosis of the patients with or without COVID-19 NAT ( $-0.3$ , 95% CI -1.4 to 0.9,  $P=0.653$ ) (**Table 3**).

Characteristics	Normal (Conventional OR)	Mild Suspected (Conventional OR)	Mild Suspected (Negative Pressure OR)	P value <sup>a</sup>
No. of patients	34	6	2	
Duration between admission and craniotomy, hours	38.5±17.6	32.8±7.4	25.5±23.3	0.456
Preoperative adverse events during hospitalization				
Rebleeding	0 (0.0)	0 (0.0)	0 (0.0)	>0.99
Infarction	0 (0.0)	0 (0.0)	0 (0.0)	>0.99
Epilepsy	1 (2.9)	1 (16.7)	0 (0.0)	0.438
Duration of surgery, hours	3.4±0.9	3.3±0.9	5.5±0.0	0.007*
Intraoperative blood loss, ml	233.8±136.9	200.0±154.9	900±848.5	<0.001*
Mean hospital LOS, days	13.8±7.3	19.3±15.6	20.5±0.7	0.250
Hospitalization cost, dollars <sup>b</sup>	12695.9±5226.2	17568.7±10863.7	12560.6±397.0	0.290
Postoperative complications				
Postoperative hemorrhage	0 (0.0)	0 (0.0)	0 (0.0)	>0.99
Postoperative DCI	9 (26.5)	3 (50.0)	1 (50.0)	0.453
Postoperative DVT	9 (26.5)	1 (16.7)	0 (0.0)	0.497
Postoperative intracranial infection	3 (8.8)	2 (33.3)	0 (0.0)	0.255
Discharge mRS score				
Mean	1.9±1.6	2.2±1.7	1.0±1.4	0.678
0-2	23 (67.6)	4 (66.7)	2 (100.0)	0.466
3-6	11 (32.4)	2 (33.3)	0 (0.0)	

aSAH = aneurysmal subarachnoid hemorrhage; COVID-19 = coronavirus disease 2019; DCI = delayed cerebral ischemia; DVT = deep vein thrombosis; LOS = length of stay; mRS = modified Rankin Scale; OR= operating room;

<sup>a</sup> P values indicate differences among different preliminary COVID-19 screening result, and P less than 0.05 was considered statistically significant.

<sup>b</sup> The exchange rate between RMB and USD is 1 USD = 7.0942 RMB.

Values are numbers of cases (%) unless otherwise indicated. Mean values are presented with SDs.

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Table 2

Subgroup comparison of different preliminary COVID-19 screening result.

Characteristics	Absent	Accept	P value <sup>a</sup>
No. of patients	30	12	
Duration between admission and craniotomy, hours	35.9±15.3	40.2±20.4	0.453
Admission stratification			
Normal patient	26 (86.7)	8 (66.7)	0.151
Mild suspected patient	4 (13.3)	4 (33.3)	
Suspected patient	0 (0.0)	0 (0.0)	
Confirmed patient	0 (0.0)	0 (0.0)	
Preoperative hospitalized adverse events			
Rebleeding	0 (0.0)	0 (0.0)	>0.99
Infarction	0 (0.0)	0 (0.0)	>0.99
Epilepsy	1 (3.3)	1 (8.3)	0.513
Duration of surgery, hours	3.5±0.9	3.5±1.2	0.913
Intraoperative blood loss, ml	236.7±130.6	320.8±400.8	0.490
Mean hospital LOS, days	14.4±9.7	16.3±6.4	0.547
Hospitalization cost, dollars <sup>b</sup>	14268.4±7811.7	11178.5±3596.8	0.198
Postoperative complications			
Postoperative hemorrhage	0 (0.0)	0 (0.0)	>0.99
Postoperative DCI	9 (30.0)	4 (33.3)	0.833
Postoperative DVT	8 (26.7)	2 (16.7)	0.481
Postoperative intracranial infection	3 (10.0)	2 (16.7)	0.558
Discharge mRS score			
Mean	2.0±1.6	1.8±1.5	0.653
0-2	20 (66.7)	9 (75.0)	0.874
3-6	10 (33.3)	3 (25.0)	

aSAH = aneurysmal subarachnoid hemorrhage; COVID-19 = coronavirus disease 2019; DCI = delayed cerebral ischemia; DVT = deep vein thrombosis; LOS = length of stay; mRS = modified Rankin Scale; NAT= nucleic acid test;

<sup>a</sup> P values indicate differences between patients with or without COVID-19 NAT, and P less than 0.05 was considered statistically significant.

<sup>b</sup> The exchange rate between RMB and USD is 1 USD = 7.0942 RMB.

Values are numbers of cases (%) unless otherwise indicated. Mean values are presented with SDs.

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Table 3

Comparison of emergency aSAH patients with/without COVID-19 NAT.

## Illustration case

A 61-year-old male presented with sudden severe headache for 23 hours with nausea and vomiting. Preoperative computed tomography angiography (CTA) revealed a right MCA M1 bifurcation irregular aneurysm (**Figure 3**). The modified Fisher grade was 4 and Hunt-Hess grade was 2. The preliminary COVID-19 screening suggested positive axillary temperature (38.4°C), positive lung CT, and negative COVID-19 NAT (once), and was classified as a preliminary undetermined (2) patient. The consultation group of COVID-19 prevention and control experts judged that the operation should be carried out in the negative pressure OR. The surgical team protected themselves according to the third-levels of protection standards. The operation was performed by a senior neurosurgeon (XLC) with 15 years of experience in aneurysm clipping. During the operation, the field of view under the microscope was relatively limited due to the fogging goggles, and the duration of the operation was 5.5 hours. Intraoperative blood loss was about 300ml. The patient was transferred to the isolation negative pressure intensive care unit (ICU) after operation, and the reexamination of COVID-19 NAT was still negative 24 hours after the first NAT. Then, he was transferred to the ordinary neurosurgical ward (single bed) on the second postoperative day. No postoperative complications occurred and the patient was discharged on the 7th postoperative day, with a modified Rankin Scale (mRS) score of 0.

## Discussion

COVID-19 was identified as a Public Health Emergency of International Concern (PHEIC) by WHO in February 2020. A recent retrospective clinical study suggested that the nosocomial infection rate of COVID-19 was up to 41% (15). which means that the front-line medical workers carry a huge risk of infection of COVID-19 at work, especially in the absence of medical protection supplies. ASAH is a significant cause of morbidity and mortality throughout the world, which was reported a quarter of patients die and 4%-13.6% occurred re-bleeding events within the first 24 hours (14, 16). Therefore, in this special period, how to effectively implement the "safe rescue principle" diagnosis and treatment for emergency aSAH patients with limited medical resources is particularly important (17, 18). After two months of practice and revision, we believe that our admission protocol (BTP) can complete the surgical treatment for emergency aSAH on the premise of ensuring safety in non-main COVID-19 epidemic areas.

Compared with the retrospective period last year, the number of emergency aSAH patients significantly increased and the preoperative Hunt-Hess grade significantly decreased. This might be due to the closure of emergency department in some other hospitals, resulting in more mild aSAH patients transported to our tertiary neurosurgical center. There is currently no evidence to confirm whether there is a correlation between aSAH and SARS-CoV-2.

Previous studies have been indicated that COVID-19 could cause neurological disorders (19, 20). For the central nervous system, patients with COVID-19 infection are at increased risk for ischemic stroke due to the increased D-dimer (6, 21). Severe thrombocytopenia and increased blood pressure (BP) often occurs in critical patients of COVID-19, which might be responsible for the subsequent intracranial hemorrhage (ICH) and SAH. Besides, Chinese center of disease control (CDC) reported a case of COVID-19 whose cerebrospinal fluid (CSF) gene sequencing confirmed the presence of SARS-CoV-2.

In this protocol, we set up an definition of quarantine transition ward for COVID-19 epidemic. Patients before craniotomy were admitted to the transitional ward. If the reexamination of NAT is negative/positive, the patient would be transferred to specialist ordinary ward or isolation ward after the surgery, respectively. The existence of the transitional ward enabled us to efficiently complete the preoperative preparation of emergency patients under the premise of safety. In addition, the establishment of specialized surgical transport channels, neurosurgeons, anesthesiologists, instrument nurses, itinerant nurses, and operating rooms are also crucial (18).

The current surge in suspicious infections worldwide has resulted in a shortage of COVID-19 NAT reagents, so whether NAT is needed to guide further treatment is an urgent question faced by most non-major epidemic areas. Due to the lack of COVID-19 NAT reagents at the early stage of the epidemic, our screening protocol didn't included COVID-19 NAT. Since February 28, COVID-19 NAT was added to our screening protocol with the sufficient supply of NAT reagents. In this study, all 12 patients who underwent preoperative COVID-19 NAT were negative, with a false negative rate of 0.0%. All patients in this cohort were excluded as preliminary undetermined cases upon discharge. Therefore, we believe that in non-major epidemic areas, with strong epidemic prevention and control measures (such as screening of population epidemiological history, timely isolation of close contacts, adequate protective materials, and reduction of population movement), non-designated COVID-19 hospitals will have fewer opportunities to treat infected patients with aSAH. Therefore, excessive panic is unnecessary, and it may be more important to enhance the clinician's confidence and personal hygiene awareness as well as adequate protective materials. Besides, we found no significant differences in preoperative hospitalized adverse events and postoperative prognosis of the patients with or without COVID-19 NAT, although patients undergoing COVID-19 NAT required slightly longer time from admission to craniotomy (no statistical differences). Therefore, we believed that in a non-major epidemic city (416 to 21.53 million) lacking COVID-19 NAT reagents, it is advisable to adopt a screening method combining epidemiological history with clinical characteristics. However, we should be vigilant for false negative COVID-19 NAT and asymptomatic infections. It was reported that the positive detection rate of COVID-19 NAT was thought to be only 30-50% (13). And about 30-60% of COVID-19 asymptomatic infections may exist in the current

population (22), and the virus load of asymptomatic infections is similar to that of symptomatic patients (23). However, the implicit transmission ability of asymptomatic infections is still uncertain (24).

In this study, two patients were operated in the negative pressure OR, during which the neurosurgeon followed the highest protection standards. However, the protective mask and the negative pressure in the OR often make the operators feel difficult to breathe, and the goggles are easy to fog, which makes the vision of the operator under the microscope very fuzzy and narrow. Therefore, we recommended experienced senior neurosurgeons to perform the surgery, otherwise endovascular intervention was more recommended, but the high incidence of DCI after endovascular intervention should not be underestimated (25).

COVID-19 pneumonia is a huge challenge for all of humanity, and we hope that our research will serve as a reference for neurosurgical centers around the world. There are some limitations in this study. First, there are no confirmed COVID-19 patients in this study, so the effectiveness of the screening protocol cannot be verified. However, this protocol is based on the diagnostic criteria recommended by the CDC in Wuhan, China, which has been verified by a large number of patients, so we think this protocol is referential. Second, less operating experience in the negative pressure OR may not provide a reference for craniotomy in patients with confirmed COVID-19.

## Conclusions

Our study suggests that BTP could effectively complete the admission screening and surgical treatment of emergency aSAH patients in non-major COVID-19 epidemic areas, and it may be used as a reference in local neurosurgical practices.

## List Of Abbreviations

ACoA= Anterior Communicating Artery; aSAH= aneurysmal subarachnoid hemorrhage; BP= Blood Pressure; BTP= Beijing Tiantan Hospital; CDC= Center of Disease Control; CI= Confidence Intervals; CTA= Computed Tomography Angiography; CSF= Cerebrospinal Fluid; DCI= Delayed cerebral ischemia; DSA= Digital Subtraction Angiography; ER= emergency room; GCS= Glasgow Coma Scale; ICH= Intracranial Hemorrhage; ICU= intensive care unit; MCA= Middle Cerebral Artery; mRS= modified Rankin Scale; NAT= Nucleic Acid Testing; OR= operating room; PCoA= Posterior Communicating Artery; PHEIC= Public Health Emergency of International Concern; PPE= personal protective equipment; SD= Standard Deviations; WFNS= World Federation of Neurological Surgeons; WHO= World Health Organization;

## Declarations

## Ethics approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional review boards at both institutions and with the 1964 Helsinki declaration

and its later amendments or comparable ethical standards.

## Consent for publication

Not applicable.

## Availability of data and materials

All data relevant to the study are included in the article or uploaded as supplementary information.

## Competing interests

On behalf of all authors, the corresponding author declare that they have no competing interests.

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## Author Contributions

YC and XC contributed conception and design of the study; YC, XC, LM, ZL and XD organized the database; YC and LM performed the statistical analysis; YC wrote the first draft of the manuscript; XY, HW, SK, YZ, RW, DZ, YC, YZ, SW and JZ critically revised the manuscript and approved the final manuscript as submitted. All authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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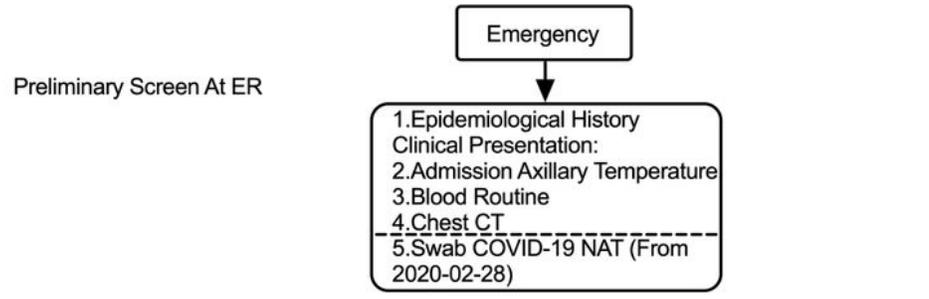
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## Figures



Emergency Surgery Schedule

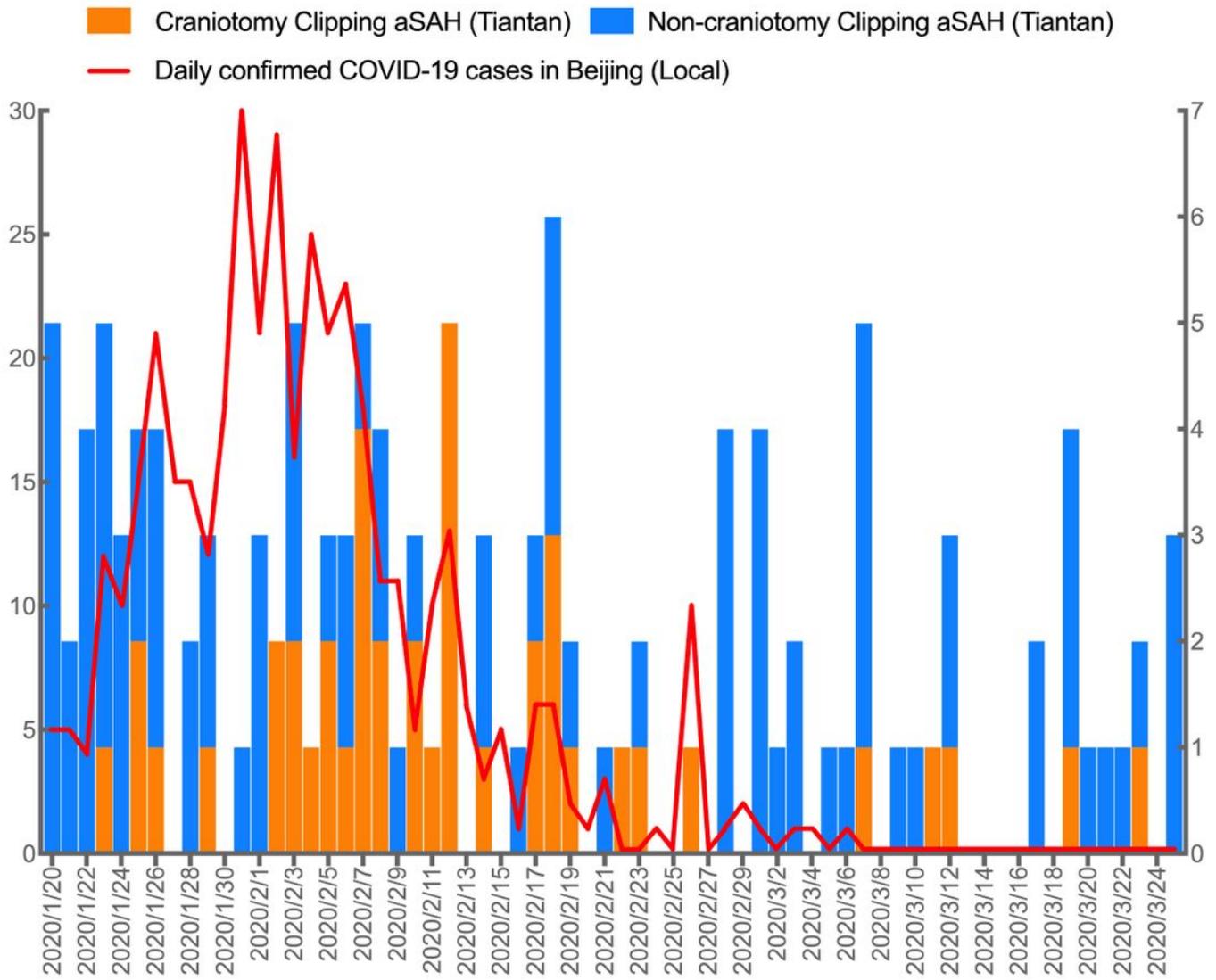
Group	Diagnostic Criteria	PPE	OR	Postop Transfer
Negative	All of the above (-)	Level 1	Ordinary	Ordinary ICU
Preliminary Undetermined (1)	Any 1 item of epidemiological history and clinical presentation (+)	Level 1	Ordinary	Ordinary ICU
Preliminary Undetermined (2)	Any 2 items of epidemiological history and clinical presentation (+)	Level 3	Negative Pressure	Negative Pressure ICU
Suspected	(1) Epidemiological history (+) + any 2 clinical presentation items (+) or (2) All 3 clinical presentation items (+)	Level 3	Negative Pressure	Negative Pressure ICU
Confirmed	Suspected patient + COVID-19 NAT (+)	Level 3	Negative Pressure	Negative Pressure ICU

Postop Step-Down Ward Schedule Based On 2nd Swab COVID-19 NAT

Preliminary Group	Diagnostic Criteria	PPE	Step-down Ward
Normal	Swab COVID-19 NAT (-)	Level 1	Ordinary Ward
Preliminary Undetermined (1)	Swab COVID-19 NAT (-)	Level 2	Ordinary Ward (single bed)
Preliminary Undetermined (2)	Swab COVID-19 NAT (-)	Level 3	Transition Ward (refer to ordinary ward 14 days later if confirmed negative)
Suspected	Swab COVID-19 NAT (-)	Level 3	
Any of the above and confirmed	Swab COVID-19 NAT (+)	Level 3	Isolation Ward and Refer to Designated Hospital for COVID-19

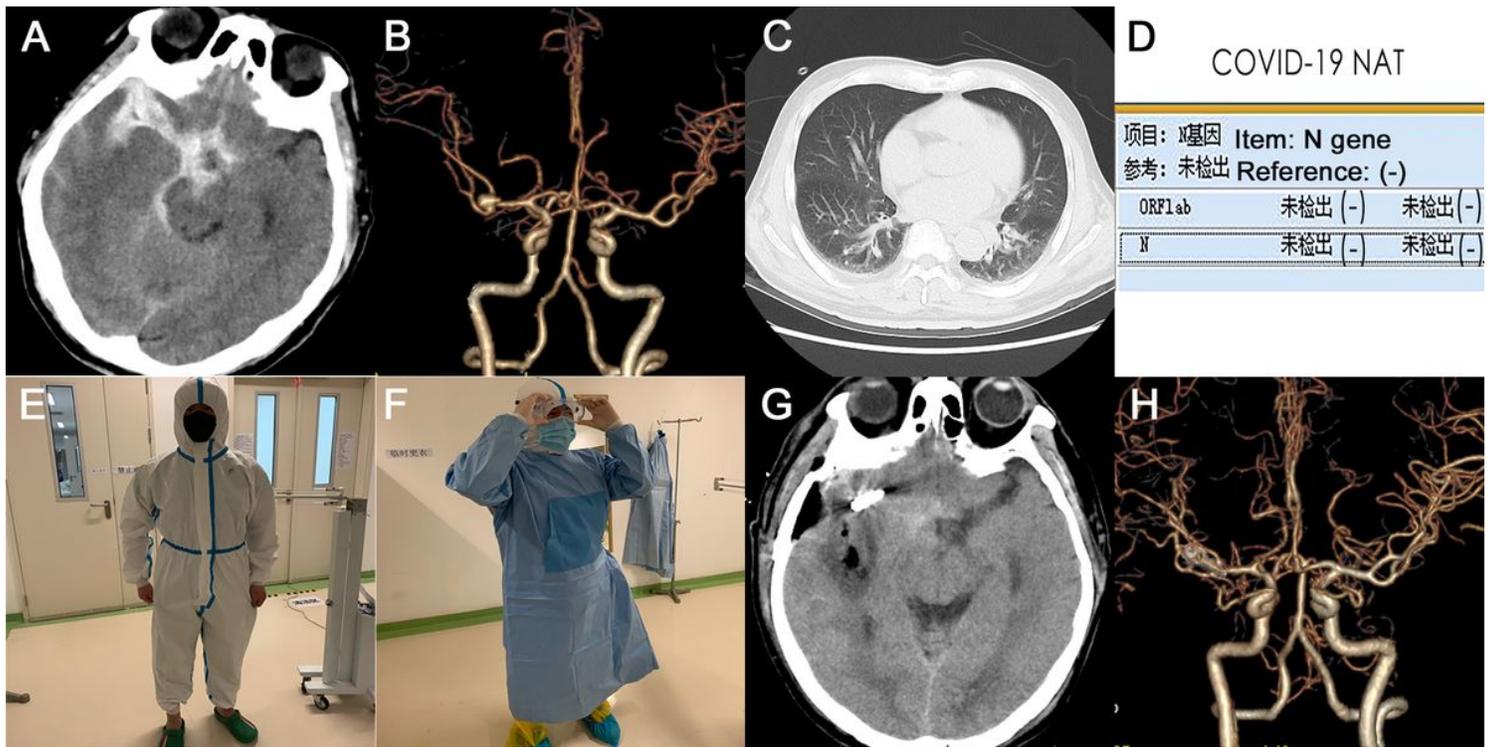
Figure 1

Beijing Tiantan Protocol for aSAH during the COVID-19 outbreak.



**Figure 2**

Emergency aSAH in our hospital at different stages of the epidemic.



**Figure 3**

Illustration case.