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Research Article

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A Surgical First: Application of Indocyanine Green Fluorescence Imaging for Endoscopic Third Ventriculostomy in an Infant

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Abstract

Introduction: Neonatal hydrocephalus requires early recognition and appropriate surgical management to prevent long term sequalae. Definitive surgical management includes cerebrospinal fluid (CSF) diversion through a CSF shunt insertion, or neuro-endoscopic third ventriculostomy with or without choroid plexus cauterization. Surgical decision-making and the chosen approach are based on patient age, etiology, imaging, and comorbidities. Endoscopic third ventriculostomy (ETV) has been proven to provide a reasonable treatment option for hydrocephalus in children under 12 months of age. To our knowledge we report for the first time the application of indocyanine green fluorescence imaging to visualize the basilar artery during an ETV to prevent from harming the vessel.

Patients and methods: A 7mo old patient with a history of preterm delivery at 27 weeks of gestation and intraventricular bleeding grade 2 developed consecutive hydrocephalus due to aqueductal obstruction. Indication was made for ETV.

Results: ETV was carried out. During the procedure indocyanine green was applied to visualize the basilar artery prior to opening the floor of the third ventricle. This provided the surgical team with a clear picture of the anatomy thus enabling ETV while safely sparing the basilar artery.

Discussion: ETV in infants are demanding procedures. The risk of harming the basilar artery is immanent as the vessel with its known anatomical variants cannot be clearly visualized through the floor of the third ventricle. With the application of indocyanine green fluorescence imaging this can be overcome providing an increased safety during the actual ETV. To our knowledge this is the first report on the use of indocyanine green fluorescence imaging for pediatric ETV. It might offer a new range of safety while providing minimal invasive neuro-endoscopic procedures to infant patients.

Keywords: Endoscopic; Preterm delivery; Ventriculostomy; Ultrasound; Visualization

Introduction

Neonatal hydrocephalus requires early recognition and appropriate surgical management to prevent long term sequalae. Definitive surgical management includes cerebrospinal fluid (CSF) diversion through a CSF shunt insertion, or neuro-endoscopic third ventriculostomy with or without choroid plexus cauterization. Surgical decision-making and the chosen approach are based on patient age, etiology, imaging, and comorbidities. Endoscopic third ventriculostomy with or without choroid plexus cauterization (ETV/CPC)

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has been proven to provide a reasonable treatment option for hydrocephalus in children under 12 months of age. The use of indocyanine green fluorescence imaging has been applied in pediatric neurosurgery so far only for tumor surgery or the surgery of vascular anomalies such as aneurysms respectively. To our knowledge we report for the first time the application of indocyanine green fluorescence imaging to visualize the basilar artery during an ETV to prevent from harming the vessel.

Patients and Methods

A 7mo old patient with a history of preterm delivery at 27 weeks of gestation and intraventricular bleeding grade 2 developed consecutive hydrocephalus due to aqueductal obstruction. The patient was born by cesarian section because of amnion infection syndrome. On day 4 she was evaluated with a trans-fontanellar ultrasound, that showed ICH °III (Volpe) on the right side and °II (Volpe) on the left side (Figure 1). In addition, along with prematurity the patient showed ANS, PPHN and a mild BPD, however, no surgical procedures were necessary during the premature period. Neuroendoscopy was then indicated due to a rapidly growing head circumference >97% percentile at the age of 6 months (corrected). Preoperative MRI of the head consecutively showed a massive ventricular dilatation as shown in Figure 2. In addition, the T2 TSE showed no flow void over the aqueduct with an enlargement of the side ventricles and the third ventricle. Therefore, indication was given for a neuro-endoscopic third ventriculostomy. A flexible neuroendoscope with a diameter of 4mm and a working channel of 1.2 mm (Karl Storz Endoskope, Tuttlingen, Germany) was used. For visualization a camera system with fluorescence technology was used to allow visualizing anatomy and blood flow (Stryker, Kalamazoo, MI, USA). The intraoperative view showed a total closure and an aqueductoplasty was therefore indicated. Subsequently a neuro-endoscopic third ventriculostomy without choroid plexus cauterization was carried out. During the procedure and prior to opening the floor of the third ventricle indocyanine green (ICG) was applied intravenously in a fractured fashion with a concentration of 0.25 mg/ml dissolved in distilled water with a single dosage of 0.5-1.0 ml. With a patient weight of 8.3 kg a total daily dose of 1.25 mg/kg of body weight has not been exceeded. ICG was administered through a peripheral venous line. ICG immunofluorescence of the basilar artery was visible 6 seconds after injection. This was repeated 3 times to visualize the basilar artery before and after the actual ETV. The entry point was defined as the Kocher's point to the frontal horn of the right ventricle. Thereafter an aqueductoplasty was carried out using a 3mm PTCA balloon (Boston Scientific, Marlborough, MA, USA). A burr hole reservoir (Rickham) was placed connected to a 3.5 cm Bactiseal catheter (Codman, Raynham, MA, USA) to provide access for potential emergency puncture. The procedure itself, the perioperative as well as the postoperative course were uneventful.

Results

During ventriculoscopy, a clear visualization of the basilar artery could be achieved compared to before without the application of ICG. (Figure 3 and 4) This provided the surgical team with a clear picture of the anatomy and thus enabled the surgeon to safely carry out the ETV while sparing the basilar artery. After the ETV indocyanine green was applied again to double-check the integrity of the vessel. (Figure 5) On postoperative day 12 the patient showed a CSF pouch around the frontal Rickham's reservoir. A puncture and measurement of the ICP was performed. ICP was within normal range with 15 cm H_2O and without any signs for infection. 15ml of CSF were drawn and a postoperative MRI was performed revealing

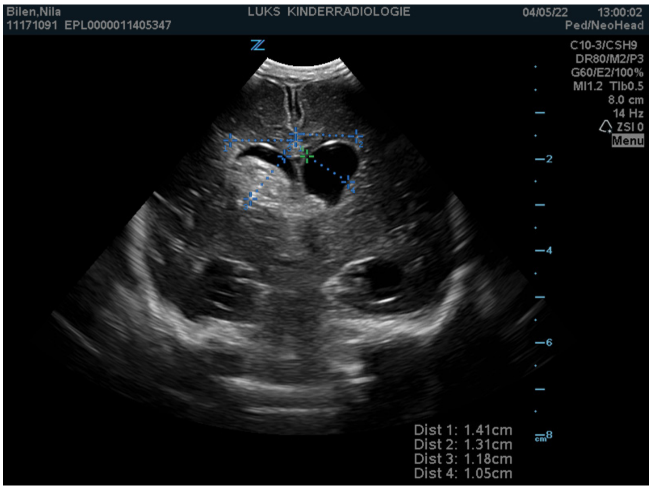

Figure 1: Trans-fontanellar ultrasound, showing ICH °III (Volpe) on the right side and °II (Volpe) on the left side

Figure 2: Preoperative MRI T2 TSE of the head with massive ventricular dilatation and no flow void over the aqueduct with an enlargement of the side ventricles and the third ventricle.

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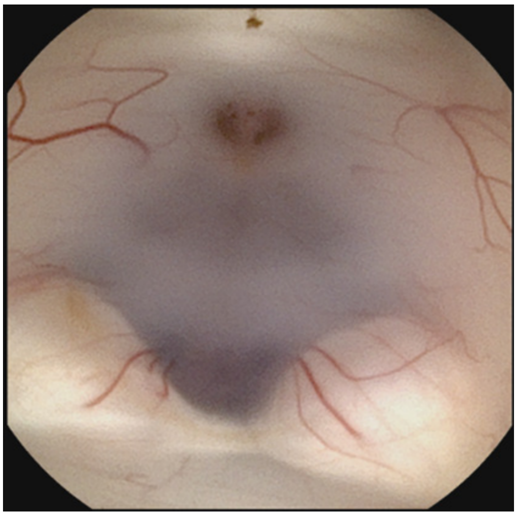

Figure 3: Endoscopic view onto the floor of the third ventricle.

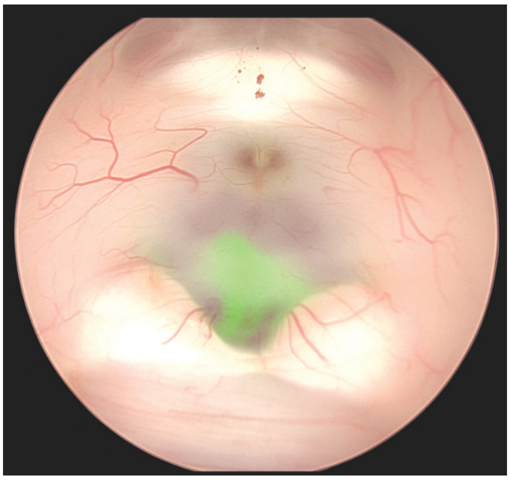

Figure 4: Endoscopic view onto the floor of the third ventricle following the application of indocyanine green with the visualization of the bulbus of the basilar artery

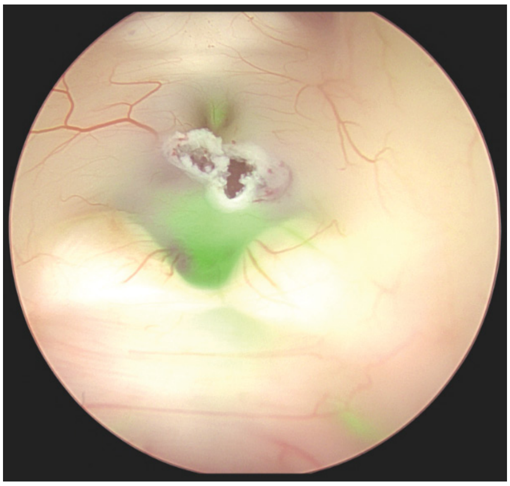

Figure 5: Endoscopic view onto the floor of the third ventricle following the opening of the floor and after the application of indocyanine green.

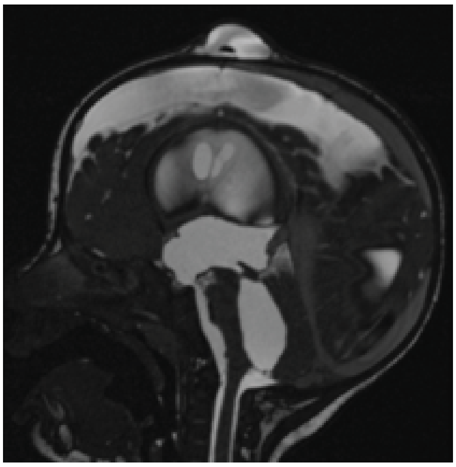

Figure 6: Postoperative MRI was performed revealing a patent ETV but signs of an entrapped 4th ventricle

a patent ETV but signs of an entrapped 4th ventricle. (Figure 6) A second neuro-endoscopic surgery was performed with a re-aqueductoplasty, and a VP-shunt (Miethke, Potsdam, Germany: proGAV 2.0 gravitational valve) was placed with an opening pressure of 8 cm H_2O in the supine position and +25 cm H_2O in the upright position. The further course was uncomplicated, and follow-up for 6 months was uneventful.

Discussion

Schulz et al. could demonstrate the feasibility and safety of neuro endoscopic lavage for the treatment of posthemorrhagic hydrocephalus in neonates with IVH [1]. In a current meta-analysis, Parenrengi et al. concluded that ventricular lavage reduces the shunt dependency on the PHH, as well as decreases shunt's related infection rate [2]. In addition, neurocognitive outcome may benefit from early ventricular lavage. Therefore, in our treatment algorithm flexible neuro-endoscopic lavage in patients with PPH with or without neuro-endoscopic intervention is considered to be a primary treatment option. However, authors are aware that there is controversy in performing an ETV under one year of age because of a reasonable high failure rate, even in the most favorable cases thus leading to the indication for a ventriculoperitoneal shunt in the end for many patients. However, our strategy is also to postpone this definitive surgery for VP-shunts. So far there is little evidence in literature for the application of ICG in pediatric neurosurgery. A few studies report on the application and use of ICG fluorescence in pediatric neurosurgical procedures while obviously showing that ICG fluorescence might offer improved visualization of vascular structures for tumor resection and arteriovenous malformation surgery. None of them dealt with the application of ICG fluorescence for ETV so far. ETV in infants are demanding procedures. The risk of harming the basilar artery is immanent as the vessel with its known anatomical variants [3]. This includes fenestrations,

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duplications, and persistent fetal arteries. In addition, it cannot be clearly visualized through the floor of the third ventricle during ventriculoscopy thus making it more difficult to choose a safe spot for the opening of the floor of the third ventricle. With the application of indocyanine green fluorescence imaging this can be overcome providing an increased safety during the actual ETV. With little or no evidence of dosing of indocyanine green and a considerable variability authors decided to dose according to the product guidelines from a recognized ICG distributor [4], not exceeding a maximum daily dosing for infants (0 months to 2 years) of 1.25 mg/kg of body weight. The application of near infrared spectroscopy (NIRS) imaging in surgery is evolving rapidly. The use of indocyanine green fluorescence imaging has been established in many fields of pediatric specialties, such as oncology, urology, thoracic, hepato-biliary and bowel surgery respectively [5]. The application of indocyanine green for pediatric applications has been proven so far to be safe and being without adverse side effects [6]. This could be shown also for pediatric neurosurgical indications such as surgery of the brainstem in children [7]. So far, the use of indocyanine green fluorescence imaging in pediatric neurosurgical applications has been limited to tumor surgery and to surgery of vascular malformations such as aneurysm only [8]. To our knowledge this is the first report on the use of indocyanine green fluorescence imaging for pediatric neurosurgery. It might offer a new range of safety while providing minimal invasive neuro-endoscopic procedures to infant patients.

Declarations

Ethical Approval

Not applicable. (There were no ethical committees, or Internal Review Board respectively obtained as the study was done during a regular case while having no implications on the patient, the procedures safety or any other aspect which would require ethical approval.

Therefore, a **consent to participate** and/or **consent to publish** were not obtained from the parent and/or legal guardian of the patient as this was not applicable.)

Competing interests

There are no competing interests.

Authors' contributions

Philipp Szavay and Markus Lehner were designing the study as well as writing the manuscript. Philipp Szavay and Markus Lehner were providing the images. Philipp Szavay and Markus Lehner were reviewing and approving the final version of the manuscript. Peter Esslinger was reviewing and revising the manuscript. Peter Esslinger has approved the final version of the manuscript.

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Availability of Data and Materials

All data and materials were delivered for the submission; all data and materials can be obtained through the corresponding author.

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