MODULE SIX

Impact of Alcohol on Fetal Development

Teratogens

Paternal Alcohol Use

Fetal Development

Brain Function

Basic Brain Anatomy

Impact of Alcohol on a Developing Fetal Brain

saskatchewan
preventioninstitute
our goal is **healthy** children

Impact of Alcohol on Fetal Development

TERATOGENS

A teratogen is an environmental substance that interferes with the normal development of the fetus, causing fetal death or congenital abnormalities (a condition or defect that exists at birth) (University of Virginia, 2006).

Teratogens can be classified into four categories (Berk & Shanker, 2006), including:

- radiation
- maternal infections (measles/rubella, HIV, hepatitis)
- chemicals (mercury, lead)
- drugs, such as thalidomide (a drug given to pregnant women for morning sickness that caused birth defects) and alcohol

Alcohol is the most common teratogen used by women during pregnancy. Alcohol is called a neurobehavioural teratogen because it can cause injury to the brain that results in behavioural problems. Stratten, Howe, & Battaglia (1996) state that of all the substances of abuse (including cocaine, heroin, and marijuana), alcohol produces by far the most serious neurobehavioural effects in the fetus.

The harm done by alcohol and other teratogens is not always straightforward. There are many factors that determine the resulting damage. These are:

- dose or amount of exposure
- genetic makeup and resilience of the mother and developing infant
- time of exposure
- other influences, such as nutrition, medical care, and the interplay with other teratogens

The time of alcohol exposure is especially important given the concept of sensitive periods of development (Berk & Shanker, 2006). A sensitive period (critical period) is a span of time in which a specific body part and/or system are in rapid development, and therefore, the effects of a teratogen can be most devastating. For example, although the brain develops throughout the entire pregnancy, it goes through a highly sensitive period between 4-12 weeks, the embryonic period. If alcohol is consumed during this period of rapid brain development, damage can be most severe.

Alcohol's potential effects on the developing fetus' central nervous system (brain and spinal cord) include (Chudley et al., 2005):

- cell death
- interference with neural connections
- changes in the normal migration of cells
- reducing the neuronal pathways, or connections, between cells
- altering the neurochemistry
- reducing myelination of the axons

PATERNAL ALCOHOL USE

There is little known about the effect of paternal drinking before conception on pregnancy and outcomes (Passaro et al., 1998). It is important, however, to note that there have not been any cases of FASD documented where there was no maternal alcohol use during pregnancy (Abel, 1998). Alcohol consumed by the mother can only affect the fetus after the placenta and umbilical cord are established.

There have been studies involving animals and the paternal use of alcohol. These studies have shown that paternal use of alcohol among animals is associated with a number of genetic conditions, birth defects, reduced fertility, reduced percentage of pregnancies carried to term, fetal development, and higher fetal mortality (Cicero et al., 1994; Tanaka, Suzuki, & Arima, 1982). There have also been behavioural attributes associated with paternal exposure to alcohol. These include: hyperactivity, changes in adult locomotor activity, decreased ability to deal with stress, and a variety of learning and memory deficits (Cicero, 1994; Bielawski & Abel, 1996; Ledig et al., 1998; Abel, 1993). "While it is impossible to extrapolate these findings to humans, it is important to consider the genetic implications of alcohol exposure derived from the field of animal studies" (Gearing et al., 2005, pp 3).

FETAL DEVELOPMENT

In order to understand how alcohol creates damage in a developing fetus, one needs to have a basic understanding of how a baby develops throughout pregnancy. Knowledge about how alcohol interferes with normal fetal development is also important.

The Beginning of Life

At the very beginning stage of pregnancy, the egg and sperm fuse to form the developing baby called a zygote. The single cell multiplies for the first two weeks, and becomes a blastocyst, a hollow ball of cells. At about day 7 – 9, implantation occurs; that is, the blastocyst connects itself to the lining of the woman's uterus (Bolane, 1991). At this time, there are a number of structures that begin to form. These structures include the amnion, chorion, yolk sac, placenta and umbilical cord and their roles, described on the next page, are to nourish and protect the developing zygote (Berk & Shanker, 2006).

A membrane called the amnion forms around the zygote and this protects the zygote with amniotic fluid. This fluid maintains a constant temperature and provides a 'soft ride'; a cushion against the movements of the mother. The yolk sac produces blood cells for the baby until the developing liver, spleen and bone marrow are able to do their jobs. The chorion is a further layer of protection and surrounds the amnion. The chorion develops tiny, hair-like blood vessels that will burrow into the wall of the uterus, and the placenta then begins to develop.

The placenta brings the mother's and embryo's blood systems close together but does not allow them to mix (Berk & Shanker, 2006). The membrane that separates the systems allows nutrients and oxygen from the mother's bloodstream to enter the embryo's bloodstream through the process of diffusion into the umbilical vein. Fetal waste products are then returned to the mother via the umbilical arteries to the placenta and through the protective membrane into the maternal blood vessels. Once this system of exchange exists between the mother and the developing baby, anything in the mother's blood can now cross over to the baby's blood.

Three Trimesters of Pregnancy

Pregnancy is divided into three equal parts or trimesters. Each trimester is approximately 12 weeks (3 months) long.

Table 6.1: Development of zygote, embryo & fetus within three trimesters of pregnancy

First Trimester 0-12 weeks	Second Trimester 13-24 weeks	Third Trimester 25-40 weeks
0-3 weeks: Zygote 3-9 weeks: Embryo 9-12 weeks: Fetus	Fetus	Fetus

First Trimester (0-3 months)

The first trimester is a time when the cells of the zygote divide, become implanted in the lining of the uterus and develop the necessities to continue life. Alcohol consumed at this time may cause cell death or problems with implantation (Berk & Shanker, 2006). Three weeks after the sperm cell enters the egg, the developing baby is no longer referred to as a zygote, and is now called an embryo.

During the five weeks the baby is called an embryo (3-9 weeks), the central nervous system (brain and spinal cord) and major organs develop. In fact, the heart starts to beat 3 weeks after conception and brain waves are recorded at 6 weeks. This is the most sensitive period for damage to the CNS and the structure of the face (Berk & Shanker, 2006). This is a time when the most damage occurs to all body parts and systems. It is important to note that maternal use of alcohol past this stage of development can still damage the growing fetus.

At nine weeks, the baby is now referred to as a fetus (Berk & Shanker, 2006). This is often referred to as the period of growth and finishing. The brain, spinal cord, organs and muscles become more organized and begin to work together. Connections are made so that the fetus has the capability for movement and behaviour. This is when ultrasounds reveal kicking, arm and hand movements, thumb sucking, and mouth opening.

By 12 weeks, all of the body systems, with the exception of the immune system, are working.

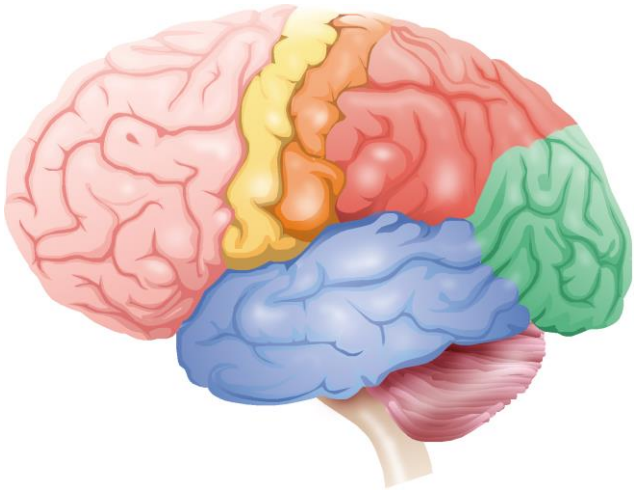
Second Trimester (3-6 months)
In the second trimester of pregnancy, the developing fetus continues to grow and mature. The mother can usually begin to feel her baby moving inside her at around 4½ months. By the end of the second trimester, most of the brain's neurons are present. Details such as eyelashes, eyebrows, and hair are apparent.

Third Trimester (6-9 months)
Development from this point on is mostly size and maturation. The brain, however, continues to develop during the entire pregnancy. The cerebral cortex, the basis of human intelligence, gets bigger. During this period of brain development, the grooves and convolutions characteristic of adult brains deepen, thereby increasing brain size and capacity without increasing head size.

Maternal use of alcohol can damage the fetus and the brain at any point during the pregnancy.

BRAIN FUNCTION

The brain is extremely complex and no one completely understands its capacities. Once fully developed, the adult brain weighs between 1 and 1.5 kg (about 3 pounds) containing about 100 billion nerve cells. Ongoing neuroscience research continues to discover new information that extends our understanding of human behaviour and functioning.



BASIC BRAIN ANATOMY

The brain is divided into three parts.

Table 6.2: Parts of the Brain

Structure	Description
Forebrain	• includes the cerebrum, thalamus and hypothalamus and is the largest part of the brain with the highest intellectual functioning
Midbrain	• located at the top of the brain stem, it contains centres that receive information and then make sense of it; relays auditory and visual information
Hindbrain	• contains the pons, medulla oblongata and the cerebellum and acts somewhat like the body's computer, regulating automatic processes

The following anatomical description of the brain includes the cerebrum, the diencephalon, the cerebellum and the brain stem.

Cerebrum: This is the largest brain structure. It is identified by a grooved appearance and is the top portion of the brain. It is divided into two hemispheres, the right and the left. The cerebrum is called the "thinking" part of the brain. The nerve centers for thought, communication, personality, the senses and voluntary movement are in the cerebrum (Encyclopedia Britannica & Fine, 2008).

Within the cerebrum there are four main sections/lobes.

Table 6.3: Four Lobes of the Cerebrum

Lobe	Description
Occipital Lobe	• located at the back of the brain • processes visual images by interpreting the signals sent by the eyes
Temporal Lobe	• located above the ear and behind the temple • processes sound and, in turn, language • because the temporal lobe is connected to the hippocampus, it also functions in memory formation and retention (Encyclopedia Britannica & Fine, 2008).
Parietal Lobe	• located behind the frontal lobe and at the top of the head • integrates information from various bodily senses such as touch, pressure and pain • passes this information to the cerebral cortex and only then can the information be processed in the parietal lobe.
Frontal Lobe	• largest of the lobes and is located behind the forehead • responsible for the executive functioning of the brain. It is the intelligence centre of the brain • performs abstract intellectual functions such as understanding cause and effect and connecting consequences to the preceding action, as well as being the centre for critical thinking, problem solving, decision making, self-control and self regulation • controls complex movement and speech.

The cerebrum also contains the basal ganglia and corpus callosum. Basal ganglia are structures deep within the cerebrum that are very important in fine motor coordination. Corpus callosum is a thick flat bundle of nerve fibres that transfers information between the two hemispheres of the brain so that the two halves can work together to analyze situations.

Diencephalon : This part of the brain contains the thalamus and hypothalamus, along with a number of other components including the pituitary gland. The diencephalon is located below the cerebrum. (Society for Neuroscience, 2008; Parker, 2007).

Table 6.4: Parts of the Diencephalon

Structure	Description
Thalamus	• relays most of the sensory and motor information to the various parts of the cerebrum • shaped like two eggs, which are masses of nerve tissue.
Hypothalamus	• located below the thalamus and secretes hormones • helps to control the sympathetic and parasympathetic divisions of the autonomic nervous system, which maintains the constant conditions of the body. • sympathetic division mobilizes the energy and resources of the body, while the parasympathetic division conserves energy and resources • is essential to what an individual finds rewarding – from sex, music, alcohol and drugs to maternal behaviour. (Gibb, 2007)

Cerebellum: The cerebellum is located at the bottom and back of the brain and is connected to the brain stem. It is divided into two hemispheres, contains approximately half of the brain's neurons and provides the coordination of voluntary movement. If one of the hemispheres of the cerebellum is damaged, the same side of the body and its movement will be affected. (Encyclopedia Britannica & Fine, 2008).

Table 6.5: Parts of the Cerebellum

Structure	Description	Parts of Structure
Brainstem	• located at the base of the brain and the top of the spinal cord and reaches into approximately the middle of the brain or at a level behind the eyes	• **Medulla oblongata** is responsible for the automatic functions that keep the body alive such as the heartbeat and breathing • **Pons,** helps to regulate automatic functions and sends messages from the spinal cord to the forebrain and back again. The midbrain is the top of the brainstem.

Limbic System	• referred to as the "primitive brain", influences instinctive behaviour such as the "fight or flight" reaction to a situation • behaviours triggered by the limbic system can be controlled most of the time by the higher functioning components of the brain	• **Amygdala** is located beneath the hypothalamus; it plays an important role in emotional responses such as fear, anger, sexual desire and how the individual relates to the world and people around him or her. • **Hippocampus** helps in the recognition of new experiences and amalgamating memories to help the individual in his or her responses to situation.

Neurotransmission in the Brain

There are over 100 billion neurons in the brain and many more glial cells that support the neurons. The components of the brain communicate with each other. This communication within the brain and with other systems of the body happens because of the nerves and neurons in the brain and body.

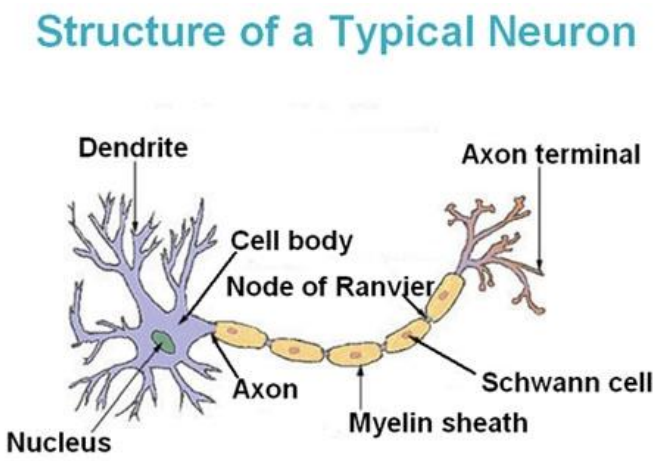


Table 6.6: Neurons and Parts of Neurons

Structure	Description
Neuron	• has a cell body with a nucleus along with branch-like structures that are called axons and dendrites. These branch-like structures send and receive messages.
Axons	• send signals away from the cell body to other neurons
Dendrites	• receive signals from other neurons and move them toward the cell body of the neuron.
Synapse	• is the very small gap between two neurons that allows neurotransmission to occur through an electrical impulse that causes a chemical to be released from the sending neuron to the receiving neuron.
Glial Cells	• are cells that surround, support, protect and feed the neurons.

If neurotransmission within the brain is altered, individuals may have difficulties with things like sleep, depression and anxiety or insensitivity to pain.

IMPACT OF ALCOHOL ON A DEVELOPING FETAL BRAIN

Table 6.7: Impact of Alcohol on a Developing Fetal Brain

Brain Area	Type of Damage	Impact
Corpus Callosum	• Agenesis (failure to grow) • Displacement • Surface area reductions (anterior and posterior) • Variability in shape	• Neuropsychological deficits, particularly impacting bimanual coordination, verbal learning and executive function
Cerebellum	• Smaller volume • Smaller surface area • Displacement • Reduction in cranial vault size (space inside the skull that the brain occupies)	• Related to difficulties with balance, attention, conditioning, verbal learning and memory
Basal Ganglia	• Smaller volume	• Affects executive functioning, attention and response inhibition
Grey and White Matter	• Abnormalities of density and distribution.	• Causes irregular cortical thinning • Linked to executive dysfunction and visual processing deficits
Thalamus and Caudate	• Reduction in glucose metabolism • Decreased cerebral blood flow • Decrease dopamine and serotonin neurotransmission	• Delayed communication of sensory and motor information • Decreases inhibition
Cranium	• Reduction in cranial vault size	

(Fryer et al., 2009; Spadoni et al., 2006)

Activities

Activity 6.1: Alcohol Can Fry the Brain

Purpose: To provide a visual representation or metaphor showing that alcohol can damage a fetus' brain.

Materials:

- One raw egg
- One wine glass
- One ounce of alcohol

Instructions:

- Break the raw egg into the glass and add alcohol.
- Watch the clear part of the egg develop white streaks as the alcohol "cooks" it. This represents an infant's brain that is exposed to alcohol.
- Check back occasionally to see how it changes.

Discussion:

1. If alcohol can do this to an egg, what affect does it have on a fetus?

Activity 6.2: 4 Week Fetus Teaching Model

Purpose: To provide a visual, 'life-like' reference with details about the development that has occurred up to that time.

Materials (found in the Resource Kit):

- Four week fetus from Maternal Source
- Laminated fetal development statement cards

Instructions:

- If you have a small group, hand out laminated development description cards and have participants read them out loud to the group.
- Pass around the fetal model so participants can hold it in their hand if they wish.

Discussion:

1. If there are pregnant women in the audience, relate it to them.

Activity 6.3: 12 Week Fetus Teaching Model

Purpose: To provide a visual, 'life-like' reference with details about the development that has occurred up to that time.

Materials (found in the Resource Kit):

- 12 week fetus from Maternal Source
- Laminated fetal development statement cards

Instructions:

- If you have a small group, hand out laminated development description cards and have participants read them out loud to the group.
- Pass around the fetal model so participants can hold it in their hand if they wish.

Discussion:

1. If there are pregnant women in the audience, relate it to them.

VIDEOS

- YouTube: "Human Reproduction: Fertilization and Fetal Development"
- YouTube: "You Make Me Feel" (ilathedreamer, 2008)

DISCUSSION QUESTIONS

1. **What are some common teratogens?**
   - *Radiation*
   - *Maternal infections (rubella, HIV, hepatitis)*
   - *Chemicals (mercury, lead)*
   - *Drugs (thalidomide, alcohol)*

2. **Can a father's alcohol use affect the fetus?**
   - *Paternal alcohol use cannot cause FASD*
   - *There have been some studies with animals that show that paternal use of alcohol is associated with some genetic conditions, birth defects, reduced fertility, and higher fetal mortality.*
   - *There have also been some behavioural attributes associated with paternal alcohol use. These include: hyperactivity, changes in adult locomotor activity, decreased ability to deal with stress, and a variety of learning and memory deficits.*

References

Abel, E. L. (1993). Rat offspring sired by males treated with alcohol. *Alcohol, 10*(3), 237-242.

Abel, E. L. (1998). Protecting fetuses from certain harm. *Politics and the Life Sciences, 17*(2), 113-117.

Berk, L. E. & Shanker, S. G. (2006). Child development (2nd ed.).

Bielawski, D. M., & Abel, E. L. (1996). Acute treatment of paternal alcohol exposure produces malformations in offspring. *Alcohol, 14*(4), 397-401.

Bolane, J. E. (1991). Life unto life: Fetal growth and development. Rochester, NY: Childbirth Graphics Ltd.

Chudley, A. E., Conry, J., Cook, J. L., Loock, C., Rosales, T., & LeBlanc, N. (2005). Fetal alcohol spectrum disorder: Canadian guidelines for diagnosis. *Canadian Medical Association Journal,* 172(Suppl. 5), S1-S21.

Cicero, T. J. (1994). Effects of paternal exposure to alcohol on offspring development. *Alcohol Health and Research World, 18*(1), 37-41.

Cicero, T. J., Nock, B., O'Connor, L. H., Sewing, B. N., Adams, M. L., & Meyer, E. R. (1994). Acute paternal alcohol exposure impairs fertility and fetal outcome. *Life Sciences, 55*(2), PL33-36.

Encyclopedia Britannica and Fine, C. (2008). *The Britannica Guide to the Brain: A guided tour of the brain – mind, memory, and intelligence*. Philadelphia. Running Press Book Publishers.

Fryer, S. L., Schweinsburg, B. C., Bjorkquist, O. A., Frank, L. R., Mattson, S. N., Spadoni, A. D. & Riley, E. P. (2009). Characterization of white matter microstructure in fetal alcohol spectrum disorders. *Alcoholism: Clinical and Experimental Research,* 33 (3), 1-8.

Gearing, R. B., McNeill, T., & Fernand, A. L. (2005). Father involvement and fetal alcohol spectrum disorder: Developing best practices. *Journal of FAS International, 3*(e14), 1-11.

Ledig, M., Misslin, R., Vogel, E., Holownia, A., Copin, J. C., & Tholey, G. (1998). Paternal alcohol exposure: Developmental and behavioral effects on the offspring of rats. *Neuropharmacology, 37*(1), *57-66.*

Parker, S. (2007). *The Human Body Book*. New York. Dorling Kindersley Limited.

Passaro, K. T., Little, R. E., Savitz, D. A., & Noss, J. (1998). Effect of paternal alcohol consumption before conception on infant birth weight. *Teratology, 57(6)*, 294-301.

Society for Neuroscience. (2008). *Brain Facts: A Primer on the Brain and Nervous System*. Washington, DC.

Spadoni, A. D., McGee, C. L., Fryer, S. L. & Riley, E. P. (2006). Neuroimaging and fetal alcohol spectrum disorders. *Neuroscience and Biobehavioral Review,* 31, 239-245.

Stratton, K., Howe, C., Battaglia, F. C. (1996). *Fetal alcohol syndrome: Diagnosis, epidemiology, prevention, and treatment*. Washington, DC: Institute of Medicine and National Academy Press.

Tanaka, H., Suzuki, N., & Arima, M. (1982). Experimental studies on the influence of male alcoholism on fetal development. *Brain & Development, 4*(1), 1-6.

University of Virginia. (2006). *Medical genetics: Teratogens*. Retrieved February 20, 2009, from www.healthsystem.virginia.edu/uvahealth/peds_genetics/terathub.cfm.