BRIEF REPORT

COVID-19 and Decompressive Hemicraniectomy for Acute Ischemic Stroke

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BACKGROUND AND PURPOSE: Young patients with malignant cerebral edema have been shown to benefit from early decompressive hemicraniectomy. The impact of concomitant infection with coronavirus disease 2019 (COVID-19) and how this should weigh in on the decision for surgery is unclear.

METHODS: We retrospectively reviewed all COVID-19–positive patients admitted to the neuroscience intensive care unit for malignant edema monitoring. Patients with >50% of middle cerebral artery involvement on computed tomography imaging were considered at risk for malignant edema.

RESULTS: Seven patients were admitted for monitoring of whom 4 died. Cause of death was related to COVID-19 complications, and these were either seen both very early and several days into the intensive care unit course after the typical window of malignant cerebral swelling. Three cases underwent surgery, and 1 patient died postoperatively from cardiac failure. A good outcome was attained in the other 2 cases.

CONCLUSIONS: COVID-19–positive patients with large hemispheric stroke can have a good outcome with decompressive hemicraniectomy. A positive test for COVID-19 should not be used in isolation to exclude patients from a potentially lifesaving procedure.

Key Words: brain edema ■ cause of death ■ decompressive craniectomy ■ heart failure ■ stroke

METHODS

In this retrospective single-center study, we included all hospitalized patients aged ≥18 years diagnosed with COVID-19 and at risk for ischemia-induced MCE from March 24, 2020, to April 30, 2020. A positive result on nasopharyngeal swab utilizing real-time reverse-transcriptase polymerase chain reaction for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was used for diagnosing COVID-19. All patients had a computed tomography (CT) angiogram that confirmed an ELVO in the internal carotid artery or middle cerebral artery. Patients were considered at risk for MCE if they had >50% of middle cerebral artery involvement on CT imaging. Data on demographics, brain imaging, laboratory results, and hospital course were abstracted. All patients were followed...
Patient 4 presented with a right internal carotid artery occlusion and received alteplase intravenously and mechanical thrombectomy. Emergent DHC was performed on poststroke day 1 due to worsening lethargy and a fixed dilated right pupil. Preoperative CT showed significant midline shift of 10 mm and was taken for emergent DHC. Unfortunately, the patient’s cardiac status worsened postoperatively, and she expired after cardiac arrest.

Patient 5 presented with a left middle cerebral artery occlusion and received alteplase intravenously and mechanical thrombectomy. Emergent DHC was performed on poststroke day 1 due to lethargy and CT showing 13 mm of midline shift. He had an uneventful intensive care unit (ICU) course and was successfully extubated. On poststroke day 12, he experienced bilateral pulmonary embolism and was found to have deep venous thrombosis of the right popliteal vein for which systemic anticoagulation was started. On exam, he attempts to verbalize and can follow midline commands. As of the data cutoff date, he remains in the hospital awaiting acceptance to rehabilitation.

Patient 6 experienced an ST-segment–elevation myocardial infarction on poststroke day 1. His follow-up CT scan had 5 mm of midline shift, but he did not require DHC. His ICU course was complicated by severe acute respiratory distress syndrome, pneumothorax, refractory shock, and renal failure requiring continuous renal replacement therapy. Despite systemic heparin at therapeutic dosages, his dialysis catheter clotted several times, and he was transitioned to peritoneal dialysis. He remained critically ill in the ICU.

A total of 4 of 7 (57%) patients died in the data cutoff date (Figure). Patients 1 and 7 died within the first 24 hours of ICU admission from refractory shock. No follow-up CT was obtained in these patients after the initial scan. Patient 3 did not develop significant cerebral edema warranting DHC on follow-up imaging. The patient was ultimately transitioned to hospice after an ICU course complicated by severe acute respiratory distress syndrome and renal failure. We did not find a correlation between measured inflammatory markers and the severity of stroke or respiratory status.

RESULTS

COVID-19 cases with ELVO who required MCE monitoring (n=7) were young patients with an independent baseline functional status. One patient had atrial fibrillation and was not on chronic anticoagulation, and another had coronary artery disease. The remainder of patients had no major risk factors for ELVO. Two patients presented with stroke symptoms and mild COVID-19 symptoms. One patient presented with COVID-19 symptoms and developed an in-hospital stroke. The detailed clinical features of patients are shown in the Table.

Three patients required and underwent decompressive hemicraniectomy (DHC) of whom 1 died. She (patient 2) experienced a concomitant ST-segment–elevation myocardial infarction with the ELVO stroke and was placed on a heparin infusion. Her follow-up CT scan showed significant midline shift of 10 mm and was taken for emergent DHC. Unfortunately, the patient’s cardiac status worsened postoperatively, and she expired after cardiac arrest.

We present the clinical outcome of consecutively admitted COVID-19 stroke patients who required monitoring for MCE at a large urban health center in New York City during the COVID-19 crisis. Two patients did not develop significant cerebral edema and were managed medically. Three patients had clinical and radiological evidence of MCE and underwent DHC. Two had a good clinical outcome while 1 patient died from her concurrent ST-segment–elevation myocardial infarction.

DISCUSSION

We saw a surge of COVID-positive patients presenting with ELVO and required MCE monitoring during the peak of COVID-19 in NYC. All patients included in this report were admitted over a span of 8 days. Our experience shows that COVID-19 patients with large territorial infarction can have a good outcome after DHC. This is particularly true in patients presenting with minimal respiratory involvement or other extracranial organ injury. While we have limited follow-up data for survivors and neurological recovery, it is reasonable to expect similar neurological outcomes as shown in prior DHC trials. Clinicians should be mindful of increased risk for early rapid herniation due to both permissive hypercapnia and hypoxia-induced cerebral vasodilation, particularly among patients with acute respiratory distress syndrome. An early prophylactic DHC strategy in otherwise surgically eligible patients may be appropriate due to the lack of a reliable neurological exam with sedatives and paralytic usage.

Mortality in our patients appeared related to the downstream complications of severe COVID-19 infection

Nonstandard Abbreviations and Acronyms

| Acronym   | Description                                      |
|-----------|--------------------------------------------------|
| COVID-19  | coronavirus disease 2019                         |
| CT        | computed tomography                              |
| DHC       | decompressive hemicraniectomy                    |
| ELVO      | emergent large vessel occlusion                  |
| MCE       | malignant cerebral edema                         |
| MCE       | malignant cerebral edema                         |
including refractory shock and renal failure, rather than the stroke itself. The frequency of systemic complications in critically ill patients with COVID-19 and stroke is unclear but appears to be high. In our cohort, we saw very early mortality in patients who ordinarily would be considered as medically unstable for DHC, and we also saw systemic complications several days into the ICU course after the typical window of malignant cerebral swelling. It would be difficult to base DHC eligibility on otherwise medically stable patients as it is currently unknown which patient will go

### Table. Patient Characteristics

| Characteristics                  | Patient 1 | Patient 2 | Patient 3 | Patient 4 | Patient 5 | Patient 6 | Patient 7 |
|----------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Age/sex                          | 57/M      | 51/F      | 61/M      | 61/M      | 41/M      | 57/M      | 53/M      |
| Presenting signs/symptoms        |           | +         |           |           | +         | +         | +         |
| Fever                            |           |           | +         |           | +         | +         | +         |
| Cough                            |           |           |           | +         |           |           | +         |
| Hypoxia                          | +         |           |           |           | +         |           |           |
| Stroke                           | +         | +         | +         | +         | +         | +         | +         |
| Other                            | STEMI     | STEMI     | hypoglycemia | +         |           |           | +         |
| Past medical history             |           |           |           |           |           |           |           |
| Hypertension                     | +         | +         |           |           |           |           |           |
| Diabetes mellitus                | +         | +         | +         | +         | +         | +         | +         |
| Atrial fibrillation              | +         |           |           |           |           |           |           |
| Coronary artery disease          |           |           |           |           |           |           | +         |
| Congestive heart failure         |           |           |           |           |           |           | +         |
| Chronic kidney disease           |           |           |           |           |           |           | +         |
| Stroke                           |           |           |           |           |           |           |           |
| Baseline mRS                     | 2         | 0         | 0         | 0         | 0         | 0         | 0         |
| NIHSS                            | 18        | 20        | 17        | 12        | 23        | 22        | 12        |
| Occlusion                        | L M1      | L ICA     | L ICA     | R ICA     | L M1      | L M1      | R M1      |
| tPA                              | +         | +         | +         | +         | +         | +         | +         |
| Thrombectomy                     |           |           | TICI 2B   | TICI 2B   | TICI 2B   |           |           |
| Time from last known well to imaging qualifying patient as high risk | 5 h 10 min | 23 h 50 min | 5 h 7 min | 5 h 18 min | 17 h 40 min | 8 h 46 min | 6 h 58 min |
| Peak midline shift               | 10 mm     | ≤5 mm     | 11 mm     | 13 mm     | ≤5 mm     |           |           |
| DHC poststroke day               | 2         | 1         | 1         |           |           |           |           |
| Medical management               |           |           |           |           |           |           |           |
| Oxygen requirement on presentation | MV       | Room air  | MV       | Room air  | 2 L       | MV       | MV       |
| P/F ratio (lowest)               | 165       | >300      | 70       | >300      | >300      | 100      | >300      |
| ≥2 pressor requirement           | +         |           | +         |           | +         |           | +         |
| Paralytic/prone                  |           |           | +         |           |           |           | +         |
| Inhaled epoprostanol             | +         |           |           |           |           |           |           |
| AKI requiring CRRT               | +         |           |           |           |           |           | +         |
| Outcome                          |           |           |           |           |           |           |           |
| Deceased despite max therapy     | +         | +         | WLST     |           |           |           | +         |
| DNR/DNI                          | +         |           | +         |           |           |           |           |
| Trach                            |           |           |           |           | +         |           |           |
| ICU LOS                          | 1         | 3         | 10        | 10        | 6         | 1         |           |
| Hospital LOS                     | 1         | 3         | 11        | 14        | Floor     | ICU       | 1         |
| Complications                    | Refractory shock | STEMI | AKI | Hemorrhagic conversion, uncal herniation | DVT/PE | Shock, renal failure, pneumothorax | Cardiogenic shock | + |

AKI indicates acute kidney injury; CRRT, continuous renal replacement therapy; DHC, decompressive hemicraniectomy; DNI, do not intubate; DNR, do not resuscitate; DVT, deep vein thrombosis; F, female; ICA, internal carotid artery; ICU, intensive care unit; L, left; LOS, length of stay; M, male; mRS, modified Rankin Scale; MV, mechanical ventilation; NIHSS, National Institutes of Health Stroke Scale; P/F ratio, ratio of $P_{O_2}$ in arterial blood divided by fraction of inspired oxygen; PE, pulmonary embolus; R, right; STEMI, ST-segment–elevation myocardial infarction; tPA, tissue-type plasminogen activator; and WLST, withdrawal of life-sustaining therapy.
on to develop COVID-19–related systemic complications later in the hospital course. Therefore, we suggest that the decision to offer DHC or not should be individualized using the same selection criteria as the pre–COVID-19 era.

CONCLUSIONS

COVID-19–positive patients with large hemispheric stroke can have a good outcome with DHC. A positive test for COVID-19 should not be used in isolation to exclude otherwise DHC-eligible patients from a potentially lifesaving procedure.

ARTICLE INFORMATION

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