Non-invasive pulse contour cardiac output by Nexfin technology

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In many patients, continuous knowledge of the hemodynamic status would be of great value, however, invasive measurement of blood pressure (BP) or cardiac output (CO) may not be warranted. BP can be measured intermittently with an upper arm cuff. However, continuous non-invasive measurement of arterial pressure in humans is available since the early 1980s when Wesseling et al. [1] introduced the first Finapres device based on the volume-clamp method invented by the Czech physiologist Jan Peňáz [2]. Monitoring of a continuous CO allows for the detection of rapid changes in systemic flow that would otherwise be unnoticed by the recording of arterial pressure and heart rate [3]. Non-invasive and continuous tracking of changes in stroke volume (SV) can be obtained by ultrasound, thoracic electrical impedance or by minimally invasive methods that use arterial pulse wave analysis from an arterial line that is already in place for BP monitoring or sampling of blood gases. Recently a device became available for truly noninvasive and continuous monitoring of BP and CO, the Nexfin HD monitor [4,5]. We will review past and present developments in the methodology of finger pressure and continuous stroke volume/cardiac output by focusing on the methods and technologies that the Nexfin uses to measure noninvasive, beat-to-beat hemodynamics.

Nexfin uses the established volume clamp methodology and Physiocal criteria [6] for measurement of continuous BP in a finger. An inflatable cuff around the finger with an optical blood volume measuring system clamps the blood volume to a preset level by applying a pressure equal to arterial pressure throughout the cardiac cycle. In combination with Physiocal, calibrated recordings of the entire finger arterial pressure wave are obtained [6]. As a next logical step brachial pressure reconstruction was developed, which counteracted the pressure wave amplification in peripheral measurement sites like the finger. In addition, application of a level correction compensates for the pressure drop due to resistance to flow in the smaller arteries. The combination of these two methods results in pressures that are comparable to invasively measured brachial or radial BP. This resolves issues with earlier devices, which sometimes displayed mean finger arterial pressures that were much lower than invasive pressures. Further important improvements were established by an update of the cuff design using modern materials and optical components.

Nexfin uses a recently developed pulse contour method to determine CO (Nexfin CO-trek), building on earlier developments. The area under the systolic part of the pressure curve is divided by the aortic input impedance to obtain stroke volume, similar to the cZ pulse contour method (early Seventies). This cZ method used a simple formula containing heart rate, mean arterial pressure and patient age to determine input impedance. Tracking of changes was very good, but the absolute values could have a bias. More recent, the Modelflow method (Nineties) used a 3-element Windkessel description of aortic input impedance to calculate a flow curve from the pressure curve [7-10]. Integration of the flow curve yields stroke volume. In the Windkessel, the nonlinear pressure-area relation of the aorta was described as function of pressure, age, gender, height and weight assuring better absolute CO values and tracking of changes over wider ranges of pressure changes. The Windkessel model, incorporating nonlinear pressure dependency and patient data, is also used with the Nexfin CO-trek method, although in this case to calculate aortic input impedance. Combined with the area under
the systolic part of the pressure curve stroke volume can now be calculated. Whereas earlier methods were developed to use invasively measured pressures, CO-trek method operates equally well with noninvasive measured BP, enabling routine clinical application [5].


