CNAP – EVOLUTION OF CONTINUOUS NON-INVASIVE ARTERIAL BLOOD PRESSURE MONITORING

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Abstract: Blood pressure (BP) is one of the most important cardiovascular parameters in nearly every care area. A method for continuous non-invasive arterial pressure (CNAP) monitoring is described. CNAP is especially designed for perioperative, critical and emergency care. It concentrates on the clinically important BP-information such as absolute BP and BP-changes as well as physiological BP-rhythms and BP-waveforms, where other hemodynamic parameters like cardiac output (CO) and dynamic fluid management parameters (e.g. pulse pressure variation PPV) can be derived. For this kind of hemodynamic information, tailor-made mechanisms have been developed. Recent validation studies underline accuracy and clinical acceptance of the CNAP technology.

Keywords: Continuous, non-invasive, blood pressure

Introduction

Up to now beat-to-beat BP monitoring has required invasive placement of an intra-arterial catheter (IBP). Due its invasive nature, IBP is applied in less than 20% of surgical patients [1]. The remaining 80% are monitored with intermittent upper arm sphygmomanometers (NBP), although discontinuous NBP is unable to track hemodynamic instabilities in up to 40% of all cases [2].

In addition, the concept of hemodynamic optimization using continuous BP and its derived parameters such as CO, PPV, etc. has shown an increase in medical outcome and thus has rapidly found acceptance in anesthesia and

critical care [3]. Hemodynamic optimization could be performed in about 30% of all surgical procedures, if non-invasive continuous BP information would be available [1]. Non-invasive BP monitoring with accurate BP tracing as well as high-fidelity waveform to obtain hemodynamic parameters would be of high clinical interest.

However, patients in the OR, ICU or ER often receive high dose rates of vasoactive drugs to get their hemodynamic status regulated. These drugs not only induce fast changes in BP but also change the vascular tone of the peripheral arteries. Such vasomotor changes have a significant impact on the accuracy of BP in non-invasive technologies. Thus, older technologies have struggled with providing accurate values due to their lack of vasomotor artefact rejection [4, 5, 6]. CNAP was specifically designed to overcome these limitations. In this article the technological principles of CNAP and its advantages are briefly described and validation data is shown.

Methods

Continuous BP is measured with the help of a finger sensor combining two methods: The “Vascular Unloading Technique” (VUT) [7] is used for BP-rhythms and BP-waveforms and the new VERIFI-technology controls periods of slower BP-changes, where vasomotor tone may influence the measurement. Further, the resulting BP-signal is scaled to an initial upper arm NBP (absolute BP) by means of a mathematical transfer function (Figure 1).

Figure 1: Interaction between the measurement locations (upper arm cuff and finger sensor) and technological methods (NBP-calibration, VERIFI and VUT) used for different BP-information.

Upper arm cuff BP is the gold standard in clinical practice [8]. Due to its daily use in clinical routine it is obvious that the physician wants to obtain continuous BP that is as accurate as the gold standard. Thus, a mathematical calibration to NBP is performed using a transfer function [9]. VUT is a sound method for measuring BP rhythms and waveforms. Typical VUT methods use a single control loop [10], which has to deal with fast pressure increase and release in the cuff as well as with the tracking of BP changes for the stability of the system. In contrast to older methods, a number of interlocking control loops is used within CNAP. Each inner loop is responsible for a well-defined characteristic of its underlying control mechanism and provides near-ideal conditions for the surrounding outer control loops. There are multiple loops for BP-waveforms and a loop for slower BP-rhythms [11].

However, for BP-changes and long-term stability VUT is directly affected by changes in vasomotor tone. Thus, for the measurement of BP-changes, the so-called VERIFI-algorithm has been designed:

Vasomotor changes typically affect the long-term BP changes in a time range below physiological BP-rhythms. This time range is filtered out and the VUT system operates with the signal content of BP-rhythms and pulse waves only. Thus, the vasomotor effect is eliminated, but also all relevant information of BP-changes. For the restoration, the VERIFI-algorithm inspects the waveforms on a beat-per-beat basis and identifies, if the control loop set point corresponds to mean BP. When there is a deviation, the system corrects the set point on an adaptive basis until the set point equals mean BP [9]. This "Vasomotoric Elimination and Reconstructed Identification of the Initial set point" names the VERIFI-algorithm.

The accuracy and clinical value of CNAP was tested in several international clinical trials shown in Tab. 1 and 2.

Results

Table 1: Differences of IBP and CNAP (BP-changes):

Study (First Author)	Care Area	Pa-tients	Bias mmHg	SD mmHg
Jagadeesh, 2012 [12]	ICU	30	-0,04	2,05
Neuner, 2012 [13]	OR	100	-3,1	9,45
Bias 2012 [14]	OR	25	-1,8	10,3
Ilies, 2012 [15]	OR	90	-4,3	10,4
Jelezcov, 2010 [16]	OR	88	-1,6	11
Monnet, 2012 [17]	ICU	47	5	11

Table 2: Validation of BP-rhythms (PPV):

Study (First Author)	Care Area	Pa-tients	Bias %	SD %
Monnet, 2012 [17]	ICU	47	-0,6	2,3
Bias 2011 [18]	OR	35	0,6	2,6

Discussion

Studies in Tab.1 show that CNAP provides BP traces in OR and ICU during daily routine within a clinically acceptable difference to IBP. PPV can accurately be derived from the CNAP-signal (Tab. 2). Further ongoing research shows accurate CO-estimation from pulse wave analysis

(not shown). This high fidelity BP has technically become possible by combining VUT, NBP calibration and the VERIFI algorithm. The demonstrated accuracy, ease of use and non-invasive nature of the new CNAP technology allows clinicians to rapidly obtain all relevant BP information. CNAP allows for a new standard in routine patient monitoring in such areas where continuous hemodynamic information can clearly increase patient outcome.

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