Blood Pressure, Hypertension, and Ambulatory Blood Pressure Monitoring in Children and Adolescents

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Fixed essential hypertension in children is uncommon. Confusion surrounding the definitions and tools used in measuring blood pressure (BP), and the variable capacity to apply the definitions despite the device used explains this in part. In children, hypertension is defined statistically, based on a large normative population that is ethnically diverse. The standards were developed from the first BP measurement obtained in large studies, and the measurements were obtained using standard auscultatory sphygmomanometry. Technologic advances have seen the widespread introduction of oscillometric devices, which determine BP in a different fashion from auscultation, and the two values are not identical. In fact, as oscillometric devices use proprietary algorithms to calculate the BP, results are not readily interchangeable. Ambulatory BP devices have been added to this mix and offer unique opportunities for accurate diagnosis, and more effective therapies. Most ambulatory BP devices have neither been validated for use in children, nor have passed the validation process. A consensus document may be needed to optimize use and interpretation of data from ambulatory BP monitoring. Am J Hypertens 2002;15:64S–66S © 2002 American Journal of Hypertension, Ltd.

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The diagnosis and evaluation of hypertension in children remains elusive, despite nearly a century of blood pressure (BP) monitoring. Even the optimal technique by which to determine a child’s BP is controversial. The definition of BP from a physiologic perspective is clear. Stedman’s Medical Dictionary defines BP as the pressure of the blood within the arteries, maintained by the contraction of the left ventricle, the elasticity of the arterial walls, as well as the viscosity and volume of the blood.1 Systolic pressure is defined as the pressure occurring at the moment of ventricular systole, whereas the diastolic pressure is the pressure noted during ventricular diastole, immediately preceding systole.1 The actual values applied to these definitions have been based on the use of indwelling arterial lines, end-on to the flow of the blood with simultaneous electrocardiographic monitoring to determine the end of diastole precisely. Other methods to determine the BP have been developed, including palpation of the pressure, auscultation, and oscillometry. It is widely assumed that these methods are equivalent.

Are BP Measures Equal?
Direct measurement of the BP with indwelling arterial lines is technically difficult; existing standards must be followed to make the pressure reliable.2 Many early articles comparing BP by different measures with direct readings do not provide information to allow the reader to determine whether the direct intraarterial method was likely to be accurate. In addition, the site of the arterial line (ie, the size of the vessel into which it is placed) has an impact on the reported BP.3

Palpation
Palpation of the pulse is an ancient art. Determining pressure by palpation is comparatively newer. It is reasonable to ask how well palpation agrees with direct intraarterial BP measurement, but data are lacking. Indirect evidence suggests that directly measured systolic BP is higher than values detected by palpation. Korotkoff himself demonstrated that the first Korotkoff sound (K1, tapping) appeared before the pulse could be palpated.4 It has also been shown that K1 appears after the directly measured systolic
body awareness of digit preference, and must know the
server. This person must have good hearing acuity, must
the auscultatory method. Subsequent auscultatory efforts should be made by rapidly
inflating the pressure in the cuff to 30 mm Hg more than the palpated BP. Korotkoff demonstrated that K1 appeared
10 to 12 mm Hg higher than the pulse could be palpated. Korotkoff guessed that this was because the necessary
volume for the pulse to be palpated was greater than the
flow necessary to make the tapping sound he described.

Auscultation

How do Korotkoff sounds compare with direct measures? Recall first that the system necessary to measure BP by
auscultation is quite complex, and the observer com-
Figure 8: First-order model
pounds the complexity. Issues that need to be addressed in
auscultation studies include the manometer (mercury
[soon to be a historical note] o aneroid), the tubing, the
stethoscope, as well as the cuff and bladder. The state of
the subject whose BP is variable. Has he or she had
stimulants (eg, coffee or nicotine)? Has the subject been
resting for 5 min? Is he or she sitting with feet on the
floor and back supported? Is the arm supported? To all this, we
introduce the person measuring the pressure—the ob-
server. This person must have good hearing acuity, must
be aware of digit preference, and must know the “rules” of
the auscultatory method.

Assuming “ideal” auscultation, how good is the match between
the Korotkoff sounds and direct BP? These mea-
ures, as all relate to some component of BP, have strong
statistical correlations. Nevertheless, there can be some
remarkable differences between the two. K1 appears on
average 3 mm Hg below direct systolic pressure; K5
disappears on average 9 mm Hg above direct diastolic
pressure. There is still some controversy over the use of
K4 or K5 to reflect the “true” diastolic pressure in pedi-
atic patients. If the data cited here apply to children, K4
would clearly be much higher than the true diastolic.

Oscillometry

Recently, oscillometric devices have been widely intro-
duced for the measurement of BP. These devices are based
on the correlation between the oscillation generated by
pulses and the BP. The devices, at a minimum determine
mean arterial pressure, and may also estimate systolic
pressure. Systolic and diastolic pressures are reported us-
ing algorithms that are proprietary to the companies that
manufacture each device. Recently, it has been reported
that at least one oscillometric device has clear-cut skip
patterns, that is, the device does not ever report certain
systolic pressures. It is difficult to rely with certainty on
oscillometric results, unless one can find the validation
data. Calls for closer regulation of these devices have been
issued.

Given that background, one could expect a priori that
oscillometric devices would not give values that equal
intraarterial BP. Interestingly, one device was shown to
correlate quite closely with direct measures. In practice,
however, treatment decisions are based on casual BP that,
most often, are measured by auscultation (although it has
been established that auscultatory pressures are not the
same as directly determined values). Accordingly, it is
reasonable to expect that oscillometric devices will closely
approximate auscultatory results. However, it is not at all
clear that oscillometric devices yield values that equal
auscultatory readings. In addition, it has also been shown
that oscillometric values from one device do not necessarily
equal values obtained from devices made by other
manufacturers.

Ambulatory BP Monitoring

Using ambulatory BP monitoring (ABPM) may have some
advantages for evaluating a child for hypertension. For
example, ABPM provides multiple measures using a de-
vice that is consistent over the measures. This may well
provide a “truer” picture of the BP in a child. In adults, and
in a few small pediatric studies, there is also a better
correlation between ABPM data and cardiac outcomes.
The ABPM also identifies white coat hypertension and can
identify patients with nocturnal hypertension (nondip-
ners).

Most, but not all, ABPM devices are based on oscil-
lometry. Criteria to validate the monitors have been published
by both the British Hypertension Society (BHS) and
the Association for the Advancement of Medical Instrumentation (AAMI). As of April 2000, 23 devices had
been subjected to the validation procedure and results had
been published. Only two devices had undergone valida-
tion for children; both failed and could not be recom-
Yed based on the standards, although these devices
had achieved passing grades for adults. Five other devices
had been rated only C or D by the BHS standards, which
are below the level at which a device can be recommend-
ed.

What Is Hypertension?

For the adult population, the definition of hypertension is
more epidemiologic than statistical, with the cut-off value
determined based on the population’s risk of morbid
events at pressures higher than the cut-off. In contrast, for
children, the definition of hypertension is far more statis-
tical, using the 95th percentile of distribution of population
measures, based on height, age, and gender. The Task
Force on Blood Pressure Control in Children and Adoles-
cents compiled data on 61,206 children to determine these
percentile distributions. It is critical to recall that these
data are from the first measure obtained on each child in
each study. It is well recognized, however, that with repeated measures, BP regresses to a lower average value. The pediatric definition of hypertension, therefore, is arbitrarily higher than the true 95th percentile for the pediatric population.

For ABPM, the BHS has recommended the following upper limits of normal in adults: 24-h mean, 135/85 mm Hg; daytime mean, 140/90 mm Hg; nighttime mean, 125/75 mm Hg. In addition, the following patterns were recognized: normal, white coat hypertension, borderline hypertension, systolic or diastolic hypertension with a nocturnal dip, systolic or diastolic hypertension without a nocturnal dip, isolated systolic hypertension, and isolated diastolic hypertension. The BHS did not use other values, such as BP loads.14

No clear standards define hypertension as measured by ABPM in children. The obvious initial hurdle is to decide whether or not to use the Task Force casual values as the cut points for the normative data. Recall the Task Force values are from first measurements.15 Means obtained from ABPM, by definition, are not initial BP, and the means will likely be lower for any age, gender, and height than the corresponding Task Force values. In addition, most ABPM devices are oscillometric, and the Task Force norms are auscultatory. Is a comparison fair? Finally, assuming we can reach consensus, do we use the BHS divisions (mean 24-h, daytime, and nighttime)? How do we determine the bounds on “daytime” and “nighttime” in children?

**Potential Solutions**

The steps needed to address these issues and develop standards for the use and interpretation of ABPM in children will, on the basis of the points reviewed, more likely be solved by consensus than by rigorous science. Pediatricians will need to accept that, much like hemoglobin and hematocrit, the various tools to measure BP actually are measuring different physiologic expressions of the same phenomenon. It is appropriate that values from oscillometric devices approximate auscultatory values, but they need not be identical, and neither method should be held to equal the directly measured BP. When a pediatric ABPM article is reviewed, it should be acceptable if the device has passed validation studies, if that device is used as it was during the validation study, and if the values derived are clearly presented in a format that will also be the result of a consensus agreement. Ideally, the values should be correlated against another physiologic outcome measure, so that the clinical importance can be determined.

There is little doubt that without a consensus conference, there will be no way to end much of the potential for confusion and apparently conflicting data. The goals of such a conference would be to develop appropriate validation standards for pediatric use of BP devices. Once devices can be validated, then normative data can be developed. Such data would require that the consensus group has also developed criteria for analysis of the data. The group would need to determine how the population considered “normal” should be selected (eg, given the increased incidence of childhood obesity, and the direct relationship between obesity and elevated BP, normal children may need to be defined as those with certain body mass indices). The criteria would need to be simple to apply. Finally, such a consensus group would need to address the important issue of funding these critically necessary studies.

**References**