

Comparison of Auscultatory and Oscillometric Blood Pressures

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Objective: To study the differences in blood pressure readings between the auscultatory and oscillometric (Dinamap model 8100; Critikon, Tampa, Fla) methods.

Design: Survey of 2 blood pressure instruments.

Setting: Public schools.

Participants: Seven thousand two hundred eight school-children aged 5 through 17 years.

Main Outcome Measure: Blood pressure levels.

Results: For all children combined, Dinamap systolic pres-

sure readings were 10 mm Hg higher (95% confidence interval, -4 to 24 mm Hg) than the auscultatory systolic pressure readings. Dinamap diastolic pressure readings were 5 mm Hg higher (95% confidence interval, -14 to 23 mm Hg) than the auscultatory Korotkoff phase V diastolic pressure readings.

Conclusion: These findings preclude the interchange of readings by the 2 methods. Caution must be exercised in the diagnosis of hypertension when an automated device is used.

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AN IMPORTANT element in pediatric practice is the routine measurement of blood pressure (BP). Since the accuracy of an oscillometric device in reflecting direct arterial pressure was reported in the neonate,^{1,2} infant and child,^{1,3,4} and adult,⁵ the Dinamap monitor (Critikon, Tampa, Fla) has become widely used in pediatric patient care. The comparison of BP values obtained during office visits against normative values is used as a screen for asymptomatic hypertension, assuming that those values are comparable whether or not the same methods for measurement were used. In a previous study, we reported that the systolic pressure levels obtained by the Dinamap method (model 1846SX) were 6 mm Hg higher ($P < .05$) than those obtained by the auscultatory method in fifth-grade children.⁶ It is not known if there is also a clinically important magnitude of difference in BP levels measured by the 2 devices for other age groups or how the newer model (8100) of Dinamap device compares with auscultatory BP measurement. This information is important in view of the wide clinical use of the new model of the Dinamap monitor.

The San Antonio (Tex) Triethnic Children's Blood Pressure Study was con-

ducted to test for possible ethnic differences in BP levels among 3 major ethnic groups of children. We used both the auscultatory method and Dinamap model 8100 because the latter was devoid of observer-related variability in BP readings. We found that there were significant differences between BP readings obtained by the 2 methods. This report addresses the magnitude and clinical implications of these differences.

RESULTS

Blood pressure readings obtained by the 2 Dinamap monitors (both model 8100) were similar. The mean (95% CI) of the systolic pressure by machine A was 111.4 mm Hg (92.2-130.6 mm Hg) and that by machine B was 112.0 mm Hg (92.8-131.2 mm Hg). Auscultatory BP readings obtained by the 2 observers were also similar. The mean (95% CI) of the systolic pressure obtained by observer 1 was 100.2 mm Hg (80.8-119.6 mm Hg) and that obtained by observer 2 was 102.8 mm Hg (83.0-122.6 mm Hg). The diastolic K5 readings obtained by the 2 observers were 56.2 mm Hg (37.2-75.2 mm Hg) and 56.3 mm Hg (40.6-72.0 mm Hg), respectively. For a given method, BP readings were similar between children who had their BP

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METHODS

In the San Antonio Triethnic Children's Blood Pressure Study, both oscillometric and auscultatory BP readings were obtained on 7208 schoolchildren aged 5 through 17 years. A letter of invitation was sent to the parents of each child enrolled in kindergarten through 12th grade. The parents of the participating children signed their consent and the children assented to participate in the study. The University of Texas Health Science Center's institutional review board approved the proposal. There were 3356 boys (46.6%) and 3852 girls (53.4%) of whom 4215 were Mexican American (58.5%), 2040 were non-Hispanic white (28.3%), and 953 were African American (13.2%).

The Dinamap model 8100 was used to measure BP, which was either preceded or followed by auscultatory measurement of BP. The order of the measurement was randomized so that about half of the children had their BP measured by the auscultatory method first followed by the Dinamap method (A rotation), and the remainder of the children had their BP measured first by the Dinamap followed by the auscultatory methods (D rotation). Two Dinamap monitors were used in this study. Research nurses who took oscillometric BP readings were taught to use the Dinamap monitor through in-service training, familiarization with the manual, and "hands-on" practice. The oscillometric device was calibrated for accuracy by the bioengineering department of our institution once every month or whenever a malfunction was suspected.

The auscultatory method of BP measurement used a Baumanometer mercury gravity sphygmomanometer (WA Bauman Co, Copiague, NY). Because of well-known observer-related variability,⁷ only those research nurses who successfully completed the 6-hour Instructor's Course for Blood Pressure Determination offered by the American Heart Association, Texas Affiliate,⁸ were selected to measure auscultatory BP. To ensure acceptable consistency among these nurses, a small group of children had their BP measured by several nurses. Two nurses, whose obtained readings were most similar and not statistically different, were selected to do the BP measurements. In the pilot study, the means of the systolic BP readings differed by 0.5 mm Hg (95% confidence interval [CI], -11.2 to 12.2) and the means (95% CI) of the diastolic BP readings differed by 2.4 mm Hg (95% CI, -11.6 to 16.5 mm Hg).

Three BP readings were obtained by each method on the right arm, with the patient sitting. The width of the BP cuff was selected to be 40% to 50% of the circumference of the upper arm as recommended by the American Heart Association⁹ and the Working Group of the National High

Blood Pressure Education Program (NHBPEP).¹⁰ This cuff selection method was shown to be appropriate for the oscillometric BP measurement in children by a previous study.⁴ Blood pressure cuffs manufactured by the Critikon Company were easily adaptable to the Baumanometer and were used for both the auscultatory and oscillometric methods. Dinamap BP readings were unknown to the observers at the auscultatory BP station.

The mean of the 3 BP readings was used for statistical analyses using the SAS Software (SAS Institute Inc, Cary, NC). For the analysis of the difference between BP readings by the auscultatory and the Dinamap methods, the mean of the 3 BP readings by the auscultatory method was subtracted from the mean of those by the Dinamap method for each subject, and the mean and 95% CI of the difference were computed. For diastolic pressure, only the Korotkoff phase V diastolic pressure (K5) was compared with the oscillometric BP readings, as recommended by the Working Group of the NHBPEP.¹⁰

Because of an unexpectedly large difference observed in BP readings between the Dinamap model 8100 and auscultatory methods, we compared measurements by this model with those by the earlier model (1846SX) in 2 different ways. First, we compared BP readings obtained by the auscultatory and Dinamap methods in an earlier study⁶ with those from the current study for fifth-grade children from the same school district. In that study, BP readings obtained by the model 1846SX and the auscultatory method were compared in the fifth-grade children.⁶ Second, BP readings were obtained by both models of the Dinamap monitor in 48 17-year-old students and the results were compared to test whether the 2 models gave significantly different readings. Triplicate BP readings were obtained in both arms simultaneously using model 1846SX on 1 arm and model 8100 on the other arm. The arm used for each model was alternated from subject to subject.

The difference in BP readings between the 2 different devices was related to the mean of those pressures suggested by Bland and Altman.¹¹ The rating system for automated BP devices recommended by the British Hypertension Society¹² was used to evaluate the Dinamap model 8100. This system grades the degree of agreement with auscultatory measurements based on the percentage of comparisons that fall within particular ranges of difference between the 2 measures. A grade of A indicates the differences to be relatively small in most comparisons, whereas B and C grades indicate a progressively lower degree of agreement.¹² A grade of D indicates an even lower degree of agreement, (less than 45% of the measurement difference is less than 5 mm Hg¹²).

measured first by the auscultatory method followed by the Dinamap monitor (A rotation) and those children who had their BP measured in the reverse order (D rotation) (**Table 1**). Regardless of the order of measurements, Dinamap systolic and diastolic pressures were higher than auscultatory measurements for both the A and D rotation groups.

There were large and clinically important differences in BP readings between the Dinamap and auscultatory methods throughout the ages studied (**Table 2**). The overall average systolic pressure obtained by the Dina-

map was consistently higher than that obtained by the auscultatory method. The mean (95% CI) differences were 10.2 mm Hg (-3.5 to 24.0 mm Hg) for systolic pressure and 4.7 mm Hg (-13.5 to 22.9 mm Hg) for diastolic pressure for all age groups combined (Table 2). The mean differences between the 2 BP methods were also similar among the ethnic groups and between the genders (**Table 3**).

Figure 1 shows the difference in systolic pressure between the 2 methods (Dinamap minus auscultatory) in 9- to 10-year-old boys plotted against the means of sys-

Table 1. Auscultatory and Dinamap Blood Pressure Readings According to the Order of Measurements*

	A Rotation	D Rotation
Auscultatory		
Systolic	101.9 (81.9-121.9)	100.8 (81.5-120.1)
K5 Diastolic	56.1 (38.3-73.9)	56.4 (39.1-73.6)
Dinamap		
Systolic	111.2 (92.0-130.5)	112.2 (93.1-131.1)
Diastolic	60.4 (45.4-75.4)	61.5 (46.5-76.1)

*Data are given as mean (95% confidence interval) mm Hg. A rotation indicates blood pressure measured first by the auscultatory method followed by the Dinamap monitor (Critikon, Tampa, Fla); D rotation, blood pressure measured first by the Dinamap monitor followed by the auscultatory method; and KS, Korotkoff phase V diastolic pressure.

Table 2. Mean Difference Between Dinamap* and Auscultatory Blood Pressure Readings According to Age Group†

Age Group, y	Dinamap SP Minus	Dinamap DP Minus
	AUS SP, mm Hg	AUS K5, mm Hg
5-6	11.6 (-1.1 to 24.3)	7.4 (-10.4 to 25.2)
7-8	11.3 (-1.4 to 24.0)	4.9 (-13.7 to 23.5)
9-10	10.6 (-2.9 to 24.1)	3.2 (-15.4 to 21.8)
11-12	9.9 (-3.8 to 23.6)	5.7 (-12.3 to 23.7)
13-14	10.0 (-3.7 to 23.7)	5.4 (-11.3 to 22.1)
15-17	8.3 (-6.4 to 23.0)	3.2 (-14.2 to 20.6)
Total	10.2 (-3.5 to 24.0)	4.7 (-13.5 to 22.9)

*Manufactured by Critikon, Tampa, Fla.
†Data are given as mean (95% confidence interval) difference. SP indicates systolic pressure; AUS, auscultatory; DP, diastolic pressure; and K5, Korotkoff phase V diastolic pressure.

Table 3. Mean Difference in Dinamap* and Auscultatory Blood Pressure Readings by Ethnicity and Sex†

	Dinamap SP Minus	Dinamap DP Minus
	AUS SP, mm Hg	AUS K5, mm Hg
Ethnicity		
African American	9.4 (-3.9 to 22.7)	5.9 (-11.3 to 23.1)
Mexican American	10.3 (-3.6 to 24.2)	4.6 (-13.6 to 22.8)
Non-Hispanic white	10.4 (-2.9 to 23.7)	4.4 (-14.0 to 22.8)
Sex		
Female	9.9 (-4.0 to 23.8)	4.7 (-13.3 to 22.7)
Male	10.6 (-3.3 to 24.5)	4.7 (-13.5 to 22.9)

*Manufactured by Critikon, Tampa, Fla.
†Data are given as mean (95% confidence interval) difference. SP indicates systolic pressure; AUS, auscultatory; DP, diastolic pressure; and K5, Korotkoff phase V diastolic pressure.

tolic pressures by the 2 methods. The figure was a typical plot for boys and girls of all age groups and is shown as a representative plot. The figure shows that the difference is independent of the BP readings observed in the study population. The differences in the diastolic pressure were also unrelated to the level of BP.

When the results of the current study were compared with those of the earlier study,⁶ the mean ages of the fifth graders were comparable between the 2 studies

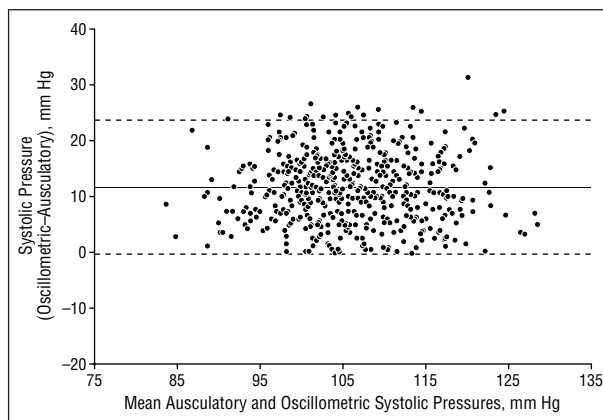


Figure 1. Magnitude of difference in systolic blood pressure readings by the Dinamap and auscultatory methods plotted against the means of systolic blood pressure readings by the 2 methods for boys aged 9 to 10 years. Two broken horizontal lines represent the 95% confidence intervals for the mean difference. The solid horizontal line represents the mean difference.

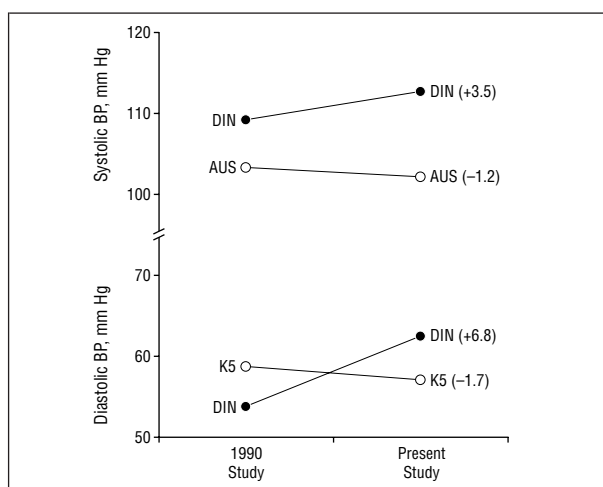


Figure 2. Comparison of blood pressure levels of fifth-grade students from 2 studies. Dinamap model 1846SX was used in the 1990 study⁶ and Dinamap model 8100 (Critikon, Tampa, Fla) in the current study. Although the populations were different, they are both fifth-grade students from the same school district. BP indicates blood pressure; DIN, Dinamap; AUS, auscultatory; and K5, Korotkoff phase V diastolic pressure.

(11.4 vs 11.6 years). The group means of systolic and diastolic pressures obtained by the Dinamap model 8100 were 3.5 mm Hg higher and 6.8 mm Hg higher, respectively, than those obtained by the model 1846SX in the 1990 study.⁶ Auscultatory pressures did not differ significantly between the 2 cohorts. In the current study, the mean auscultatory systolic pressure was 1.2 mm Hg lower and the mean K5 pressure was 1.7 mm Hg lower than those found in the earlier study (**Figure 2**). When readings obtained by the 2 models of the Dinamap monitor were compared for the 17-year-old subjects, the mean of the 3 BP readings by model 8100 was 1.8 mm Hg higher (95% CI, -10.2 to 13.0) for systolic pressure and 1.3 mm Hg lower (95% CI, -11.4 to 8.8) for diastolic pressure than those obtained by model 1846SX.

According to the British Hypertension Society grading system,¹² the systolic pressure readings of the Dinamap monitor 8100 achieved grade D. When compared with auscultatory K5 pressures, Dinamap diastolic pres-

sure also achieved grade D. The grade was D each time, whether examined according to sex, ethnicity, or age.

COMMENT

In this study, we demonstrated that there are large, clinically important differences between BP levels measured by the auscultatory method and those measured by the Dinamap model 8100, a popular oscillometric device. Thus, BP obtained by 1 method is not interchangeable with that obtained by the other. Although a significant, but small, difference in BP readings between the 2 methods might have been expected based on our earlier study in fifth-grade children,⁶ the large difference we observed was unexpected. In the earlier study, using the Dinamap monitor model 1846SX, the mean systolic pressure was 6.4 mm Hg higher than the auscultatory systolic pressure and the mean diastolic pressure was 3.4 mm Hg lower than the auscultatory K5 diastolic pressures.⁶ In the current study, the magnitude of the difference in systolic pressure was 10 mm Hg, which was higher than that reported in the earlier study,⁶ whereas the Dinamap diastolic pressure was 5 mm Hg higher than the auscultatory K5 diastolic pressure. The reasons for the large difference in systolic BP levels measured by the 2 methods are not clear. The difference may be due either to higher BP readings by model 8100 than the earlier model 1846SX, lower auscultatory systolic pressure readings by the current research team than the previous team, or a combination of the 2. Different models use different algorithms, measure different quantities,^{13,14} and thus may result in different BP readings.

O'Brien et al¹⁵ compared the Dinamap model 8100 with auscultatory BP readings using BP data from 86 subjects aged 15 to 80 years with a wide range of BP readings. According to the British Hypertension Society evaluation system,¹² the Dinamap model 8100 achieved a grade B for systolic pressure and a grade D for diastolic pressure.¹⁵ In our study, the Dinamap model 8100 achieved a grade D for both systolic and diastolic pressures. The reason(s) for the different ratings between the study of O'Brien et al and this study are not clear. The different age groups with different BP ranges and different auscultatory BP observers could have been contributing factors. In both children and adults, however, BP readings by the auscultatory and Dinamap methods were shown to be not interchangeable, at least for the model 8100. However, these data do not address whether the auscultatory or oscillometric measurement of BP, or which model of Dinamap, is more accurate. The important point, however, is that different methods can yield different values and that abnormal BP readings must be interpreted with this inconsistency in mind.

In conclusion, systolic pressure levels measured by the Dinamap model 8100 are approximately 10 mm Hg higher than those assessed by the auscultatory method in children aged 5 to 17 years. Dinamap diastolic pressures were on the average 5 mm Hg higher than auscul-

tatory K5 pressures. This finding precludes the interchange of BP readings by the 2 methods and indicates that caution must be exercised in the diagnosis of hypertension when this device is used. Similarly, the BP readings obtained by other automated BP measuring devices should not be considered interchangeable with auscultatory pressure readings.

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