This Week's Citation Classic™ CC/NUMBER 8 FEBRUARY 20, 1984

Moulopoulos S D, Topaz S & Kolff W J. Diastolic balloon pumping (with carbon dioxide) in the aorta—a mechanical assistance to the failing circulation. *Amer. Heart J.* **63**:669-75, 1962.
[Dept. Artif. Organs, Cleveland Clinic Fndn. and Frank E. Bunts Educ. Inst., Cleveland, OH]

This paper presents a method based on the principle of counterpulsation to assist the blood circulation when the heart is unable to maintain it. It consists of inflating during ventricular diastole and deflating during systole an elongated balloon introduced into the descending aorta. [The *SCI*® indicates that this paper has been cited in over 205 publications since 1962.]

Spyridon D. Moulopoulos
Department of Clinical Therapeutics
School of Medicine
University of Athens
Athens, Greece

January 8, 1984

"When I started working at the Cleveland Clinic in December 1960, Willem Kolff had already embarked upon the project of making an 'artificial heart' to replace the irreparably ailing human heart. To the scientific community at that time, the effort appeared Utopian. To me, it represented an extremely interesting but long jump in that line of research, so I tried to find a way to assist the heart until Kolff was successful in replacing it, which he did 22 years later.

"Several cardiac assistance techniques were then already in existence, but most were handling blood outside the body. The intra-aortic balloon did not require an extracorporeal blood circuit. Instead of drawing the blood outside the body during ventricular systole and pumping it back during diastole, as was done by Harken, we introduced a long polyurethane balloon, mounted on a catheter, into the descending aorta and pumped the blood 'intra-aortally' toward the peripheral (and coronary) vessels during diastole, while deflating it during systole. Thus, peripheral resistance to the heart was reduced without reducing perfusion pressure to the tissues. The device, operating with an inexpensive solenoid valve and a delay circuit triggered from the R-wave of the electrocardiogram, was tested in mock circulation in dogs and in a human cadaver.

"There were practically no obstacles in the realization of the project. The equipment needed was available, the laboratory offered all facilities, but, mostly, the unique experience of Kolff in the field of artificial organs helped in quickly solving all emerging problems. The contribution of the engineer, Topaz, in setting and testing the equipment was valuable.

"The clinical application of the device started in 1967, when Adrian Kantrowitz used it in a number of patients.[1] The method has since been used all over the world to provide lifesaving temporary assistance, mainly in cases of post open-heart surgery when the patient cannot be 'weaned' from the extracorporeal heart-lung machine. It is also used in cardiogenic shock after acute myocardial infarction, in unstable angina or in pericardial tamponade in preparation for surgery, in rupture of the intraventricular septum, in irreversible ventricular tachycardia, etc.

"The method was presented for the first time at an American Society for Artificial Internal Organs meeting.[2] A comprehensive review of circulatory assistance techniques appeared in 1969.[3] The most recent review, with emphasis on intra-aortic balloon pumping, can be found in *Clinical Essays on the Heart*.[4] Further developments in the same field can be found in two other recent publications.[5,6]

"The paper is frequently cited because the method reported therein has been widely used in several experimental settings in order to investigate its peculiar effects on the circulation, as well as in patients for the treatment of various clinical syndromes. It made mechanical assistance practical, divulged the principle of counterpulsation, and pointed out the effectiveness of optimally timed interventions within a cardiac cycle.

"There is evidence that this work contributed significantly to the award of an honorary degree (Doctor of Science) to me by the University of Utah in 1983."

1. **Kantrowitz A, Tjonneland S, Krakauer J, Butner A N, Phillips S J, Yahr W Z, Shapiro M, Freed P S, Jaron D & Sherman J L, Jr.** Clinical experience with cardiac assistance by means of intraaortic phase-shift balloon pumping. *Trans. Amer. Soc. Artif. Intern. Org.* **14**:344, 1968.
2. **Moulopoulos S, Topaz S & Kolff W.** Extracorporeal assistance to the circulation and intraaortic balloon pumping. *Trans. Amer. Soc. Artif. Intern. Org.* **8**:85-8, 1962.
3. **Kolff W, Moulopoulos S, Kwan-Gett C & Krallos A.** Mechanical assistance to the circulation: the principle and the methods. *Progr. Cardiovasc. Dis.* **12**:243-70, 1969.
4. **Moulopoulos S.** Mechanical cardiac assistance. (Hurst J W, ed.) *Clinical essays on the heart*. New York: McGraw-Hill, 1983. p. 233-47.
5. **Moulopoulos S, Stamatelopoulos S, Petrou P, Saridakis N, Yannopoulos N & Jarvick R.** Left intraventricular "pseudoaugmentation." A new principle of mechanical assistance. *Trans. Amer. Soc. Artif. Intern. Org.* **27**:588-91, 1981.
6. **Sideris D, Nanas J, Chrysos D & Moulopoulos S.** Intra-aortic balloon assistance without a pump. *Eur. Heart J.* **4**:536-46, 1983.

