Der mittlere Druck der Flüssigkeit

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E. H. Weber is regarded as one of the fathers of experimental psychology and physiology (Figure 1). He and his two younger brothers are considered the Da Vincis of their time because of their seminal contributions to wide-ranging areas in medicine and physiology. Among their numerous discoveries were those in the 1825 publication of *Wellenlehre* (wave teachings), in which they formulated the basic laws of hydrodynamics and were the first to apply this branch of physics to the circulation of the blood. In 1850, realizing the importance of blood volume and vascular capacitance in a closed circuit, Weber described the equilibration of pressures throughout the circulatory system at zero flow (ie, cardiac arrest) as “mittlere Druck der Flüssigkeit” (mean pressure of the liquid).¹ Nearly 50 years later, on February 24, 1897, E. H. Starling, in his Arris and Gale Lecture at the Royal College of Surgeons of England, called to attention that this mean circulatory filling pressure (Pmcf) describes the fullness of the circulatory system and is inherently a measure of venous capacitance or venomotor activity.²

In the Fontan circulation, the paradoxical association of systemic venous hypertension with pulmonary arterial hypotension results in reduced cardiac preload and loss of venous capacitance. Because Pmcf provides an estimate of the upstream pressure that determines the rate of flow returning to the heart, its quantification, along with central venous pressure (CVP, or Fontan pressure), could be invaluable as a physiological gauge of venous well-being in patients with Fontan circulations. The problem, however, resides in how to measure Pmcf without stopping a patient's heart and waiting for blood to redistribute so that all the vascular pressures are equalized. Similarly, a less-invasive method to assess CVP in the ambulatory setting would certainly be a welcome tool for those looking after patients with Fontan circulations.

In this issue of the *Journal*, Masutani and colleagues³ present their study of a cohort of patients with Fontan

Ernst Heinrich Weber (lithograph by Rudolf Hoffmann, 1856).

Central Message

In patients with Fontan circulations, central venous and mean circulatory filling pressures can be estimated peripherally to provide valuable insights into their venous circulatory well-being.

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circulations to estimate CVP from peripheral venous pressure (PVP) and Pmcf from the arm equilibrium pressure (Parm-occ), which required acute and rapid occlusion of arterial and venous flow to the upper arm. Masutani and colleagues³ derived a regression equation that could predict CVP from PVP and demonstrated close correlation between Parm-occ and Pmcf (which they estimated by applying a Valsalva maneuver during diagnostic catheterization). They concluded that the adaptation of PVP and Parm-occ could assist in the monitoring of patients with Fontan circulations and guide pharmacologic interventions to improve hemodynamics. Although both the study and methodology employed were elegant, the concept that PVP is a surrogate for CVP in Fontan patients is intuitive. PVP approximates CVP in patients with Fontan circulations because the difference between PVP and CVP is simply a reflection of the venous resistance from the periphery to the vena cava. With obligatory loss of venous capacitance and resistance, along with inability to lower CVP through atrial filling, the difference between PVP and CVP becomes small and predictable. Interestingly, the observation of the abolition of a pressure difference between PVP and CVP was first seen in another vascular region of interest in patients with Fontan circulations, the splanchnic circulation. In 2001, the Great Ormond Street group⁴ demonstrated that the portal venous and hepatic venous pressures (ie, CVP) were essentially equal in patients with Fontan circulations. Whereas a transhepatic venous pressure gradient of 2 to