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Imaging in Women's Health

Sabrina Gilbert

Murray State University

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G. Michael Barton

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Abstract

Women's health is a large area of the medical field that is continuing to see growth and technological advancement. Gynecological, obstetric, and breast health are fields that are always in demand, and imaging plays a large role in caring for patients in these fields. This paper will discuss different areas of women's health and explain how imaging can be used to assist in diagnosis and treatment. Imaging can include MRI, 2D ultrasound, 3D ultrasound, and x-ray. This paper will discuss basic gynecological health, complications that can arise in gynecological health, women's health in college, preconception care, obstetrics, obstetric complications, breast health, post menopausal health, and other women's health issues. Some topics discussed will be endometriosis, adenomyosis, breast cancer screening and treatment, endometrial cancer, pregnancy, pelvic floor health, and ovarian masses. It will also discuss the future of women's health. From basic gynecological health through pregnancy, breast health and menopause, imaging is a vital tool used to help medical professionals diagnose, monitor and treat women through many stages of life.

Keywords: women, health, imaging, breast, pregnancy

Table of Contents

Imaging in Women's Health

Women experience unique health care challenges and are more likely to be diagnosed with certain diseases. Some health issues that women contend with are reproductive health, gynecological health, sexually transmitted infections, breast health, obstetric health and cancer. Two of the most common cancers that affect women are breast and cervical cancer(Bustreo, 2015). There are a wide variety of women's health conditions that require or benefit from diagnostic imaging tools. Health imaging for women has grown in importance and helps to diagnose conditions from breast cancer to osteoporosis. In 1895, German physicist Professor Wilhem Röntgen performed the first x-ray(*Health Imaging for Women: Medical Applications, Benefits, and Careers*, 2020). Soon after this, scientist began to develop x-ray technology. Scientist began to experiment with sonar and sound which led to ultrasound. After ultrasound was developed, it began to grow in prominence during the 1960s. Dr. Raymond Damadian created the first Magnetic Resonance Imaging machine and Sir Godfrey Hounsfield creat the first Computed Tomography machine in the 1970s(*Health Imaging for Women: Medical Applications, Benefits, and Careers*, 2020). All of these technologies have developed exponentially over the years. Imaging for women began to evolve and grow, leading to improved patient care and quality of life. With mammograms, doctors began to find tumors and breast cancers at earlier stages than ever before, which resulted in lives saved. Another imaging modality that is useful in women's health is Positron Emission Mammography, which is a type of nuclear medicine scan that can detect breast cancer at early stages, and Bone Mineral Density exams are used to test for osteoporosis(*Health Imaging for Women: Medical Applications, Benefits, and Careers*, 2020).

Ultrasound or sonography is an imaging method that uses high frequency sound waves to produce images of the organs and anatomy of the body(*Ultrasound*, n.d.). Ultrasound is commonly used since it does not use radiation and can evaluate a wide variety of organs and anatomy. It can also be done portably in patient rooms, operating rooms or emergency room. There are multiple different ultrasound exams that are often used in women's health. Breast ultrasound exam are often performed if the patient feels a lump or mass in her breast or if the radiologist sees something on her mammogram that requires further imaging. Ultrasound guided breast biopsies can help by using ultrasound imaging to guide the radiologist or physician during a biopsy of a suspicious mass. Transabdominal pelvic ultrasounds and transvaginal pelvic ultrasounds are performed to evaluate the pelvic organs and obstetric ultrasounds are performed to evaluate fetuses at different stages of growth. These images can provide valuable medical information. Mammography is a low-energy X-ray method used to evaluate breast tissue for cancer or other diseases. During a mammogram, the breasts are compressed between two firm surfaces or plates to spread out the breast tissue, then X-ray images are taken(*Mammography*, n.d.). Computerized Tomography or CT is an X-ray procedure that combines many X-ray images with the aid of a computer to provide cross-sectional and three-dimensional images of the organs and anatomy of the body(*CT Scan*, n.d.). Magnetic Resonance Imaging or MRI is an imaging technique that involves a magnetic field and radio waves to create detailed images of the organs and anatomy of the body. MRI scans can provide very detailed images of organs, tissues, muscles, bones, and ligaments(*MRI*, n.d.). It provides 3D imaging and can be very helpful. A Bone Density scan or Dexa Scan is a low dose X-ray exam that can measure calcium and other minerals in your bones(*Bone Density Scan*, n.d.). X-ray uses a low does of ionizing radiation that is used to obtain medical images of the body's internal structures. X-rays are the oldest and most

frequently used form of medical imaging(*X-ray*, n.d.). All of these imaging modalities are used in women's health.

There are many benefits to this woman focused branch of radiology, these include providing immediate results and the ability to detect cancer years in advance of the disease's first signs(*What Is Women's Imaging?*, n.d.). Additional benefits are the ability to monitor the after effects of treatment and alert physicians of recurrence in recovering cancer patients. Imaging can also help evaluate patients with dense breast tissue, so small tumors are not missed(*What Is Women's Imaging?*, n.d.). Overall, medical imaging in women's health increases quality of life and the chance of survival and recovery for women everywhere.

Gynecological Health

All women go through menstruation, a monthly cycle where your body discards or sheds the monthly buildup of the uterine lining. Throughout the monthly menstrual cycle, the uterus lining builds up to prepare for pregnancy. If the woman does not get pregnant, estrogen and progesterone hormone levels begin falling(*Your Menstrual Cycle*, n.d.). Low levels of estrogen and progesterone tell your body to begin menstruation. A typical menstrual cycle is 28 days long, but each woman is different. Ovulation is when the ovary releases an egg, so it can be fertilized by a sperm. Each woman's cycle is different and the time between ovulation and the next period can range from 7 to 19 days(*Your Menstrual Cycle*, n.d.). The menstrual cycle has four phases: The menses phase- which typically lasts day 1 to 5, is when the lining of the uterus is shed, the follicular phase- typically lasts between day 6 to 14 and is the time when the estrogen level rises causing the endometrium to thicken. Hormones also cause the follicular cysts in the ovaries to grow(*Normal Menstruation*, n.d.). During days 10-14, one of these follicular ovaries will develop a mature egg. The ovulation phase occurs roughly around days 14 to 28. During the

ovulation phase, hormones caused the ovary to release an egg. The last phase is the luteal phase, this phase lasts around days 15 to 28. During this phase, the egg that was leased travels through the fallopian tubes to the uterus. If the egg becomes fertilized, the woman becomes pregnant. If the egg is not fertilized, the hormone levels drop and the menstrual cycle begins again(*Normal Menstruation*, n.d.). As a woman gets older, her menstrual cycle might become irregular, and as your body transitions toward menopause, Your menstrual period might start and stop or be shorter or last longer than usual.

Imaging, ultrasound in particular, can be very helpful in assessing the uterus and ovaries. Ultrasound can be used to evaluate the endometrial lining of the uterus or to check the ovaries for masses or cysts. If a patient presents to the Emergency Room for pelvic pain, the doctor will more than likely order a pelvic ultrasound to evaluate the ovaries for cysts or ovarian torsion. If a patient presents to the Emergency Room for heavy vaginal bleeding, the doctor will probably order a pelvic ultrasound to check the lining of the uterus.

There are many types of birth control prescribed to women and imaging can be used to evaluate and monitor the pelvic organs during birth control use. Starting a new birth control can sometimes cause the menstrual cycle to become irregular and pelvic ultrasounds can be performed to evaluate the lining of the uterus. One type of birth control, the IUD or intrauterine device, is implanted into the uterus and ultrasound is used to monitor the device and ensure it is properly placed. Occasionally, the IUD birth control device can move or migrate and cause a lot of pain and abnormal vaginal bleeding. In these cases, ultrasound is performed to evaluate the IUD placement. If the IUD has moved or is not in proper position, the doctor will remove it.

Ovarian Cysts

Ovarian cysts are fluid filled pockets in an ovary and most women have ovarian cysts at some point. Ovarian cysts are very common, and they can occur during childbearing years or after menopause. Most of these cysts cause little or no discomfort and are harmless, however some ovarian cysts can grow large and cause pain. Some large ovarian cysts can rupture and cause pelvic pain, bloating or vomiting. Transabdominal or transvaginal pelvic ultrasound can be very useful in evaluating for ovarian cysts. On ultrasound, ovarian cysts appear as black or anechoic, if the cyst has internal echoes or blood products it is considered complex or hemorrhagic.

There are different types of ovarian cysts. A functional cyst is the most common type of cyst. It usually causes no symptoms and often go away without treatment(*Ovarian Cysts*, n.d.). A Teratoma or Dermoid cyst is an interesting finding. A Teratoma contains different types of body tissues, such as skin, hair and teeth. These may be present from birth, but can grow during reproductive years. In rare cases, some teratomas can become cancerous(*Ovarian Cysts*, n.d.). Dermoid cysts are considered slow growing tumors. On ultrasound, the characteristics of a dermoid cyst is a complex or cystic adnexal mass that may contain a hyperechoic nodule, fat-fluid level, thin echogenic lines(hair), or echogenic focus with shadowing (teeth)(Deguchy et al., 2017). It has been shown that if classic features of a teratoma or dermoid are seen on sonography, there is a 100% positive predictive value in the mass being a dermoid(Deguchy et al., 2017). A Cystadenoma is a cyst that can form on the outer surface of the ovary, they can grow very large but are usually benign(*Ovarian Cysts*, n.d.). A cyst called an Endometrioma is a cyst caused by Endometriosis, which will be covered in a later section. Sometimes cyst can be hemorrhagic or blood filled. Hemorrhagic ovarian cysts often present with acute abdomen or pelvic pain and are usually unilateral. These are best evaluated using transvaginal

ultrasound(Singhal & Tiwari, 2010). Sometimes a large cyst or a hemorrhagic cyst can rupture, releasing the fluid into the pelvic cavity. When a cyst ruptures, it can cause a severe acute onset of pelvic pain(*Ovarian Cysts*, n.d.).

Polycystic Ovary Syndrome

Polycystic Ovarian Syndrome or PCOS is a hormonal condition common among women of reproductive age. Women with PCOS may have infrequent or prolonged menstrual periods or excess male hormone levels. The ovaries may develop numerous follicular cysts and fail to release eggs regularly(*Polycystic Ovarian Syndrome*, n.d.). Signs and symptoms of PCOS can include irregular periods, excess androgen, and polycystic ovaries. Complications of Polycystic Ovarian Syndrome can include infertility, gestational diabetes, pregnancy induced hypertension, miscarriage or premature birth, nonalcoholic steatohepatitis, type 2 diabetes, sleep apnea, abnormal uterine bleeding, depression or anxiety, and cancer of the uterine lining(*Polycystic Ovarian Syndrome*, n.d.). Obesity is often associated with PCOS and can add to the complications of this disorder(*Polycystic Ovarian Syndrome*, n.d.).

Polycystic ovary syndrome is a heterogenous endocrine disorder that affects about one in 15 women(Norman et al., 2007). The exact cause is unknown, but some factors that could play a role include excess insulin, low grade inflammation, heredity or excess androgen(*Polycystic Ovarian Syndrome*, n.d.). The major endocrine disruption is excessive androgen secretion or activity, and a large proportion of women also have abnormal insulin activity(Norman et al., 2007). Since PCOS can affect many body systems, it can result in several health complications. Hyperandrogenism is the most constant and prominent diagnostic component of polycystic ovary syndrome(Norman et al., 2007). Hirsutism is the most common symptom of hyperandrogenism, being present in about 60% of women with polycystic ovary syndrome,

although rarely present in asian women. Hirsutism is a condition in women that results in excessive growth of dark or coarse hair in a male-like pattern, such as the face, chest and back(*Hirsutism*, n.d.). The extra hair growth often arises from excess male hormone, primarily testosterone. Some other signs of the disease include a deepening voice, balding, acne, decreased breast size or increased muscle mass(*Hirsutism*, n.d.). Another major component of PCOS is chronic anovulation. Chronic anovulation is easier to diagnose than hyperandrogenism due to the major clinical signs, mainly, oligomenorrhea or amenorrhea(Norman et al., 2007). Oligomenorrhea is characterized by less than eight periods per year, or cycles that are longer than 35 days. Amenorrhea is the absence of menstruation for more than 3 months without pregnancy(Norman et al., 2007). Blood work to evaluate progesterone, serum prolactin and luteinising hormone should be also be done to evaluate for PCOS. Progesterone levels should be evaluated to check if ovulation has taken place(Norman et al., 2007).

High frequency transvaginal ultrasound or sonography is best to evaluate for polycystic ovary syndrome. This technique has improved resolution and measurement capabilities(Norman et al., 2007). The guidelines for features of PCOS state that in the follicular phase of menstruation, the presence of 12 of more follicles measuring 2-9 mm in diameter, or increased ovarian volume of >10 would suffice for a diagnosis of polycystic ovaries(Norman et al., 2007). The polycystic ovary is usually enlarged and contains an abnormally increased number of developing follicles(Norman et al., 2007).

Ovarian Torsion

Ovarian torsion is a rare but emergent condition in women that requires rapid evaluation and treatment in order to salvage the ovary(Evans & Fowler, 2019). Early diagnosis is necessary to preserve the function of the ovaries and tubes and to prevent severe morbidity. Ovarian torsion

refers to complete or partial rotation of the adnexal supporting organ(Huang et al., 2017). The ovary and often the fallopian tube become twisted around their vascular pedicle(Evans & Fowler, 2019). The twisting of the ovary causes obstruction of venous return which leads to vascular congestion, engorgement and edema. This vascular congestion will progress until arterial flow is compromised leading to ischemia and infarction. If left untreated, ovarian torsion can lead to complete loss of the ovary as well as ovarian necrosis and infection(Evans & Fowler, 2019).

The greatest risk for an ovarian torsion is ovarian enlargement, this is typically caused by a large mass or cyst. Torsion is more common in an ovary that is greater than 5 cm in diameter. Ovarian torsion can occur in all ages. The greatest percentage of cases occur in reproductive years, but torsion can also occur in children and post-menopausal females(Evans & Fowler, 2019). Ovarian torsion is not common with ovarian malignancy(Evans & Fowler, 2019). Patients will typically present with symptoms such as acute onset of lower abdomen pain, nausea and vomiting. Imaging studies are very important in diagnosing ovarian torsion(Huang et al., 2017).

Ultrasound is the first step in diagnostic assessment. Transvaginal ultrasound can evaluate for an ovarian mass or cyst and can also evaluate the blood flow in the ovary. If ovarian torsion is present, there will be decreased or absent doppler flow on ultrasound exam(Huang et al., 2017).Magnetic Resonance Imaging or MRI is helpful in diagnosing ovarian torsion, but is expensive. MRI can show a detailed view of the components of an ovarian mass. Definitive diagnosis of ovarian torsion can only be obtained by direct visualization, so if imaging studies show decreased or absent blood flow or a large ovarian mass, surgery will be performed to evaluate and fix the twisted ovary. The goal of surgery is to assess ovarian viability and preserve its function by returning normal blood flow to the ovary(Huang et al., 2017).

Fibroids

Muscular tumors that grow in the wall of the uterus are call Fibroids(*Uterine Fibroids*, n.d.). “Uterine fibroids, also known as leiomyomas, are the most common benign uterine tumor, with an estimated incidence of 20% to 40% in women during their reproductive years. They are monoclonal tumors of the uterine smooth muscle cells and consist of large amounts of extracellular matrix that contain collagen, fibronectin, and proteoglycan”(Khan et al., 2014, p. 95). “They rarely appear before menstruation begins and regress after menopause”(Khan et al., 2014). There can be single fibroids or numerous fibroids in the uterus. They can also vary greatly in size. Fibroids “are classified by their location relative to the layers of the uterus”(Khan et al., 2014, p. 95). “Submucosal fibroids grow into the uterine cavity, intramural fibroids grow within the wall of the uterus, and subserosal fibroids grow on the outside of the uterus. Some fibroids grow on stalks that grow out from the surface of the uterus or into the cavity of the uterus”(*Uterine Fibroids*, n.d.). “Fibroids are more common in African American women with an incidence by age 35 of 60%, increasing to >80% by age 50. Caucasian women show an incidence of 40%, increasing to almost 70% by age 50”(Khan et al., 2014, p. 96). There are certain things that make a womans chance for having fibroids higher. Early age of menstruation is associated with an increased risk of fibroids, along with other hormonally fed conditions such as endometrial and breast cancers(Khan et al., 2014). There is some evidence of a link between the amount of alcohol and caffeine intake and the risk of developing fibroids(Khan et al., 2014). “Fibroids become more common as women age, especially during the 30s and 40s through menopause. After menopause, fibroids usually begin to shrink. Family history is also a factor, having a family member with fibroids can increase your risk. If a woman’s mother had fibroids, her risk of having them is about three times higher than average”(*Uterine Fibroids*, n.d.). Obese women are at an increased danger for fibroids, the danger is two to three times higher than

normal(*Uterine Fibroids*, n.d.). “Also, eating a lot of red meat and ham is linked to a higher risk of fibroids. And eating a lot of green vegetables seems to protect women from developing fibroids”(*Uterine Fibroids*, n.d.). “We know that fibroids are under hormonal control- both estrogen and progesterone. They grow rapidly during pregnancy, when hormone levels are high, and they shrink when anti-hormone medication is used”(*Uterine Fibroids*, n.d.). Uterine fibroids are the cause for some of the most common gynecological problems among women presenting to emergency and outpatient departments(Khan et al., 2014). “Most fibroids do not cause any symptoms, but some women with fibroids can experience heavy or abnormal uterine bleeding, pelvic pressure or a feeling of fullness, bloating or enlargement of the lower abdomen, frequent urination, pain during sex, lower back pain, complications during pregnancy and labor- including a six-time greater risk of cesarean section, and reproductive problems”(*Uterine Fibroids*, n.d.). The most common of these symptoms is abnormally heavy uterine bleeding or menstruation.

Ultrasound or sonography using the transabdominal and transvaginal approach most frequently due to accessibility and relatively low cost. Ultrasound is most cost-effective, however it is very operator dependent, so MRI is considered superior(Khan et al., 2014). Ideally both transabdominal and transvaginal ultrasound exams should be performed. Transvaginal ultrasounds are most sensitive for the diagnosis of small fibroids. However, when the uterus is enlarged or retroverted, the uterus may lie outside the field of view for transvaginal ultrasound. Transabdominal ultrasound imaging can be difficult if the patient is obese(Khan et al., 2014). In the hands of a skilled ultrasonographer, fibroids as small as 5 mm can be detected transvaginally. Typically, on ultrasound, fibroids appear as well-defined solid masses that may cause the uterus to appear bulky or change the outline of the uterus(Khan et al., 2014). If the fibroid appears to be bulging into the endometrial cavity, sometimes saline infusion sonohysterography can be used to

clearly evaluate the fibroid. This technique can help to distinguish a fibroid from a polyp or a blood clot(Khan et al., 2014). In saline infusion sonohysterography, saline is pushed into the endometrial cavity at the time of the transvaginal scan. The saline pushes apart the uterine cavity to provide better visualization of any abnormality in that area(Khan et al., 2014). MRI or Magnetic resonance imaging is more costly, but is the most sensitive imaging modality for evaluating uterine fibroids and there location among the muscle layers of the uterus. The location of the fibroids is very important, especially if surgical intervention is needed(Khan et al., 2014). MRI is also useful in distinguishing between a fibroid and an ovarian mass in some cases.

Management of uterine fibroids is highly dependent on the presentation and patient wishes, since most patients are asymptotic or have mild symptoms(Khan et al., 2014). If the fibroids cause more severe symptoms, surgery may be the best option for treatment. A myomectomy is a surgery to remove the fibroids without taking out the healthy tissue of the uterus. This can be a good option for those women who still want to have children. With a myomectomy, new fibroids can grow and cause problems later(*Uterine Fibroids*, n.d.). The only way to completely cure or remove fibroids is a hysterectomy. A hysterectomy is when the entire uterus is removed. A hysterectomy is usually performed when the fibroids are large, the women is having heavy vaginal bleeding, or if the women is near or past menopause(*Uterine Fibroids*, n.d.). Myolysis is a procedure that involves a needle being inserted into the fibroids, and an electric current or freezing is used to destroy the fibroids. An endometrial ablation is when the lining of the uterus is removed or destroyed to control very heavy vaginal bleeding. This can be performed with laser, wire loops, boiling water, electric current, microwaves, freezing, or other methods. A woman cannot have children after this procedure(*Uterine Fibroids*, n.d.).

Endometriosis

Endometriosis is an often painful disorder in which tissue from the lining of the uterus, the endometrium, grows outside the uterus. This most commonly involves the ovaries, fallopian tubes, and the tissue lining your pelvis. In rare cases endometrial like tissue may be found beyond the pelvic organs. Endometrial tissue in the lining of the uterus thickens, breaks down and bleeds with each menstrual cycle. The endometriosis tissue would react the same way in the location it implanted, but because the tissue has no way to exit the body, it becomes trapped. Surrounding tissue may become irritated, developing scar tissue and adhesions. Adhesions are bands of fibrous tissue that can cause pelvic organs to stick to each other.

Symptoms of endometriosis include painful periods (dysmenorrhea), pain with intercourse, pain with bowel movements or urination, excessive menstruation or bleeding between periods, infertility, fatigue, bloating or nausea. The primary symptom of endometriosis is pelvic pain, often associated with menstrual periods.One of the possible causes of endometriosis is retrograde menstruation. In retrograde menstruation, menstrual blood containing endometrial cells flows back through the fallopian tubes and into the pelvic cavity instead of out of the body. These endometrial cells stick to the pelvic wall and pelvic organs where they continue to grow and bleed. Some risk factors that can place a woman at greater risk for developing endometriosis are never giving birth, staring menstruation at an early age, going through menopause at an older age, short menstrual cycles, higher levels of estrogen, low body mass index, relatives with endometriosis and disorders of the reproductive tract. The main complication of endometriosis is infertility. One-third to one-half of women with endometriosis have difficulty getting pregnant. Endometriosis may obstruct the fallopian tubes and keep the egg and sperm from uniting. It can also damage the eggs or sperm. Ovarian cancer also occurs at a higher rate in those with endometriosis, but it’s relatively low.

Endometriomas are cystic lesions that can arise from endometriosis. Endometriomas are filled with dark brown endometrial fluid and are often called a “chocolate cyst”(Hoyle & Puckett, 2021). They are most commonly found in the ovaries, but they can be found in other locations in the body such as abdominal surgical incision scars. The presence of endometriomas is an indication of a more severe stage of endometriosis(Hoyle & Puckett, 2021). If an endometrioma ruptures, the thick endometrial fluid collects into the pelvic cavity and can cause significant pain and inflammation. Endometriomas can cause chronic pelvic pain and infertility, and they often require surgery for treatment(Hoyle & Puckett, 2021). Endometriomas can often be seen with diagnostic imaging, however they appear similar to other cystic lesions. On transvaginal pelvic ultrasound, an endometrioma will appear cystic, loculated, or complex. Their appearance on ultrasound is consistent with a hemorrhagic cyst, with internal debris and echogenic material. Magnetic Resonance Imaging or MRI and Computed Tomography or CT can also be useful in evaluating pelvic masses such as endometriomas. Even with imaging, final pathology diagnosis can only be determined through surgery(Hoyle & Puckett, 2021).

Adenomyosis

Adenomyosis is a frequently seen benign pelvic disorder that results from an overabundant development of the endometrium at the junction of the myometrium and endometrium. Continued invasion of the endometrial cells into the myometrium can result in the hyperplasia of the smooth muscle that can make the uterus enlarged(Schneider et al., 2002, p. 71). Adenomyosis most frequently affects women ages 40-50 who have had children previously. The symptoms of adenomyosis are pelvic pain and abnormal uterine bleeding. The most common symptom of adenomyosis is abnormal or profuse uterine bleeding, with an incidence of 60%(Schneider et al., 2002, p. 71). About 25% of women with adenomyosis experience pelvic

pain during menstruation. The three most common symptoms are uterine enlargement, pelvic pain, and abnormal bleeding. Until recently, adenomyosis could only be diagnosed only after hysterectomy(Schneider et al., 2002). Diagnostic imaging is being used more commonly to diagnose this condition. “The MRI hallmark of adenomyosis is the appearance of diffuse or focal widening of the junctional zone or the appearance of an indistinctly bordered myometrial mass. MRI is currently thought by many to be the best technique for the presurgical diagnosis of adenomyosis”(Schneider et al., 2002, p. 72). Unfortunately, MRI is costly and not easily accessible, so it cannot be done routinely(Schneider et al., 2002). The enhanced resolution and technological advancements in ultrasonography have shown that ultrasound can also be useful in diagnosing adenomyosis. On ultrasound imaging, the uterus will appear enlarged, and the endometrial cavity may be displaced by thickened myometrium and may have a heterogenous appearance(Schneider et al., 2002). Other sonographic features of adenomyosis is the mall of small fluid-filled areas within the myometrium, an ill-defined myometrial/endometrial margin, and irregular areas of vascularity. The detection of adenomyosis by transvaginal ultrasound is often complicated by presence of other pathologies such as fibroids or vascular calcifications. Adenomyosis can sometimes be misdiagnosed on transvaginal ultrasound as a fibroid(Schneider et al., 2002). Transvaginal ultrasound is still considered the primary screening tool for adenomyosis due to its widespread availability and patient tolerance. The examinations are very operator dependent and require a skilled diagnostic medical sonographer to evaluate the subtle sonographic signs of adenomyosis(Schneider et al., 2002).

Ovarian Cancer

“Ovarian cancer is a growth of cells that forms in the ovaries. These cells multiply quickly and invades the healthy tissues of the ovaries”(*Ovarian Cancer*, n.d., para. 1). “Ovarian

cancer ranks fifth in cancer deaths among women, accounting for more deaths than any other cancer of the female reproductive system. A women's risk of getting ovarian cancer in her lifetime is 1 in 78"(*Key Statistics for Ovarian Cancer*, n.d., para. 2). Her lifetime chance of dying from ovarian cancer is 1 in 108. About half of women who are diagnosed with ovarian cancer are 63 years of age or older, and it is more common in white women than African American women(*Key Statistics for Ovarian Cancer*, n.d.). When ovarian cancer first develops it usually does not cause symptoms, and when symptoms do occur, they are usually attributed to more common conditions(*Ovarian Cancer*, n.d.). Some signs and symptoms of ovarian cancer include abdominal bloating or swelling, quickly feeling full when eating, weight loss, discomfort in the pelvic area, fatigue, back pain, changes in bowel habits, or a frequent need to urinate(*Ovarian Cancer*, n.d.). Ovarian cancer begins when cells in or near the ovaries begin to mutate. There are different types of ovarian cancer and these types are determined by the type of cell where the cancer begins. It is important for the doctors to know which type of cancer a patient has, so they can determine which treatments are best(*Ovarian Cancer*, n.d.). One type of ovarian cancer is Epithelial Ovarian Cancer, this type is the most common, and it includes several subtypes including serous carcinoma and mucinous carcinoma. The second type of ovarian cancer is Stromal Tumors, these are rare tumors and are usually diagnosed at an earlier stage than other ovarian cancers. The third type of ovarian cancer is Germ Cell Tumors, these are rare ovarian cancers that tend to occur at a younger age(*Ovarian Cancer*, n.d.). There is no definite cause of ovarian cancer, but there are some risk factors. Factors that can increase your risk of ovarian cancer include older age, inherited gene changes such as BRCA1 and BRCA2- these genes increase the risk for ovarian and breast cancer, family history of ovarian cancer, being overweight or obese, postmenopausal hormone replacement therapy, endometriosis, age when

menstruation begins, and never having been pregnant(*Ovarian Cancer*, n.d.). There is no definite way to prevent ovarian cancer, but there are some things that can be done to reduce the risk. Taking birth control pills reduces the risk of ovarian cancer, and discussing family history and possible genetic testing may be beneficial. Preventative hysterectomies are occasionally performed in women with an unusually high genetic risk for ovarian cancer(*Ovarian Cancer*, n.d.).

Early detection of ovarian cancer is a challenge and the poor prognosis of ovarian cancer is associated with the advanced stages at the time of diagnosis. The introduction of transvaginal ultrasound has improved visualization of normal ovaries and ovarian pathology(Twickler & Moschos, 2010). Ovarian cancer can present on transvaginal ultrasound as a large solid or complex mass, that is usually large. CA125 tumor markers are also effective and usually done in conjunction with imaging(Twickler & Moschos, 2010).

Endometrial or Uterine Cancer

Endometrial cancer begins in the layer of cells that form the lining of the uterus. Endometrial cancer is often detected at an early stage because it frequently causes abnormal vaginal bleeding(*Endometrial Cancer*, n.d.). If discovered early, removing the uterus surgically often cures the endometrial cancer(*Endometrial Cancer*, n.d.). More than 90% of uterine cancers occur in the endometrium. The number of people diagnosed with endometrial cancer is increasing, mostly because of an increase in obesity(*Uterine Cancer: Statistics*, n.d.). There is no known cause of endometrial cancer, but there are factors that can increase the risk. Risk factors include changes in the hormone levels, more years of menstruation, never having been pregnant, older age, obesity, hormone therapy for breast cancer, and lynch syndrome- an inherited colon cancer syndrome(*Endometrial Cancer*, n.d.). Some signs and symptoms of endometrial cancer

are vaginal bleeding after menopause, bleeding between periods, and pelvic pain. Some ways a patient can reduce their risk of endometrial cancer are taking birth control pills- which controls hormone levels, maintaining a healthy weight, and discussing hormone therapy options with a doctor(*Endometrial Cancer*, n.d.). Transvaginal ultrasound imaging is the best modality for evaluating the endometrial lining of the uterus. Ultrasound characteristics of endometrial cancer, include a thickened endometrial lining that can appear heterogenous and have cystic areas or fluid pockets within it(Epstein et al., 2017). It will also usually have an irregular endometrial/myometrial margin. A well-defined tumor or mass is sometimes seen, but not always identified(Epstein et al., 2017). To definitively diagnose endometrial cancer, a hysteroscopy can be performed where a doctor can closely view the endometrial lining, and an endometrial biopsy will be performed to obtain a tissue sample for testing(Epstein et al., 2017). If enough endometrial tissue is not obtained during the biopsy, the physician may do an D & C procedure or Dilation and Curettage in surgery. During this procedure, the lining of the uterus is scraped and tissue obtained, so they can test the microscopic cells for cancer(Epstein et al., 2017). There stages of endometrial cancer range from I-IV, the lowest range indicating that the cancer hasn't grown beyond the uterus, By stage IV, the cancer has grown to involve nearby organs, such as the bladder or has spread to distant areas of the body(Epstein et al., 2017). Treatment for endometrial cancer is usually surgery to remove the uterus or a hysterectomy. Radiation and chemotherapy may also be treatments that are used to target and treat endometrial cancer. Radiation therapy uses powerful energy beams to kill cancer cells. Chemotherapy uses chemicals and medications to kill the cancer cells. These drugs enter your bloodstream and travel through the body, killing the cancer cells(Epstein et al., 2017).

Pelvic Inflammatory Disease

"Pelvic Inflammatory Disease or PID is an infection of the upper genital tract in women that can include endometritis, parametritis, salpingitis, oophoritis, tubo-ovarian abscess, and peritonitis"(Crossman, 2006, p. 1). With around 1 million women treated every year, PID is a prevalent medical problem in women of reproductive age(Revzin et al., 2016, p. 1579). "Pelvic inflammatory disease is a Polymicrobial infection that originates from upward spread of infecting organisms through the cervix and into the uterus, fallopian tubes, or peritoneal cavity"(Crossman, 2006, p. 2). The origin of PID is commonly associated with sexually transmitted infections such as gonorrhea, chlamydia and bacterial vaginosis(Revzin et al., 2016, p. 1580).

> According to Revzin (2016), Patients with pelvic inflammatory disease frequently experience vaginal odor, fever, vaginal itching and discharge, vomiting and pelvic pain. These symptoms can often be mild and non-specific, which can make it difficult for physicians to correctly diagnose pelvic inflammatory disease without imaging guidance. Obtaining a thorough history from the patient and transvaginal ultrasound can often be diagnostically helpful. Since symptoms are often vague, catscan is often the modality done initially. The most common finding on catscan imaging is "described as thickening of the uterosacral ligaments, obliteration of fascial planes, free fluid in the cul-de-sac, loss of definition of the uterine border, pelvic fat infiltration or haziness and pelvic edema, reactive lymphadenopathy, and signs of peritonitis. Pelvic fat haziness refers to increased attenuation of the pelvic fat when compared with retroperitoneal fat. Pelvic fat haziness is one of the most sensitive findings of acute PID and is seen in as many as 65% of patients". "Salpingitis should be suspected at CT when the fallopian tubes are thickened, measuring more than 5mm and showing enhancing walls. Associated free

fluid may be seen in the cul-de-sac. Salpingitis is defined as inflammation of one or both of the fallopian tubes, and it is the most common early acute form of PID. Salpingitis is associated with the highest risk of infertility and accounts for most of the ectopic pregnancies related to PID. The fallopian tubes become edematous and congested". The tubal lumen can fill with pus, which subsequently spills into the peritoneal cavity and coats the surface of the uterus and ovaries. "The tubal fimbriae may adhere to the ovary, resulting in salpingo-oophoritis or tubo-ovarian complex. In tubo-ovarian complex, although the tubes and ovaries partially adhere to one another, they will largely remain separate. Pyosalpinx is an infection of the fallopian tube that is complicated by tubal obstruction. The obstruction results in accumulation of trapped infected fluid or pus, with resulting tubal distention". This finding is usually well seen on ultrasound, with thickening of the tubal wall and debris within the tube. "Hydrosalpinx occurs when the fallopian tube fills with serous fluid as a result of a distal blockage. The most common cause of hydrosalpinx is previous episodes of PID". Ultrasound imaging will show a dilated fallopian tube containing simple appearing fluid. "Tubo-ovarian abscess is one of the major and serious late complications of acute salpingitis and occurs in as many as 15% of women with PID. The Tubo-ovarian abscess represents further progression of infection and inflammation, which results in the formation of a complex cystic and solid mass with complete destruction of the normal adnexal architecture. The ovary and fallopian tube can no longer be identified". At this point of the infection, clinical symptoms will include "pelvic pain, fever, leukocytosis, and an adnexal mass. Patients may also have vomiting" and vaginal discharge. The most common finding on imaging is a complex loculated mass with a thick wall. There is commonly free fluid in the pelvis

also. “Tubo-ovarian abscess can be complicated by rupture, which may result in life-threatening peritonitis and acute respiratory distress syndrome”. PID can also cause permanent damage to the fallopian tubes, leading to increased risk for ectopic pregnancies and infertility. Risk factors for PID include the presence of sexually transmitted infection, a previous episode of PID, sexual intercourse at an early age, a high number of sexual partners, and alcohol use. CT is often the first imaging modality used to evaluate a patient with presenting symptoms with ultrasound imaging performed soon after. Finding and treating PID early can lower the chance of complications and long-lasting effects. Most cases of PID can be treated with a strong course of antibiotics, with the most severe and late stage cases requiring surgical intervention(Revzin et al., 2016, pp. 1579–1595).

Preconception Care

Infertility is diagnosed after a woman is not able to become pregnant after one year of trying or six months if a woman is 35 or older. Women who can get pregnant but are unable to stay pregnant may also be infertile(*Infertility*, n.d.). While infertility is not only a problem for women, this paper will only discuss affect infertility has on women’s health. About 10 percent of women in the United States have difficulty getting pregnant or staying pregnant(*Infertility*, n.d.). Most cases of female infertility are caused by problems with ovulation. Without ovulation, there are no eggs to be fertilized(*Infertility*, n.d.). Ovulation problems are often caused by PCOS or polycystic ovarian syndrome. As discussed earlier, PCOS is a hormone imbalance problem that can interfere with normal ovulation. PCOS is the most common cause of female infertility(*Infertility*, n.d.). Primary ovarian insufficiency (POI) is another cause of ovulation problems. POI occurs when the ovaries stop working, normally before she is 40. Less common

causes of fertility problems in women are blocked fallopian tube due to pelvic inflammatory disease, endometriosis, or surgery for an ectopic pregnancy, physical problems with the uterus, or uterine fibroids(*Infertility*, n.d.).

There are multiple imaging procedures that can be performed to evaluate a woman when she is having difficulty conceiving. Hysterosalpingography is an x-ray procedure used to view the inside of the fallopian tubes and uterus. It is often used to see if the fallopian tubes are partly or fully blocked(*Hysterosalpingography*, n.d.). It can also show if the inside of the uterus is of normal shape and size. During this procedure, a contrast or dye is injected into the uterus and fallopian tubes. Then x-ray images are taken to show how the dye moves through the body structures(*Hysterosalpingography*, n.d.). A hysteroscopy is another procedure that can be performed to evaluate the uterus. In a hysteroscopy, a slender light -transmitting device is inserted into the uterus through the cervix to view the inside of the uterus. This can evaluate the uterus, but it does not evaluate the fallopian tubes(*Hysterosalpingography*, n.d.). Sonohysterography is a procedure in which sterile fluid is injected into the uterus through the cervix while ultrasound images are taken of the inside of the uterus(*Hysterosalpingography*, n.d.). This can show the inside of the endometrial canal and evaluate for polyps or masses possibly preventing implantation. This evaluates the uterus but not the fallopian tubes(*Hysterosalpingography*, n.d.).

To evaluate egg supply and ovulation, doctors will order transvaginal ultrasounds to evaluate the follicles of the ovaries. Antral follicle counts are one of the best ways to evaluate ovarian reserve, the expected response to ovarian stimulating drugs, and the chance for successful pregnancy with IVF(*Antral Follicle Counts, Resting Follicles and Ovarian Reserve*, n.d.). Antral follicles are small follicles that are about 2-9 mm in diameter that we can see,

measure and count with ultrasound. Transvaginal ultrasound is the best technique to evaluate the antral follicles of the ovary(*Antral Follicle Counts, Resting Follicles and Ovarian Reserve*, n.d.). The number of follicles seen on the ultrasound is indicative of the microscopic primordial follicles remaining in the ovary. Each primordial follicle contains an immature egg that can potentially develop and ovulate. The follicle counts are a good predictor of the number of mature follicles that could be stimulated if medication is given(*Antral Follicle Counts, Resting Follicles and Ovarian Reserve*, n.d.).

Assisted Reproductive Technology

Assisted Reproductive Technology (ART) refers to treatments and procedures that aim to achieve pregnancy. There are different types of ART including ovulation induction, Intrauterine insemination, and In Vitro Fertilization(*Assisted Reproductive Technology (ART)*, n.d.).

Ovulation induction is the process of using medications to stimulate ovulation in women who have irregular or absent ovulation(*Ovulation Induction*, n.d.). Normal ovulation occurs when the ovary releases a mature egg in preparation for that egg to be fertilized. Normal ovulation occurs roughly every 28 days during a women's menstrual cycle. Intervals of 21 to 35 days are considered acceptable as normal ovulation(*Ovulation Induction*, n.d.). The goal of ovulation induction is to increase a woman’s chance of conceiving a child. Ovulation induction uses a variety of hormone-based medications to regulate a women’s reproductive hormones and increase ovulation(*Ovulation Induction*, n.d.). Some common ovulation inducing medications include Clomid, Femara and Metformin. Ovulation induction is usually one of the first treatments used for infertility due to its low cost and non-invasive technique(*Ovulation Induction*, n.d.). Transvaginal pelvic ultrasounds are usually performed periodically throughout the time a woman is receiving ovulation induction medication. The transvaginal ultrasound

monitoring is to evaluate ovarian follicle and to watch for signs of ovarian overstimulation(Magarelli, 2021). By monitoring follicular development and egg growth along with blood work, physicians are able to identify a window of time in which the woman is ovulating and would have the greatest chance of conception from intercourse(Magarelli, 2021).

Intrauterine insemination (IUI) is a procedure that places sperm past the cervix and in a woman's uterus around the time of ovulation(*Intrauterine Insemination*, n.d.). This makes the passage to the fallopian tubes much shorter, increasing the chance for the sperm to reach an egg. When a woman conceives naturally, the sperm travel from the vagina through cervix into the uterus, and into one of the fallopian tubes(*Intrauterine Insemination*, n.d.). The cervix is a narrow part of the uterus, that naturally limits the number of sperm that make it through to the uterus(*Intrauterine Insemination*, n.d.). There are several instances where IUI would be beneficial. IUI is helpful when a women's cervix has scarring that could prevent the sperm from entering the uterus or when the cervix is shaped abnormally(*Intrauterine Insemination*, n.d.). IUI can also be used when there are problems with sperm delivery, if the male partner is not able to stay erect or is unable to ejaculate effectively. For example, retrograde ejaculation is when the sperm is released backwards into the bladder instead of through the penis. Fertility preservation is also an example of how IUI can be useful, if sperm has been collected and stored for future use(*Intrauterine Insemination*, n.d.). Once the semen sample is collected, it is "washed" in the lab to concentrate the sperm and remove the seminal fluid, this process can take up to 2 hours to complete(*Intrauterine Insemination*, n.d.). IUI is always performed around the time of ovulation, a doctor insert a catheter through the cervix into the uterus and the washed semen sample is slowly injected(*Intrauterine Insemination*, n.d.).

In vitro fertilization (IVF) is another method of assisted reproduction. In this method, a man's sperm is combined with a woman's eggs outside the body in a laboratory dish(*In Vitro Fertilization (IVF): What Are the Risks?*, n.d.). One or more of the fertilized eggs or embryos will be transferred into the woman's uterus, where they may implant in the uterine lining. Usually injectable fertility medications are used for an IVF cycle(*In Vitro Fertilization (IVF): What Are the Risks?*, n.d.). These medications help to stimulate more follicles with eggs to grow in the ovaries.The possible side effects of the injectable fertility medicines include mild bruising and soreness at injection site, nausea and/or vomiting, breast tenderness, vaginal discharge, mood swings, fatigue and ovarian hyperstimulation syndrome(*In Vitro Fertilization (IVF): What Are the Risks?*, n.d.). During the egg retrieval process, vaginal ultrasound is used to guide the insertion of a long thin needle through your vagina, into the ovary and then into each follicle to retrieve eggs(*In Vitro Fertilization (IVF): What Are the Risks?*, n.d.). The egg retrieval process can cause some mild to moderate pelvic pain. Once the eggs and sperm are combined, the doctor gently places a catheter containing the embryos into the uterus to transfer them to the uterine lining(*In Vitro Fertilization (IVF): What Are the Risks?*, n.d.).

Complications with Assisted Reproductive Technology

With increased popularity of assisted reproductive technology, associated complication are being seen more often with imaging modalities. These complications include ovarian hyperstimulation syndrome, ovarian torsion, and ectopic and heterotopic pregnancy(Baron et al., 2013).

Ovarian hyperstimulation syndrome (OHSS) is an excessive response to the fertility medications given to increase egg production(*Ovarian Hyperstimulation Syndrome (OHSS)*, n.d.). Women with OHSS have numerous growing follicles along with high estradiol levels. This

leads to fluid leaking into the abdomen, which can cause bloating, nausea, and swelling of the abdomen(*Ovarian Hyperstimulation Syndrome (OHSS)*, n.d.). OHSS can be classified as mild, moderate or severe and can even be life-threatening. Severe cases of OHSS can cause vomiting and the inability to keep down liquids, significant discomfort from swelling of the abdomen, shortness of breath, and blood clots in the legs(*Ovarian Hyperstimulation Syndrome (OHSS)*, n.d.). In all cases of OHSS the ovaries will be enlarged, often greater than 12 cm. It occurs during the luteal phase of the menstrual cycle or in early pregnancy(Baron et al., 2013). OHSS manifests with a combination of ovarian enlargement by multiple follicular cysts and acute fluid shift out of the intravascular space, resulting in ascites and hemoconcentration(Baron et al., 2013). Pleural effusions or fluid in the lining of the lungs can also develop, compromising lung function and resulting in adult respiratory distress syndrome(Baron et al., 2013). The hallmark imaging findings on ultrasound, cat scan, and MRI imaging are bilaterally symmetrically enlarged ovaries containing multiple variable-sized cystic lesions representing enlarged follicles or corpus luteum cysts, in the presence of ascites or fluid in the abdomen or pelvic cavity(Baron et al., 2013).

The enlarged hyper-stimulated ovaries are at risk for torsion, which is reported to occur 11 times more frequently in ART patients than in non-ART patients(Baron et al., 2013). The large cysts serve as a lead point for the ovary to twist on it's vascular pedicle, possibly facilitated by pelvic ascites(Baron et al., 2013). As discussed earlier in this paper, ovarian torsion is the twisting of ovary resulting in loss of blood supply to the ovary. This can lead to loss of the ovary or infection, which when left untreated, could lead to peritonitis or even death(Baron et al., 2013).

Ectopic pregnancy occurs when a fertilized egg grows outside the uterus. More than 90% of ectopic pregnancies occur in the fallopian tube(Mummert & Gnugnoli, 2021). There is an increased risk of ectopic pregnancy following ART(Baron et al., 2013). Some things could put a woman at increased danger for an ectopic, including being an older mother, lifestyle choices such as smoking, history of IUD use, or having had an ectopic previously(Mummert & Gnugnoli, 2021, p. 2). “Women interested in utilizing IVF have a higher chance of getting a pregnancy outside the uterus with an existing pregnancy in the uterus.The chance is considered as elevated as 1:100 women seeking IVF. Ectopic pregnancies carry high rates of morbidity and mortality if not recognized and treated promptly”(Mummert & Gnugnoli, 2021, p. 2). An ectopic can implant at multiple sites including the “cervix, uterine cornua, myometrium, ovaries and abdominal cavity”(Mummert & Gnugnoli, 2021, p. 2). Women who have an ectopic often report having low abdomen pain, but not all women experience this with an ectopic pregnancy. Patients presenting with symptoms such as abdomen or pelvic pain, nausea/vomiting, dizziness, and vaginal bleeding should be evaluated for ectopic pregnancy(Mummert & Gnugnoli, 2021, p. 3). Providers should establish the patient's last menstrual period was and if they have regular monthly periods. If they have missed their last period or have abnormal uterine bleeding and are sexually active need to be given a pregnancy test. Providers should ask if the patient has a history of ectopic pregnancy, tubal disease, pelvic inflammatory disease, or are undergoing infertility treatment(Mummert & Gnugnoli, 2021)The best way to evaluate for an ectopic pregnancy is by using transvaginal ultrasound, repeating TV ultrasounds and blood levels can help the physician evaluate for ectopic(Mummert & Gnugnoli, 2021, p. 3). The absence of an intrauterine pregnancy with rising hCG levels is indicative of an ectopic pregnancy.The only way to definitively diagnose an ectopic pregnancy is to visualize a fetus with a heartbeat outside the

uterus, but not all ectopic pregnancies will show this(Mummert & Gnugnoli, 2021, p. 3).If unable to identify a fetus with a heartbeat, a gestational sac or a complex mass may be seen in the adnexa. If unable to identify an ectopic or suspicious mass with a rising serum hCG level, direct visualization can be done with laparoscopic surgery"(Mummert & Gnugnoli, 2021, pp. 3–4). Depending on the patients clinical symptoms, methotrexate injection or surgery to remove the ectopic are effective treatment methods. "Women with a relatively low hCG level would benefit from a single dose methotrexate protocol. Patients with a high hCG level may necessitate two-dose methotrexate regimen"(Mummert & Gnugnoli, 2021, p. 4). Surgical intervention is necessary when the patient demonstrates bleeding into the pelvic cavity, signs of a continuing ruptured ectopic mass, or instable blood pressure(Mummert & Gnugnoli, 2021, p. 4). Surgical management could include salpingostomy and salpingectomy, and could affect the women's future fertility. ART patients are at increased risk for rarer and more lethal forms of ectopic pregnancy, including interstitial and cervical ectopic pregnancy(Baron et al., 2013). Interstitial pregnancies occur when an embryo implants in the intramyometrial portion of the fallopian tube. These ectopic pregnancies tend to manifest later, and rupture may result in catastrophic hemorrhage, due to proximity of the uterine artery(Baron et al., 2013). At ultrasound, an eccentrically located gestational sac surrounded by a thin layer of myometrium measuring less than 5mm may be seen(Baron et al., 2013). Cervical ectopic pregnancy is 10 times more common than spontaneous conception in ART patients and results from embryo implantation in the endocervical canal(Baron et al., 2013). Imaging findings include an hourglass or figure eight-shaped uterus secondary to cervical expansion, as well as a gestational sac in the region of the cervix with or without cardiac activity below the internal os(Baron et al., 2013).

Obstetrics

The gestation period in women consists of a first, second and third trimester, lasting 40 weeks. Each trimester is marked by specific fetal developments. The history of ultrasound in obstetrics dates back from 1958. Advancements in ultrasound technology such as real-time imaging and transvaginal ultrasound has enhanced the examination and treatment of patients during pregnancy(Jabaz & Abed, 2021, p. 1).

First Trimester

The first trimester is considered as the first 12 – 13 weeks of pregnancy(Murugan et al., 2020, p. 1). The first trimester is the most crucial to fetal development. During this time, the fetal structures and organ systems develop. In the early weeks of pregnancy, transvaginal ultrasound is the optimal imaging tool. Ultrasound is considered advantageous due to its low cost, easy availability, and real time imaging(Murugan et al., 2020, p. 1). The original diagnosis of pregnancy is established by testing for beta hCG levels. Ultrasound is subsequently used to evaluate fetal age and anatomy(Murugan et al., 2020, p. 1). First trimester ultrasounds are used to show if a gestational sac can be visualized within the uterus and to determine viability(Murugan et al., 2020, p. 1).

First Trimester Ultrasound Findings

The last menstrual period is used to determine how far along the pregnancy is. About halfway through the menstrual cycle, ovulation is expected to occur. This is the time that the women is most fertile.The gestational sac is able to be visualized on transvaginal ultrasound at around 4.5-5 weeks of pregnancy, this will appear as a circular black or anechoic area located in the echogenic decidua. The double decidual sac sign is the two side-by-side bright rings surrounding the gestational sac. The outside circle or ring is the decidua parietalis, while the inside circle or ring the decidua capsularis and chorion. The

> double decidual sign is a definitive sign of pregnancy. The gestational sac is measured in three dimensions and is used to help determine gestational age. The yolk sac is not seen on transvaginal ultrasound until around 5.5 weeks. The yolk sac first looks like as two bright lines at the outer edge of the gestational sac, by the end of the 5.5 weeks the yolk sac will later develop its classic circular look. First appearing as a characterless echogenic or bright oblong area, the baby or the fetal pole is visualized at 6 weeks of pregnancy. The CRL or crown-lump length is the most exact measurement of fetal dating in the first trimester, this is the measurement from crown to rump. The lack of an embryo visible on transvaginal ultrasound once the gestational sac extends to a minimum of 25 mm is considered pregnancy failure. The fetal pole starts to develop characteristics as the first trimester develops. The spine becomes visible at 7-8 weeks and the hindbrain is visible at 8-10 weeks. The amniotic membrane can be seen at about 7 weeks. After 14-16 weeks, the amnion and chorion will mesh and combine. A heart rate or cardiac motion can be visualized as soon as 6 weeks of pregnancy, at this time the baby is only about 1-2 mm in size. Pregnancy failure is diagnosed if heart motion cannot be detected after the baby reaches 7mm. The heart rate will steadily rise with fetal age from about 110 beats per minute (bpm) at 6.2 weeks to about 159 bpm at 7.6-8 weeks. A slow heart rate correlates to an increased risk for pregnancy failure(Murugan et al., 2020, pp. 179–182).

First trimester ultrasound is often done on women with pain or bleeding. Transvaginal is used in the emergency room setting to evaluate for a pregnancy in the uterus, to evaluate the health of the pregnancy, to evaluate for a possible miscarriage and to find an explanation of why a pregnancy in the uterus is not identified(Murugan et al., 2020).

Complications in the First Trimester

“A common complication in the first trimester of pregnancy is vaginal bleeding, with an incidence of 16 to 52%”(Bondick et al., 2021, p. 1). “Subchorionic hemorrhage or subchorionic hematoma are the most common cause of vaginal bleeding in the first trimester. Subchorionic hemorrhage is bleeding beneath the chorion membranes that enclose the embryo in the uterus”(Bondick et al., 2021, p. 1). It seems to occur due to partial detachment of the chorion membranes from the wall of the uterus(Bondick et al., 2021). “On transvaginal ultrasound, subchorionic hemorrhage or SCH appears as a crescent-shaped, heterogenous avascular collection between the gestational sac and decidua basalis. Larger subchorionic hemorrhages are associated with an increased risk of pregnancy loss, especially if the hemorrhage is greater than two-thirds of the chorionic circumference”(Murugan et al., 2020, p. 185). “Patients can be asymptomatic or experience vaginal bleeding. Abdomen pain is usually absent, however, a minority of patients can experience cramping or contractions”(Bondick et al., 2021, p. 2).

Another complication in the first trimester is spontaneous abortion or miscarriage. Spontaneous abortion is clinically defined as the loss of pregnancy before the 20th week. There are various stages of spontaneous abortion. A threatened abortion refers to a clinical scenario in which a patient presents with vaginal bleeding or spotting and cramping/contractions with a closed cervical os. The pregnancy itself may appear normal or may demonstrate abnormal features. Poor prognostic indicators include abnormal morphology such as a small or irregular gestational sac, fetal bradycardia, or a large subchorionic hemorrhage. An inevitable abortion refers to a similar clinical situation with vaginal bleeding and abdominal cramping, but with an open cervical os on transvaginal ultrasound. The products of conception may be normally or abnormally positioned with the uterus or may protrude into the cervix. An incomplete abortion is the term used when

the retained products of conception remain in the uterus after the passage of the pregnancy. This can appear on ultrasound imaging as a heterogenous collection or mass within the uterus. This can be avascular or have blood flow. The presence of blood flow enables the diagnosis of retained products. A complete abortion is the cessation of vaginal bleeding following the passage of the pregnancy without retained products of conception. A missed abortion is a nonviable pregnancy with a closed cervix and no clinical symptoms of miscarriage(Murugan et al., 2020, pp. 185–187).

Another first trimester complication is gestational trophoblastic disease. Gestational trophoblastic disease is a broad term which encompasses both benign entities, such as partial and complete mole, gestational trophoblastic neoplasia (GTN), and malignant diagnoses, such as invasive mole, choriocarcinoma, and epithelioid and placental site trophoblastic tumors. Patients will often present with vaginal bleeding. On transvaginal ultrasound in the first trimester, the endometrial cavity will contain an echogenic solid mass, usually with numerous cystic spaces, which are hydropic villi and trophoblastic hyperplasia. It is important to carefully scrutinize the mass to determine if it is a complete mole (no fetal parts), partial mole (some fetal parts), and GTN (myometrial invasion)(Murugan et al., 2020, p. 188).

Second Trimester Imaging

The second trimester of pregnancy is during the 14th -26th weeks of pregnancy. Between the 18th and 22nd week of pregnancy, an anatomy screening ultrasound is performed(Jabaz & Abed, 2021). The second trimester ultrasound is a common scan that is used to evaluate fetal anatomy and determine if there are any fetal abnormalities. Ultrasound is commonly performed in pregnancy to evaluate the baby’s size and organs(Jabaz & Abed, 2021, p. 1). Ultrasound is

used to evaluate the number of fetuses, age and weight, fetal health, placenta, amniotic fluid, and maternal and fetal organs(Jabaz & Abed, 2021, p. 1). The determination of a fetal abnormality greatly lower fetal and maternal complication. Ultrasound can now correctly determine more than 200 anomalies(Jabaz & Abed, 2021, pp. 1–2). Measurements of the fetus are obtained to establish an estimated gestational age and weight. The fetal head is measured in two different ways, the circumference or HC and the biparietal diameter or BPD, these measurements are taken at the level of the thalamus, a small butterfly shaped structure(Jabaz & Abed, 2021, p. 3). Another measurement obtained is the abdominal circumference (AC), which is taken around the fetal abdomen at the level of the stomach(Jabaz & Abed, 2021). This is measuring around baby's belly like for a belt. The last measurement that is taken is the femur length (FL). The FL is taken along the longest angle of the femur bone(Jabaz & Abed, 2021).

The structures of the fetal head are evaluated, included the skull and brain. A normal fetal skull will have a nice oval shape with no protuberances(Jabaz & Abed, 2021, p. 4). Any different shapes of the skull, including cloverleaf, lemon or strawberry shapes, should be evaluated and noted. The fetal brain should be thoroughly examined(Jabaz & Abed, 2021, p. 4). “In the transventricular plane, the lateral ventricles, cavum septum pellucidi are visualized. In a normal fetus, each lateral ventricle measures up to 10 mm. The cavum septum pellucidi should always be visualized between 18 and 37 weeks”(Jabaz & Abed, 2021, p. 4). Many brain abnormalities will display an abnormal CSP, including hydrocephaly, holoprosencephaly, and agenesis of the corpus collosum(Jabaz & Abed, 2021, p. 4). “The trans-cerebellar plane shows the thalami, cavum septum pellucidi, cisterna magna, nuchal fold and the cerebellum. The cerebellum is a dumbbell shaped structure with symmetrical lobes”(Jabaz & Abed, 2021, p. 4). The trans-cerebellar measurement “in millimeters correlates with the gestational age up to 20 weeks. A

cerebellum measuring less than gestational age is a concerning finding"(Jabaz & Abed, 2021, p. 4). "The cisterna magna is measured from the posterior margin of the cerebellar vermis to the inside of the occipital bone in the midline. A measurement of 2-10 mm is normal in the second and third trimesters"(Jabaz & Abed, 2021, p. 4). "The nuchal fold is a measurement taken from the outer skin line to the outer bone in the midline. Less than 6 mm is considered normal up to 22 weeks. The trans-thalamic plane shows anatomic landmarks including frontal horns of the lateral ventricles, the cavum septi pellucidi, the thalami, and the hippocampal gyruses"(Jabaz & Abed, 2021, p. 4).

Examples of fetal head abnormalities include a thickened nuchal fold, which is considered with a "thickness of greater than 6 mm and is seen with 80% of newborns with down syndrome"(Jabaz & Abed, 2021, p. 5). Another example is a cystic hygroma, which is "a localized, single or loculated fluid-filled cavity that usually occurs in the neck. This is seen in fetuses with nonimmune fetal hydrops, Turner syndrome, and trisomy syndromes 13, 18, and 21"(Jabaz & Abed, 2021, p. 5). If a cystic hygroma is seen, an amniocentesis should be done. "Meningoceles are seen as fluid-filled cystic structures and Encephaloceles are brain-filled cystic structures that extend through a bony calvarial defect, usually in the occipital or frontal region"(Jabaz & Abed, 2021, p. 5). Meningoceles are commonly mistaken for a cystic hygroma, but thorough evaluation will demonstrate no upper skull abnormality if it is a cystic hygroma(Jabaz & Abed, 2021). Associated abnormalities "include Arnold-Chiari malformation, Dandy-Walker syndrome, and Meckel -Gruber syndrome"(Jabaz & Abed, 2021, p. 5).

The face and neck are also evaluated. It is better to find any facial abnormalities early, so to evaluate for other associated disorders. Diagnosing these early can help with better care and

parental preparation(Jabaz & Abed, 2021, p. 5). The fetal nose/lips, facial profile and the cervical spine are evaluated thoroughly(Jabaz & Abed, 2021, p. 5).

Examples of face and neck abnormalities include nasal bone absence/hypoplasia which is associated with Trisomy 21(Jabaz & Abed, 2021). Hypertelorism and hypotelorism is another abnormality, which is the interocular distance (IOD). “Hypertelorism is associated with frontal Encephaloceles, craniosynostoses, exposure to phenytoin, and cleft lip and palate”(Jabaz & Abed, 2021, p. 5). Hypotelorism is normally linked with holoprosencephaly and more brain malformations. The most common facial deformities are cleft palate and cleft lip(Jabaz & Abed, 2021, p. 5). “Neck masses include teratoma, lymphangioma, enlarged thyroid, branchial cleft cyst, and rarely a sarcoma”(Jabaz & Abed, 2021, p. 5).

Also evaluated are the thorax, ribs, echotexture of lungs, and the diaphragm(Jabaz & Abed, 2021, p. 5).

The heart is always thoroughly evaluated. A proper 4-chamber heart view is demonstrated, the right and left outflow tracts are demonstrated, and a heart rate is obtained(Jabaz & Abed, 2021). Two atria and two ventricles are demonstrated. The location and axis of the heart is examined, it should be in the left chest of the fetus and at 45 degrees to the left side of the chest(Jabaz & Abed, 2021). “Abnormalities like mediastinal shift, lung masses, pleural effusions, diaphragmatic hernia, tachycardia, dextrocardia, cardiomegaly, pericardial effusion, ventricular septic defect, and abnormal chamber size can be detected”(Jabaz & Abed, 2021, pp. 5–6). Ventricular septic defect is the most common congential heart disease, seen in 1.5-3.5 per 1000 births. VSD is best visualized in the 4-chamber view of the heart(Jabaz & Abed, 2021). Atrial septal defect is the fifth most common congential heart disease and is characterized by a defect in the atrial septum(Jabaz & Abed, 2021).

The fetal abdomen is also thoroughly evaluated. The stomach of the fetus should be visualized on the left of the abdomen(Jabaz & Abed, 2021, p. 6). The kidneys should be evaluated and should be seen on each side of the spine below the level of the stomach. The cord insertion should also be thoroughly examined for any defects in the abdominal wall(Jabaz & Abed, 2021, p. 6). The fetal bladder will appear hypoechoic and be positioned in the fetal pelvis(Jabaz & Abed, 2021).

Abnormalities in the abdomen include ventral wall defects. Fetal gut herniation is a normal part of intrauterine development, this begins at 6-8 weeks gestation and completes 10-12 weeks(*Omphalocele Vs. Gastroschisis*, n.d.). The gut elongates and grows at a rate that surpasses the growth rate of the abdomen, leading to gut herniation into the base of the umbilical cord. The bowel then rotates 90 degrees counter-clockwise around a superior mesentery artery axis, establishing the anatomical position of the large intestine within the abdominal cavity(*Omphalocele Vs. Gastroschisis*, n.d.). By the eleventh week of gestation, the intestines normally go back into the abdomen(*Facts About Omphalocele*, n.d.). If they do not go back into the abdomen then ventral wall defects occur. An omphalocele is a birth defect of the abdominal wall(*Facts About Omphalocele*, n.d.). The infant's intestines, liver or other organs stick outside the belly through the belly button. The organs are covered in a thin, nearly transparent sac(*Facts About Omphalocele*, n.d.). Another ventral wall defect is gastroschisis. Gastroschisis is when the fetal intestines are outside the baby's body, but not covered in the thin membrane(*Facts About Gastroschisis*, n.d.). Gastroschisis occurs when the muscles of the abdominal wall do not form correctly(*Facts About Gastroschisis*, n.d.). Both of the abdominal wall defects need to be corrected with surgery after birth. Other abnormalities in the abdominal cavity include kidney

disorders such as hydronephrosis, dysplastic kidneys and infantile polycystic kidney disease(Jabaz & Abed, 2021).

The fetal spine should be evaluated well in multiple planes. A longitudinal view of the spine should always be demonstrated because it best shows spinal malformations. This can sometimes be difficult, depending on fetal positions(Jabaz & Abed, 2021).

The fetal extremities should also be demonstrated well. Thanophoric dysplasia, achondroplasia, and osteogenesis imperfecta are examples of skeletal disorders of the extremities. The fetal legs and feet should also be evaluated for club foot(Jabaz & Abed, 2021).

The amniotic fluid, placenta and cervix should also be examined in the second trimester scan. “It is important to assess the placental location, appearance, and its relation with the internal cervical os”(Jabaz & Abed, 2021, p. 8).

Acceptable amounts of amniotic fluid are required for normal development of the fetus, and variations can be indicative a fundamental disorder that could impact the pregnancy(Crellin & Singh, 2021, p. 1). Amniotic fluid evaluations are an important component of the routine fetal anatomy evaluation. Ultrasound provides a quick, unobtrusive way to examine amniotic fluid(Crellin & Singh, 2021, p. 1). A normal AFI index of a single gestation at 20 wks is between 5-24 cm(Crellin & Singh, 2021, p. 3). Oligohydramnios is determined when amniotic fluid estimations go under the expected range. Probable causes consist of any disorder causing uteroplacental insufficiency, issues with urine production, and urinary tract obstruction(Crellin & Singh, 2021, p. 3). “Oligohydramnios' mortality has been shown to have a 50-fold increase compared to a fetus with a normal amniotic fluid level”(Crellin & Singh, 2021, p. 3). Numerous problems can occur with oligohydramnios, including increased measures of intrauterine growth restriction, heart monitoring that shows fetal distress, meconium-stained amniotic fluid, below

normal Apgar scores, and increased measures of cesarean section(Crellin & Singh, 2021, p. 3). Polyhydramnios comes from disorders that result in a higher than normal production of amniotic fluid or a lower incidence of fetal swallowing(Crellin & Singh, 2021, p. 3). “Causes of overproduction of amniotic fluid include hyperglycemia or hydrops, cardiac dysfunction, infection leading to decreased fetal swallowing due to GI tract obstruction, impaired neurological swallowing pathways, and some cranial facial abnormalities”(Crellin & Singh, 2021). “As the severity of polyhydramnios increases, so does the incidence of fetal structural and genetic anomalies”(Crellin & Singh, 2021, p. 3). Twin-twin transfusion syndrome is a particular case that involves abnormal amniotic fluid levels. “This syndrome occurs in 10%-15% of diamniotic-monochorionic twins due to shared chorionic vessels”(Crellin & Singh, 2021, p. 3). “This diagnosis requires a single placenta and the findings of oligohydramnios in one twin and polyhydramnios in the other. It is often associated with hydrops of the twin with polyhydramnios and growth restriction of the twin with oligohydramnios”(Crellin & Singh, 2021, pp. 3–4).

Placental abruption complicates a small fraction of pregnancies, but has the potential to be very serious. Placental abruption is the premature separation of a normally implanted placenta after 20 weeks gestation(*Placental Abruption*, n.d.).The separation can be complete, where the entire placenta separates, typically resulting in fetal death(*Placental Abruption*, n.d.). Or partial abruption, where only a portion of the placenta separates from the uterus(*Placental Abruption*, n.d.). An abruption can cause vaginal bleeding and abdominal pain, but can sometimes cause no symptoms(*Placental Abruption*, n.d.). On ultrasound imaging, there will often be a hypoechoic fluid collection behind the placenta, which is a result of blood pooling from the separation. Over half of the cases of abruption occur before 37 weeks gestation, with the highest incidence occurring between 24 and 26 weeks(*Placental Abruption*, n.d.).

Third Trimester Imaging

The third trimester is 27-40 weeks gestation and most of the imaging done during this time is because of a complication. Imaging is usually done if there is decreased fetal movement, pain, bleeding, abnormal NST, premature labor, or if abnormal growth is suspected. An ultrasound Biophysical Profile or BPP is a fast evaluation that can provide valuable data regarding fetal health(Sapoval et al., 2021). The BPP is an ultrasound exam that can take as long as 30 minutes and is used to check the health of the fetus(Sapoval et al., 2021). The elements evaluated are the amniotic fluid measurement or AFI, fetal breathing movements, whole body movements, and fetal tone or limb movements. A biophysical profile is most commonly performed due to a non-reactive NST or decreased fetal movement(Sapoval et al., 2021, p. 2). Each element is worth 0 or 2 points for a total of 8 points. These exams are considered useful after 32 weeks gestation(Sapoval et al., 2021, p. 2). “If there is fetal distress, acidosis, hypoxia or asphyxia, the fetal breathing movements are lost first, followed by body movements, then extremity tone”(Sapoval et al., 2021, p. 2). In a normal exam, the fetus should demonstrate at lease one occurrence of fetal breathing motion(Sapoval et al., 2021, p. 2). There should be at least 3 fetal body movements and at least one extension or flexion of an arm, leg or hand during the exam(Sapoval et al., 2021, p. 2).

Ultrasound can also be performed to evaluate fetal size if growth needs to be assessed or to assess the length of the cervix. Often during late pregnancy, transvaginal ultrasound is used better visualize the cervix.

Chromosomal Abnormalities

Ultrasonography is also used for chromosomal abnormality screening along with maternal serum testing(Anderson & Brown, 2009). Targeted imaging for fetal anomalies can

help determine whether invasive testing should be persued(Anderson & Brown, 2009).Various markers of fetal chromosomal anomalies may be detected by ultrasound imaging, including facial cleft, micrognathia, atrioventricular septal defects, and echogenic bowel(Anderson & Brown, 2009). If markers for fetal chromosomal abnormalities are identified sonographically, further testing will be recommended(Anderson & Brown, 2009).

In the first trimester, the screening for chromosomal abnormalities includes nuchal translucency scans(Anderson & Brown, 2009). Nuchal translucency refers to an ultrasonographic sonolucency in the posterior fetal neck. This measurement is gestational age dependent, on average it increases 15 to 20 percent per week(Anderson & Brown, 2009).Using only nuchal translucency testing, there is a detection rate of approximately 70 to 71 percent for Down syndrome(Anderson & Brown, 2009). Increased nuchal translucency of greater than 3.5 mm is associated with major congenital heart defects, defects of the great vessels, fetal malformations, dysplasia, deformations, disruptions, and genetic syndromes(Anderson & Brown, 2009). Measuring nuchal translucency require special training and certification to learn the standardized technique(Anderson & Brown, 2009).

In the second trimester, a combination of serum screening and ultrasonography can assist to evaluate for chromosomal abnormalities(Anderson & Brown, 2009).

Down syndrome or Trisomy 21 is the most common chromosomal abnormality among newborns(*Significance of Second Trimester Markers for Down's Syndrome Revealed*, 2013). There are now several sonographic signs which significantly increase the risk of Down syndrome. These finding include a short femur, short humerus, congential heart defect, pyelectasis, thickened nuchal fold, duodenal atresia, hypoplasia of the middle phalanx of fifth digit, and an abnormal facial profile(*Significance of Second Trimester Markers for Down's*

Syndrome Revealed, 2013). A thickened nuchal fold is the most reliable predictor for identifying fetuses with Down syndrome between 14 and 20 weeks gestation. A nuchal fold of 6 mm or more is considered abnormal and should prompt counseling and option of amniocentesis(*Significance of Second Trimester Markers for Down's Syndrome Revealed*, 2013). Between 40% and 70% of second trimester fetuses with Down syndrome have a thickened nuchal fold, compared with less than 0.05% of normal fetuses(*Significance of Second Trimester Markers for Down's Syndrome Revealed*, 2013). Pyelectasis has been noted in 20% of second trimester fetuses with Down syndrome, but the positive predictive value of fetal pyelectasis for predicting Down syndrome was only 3% or less(*Significance of Second Trimester Markers for Down's Syndrome Revealed*, 2013). Other structural findings, such as heart defects, duodenal atresia, and hydrocephalus, have been associated with Trisomy 21. However, only approximately 30% of fetuses with Down syndrome will have a sonographically visible structural defect(*Significance of Second Trimester Markers for Down's Syndrome Revealed*, 2013). Many second trimester fetuses have a normal facial profile, however, some fetuses will display the typical flat facies with maxillary hypoplasia(*Significance of Second Trimester Markers for Down's Syndrome Revealed*, 2013). Using ultrasound findings to identify fetuses at risk for Down syndrome could result in the identification of as many as 80% of fetuses with Down syndrome during the second trimester(*Significance of Second Trimester Markers for Down's Syndrome Revealed*, 2013).

Turner syndrome is the most common sex chromosome abnormality in female fetuses, in which all or part of one of the x chromosomes is absent or has some other abnormality(Polivka & Merideth, 2015). Turner syndrome affects 1 in 2000 live births, but over 90% of Turner cases result in miscarriage, making its in utero incidence much higher. There are two types of Turner

syndrome-classic and mosaic(Polivka & Merideth, 2015). Classic Turner syndrome results in an entire x chromosome missing. Mosaic Turner syndrome signifies that the abnormalities only occur in the x chromosome of some cells in the body(Polivka & Merideth, 2015). Turner syndrome is usually not inherited, because it occurs during a random event during the formation of reproductive cells in the affected person's parents(Polivka & Merideth, 2015). Classic sonographic findings of Turner syndrome include diffuse fetal edema, cystic hygroma with septations, renal and cardiac anomalies such as horseshoe kidney, coarctation of the aorta, nonimmune fetal hydrops, a short cervical spine, increased nuchal translucency, brachycephaly, hydramnios, and growth retardation(Polivka & Merideth, 2015). While sonography is the best method to prenatally diagnose Turner syndrome, a genetic amniocentesis or chorionic villus sampling should be done to confirm(Polivka & Merideth, 2015).

Breast Imaging

Breast cancer is the second leading cause of death in women(Sree et al., 2011). It occurs when cells in the breast start to grow out of proportion and invade neighboring tissues or spread throughout the body(Sree et al., 2011). Mammography is one of the most effective and popular modalities presently used for breast cancer screening and detection. Ultrasound and magnetic resonance imaging have been used to detect breast cancers in high risk patients(Sree et al., 2011). The breast is composed of identical tissues in both men and women, so breast cancer aloes occurs in men(Sree et al., 2011).The National Breast Cancer Foundation has estimated around 200,000 new breast cancer cases and 40,000 deaths every year in women(Sree et al., 2011).

Mammography

The breast is made of fat and fibroglandular tissue, containing a system of connective tissue, nerves, ducts, vasculature, and exocrine glands. The breast tissue continues from the 2nd

through 6th ribs and is surrounded by the sternum and midaxillary line. The breast is separated in medial/lateral and superior/inferior sections resulting in four quadrants of the breast, this makes it easier for pinpointing an area of interest.(*Mammography*, n.d., para. 6).

Mammography is the most common method of breast imaging. It uses low-dose amplitude x-rays to examine the breast(Sree et al., 2011). Cancerous masses and calcium deposits appear brighter on the mammogram. Mammography has helped to decrease the mortality rate by 25-30% in screened women(Sree et al., 2011). Mammography is considered the gold standard method to detect early stage breast cancer before lesions become clinically palpable. In digital tomosynthesis mammography, the basic mammography technique has been modified to acquire 3D views of the breast(Sree et al., 2011). Mammograms are done in two categories, screening and diagnostic. If a patient has no problems and a normal breast exam by their doctor, then a screening mammogram is performed(Magney et al., n.d.). A diagnostic mammogram is for patients with a concern, including a palpable lump or an abnormal screening mammogram(Magney et al., n.d.).

> Mammograms are performed in multiple views, including the craniocaudal or CC view and the mediolateral or MLO view. Additional views that may be utilized are spot compressions or variant angles such as mediolateral or ML view and true lateral view. The American College of Radiology recommends an annual screening mammogram beginning at age 40 for all women with an average risk of developing breast cancer. Breast cancer is most commonly diagnosed in the 50-60 age range. Risk increases with age and screening offers the opportunity to detect early cancer. Patients with an increased risk of developing breast cancer require special consideration. Patients are considered to

have an intermediate risk or 15-20% lifetime risk of developing breast cancer if they have any of the following, personal history of breast cancer, atypical ductal hyperplasia on a prior breast biopsy, or lobular neoplasia on a prior biopsy. Patients with a 20% or higher lifetime risk of developing breast cancer are considered high risk. These patients should initiate screening at a younger age. High risk patients are those with specific gene mutations, including BRCA 1 and 2, strong family history of breast cancer, or patients that have received radiation therapy of the chest between 10-30 years of age. Patients with a family history of breast cancer should begin screening 10 year earlier than the age at which the youngest first-degree relative developed breast cancer, but not before the age of 30. In addition to mammography, screening MRI scan are recommended for these high-risk patients. During a mammogram, the breast is positioned on the image detector and a paddle is brought in to compress the breast tissue, to flatten it out. Without adequate compression, the breast tissue may not adequately separate the parenchymal tissues. Compression is adjusted based on breast size and patient tolerance(*Mammography*, n.d., paras. 3, 6, 9-15, 27).

If an area of concern is seen on mammography, additional views, such as spot compressions or ultrasound imaging are done.

Breast Ultrasound

Ultrasonography has become a vital tool in imaging the breast. Ultrasound of the breast was initially used in the 1950s and over the next several decades was used to determine cystic lesions from solid lesions(Hooley et al., 2013, p. 643). Advancements in ultrasound technology now make it easier to determine between benign solid masses and those concerning for cancer. Ultrasound is very operator dependent and requires great attention to detail and knowledge of all

technical options available for imaging(Hooley et al., 2013). Specialized courses and training are necessary to become proficient and to assist with an accurate diagnosis.Benign ultrasound features of a solid mass include few gentle lobulations, ellipsoid shape, thin capsule, smooth margins, posterior acoustic enhancement and homogeneously echogenic echotexture(Hooley et al., 2013). “Malignant ultrasound features include speculation, taller-than-wide orientation, angular margins, micro-calcifications, and posterior acoustic shadowing”(Hooley et al., 2013). Ultrasound is used as a great addition to mammographic imaging. “Advances in ultrasound technology include harmonics, compound imaging, power doppler, faster frame rates, higher resolution, transducers, elastography, and 3D imaging”(Hooley et al., 2013). Indication for ultrasound in breast imaging include evaluation of palpable abnormality, focal breast pain, and nipple discharge and characterization of masses detected on mammography or magnetic resonance imaging (MRI)(Hooley et al., 2013). Ultrasound can also be used as an additional breast cancer screening in women with dense breast tissue and a negative mammogram(Hooley et al., 2013). Ultrasound is also the primary and most recommended modality for interventional breast procedures(Hooley et al., 2013).

Simple cysts on ultrasound are seen as circumscribed, anechoic masses with a thin imperceptible wall and enhanced through transmission(Hooley et al., 2013). Complicated cysts are hypoechoic with no discernable doppler flow, contain internal echoes, and may also have indistinct margins, and/or lack posterior acoustic enhancement(Hooley et al., 2013). Clustered microcysts consist of tiny anechoic foci with thin intervening septations. Complicated cysts are very common sonographic findings and the majority are benign(Hooley et al., 2013). Most complicated cysts and clustered microcysts are classified as BI-RADS 3 and require short-interval imaging follow-up. However, if multiple simple and complicated cysts are present, these

complicated cysts can be assessed as benign BI-RADS 2, requiring no additional follow-up(Hooley et al., 2013).

Sonographic features of benign-appearing solid masses include oval or ellipsoid shape, wider-than-tall orientation parallel to the skin, circumscribed margins, gentle and smooth lobulations- less than three, as well as lack of any malignant features(Hooley et al., 2013). Lesions with these features are commonly fibroadenomas or other benign masses and can be safely followed, even when palpable(Hooley et al., 2013). Malignant features of solid masses include spiculation, angular margins, marked hypoechogenicity, posterior acoustic shadowing, micro calcifications, ductal extension, branching pattern, and micro lobulations(Hooley et al., 2013). These lesions also most often display a taller-than-wide shape with a nonparallel orientation to the skin(Hooley et al., 2013).

Ductal carcinoma in situ(DCIS) is characteristically associated with micro-calcifications seen on mammography, but it may be detected at ultrasound since they are often associated with a subtle mass(Hooley et al., 2013). Ultrasound features associated with DCIS most commonly include a hypoechoic mass with an irregular shape, micro lobulated margins, no posterior acoustic features, and no internal vascularity(Hooley et al., 2013).

Ultrasound is also used to monitor known malignant lesions when the patient is undergoing radiation or chemotherapy treatment. Ultrasound scans are done to evaluate for reduction is size of the lesion.

Breast MRI

Breast MRI is a vital tool, along with mammography and ultrasound, used to evaluate the breast tissue(Mann et al., 2019). “The main indications for a breast MRI are staging of known cancer, screening for breast cancer in women at high risk, and evaluation of response to

neoadjuvant chemotherapy"(Mann et al., 2019, p. 520). "Breast MRI exams should be read or interpreted by radiologist with expertise in breast imaging, including mammographic and ultrasound studies, since these studies are often complementary"(Mann et al., 2019, p. 520). "Women lie in the prone position with the breasts hanging free in the recesses of the coil. This position allows the tissue to spread out, which aids in the detection of abnormalities and prevents motion artifact from breathing"(Mann et al., 2019, p. 520). The radiologist will describe the morphologic and kinetic features of findings by using the BI-RADS lexicon. Lesions are categorized as foci (< 5 mm of enhancement and by definition too small to characterize any further, but standing out from the surroundings), masses (space-occupying lesions), and non-mass enhancement (NME) (areas of enhancement without a clear space-occupying lesion present)(Mann et al., 2019). "Masses are further characterized by their shape, margins, and internal enhancement pattern. Areas of NME are further characterized according to distribution and internal enhancement pattern"(Mann et al., 2019, p. 524). "Most studies show that size estimates of lesions done with MRI area more reliable than those with clinical examination, mammography, or ultrasound. Accuracy decreases in larger cancers and is worse in NME than in mass lesions. The benefit of using MRI to assess tumor size is particularly strong for invasive lobular carcinoma"(Mann et al., 2019, p. 525). "Breast MRI is also more accurate in the depiction of pure DCIS lesions, Particularly high-grade lesions. In high-risk patients, MRI is recommended as a supplemental screening examination by multiple national and international guidelines"(Mann et al., 2019, p. 525). "Multiple studies have shown that combined MRI and mammography is associated with improved survival rates. Patients are considered high-risk if they have a lifetime risk of more than 20%. Technical developments have improved the quality of breast MRI, allowing for the acquisition of isotropic high-resolution images"(Mann et al.,

2019, p. 528,533).MRI is also used to evaluate the breasts for implant rupture. A breast implant rupture is when there is a tear or a hole in the outer shell of the breast implant(*MRI Detecting the Rupture of Breast Implants*, 2018). MRI is considered the gold standard when evaluating the integrity of both saline and silicone implant shells, because of its high spatial resolution and excellent contrast between the implant and adjacent soft tissues(*MRI Detecting the Rupture of Breast Implants*, 2018). MRI's ability to suppress or enhance silicone, as well as suppress signal intensity of water and fat allows this modality to provide the highest sensitivity and specificity for implant rupture(*MRI Detecting the Rupture of Breast Implants*, 2018). MRI's sensitivity and specificity for rupture is between 80-90% and 90-97% respectfully. Another added benefit, is that it can be used without harmful ionizing radiation(*MRI Detecting the Rupture of Breast Implants*, 2018). The FDA recommends follow-up MRI scanning biannually starting after the third year of implant placement. However, if the patient is asymptomatic, mammography and ultrasound are useful and more cost-effective tools in evaluating the augmented breast(*MRI Detecting the Rupture of Breast Implants*, 2018).

Breast Imaging Reporting and Data System-BI-RADS

> According to Magney, "The BI-RADS is a classification system proposed by the America College of Radiology (ACR) in 1986 that began in 1993. The ACR used scientific analysis and literature review to create a lexicon of descriptors that had shown to correlate with high predictive values associated with either benign or malignant disease. The BI-RADS system was the category classification for the overall assessment of the imaging findings. BI-RADS has a 0-6 categorization. BI-RADS 0 refers to an incomplete evaluation with further imaging required, this could be further mammographic views and/or ultrasound. BI-RADS 1 refers to a negative examination,

meaning there are no masses, suspicious calcifications, or areas of architectural distortion. BI-RADS 2 is consistent with benign finding. This could include fibroadenomas, simple cysts, intramammary lymph nodes, or secretory calcifications. BI-RADS 3 is probably benign and should have a shortened interval follow-up to determine stability. The risk of malignancy is below 2%. There are very strict classifications to qualify a finding in BI-RADS 3, such as non-palpable, circumscribed mass on a baseline mammogram, a focal asymmetry which becomes less dense on spot compression images, or a solitary group of punctate calcifications. BI-RADS 4 is a suspicious abnormality which can represent the chance of being malignant. BI-RADS 4 is divided into a, b, and c categories. The (a) category has a low probability of being malignant with a 2-10% chance. The (b) category has an intermediate chance of malignancy with a 10-50 % chance. The (c) category has a high probability of being malignant with a 50-95% chance(Magney et al., n.d.). BI-RADS 5 is highly suggestive of malignancy, more than 95%. BI-RADS 6 is used for a biopsy proven malignancy. The BI-RADS classification system is used for mammographic, ultrasound and MRI findings in breast imaging"(Magney et al., n.d., pp. 1–2).

Image Guided Breast Biopsy

When breast lesions classified as BI-RADS 4 and 5 are seen on ultrasound, ultrasound guided biopsies are performed(Apesteguia & Pina, 2011). When performing an ultrasound guided breast biopsy, the patient is positioned similarly to when they had the original ultrasound exam. The radiologist can view the breast lesion live, so can easily and safely target the area of interest. The radiologist will view the lesion with the ultrasound sonographer and decide on the best approach. The radiologist will then inject a local anesthetic at the skin, then will numb

deeper in the tissue around the lesion. The radiologist will then insert and guide the biopsy needle, using ultrasound to watch their progress and placement, to obtain samples of the lesion in question. Some advantages to ultrasound guided biopsies are that ultrasound does not involve ionising radiation, the radiologist can have full control of the needle position in real time, accessibility of difficult places, such as the axilla or near the nipple, the breast is not compressed, excellent comfort for patients and radiologist, cost-effective technique, and multiple lesions can be safely biopsied in one session(Apesteguia & Pina, 2011).

Stereotactic breast biopsy uses mammography to help locate a breast abnormality and remove a tissue sample(*Stereotactic Breast Biopsy*, n.d.). It is less invasive than surgery and is an excellent way to image calcium deposits or tiny masses that are not visible on ultrasound(*Stereotactic Breast Biopsy*, n.d.). In a stereotactic biopsy, the patient will lie face down on a moveable exam table with the breast that is being biopsied hanging down in an opening in the table. The breast is compressed and held in position during the procedure. Preliminary images are taken and the area of interest is localized for the biopsy device(*Stereotactic Breast Biopsy*, n.d.). The radiologist performs the stereotactic biopsy on an outpatient basis. The radiologist will inject a local anesthetic at the skin and then deeper into the tissue surrounding the area of interest(*Stereotactic Breast Biopsy*, n.d.). The radiologist will make a small nick in the skin and then insert the needle and advances it to the location of the abnormality(*Stereotactic Breast Biopsy*, n.d.). Mammogram images are obtained to confirm that the needle is in the correct location for biopsy. Tissue samples are then taken, and if calcium deposits are being sampled, x-rays of the removed tissue will be obtained to confirm enough calcium deposits are obtained for analysis(*Stereotactic Breast Biopsy*, n.d.).

Conclusion

Diagnostic imaging is a vital tool in women’s health. Women go through many life stages and have gender-specific health needs. There are a wide variety of women's health conditions that benefit from diagnostic imaging, including gynecological health, reproductive health, obstetric health, breast health and cancer. Imaging can help prospective parents reach their dream of having a baby. Ultrasound imaging can help detect abnormalities in utero, so better treatment and outcomes can be prepared for. Early diagnosis of breast or endometrial cancer can let a woman have many more years with her loved ones. Diagnostic imaging is indispensable and with technological advancements, many more women can be helped.

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