Single cuff comparison of two methods for indirect measurement of arterial blood pressure: standard auscultatory method versus automatic oscillometric method

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Summary: With the introduction of automatic oscillometric systems for indirect measurement of arterial blood pressure (e.g. DINAMAP), the problem of correspondence between that method and the standard auscultatory method arose. For an exact and valid comparison of two methods, for physiological and methodological reasons, both measurements have to be performed simultaneously and using only one single cuff.

Applying a methodological approach fulfilling these preconditions and offering in addition the advantage of a graphic documentation of the individual measurement cycles, we were able to investigate both methods in a sample of 216 comparative experiments.

We found a mean difference (auscultatory method minus oscillometric method) between the methods (bias) of $-0.82 \text{ mm Hg} (-0.109 \text{ kPa})$ for systolic pressure, $1.25 \text{ mm Hg} (0.166 \text{ kPa})$ for diastolic pressure and $1.00 \text{ mm Hg} (0.133 \text{ kPa})$ for mean pressure. Except for systolic pressure, the differences were statistically significant (paired t-test and analysis of variance). We also obtained a significant negative correlation between the differences and the average of both pressure values (decreasing error with increasing pressure) and a significant negative correlation between differences and heart rate (decreasing differences with increasing heart rate).

The conclusions drawn from the comparative study are that, although the oscillometric method exhibited a tendency to higher systolic and lower diastolic measurement values compared to the auscultatory method, both methods are well comparable and the differences are below the level of physiological and clinical significance.

Key words: blood pressure measurement, noninvasive methods, auscultatory method, oscillometric method, comparison study

Introduction

The indirect and noninvasive measurement of arterial blood pressure using standard sphygmomanometry is one of the most frequently applied methods in clinical medicine. Although introduced in its basic form as early as 1896 by Riva-Rocci, cuff methods for the measurement of blood pressure have regained interest within the last few years, due to the fact of increasing introduction of automatization in medical technology. In this context the automatic detecting and processing of Korotkoff sounds (auscultatory method) proved to be a method susceptible for artefacts, especially in a noisy environment, during anaesthesia or in intensive care (6, 10). For this reason the principle of oscillometric recording, proposed originally by Erlanger and v. Recklinghausen was modified and implemented in a new generation of automatic sphygmomanometric systems (9). In addition to medical aspects instruments for the measurement of blood pressure have to meet certain requirements of the
bureau of standards. Therefore it is important to examine the problem of agreement of measurements performed via the automatic oscillometric method to measurements via the introduced standard auscultatory method.

At the first glance the comparison of two methods for indirect measurement of blood pressure seems very simple. However, if one takes a closer look at human cardiovascular physiology, a series of questions concerning the site of measurement, the simultaneity of both measurements to be compared and the specific characteristics of different methodological approaches has to be answered. In other terms, both methodological and physiological validity of the comparative measurements must be assured.

Referring to literature, most of the comparison studies reported are based on a design of successive measurements with both methods (e.g. 1, 4, 14, 15). A few (e.g. 5) take measurements simultaneously, but relying on the rather subjective decision of a technician using a stethoscope for detection of Korotkoff sounds. To our knowledge, there is only one paper describing a methodologically proper version of a comparison study, using invasively obtained pressure values for an estimation of the precision of the oscillometric method (11, 12). A methodologically as well as physiologically adequate approach for the comparison of two indirect methods for measurement of blood pressure is still lacking.

It is the goal of this paper to demonstrate a methodological approach for simultaneous comparison of indirect procedures for measurement of blood pressure to the standard auscultatory method using only a single cuff. The approach is demonstrated in a study evaluating the performance of the oscillometric method represented in the automatic instrument Dinamap (manufactured by Criticon). With the additional advantage of a fully documented experimental procedure even sophisticated demands of official commissions can be met. The evaluation of the comparison study is performed on the methodologically and physiologically valid basis using appropriate statistical methods. In this way both the errors between the methods under comparison and the statistical properties of the errors in relation to the absolute value of blood pressure and heart rate can be obtained.

Fundamental aspects concerning the comparison of two methods for measurement of blood pressure

All methods for the indirect measurement of blood pressure currently known are based on the same principle: the intravascular (arterial) pressure is compared to the pressure of an externally applied occluding cuff. When the pressurized occluding cuff is deflated, certain "indicators" are used to point out the equivalence of intravascular and cuff pressure. Such indicators are the appearance of sound phenomena (Korotkoff sounds, auscultatory method), oscillations in the pressure of the occluding cuff (oscillometric method), reappearance of palpable pulse distal to the occlusion (palpatory method) or the movement of the collapsed vascular wall itself, measured via ultrasonic devices (ultrasound-kinetoarteriography). All indicators are derived from the same phenomenon, the vibrational movement of the temporarily collapsed elastic vascular wall under the impact of the arterial pressure pulse wave.

For a reliable and exact comparison of methods for measurement of blood pressure the following conditions are an absolute prerequisite:

1. The measurement with both methods has to be performed simultaneously, because arterial pressure is subjected to rather large spontaneous fluctuations even in the absence of physical or psychical alterations of the subject.
2. The site of both measurements must be identical because differences in location may produce different absolute values due to hydrostatic pressure differences, changes of pressure amplitudes caused by alterations of arterial wall elasticity or by pressure drop across resistances in the arterial bed proximal to the location of the occluding cuff.