## On Bypass

**Kelly Hedlund**, MS, CCP
Hayes, KS

and

**Mike Sanford**, CCP
Wheaton, KS

# REMEMBERING THE LINDBERGH PERFUSION PUMP

Charles Lindbergh had a knack for machinery. At the age of 9, he designed a wire-and-pulley system for moving large blocks of ice from his family's icehouse in Minnesota. Prior to becoming a teenager, he disassembled his father's Model T Ford to fix a timing trigger that had given out. And of course, his exploits in aviation demonstrated the ability of air-cooled engines to fly great distances. Little wonder, then, that in 1930 Lindbergh set out to tackle a most audacious problem - building a perfusion pump to keep tissue and organs alive outside the body. Lindbergh was a thinker, no doubt the result of his solitary time spent in the cockpit. Upon learning that his wife's older sister was dying of rheumatic fever, Lindbergh assumed that a simple fix was available. Likening it to a faulty valve in an engine, Lindbergh was soon puzzled to learn that nothing could be done for a diseased heart. Mitral commissurotomy procedures, first attempted in 1923, had largely been abandoned. Open-heart surgery wouldn't be perfected for decades.

Enter Alex Carrel …

Lindbergh had been famous since 1927, the year he piloted his *Spirit of St. Louis* airplane across the Atlantic. Carrel, on the other hand, had been studying vascular surgery since 1901 and had won the Nobel Prize in Physiology and Medicine in 1912. When the two men first met at the Rockefeller Institute in New York in November of 1930, each knew the other was a hero. Lindbergh's purpose in visiting Carrel was to propose his ideas about a mechanical heart to help his ailing sister-in-law. He even presented Carrel with a simple drawing of a crude artificial circulation system. Carrel was smitten with the pilot's enthusiasm, but shook his head in dismay. Pistons, necessary for an artificial pump to work, would surely damage the blood. Moreover, clotting and infection would occur. Though rejected, Lindbergh accepted Carrel's viewpoints as conventional wisdom and prepared to leave. In recent years, Carrel's focus had shifted to tissue and organ culture. In fact, for some time Carrel had been using a perfusion pump designed by one of his technicians, Heinz Rosenberger, to preserve whole organs. Unfortunately, the organs became contaminated with bacteria in every experiment. Carrel was keenly aware that Lindbergh understood machines like few people of his time. And so on a whim, before showing him to the door, Carrel asked Lindbergh if he wanted to see the perfusion pump. Lindbergh examined the device as if he had x-ray vision, and was astounded by its crudeness. In rather sly fashion, Carrel challenged Lindbergh to build a better perfusion pump. Lindbergh eagerly accepted, and promised to return in a couple weeks with a new design.

A Roman candle with twin glass spirals …

Lindbergh's initial sketches for a workable perfusion pump impressed Carrel (see Figure 1). So delighted, in fact, was Carrel with Lindbergh's innate sense of bioengineering that he invited him to join his laboratory. More designs from Lindbergh followed, and numerous prototypes were fashioned

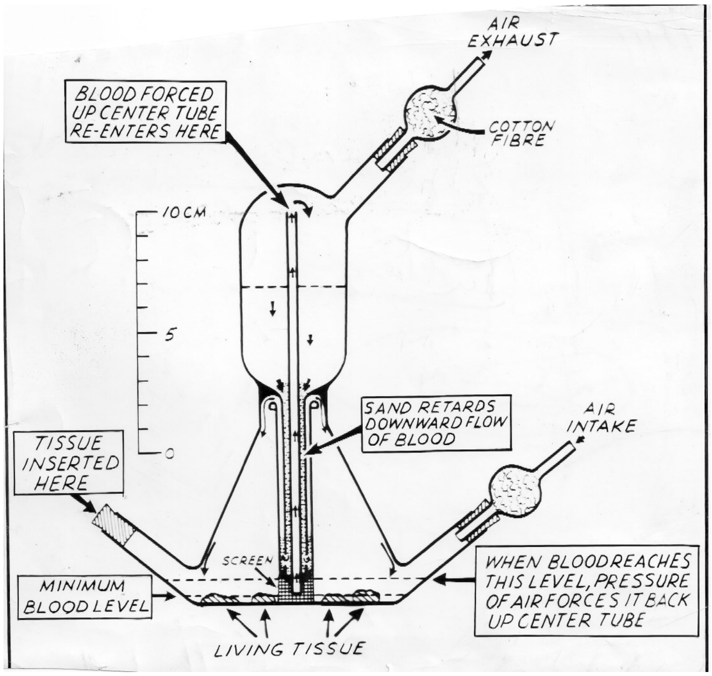


*Figure 1 – Design sketch of an early Lindbergh perfusion pump (circa 1931). Note tissue samples at bottom of device.*

and discarded. Each version of Lindbergh's perfusion pump was painstakingly hand blown from Pyrex glass. Early versions resembled a Roman candle with twin glass spirals, or a double-headed glass goose. Time magazine referred to Lindbergh's device as a "… twist of vitrified bowel oozing out of a clear glass bottle". In the spring of 1935, Lindbergh announced that his latest design could perfuse whole organs, not just tissue (see Figure 2). Standing eighteen inches tall, the sterilized apparatus had three main chambers, as well as non-absorbent cotton balls at each entry port to filter germs. The perfusate medium, developed by Carrel, consisted of blood serum, amino acids, and insulin tinted with sterile red dye. An external gas supply of 40% oxygen, 4% carbon dioxide, and 56% nitrogen served to both oxygenate the perfusate and continuously propel it through the organ in a pulsatile manner (see Figure 3). Floating valves prevented backflow of the perfusate. The apparatus was housed in an incubator during use at a temperature of 37°C. Between 1935 and 1939, nearly 900 perfusion experiments were carried out using ovaries, spleens, kidneys, and adrenal glands from cats, dogs, and birds. Thyroid glands were amazingly well preserved for up to 30

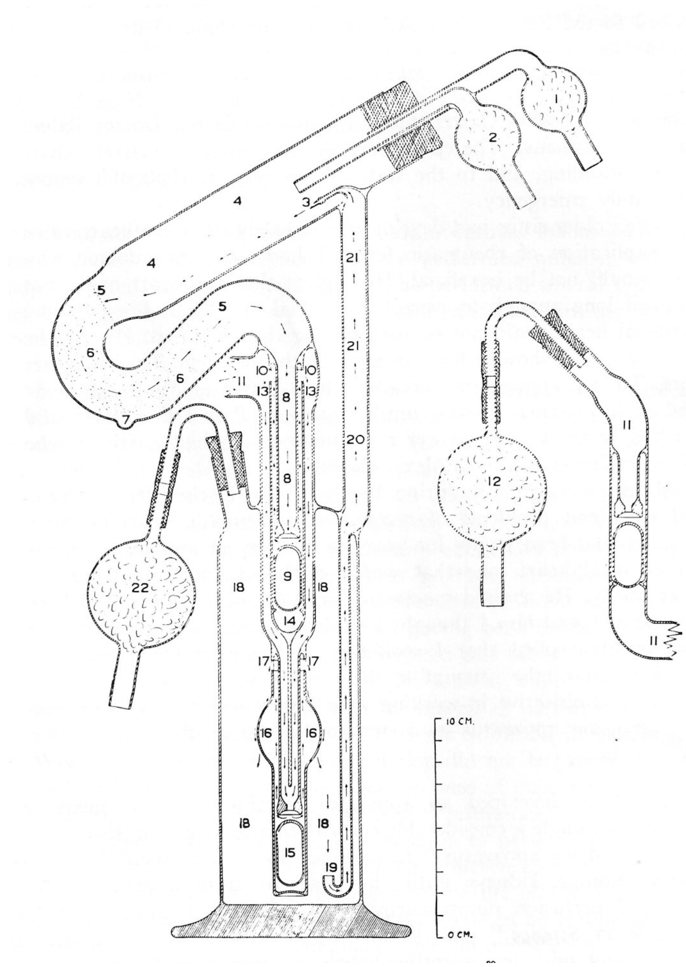


*Figure 2 – Design sketch of Lindbergh's 1935 perfusion pump. Note upper-most chamber where tissue or whole organs would be placed.*

days. Cat hearts would continue to beat for up to 12 hours. Lindbergh's device became an object of wonder, having been exhibited before large crowds at the 1939 World's Fair in New York City. Lindbergh and Carrel were once again hailed as heroes, gracing the cover of Time magazine in 1938 (see Figure 4). Excitement raged, as laboratories across America and Europe ordered dozens of Lindbergh pumps. Most researchers, however, found the device impractical and difficult to use. By the early 1940s, the pump's time in the spotlight had run out. Carrel was forced into retirement by the Rockefeller Institute and returned to his native France. Lindbergh, a one-time conscientious objector to the United States' involvement in WWII, joined the fight and flew combat missions in the South Pacific.

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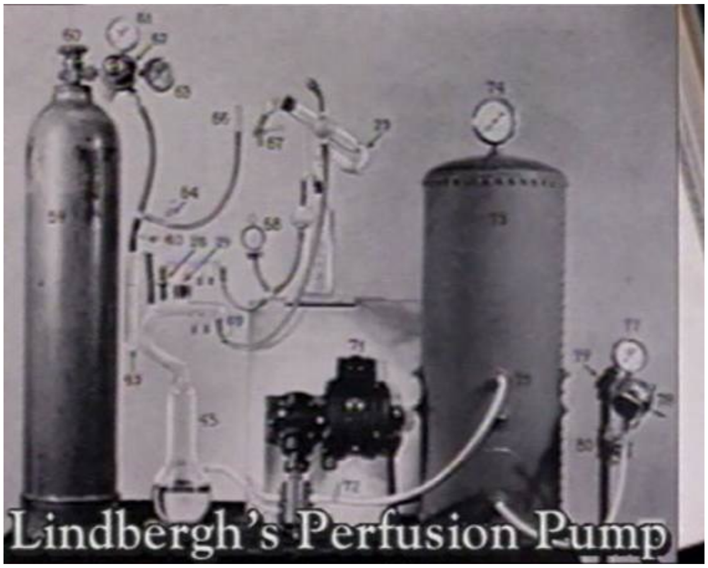


*Figure 3 – External gas supply and pressure-regulating system attached to the Lindbergh perfusion pump (center of photo).*

A renewed interest …

During the 1960s, researchers at the Navy Medical Research Institute (NMRI) in Bethesda, Maryland employed freeze-drying technology to study the preservation of whole organs. Lindbergh's perfusion pump, having sat dormant for over 20 years, was rediscovered and utilized by the NMRI Tissue Bank scientists. In fact, Lindbergh himself came out of retirement and was appointed as guest scientist to the project. The collaboration produced two publications, and reaffirmed Lindbergh's device as one of the world's greatest technological and medical marvels.


*Figure 4 – 1938 issue of Time magazine.*

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