Original research

Mechanical thrombectomy for acute ischemic stroke in COVID-19 patients: multicenter experience in 111 cases

Hanna Styczen,1 Volker Maus,2 Lukas Goertz,3 Martin Köhrmann,4 Christoph Kleinschnitz,4 Sebastian Fischer,2 Markus Möhlenbruch,5 Iris Mühlen,6 Bernd Kallmünzer,7 Franziska Dorn,8 Asadeh Lakhgomi,8 Matthias Gawlitza,9 Daniel Kaiser,9 Joachim Klisch,10 Donald Lobesien,10 Stefan Rohde,11 Gisa Ellrichmann,12 Daniel Behne,13 Maximilian Thomann,14 Fabian Flottmann,15 Laurens Winkelmeier,15 Elke R Gizewski,16 Lukas Mayer-Suess,17 Tobias Boechk-Behrens,18 Isabelle Riederer,18 Randolf Klingebiel,19 Björn Berger,19 Martin Schlunz-Hendann,20 Dominik Grieb,20 Ali Khanaf,21 Richard du Mesnil de Rochemont,22 Christophe Arendt,22 Jens Altenbernd,23 Jan-Ulrich Schlump,24 Adrian Ringelstein,25 Vivian Jean Marcel Sanio,25 Christian Loehr,26 Agnes Maria Dahlke,26 Alexander Bock,32 Omid Nikoubashman,33 Martin Wiesmann,34 Michael Forsting,1 Cornelius Deuschl1

ABSTRACT

Background  Data on the frequency and outcome of mechanical thrombectomy (MT) for large vessel occlusion (LVO) in patients with COVID-19 is limited. Addressing this subject, we report our multicenter experience.

Methods  A retrospective cohort study was performed of consecutive acute stroke patients with COVID-19 infection treated with MT at 26 tertiary care centers between January 2020 and November 2021. Baseline demographics, angiographic outcome and clinical outcome evaluated by the modified Rankin Scale (mRS) at discharge and 90 days were noted.

Results  We identified 111 out of 11,365 (1%) patients with acute or subacute COVID-19 infection who underwent MT due to LVO. Cardioembolic events were the most common etiology for LVO (38.7%). Median baseline National Institutes of Health Stroke Scale score and Alberta Stroke Program Early CT Score were 16 (IQR 11.5–20) and 9 (IQR 7–10), respectively. Successful recanalization (mTICI ≥2b) was achieved in 97/111 (87.4%). Median time interval from symptom onset to groin puncture were independent predictors for an unfavorable outcome in a logistic regression analysis.

Conclusion  Our study showed a poor clinical outcome and high mortality, especially in patients with severe acute COVID-19 infection undergoing MT due to LVO.

BACKGROUND

Neurological complications during infection with the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) are common, ranging from 25% to 80% of patients hospitalized with COVID-19.1,2 A clear association of acute cerebrovascular disease with COVID-19 has been observed, with an overall pooled incidence of 1.4% in a recent meta-analysis.3 Acute ischemic stroke (AIS) is the most common manifestation of acute cerebrovascular disease in patients suffering from COVID-19 and is reported as a presenting feature of the young.1,4,5 Compared with the pre-pandemic period, younger patients with COVID-19 without vascular risk factors have been undergoing mechanical thrombectomy (MT) for AIS due to large vessel occlusion (LVO).6,7 Studies suggest that the activation of the coagulation pathway is related to the infection-induced systemic inflammatory response.8 SARS-CoV-2 enters the blood stream by breaching the blood–air barrier via the lung capillary adjacent to the alveolus. As the blood–air barrier is breached, a cascade of events unfolds including endothelial...
The pandemic and neurointervention

dysfunction, formation of antiphospholipid antibody complexes promoting platelet aggregation, coagulation cascade, and formation of cross-linked fibrin blood clots, leading to thrombosis and stroke in individuals with COVID-19 infection.8

Due to the systemic effect of the coronavirus with hypercoagulation, hyperinflammation and respiratory insufficiency, a poor prognosis and increased mortality among COVID-19 patients treated by MT for LVO must be assumed.9 Specific characteristics of COVID-19-associated stroke still remain unknown, and data on the frequency and outcome of patients with COVID-19 undergoing MT for AIS are limited.10

We aimed to report our multicenter experience with MT in patients with AIS and associated COVID-19 infection, evaluating the angiographic and clinical outcome.

METHODS

We conducted a retrospective study of patients with AIS with laboratory-confirmed acute or subsided (within 6 months) COVID-19 infection who were treated endovascularly at 26 tertiary care centers in Germany and Austria between January 2020 and November 2021. We identified all patients who received MT or were treated with the intention for thrombectomy due to LVO in cerebral arteries including the distal internal carotid artery, middle cerebral artery (M1, M2 and M3), anterior cerebral artery (A1 and A2), distal vertebrobasilar artery, and posterior cerebral artery (P1 and P2). A confirmed diagnosis of COVID-19 was defined by a positive laboratory result for SARS-CoV-2 on high-throughput sequencing or reverse transcription PCR assay of nasal and/or oropharyngeal swab specimens.

Demographics, comorbidities, technical features, complications, angiographic and clinical outcomes were noted. The etiology of the occlusion was based on the TOAST classification. There were no limitations on procedural characteristics including the use of different thrombectomy techniques and intra-arterial thrombolysis, which were left to the attending neuroradiologist’s discretion. Endovascular treatment was performed with approved MT devices, using stent-retrievers or large-bore aspiration catheters or a combination of both.

Complete reperfusion was defined as a modified Thrombolysis in Cerebral Infarction (mTICI) scale score of 3. Successful reperfusion was defined as mTICI 2b. The clinical efficacy outcome was the rate of functional independence measured by the modified Rankin Scale (mRS) and defined as 0–2 at discharge and 90 days. All National Institutes of Health Stroke Scale (NIHSS) and mRS grades were assessed by a consultant neurologist. Post-interventional symptomatic intracranial hemorrhage (sICH) was graded according to the European Cooperative Acute Stroke Study criteria.11

According to the guidelines of the respective local ethics committees, ethical approval was given when necessary for this anonymous retrospective study, which was conducted in accordance with the Declaration of Helsinki. Patient consent for treatment was obtained according to the individual institutional guidelines. Due to the retrospective nature of the study, additional informed consent was deemed unnecessary.

Statistical analysis

Categorical variables are presented as numbers and percentages and compared using the χ² and Fisher’s exact test, as appropriate. Ordinal variables are presented as median and IQR and compared using the Mann–Whitney U test. Continuous variables are presented as mean with SD and compared using the Student’s t-test and Mann–Whitney U test, as appropriate.

Factors predictive of an unfavorable outcome (mRS 3–6) at discharge in the univariate analysis (p<0.05) were entered into a binary logistic stepwise regression model to identify independent factors for an unfavorable outcome. Independent variables included in the logistic regression analyses were tested for multicollinearity calculating the variance inflation factor (VIF). A VIF >5 was assumed to indicate high multicollinearity between the respective independent variable and the others. In this case, strongly correlating variables were identified and stepwise eliminated until all independent variables had a VIF ≤5. All calculations were performed using SPSS software version 25 (IBM SPSS Statistics for Windows, IBM Corp, Armonk, New York, USA). A p value <0.05 was considered statistically significant.

RESULTS

Of 11,135 patients from 26 tertiary stroke centers screened, 111 patients with acute or subsided COVID-19 infection underwent MT due to LVO between January 2020 and November 2021. The prevalence of MT in COVID-19 patients measured by the case volume of all centers during the inclusion time was 1%.

Baseline characteristics

Out of 111 patients, 97 patients had a laboratory-confirmed diagnosis of acute COVID-19 infection and 14 patients presented after subsided COVID-19 infection. The acute COVID-19 infection was determined during hospitalization, immediately before or after the endovascular thrombectomy, with a reverse transcription PCR test. Patient baseline characteristics are shown in Table 1.

Of 97 patients with acute COVID-19 infection, 31 (32%) presented with a severe course requiring intubation due to acute respiratory failure during hospitalization. Mild (without respiratory distress) and moderate (requiring non-invasive ventilation) courses of COVID-19 infection were found in 43 (44.3%) and 23 (23.7%) patients, respectively. The median age was 74 (IQR 63–82) years and 70/111 (63.1%) were male. Seven patients (6.3%) were younger than 50 years.

LVO was localized in the anterior circulation in 101/111 (91%) patients, with most common sites in M1 (51/101; 50.5%) and distal internal carotid artery (25/101; 24.8%), followed by M2 (21/101; 20.8%). Basilar artery occlusion represented 9% (10/111) of cases.

Tandem occlusion occurred in 19/111 (17.1%) patients. In 5/111 (4.5%) cases re-occlusion within 30 days was observed. Of these, three cases of large vessel re-occlusion were localized in the same territory and in two cases a different territory was affected. Intravenous thrombolysis (IVT) was administered in 48/111 (43.2%) patients.

Median baseline NIHSS and ASPECTs were 16 (IQR 11.5–20) and 9 (IQR 7–10), respectively.

The median interval between onset and groin puncture was 220 (IQR 150–290) min. Thirty-nine (35.1%) patients presented as wake-up strokes. The rate of pretreatment functional independence (mRS ≤2) was 73% (81/111).

Cardioembolic cause was the most common etiology for LVO and was found in 43/111 (38.7%) patients, followed by large artery atherosclerosis (22/111; 19.8%). In 11/111 (9.9%) patients other etiology (eg, dissection, infectious) was found. Stroke etiology remained unknown in 34/111 (30.6%) patients.

Procedural and functional outcome

MT was performed under general anesthesia in 100/111 (90.1%) and conscious sedation in 11/111 (9.9%) patients. The median
Spontaneous recanalization occurred in three cases and in two cases the thrombus localization could not be reached. One patient with intention to MT presented with ventricular fibrillation at the beginning of the endovascular procedure and died eventually of pulmonary artery embolism.

Successful reperfusion was achieved in 97/111 (87.4%) patients and 46/111 (41.4%) patients were reperfused completely. The procedure-related complication rate was 12.6% (14/111), sICH occurred in 6/111 (5.4%) patients. Of these, one patient presented with additional subarachnoid hemorrhage (SAH) and another with iatrogenic intra-arterial dissection. Since the dissection was localized extracranially in the internal carotid artery without hemodynamic relevance, no further treatment was required. Of six patients with sICH, parenchymal hematoma (PH) was found in three cases (2 cases of PH-1 and 1 case of PH-2) and hemorrhagic infarction (HI) was found in three cases (2 cases of HI-1 and 1 case of HI-2). In total, nine patients presented with SAH (8.1%).

Functional independence was achieved in 20/108 (18.5%) patients at discharge and 14/66 (21.2%) at 90 days follow-up. The mortality rate was 30.6% (33/108) at discharge and 56.1% (37/66) at 90 days follow-up. Clinical outcome at discharge and at 90 days was not documented in 3 and 45 patients, respectively.

Clinical outcome of the seven patients under the age of 50 years was mRS 2, mRS 3, mRS 6 in two cases and mRS 4 in one patient. The clinical outcome was not noted. In two patients one risk factor (smoking) in each case was determined. In one patient the clinical outcome was not noted. In two cases mortality occurred in 3 and 45 patients, respectively. Successful reperfusion was achieved in 97/111 (87.4%) patients and 46/111 (41.4%) patients were reperfused completely. The procedure-related complication rate was 12.6% (14/111), sICH occurred in 6/111 (5.4%) patients. Of these, one patient presented with additional subarachnoid hemorrhage (SAH) and another with iatrogenic intra-arterial dissection. Since the dissection was localized extracranially in the internal carotid artery without hemodynamic relevance, no further treatment was required. Of six patients with sICH, parenchymal hematoma (PH) was found in three cases (2 cases of PH-1 and 1 case of PH-2) and hemorrhagic infarction (HI) was found in three cases (2 cases of HI-1 and 1 case of HI-2). In total, nine patients presented with SAH (8.1%).

Functional independence was achieved in 20/108 (18.5%) patients at discharge and 14/66 (21.2%) at 90 days follow-up. The mortality rate was 30.6% (33/108) at discharge and 56.1% (37/66) at 90 days follow-up. Clinical outcome at discharge and at 90 days was not documented in 3 and 45 patients, respectively.

Clinical outcome of the seven patients under the age of 50 years was mRS 2, mRS 3, mRS 6 in two cases and mRS 4 in one patient. The clinical outcome was not noted. In two patients one risk factor (smoking) in each case was determined. |
In a subgroup analysis, patients with severe acute COVID-19 infection with respiratory failure requiring intubation showed a significantly lower rate of functional independence with significantly higher mortality compared with patients with mild or moderate acute COVID-19 infection (mRS 0–2 at discharge: 0/30 (0%) vs 15/64 (23.4%), p=0.004; mRS 6 at discharge: 15/30 (50%) vs 16/64 (25%), p=0.016).

Univariate and multivariate analyses
We performed univariate and multivariate analyses to identify predictors for an unfavorable outcome (mRS 3–6) at discharge. In the univariate analysis, factors potentially associated with an unfavorable outcome were: no administration of IVT (p=0.001), ventilation (non-invasive or intubation due to respiratory failure, p<0.001), occlusion site in the ICA (p=0.041) or M1 (p=0.001), cardioembolic cause of AIS (p=0.075), higher pre-stroke mRS (p<0.001), tandem occlusion (p=0.021), lower ASPECTS at baseline (p=0.046) or after 24 hours (p=0.001), higher NIHSS at baseline (p=0.002) or at discharge (p<0.001), higher interval time between onset to groin puncture (p=0.042) and lower rates of mTICI 3 (p=0.026). After multicollinearity testing, administration of IVT, ventilation, cardioembolic cause of AIS, ASPECTS at baseline, NIHSS at baseline, interval time between onset to groin puncture and mTICI 3 rates were entered into a binary logistic regression analysis. Ventilation (OR 35.3, 95% CI 2.4 to 523.0; p=0.010) and interval time from onset to groin puncture (OR 1.02, 95% CI 1.00 to 1.04; p=0.016) remained as independent predictors for an unfavorable outcome.

DISCUSSION
We report a large series of patients with COVID-19 infection treated with MT due to LVO focusing on angiographic and clinical outcome. MT in patients with acute or subsided COVID-19 infection remains an infrequent event to date.

Recent studies have reported a prevalence rate of acute stroke in COVID-19 patients of 1.4–1.5%, including endovascular treatment due to LVO in about one of four patients (238/1223). These findings correspond with the low incidence and frequency of 1% in our study and might be due to several factors. First, our database included patients from 26 different stroke centers with its inherent heterogeneity in the respective populations. Other stroke patients with LVO and COVID-19 might have been admitted to other stroke centers in the various corresponding metropolitan areas. Second, MT in patients with acute severe COVID-19 infection could be complicated by diagnostic delays imposed by the fact that these patients are more likely to be sedated and intubated, thus impeding the early detection of neurological deterioration. Third, the COVID-19 pandemic compromised the application of well-established therapies and appears to be disruptive for acute stroke pathways. Stroke patients without respiratory symptoms of COVID-19 might not seek care at all, preferring to stay at home than taking the risk of getting exposed to SAR-CoV-2 at the hospital.

Our patient characteristics in terms of age (median age of 74), baseline NIHSS and ASPECTS are comparable with individual patient data meta-analysis on MT before the pandemic. In contrast, recent small-case series (n <15) have reported that patients with AIS with COVID-19 treated with MT were younger with median ages ranging from 39 to 59.5 years, had higher baseline NIHSS scores (median 17–27) and lower ASPECTS (median 5) at admission.

It remains unclear whether the lower rate of young patients in our study (6.3% of patients aged <50 years)—in comparison to results of a recent systematic review which reported a corresponding rate of 17.4% of young patients with AIS with COVID-19—is underestimated due to patients preferring not to enter the hospital at all, as mentioned above.

Our retrospective analysis revealed several findings including high rates of successful and complete final reperfusion of up to 87% and 41%, respectively. The reperfusion rates are in line with recent analyses of MT in patients with COVID-19. In addition, the angiographic outcome is comparable to MT studies before the pandemic, suggesting that there is no distinction between MT being performed in an infected or non-infected patient with regard to technical feasibility, safety, and time to flow restoration.

This implies that thrombectomy in COVID-19 patients should be pursued with the same extensive effort as in non-infected patients, as these patients may achieve similar good angiographic outcomes. Otherwise, there is a high probability that mortality and functional independence would increase even more.

Most importantly, our study showed the devastating outcome of patients with COVID-19 with AIS due to LVO, even though the reperfusion rates were high. Our results are consistent with another large European multicenter study of MT in COVID-19 patients (n=93) and meta-analyses of AIS patients with COVID-19 infection which reported mortality rates ranging from 29% to 35%. The mortality is therefore twice as high as in the meta-analysis from HERMES (15%). Several aspects related to the COVID-19 infection may explain our findings, including the respiratory distress observed in some patients. Acute respiratory failure requiring non-invasive ventilation or intubation proved to be an independent factor for an unfavorable outcome in multivariate analysis. In fact, mortality was 50% in patients with acute respiratory failure due to COVID-19 infection undergoing MT and comparable to mortality data among COVID-19 patients with acute respiratory distress syndrome in national reports (all countries 39%). Besides, COVID-19 patients with stroke tend to have an elevated incidence of potentially fatal thrombotic complications that could have contributed to the increased risk of death. Indeed, we found a noticeably higher rate of re-occlusion within 30 days compared with a previous analysis of non-infected patients (4.5% vs 0.4%). Re-occlusions might be promoted by a prothrombotic state, antiphospholipid syndrome, cytokine storm or other coagulopathies—factors that have already been described with COVID-19 and related stroke pathogenesis.

Notably, patients with subsided COVID-19 infection tend to have a better clinical outcome than patients with acute COVID-19 infection. The mortality in this subgroup of our cohort corresponds to rates of mortality in non-infected stroke patients undergoing MT, indicating that recovered COVID-19 patients should be given separate consideration and stroke pathogenesis might be dissimilar to patients with acute SAR-CoV-2 infection.

Another important factor potentially negatively affecting the clinical outcome of infectious patients treated with MT due to LVO is the significant delay in performing thrombectomy. The median time interval from symptom onset to groin puncture in our study was higher than findings of the German Stroke Registry in 2019 (median 220 min vs 160 min). Additionally, the time interval from onset to groin puncture presented as an independent predictor for an unfavorable outcome in our multivariate analysis. Multiple studies have shown declines in the volumes of MT, IVT and stroke hospitalizations over the pandemic with delays in hospital arrival times and treatment workflow.

It is notable that 90% of thrombectomy procedures in our study were performed under general anesthesia. To date, there...
are no current studies comparing the efficacy of general anesthesia and conscious sedation for MT in patients diagnosed with COVID-19. The decision to intubate for MT must be justified to the patient’s need for airway protection and the risk of aerosol exposure to the staff.

It remains unknown whether COVID-19 was primarily responsible for AIS in our study. Cardioembolic etiology for the LVO was found in most patients (38.7%) and could be potentially associated with the systemic hypercoagulability seen in patients with COVID-19. On the other hand, there is no indication of causality as the majority of patients had at least one known stroke risk factor.

An important limitation of our study is the retrospective and multicenter design including attendant selection bias and the use of different thrombectomy equipment and techniques although, notably, the reperfusion rates were high. Furthermore, our study is limited by the fact that the study did not consider a control group of non-infected patients.

CONCLUSIONS

Our study supports the fact that COVID-19 infection is associated with a devastating clinical outcome of patients with AIS due to LVO treated with MT. Patients with acute severe COVID-19 infection and respiratory failure tend to have the highest rate of mortality.

Author affiliations

1Department of Radiology, Neuroendocrinology, University Hospital Essen, Essen, Germany
2Department of Radiology, Neuroendocrinology and Nuclear Medicine, University Medical Center Langendreer, Bochum, Germany
3Department of Diagnostic and Interventional Radiology, University Hospital Cologne, Cologne, Germany
4Department of Neurology and Center for Translational Neurosciences and Behavioral Sciences (CTNBS), University Hospital Essen, Essen, Germany
5Department of Neuroradiology, University of Heidelberg, Heidelberg, Germany
6Department of Neuroradiology, University of Erlangen-Nuremberg, Erlangen, Germany
7Department of Neurology, University of Erlangen-Nuremberg, Erlangen, Germany
8Department of Radiology, University Hospital Bonn, Bonn, Germany
9Institute and Polyclinic of Neuroradiology, Universitätsklinikum Carl Gustav Carus, Dresden, Sachsen, Germany
10Department of Diagnostic and Interventional Radiology and Neuroradiology, Helios General Hospital Erfurt, Erfurt, Germany
11Department of Radiology and Neuroradiology, Klinikum Dortmund gGmbH, Dortmund, Germany
12Department of Neurology, University Hospital Magdeburg, Magdeburg, Germany
13Department of Radiology, University Hospital Magdeburg, Magdeburg, Germany
14Department of Diagnostic and Interventional Neuroradiology, University Hospital Hamburg-Eppendorf, Hamburg, Germany
15Department of Neuroradiology, Medical University of Innsbruck, Innsbruck, Austria
16Department of Diagnostic and Interventional Neuroradiology, University Hospital Innsbruck (Innsbruck), Innsbruck, Germany
17Department of Radiology and Neuroradiology, Klinikum Düsseldorf - Sana Kliniken, Düsseldorf, Germany
18Clinic for Neuroendocrinology, Klinikum Stuttgart, Stuttgart, Germany
19Institute of Neuroradiology, University Hospital Frankfurt and Goethe University, Frankfurt am Main, Germany
20Department of Radiology and Neuroradiology, Gemeinschaftskrankenhaus Herdecke, Herdecke, Germany
21Department of Neuroradiology, Klinikum Fulda, Fulda, Germany
22Department of Neuroendocrinology, Klinikum Veste, Recklinghausen, Germany
23Department of Neuroradiology, University Hospital Essen, Essen, Germany
24Department of Radiology, University Hospital Magdeburg, Magdeburg, Germany
25Department of Radiology, Neuroradiology and Nuclear Medicine, University Medical Hospital Aachen, Aachen, Germany
26Department of Neuroradiology, Alfried Krupp Klinikinstitut, Essen, Germany

Contributors

Guarantor: HS. Conception and design: CD, HS. Acquisition of data: HS, VM, MM, IM, FD, DK, DL, SR, MT, FE, ERG, TB-B, RK, MS-H, AK, RdMdR, JA, AR, AMD, CB, RM-B, KK, PS, AB, ON, FJM. Analysis and interpretation of data: VM, LG, MK, CK, SF, BK, AI, MG, IK, GE, DB, LW, LM-S, IR, BB, DG, CA, J-US, VIMS, CL, SR, US, VL, TR, AD, ME, MGS, MW, HH, RC, MF, CD, HS. Drafting the article: HS, LG. All authors have read and approved the manuscript. HS is the guarantor of this study.

Funding

The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests

MM: Grants or contracts from Balt, Medtronic, MicroVention and Stryker. FD: Consultant for Balt, Cereus Endovascular, Phenox and Cereos. Ernakon, honoraria for lectures from Cereos, Acandis and Asahi, support for attending meetings from MicroVention, Cerebus and Cereus Endovascular, advisory board member for Ernakon, Johnson & Johnson, and associate editor for Journal of Neurointerventional Surgery. MG: Grants or contracts from Else Kröner Fresenius Stiftung, payment of honoraria for lectures from Phenox, procuring contract with MicroVention, participation on clinical event committee from MicroVention, chair of ESMINT Examination Committee, received stents from Phenox for research purposes. DK: Grants or contracts from Else Kröner Fresenius Center of Digital Health and Joachim Herz Foundation, spokesman of the "Junge Neuroradiologie" in the German Society of Neuroradiology. CL: Consulting fees, payment of honoraria for lectures and support for attending meetings from Phenox, Penumbra and Acandis. MW: Grants from ab medica, Acandis, Bracco Imaging, Cereos, Kaneka Pharmaceuticals, Medtronic, Mentice AB, Microvention, Phenex, Siemens Healthcare and Stryker Neuroradiology; Consulting fees from Stryker Healthcare; Payment honoraria for lectures from Stryker Neuroradiological. The other authors declare no specific conflict of interest.

Patient consent for publication

Not applicable.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data availability statement

Data are available upon reasonable request. Not applicable.

Supplemental material

This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

This article is made freely available for personal use in accordance with BMJ’s website terms and conditions for the duration of the covid-19 pandemic or until otherwise determined by BMJ. You may download and print the article for any lawful, non-commercial purpose (including text and data mining) provided that all copyright notices and trade marks are retained.

ORCID iDs

Volker Maus http://orcid.org/0000-0001-5097-2631
Lukas Goertz http://orcid.org/0000-0002-6260-7611
Daniel Kaiser http://orcid.org/0000-0001-5258-0025
Stefan Rohde http://orcid.org/0000-0002-6184-8617
Daniel Behne http://orcid.org/0000-0002-5353-9515
Fabian Flottmann http://orcid.org/0000-0001-8358-8089
Tobias Boech-Behrens http://orcid.org/0000-0003-0266-8947
Omid Nikoubashman http://orcid.org/0000-0002-2055-4217
Martin Wiesmann http://orcid.org/0000-0002-8621-5573
René Chapot http://orcid.org/0000-0002-2584-8361
Cornelius Deuschl http://orcid.org/0000-0001-9262-7289

REFERENCES

The pandemic and neurointervention


