

Fetal Surgery

Fetal surgeries are a range of medical interventions performed in utero on the developing fetus of a pregnant woman to treat a number of congenital abnormalities. The first documented fetal surgical procedure occurred in 1963 in Auckland, New Zealand when A. William Liley treated fetal hemolytic anemia, or Rh disease, with a blood transfusion. Three surgical techniques comprise many fetal surgeries: hysterotomy, or open abdominal surgery performed on the pregnant woman; fetoscopy, for which doctors use a fiber-optic endoscope to view and make repairs to abnormalities in the fetus; and percutaneous fetal therapy, for which doctors use a catheter to drain excess fluid. As the sophistication of surgical and neonatal technology advanced in the late twentieth century, so too did the number of congenital disorders fetal surgeons treated, such as myelomeningocele, blocked urinary tracts, twin-to-twin transfusion syndrome, polyhydramnios, diaphragmatic hernia, tracheal occlusion, and other anomalies. Many discuss the ethics of fetal surgery, as many consider it contentious, as fetal surgery risks both the developing fetus and the pregnant woman, and at times it only marginally improves patient outcomes. Some argue, however, that as more advanced diagnostic equipment and surgical methods improve, advanced clinical trials in a few conditions may demonstrate more benefits than risks to both pregnant women and their fetuses.

Fetal surgery is often performed to drain blocked bladders, repair heart valves, spinal openings, and remove abnormal growths from fetal lungs. Many fetal surgeries occur in university medical centers, as patients often require specialty care. Selection of candidates for the surgery is often based on prenatal diagnosis of a relevant condition, coupled with a pregnant woman's viability for the surgery, including age, body mass index, a case history of preterm labor, co-morbidities, and the availability of social and medical support systems for before and after surgery.

The fetus is also carefully assessed to weigh the risks of surgery, with consideration given to potential complications and to survival before and after delivery. Often, post-natal surgery in a neonatal intensive care unit to repair congenital defects is preferred.

The risks that open surgery introduces to the fetus include death and premature birth. The surgery may also cause complications to the otherwise healthy pregnant woman due to the intervention of opening and closing the uterus while trying to maintain a pregnancy. At the same time, therapeutic drugs administered to continue the pregnancy may lead to side effects that result in women requiring care in intensive care units. Minimally, the pregnant women must stay in hospitals for close monitoring in the event of an emergency delivery.

Many discuss fetal surgery with the pregnant woman as a high risk procedure to the fetus and to the woman. The surgery is for the benefit of the fetus, but the outcome depends not only on the fetus' recovery and continued growth and development in utero, but on the recovery of the pregnant woman as well. The risks to the woman include preterm membrane rupture, preterm labor, wound infection, hemorrhage, side effects from anti-labor therapies, loss of the uterus, and damage to the organs near the uterus. At the same time, not every general surgery offers the success anticipated prior to the surgery, and this is true of fetal surgery.

Ultrasounds, amniocentesis, and chorionic villi sampling were some of the first techniques physicians performed to gather information that necessitates the risks of surgical intervention. Fetal surgery became a possibility in part, by developments in ultrasound technology in the early 1960s, which offered physicians a way to visualize the womb and the developing fetus. Additionally, modern amniocentesis techniques are often one of the first steps taken by doctors before the option of fetal surgery is presented to the pregnant woman. Amniocentesis involves the insertion of a hollow needle through the abdominal wall and into the uterus of a pregnant female to obtain amniotic fluid,

which can be tested for chromosomal abnormalities as well as determining the sex of the fetus.

Using a similar procedure, Liley conducted the first documented fetal surgical procedure in 1963 in Auckland, New Zealand. Liley guided a hollow needle through the abdomen of a pregnant woman and into the abdominal cavity of her fetus diagnosed with hemolytic anemia, or Rh disease. Rh disease occurs when a pregnant woman, who is negative for the Rhesus antigen, carries a fetus that is positive for the Rhesus antigen. The woman's immune system, not recognizing the foreign antigen, launches an immune response against the fetus that can result in hydrops fetalis or stillbirth. Liley conducted the blood transfusion as a means of treating a disease that generally leads to fetal death in the second or third trimester of pregnancy, and his work was subsequently adopted and advanced by other obstetricians.

Chorionic villus sampling, developed in 1968 by geneticist Jan Mohr in Copenhagen, Denmark, is another technique doctors use to diagnose conditions that may require fetal surgery. To perform chorionic villus sampling, doctors obtain, at ten to twelve weeks of gestation, a tissue sample of the chorion, a membrane surrounding the developing fetus. The doctors sample the chorion by going through the woman's abdomen or through her vagina and cervix. The process allows doctors to obtain fetal cells at an early stage of development and allows for the prenatal diagnosis of chromosomal abnormalities.

In the 1970s, fetal surgical techniques further evolved, but interest in them waned due to ethical, political, and professional opposition to the perceived risks of surgery. In the early 1980s, as diagnostic and surgical techniques improved, surgeons began renew their interests in fetal surgery, and subspecialists began to emerge in the areas of obstetrics, genetics, neonatology, and pediatric surgery. Fetal conditions that have been identified as responsive to surgical intervention encouraged the foundation in 1983 of The International Fetal Medicine and Surgery Society, which supports the efforts of those involved in the emergent medical specialty of fetal surgery.

Open hysterotomy, characterized by a surgical incision through the multiple layers of the uterus, including the maternal abdominal wall, uterus, and the membrane surrounding the fetus, was developed by pediatric surgeons Alfred de Lorimier and Michael R. Harrison in the early 1980s at the University of California, San Francisco (UCSF). The surgeons developed the technique to repair fetal myelomeningocele. Myelomeningocele is a common form of spina bifida, a neural tube defect whereby the lower spine does not close during development. In some cases myelomeningocele can result in a protrusion of the spinal cord outward from the fetus' back, exposing the area to amniotic fluid, which can cause paralysis, malformation of the central nervous system, and depending of the location of the opening, bowel and bladder problems.

In 1981 at the USCF, Harrison also performed the first surgical repair of a fetus's blocked urinary tract by passing a needle through the pregnant woman's uterus and withdrawing urine from the fetus's bladder. The fetus was born healthy, and as news spread in the medical community about this technique, more interest in fetal surgery fostered new methods to treat other life-threatening conditions facing the fetus in utero.

Around the same time, doctors began to conduct fetal surgery to mitigate twin-to-twin transfusion syndrome, an often fatal circulatory disorder that impacts identical twins, whereby one twin monopolizes the blood supply from the pregnant woman. The most common consequences of twin-to-twin transfusion syndrome are preterm delivery or the death of one or both twins. By using percutaneous fetal therapy to reduce excess volumes of amniotic fluid (hydramnios) doctors improve fetal hemodynamics, which decreases pressure on the placental surface and results in a more even distribution of blood between twins. In 2004 doctors in France, Switzerland, and Belgium began to treat twin-to-twin transfusion syndrome with fetoscopic laser coagulation. For that technique, doctors use endoscopic laser coagulation to sever the fetal circulatory tissues responsible for the abnormal distribution of blood between twins, while the pregnant woman is under local or regional anesthetic. The institutes conducting the study concluded that the treatment was more effective than frequent amniotic fluid withdrawals when the condition is diagnosed before 26 weeks of gestation.

In 1989, UCSF surgeons also attempted to repair congenital diaphragmatic hernia, a condition where a fetus's abdominal organs migrate through a hole in its diaphragm up into its chest cavity. The area occupied by the abdominal organs severely limits lung development, leaving newborns

with underdeveloped hypoplastic lungs. Michael Harrison led an early clinical trial 1989 to test how effective hysterotomy was in treating congenital diaphragmatic hernia in fetuses. With hysterotomy, the pregnant woman's uterus was opened and the fetus partially removed for the operation, then doctors repaired the congenital abnormality and returned the fetus to the womb. Harrison developed a second technique for repairing congenital diaphragmatic hernia in 1997 by working with lambs to test a considerably less invasive endoscopic technique called tracheal occlusion. Harrison and colleagues demonstrated that by blocking the trachea, pressure increased within the fetal lung cavity, counteracting lung hypoplasia. Tracheal occlusion increased lung growth in normal and hypoplastic lungs and allowed the lungs to mature in utero, limiting the effect of the diaphragmatic hernia.

Fetal endoscopic tracheal occlusion surgery has been offered since 2001 to pregnant women whose fetuses have diaphragmatic hernia. Three European centers, one in Spain, one in the UK, and another in Belgium, reported in 2009 of an ongoing clinical study in which doctors closed holes in fetal diaphragms by using a balloon to block the trachea and to increase pressure in the fetuses' chest cavities. The balloon was removed pre-birth by fetoscopy or ultrasound-guided puncture, or after birth by tracheoscopy using an endoscope or a percutaneous puncture. Greater than 200 women participated in the European study, which showed that fetal endoscopic tracheal occlusion, compared to open surgery, to be a minimally invasive procedure for improving diaphragmatic hernias.

Fetal surgery's emergence relied on improved diagnostic equipment, radiological techniques, surgical training, and specialized instrumentation. Aiding in diagnoses of fetal anomalies are improved imaging technologies, such as magnetic resonance imaging (MRI) and high resolution ultrasound—with its ability to measure the flow of blood through vessels to detect leaks. Many people assist in fetal surgeries, such as pediatric radiologists, ultrasonographers, perinatologists, neonatologists, neonatal surgeons, anesthesiologists, obstetrical and neonatal intensive care nurse practitioners, social workers, and chaplains, who all often work together to provide information, coordination, education, technical skills and support. Fetal surgery remains an option in less than one percent of all births.

Sources

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