

Reintroduction of Riva-Rocci measurements to determine systolic blood pressure?

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ABSTRACT

Introduction: In 1896, Riva-Rocci introduced the upper arm cuff to measure systolic blood pressure. In 1905, Nicolai Sergeivich Korotkoff added the auscultatory technique, allowing measurement of both systolic and diastolic blood pressure. Both methods have, to our knowledge, never been formally tested against each other. In this study, we want to fill this gap in history. **Methods:** We measured systolic blood pressure by the Korotkoff sound technique and approximated the Riva-Rocci technique by measuring cuff pressure at the moment that the first pulsation became visible in Finapres readings, at the finger. This proxy of the Riva-Rocci technique allows an objective, offline, analysis. Measurements were performed simultaneously on the same arm in 57 subjects. **Results:** Systolic blood pressure measured by the Korotkoff sound technique was 167 ± 30 mmHg (mean \pm SD). Systolic blood pressure according to the Riva-Rocci technique was 165 ± 32 mmHg. The Riva-Rocci technique underestimated measurements with the Korotkoff technique by 1.8 ± 4.4 mmHg (NS, $p=0.79$). **Conclusion:** Riva-Rocci measurements of systolic blood pressure may be as good as the traditionally used Korotkoff measurements.

KEYWORDS

Blood pressure determination, Korotkoff, Riva-Rocci, systole

INTRODUCTION

In 1896, Scipione Riva-Rocci introduced the upper arm cuff to measure systolic blood pressure (BP) at the upper arm.¹ The radial artery was palpated while

the upper arm cuff was inflated. The pressure in a mercury sphygmomanometer, at the moment that the radial artery pulsations disappeared, marked the level of systolic BP. In 1905, Nicolai Sergeivich Korotkoff added the auscultatory technique. Korotkoff described the appearance and disappearance of sounds over the brachial artery, distally of the Riva-Rocci cuff, allowing the measurement of both systolic and diastolic BP.¹ BP measurement with an upper arm cuff in combination with auscultation of sounds, hence known as Riva-Rocci/Korotkoff (RRK) measurements, has become one of the most commonly performed measurements in clinical practice. RRK measurements are the gold standard against which other BP-measuring devices are tested.² In the original paper by Korotkoff in 1905, he mentioned that the systolic BP, measured by the appearance of the first sound, is several mmHg higher than the value determined by palpation of the radial pulse.³ To our knowledge, the Riva-Rocci method and the Korotkoff method, which were introduced before the era of evidence-based medicine, have not been formally tested against each other. In this study we want to fill this gap in history.

In order to compare the two techniques optimally, we approximated Riva-Rocci measurements by recording arterial finger pressure using Finapres.

MATERIALS AND METHODS

Patients

Measurements were performed in 57 healthy elderly subjects and patients with vascular disease and/or hypertension. Twenty-nine of them were women. These subjects were 34 to 83 years of age. Mean height was 1.68 ± 0.10 metres, weight was 82 ± 21 kg. Thirty-nine subjects were on antihypertensive medication at the time

of BP measurement. Three subjects were using nitrates, seven calcium antagonists, 15 ACE inhibitors, 19 β -blockers and 23 were taking diuretics. The subjects had been included in previous studies.⁴ We used previously collected BP registrations. These registrations were obtained in studies where BP measurements were performed to rule out pseudohypertension in patients with therapy-resistant hypertension and signs of arteriosclerotic vascular disease (n=13), to validate Finapres BP measurements in an elderly population (n=15) and to study the effects of cuff size on RRK measurements (n=29).⁴ The moment of return of flow measurements were performed offline and were done without knowing the RRK values. These studies were approved by the institutional review committees. All participants had given informed consent.

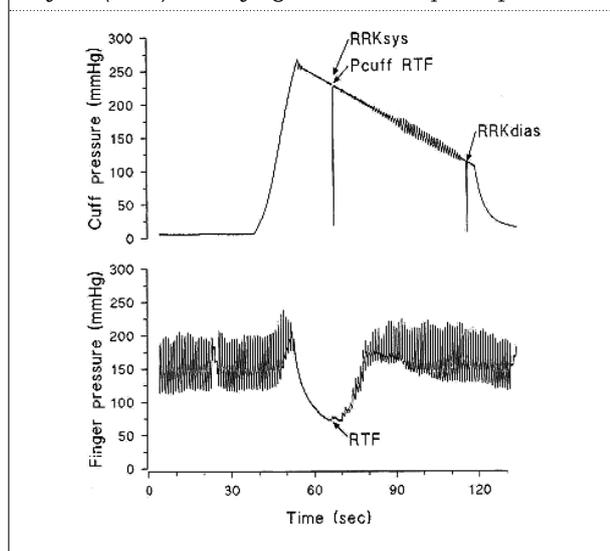
Measurements

Finger pressure (measured with Finapres, TNO model 5, BMI-TNO, Amsterdam, the Netherlands) measurements and RRK measurements were simultaneously performed on the same arm. The RRK measurements were performed by well-trained observers who had recently passed audiographic testing,³ using a 14 x 38 cm cuff on the dominant arm.

The cuff was inflated rapidly and deflated automatically at a fixed rate of 2.5 mmHg/sec. Cuff pressure was recorded with a strain gauge transducer (Motorola MPX 2050). At Korotkoff phase 1 and 5 a marker was given (figure 1).

Riva-Rocci systolic BP was measured offline determining the upper arm cuff pressure (Pcuff) at the moment that the first pulsation became visible at the finger (moment of return to flow, RTF) (figure 1).

Figure 1. Upper panel: Cuff pressure at Korotkoff phase 1 and 5 (RRKsys and RRKdias) and at return to flow at the finger (Pcuff RTF), lower panel: return to flow (RTF) at the finger indicated by Finapres



Statistical analysis

Data are presented as mean value \pm SD. In this analysis we used the average of two measurements in each subject. We compared the two different types of BP measurement using a paired Student's *t* test.

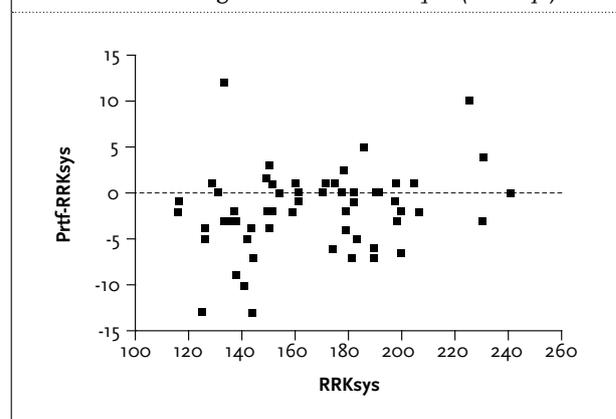
RESULTS

RRK systolic BP was 167 ± 30 mmHg. Heart rate was 67 ± 12 per sec. Pcuff at the time of RTF was 165 ± 32 mmHg. The mean underestimation by Pcuff at RTF compared with RRK systolic BP was 1.85 ± 4.4 mmHg (NS, $p=0.79$). This underestimation was independent of the RRK systolic BP level. The absolute BP difference between Pcuff at RTF and RRK systolic pressure was 0 to 5 mmHg in 45 subjects, 5 to 10 mmHg in nine subjects and >10 mmHg in three subjects (figure 2). There are no significant relationships between the systolic RRK measurements, heart rate and age and Pcuff RTF-RRKsyst. The first Korotkoff sound was noticed at the same time as RTF in 37 subjects, one beat before RTF in eight subjects and two beats before RTF in six subjects. Remarkably, in some subjects the RTF was noticed before the first Korotkoff sound was heard. The RTF was noticed one beat before the first Korotkoff sound was heard in five subjects and six beats before in one subject.

DISCUSSION

Riva-Rocci measurements of the systolic BP did not differ significantly from the Korotkoff measurements. As described by Nicolai Korotkoff himself, Riva-Rocci measurements underestimate Korotkoff measurements.³

Figure 2. Difference between cuff pressure at the moment of return to flow at the finger (Prtf) and the systolic BP measured with the Korotkoff sound technique (RRKsys) in relation to the systolic blood pressure measured according to the RRK technique (RRKsys)



However, the difference in this study is small (1.85 ± 4.4 mmHg) and nonsignificant. This difference might be explained by the time delay when the pressure wave travels from the upper arm to the periphery. Due to the lower pressure in the arterial system behind the upper arm cuff, the pressure wave propagates more slowly than at normal arterial pressure levels.⁶ Since we measured intra-arterial pressure contralaterally in the original study,^{4,6} we were able to measure the delay of the pressure wave arriving at the finger of the 'cuff-arm'. At the moment of RTF, this delay was 0.2 to 0.3 seconds. With a cuff deflation rate of 2.5 mmHg/sec, this delay accounts for 0.5 to 0.75 mmHg of the observed average difference of 1.85 mmHg difference. Furthermore, as already suggested by von Recklinghausen, the pressure wave may weaken on its way to the periphery.⁷ This explains the delay by one or two beats in eight and six subjects, respectively. On the other hand, we found that RTF preceded the first Korotkoff sound in some subjects. Apparently audible Korotkoff sounds are not always generated at the first passage of a pulse wave.⁸ This delay in generation of audible Korotkoff sounds might explain the slight underestimation of systolic RRK measurements when RRK measurements are compared with intra-arterial measurements.⁹

Limitations

The use of finger pressure measurements allowed us to register the pressure distally of the upper arm cuff. This pressure registration at the finger allowed us to make an optimal offline analysis. We were able to register the timing of RTF in relation to the Korotkoff sounds. It is, of course, possible that the finger of a human is less sensitive in detecting minor pressure excursions than finger pressure measurements with Finapres. If this is the case, Riva-Rocci measurements might further underestimate auscultatory measurements. Additional comparisons of RTF measurement, palpatory measurements and auscultatory measurements are needed to settle this issue, and to validate the palpatory Riva-Rocci measurements. Secondly, our study group is predominately made up of elderly patients with vascular disease and/or hypertension. Therefore, we do not know whether the outcome of this study can be applied to the general population. We did not follow the British Hypertension Society (BHS) protocol for validation of blood pressure measuring devices.¹⁰ This protocol was developed to compare a device to be tested with RRK measurements. In order to be able to use measurements on the same arm, the protocol prescribes sequential measurements of the device and RRK measurements, since the device measurements and the RRK measurements cannot be performed at the same time on the same arm. The trade-off for using same arm measurements is the introduction of small errors due to spontaneous blood pressure variability. In our study we compare Korotkoff measurements with a proxy of Riva-Rocci measurements. In

this case simultaneous performance of both measurements is possible. Since simultaneous comparisons are by nature superior to comparisons of sequential measurements, we felt justified not to follow the BHS protocol.

CONCLUSION

Riva-Rocci introduced the upper arm cuff and the palpatory technique to measure systolic blood pressure 112 years ago. Korotkoff added the auscultatory technique, allowing measurement of systolic and diastolic pressure. Nowadays, more emphasis is placed on the treatment of systolic, rather than on diastolic blood pressure in the management of cardiovascular disease. We therefore re-evaluated the potential value of systolic blood pressure measurements by the Riva-Rocci technique. We want to stress that studying the measurement of systolic pressure by no means means that we consider measurement of the diastolic pressure irrelevant. One hundred and three years after Korotkoff introduced the auscultatory technique, we have shown that Riva-Rocci and Korotkoff measurements of systolic blood pressure agree well. In doing so, we fill a gap in history. Riva-Rocci measurements of systolic blood pressure might therefore not only be a relic of the past, but also an accurate substitute for Korotkoff measurements.

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