

The Mustard Operation

The Mustard Operation is a surgical technique to correct a heart condition called the transposition of the great arteries (TGA). TGA is a birth defect in which the placement of the two arteries, the pulmonary artery, which supplies deoxygenated blood to the lungs, and the aorta, which takes oxygenated blood to the body are switched. William Thornton Mustard developed the operation later named for him and in 1963 operated on an infant with TGA, and ameliorated the condition, at the Hospital for Sick Children in Toronto, Canada. Afterwards, the Mustard Operation became the primary form of corrective surgery for TGA, until the arterial switch operation largely replaced the Mustard Operation by the late 1990s. The Mustard Operation enabled surgeons to correct TGA in infants born with the life-threatening anomaly, increasing their life spans and quality of life.

The transposition of the great arteries is a congenital heart defect of the cardiovascular system. The cardiovascular system is responsible for distributing oxygen and nutrients to cells throughout the body. The human cardiovascular system is composed of two circuits, the systemic circuit and the pulmonary circuit. Each circuit is comprised of an atrium and a ventricle. The systemic circuit supplies the body with oxygen-rich blood from the aorta, while the pulmonary circuit delivers de-oxygenated blood from the body and transports it to the lungs through the pulmonary artery where it can be oxidized. For those with TGA, proper oxygenation of the blood is not possible because the pathway of the circuits is switched. TGA becomes a problem for infants only after birth. During pregnancy, a pregnant woman provides her fetus with oxygenated blood and nutrients through the umbilical cord. Fetuses with TGA can survive throughout an entire pregnancy, but once born they rarely live longer than a year.

After birth, a newborn's lungs are emptied of amniotic fluid, which is in the lungs until birth, and the newborn begins to breathe on its own. Also, shortly after birth, an opening called ductus arteriosus, normally present between the pulmonary artery and the aorta in the fetal heart, closes and partially enables the infant to take its first breath. In a fetus, the ductus arteriosus enables oxygenated blood and de-oxygenated blood to mix by connecting the pulmonary artery to the descending aorta. In a newborn with TGA, the position of the aorta and the pulmonary artery are switched. As a result, the newborn does not get sufficient amounts of oxygen. Physicians recognize TGA in newborns immediately after birth due to the presence of cyanosis, a condition in which the skin and mucous membranes appear blue due to lack of oxygen. Cyanosis can lead to organ failure and ultimately death.

Although corrective surgery for TGA existed in the 1950s, Mustard adjusted and improved the techniques of other surgeons including Åke Senning at the Karolinska Institute in Stockholm, Sweden, and Thomas G. Baffes at the Mt. Sinai Hospital Medical Center in Chicago, Illinois. After observing the Senning and Baffes procedures, Mustard experimented with alternative techniques to modify and simplify both. Mustard had operated on newborns with TGA in the 1950s with little success. He developed his technique for treating TGA by first testing it on dogs and rhesus monkeys in the early 1960s.

Mustard took Baffes's technique of using a baffle, an artificial wall, to route blood in a different direction. Mustard created a baffle by cutting a section of the patient's pericardium, the outside layer of the heart, in a size that was appropriate for an newborn's developing heart. He then sutured one side of the baffle along both the front portion of the left pulmonary vein and the back portion of the superior and inferior vena cava. Mustard sutured the other edge of baffle along the right, away from midline, and anterior inferior vena cava. He sutured one of the ends to the superior vena cava and the anterior atrial septum, or the separation between the right and left atria. Mustard

then sutured the final edge of the baffle to the anterior end of the atrial septum. Before placing the baffle in the heart, Mustard treated the patient with a blood thinner to prevent blood clots from developing during and after surgery and sewed the baffle to the heart to redirect blood flow. With this operation, he enabled oxygenated blood to flow from the lungs and directly to the right atria then out the right ventricle to the body. This allowed for a reversal of typical blood flow, enabling blood to be oxygenated and travel throughout the body.

To operate on the inside of the heart, Mustard developed a heart-lung machine that oxygenated and circulated the blood throughout the body while bypassing the heart and lungs. Once Mustard had a working prototype of the machine, he tested his surgery on dogs by artificially creating TGA, and then he attempted to correct it, but wasn't successful. Despite not succeeding with his dog trials, Mustard believed that the operation could work on human infants.

In 1963, Mustard used his modified procedure, operating on an eighteen-month-old girl called Maria Surnoski. Surnoski survived the procedure and recovered, remaining in contact with Mustard, who later attended her sixteenth birthday. In 1968, Mustard detailed his procedure in "The Role of Surgery in the Treatment of Transposition of the Great Vessels."

Afterwards, cardiovascular surgeons throughout the world learned and applied the procedure. By the year 1971 it was estimated that the Mustard Operation had been used on about 1,000 infants suffering from TGA. Up to the mid 1990s, surgeons at the University of Toronto in Toronto, Canada, had performed over 550 Mustard Operations to correct transposition of the great arteries, 90 percent of which had long-term success. By the late 1990s, surgeons increasingly used a procedure largely developed by Adib Jatene in Brazil in the 1970s to correct TGA, and the Mustard Operation became less widely used.

Sources

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