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Visualization of pressure related vessel compression in the perihemorrhagic zone during endoscopic ICH evacuation

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ABSTRACT

Objectives: The existence of perihemorrhagic ischemia in intracerebral hemorrhage (ICH) has been subject to intense debate. In contrast, the concept of reduced cerebral blood flow (CBF) in the perihemorrhagic zone (PHZ) is widely accepted. This report aims to demonstrate preliminary experience with endoscopic visualization of perihemorrhagic vessel compression in patients with ICH.

Patients and methods: Endoscopic findings in the PHZ during minimally invasive hematoma evacuation in six patients with basal ganglia ICH are described. 3D-Neuronavigation for exact real-time orientation and a translucent working channel for tissue visibility are used.

Results: While entering the hematoma with the endoscope, the same distinct areas are illustrated in five patients: In the cortical entry zone, uncompressed vessels are present. In the subcortical white matter, vessel quantity shows its physiological rarification. In perihemorrhagic white matter adjacent to the ICH however, vessels appear to be almost completely absent. After hematoma-evacuation, the lack of vessels in the PHZ vanishes and in contrast, correlates of hyperperfusion are observed. Occurrence of these findings does not show correlation with clinical or radiological parameters. However, the only patient without vessel compression in the PHZ had the best neurological outcome in this small case series.

Conclusion: We present visual correlates of mechanical vasoconstriction due to tissue compression in the PHZ of patients with basal ganglia ICH. Removal of the hematoma leads to visible reperfusion of the PHZ. These findings may help to understand the perihemorrhagic pathophysiology associated with focal reduction of cerebral blood flow and possibly ischemic changes in ICH.

1. Introduction

The concept of an ischemic "penumbra" has been established for ischemic stroke and early reperfusion of this "penumbral" tissue at risk has become the target of acute ischemic stroke interventions. However, the presence of an ischemic "penumbra" in the context of intracerebral hemorrhage (ICH) has been discussed controversially. While some authors support the existence of ischemic tissue in the perihemorrhagic zone (PHZ) based on experimental and clinical findings [1–5], others did not find convincing evidence for its presence [6–9].

Nevertheless, the concept of reduced cerebral blood flow (CBF) in the PHZ, e.g. measured by positron emission tomography (PET) [6,10] or perfusion computed tomography (CT) [8] is widely accepted today. Whether this CBF-reduction is induced by mechanical disruption or compression due to the sudden and forceful introduction of the hematoma mass [11,12], the toxic effects of blood constitutes or metabolites [13–15] or reduced metabolism with subsequent diaschisis [16] remains unclear.

Although conventional surgery has an important role in the treatment of ICH, visual tissue abnormalities in the PHZ during surgical procedures have not yet been reported. This may be due to limited overview and low differentiability of grey and white matter during conventional ICH evacuation. However, with the recent introduction of endoscopic ICH surgery, macroscopic evaluation of the different layers of brain tissue surrounding the hematoma core became more feasible and comparable in different ICH patients. We therefore sought to find visual correlates of vasoconstriction in the PHZ during endoscopic minimal invasive ICH evacuation. Here we present preliminary findings that illustrate a direct effect of intracerebral hematomas on the surrounding brain tissue with visible vessel compression in the PHZ.

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2. Methods

Available intraoperative video recordings of minimally invasive endoscopic surgery for basal ganglia hematoma from one author's (B.O.) consecutive series of 40 patients were reviewed retrospectively. All cases with full video recording from the cortical entry point to the inner core of the hematoma before and after evacuation of the hemorrhage were selected for further analysis: Age, sex, preoperative GCS, neurological status, NIHSS, blood pressure on admission, intraventricular involvement of the hemorrhage, time to surgery and GOSE at transfer from our institution to a rehabilitation facility were obtained from patient records.

All patients received preoperative cranial native CT scans as well as CT-angiograms and hematoma size was estimated by the ABC/2 method on native images prior to surgery [17]. The full video sequence from the endoscope's first insertion into the translucent working channel, the advance of its tip into the hematoma core as well as it's extraction directly after complete removal of the hematoma were then reviewed in slow motion (QuickTime Player 10.4, Apple Inc., Cupertino, USA) for each patient by three different investigators. Screenshots were taken from the video sequences for illustration of the findings when appropriate (FastStone Capture 8.3, FastStone Soft, USA). A consensus decision on the amount and intensity of the vasculature in the PHZ before and after hematoma evacuation was then made for each patient.

All included patients had basal ganglia ICH and in all cases, a frontal forehead approach above the frontal sinus was performed under general anesthesia and in supine position. Patient selection for endoscopic hematoma evacuation, the operative setup and the surgical technique have been previously described in more detail [18,19].

In short, a burrhole is performed at the projected trajectory entry site, the dura is coagulated and then incised. A transparent sheath (Neuroport, Olympus, Tokyo, Japan), which is used as a working channel, together with the rigid endoscope (0–30°, 2.7–4 mm diameter; Karl Storz, Tuttlingen, Germany; Richard Wolf GmbH, Knittlingen, Germany), and a tracking device (Stryker Navigation System II, Stryker GmbH, Duisburg, Germany) are inserted and tracked into the hematoma cavity. The Nagasaka-combined irrigation-coagulation suction cannula (Fujita Medical Instruments, Tokyo, Japan) is used to evacuate the hematoma. For safety reasons, 3D-Neuronavigation based on preoperative native cranial CT-scans is used to permanently track the endoscope tip during the procedure.

3. Results

Of 40 patients who underwent endoscopic ICH evacuation in our institution between 2009 and 2015, six patients with sufficient video material of the surgical procedure from first insertion of the endoscope until its final removal were identified. Table 1 shows patient details and characteristics. There were more male than female patients (4:2). Median age was 56 (49–78) years. All patients suffered from arterial hypertension on admission and CT scans revealed basal ganglia ICH with volumes varying from 22.5 to 107.5 ml (median 74 ml). Only one patient had been treated with antiplatelet medication when the bleeding occurred. Intraventricular involvement of the hemorrhage was present in 50% of the cases. Median GCS and NIHSS on admission were 8 (4–9) and 25 (14–35) points, respectively. Median time from initial CT-scan to operation was 8 (5–22) h. Median duration of surgical procedures was 68 (55–81) min. No surgery-related complications occurred and furthermore, no patient developed posthemorrhagic hydrocephalus or required insertion of a permanent shunt system.

Slow motion analysis of the intraoperative endoscopic video recordings of patient no. 1 (exemplarily) revealed multiple vessels right below the dural layer on the cortical entry site that were adjacent to the translucent working channel (Fig. 1A). Further advancement of the endoscope showed a clearly reduced quantity of vessels once the cortico-subcortical border was passed. In parenchymal white matter areas distant to the hematoma, no signs of compression could be visualized (Fig. 1B). Approximately 1 cm before entering the hematoma, a considerable vessel rarification was observed (Fig. 1C). Finally, when entering the hematoma core, no intact vascular structures could be identified (Fig. 1D).

Slow motion video analysis of intraoperative video recordings confirmed these findings in five of the six patients: The cortex with multiple vessels of different sizes and considerable vascular drawing, a subcortical boundary layer with sporadic smaller vessels and reduced vascular drawing as well as the PHZ with signs of compressed vessels and complete disappearance of all cerebral vessels. Those regions could each be distinguished as distinct areas along the trajectory from cortex to hematoma core. Illustrative screenshots from the intraoperative endoscopic video recordings of patient no. 2 show the three distinct layers and the corresponding location of the endoscope tip on 3D-Neuronavigation (Fig. 2).

Only one patient (patient no. 3) in our series lacked this clear visual distinction of the subcortical boundary layer and the PHZ with no further vessel compression and missing disappearance of all vasculature before penetration of the hematoma core.

For all other patients with prominent vessel reduction in the PHZ, slow motion video analysis of the endoscope's final withdrawal after hematoma evacuation revealed an alteration in PHZ appearance, now clearly showing increased vascular drawing that was even more prominent than in the overlying parenchyma layers. Again, this finding was not present in the one patient (patient no. 3) who had not shown the phenomenon prior to hematoma evacuation. An overview of all patients with respective screenshots of the three different areas including the PHZ before and after hematoma evacuation is illustrated in Fig. 3.

4. Discussion

Poor prognosis in ICH is not only determined by the initial insult and the respective primary brain damage but for a major part also by secondary brain damage. In addition to secondary hematoma expansion, the development of perilesional edema is an important cause of secondary neurological deterioration and seems to correlate with the size of the original hematoma [9,20]. Minimally invasive procedures for hematoma evacuation have been associated with benefits for a certain subgroup of patients compared with other surgical or conservative treatment options, but the decision to perform hematoma removal remains an individual one [18,21]. In contrast to the ischemic "penumbra" in ischemic stroke, experimental and clinical studies have delivered inconsistent results regarding potentially salvageable ischemic brain tissue surrounding an intracranial hematoma [7,22].

To the best of our knowledge, the visual impression of vasculature during endoscopic hematoma evacuation has not been described yet. Our endoscopic observations of the vessels within the cortex and the subcortical parenchyma first showing a strong and then reduced subcortical vascular drawing correlate well with the anatomic vascular architecture. However, a "penumbra"-like appearance within the narrow PHZ caught our interest during 3D neuronavigated endoscopy for minimal invasive hematoma evacuation and triggered this retrospective video review of nearly 40 surgical cases. Although we fail to objectify the reduction of vessels in this zone compared to the overlying white matter parenchyma due to software and hardware limitations and the retrospective