Original Article

Algorithm of Traumatic Brain Injury in Pregnancy (Perspective on Neurosurgery)

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Abstract

Background: The maternal deaths due to obstetrical cases declined, but the maternal deaths that caused by nonobstetrical cases still increase. The study reported that traumatic cases in pregnancy are the highest causes of mortality in pregnancy (nonobstetrical cases) in the United States. Another study reported that 1 in 12 pregnant women that experienced traumatic accident and as many as 9.1% of the trauma cases were caused by traumatic brain injury (TBI). The female sex hormone has an important role that regulates the hemodynamic condition. Anatomical and physiological changes during pregnancy make the examination, diagnosis, and treatment of TBI different from non-pregnant cases. Therefore, it is very important to lead the algorithm for each institution based on their own resources. **Case Series:** A 37-year-old woman with a history of loss of consciousness after traffic accident. She rode a motorbike then hit the car. She was referred at 18 weeks' gestation. Glasgow Coma Scale (GCS) $E_1V_1M_4$, isochoric of the pupil, reactive to the light reflex, and right-sided hemiparesis. The non-contrast head computed tomography (CT) scan revealed subdural hematoma (SDH) in the left frontal-temporal-parietal region, SDH of the tentorial region, burst lobe intracerebral hemorrhage, and cerebral edema. There was not a fetal distress condition. The next case, a 31 years old woman, in 26 weeks gestation, had a history of unconscious after motorcycle accident then she fell from the height down to the field about 3 m. GCS $E_1V_1M_3$, isochoric of the pupil, but the pupil reflex decreased. Noncontrast CT scan revealed multiple contusion, subarachnoid hemorrhage, and cerebral edema. She had a good fetal condition. **Discussion:** We proposed the algorithm of TBI in pregnancy that we already used in our hospital. The main principle of the initial management must be resuscitating the mother and that also the maternal resuscitation. The primary and secondary survey is always prominent of the initial treatment. **Conclusion:** The clinical decision depends on the condition of the fetal, the surgical lesion of the intracranial, and also the resources of the neonatal intensive care unit in our hospital.

Keywords: *Timing of surgery, traumatic brain injury, traumatic brain injury in pregnancy*

Introduction

The maternal deaths due to obstetric cases are declining, while maternal deaths caused by non-obstetric cases continue to increase.[1] The study reports that trauma in pregnancy is the highest cause of mortality in pregnancy in nonobstetric cases in the United States. The study reported that 1 in 12 pregnancies experienced trauma[2] which caused maternal deaths and as many as 9.1% of cases were caused by brain injury due to blunt trauma.[3] Anatomical and physiological changes during pregnancy make examination, diagnosis, and treatment of brain injuries in pregnant women different from nonpregnant women. For example, in pregnancy plasma volume and cardiac output are increased. This is caused by the increased production of the hormones estrogen and progesterone produced by trophoblast cells.[4,5] These physiological changes during pregnancy can affect clinical judgment for traumatic brain injury (TBI) in pregnancy and also the resuscitation process.

The treatment of TBI in pregnancy, we must always remember that there are two patients treated, the mother and the fetus. Resuscitation of the mother is the main initial action and is followed by intrauterine resuscitation. Resuscitation of pregnant women by preventing hypotension and hypoxia is essential in fetal development[6,7] so that adequate treatment of pregnant women has a direct impact on the fetus. Planning a diagnosis using radiological

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devices needs to be considered for the impact of radiation to the fetus inside and also the administration of teratogenic drugs that can endanger the condition of the fetus. Decision-making actions require good cooperation between neurosurgeons, obstetricians, neonatologists, and anesthetist.[8] In addition, the ability of each hospital neonatal intensive care unit is a significant consideration in the treatment of posttermination of brain injury patients in pregnancy. The American College of Obstetricians and Gynecologists states that there are no data that recommend specific recommendations. This is adjusted to the condition of each patient, gestational age, type of surgery, and existing facility with the main objective being the optimization of the safety of pregnant women and their babies bayinya.[9]

Case Reports

The first case

The patient and caretaker have both given consent to the publication of the patient's data to be reported and published. A 37-year-old woman, with 18 weeks pregnant, suffered from severe TBI after a motor vehicle accident. The patient never regained consciousness after the incident. The patient experienced seizures and vomiting. After resuscitation, neurological examination showed Glasgow Coma Scale (GCS) $E_1V_1M_4$, isochoric pupils, reactive to light, and right-sided hemiparesis. The condition of the fetus was normal according to obstetricians. The primary survey was conducted and the patient was intubated. On non-contrast head computed tomography (CT) scan showed subdural bleeding (subdural hematoma [SDH]) and burst lobe intracerebral hemorrhage (ICH) in the left frontotemporal region with a volume of 80 cc, subarachnoid hemorrhage (SAH), midline shift 11.3 mm to the right, and cerebral edema [Figures 1 and 2]. The patient was given mannitol and phenytoin. The patient then underwent SDH-ICH evacuation craniotomy. Intraoperative findings found a tense duramater that suggests cerebral edema. SDH-ICH was evacuated and the brain remained swollen so the dural and bone decompression was decided until the cranial base. Finally, the dural and bone decompression was decided until the cranial base of temporal. Precaution measures were taken during surgery to protect the fetus.

After surgery, the patient continued treatment in the intensive care unit (ICU) with a ventilator. Clinical examination showed GCS $E_1V_{ET}M_5$, light isocorous pupils reactive to light, and improved hemiparesis. Based on

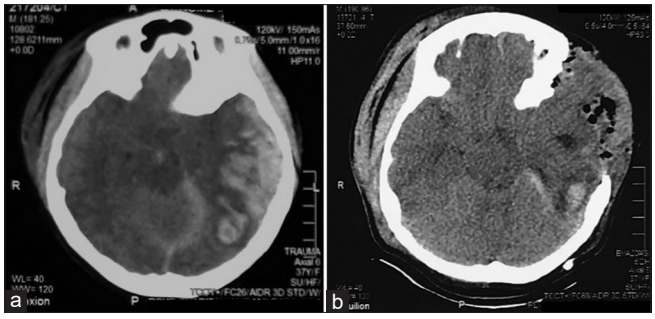

Figure 1: Head computed tomography scan without contrast. (a) Before craniotomy (b) after evacuation and decompression craniotomy

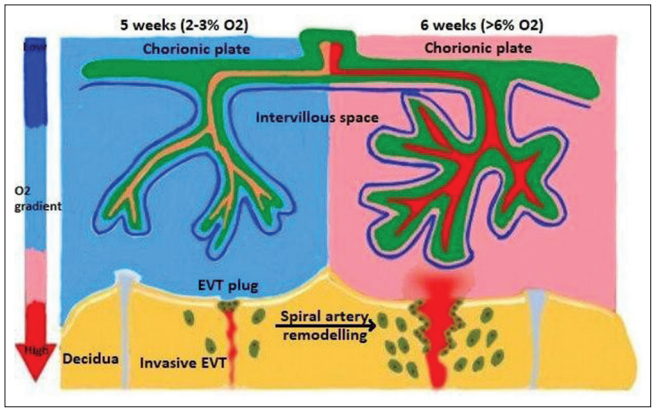

Figure 3: Spiral artery remodeling process

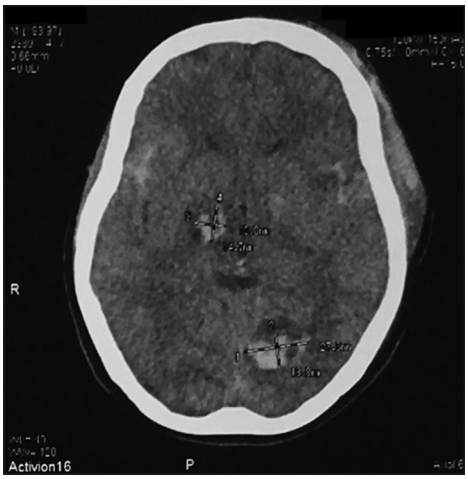

Figure 2: Preoperative head computed tomography scan

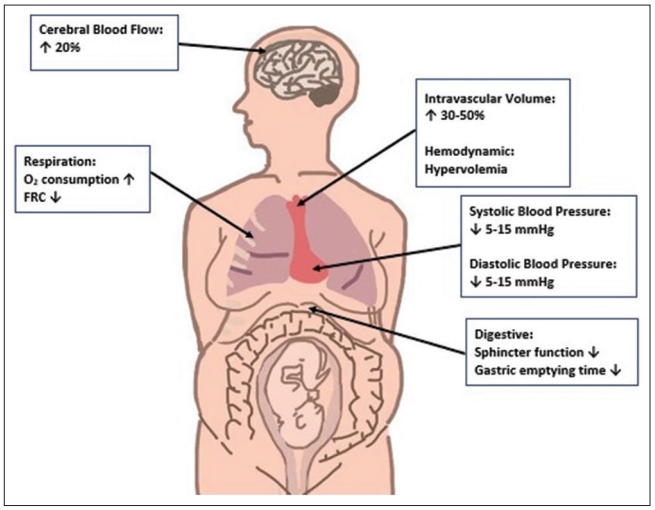

Figure 4: Summary of physiological changes during pregnancy by the system organ

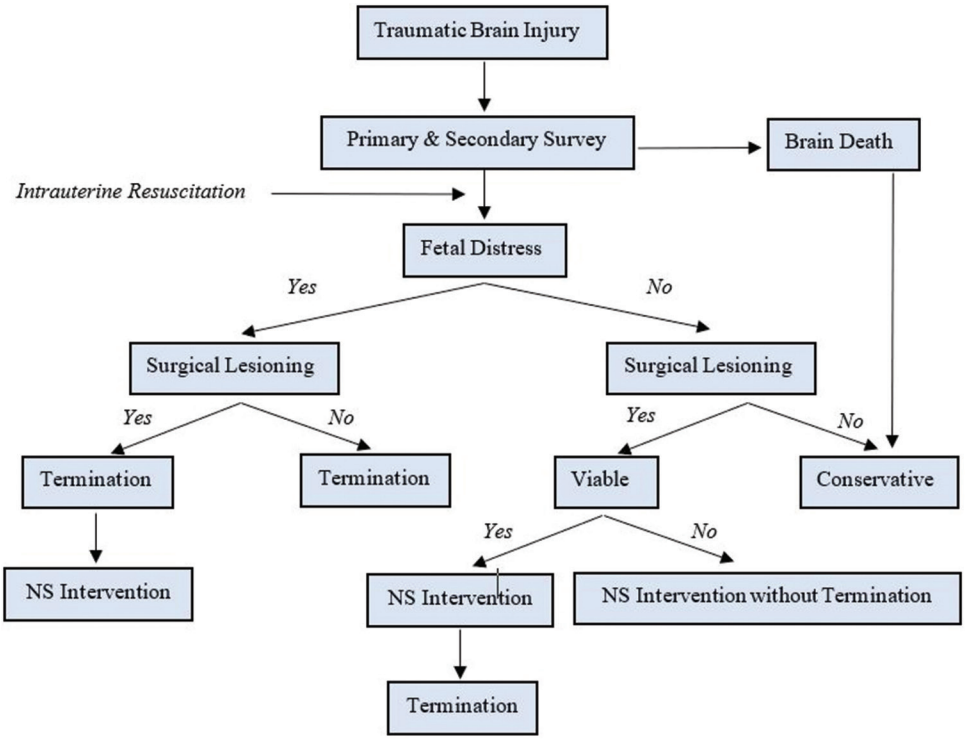

Figure 5: Algorithm of traumatic brain injury in pregnancy

postoperative noncontrast head CT scan evaluation, no sign of SDH-ICH shown, the midline shift disappeared, but cerebral edema remained. The lateral ventricular horn had begun to open and the basal cyst had started to open (the quadrigeminal cystern). Subsequent treatment was continued in the high care unit (HCU) 36 hours after surgery and patient with GCS $E_4V_XM_6$ (aphasia, extubated). Lesions in the frontotemporal region of the dominant hemisphere are the Broadman area, the arcuate fasciculus, and the Wernicke area. Precaution measures were taken during intensive care to protect the fetus. The fetus condition was stable and there is no sign of fetal distress.

The second case

A women 31–year-old with a gestational age of 20 weeks, came with decreased of consciousness after a motorcycle accident. The patient has a history of vomiting after that event, without seizures. The patient arrived at the hospital 10 hours after the incident. After resuscitation, a neurological examination revealed the GCS of $E_1V_1M_4$, isochoric pupils, and decreased light reflexes on both sides. There are no signs of fetal distress. The patient was intubated and ventilated. From noncontrast head CT scan, there are multiple contusions, SAH and cerebral edema shown. The patient was then given mannitol and surgery was immediately performed. The patient underwent an ICP monitor installation. Intra-operative finding found an initial pressure of 25 cmH_2O. Precaution measures were taken during surgery and intensive care to protect the fetus. The condition of the fetus is maintained without obstetric intervention after the ICP monitoring was performed.

Discussion

Important physiological changes in pregnancy are related to brain injury

Central nervous system

Cardiac output, systolic blood pressure, and vascular resistance contribute to cerebral perfusion. Therefore, significant changes to hemodynamic affect physiological adaptations to cerebral endothelial pressure and permeability. The incidence of cerebrovascular accident often occurs on several days before or after delivery.[10] In addition, a study reported that an increase in the anterior circulation, middle cerebral artery, by 20% is based on magnetic resonance imaging studies with velocity encoded phase-contrast sequences during gestation and will return to normal values near to the term phase and return to normal in the phase of puerperium.[11]

Hematology

During pregnancy, cytotrophoblast invasion is followed by alteration of the uterine spiral artery with the aim of facilitating hemodynamic synchronization and the flow of nutrients from the mother to fetus [Figure 3]. Hemodynamic changes included a significant 50% increase in plasma volume[2] at 34 weeks' gestation [Figure 4]. Increasing the plasma volume expansion exceeds its ratio to an increase in red blood cell mass so that hemoglobin, hematocrit, and erythrocytes decrease. This causes hemodilution, but

Table 1: Laboratory values during pregnancy

Variable	Value when pregnant
Hematocrit (%)	32-42
Leukocytes (µL)	5000-25,000
Platelets ($\times 10^9$ cells/l)	100-150
arterial Ph	7.4-7.45
Bicarbonate (mEq/L)	17-22
PaO_2 (mmHg)	100-108
$PaCO_2$ (mmHg)	25-30
Fibrinogen (mg/dL)	400-450 (third trimester)
Factors I, II, V, VII, X, XII	Increase
Prothrombine time (%)	Decreased by 20
Partial thromboplastin time (%)	Decreased by 20
S protein	Decreased
Protein C	Increased
Plasminogen activator inhibitor-1/-2	Increased (fixed fibrinolytic)

Table 2: Changes in the respiratory system during pregnancy

Parameter	Change during pregnancy (%)
Expiratory reserve volume	Decrease 25
Residual volume	Decrease 15
FRC	Decrease 20
Tidal volume	Increase 45
Inspiratory reserve volume	Increase 5
Inspiratory capacity	Increase 15
Vital capacity	No change
Total lung capacity	Decrease 5
FEV_1	No change
FEV_1/FVC	No change
Closing capacity	No change

FVC-Forced vital capacity; FEV_1-Forced expiratory volume in 1 s; FRC-Functional residual capacity

Table 3: Summary of physiological changes during pregnancy

Organ system	Change
Systolic blood pressure (mmHg)	Decreased 5-15
Diastolic blood pressure (mmHg)	Decreased 5-15
Cerebral perfusion (MCA) (%)	Increased by 20
Intravascular volume (%)	Increases 30-50
Hemodynamics	Hypervolemia
Respiration	Increased O_2 consumption FRC declining
Digestion	Gastric emptying decreases

MCA-Middle cerebral artery; FRC-Functional residual capacity

there is no change in mean corpuscular volume and mean corpuscular hemoglobin concentration.[12] The decrease in the amount of hemoglobin causes physiological anemia in pregnancy caused by the hemodilution.[5] The platelet count will decrease progressively during pregnancy. Normal values during pregnancy are 100–150 × 10^6 cells/L and if there is a pathological process that causes thrombocytopenia with platelet counts <100 ×10^6 cells/L. Under normal pregnancy conditions, leukocytosis ranges from 5000 to 25,000/mm^3.[2] Estrogen increases the production of liver coagulation factors. There is an increase by 30–50% of fibrinogen and factor VII, VIII, IX, and X [Table 1].[13,14,15]

Cardiovascular

Changes in the cardiovascular system begin in early pregnancy, started on 8 weeks of pregnancy. These changes are caused by peripheral vasodilation. The vasodilation is mediated by nitric oxide, an endothelium-dependent factor, which is regulated by estradiol and prostaglandin (PGI_2).[12] Peripheral vasodilation causes a decrease in systemic vascular resistance so that cardiac output increases by 30%–50% as compensation during pregnancy and it is reported that progesterone has a significant role in decreasing total vascular systemic resistance.[16] The decrease in total vascular resistance causes blood pressure to decrease gradually between 5 and 15 mmHg in both systolic and diastolic pressure, while oxygen consumption continues to increase because of 15% increased metabolic requirements and 20% increased oxygen consumption delivered to the fetus [Table 2]. This causes an increase in the oxygen-carrying capacity of red blood cells, an increase in blood volume, to an increase in cardiac output and heart rate by 10–15 times/min [Table 3].[17,18]

Hemodynamics

At the beginning of gestation, about 30th days of gestational age, cytotrophoblast cell, proliferation occurs to fill the intervillous space and aggregates to attach the maternal blood vessel flow.[19] Cytotrophoblast cell growth begins with conditions with low oxygen levels. Oxygen levels in intervillous space are lower than those in endometrial oxygen.[20] A study reported that oxygen levels in the intervillous space of 8–10 weeks gestation were 2%–3% and gestational age after 12 weeks were >6%.[21] This causes physiological changes in the spiral arteries and secondary changes caused by invasion and migration of extravillous trophoblast (EVT) [Figure 3]. During the growth process, the placenta experiences relative hypoxia. EVT undergoes extensive differentiation at the end of the first trimester and causes vascular remodeling. Endovascular EVT invades the spiral arteries to form EVT plugs, thereby preventing maternal blood flow from filling up the intervillous space, making the surrounding environment with low oxygen levels. The end of the first trimester EVT plug gradually disappears and the endovascular trophoblast begins to migrate proximally along the spiral arteries causing a decrease in total vascular resistance leading to dilatation of the spiral arteries. This is important in the formation of maternal-placental blood circulation so that oxygen levels increase in fulfilling fetal growth.[4]

The hypervolumatic and hyperdynamic conditions make the fetomaternal adapt to the increased metabolic requirements

of fetal growth and also the bleeding produced during labor. Hemorrhage produced during vaginal or cesarean actions ranges from 500 to 1,000 ml and does not affect significant hemodynamic changes.[16] Bleeding >2500 ml can undergo rapid and significant clinical deterioration.[2] Pregnancy that exceeds 20 weeks has an enlarged uterus which can compress the inferior vena cava (IVC) on the abdomen, because of that the venous and the cardiac output decrease 30%.[2]

Respiration

Anatomical adaptations and changes of the airways are caused by increased metabolic requirements and oxygen delivery in the fetus [Table 2].[22] Metabolic rate increases by 15% and oxygen consumption increases by 20% on the pregnant condition.[12] The stimulation of progesterone hormone which stimulates the breathing center in the medulla oblongata that causes hyperventilation.[15] Hyperventilation increases PO_2 and decreases PCO_2 so that the metabolic buffer compensates by decreasing the value of serum bicarbonate (18–22 mmol/L) to respiratory alkalosis.[12] Ventilation minutes increases by 50% due to an increase that is directly proportional to the tidal volume which increases by 45%.[2] The diaphragm shifts 4 cm above the head (cephalad) and the diameter of the anteroposterior thorax increases due to changes in the size of the enlarged uterus causing expiratory reserve volume to decrease by 25% and residual volume to decrease by 15% causing a decrease in functional residual capacity by 20%.[2] Therefore, pregnant women who experience trauma could easily having desaturation, distress of breath, until apneu.

Table 4: Fetal radiation dose received on radiological examination in traumatic brain injury

Type of examination	Fetal dose (mGy)	Dose level
Cervical spine radiography	<0.001	Low
Chest radiography	0.0005-0.01	Very low
Lumbar spine radiography	1.0-10	Moderate
CT scan head or neck	1.0-10	Moderate

CT-Computed tomography

Table 5: Neurosurgery with obstetric measures[41]

Trimester	Indication	Procedure
First	Urgent	Neurosurgical (increased risk of spontaneous abortion)
	Nonurgent	Medical therapy
Second	Urgent	Neurosurgery
	Nonurgent	Pregnancy continued
Third	Urgent	Termination followed by neurosurgery
		Simultaneous. Termination and action for neurosurgery
	Nonurgent	Termination
	SC indications	Low maternal GCS
		Simultaneous actions
		After neurosurgery is done

GCS-Glasgow Coma Scale; SC-Caesarean Section

Gastrointestinal tract

Gastroesophageal sphincter activity decreases so that emptying of the stomach becomes slow. This is because of increasing the hormone progesterone. Increasing progesterone can reduce gastric motility and tone caused by the relaxation of smooth muscle in the gastroesophageal sphincter.[2] The changing of the stomach position in pregnant patient with decreased of consciousness caused by traumatic brain injury may increase the risk of aspiration, which cause difficulty in maintaining the patency of the airway. Normal pregnancy often results in complaints of nausea, vomiting, and abdominal pain. These complaints can weigh on brain injury patients with pregnancy. Nasogastric tube insertion is needed to prevent pneumonic aspiration caused by gastroesophageal reflux.[23]

Prehospital care

Most of TBI in pregnancy came with complaints of decreased consciousness and some of them have a gestational age <24 weeks of pregnancy so that the size of the abdomen has not been seen to increase significantly. Hence, there is a need of vigilance for doctors and paramedics in assessing. Every young woman of reproductive age must be treated as a pregnant patient until proven otherwise.[23] Based on the Advanced

Table 6: Resume case report of traumati brain injury in pregnancy

Reference	GCS	Gestational age (weeks)	Timing surgery	Nature	Exodus
Dawar *et al*., 2013	11	36	CS → craniotomy	Simultaneous	BL
Whitney *et al*., 2012	3	20	ICP monitor	Alone	FC
Goldschlager *et al*., 2009	9	34	CS → Craniotomy	Simultaneous	BL
Satapathy *et al*., 2004	11	24	Craniotomy	Alone	BL
	14	16	Both conservative	None	BL
	7	28			
Cirak *et al*., 2003	NA	38	CS	Single	BL
	NA	39	Pervagina	Single	BL

BL-Both materanl-fetal live without complication; FC-Fetal complication because there is a delaying time to do CS (36 weeks gestation). CS-Caesarean section; ICP-Intracranial pressure; NA-Not available; GCS-Glasgow Coma Scale

Trauma Life Support in 2018, the handling of pre-hospital trauma patients in pregnancy is the same as handling non-pregnant patients.[14] The priority of pre-hospital treatment in brain injury patients in pregnancy is the prevention of hypoxia and hypotension.[24] Primary survey management which includes airway management cervical spine control, breathing, and circulation is first performed when getting a patient with a brain injury in pregnancy. Furthermore, intrauterine resuscitation is performed which includes oxygen supplementation with a target of peripheral saturation >95%, installation of intravenous access with a large catheter diameter, and positioning the patient on a flat board with a slope of 30°. The position aims to reduce uterine compression to aortocaval which can reduce 30% cardiac output due to decreased venous return, especially at gestational age >20 weeks.[25] If a primary survey and intrauterine resuscitation have been performed, tachycardia (pulse >110 beats/min), decreased consciousness, chest pain, that occur in the third trimester of pregnancy are conditions that indicate the need for further treatment at the Trauma Referral Hospital.[26,27]

Hospital care

Primary survey

Airway

The airway assessment with a look-listen-feel for the look of any signs of breath distress. Trauma patients with GCS ≤8 cannot maintain airway patency, so early intubation with SpO_2 <90% is needed.[28] Intravenous induction with the use of propofol and sodium thiopental can cause severe hypotension even to cardiac arrest. Ketamine can be a safer choice because it works through stimulation of the central nervous system.[29] In addition, succinylcholine is a choice as a muscle relaxant compared to the use of recuronium.[29] Pregnant women have more risk of airway disorders compared to non-pregnant women due to anatomic and physiological changes, including weight gain during pregnancy especially at the end of the semester, respiratory tract edema, decreased residual volume, reduced respiratory system compliance, increased airway resistance, and increased oxygen demand. A smaller endotracheal tube size is recommended if a larger one is difficult. Nasogastric tube placement can be done as early as possible to prevent aspiration of gastric contents due to the hypomotility of the gastroesophageal sphincter.

Breathing

Assessment of breathing by assessing of respiratory rate and peripheral oxygen saturation uses pulse oxymetry. If you get signs of interference with breathing, give the right oxygenation and accordingly. This can be done by administering oxygen with nasal cannula, masks, or endotracheal tubes to maintain peripheral saturation >95% (level of evidence, II-1B).[23]

Circulation

Management of circulation is carried out by evaluating hemodynamics quickly and precisely to evaluate signs of shock. Furthermore, installation of intravenous access, installation of double iv-line if needed, with a large venous catheter (14–16 gauge) (Level of evidence II-C).[23] Fluid resuscitation is given as soon as possible by giving normal saline fluids to replace blood or fluid loss and possible blood transfusion if needed further. Tilting the position of pregnant women by 30° so that IVC is not oppressed and CO is not disturbed.[25] Hemodilution in pregnancy causes signs of shock to appear late after the patient loses a large amount of blood. Vasopressor agents should not be given unless the hypotensive state cannot be overcome by adequate fluid resuscitation because the administration of these vasopressor agents can decrease uteroplacenta circulation (Level of evidence, II-3B).[23]

Disability

Neurological evaluation can be done at this point. Evaluation of the level of consciousness, pupil size and reflexes, as well as lateralization signs should also be assessed subsequently. GCS is a method for evaluating consciousness levels. Decreased level of consciousness can indicate poor cerebral perfusion.

Exposure

Opening all patients' clothing and giving a warm blanket to the patient prevent hypothermia and can also evaluate the presence or absence of injury that might occur in other organs. If there is a suspicion of spinal cord injury, inline immobilization of the spine must be done.

The initial target for resuscitation is achieving (1) systolic blood pressure 80–100 mmHg (2) SpO_2 >95% (3) hematocrit 25–36% (4) platelets >50,000/cell mm^3 (5) normal calcium serum (6) temperature serum (6) temperature >35°C (7) Prevention of metabolic acidosis and elevated serum lactate (8) adequate analgesics.[30]

Diagnostic radiation

Investigations of radiological studies are still based on indications such as cases of trauma in pregnancy with the condition that the uterus is protected as much as possible with personal protective equipment.[2] Radiation has a risk to the fetus based on gestational age, the type of radiological examination performed, the proximity of the radiation transmitter to the uterus, the use of personal protective equipment, and the type of machine used [Table 4].[26,31,33] Fetuses that are not protected by personal protective equipment receive a radiation dose of 30% of the total radiation dose received by pregnant women. Radiation has the greatest risk at gestational age 2–7 weeks postconception during the period of major organogenesis. The formation of the central nervous

system mainly takes place during the 8–15 weeks period of pregnancy. Negligible radiation has no risk of anomaly when gestational age exceeds 20 weeks.[2] Radiation doses of <1 rad (10 mGy) have a low risk to the fetus, doses of less than 5 rads (50 mGy) are not associated with an increased risk of miscarriage or fetal anomalies (ACOG, 2016). Radiation exposure exceeds 15 rads (150 mGy) related to the occurrence of microcephaly by 15%, mental retardation by 6%, and the occurrence of cancer in childhood by 3%.[26,32] Head CT scans have little radiation exposure to the fetus due to the distance of the head to the fetus far and if protective tools are added to the uterus, the risk will be reduced.[26]

Intracranial management

Hyperventilation

Decreased $PaCO_2$ causes cerebral vasoconstriction and decreases cerebral blood flow (CBF) and ICP.[34] Prolonged hyperventilation can cause cerebral hypoperfusion exacerbation which results in ischemia.[35] Hyperventilation is reportedly controversial in the management of intracranial hypertension. Extreme decrease of PCO_2 can cause severe vasoconstriction of blood vessels, causing direct utero-plancetal circulation vasoconstriction which can cause fetal hypoxia.[36] Moderate hyperventilation with $PaCO_2$ 4.0–4.5 kPa is maintained in refractory intracranial hypertension under the condition of monitoring cerebral oxygenation using jugular intravenous oxygen saturation[24] and PaO_2 targets >8 kPa.[28]

Mannitol

Management of increased intracranial pressure, one of them is by administering osmotic diuresis which is mannitol. It is given only in cases of increased acute intracranial pressure.[24] Plasma osmolarity in pregnancy decreases around 280 mOsmol/kg.[37] A study reports that mannitol given to rabbit animals can increase intrafetal plasma osmotic pressure so that fluid moves from the fetal circulation to the maternal circulation. This causes intrafetal dehydration.[38] A study reported that administration of 200 g intravenous mannitol in pregnant women with term pregnancy increased plasma osmotic pressure from 290 mOsmol/kg to 320 mOsmol/kg and fetal osmotic pressure by 312 mOsmol/kg. Administration of 100 g mannitol intravenously is reported to be safe in cases of neurosurgery with pregnancy.[38]

Hypothermia

Moderate hypothermia is reported to be effective in reducing ICP and is neuroprotective in animals that have theoretical benefits.[39]

Perspective of neurosurgical intervention

The main objective of action in the field of neurosurgery is to maintain maternal and fetal survival.[9,40] The action was carried out with the aim of preventing the occurrence of fetal asphyxia, preventing prolonged exposure to the use of drugs that are teratogenic, and preventing preterm labor.[41] Timing of surgery is a big challenge for neurosurgeons and obstetricians [Tables 5 and 6]. The first trimester is the highest risk of fetus' age for spontaneous abortion caused by general anesthesia (risk ratio = 1.58).[42] In addition, a study reported the incidence of spontaneous abortion of 15%–20% and can cause congenital abnormalities 3%–5% when the surgery is performed in the first trimester at 13 weeks gestation.[30] Gestational age ranging from 13 to 23 weeks is a safe period for surgery for trauma cases in pregnancy and other cases of emergency using general anesthesia.[29,43] Fetal viability is reported at >24 weeks' gestation. The gestational age has 3 risks of complications to be faced, namely (1) supine hypotension, (2) neurodevelopmental delay in offspring, (3) premature pregnancy.[30] Intrafetal oxygenation is highly dependent on intramaternal oxygenation conditions.[44] If the time of trauma occurs with a viable fetal condition (>24 weeks of pregnancy), the appropriate decision is to terminate the fetus, especially in cases of acute neurological deterioration [Figure 5]. The procedure can be considered by terminating cesarean with general anesthesia followed by neurosurgery.[6,34,45] Soetomo Academic General Hospital can handle neonates with a minimum gestational age of 34 weeks or a minimum birth weight of 1500 g. So that at 34 weeks' gestation, pregnancy is expected to be directly terminated if there are cases of brain injury in pregnancy by ensuring fetal pulmonary maturity. This can be adjusted to the capability of each hospital's resources. Hence, that at 34 weeks' gestation, pregnancy is expected to be directly terminated if there are cases of brain injury in pregnancy by ensuring fetal pulmonary maturity. This can be adjusted to the capability of each hospital's resource.

The neurosurgeon will encounter conditions (1) only by the termination of the fetus by c-section or followed by the simultaneous neurosurgical intervention. It occurs when the condition of the uterus blocks the course of neurosurgical intervention or the condition of a viable fetus and the mother's condition is hemodynamically stable. Furthermore (2) neurosurgical intervention is followed by caesarean or pervaginal fetal termination if cardiopulmonary resuscitation is unsuccessful after 4 min or signs of impending or recent maternal death.[23]

The retrospective study reported that there was no significant association with the mortality rate in moderate brain injury/severe brain injury in pregnancy compared to nonpregnant patients. The study was based on data collected from 2000 to 2005 as many as 71 pregnant patients who suffered moderate brain injury and severe brain injury had a mortality rate of 9.9% versus 9.3% with $P = 0.84$. Setting the confounding factor, brain

injury in pregnancy has a trend of increasing mortality with an adjusted odds ratio = 2.2; 95% confidence interval [CI], 9-5.1; P = 0.07).[46] Significant increase in steroid hormones is reported to have an important role in this case which is neuroprotectant.[46] This sex hormone receptors are expressed in blood vessel endothelium which has implications for the regulation of brain perfusion. Estrogen decreases cerebral vascular tone, vasodilation, and increases brain blood flow. Whereas progesterone works in contrast, vasoconstriction.[47] Neuroprotective mechanisms of steroid hormones are reported through several mechanisms, (1) antioxidants (2) protection against glumate-induced excitotoxicity (3) increase CBF (4) are anti-inflammatory (5) induce expression of pro-survival genes against apoptotic pathways.[48,49]

Conclusion

TBI in pregnancy is not an easy case to handle. Physiological changes in pregnancy have an important role in the management of TBI in pregnancy. The main principle of the primary survey is maternal resuscitation as part of fetal resuscitation. The main goal for the management of TBI in pregnancy is saving the maternal-fetal condition. Gestational age has an important factor in choosing timing surgery both neurosurgery and obstetric measures. Therefore, it requires multidisciplinary discussion in the treatment of TBI in pregnancy which includes neurosurgeons, obstetricians and obstetricians, neonatologists, and anesthetists.

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Conflicts of interest

There are no conflicts of interest.

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