

Intracranial emergencies during pregnancy requiring urgent neurosurgical treatment

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ABSTRACT

Objective: Despite contemporary diagnostic and therapeutic techniques intracranial emergencies in the obstetric setting pose still a major challenge for the clinicians. There are limited guidelines and differing ethical views. Multidisciplinary teams are needed to support the pregnant woman in a way that she can deliver a viable and healthy child. The aim of the present study was to scrutinize the management of intracranial emergencies during pregnancy which needed urgent neurosurgical treatment.

Patients and methods: Data of all pregnant women who presented with newly diagnosed intracranial pathologies and neurological symptoms caused by these pathologies in an emergency setting were collected over a 10-year period (2008–2018). Patient characteristics including maternal age, gestational age, and preoperative work-up of both mother and fetus were recorded. Furthermore, the surgical treatment, mode of delivery, and neonatal and maternal outcomes were analysed.

Results: The mean maternal age was 32.7 years and most patients were in their third trimester. There was one twin pregnancy (total of 12 fetuses). Five out of eleven pregnant women suffered from intracerebral haemorrhage (epidural haematoma (1), arteriovenous malformation (1), subarachnoid haemorrhage (2) and intracerebral haemorrhage (1)) and the other six patients had intracranial neoplasms (primary meningeal sarcoma (1), trigeminal schwannoma (1), anaplastic astrocytoma (2), glioblastoma (1) and sphenoid wing meningioma (1)). Neurosurgical procedures were performed via craniotomies in eight patients. A stereotactic biopsy via a frontal burr hole was achieved one patient. The two other patients with subarachnoid haemorrhage due to rupture of PICA aneurysms were treated with coil embolization. Depending on the gestational age and the clinical condition of the pregnant women it was decided to perform an emergency Caesarean section prior to further therapeutic measures in seven patients. Two out of 12 fetuses were unviable. Six women survived, while five women succumbed to the intracranial pathology.

Conclusion: The individualized treatment approach in this peculiar obstetric scenario needs to consider various issues such as the clinical condition of the pregnant woman, prognosis of the disease, gestational age and the status of the pregnancy. The primary concern in this context must be the mother's health and safety. Caesarean section is the primary mode of delivery in most cases. While contemporary care can insure survival for the majority of infants, maternal mortality still poses an extraordinary challenge. Interdisciplinary consulting of the patient and/or her family is necessary to develop a treatment strategy for both the expectant woman and her offspring.

Abbreviations: MRI, magnetic resonance imaging; CT, computed tomography; DSA, digital subtraction angiography; KPS, Karnofsky performance status; PICA, posterior inferior cerebellar artery; AVM, arteriovenous malformation; G, gavidity (number of pregnancy times); P, parity (number of pregnancies carried to viable gestational age); A, abortion; gr, gram

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1. Introduction

Despite a growing body of experience on timing of neurosurgical procedures in pregnant women with intracranial pathologies diagnosed during pregnancy [1–4], the occurrence of intracranial emergencies in clinical routine still poses major challenges for both mother and child [3,5,6]. Various case series and reviews have been published in the last decade reporting on timing of the management of intracranial disorders during pregnancy [7–14]. Contemporary diagnostic and therapeutic measures including multidisciplinary teams of neurosurgeons, obstetricians, neonatologists and anaesthesiologists have reduced both maternal and fetal mortality [2].

Different strategies to support the mother in a way that she can deliver a viable and healthy child have been suggested [3,8]. Furthermore, ethical questions considering the control of disease and well-being of the mother on one hand, and maintenance of pregnancy or preterm termination on the other hand have been addressed [15–17].

Previous studies focusing on pregnancy and neurosurgery either reported mixed series with cranial or spinal pathologies [3,18,19] or they concentrated on specific entities such as aneurysms, cavernomas or gliomas [11,20,21]. Less attention has been paid, however, to the management of pregnant women who present with previously undiagnosed intracranial lesions requiring urgent treatment [19,20]. Therefore, the aim of the present study was to scrutinize the multidisciplinary management of intracranial emergencies during pregnancy focusing on both maternal and fetal outcome.

2. Patients and methods

Data of all women who presented to the Department of Neurosurgery as medical emergencies during any phase of pregnancy were collected over a 10-year period. Inclusion criteria for the present study were (1) intracranial pathologies which were diagnosed at the time of presentation and (2) neurological symptoms caused by these pathologies. Exclusion criteria were (1) incidental diagnosis, (2) no or mild neurological symptoms, and (3) elective surgery after delivery.

Patient characteristics which were recorded included maternal age, gestational age, number of pregnancies (gravidity), and number of pregnancies carried to a viable gestational age (parity). The pre-operative work-up included assessment of maternal and fetal medical status and complications. Imaging studies involved magnetic resonance imaging (MRI) or computed tomography (CT), and digital subtraction angiography (DSA) in selected cases.

Individual treatment plans were assigned according to an interdisciplinary conference with neurosurgeons, obstetricians, neonatologists and anesthesiologists considering preference and wishes of the pregnant women and their families. In general, and whenever feasible a "mother first policy" was suggested. To allow maternal treatment urgent Caesarean section was suggested before surgery whenever possible, however, the final choice was given to the mother. All treatment steps were coordinated in the interdisciplinary setting and explained in detail to the patients and/or their families.

Neurosurgical procedures were performed using departmental standard techniques [22–24]. In two patients, endovascular coiling of ruptured aneurysms was carried out. Caesarean sections were performed under general anaesthesia in all instances. In patients with maintained pregnancy utmost care was taken to avoid fetal asphyxia by ensuring adequate maternal oxygenation and ventilation. Adequate pre-oxygenation was achieved by delivery of 100 % oxygen via a facial mask for 3–5 min. Sodium thiopental was used for induction of anaesthesia. Succinylcholine was administered for muscle relaxation, with subsequent application of tracrrium. After intubation sufentanil and sevoflurane were given for maintenance of anaesthesia. During the operation fetal heart rate monitoring with cardiotocography was used by obstetrics' team.

Postoperatively, patients were treated on the neurosurgical

Table 1
Demographic data and diagnosis in 11 pregnant women with intracranial emergencies.

Patient Nr.	Age (yr)	Gestational age (weeks)	Status of gravidity/parity/ abortion at admission	Symptoms	Diagnosis
1	25	28	G2 P1 A1	Aphasia, hemiparesis, somnolence	Primary meningeal sarcoma
2	27	18	G3 P2 A0	Hemiparesis, somnolence	Intracerebral haemorrhage
3	38	40	G1 P0 A0	Somnolence	Traumatic brain injury, epidural haematoma
4	45	29	G2 P1 A0	Somnolence	Subarachnoid haemorrhage due to rupture of a PICA aneurysm
5	40	25	G3 P2 A0	Somnolence	Subarachnoid haemorrhage due to rupture of a PICA aneurysm
6	43	40	G2 P0 A1	Somnolence	Intracerebral haemorrhage due to bleeding from an arteriovenous malformation
7	30	37	G1 P0 A0	Gait ataxia, facial palsy, trigeminal hypoesthesia	Cystic trigeminal schwannoma with brainstem compression
8	22	36	G2 P1 A0	Seizures	Anaplastic astrocytoma
9	32	30	G2 P2 A0	Hemiparesis, somnolence	Secondary glioblastoma
10	27	8	G2 P0 A0	Hemiparesis	Anaplastic astrocytoma
11	32	37	G2 P1 A0	Posis, diplopia	Meningioma sphenoid wing

PICA = posterior inferior cerebellar artery.

G = gravidity (number of pregnancy times).

P = parity (number of pregnancies carried to viable gestational age).

A = Abortion.

Table 2

Treatment and outcome of 11 pregnant women with intracranial emergencies gr = gram.

Patient Nr.	Neurosurgical treatment	Maternal outcome (mean follow up: 11.5 ± 15.1 months)	Mode of delivery	Infant weight (gr)	Apgar score at 1/5/ 10 minute,	Neonatal outcome,
1	Tumor resection via osteoclastic craniotomy	Death secondary to pulmonary metastasis two months later	Caesarean section before surgery	1.150	8/9/9	Alive
2	Haematoma evacuation via osteoplastic craniotomy	Death due to septic shock five days later	Spontaneous abortion after surgery	-	-	Dead
3	Haematoma evacuation via osteoplastic craniotomy	Complete recovery (Karnofsky: 100%)	Transvaginal delivery	3.240	9/10 /10	Alive
4	Endovascular coiling, insertion of bilateral ventricular drains	Death due to cerebral vasospasmus 10 days later	Caesarean section before coiling	1.155 (twin 1) 1.300 (twin 2)	4/6/7 4/6/7	Alive Alive
5	Endovascular coiling, insertion of unilateral ventricular drain	Death due to cerebral vasospasmus 4 days later	Caesarean section 3 days after coiling	4.050	5/6/7	Alive
6	Decompressive craniectomy, haematoma evacuation, insertion of unilateral ventricular drain	Dysarthria, paresis of the left leg, focal seizures (Karnofsky: 80%)	Caesarean section before surgery	3500	9/10/10	Alive
7	Tumor removal via craniotomy, insertion of lumbar drain	Residual trigeminal hypaesthesia (Karnofsky: 100%)	Caesarean section before surgery	3.340	3/8/9	Alive
8	Stereotactic biopsy and radiation therapy	Complete recovery (Karnofsky: 100%)	Caesarean section before surgery	2.740	9/10/10	Alive
9	Tumor removal via osteoplastic craniotomy and chemotherapy	Death three weeks later	Caesarean section before surgery	1.680	7/8/9	Alive
10	Tumor removal via osteoplastic craniotomy, radiochemotherapy	Complete recovery (Karnofsky: 100%)	Medical abortion 3 weeks after surgery	-	-	Dead
11	Tumor removal via osteoplastic craniotomy, radiotherapy	Good recovery, ptosis, (Karnofski: 100%)	Caesarean section before surgery	2140	9/10/10	Alive

intensive care unit in a multidisciplinary setting. The fetuses were examined carefully by ultrasound. Daily fetal heart rate monitoring with cardiotocography was performed routinely. Both, women and newborns were followed-up for up to a year after hospital discharge. Maternal outcome was assessed by the Karnofsky performance status (KPS) score.

For statistical analysis Fisher's two-tailed exact test was used. The significance level was set to $\alpha = 0.05$.

3. Results

Eleven pregnant women were identified and included in the present study over a 10-year period from 2008–2018. During this period, 24,701 deliveries were performed at Hannover Medical School. That is, the frequency of intracranial emergencies during pregnancy was 0.04 % with regard to all deliveries. Demographic data, patients' characteristics both for women and fetus, and treatment outcome are summarized in [Tables 1 and 2](#). The mean maternal age at presentation was 32.7 years (range, 22–45 years). Four women (36 %) were in a high-risk pregnancy category with respect to their age (age less than 18 years old or higher than 35 years). Seven women (64 %) presented with a pregnancy in the third trimester, three (27 %) in the second and one (9%) in the first trimester. The mean gestational age at the time of presentation was 29.8 weeks (range, 8–40 weeks).

Four patients (36 %) presented with intracerebral haemorrhage. Of these, two had a subarachnoid haemorrhage (Hunt and Hess grades IV and V, respectively) due to rupture of aneurysms of the posterior inferior cerebellar artery (PICA), one had an intracerebral haemorrhage due to bleeding from an arteriovenous malformation (AVM), and one had an intracerebral haemorrhage of unknown etiology. Head injury leading to an epidural hematoma occurred in one patient (9%). Six patients (55 %) presented with intracranial tumors: primary meningeal sarcoma (1), trigeminal schwannoma (1), anaplastic astrocytoma (2), glioblastoma (1) ([Fig. 1](#)) and sphenoid wing meningioma (1). Primary cranial CT scans were obtained in three patients, and eight patients had cranial MRI with gadolinium for the initial diagnostic imaging. The two

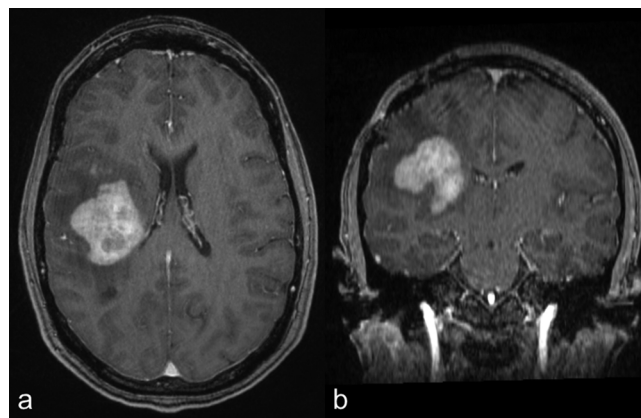


Fig. 1. Glioblastoma WHO grade IV in a 32-year-old pregnant woman. Gadolinium-enhanced axial (a) and coronal (b) T1- weighted images show a large right-sided intracerebral tumor. The patient presented at gestational week 27 with severe headaches, vomiting, and a progressive left hemiparesis.

patients with subarachnoid haemorrhage underwent transfemoral DAS. After diagnosis three patients received a ventricular drain as an emergency measure.

Depending on the gestational age and the clinical condition of the pregnant women it was decided to perform an emergency Caesarean section prior to further therapeutic measures in seven patients. A Caesarean section was performed in one patient with subarachnoid haemorrhage 3 days after aneurysm coiling. Spontaneous abortion occurred early after surgery in a 27-year-old patient (gestational age 18 weeks) with intracranial hemorrhage during septic shock, and medical abortion was induced in another 27-year-old patient with anaplastic astrocytoma (gestational age 8 week) early after surgery in order to allow radiochemotherapy ([Fig. 2](#)). A 38-year-old woman with epidural haematoma due to traumatic brain injury (gestational age 40 weeks) had a transvaginal spontaneous delivery after surgery.

Neurosurgical procedures were performed in all patients in general

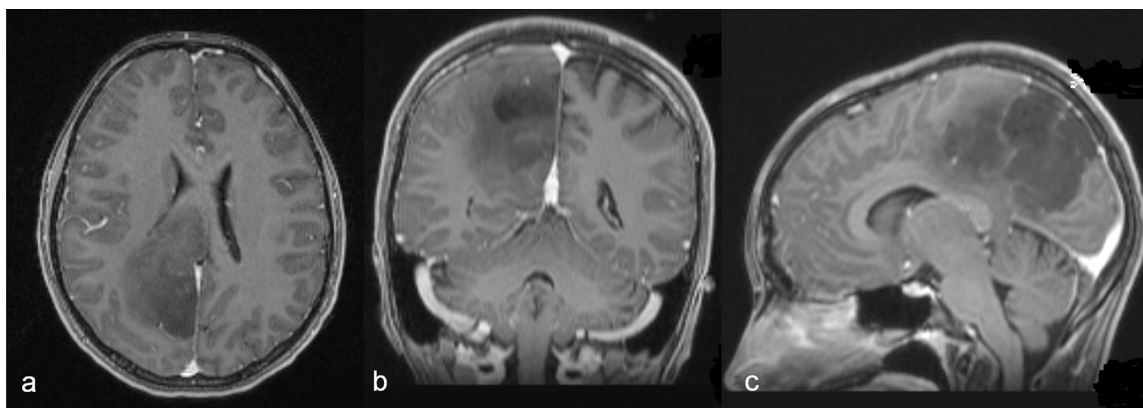


Fig. 2. Anaplastic astrocytoma WHO grade in a 27-year-old pregnant woman.

Gadolinium-enhanced axial (a), coronal (b) and sagittal (c) T1-weighted images show a large tumor in the right parietal lobe. The patient presented at gestational week 8 with complex focal seizures.

anaesthesia after endotracheal intubation. The intracranial pathologies were approached via osteoplastic craniotomies in seven instances. The patient with the primary meningeal sarcoma, which was published earlier as care report [25], had an osteoclastic craniotomy, and the patient with a spontaneous intracranial haemorrhage underwent a hemicraniectomy. A stereotactic biopsy via a frontal burr hole was obtained in another patient with a diffuse intracerebral tumor. The two patients with subarachnoid haemorrhage due to rupture of PICA aneurysms were treated with coil embolization. All surgical procedures were performed in the supine position except in the patient with trigeminal schwannoma who was approached in prone position. There was no surgery-related morbidity or mortality both for the women and the fetuses.

Overall, 2 out of 12 fetuses were unviable (one after spontaneous abortion, gestational age 18 weeks; one after medical abortion, gestational age 8 weeks). A 45-year-old woman with subarachnoid haemorrhage had a twin pregnancy at gestational week 29 + 2, both preterm newborn were alive after Caesarean section.

The mean Apgar score of all fetuses was 6.4/10, 8.1/10 and 8.7/10 at 1, 5 and 10 min, respectively. Due to persistent low Apgar scores at 10 min after birth, three infants needed immediate intensive care. The average birth weight of all fetuses was 2461 g (range, 1150–4050 g).

Neonatal outcome did not differ with regard to delivery in the second or third trimester ($p = 0.1$). There were no congenital defects. Development was normal also in the preterm infants delivered by Caesarean section in the second trimester.

There was a high overall maternal mortality. Five women succumbed due to consequences of their diseases. The two women with subarachnoid haemorrhage died subsequent to severe vasospasm, two women with tumors died because of further progress of tumor respectively metastasis, and one woman with intracranial haemorrhage had septic shock with multiorgan failure. There was no significant association between the maternal outcome (favorable vs. unfavorable) and diagnosis ($p = 0.57$). At the last follow-up, five women had fully recovered (KPS score: 100 %), and one was mildly disabled (KPS score: 80 %).

4. Discussion

Our study demonstrates that intracranial emergencies during pregnancy pose major challenges in therapeutic decision-making and treatment planning. Interdisciplinary management considering both the condition of the pregnant woman and the fetus is pivotal and allows to tailor individual treatment plans. With contemporary techniques, fetuses in the second and third trimester have high chances for survival and a normal development after timely Caesarean section immediately

prior to the treatment of the intracranial emergency of the child-bearing woman. There is a relatively high risk of mortality for the expectant mother, however, depending mainly on the underlying disorder. Remarkably, 3 out of 11 gravida with intracranial or subarachnoid haemorrhage succumbed within days after admission, and 2 died during follow-up.

In general, obstetric causes of maternal mortality have declined due to improvement of medical care. In parallel, however, non-obstetric causes of maternal morbidity and mortality appear to have increased [8,26,27]. Pregnancy may be complicated by hypertension, eclampsia and disseminated intravascular coagulation [10,18,27]. Although a pregnant woman has essentially not a higher risk to develop problems requiring neurosurgical treatment than non-pregnant women, the physiological and anatomical changes during pregnancy require special attention in pathologies such as subarachnoid haemorrhage, intraparenchymal bleeding and intracranial tumors [27,28].

Medicolegal aspects have to be considered in the context of emergencies requiring urgent neurosurgical treatment and these may differ from country to country [17,29]. An ethical dimension involves the debate about maternal versus fetal rights [15,16]. There are various aspects which need to be considered in decision-making. Once the patient has been stabilized, we suggest that ad hoc interdisciplinary counselling should be the next immediate step to develop a plan for decision-making considering both maternal stability and gestational age. Recommendations need to be communicated in detail with the patient or her family to obtain informed consent on each step of future treatment. From an ethical point of view, the first concern in this scenario should be the child-bearing woman's health and safety. If the woman's health condition is critical, saving the woman's life while taking measures to preserve the fetus need to be in the focus of attention [15,30].

A particularly difficult situation emerges in the case of maternal brain death. Clinically, it is possible to sustain a brain-dead mother's somatic functions over a longer period following the onset of brain death [14]. But different ethical and legal issues including the mother's body "as a cadaveric incubator" and the concern for possible damages to the fetus have to be considered [2,14]. In such a situation the question arises from which gestational age onward the pregnancy should be supported. As reported previously [14], prolonged somatic support can lead to the delivery of a viable child with satisfactory birth weight and normal development without problems.

Intracranial bleedings are one of the most serious conditions during pregnancy. Haemorrhages caused by rupture of intracranial aneurysms or secondary to AVMs account for 5%–12% of all maternal deaths [11,31]. Transfemoral DSA has been the gold standard in case of a suspected aneurysm or a vascular malformation [32–34]. However, it

can expose the fetus to substantial radiation and thus should be used with caution [32]. More recently, MRI has been used more often as a safer option for diagnosis without adverse fetal effects in any trimester [21,32,33]. Robba et al. after analyzing of a cumulative series of 52 cases from 23 studies suggested that when the child-bearing woman is in a life-threatening situation or the fetus is in the third trimester of gestation, an emergency Caesarean section should be considered [7]. They also indicated that when the fetus is in the first or early second trimester, the expecting mother might be treated as if she would not be pregnant [7]. In that study, the Hunt and Hess score at admission correlated with outcome as determined by the Glasgow outcome score. There was no association between the mode of delivery and the mother's outcome score. The two patients in our series, who presented with subarachnoid haemorrhage due to rupture of a PICA aneurysm, were both in a critical situation. Endovascular coiling was considered the preferred treatment option in this context. It is conceivable that the conditions associated with pregnancy contributed to the demise secondary to vasospasm in both cases despite maximal conservative treatment.

Intracranial tumors in women have been considered to manifest rarely during pregnancy with an incidence of less than 0.006 % [8,35]. Both benign and malignant intracranial glial and meningeal tumors have been described [12,25,28]. Laviv et al. suggested two options to be considered in the management of benign tumors during pregnancy [20]. First, treatment may be deferred until after delivery as long as the tumor would not result in irreversible neurological deficits. Second, a pregnant woman should not be denied surgery regardless of the gestational age [9,36,37]. Both options are feasible and valid; however, they may not be applied in more aggressive or malignant tumors. Verheecke et al. summarized the case histories of 27 pregnant women with primary cranial tumors, meningiomas or brain metastases diagnosed and treated between 1973 and 2012 in six different countries [13]. They concluded that surgical resection remains the main therapy for malignant and growing tumors.

In child-bearing women harboring tumors in deep or eloquent brain regions or in those with malignant tumors radiotherapy and/or chemotherapy might be indicated. In such situations both the woman's prognosis and the risk for the fetus need to be evaluated [38–41]. Patients with no neurological deficits might undergo regular neurological examinations and imaging [9,40,42]. In patients with neurological symptoms or tumor progress medical abortion in the first trimester or Caesarian section in the second and third trimester need to be discussed.

5. Conclusion

Diagnostic and therapeutic measures in a pregnant woman with an intracranial emergency need immediate attention. The primary concern in this context must be the mother's health and safety. Interdisciplinary consulting of the patient and/or her family is necessary to develop a treatment strategy for both the expectant woman and her offspring. Current treatment algorithms should be continuously reassessed and adapted along the growing experience and knowledge.

Author contributions

ME, NU, and BH participated in the design of the study. ME, EJH, DS, CvK and JKK participated in the design of the study and drafted the manuscript. JML, BH and NU performed the statistical analysis and revised the manuscript. JKK, PH, DS, JML and CvK were involved in drafting the manuscript or revising it critically for important intellectual content. ME, EJH, PH, and JKK revised the manuscript and gave final approval of the version to be published. All authors read and approved the final manuscript.

Conflicts of interest

The authors report no conflict of interest

Ethics approval and consent to participate

This study was performed in accordance with the ethical standards detailed in the Declaration of Helsinki. For this type of study, formal approval of the institutional ethics committee is not required at the authors' institution. The requirement to obtain signed consent form for study participation was waived.

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