ON Bypass

REMEMBERING THE DISC OXYGENATOR

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Introduction

When I began my career in perfusion 30 years ago, the hardshell disposable bubble oxygenator was king. Membrane oxygenators were certainly available, but only comprised 20% of the market. By the mid-1980's however, the use of membranes quickly surpassed that of bubblers. Today, membranes are the preferred choice of oxygenation worldwide. Incredibly, bubble oxygenators are still available and used in various parts of the world. In terms of the history of oxygenators, no discussion is complete without mentioning the rotating disc oxygenator (see Figure 1). This "filming" device was first built in 1948 by Viking Bjork whilst working in Clarence Craaford's lab. Hooker is often mentioned as the originator of the disc oxygenator. In truth, Hooker used a flat disc merely to spread blood centrifugally inside a container. Virtually all of the gas exchange in Hooker's design occurred on the walls of the device as the blood streamed downward in a filming fashion. Of course, rotating *cyclinder* oxygenators go back to the days of von Frey and Gruber in 1885, as well as to Gibbon's early attempts at extracorporeal oxygenation in the 1930's. But it was two ingenious surgeons from Ohio, Drs. Frederick S. Cross and Earl B. Kay (see Figure 2), who brought name-brand recognition to *disc* oxygenation. Their device, introduced in 1956 as the Kay-Cross Rotating Disc Oxygenator, was soon manufactured by companies like Pemco, Med-Science, American Optical, and Sarns. For a brief time, it was the oxygenator of the day - a truly commercial device to be enjoyed by the masses.

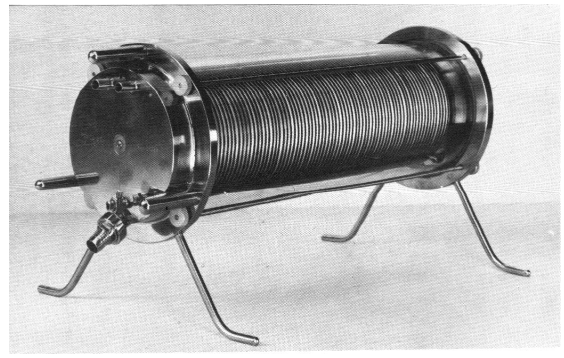

Figure 1
Kay-Cross Rotating Disc Oxygenator

Figure 2. Dr. Frederick S. Cross (left) and Dr. Earl B. Kay (right).

Disc Oxygenation

The original Kay-Cross oxygenator contained 59 silicone-coated stainless steel discs mounted on a central shaft separated by stainless steel spacers. The disc assembly was held horizontal within a pyrex glass cylinder by endplates containing gaskets that sealed the device.

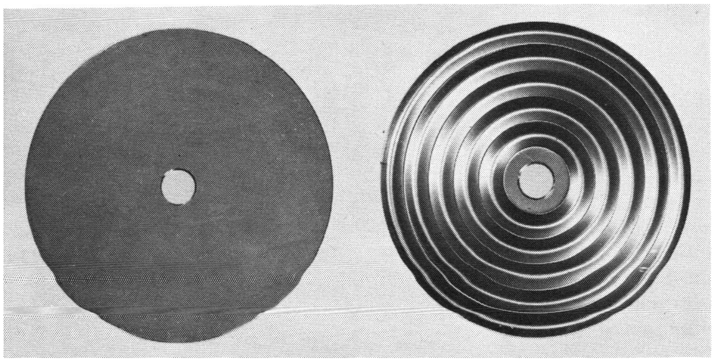

Figure 3
Flat (left) and corrugated (right) discs

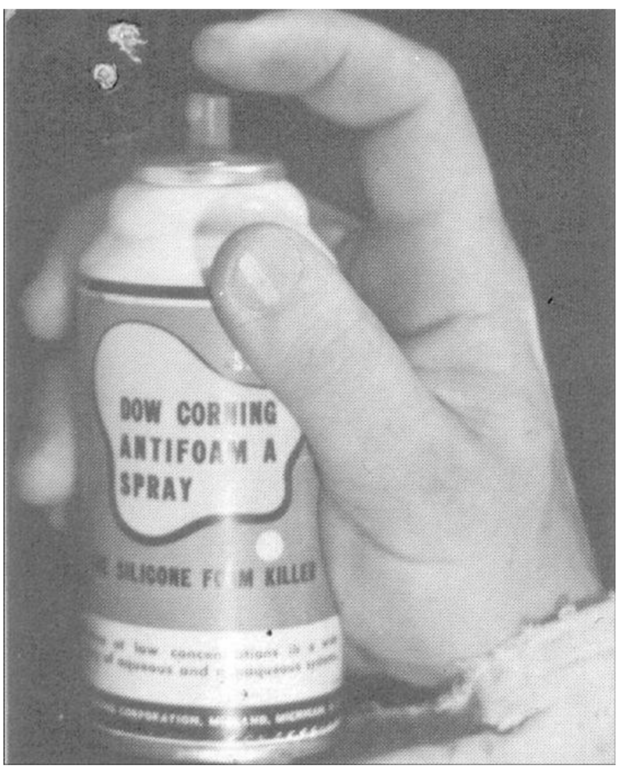

Figure 4
Dow Corning Antifoam A Silicone Spray

Cylinders, approximately 5 inches in diameter, were made available by manufacturers in various lengths (6", 9", 13", 17", 21", 25") to meet the oxygenation needs of the patient. Corrugated discs, which were stamped with 90 degree impressions in a concentric manner, offered 30% more surface area than the conventional flat disc design (see Figure 3). However, corrugated discs required more spacing between them (4.7 mm instead of 3.6 mm in one commercial model) to avoid "bridging" of blood from one disc to the next. As such, many perfusionists believed the additional space requirement for the entire corrugated disc assembly outweighed the modest advantage of increased filming area. During perfusion, the discs spun at a rate of 120 revolutions per minute. This was generally accomplished by connecting the central shaft to a motor housed inside the heart-lung machine chassis via a flexible cable. Freestanding direct drive motor units were also available. Increasing the spin rate beyond 120 revolutions did not significantly improve gas transfer, and tended to cause splashing and foaming of the blood. Reapplying the silicone coating to the discs, spacers, shaft, and endplates varied greatly between centers (see Figure 4). Kay and Cross advocated re-coating after 20 to 25 pump runs. The lack of an integrated heat exchanger was an obvious drawback of the original rotating disc design. Some centers wrapped a heating wire around the glass cylinder, or employed external heat lamps.

During his Gibbon Award acceptance speech in 1995, the late Ben Mitchell confessed to using a heating wire as a means to reduce condensation buildup inside the glass cylinder. Unfortunately, both wires and lamps frequently caused clotting at the blood-gas interface as the blood level oscillated up and down the cylinder wall. In response, companies like Olson and Pemco began manufacturing a heat exchanger that fit within the confines of the cylinder directly below the disc assembly (see Figure 5). A little known fact is that researchers began experimenting with *plastic* discs as early as 1957. Looking remarkably similar to phonograph records, plastic discs were molded from methylmethacrylate and offered disposability and quick setup (see Figure 6).

In the early 1960s, Sarns devised a rotating disc oxygenator with no endplates. Rather, the shaft and disc assembly were suspended inside a specially-contoured metal pan. The lid was made from Lexan – a new plastic at the time that could withstand repeated autoclaving up to 270º F (see Figure 7).

Summary

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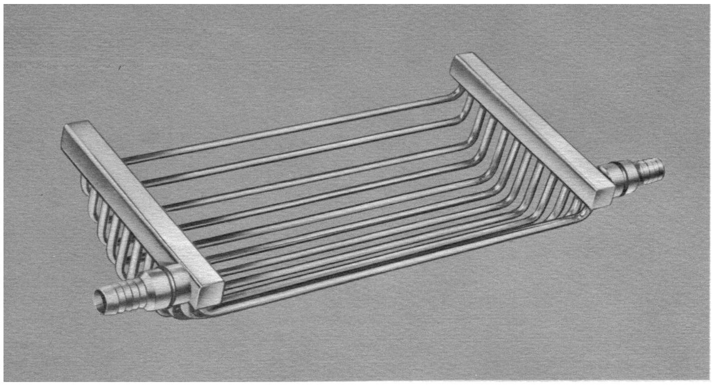

Figure 5
Heat exchanger designed to fit inside the rotating disc oxygenator

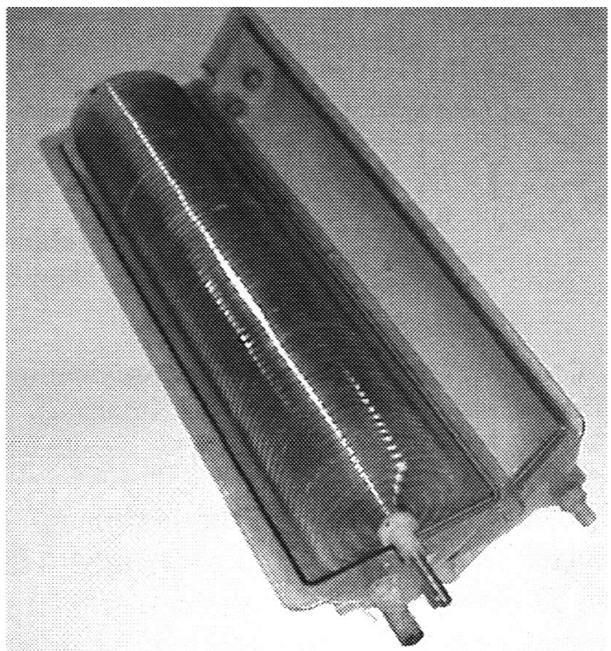

Figure 6
Disposable disc oxygenator made entirely of plastic

Recently, I obtained a rotating disc oxygenator from the Ukraine. It was machined in Kiev in 1959 using the Kay-Cross specifications. According to the perfusionist who sent it to me, it was used on thousands of cases from 1960 until the late 1970s at the Amosov Institute of Cardiovascular Surgery. In 1967, a landmark article published by Gollub, Hirose, and Everett reported that the disc oxygenator (American Optical brand) caused far less destruction of erythrocytes than the bubble oxygenator (Travenol brand) using an in vitro test circuit primed with freshly-

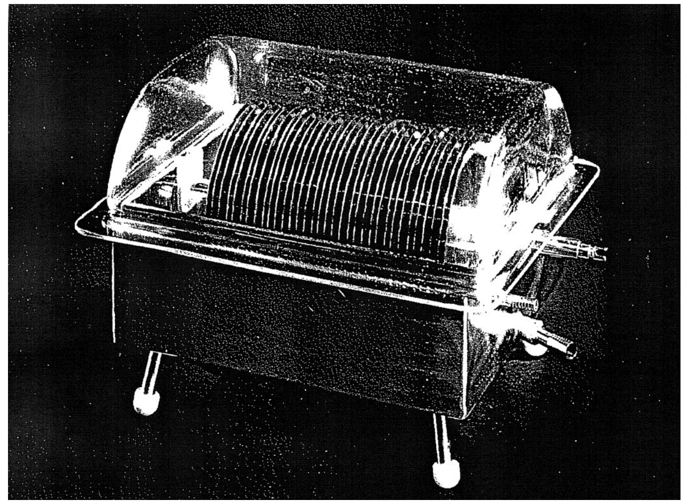

Figure 7
Sarns disc oxygenator with Lexan cover

collected whole human blood. Studies like this are likely the reason why disc oxygenators remained in clinical use for so long, and why Dr. Norman Shumway once proclaimed, “Compared with the rotating disc oxygenator, the bubbler must be considered a second-class ticket good only for the short distance, and all too frequently the return trip has been cancelled”. The disc oxygenator’s place in history is secure. For those who haven’t seen one up close, it was truly a feat of engineering - just ask the poor souls who had to clean and assemble it.

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