

Neurological Disorders Complicating Pregnancy and its Obstetric Outcomes

Shobha Giliyar¹, Jayashree V Kanavi², Annamma Thomas³

Received on: 03 February 2022; Accepted on: 08 February 2023; Published on: 12 May 2023

ABSTRACT

Objective: To find the common neurological disorders complicating pregnancy and their obstetric outcome.

Materials and methods: This was a retrospective study conducted over a period of 3 years and included all pregnant women with a diagnosis of neurologic disorders who were admitted to the Obstetrics and Gynecology Department at St John's Medical College, St John's National Academy of Health Sciences (SJNAHS), Bengaluru, Karnataka, India. The study was carried out from January 2016 to December 2018.

Results: A total of 60 patients with neurologic disorders were identified during the study period of 3 years. In our study, 57 (95%) women were in the 20–35-year age-group, and the majority were primigravida 38 (63.3%). A total of 56 women (93.3%) delivered at term. A total of 28 (46.6%) women had a cesarean section, and 27 (45%) had a vaginal delivery. Among the neurologic disorders in pregnancy, 36 (60%) women had epilepsy, seven (11.6%) cerebrovascular diseases, six (10%) polio survivors, and four (6.6%) central nervous system (CNS) infections. A total of 16 (44.4%) women with epilepsy (WVE) were seizure-free in index pregnancy, 15 (41.6%) had relapse of seizures during present pregnancy, and five (13.8%) had been newly diagnosed with epilepsy in the index pregnancy. There were no maternal or perinatal deaths.

Conclusion: Multidisciplinary approach in a tertiary care center improves both maternal and fetal outcomes.

Keywords: Antiepileptic drugs, Cesarean section, Epilepsy, Neurological disorders, Pregnancy, Seizures.

International Journal of Infertility and Fetal Medicine (2023): 10.5005/jp-journals-10016-1308

INTRODUCTION

Neurological disorders are very rarely encountered in pregnancy. It can be either a preexisting condition before pregnancy or develop during pregnancy. It is a challenge to diagnose and differentiate a few new onset neurological disorders during pregnancy from pregnancy complications manifesting with neurologic features like eclampsia. It is associated with increased morbidity and mortality. It is an important indirect cause of maternal death in India and around the globe.^{1,2} Due to its rarity in its occurrence in pregnancy, a high degree of suspiciousness and involvement of the concerned team is needed for the diagnosis and management of the patient. The altered physiology during pregnancy imposes a challenge to diagnose the various disorders. The duration of pregnancy and concern regarding the fetus make it tricky to choose appropriate investigation and treatment. Hence, this study was carried out with the intention of determining the most common neurological disorders during pregnancy and their distribution, clinical presentation, and obstetric outcome in our institution.

OBJECTIVE

The objective of our study is to find the common neurological disorders complicating pregnancy and their obstetric outcome.

MATERIALS AND METHODS

This was a 3-year retrospective study done at St John's Medical College, SJNAHS, Bengaluru, Karnataka, India, from January 2016 to December 2018. We included all the pregnant women with neurologic disorders admitted to the Obstetrics and Gynecology Department of our hospital.

Demographic data, details of the respective neurologic disorders, and obstetric outcomes of the patients were noted.

^{1–3}Department of Obstetrics and Gynaecology, St John's Medical College, St John's National Academy of Health Sciences (SJNAHS), Bengaluru, Karnataka, India

Corresponding Author: Shobha Giliyar, Department of Obstetrics and Gynaecology, St John's Medical College, St John's National Academy of Health Sciences (SJNAHS), Bengaluru, Karnataka, India, Phone: +91 9448568979, e-mail: shobhag76@yahoo.com

How to cite this article: Giliyar S, Kanavi JV, Thomas A. Neurological Disorders Complicating Pregnancy and its Obstetric Outcomes. *Int J Infertil Fetal Med* 2023;14(2):59–64.

Source of support: Nil

Conflict of interest: None

The study included all pregnant women with preexisting neurologic disorders or newly diagnosed neurologic disorders during pregnancy. Pregnant women with eclampsia were excluded from the study.

The detailed history of the patients, clinical examination findings, and basic investigations were studied. The management by various multidisciplinary teams as per institutional guidelines was noted. Radiological imaging was done in relevant patients as per the advice of the neurophysicians or neurosurgeons. The outcome measures studied included maternal and neonatal factors such as parity index, booking status, gestational age at the time of delivery, mode of delivery, birth weight of the newborn, fetal anomalies, Appearance, Pulse, Grimace, Activity, and Respiration (APGAR) score at 5 minutes, distribution of neurological diseases during pregnancy, neurological manifestations, and associated medical and obstetric complications.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences version 16 after it was manually entered in Microsoft Excel. Interquartile ranges were deduced for variables such as gestational

age, age of diagnosis, and mode of delivery for analysis of pregnancy outcomes in mothers with neurologic diseases in pregnancy. Pearson's Chi-square and Fisher's exact were used as the test for significance wherever relevant if the findings were significant.

RESULTS

We identified 60 patients with neurologic disorders in pregnancy over 3 years. The total number of deliveries during the study period was 8,215, and the incidence of neurological disorders during pregnancy was found to be 730 cases per 1,00,000 deliveries.

The demographic characteristics are depicted in Table 1. A total of 57 women (95%) were in the age groups between 20 and 35 years. There were more primigravida 38 (63.3%) than multigravida 21 (35%). A total of 31 (51.6%) pregnant women were booked at our institution. The majority of the study population had term deliveries 56 (93.3%). A total of 28 (46.6%) women had a cesarean section, while 27 (45%) had a vaginal delivery.

A total of 41 (68.3%) babies had a birth weight of 2.5 to 3.5 kg. There were two cases of mild fetal pelviectasis in WWE on levetiracetam. One neonate had an APGAR score of <7 at 5 minutes.

Among 60 women with neurological disorders in pregnancy, 48 (80%) had preexisting neurological illnesses, and 12 (20%) women were diagnosed with new onset of neurological disorders in the index pregnancy. The newly diagnosed neurologic disorder included five cases of epilepsy, four cerebrovascular diseases [one

case each of cerebral venous thrombosis (CVT), arteriovenous malformation (AVM) of the brain, subarachnoid hemorrhage (SAH) and cavernous cerebral malformation] and three CNS infections (one case each of tubercular meningitis, viral meningitis, and *Escherichia coli* (*E. coli*) encephalitis).

The most common neurologic disorder during pregnancy was epilepsy 36 (60%) (Table 2). Seven (11.6%) patients had cerebrovascular diseases, six (10%) polio survivors, and four (6.6%) women had infections affecting the CNS.

A total of 33 (55%) women were symptomatic during the present pregnancy, and 27 (45%) were asymptomatic. The seizure was the most common presenting symptom 23 (38.3%) (Table 3). Overlapping symptoms were noted.

Some women had associated obstetric and/or medical complications (Table 4). Anemia 23 (38.3%) was the most common comorbidity, followed by preeclampsia 10 (16.6%). Most of them had mild anemia.

Table 1: Demographic characteristics

Patient profile	Number N = 60	%
Age (years)		
<20	1	1.6
20–35	57	95.0
>35	2	3.3
Parity		
P1	38	63.3
P2–3	21	35.0
P4 and above	1	1.6
Booking status		
Booked outside	23	38.3
Booked at our institution	31	51.6
Referred to our institution	6	10.0
Gestational age at delivery (weeks)		
34–37	4	6.6
37–41	56	93.3
Mode of delivery		
Vaginal	27	45.0
Cesarean	28	46.6
Forceps	5	8.3
Birth weight (kg)		
1.5–2.4	8	13.3
2.5–3.5	41	68.3
>3.5	11	18.3
Fetal anomalies	2	3.3
5-minute APGAR score <7	1	1.6

Table 2: Distribution of neurological disorders in pregnancy

Neurological disorders	Number N = 60	%
Epilepsy	36	60.0
Cerebrovascular disease	7	11.6
CVT	3	
AVM	2	
SAH	1	
Cavernoma	1	
Polio survivor	6	10.0
Infections	4	6.6
TB of brain	2	
Viral meningitis	1	
<i>E. coli</i> encephalitis	1	
History of spinal surgery	3	5.0
Migraine	2	3.3
Neurofibromatosis	1	1.6
Pituitary microadenoma	1	1.6

AVM, Arteriovenous Malformation; CVT, Cerebral Venous Thrombosis; SAH, Subarachnoid Hemorrhage; TB, Tuberculosis

Table 3: Clinical manifestations at present pregnancy

Clinical manifestations	Number N = 60	%
Asymptomatic	27	45.0
Seizures	23	38.3
Headache	7	11.6
Fever	3	5.0
Vomiting	2	3.3
Loss of consciousness	2	3.3
Abnormal behavior	2	3.3
Hemiparesis	2	3.3
Loss of speech	1	1.6
Backache	1	1.6
Radicular pain in the left lower limb	1	1.6

Table 4: Medical and obstetric complications

Complications	Number N = 60	%
Anemia	23	38.3
Preeclampsia	10	16.6
Postpartum hemorrhage	6	10
Gestational diabetes mellitus	5	8.3
Hypothyroidism	4	6.6
Oligohydramnios	4	6.6
Urinary tract infection	3	5
Abruptio placentae	2	3.3
Peripartum cardiomyopathy	1	1.6

Among 36 patients with epilepsy, 16 (44.4%) were seizure-free in the index pregnancy and were taking antiepileptic drugs (Table 5). A total of 20 (55.5%) pregnant women had seizures during the index pregnancy, which included 15 (41.6%) epileptic patients with relapse of seizures and five (13.8%) with newly diagnosed epilepsy.

Among 15 (41.66%) epileptic patients with relapse of seizures during the index pregnancy, eight (22.2%) patients were already on antiepileptic drugs (AEDs), four (11.1%) were not taking AED as per the recommendations of the neurologist, and three (8.3%) patients were noncompliant with AED (Table 5). Among five patients with newly diagnosed epilepsy in pregnancy, three patients experienced seizures in the antepartum period, one during delivery, and one in the postpartum period.

All 36 patients with epilepsy received AEDs; 26 (72.2%) received monotherapy, and 10 (27.7%) polytherapy. Levetiracetam was the most commonly used drug for monotherapy (76.9%). Mild fetal renal pelviectasis was seen in two pregnant women on levetiracetam.

In our study, among 36 pregnant WWE, 13 (36.1%) had a cesarean section, 18 (50%) had a vaginal delivery, and five (13.8%) had instrumental delivery. Five (13.8%) women had hypertensive disorders, four (11.1%) gestational diabetes, four (11.1%) postpartum hemorrhages, and two (5.55%) preterm deliveries.

DISCUSSION

The diagnosis and management of neurological disease in pregnancy is a challenging issue as its occurrence is very rare during pregnancy. The incidence of neurologic disease in pregnancy is 584 cases per 1,00,000 deliveries in a study by Gupta et al.³ In our study; the incidence was 730 cases per 1,00,000 deliveries. Our institution being a tertiary care center and also being in close vicinity to another tertiary care neurological center may be the reason for the high incidence.

In our study, 57 (95%) women were in the 20–35-year age group, and the majority were primigravida 38 (63.3%).

A total of 31 pregnant women were booked at our institution either in the first trimester or early in the second trimester. A total of 23 women were showing to other obstetricians and started attending our outpatient department between 24 and 37 weeks of gestation, and few were in labor. The reason being either social or high-risk pregnancy. Six pregnant women were referred to our institution between 36 and 40 weeks, few of them were in labor.

A total of 56 women (93.3%) delivered at term. Also, 28 (46.6%) women had a cesarean section, and 27 (45%) had a vaginal delivery. Among those 28 women who underwent cesarean section, 23 were done for obstetric indications and five for neurologic indications.

Table 5: Characteristics of WWE

Characteristics of WWE	Number N = 36	%
The onset of seizures in relation to present pregnancy		
Seizure free in the index pregnancy	16	44.4
Relapse of seizures in the index pregnancy	15	41.6
On AED	8	
Not on AED	4	
Non-compliant to AED	3	
New onset of seizures in the index pregnancy	5	13.8
AED		
Monotherapy	26	72.2
Polytherapy	10	27.7

AED, antiepileptic drug; WWE, women with epilepsy

Among those who had a cesarean section for obstetric indications, five cesareans were done in polio survivors with pelvic abnormality and cephalopelvic disproportion. Neurologic indications for cesarean sections included vasculitic infarct with worsening maternal consciousness, previous spinal surgery, cavernoma, subarachnoid hemorrhage, and AVM in the brain.

The neonatal outcome was good. Around 41 (68.3%) babies had a birth weight of 2.5–3.5 kg. There were two cases of mild fetal pelviectasis in WWE on levetiracetam. One neonate had an APGAR score of <7 at 5 minutes.

Epilepsy was the most common neurologic disorder in our study, accounting for 60% of cases which is similar to other studies.^{4,5} We had 36 WWE in our study; among them, 16 were seizure-free in the index pregnancy (44.4%) and were on AED. These findings are similar to the results of Sanjeev et al., as 47.8% of women were seizure-free during pregnancy.⁶ In our study, 20 (55.5%) patients had seizures in the index pregnancy, which included 15 (41.6%) women with relapse of seizures and five (13.8%) newly diagnosed with epilepsy. Among five patients with newly diagnosed epilepsy in pregnancy, three patients experienced seizures in the antepartum period, one during delivery, and one in the postpartum period. In an observational study of the epilepsy registry by Wei et al., 2.1% of women had new onset epilepsy at pregnancy, and the first seizure occurred during the antepartum period.⁷

In our study, 15 (41.6%) women had a relapse of the seizures in pregnancy, of which eight (22.2%) patients were already on AED, four (11.1%) were not taking AED as per the recommendations of the neurologist, and three (8.3%) patients were noncompliant with AED. A recurrence of seizures was noticed in some women taking AED regularly during pregnancy. This may be due to physiological changes in pregnancy like increased glomerular filtration, decrease in albumin, increase in water retention, and altered liver metabolism, which alters the pharmacokinetics of AED. A prepregnancy seizure-free period of 9 months reduces the risk of seizures during the pregnancy.⁸

Monotherapy (72.2%) was more often preferred to polytherapy (27.7%) in our study, which was similar to the results of Sarella et al.⁴ Levetiracetam was the most common drug used for

monotherapy in our study like a study by Bhansal et al.⁹ Although levetiracetam use as monotherapy is safe in WWE of childbearing age group, mild fetal renal pelviectasis was seen in two pregnant women on levetiracetam in our study, which is unlikely to be a birth defect due to levetiracetam.^{9,10}

The study by Viale et al. shows increased odds of antepartum and postpartum hemorrhage, hypertensive disorders, cesarean section, and preterm delivery in WWE during pregnancy.¹¹ In our study occurrence of these complications was similar to the general population. This outcome may be due to good antenatal and intrapartum care along with a multidisciplinary approach.

Pregnancy and puerperium being hypercoagulable state, women are prone to CVT during this period of life. Headache is the most common presenting symptom. Cesarean section, hypertension, and anemia increase the risk for CVT.¹² All our patients presented with headaches, two had anemia, and one had gestational hypertension. On evaluation, one of the patients was found to have protein C and S deficiency.

Arteriovenous malformation (AVM) of the brain must be excluded in case of neurologic manifestations during pregnancy. In a study by Lv et al., the rupture of AVMs was seen in 83.1% of women during pregnancy and the postpartum period, and the rates of cesarean delivery were more than vaginal delivery.¹³ The unruptured cerebral AVM was managed conservatively during pregnancy.¹⁴ One of our patients was referred at 15 weeks of gestation with right hemiparesis, vomiting, and unconsciousness to another neurology center in the city. Magnetic resonance imaging (MRI) brain showed left gangliocapsular AVM in the brain with bleed. She was managed conservatively with levetiracetam and physiotherapy. As her condition improved, embolization of AVM was planned post-delivery by neurosurgeons. She was referred to our institution at 38 weeks of gestation in labor. After neurology consultation, an emergency cesarean section was done in view of the possibility of rupture of AVM. She delivered a healthy baby weighing 2.7 kg. Another woman had preexisting AVM, which was managed by stereotactic radiotherapy 8 years before the present pregnancy. She was asymptomatic in the present pregnancy and was on levetiracetam. She had a normal delivery at term.

Aneurysms of the cerebral vessels are one of the important causes for SAH.^{15,16} Peripartum SAH is commonly associated with hypertensive disorders.¹⁵ In pregnancy with a viable fetus, an emergency cesarean section followed by management of SAH due to aneurysm is widely accepted.¹⁶ Our patient was a 23-year primigravida booked outside and referred to our institution at 37 weeks of gestation with severe headache, vomiting, and one episode of convulsions. MRI brain showed SAH with anterior communicating artery aneurysm. Her blood pressure was normal. She was admitted in intensive care unit (ICU) and started on levetiracetam and nimodipine. She underwent an emergency cesarean section and delivered a healthy 2.8 kg baby. During the postpartum period headache persisted, and she was referred to another tertiary care neurology center for aneurysmal coiling.

The risk of hemorrhage in cavernous cerebral malformation (CCM) during pregnancy is like the nonpregnant state. Genetic counseling is to be considered in patients with familial and multiple CCM prior to pregnancy. Safe AED is used for the management of seizures due to CCM. Appropriate surgical intervention for CCM is considered in case of brain hemorrhage during pregnancy. Vaginal delivery is allowed if there is no evidence of a recent hemorrhage.¹⁷ Our patient was a 21-year primi presented at 25 weeks of gestation with seizures. She was diagnosed to have

right occipital cavernoma on MRI and was started on levetiracetam. She presented at term in labor, and an emergency cesarean section was done in view of the possibility of an increased chance of bleeding into the cavernoma after a neurology consultation.

In our study, there were six polio survivors; among them, five had cesarean delivery for the abnormal pelvis, which is similar to the study by Veiby et al. Their study showed a higher occurrence of obstructed labor (6.1 vs 2%) and cesarean section rate (13.2 vs 8.3%) among polio survivors compared to the reference population.¹⁸

Altered immunogenic and hormonal changes in pregnancy increase the susceptibility of both mother and fetus to infections. India has the highest number of pregnant women with tuberculosis (TB), constituting 21% of the global burden of disease in pregnancy in 2014.¹⁹ A study by Yadav et al. on extrapulmonary TB shows 10% involvement of the CNS.²⁰ Extrapulmonary TB is associated with increased incidence of preterm delivery, small for gestational age neonates, and low birth weight infants.²⁰ Both our patients with CNS TB underwent emergency cesarean section for obstetric indications. One patient was in a preterm gestational period. One more patient was a 20-year primi presented at 38 weeks gestation with fever, headache, vomiting, and abnormal behavior for 8 days. Tubercular meningitis was diagnosed based on MRI brain and cerebrospinal fluid (CSF) analysis. She was started on anti-tubercular treatment, steroids, and levetiracetam. After 3 days, she underwent an emergency cesarean section for fetal distress and delivered a 2.7 kg healthy baby. She was symptomatically better at the time of discharge.

Even though viral meningitis is usually self-limiting, it is essential to rule out bacterial meningitis as it is life-threatening if untreated.^{21,22} Our patient had viral meningitis at 23 weeks of pregnancy which was managed conservatively. She was induced at term for severe preeclampsia and fetal growth restriction.

Pneumococcal meningitis is common among pregnant women with bacterial meningitis, and the predisposing factor is otitis.²³ In our study, urinary tract infection was the predisposing factor for *E. coli* meningitis. *E. coli* meningitis develops with a high degree of bacteremia invading the blood-brain barrier.²⁴ Our patient was a 31-year woman with second pregnancy admitted at 36 weeks of gestation with right-side hemiparesis, slurring of speech, delirium, and high fever. She also had *E. Coli* urinary tract infection with acute kidney injury, anemia, and thrombocytopenia. CSF analysis showed infection with *E. Coli*. MRI brain was suggestive of vasculitic infarct. After 2 days cesarean section was done for worsening maternal condition. She delivered a healthy live baby weighing 2.6 kg. She was in ICU for 2 weeks with supportive treatment, including ventilator, followed by a tracheostomy. She later received medical rehabilitation therapy. Her condition gradually improved. She had a prolonged hospital stay of 47 days.

The incidence of radicular pain in pregnancy following a previous microsurgical lumbar discectomy for lumbar disk herniation is 18%.²⁵ The incidence and prevalence of low back aches are high, followed by leg pain in pregnancy.²⁵ The cesarean section rate is found to be high (60%) among the women with spinal cord lesions, in whom the majority had undergone prior spinal surgery.²⁶ In our study, one patient experienced low backache and radicular pain in the left lower limb. The remaining two patients were asymptomatic. Two patients underwent cesarean section as per the neurosurgeon's advice to avoid the lithotomy position.

Migraine during pregnancy is associated with an increased risk of vascular events, especially ischemic stroke, and preeclampsia.^{27,28} Paracetamol is the treatment of choice for the

management of migraine in pregnancy.²⁸ It is important to detect the cause of headaches in pregnancy as they can be associated with serious life-threatening conditions like preeclampsia, intracranial bleeding, CVT, etc.²⁷ One patient in the study had a history of stroke 4 years back and was diagnosed to have hyperhomocysteinemia while another patient had pseudoseizures. The obstetric outcome was good in both patients.

Neurofibromatosis type 1 is associated with an increased risk of development of gestational hypertension, preeclampsia, intrauterine growth restriction, preterm delivery, and cesarean section.²⁹ Our patient underwent a cesarean section at term for cephalopelvic disproportion.

Pituitary microadenomas usually do not enlarge during pregnancy; hence dopamine agonists can be stopped with close clinical monitoring.³⁰ In our study patient was found to have pituitary microadenoma on evaluation for secondary infertility. She was treated with cabergoline and conceived soon after stopping the medication. She was asymptomatic, later had gestational diabetes, and delivered a big baby vaginally.

In our study, there was no maternal or perinatal death. All pregnant women were booked either at our institution or else were admitted to our institution for delivery purposes as it is a tertiary care center. They had been referred to a neurologist, neurosurgeon, and relevant disciplines as per the need. Neurology reference was sought either during antenatal visits or labor for patients with preexisting neurologic illnesses. Among the patients with new onset neurological disorders or an acute event, the neurology team was involved in the early evaluation, diagnosis, choosing appropriate investigations, and management, including mode of delivery and throughout the hospital stay. This may be the reason for the good perinatal and maternal outcomes.

Any neurological manifestations or disease during pregnancy needs detailed history taking, examination, high degree of suspiciousness of diagnosis, involvement of a multidisciplinary team, and relevant investigations. The patients must be managed in a tertiary care center for a better outcome.

Limitations of the Study

It is a retrospective study. We have included only the patients admitted to the obstetrics and gynecology department at the time of delivery. We have not included those women admitted in other departments at various other stages of pregnancy and puerperium.

CONCLUSION

Acute onset of neurologic presentation during pregnancy needs immediate, thorough evaluation and management as it can be a life-threatening condition to both the mother and the fetus. A multidisciplinary approach in a tertiary care center improves both maternal and fetal outcomes. Eclampsia must be ruled out as it is an important cause of maternal death in India and can mimic the signs and symptoms of various CNS abnormalities.

REFERENCES

1. Paily VP, Ambujam K, Rajasekharan Nair V, et al. Confidential review of maternal deaths in Kerala: a country case study. *BJOG* 2014;121(s4):61–66. DOI: 10.1111/1471-0528.13000
2. MBRRACE-UK Maternal Report 2019 - WEB VERSION.pdf [Internet]. [cited 2020 Oct 30]. Available from: <https://www.npeu.ox.ac.uk/assets/downloads/mbrrace-uk/reports/MBRRACE-UK%20Maternal%20Report%202019%20-%20WEB%20VERSION.pdf>

3. Gupta S, Rohatgi A, Sharma SK, et al. A study of neurological disorders during pregnancy and puerperium. *Ann Indian Acad Neurol* 2006;9(3):152–157. DOI: 10.4103/0972-2327.27657
4. Sarella LK, Rao DS. Neurological disorders in pregnancy and puerperium. *Sri Lanka J Obstet Gynaecol* 2014;36(3):74–78. DOI: 10.4038/sljog.v36i3.7722
5. Renukesh S, Rai L. Neurological disorders complicating pregnancy - focus on obstetric outcome. *J Clin Diagn Res* 2016;10(12):QC06–QC09. DOI: 10.7860/JCDR/2016/19839.8955
6. Thomas SV, Syam U, Devi JS. Predictors of seizures during pregnancy in women with epilepsy. *Epilepsia* 2012;53(5):e85–e88. DOI: 10.1111/j.1528-1167.2012.03439.x
7. Li W, Hao N, Xiao Y, et al. Clinical characteristics and pregnancy outcomes of new onset epilepsy during pregnancy. *Medicine (Baltimore)* 2019;98(27):e16156. DOI: 10.1097/MD.00000000000016156
8. Harden CL, Hopp J, Ting TY, et al. Practice parameter update: management issues for women with epilepsy—focus on pregnancy (an evidence-based review): obstetrical complications and change in seizure frequency: report of the Quality Standards Subcommittee and Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology and American Epilepsy Society. *Neurology* 2009;73(2):126–132. DOI: 10.1212/WNL.0b013e3181a6b2f8
9. Bansal R, Suri V, Chopra S, et al. Levetiracetam use during pregnancy in women with epilepsy: preliminary observations from a tertiary care center in Northern India. *Indian J Pharmacol* 2018;50(1):39–43. DOI: 10.4103/ijp.IJP_692_17
10. Koubeissi M. Levetiracetam: more evidence of safety in pregnancy. *Epilepsy Curr* 2013;13(6):279–281. DOI: 10.5698/1535-7597-13.6.279
11. Viale L, Allotey J, Cheong-See F, et al. Epilepsy in pregnancy and reproductive outcomes: a systematic review and meta-analysis. *Lancet* 2015;386(10006):1845–1852. DOI: 10.1016/S0140-6736(15)00045-8
12. Sharma N, Sharma SR, Hussain M. An audit of cerebral venous thrombosis associated with pregnancy and puerperium in teaching hospital in North Eastern India. *J Family Med Prim Care* 2019;8(3):1054–1057. DOI: 10.4103/jfmpc.jfmpc_366_18
13. Lv X, Liu P, Li Y. Preexisting, incidental and hemorrhagic AVMs in pregnancy and postpartum: gestational age, morbidity and mortality, management and risk to the fetus. *Interv Neuroradiol* 2016;22(2):206–211. DOI: 10.1177/1591019915622161
14. Lv X, Li Y. The clinical characteristics and treatment of cerebral AVM in pregnancy. *Neuroradiol J* 2015;28(4):385–388. DOI: 10.1177/1971400915609332
15. Bateman BT, Olbrecht VA, Berman MF, et al. Peripartum subarachnoid hemorrhage: nationwide data and institutional experience. *Anesthesiology* 2012;116(2):324–333. DOI: 10.1097/ALN.0b013e3182410b22
16. Roman H, Descargues G, Lopes M, et al. Subarachnoid hemorrhage due to cerebral aneurysmal rupture during pregnancy. *Acta Obstet Gynecol Scand* 2004;83(4):330–334. DOI: 10.1111/j.0001-6349.2004.00281.x
17. Akers A, Al-Shahi Salman R, A Awad I, et al. Synopsis of guidelines for the clinical management of cerebral cavernous malformations: consensus recommendations based on systematic literature review by the Angioma Alliance Scientific Advisory Board Clinical Experts Panel. *Neurosurgery* 2017;80(5):665–680. DOI: 10.1093/neuros/nyx091
18. Veiby G, Daltveit AK, Gilhus NE. Pregnancy, delivery and perinatal outcome in female survivors of polio. *J Neurol Sci* 2007;258(1–2):27–32. DOI: 10.1016/j.jns.2007.02.019
19. Sugarman J, Colvin C, Moran AC, et al. Tuberculosis in pregnancy: an estimate of the global burden of disease. *Lancet Glob Health* 2014;2(12):e710–e716. DOI: 10.1016/S2214-109X(14)70330-4
20. Yadav V, Sharma JB, Kachhawa G, et al. Obstetrical and perinatal outcome in pregnant women with extrapulmonary tuberculosis. *Indian J Tuberc* 2019;66(1):158–162. DOI: 10.1016/j.ijtb.2018.10.010

21. Bartt R. Acute bacterial and viral meningitis. *Continuum (Minneapolis, Minn)* 2012;18(6):1255–1270. DOI: 10.1212/01.CON.0000423846.40147.4f
22. Logan SA, MacMahon E. Viral meningitis. *BMJ* 2008;336(7634):36–40. DOI: 10.1136/bmj.39409.673657.AE
23. Adriani KS, Brouwer MC, van der Ende A, et al. Bacterial meningitis in pregnancy: report of six cases and review of the literature. *Clin Microbiol Infect* 2012;18(4):345–351. DOI: 10.1111/j.1469-0691.2011.03465.x
24. Kim KS. Human meningitis-associated *Escherichia coli*. *EcoSal Plus* 2016;7(1):10.1128/ecosalplus. DOI: 10.1128/ecosalplus.ESP-0015-2015
25. Berkmann S, Fandino J. Pregnancy and childbirth after microsurgery for lumbar disk herniation. *Acta Neurochir (Wien)* 2012;154(2):329–334. DOI: 10.1007/s00701-011-1207-y
26. Sterling L, Keunen J, Wigdor E, et al. Pregnancy Outcomes in women with spinal cord lesions. *J Obstet Gynaecol Can* 2013;35(1):39–43. DOI: 10.1016/s1701-2163(15)31046-x
27. Bushnell CD, Jamison M, James AH. Migraines during pregnancy linked to stroke and vascular diseases: US population based case-control study. *BMJ* 2009;338:b664. DOI: 10.1136/bmj.b664
28. Negro A, Delaruelle Z, Ivanova TA, et al. Headache and pregnancy: a systematic review. *J Headache Pain* 2017;18(1):106. DOI: 10.1186/s10194-017-0816-0
29. Terry AR, Barker FG 2nd, Leffert L, et al. Neurofibromatosis type 1 and pregnancy complications: a population-based study. *Am J Obstet Gynecol* 2013;209(1):46.e1–46.e8. DOI: 10.1016/j.ajog.2013.03.029
30. Almalki MH, Alzahrani S, Alshahrani F, et al. Managing prolactinomas during pregnancy. *Front Endocrinol* 2015;6:85. DOI: 10.3389/fendo.2015.00085