Section I – Plain Film X-ray, the fetus, and the pregnant female

Figure 1 – Xray
Risks of plain film x-ray on the fetus are negligible

Patients are well aware that plain film x-ray can be damaging to them and are especially concerned when they are pregnant. Yes, ionizing radiation does have negative consequences, but how dangerous is this imaging modality to the fetus? Patients were first educated about the dangers of x-ray during pregnancy in the 1950s when the Oxford Survey of Childhood Leukemia released the results of a study showing that there was an approximate forty percent increase in the risk of childhood leukemia in children whose mothers received plain film x-rays during their pregnancy. This statistic is alarming, and rightfully so, but the study design was quite flawed. The study had no controls and did not account for any other confounding factors; therefore, attempts to replicate this study with better study designs have not been able to replicate these results. Thus, public panic about x-ray machines with pregnant females may be unfounded. The modern studies have found no statistically significant association between fetal exposure from diagnostic x-ray and the rate of childhood leukemia, central nervous system tumors or any malignancy for that matter. Here is the caveat: these modern studies are case control studies not double blinded randomized controlled trials. Even with the best studies, they are not optimal. A double blinded randomized controlled trial cannot be done in this case because you cannot expose a pregnant female to radiation to see how it will affect the fetus. No institutional review board would clear a study that uses ionizing radiation without significant clinical indication because there could be serious harm to the child and mother. Thus, studies of radiation exposure are somewhat limited. The United States Department of Health and Human Services lists diagnostic x-ray as a carcinogen and thus considers those who use it a dispenser of carcinogenic care. Because we must first, do no harm; consider the clinical necessity of x-ray exposure on any patient, not just the pregnant female.

Most of what is known about the affects of radiation on offspring comes from the atomic bomb victims of Nagasaki and Hiroshima. From these catastrophic exposures, results have been extrapolated to determine what minor exposure might cause. For example, Nagasaki and Hiroshima have taught us that high doses of radiation exposure can cause leukemia or mental retardation and thus, these disease rates can be analyzed in patients with and without diagnostic x-ray exposure. There have been studies limited by inadequate statistical power due to small sample size and a small number of observed cancer cases. From these case controlled studies, the accepted cumulative dose of ionizing radiation to the pregnant female is 5 rads. NO single diagnostic study exceeds this maximum. For example, the two view chest x-ray provides 0.00007 rads of exposure. With plain film, the only time that dose levels may be of concern is in multiple plain film series such as with trauma victims. Otherwise, a clinically indicated single diagnostic series is deemed safe to the mother and the fetus and so should be utilized to make an accurate diagnosis.

Beyond cancer risk, teratogenesis has also been a concern to physicians and patients. Microcephaly and mental retardation are also known consequences of ionizing radiation. However, these neurological consequences are only of major concern during the period of fetal development when the nervous system is forming. Thus, plain film should be avoided when possible from gestational weeks eight to seventeen to avoid central nervous system damage. After this period, microcephaly and mental retardation are not a concern. Plus, these central nervous system conditions have been noted in doses
on the order of 10 rads or more, not the small doses received from plain film. These consequences are known to be linear dose-related affects meaning that low amounts of radiation pose little risk to the fetus while high radiation doses resulted in greater mental retardation.

Besides cancer and fetal malformation, the last area of concern is mutagenesis, which is alteration in the germ line genes. Of the effects, mutagenesis has the greatest consequence because it can affect future generations. A known scientific principle is that small changes in the physical environment can have profound biological consequences and thus potentially altering the DNA, that is passed on to future generations. The “knock-on” effects when spread over generations can be catastrophic and with the limitations of knowledge about the biological effects of ionizing radiation, doctors and patients are often concerned. While bizarre new mutations can arise, most radiation induced mutations are mutations already seen in the general population, just occurring at higher frequencies. The mutation rate doubles with 50 rads of exposure, well above the exposures of a typical plain film series.

The important point that I want to highlight is that plain film radiographs do not even come close to reaching the kinds of exposure levels that would result in the effects seen at Nagasaki or Hiroshima. This is important because a questionnaire of family physicians in Israel stated that forty percent would recommend therapeutic abortion in women receiving radio-diagnostic procedures such as abdominal x-rays, barium enema, or intravenous pyelograms. Seventy percent of Israeli obstetricians would recommend abortion to these same patients and these results paralleled similar reports done in Canada. Most women who received a therapeutic abortion did so because of the fear of mutations presented by the physician. Twenty five percent of pregnant women exposed to x-ray believe that their child is at risk for serious malformations. These abortions are unnecessary. This is why I want to educate you about the real risks of x-ray and reiterate that “there is no evidence of significant risk to the developing fetus from any single diagnostic xray exposure”.

The pregnant patient tends to be more of a concern, then the pregnant technician or pregnant radiologist, especially those in interventional radiology. This should not be the case. Reports have shown that there is a higher incidence of cataracts with interventional radiologists than with the general public. In one study, interventional radiologists did not wear the protective leaded eyewear that is available and did not install ceiling screens that reduces scatter. Radiation workers, both male and female, must be cognizant of their exposure because Parker’s study demonstrated a higher rate of congenital anomalies and stillborn children born to offspring of male radiation workers. Radiation workers often become complacent when working with ionizing radiation everyday and need to remember the detrimental affect it can have on their offspring.

Key points:

- Ionizing radiation can cause an increase in leukemia and other cancers
- Ionizing radiation can cause mutations that affect future generations
- Between week ten and seventeen of gestational age, the central nervous system is at most risk for damage from ionizing radiation
  - Ionizing radiation can cause mental retardation or microcephaly
No single plain film series is above the recommended 5 rads that are deemed safe for the pregnant female
  - Patients and doctors often overestimate the impact of medical x-ray on the fetus
    - Therapeutic abortions have often been obtained unnecessarily due to the fear of fetal damage

References:

Section II – Ionizing radiation

Figure 2 Computed Tomography

It is not like if you never walked in front of an x-ray machine that you would be free from radiation. Even the ground emits radiation. On average, background radiation accounts for eighty-five percent of a person’s lifetime radiation exposure with only fifteen percent coming from man-made sources, like x-ray. Background radiation provides the average American 0.3 rad/year of radiation and those in Denver, Colorado have an additional 0.15 rad/year because of the higher altitude. The higher the altitude the more the radiation; therefore, taking an airplane ride adds radiation exposure. Jet cockpit crews have shown an increased incidence of radiation induced myeloid leukemia than the general public. Radiation comes from cosmic rays, terrestrial radiation from the ground and buildings, and naturally occurring radioisotopes that are inhaled and ingested. You cannot avoid radiation. Even high levels of background radiation have been known to cause fetal malformations. The US National Council of Radiation Protection states that risk of fetal malformation increases above background radiation levels above fifteen rads.

Avoiding ionizing radiation will not remove all risk of developing mutations or miscarriages. The risk of miscarriage without x-ray exposure is fifteen percent and three percent of patients without x-ray
exposure have children with major malformations and four percent have growth restrictions. One thing to note about these statistics is to never tell the patient she will have a healthy child despite receiving a medical x-ray. Even if the x-ray has no impact on the fetus, if a child born to a pregnant female who received medical x-ray has malformations, it would be hard to convince a mother that she did nothing to harm her offspring. On the other hand, do not forgo using necessary diagnostic imaging for fear of litigation if the child is born with malformations. Because of the high spontaneous rate of malformations, it would be difficult to prove that a given radiograph was the cause of the child’s problems.

Even computed tomography, which has much higher patient dose than plain film, falls below the 5 rads deemed safe for the pregnant female. Ninety-seven percent of man-made radiation comes from CT scanners. Remember that the dose the female receives is not the same as what the fetus receives. Fetal dose depends on the body part being imaged. For example, a chest CT would expose the fetus to only 0.45 rad, obviously higher than plain film, but still lower than the unsafe threshold. With that being said, not all CT produces the same amount of dose. For example, CT angiography has even higher dose than regular CT and also involves contrast agents. While some physicians may be comfortable with the dose received to a pregnant female using plain film, five percent who would not recommend abortion after a plain film would recommend abortion after a CT scan during early pregnancy. Even this suggestion may be unnecessary. Brenner’s study has calculated that the cancer risk of a forty-five year old man undergoing thirty annual full-body CT scans only has a 1.9% risk of cancer mortality. If a patient wants more information before making an abortion decision, a radiation physicist can calculate the estimated dose of radiation to the fetus, providing a true assessment of risk.

Not all x-rays will have the same risk of harm to the fetus. With x-ray, fetal dose is inversely related to the distance from the radiation source. Thus, x-rays of the skull, head, neck, chest, and extremities pose very little risk to the fetus. Now, just because the fetus isn’t in the direct path of the x-ray beam does not mean that the fetus is not receiving radiation. Scatter within the mother will still result in some fetal dose. This internal scatter cannot be eliminated but to reduce fetal dose, use lead shields or bismuth radioprotective latex and always use proper collimation.

What does ionizing radiation do to the body? Both x-rays and gamma rays, such as in nuclear medicine, are sources of ionizing radiation which is a short wavelength electromagnetic ray. Ionizing radiation disrupts atomic structure by removing electrons, resulting in ionization and free electrons. Free radicals are produced from the radiolysis of water. These high energy photons can damage DNA. The result of these chemical changes is either deterministic or stochastic. Deterministic effects are things directly associated with the exam such as getting a radiation burn from the exposure or cataract formation due to radiation. These are known consequences of ionizing radiation and even have determined doses, such as 0.5 Gy is the level of radiation that puts the patient at risk for cataracts. This type of injury involves repair and compensatory mechanisms thus, fractionated radiation doses allow more repair and allow for greater tolerance of radiation by the tissues. Stochastic effects occur from a single random modification in a cell component. Stochastic effects are more random and difficult to predict. For example, all patients who receive a certain amount of radiation will get a radiation burn. That is deterministic. Not all patients who receive a certain amount of radiation will get cancer. That is
stochastic which is due to radiation exposure plus hereditary factors and thus becomes more difficult to
determine who is at risk and at what level of radiation puts them at risk. Unlike deterministic, there is
no threshold for stochastic effects.

We have been talking about the direct effects of radiation on the fetus, but what about before the fetus
is even conceived? Patients who have received high doses of abdominal or pelvic radiation, typically as
treatment for abdominal cancers, often will suffer from somatic damage to the abdominopelvic
structures interfering with conception and gestation. The effects on the mother seem fairly obvious
because a reproductive woman has all the egg follicles she will ever have unlike a male who continually
produces new sperm. Therefore, radiating a woman can affect all her future offspring no matter how
far removed conception is from the source of radiation. Is there any impact on the male? Irradiation of
the testes can result in infertility just like for the ovary. The infertility can be temporary or permanent
depending on the dose and duration of the radiation.

Key Points:

- Man-made radiation accounts for only fifteen percent of a person’s lifetime radiation exposure
  o Most radiation cannot be avoided because it is background radiation
- Spontaneous mutations and miscarriages occur; therefore, linking these effects to a specific
  radiation exposure may be inappropriate
- Stay below 5 rads for the pregnant female
  o Provide lead shields and collimate to reduce impact on the fetus
- Ionizing radiation causes deterministic and stochastic effects
- Receiving ionizing radiation prior to the reproductive years can cause permanent infertility in
  both women and men

References:

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Section III – ultrasound and fetal medicine

Problems with ultrasonography

Ultrasound is the imaging modality of choice for prenatal assessment due to its high anatomical resolution, real time imaging, multiplanar three dimensional reconstructions and dynamic fetal assessment. From a practical standpoint, this modality is widely available and inexpensive. The downside is that the imaging is only as good as the operator and interpretation can be challenging. Ultrasound has been an imaging modality available to the physicians for the past thirty years. Originally, ultrasound was used by cardiologists, but ultrasound gained rapid appeal with the obstetrics and gynaecology doctors. Probably, most of you that have had a child within the last twenty years were offered an ultrasound during pregnancy. Now, you might not think this important since ultrasound does not use ionizing radiation and has no known affects on the fetus. The issue is not about the affects of ultrasound but the need for ultrasound in most pregnancies. In a low risk pregnancy, the probability of having a baby with no major birth defect is ninety-eight percent; therefore, do all pregnancies require an ultrasound, considering that fetal ultrasounds cost the health care system over one billion dollars. With runaway health care costs, this may be one test that can be eliminated in many pregnancies.
The problem comes when patient autonomy interferes with clinical decision making. At this point, pregnant women expect an ultrasound and assume it to be standard practice since seventy percent of pregnant women in the United States receive at least one ultrasound during pregnancy. Forty four percent of ultrasounds were ordered, without having clinical indication, partly because women demand them. Without proper education of the patient, what is the doctor to do? Here comes a task force to save the day! The United States Preventive Services Task Force makes the, oh so helpful, statement that there is “insufficient evidence to recommend for or against routine second trimester sonography in otherwise low risk patients”. Thanks a lot. In this consumer mentality market, pregnant women will just transfer to a doctor that will give her what she wants and not necessarily what she needs. Thirty seven percent of military women in one study stated that they would transfer doctors if they did not receive an ultrasound and were willing to pay approximately eighty-five dollars for the service. This is significant since military women do not have to pay any money for their medical care. Another study, of civilians, stated that in Boston, the women were willing to pay more than seven hundred dollars to receive an ultrasound.

Ninety-eight percent of women stated that they wanted an ultrasound during their pregnancy; some said that they were not sure but NO woman stated that they did not want an ultrasound during their pregnancy. Why the drastic need for ultrasound? The number one reason women cited for wanting an ultrasound was to determine the sex of the child. Now, that is an important reason to spend our health care dollars. The other top reasons for wanting an ultrasound included to reassure the Mom, rule out abnormalities and determine the general health of the baby. Some women just wanted to see the baby and its positioning, to determine the due date, and to look for multiples. The second most common reason to have an ultrasound was related to fetal health, but what women probably don’t know is that the sensitivity of ultrasound for detecting major birth defects prior to delivery is only thirty five percent. What this means is that if ultrasound detects a defect that it is a true positive, but there are a lot of false negatives where women will believe the child to be “healthy” based on sonography when they are not. Patients need to be educated about the low sensitivity of this apparatus. Maybe they will change their mind.

The other problem with ultrasound is the interpretation is only as good as the radiologist. For example, fetal brain imaging can be difficult to interpret and requires someone with expertise in neurosonography. Hagmann did a study comparing sonography reports from a single interpreter versus a panel of interpreters. The expert panel consisted of a geneticist, fetal medicine specialist and neonatologist. The study showed that in seventeen percent of cases, the expert panel interpreted the ultrasound findings differently than the original interpretation with eleven percent changing the diagnosis and five percent changing the clinical management. This is a significant difference and yet, an expert panel cannot practically be established like this to interpret all ultrasound cases. First, finding this level of expertise in all hospital settings is unlikely and cost prohibitive. Therefore, know that a standard ultrasound report may miss or misdiagnose fetal conditions. Even with the experts, ultrasound does not detect all brain abnormalities. Hagmann’s study also showed that ultrasound outright missed polymicrogyria, bilateral schizencephaly and unilateral schizencephaly. What this study indicates is that
ultrasound does not have a high sensitivity of detection for several fetal malformations. Thus, just because the parent is told that the child is developing normally, this may not necessarily be the case.

Key points:

- Ultrasound is often ordered without medical necessity
- Women often expect prenatal sonography
  - Reasons for wanting ultrasound included:
    - Gender determination
    - Reassurance of fetal health
    - Determination of twins
    - Due date determination
    - See the baby and determine fetal position in the uterus
- Ultrasound does not detect all fetal abnormalities
  - Diagnosis improves when ultrasound is read by a multidisciplinary panel
    - The panel would be cost prohibitive

Benefits of ultrasonography

While the above section was on the negatives of ultrasound, I want to spend the majority of the time singing the praises of ultrasound. Because of ultrasound, the trophoblastic ring can be visualized at four weeks. In the fifth gestational week, the heartbeat can be seen and in the seventh week, the head and two brain hemispheres are evident. During the ninth week, the stomach, fingers, ossification of the first bones can be seen.

Besides normal anatomy, meningoceles and holoprosencephalon can be seen as early as nine weeks. It has become almost standard for an eighteen week ultrasound to be performed. The benefits of the screening ultrasound are the following: determining if early delivery is necessary, if Caesarian would be less risky than vaginal delivery, knowing what conditions the child will be born suffering from, assembling the right team of experts for delivery, or to transfer the Mom to a place where specialists will be available. In some cases, intrauterine therapy can be administered and thus truly be a life and death situation. Currently, ultrasound has been used to guide tests of fetal blood and fluids, administer blood transfusions and drainage of fluids. Ultrasound can show increased fluid which depresses the development of the lungs and could even lead to fetal death. Under ultrasound guidance, this fluid can be removed and if the fluid is a chronic problem, a plastic pigtail catheter can be installed from the chest to the amniotic cavity and remain in place until delivery. If the fetus has severe and lethal anomalies, the parents are given the option to terminate the pregnancy. No matter what ethical beliefs you possess, everyone would agree that a parent of a fetus with severe or lethal malformation would need counseling. Knowing early can help the parents to get the needed support before the baby is delivered or terminated.

The Doppler ultrasound is the first in utero hemodynamic assessment test. With the Doppler ultrasound, practically every vessel in the fetal body can be assessed and the maternal blood supply to
the uterus can be determined. Circulation to the placenta and the fetal brain can be determined and drainage into the fetal heart is all valuable sets of information to determine fetal health.

Key points:

- Normal development can be determined with ultrasound as early as the fourth gestational week
- In utero therapies can be administered if detected by ultrasound and guided by ultrasound
- Doppler ultrasound can assess the hemodynamic status of the fetus

References:

Section IV – Acute Abdomen

Figure 4 Fluoroscopy

The acute abdomen is of most concern in the pregnant female because diagnostic imaging will occur at the abdomen where the fetus is located. Unfortunately, the abdomen is the site of many pregnancy emergencies because the gravid uterus can alter the locations and physiology of abdominal organ systems. This change in anatomy makes it challenging for the radiologist and makes diagnostic errors more likely. What is to be done when abdomen imaging is necessary? Of course, ultrasound is the modality of choice for the pregnant female because there are no known adverse effects to the fetus or the mother using this modality. However, sometimes ultrasound cannot provide the answer. In surgical emergencies, start with ultrasound, such as with appendicitis or renal colic. Pregnancy makes ultrasound imaging difficult for renal colic because dilatation of the renal collecting system occurs in greater than ninety percent of asymptomatic pregnant women. Appendicitis may be difficult to diagnose because the pregnant uterus often displaces the appendix. In some cases, sonography is useless such as is the case with cecal volvulus. Cecal volvulus is common in pregnancy because the uterus often displaces the cecum and the uterine pressure can obstruct or kink the colon. The elevated colon can undergo torsion.
The first thought is to use MRI (magnetic resonance imaging) next since there is no ionizing radiation. Well, many diagnoses require the use of contrast and gadolinium does cross the placenta and may have an affect on the fetus. Gadolinium has shown teratogenic effects in animal studies. MRI is known to be effective for diagnosing neoplasms but there are only limited studies in the effectiveness of MRI in the diagnosis of the acute abdomen. Sometimes ionizing radiation is necessary, even computed tomography (CT) which produces a higher radiation dose than plain film. For example, plain film may not show a cecal volvulus because the gravid uterus displaces bowel loops and can obscure the finding. The CT of the abdomen and pelvis provides about two to four rads of radiation exposure. Even with this high dose, a single study CT still stays below the required five rads deemed necessary for fetal safety. CT can be modified to supply a lower dose by lowering electric currents, having a high pitch, and using an increased slice thickness. Even the use of iodinated intravenous contrast is allowed with CT because it results in less dose than having to repeat a non-contrast CT when it is nondiagnostic.

The point to remember is that all procedures must be weighed in a cost/benefit analysis. What happens if the diagnosis of acute abdomen is missed? Knowing that appendicitis is THE most common nonobstetric surgical diagnosis during pregnancy, and perforation increases the chances of fetal mortality four fold, ionizing radiation for diagnosis may be the safest alternative.

Key points:

- Sonography is the first choice in diagnostic imaging for the acute abdomen but sonography is often inconclusive
- CT is the preferred test in the acute abdomen when ultrasound is unhelpful
  - Even iodinated contrast may be necessary
  - Weigh the cost of a missed diagnosis versus the ionizing radiation of CT

Appendicitis

Appendicitis is a reality for the pregnant patient because as many as one in 1250 pregnancies will have appendicitis, typically in the second trimester, and represents 25% of all acute abdomen cases during pregnancy. The typical appendicitis presentation only occurs in about half of cases; therefore, diagnostic imaging is sometimes necessary for proper diagnosis, especially in the pregnant patient. The changes in location of the anatomy during pregnancy, and the normal pregnancy inflammatory response may make diagnosing appendicitis even more challenging. The diagnostic dilemma is to forgo imaging and go straight to laparotomy or use diagnostic imaging, especially if the safer tests like ultrasound are inconclusive. Here in lies the dilemma since both procedures can have negative consequences.

If the patient is sent for laparotomy, the risks of unnecessary surgery include premature labor, fetal loss and increased rates of miscarriage. The risks are due to trocar insertion or carbon dioxide insufflations. The mother is at risk due to pneumoperitoneum and decreased blood flow to the heart. But, if surgery is delayed, fetal loss reaches thirty-five percent in patients with a ruptured appendix versus those without. Plus, increasing gestational age increases the risk of appendix rupture. On the other hand, advanced gestational age makes laparotomy more difficult, with the most advantageous gestational age for laparotomy being twenty-six to twenty-eight weeks. However, some studies have demonstrated
successful laparotomy at any stage of fetal development. This argument could continually go back and forth with no obvious choice.

Key points:

- When ultrasound is inconclusive, is it better to use other diagnostic imaging modalities to confirm appendicitis or go straight to surgery?
  - There is no clear answer to which is better

Beyond appendicitis

Nuclear medicine has higher radiation exposure than plain film but typically still has a whole fetal exposure of less than 0.5 rad. The fetus does have uptake of the decaying injected isotope. In one animal study of nuclear imaging, the radioisotope was found in the maternal liver, maternal kidney, maternal bladder, placenta, and fetus. The fetus’s liver would retain the isotope more than the mother which is important because this is the major site of hematopoiesis in the fetus. One reason for the increased uptake by the fetal liver is due to eighty percent of the umbilical blood entering the fetus through the fetal liver before going to the heart. Because of the fetal liver exposure, consider potential liver disease in the cost/benefit analysis before using nuclear medicine. One way to reduce fetal dose is having the mother void. The largest contributor to fetal dose is from the maternal bladder.

Key points:

- While nuclear medicine has relatively safe levels of radiation, the fetal liver does retain some radioisotope
  - This could lead to liver disease
- Have the mother void to reduce fetal dose

If intraoperative and endoscopic cholangiography is needed, what can be done to reduce fetal dose because this is an ionizing radiation? Chalangiography provides about 0.5 rads of exposure. Obviously, shield the lower abdomen. Place a lead apron inside the drape during surgery is helpful. Remember that radiation exposure is cumulative so evaluate the time of exposure with fluoroscopy, noting that the typical fluoroscopy machine produces up to twenty rads per minute. Instead of intraoperative cholangiography, consider intraoperative ultrasound or choledochoscopy. Endoscopic retrograde cholangiopancreatography (ERCP) has additional risks. The risk of bleeding is 1.3 percent and the risk of pancreatitis is 3.5 percent. Instead of ERCP, consider using magnetic resonance cholangiopancreatography (MRCP), where no radiation is necessary. The main point is that what would be a logical test in a standard patient may not be the best choice in a pregnant patient. Look for alternative imaging modalities that have low or no radiation exposure and if an alternative is not appropriate, then use devices that limit exposure, such as proper shielding.

Key points:

- Use lead shielding and leaded drapes to reduce dose
- Use ultrasound instead of fluoroscopy where indicated
- Use MRCP instead of ERCP if possible

References

Non-contrast magnetic resonance imaging (MRI) has not been shown to have any detrimental affect on the fetus but The American College of Obstetricians and Gynecologists state that MRI should be avoided during the first trimester. One reason is that just because there are no known consequences, does not mean that there are NO consequences and thus erring on the side of caution is always advisable. (No one wants to see another Thalidamide type consequence). In addition to the unknown, what is known is that low level magnetic fields do show damage to the DNA in rat brain cells and thus detrimental affects are seen in other animals. The concern is the negative effects that can occur to the fetus due to the hyperthermia created from the MRI scan.

MRI is not replacing ultrasound because it is more expensive, complex and is dependent on an expert radiological interpretation. Remember interpretation of fetal development with ultrasound is an everyday event, not so with MRI so expert interpretation may be difficult to find. Sometimes MRI can be used in conjunction with ultrasound for further evaluation or can be used when ultrasound is inconclusive. MRI has better soft tissue contrast and there is the possibility for reconstruction from multiple planes and a larger field of view. The use of MRI for the fetus is relatively new because until
lately, MRI was too slow to capture the fetus due to fetal motion. The motion artifacts made the images non-diagnostic. Before fast MRI scans, a pregnant female would need to receive intravenous sedation to slow fetal activity which is risky to both the mother and the fetus. Now MRI images can be acquired in seconds. The advent of Rapid Acquisition with Relaxation Enhancement (RARE) has shortened T2-weighted image acquisition time. A modified RARE known as Half-Fourier Acquisition Single-shot Turbo Spin-Echo (HASTE) can produce images in one second, meaning that each slice is acquired separately in about one second. These sequences have been used to evaluate the liver, bile ducts and urinary tracts.

The genitourinary tract is THE most common intrauterine abnormality detected. Ultrasound is used for the initial evaluation but MRI can be useful to rule out associated abnormalities, as many of these defects are part of a complex. Because ultrasound works best through fluid where the sound waves can travel, diminished fluids can make ultrasound imaging less than ideal. Not a problem for MRI. MRI is excellent in cases of oligohydramnios. Oligohydramnios is important to diagnose because oligohydramnios is associated with pulmonary hypoplasia and ultimately death. In the tenth gestational week, the fetus begins to produce urine and ultimately contributes to ninety percent of the amniotic fluid. Thus, without a functioning urinary system, there is a lack of adequate amniotic fluid. Amniotic fluid provides the fetus room to move freely and is essential in the development of the later systems, namely the skeletal and respiratory. This is how a poor urinary tract is associated with the lungs, and with lung hypoplasia, the child cannot survive. Only one kidney is needed to produce adequate amniotic fluid; therefore, oligohydramnios is seen when both sides of the urinary system fail the child. In Spain, fetal MRI studies are done around week twenty two because in Spain, abortions are allowed up until week twenty two. If the fetus is severely malformed or the condition is incompatible with life, the parents can opt to terminate the pregnancy.

The ability to detect severe abnormalities with MRI is not restricted to the urinary tract. When MRI was used in conjunction with MRI in fetal brain assessment, the MRI gave additional information about the brain malformation in thirty-seven percent of cases. In thirteen percent of these cases, the MRI results changed the counseling and management of the parent, meaning the determination of pregnancy termination was based on the added information found by MRI. What MRI can do better than ultrasound is show abnormalities in the posterior fossa, corpus callosum, migration disorders, and ventriculomegaly. MRI can also show cortical development as well as ultrasound. Cortical development malformations may be difficult to determine in the typical MRI window of eighteen to twenty-five weeks of gestation because of the late normal development. Thus, MRI may need to be repeated when the fetus is some older.

Another useful component to MRI imaging of the fetal brain is its ability to turn 2-dimensional (2D) MRI images into 3-dimensional (3D) reconstructions. The 3D images show the anatomy separately or in conjunction with the other structures. It also can show shape and location of the pathological structures. Schierlitz showed that more information about the brain’s vascular anatomy could be determined with 3D versus 2D MRI or ultrasound. One example was a malformation in the vein of Galen could only be accurately identified with 3D MRI and that finding determined the planning for surgical treatment. 3D reconstruction can also be used in other surgical planning such as has been the case with
the separation of conjoined twins. Thus, this modality adds extra information while still being non-invasive. However, remember that this modality is not considered safe prior to twelve weeks gestation.

Key points:
- MRI is used in conjunction with ultrasound, not replacing ultrasound for fetal imaging
- MRI can add information about the genitourinary system and brain development
  - MRI findings can influence the counsel of parents and ultimately determine if pregnancy termination is suggested
- MRI is now fast enough that fetal motion is no longer an issue
  - Sedation drugs are no longer necessary
- 3D reconstruction MRI can add information especially about brain vasculature

**MRI indications**

An MRI can provide valuable information when fetal abnormalities found on ultrasound need further analysis or if radiological study suggests maternal abdominal disease or if the pregnancy is high risk based on clinical findings or family history. The analysis of pathology after ultrasound is most likely in central nervous system disorders or genitourinary. Late in pregnancy, the brain is difficult to visualize with ultrasound because of the advanced cranial bone ossification and because the fetal head is located deep in the mother’s bony pelvis. MRI is not limited by ossification and actually diagnostic capability of MRI improves with gestational age. For example, the cerebral ventricles are not well visualized until week twenty, thus ventricular dilatation cannot be seen until late pregnancy. With genitourinary issues, ultrasound is limited with oligohydramnios, certain fetal positions or in obese mothers. This is not the case with MRI. MRI is limited in extremity evaluation and has limited accuracy before 24 week gestation. Fetal movement makes it near impossible to obtain anatomical planes. MRI is useful in diagnosing maternal disease because MRI is excellent at evaluating the uterus and placenta. MRI can also demonstrate multiple malformations in syndrome complexes that may be incompatible with life and thus help with pregnancy decision-making.

Key points:
- MRI is useful for
  - Characterizing findings from ultrasound
  - Demonstrating maternal abdominal disease
  - Finding features of syndromes suggested by clinical findings or family history
- MRI findings can change parent counseling and pregnancy management

This course discussed the risks and benefits of multiple imaging modalities. We have looked at different forms of ionizing radiation, as well as ultrasound and MRI. What can be learned with most diagnostic imaging is that when and when not to use the modality is variable with few clear determining factors. The main decision should be based on a cost/benefit analysis which only you and your patient can determine.
References:


