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Twenty-Four Hour Ambulatory Blood Pressure Monitoring in Adolescents with Type 1 Diabetes: Getting Started

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Abstract

Twenty-four hour ambulatory blood pressure monitoring (ABPM) is a valuable tool in the pediatric and adolescent population with type 1 diabetes. It provides useful information not readily available from sporadic clinic blood pressure (BP) measurements and a more reliable estimation of the subject's BP over an extended period of time. Ambulatory blood pressure monitoring is gaining popularity with clinicians and investigators alike. The American Heart Association has recently issued recommendations for the use of ABPM in children and adolescents. We have incorporated ABPM into our adolescent diabetes practice and present useful information for clinicians planning to initiate 24 h ABPM in their clinical practice.

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Introduction

Studies in patients with type 1 diabetes indicate that loss of the normal nocturnal dip of systolic blood pressure (SBP) may precede the development of microalbuminuria. This, in turn, suggests that nocturnal hypertension may be predictive of those individuals at risk for developing nephropathy.[1–3] Diabetic nephropathy is one of the leading causes of morbidity and mortality in patients with type 1 diabetes. It is estimated that 30–40% of patients are affected by diabetic nephropathy within four decades of the onset of diabetes. Hypertension is prevalent in renal disease, and lowering blood pressure (BP) is one of the main strategies for preserving renal function.[4] Untreated hypertension may lead to end organ damage and cardiovascular morbidity and mortality.[5]

Guidelines for normal BP values in children and adolescents have been established by the National High Blood Pressure Education Program Working Group on Hypertension Control in Children and Adolescents (**Table 1**).[6] Blood pressure measurements in clinic or office

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Abbreviations: (ABPM) ambulatory blood pressure monitoring, (BP) blood pressure, (DBP) diastolic blood pressure, (MAP) mean arterial pressure, (SBP) systolic blood pressure

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Table 1.
Classification of Blood Pressure[5]

	Systolic and Diastolic Blood Pressure
Normal	<90th percentile
Prehypertension	≥90^{+} percentile but <95th percentile or BP exceeds 120/80 mm Hg
Stage 1 Hypertension	95^{+-} (99th + 5) mm Hg
Stage 2 Hypertension	≥(99th + 5) mm Hg

settings may be falsely elevated, a condition known as "white-coat" hypertension. This phenomenon occurs in approximately 10–30% of the population[7,8] and in adults is defined as a BP of >140/90 mm Hg in a medical setting and as normal BP in the nonmedical environment.[5]

Ambulatory blood pressure monitoring (ABPM) allows for noninvasive automated BP estimations at frequent intervals during the day and night in a nonclinical setting.

The clinical value of ABPM in children and adolescents with type 1 diabetes includes the following:

1. The ability to detect white-coat hypertension.
2. The ability to assess nocturnal hypertension. In normal individuals, BP drops by at least 10% while sleeping; they are referred to as "dippers." Those whose BP does not drop during sleep by at least 10% are called "nondippers." There is increasing evidence that nocturnal hypertension is independently associated with end-organ damage, above the risk associated with daytime readings.[1,9] In addition, a "reverse dipper," one whose nocturnal BP is elevated above their recorded daytime readings, may be at even greater cardiovascular risk.[10]
3. The ability to measure the efficacy of antihypertensive treatment more accurately. Underestimation or overestimation of the BP can lead to inappropriate treatment, and thus accurate measurements and proper treatment with antihypertensive therapy is of paramount importance. Studies have shown that using 24 h ABPM instead of office random BP have resulted in significantly less need for antihypertensive medication.[11]

Recently the American Heart Association published recommendations for ABPM in children and adolescents.[12] These recommendations for ABPM included "evaluating BP levels more accurately in chronic pediatric diseases associated with hypertension"[12] such as diabetes. However, the recommendations also stated that "further research is also needed in the development of standardized protocols appropriate for validation of monitors used in pediatric patients."[12]

Getting Started

Choosing a 24 h Ambulatory Blood Pressure Monitor

A large variety of devices are available for measurement of 24 h ABPM. We use the SpaceLabs 90217 that, as of the date of this article, lists at $3385. Most similar devices list in a price range of $2000 to $4000. Software may be as expensive as $1000.

Automated devices have a cuff that occludes arterial flow and then gradually deflates. Two different BP detection techniques are in use: oscillometry[13] and the combination of oscillometry and auscultatory.[14] Auscultatory units include a microphone positioned over the brachial artery that detects the Korotkoff sounds. More popular are those that detect arterial oscillations that occur at various pressures. Systolic blood pressure corresponds to an increase in the amplitude of oscillations, and the mean arterial pressure (MAP) corresponds to the point of maximum amplitude of the oscillations. Diastolic blood pressure (DBP) is calculated using a detection algorithm. Oscillometry methodology can be used in noisy environments. When choosing a monitor, it is most important to assess whether it has been validated by either the protocol of the British Hypertension Society or the U.S. Association for the Advancement of Medical Instrumentation.[8,15] Monitors that have undergone validation testing are listed at www.dableducational.org.

Choosing the Proper Cuff Size

It is essential to use a cuff that is the proper size for the patient's arm circumference by measuring the circumference at the midpoint between the shoulder and the elbow.[14] If the cuff is too small, it will read BP as falsely high. Conversely, too large a cuff can lead to falsely low readings. The cuff width should be at least 40% of the arm circumference.

Other recommendations to consider are as follows:

- Apply the cuff snugly enough around the extremity, making sure that you can fit 1–2 fingers beneath the cuff to make sure it is not too tight. The individual should be able to bend his/her elbow freely while wearing the cuff. The indicator on the BP cuff

(midpoint of the bladder) should be placed over the brachial arterial pulsation.

- Movement can impede readings, so instruct the patient not to move while the device is attempting a reading.
- One should compare BP values with those taken on the contralateral arm to ensure that differences do not exceed 5 mm Hg. The nondominant arm is used to minimize data loss from arm motion and ensure greater success rate. In our population, we have 84% successful BP readings.
- Use of the auditory alarm reminds the patient that the cuff is starting to inflate (take a measurement); the individual should stop moving and talking to ensure an accurate reading. The auditory alarm is kept off during the expected sleep time. Talking can raise the SBP up to 17 mm Hg and DBP up to 13 mm Hg.[14]
- Assess the monitor operation by checking the BP in the office three times, waiting 30 s to 1 min between readings. We usually take readings sitting, standing, and then sitting again as follows: We place the cuff on the arm while the individual is sitting with their elbow semiflexed and obtain the first reading. We then get them to stand. While standing, we ensure that the cuff is not too loose by pulling on the cuff while their arms are at their sides (i.e., elbow extended) and then obtain a standing BP with ABPM. We obtain one more BP sitting before sending them home. We instruct them how to turn off the monitor and record the actual sleep–wake time. Initial readings may be elevated due to feelings of "first-time" or "unknown" factors. Program the monitor not to display the BP readings; inform the individual that they will not be able to view their recorded BP. This is done to minimize anxiety, which can lead to falsely elevated BP.
- Individuals are asked to wear comfortable, loose shirts and a belt. After the initial readings, teach the family how to shut off the monitor after the 24 h are complete. Failure to terminate the recorder after removing it from the arm could result in an incorrect percent of successful readings. Instructions are given to place the monitor in the protective pouch and have the person keep it securely in a pocket or belt. During sleep, they can keep it under a pillow or beside them in the bed.
- Monitors are not waterproof and therefore should be kept dry. Failure to keep dry may destroy the monitor's electronic systems. Instructions are given to keep the BP cuff in place for the full 24 h. Showering can be done before or after the 24 h period of time. There is concern that after removing the cuff, the person would not place it back on the arm correctly.
- We usually perform BP monitoring after school on a Friday afternoon so the patients are not wearing it during school hours. Even if the auditory reminder is set to the off position, the monitor makes noises as the cuff inflates, and this may cause undue stress or embarrassment for the individual, causing an increase in BP.
- We ask individuals not to participate in strenuous activities while wearing the monitor.
- New batteries need to be inserted with each use. Upon initiation of the monitor, individuals are asked what time they are planning to go to sleep and what time they are planning to awaken. We set the monitor to take readings every 20 min during the anticipated wake times and every 40 min during anticipated sleep times. They are provided with an index card and are asked to record their actual sleep and wake times so that upon downloading the recordings, the actual sleep and wake times can be used to analyze the data. This is essential to avoid underestimation of the nocturnal dip.[16] In addition, they are asked to report any unusual events. Individuals are asked not to nap during this time frame.
- Upon return of the monitor, reported actual sleep and wake up times should be recorded and reconfigured on the download.
- Wipe down the cuff with a sanicloth.
- Cuffs may be laundered without the bladder using a mild soap and air dried.
- Monitors should be stored according to the manufacturer's recommendation.

Currently there are no guidelines for defining white-coat hypertension in the pediatric/adolescent population. Therefore reimbursement is sporadic. We are located on Long Island, New York, and our current charges for ABPM is $160 with a reimbursement rate of between $0 and $130, depending on insurance and diagnosis code (see **Table 2**).

Download and Interpretations

The data obtained from the printout of the SpaceLabs ABPM system are shown in **Table 3** and **Figure 1**. Data provided includes SBP, DBP, and MAP for the entire recording period as well as for the defined day

and night time period. Percent dipping for both SBP and DBP is calculated from the mean values for daytime and nighttime BP as follows:

[(daytime BP – nighttime BP) ÷ daytime BP] × 100.

While many investigators use 24 h daytime and nighttime ambulatory BP to assess risk, some use BP load. The systolic and diastolic load refers to the percentage of ambulatory BP measurements above threshold, and this can be calculated manually or automatically, if the appropriate threshold levels are set in the analyzing software. Loads in excess of 25–30% are generally considered abnormal.[17] In one pediatric study, loads of >50% were shown to be predictive of left ventricular hypertrophy.[18] The suggested schema for staging ambulatory BP levels in children includes SBP load (**Table 4**).[12]

We make a recommendation to our patients with abnormal ABPM according to the American Diabetes Association guideline for abnormal BP in children and adolescents with diabetes (see **Table 5**).[19]

Table 2.
Coding and Reimbursement

CPT code	
93784	Ambulatory blood pressure monitoring, including recording, scanning analysis, interpretation, and report
ICD-9 Codes	
796.2	Elevated blood pressure reading without diagnosis of hypertension
V81.1	White-coat hypertension
401.9	Essential hypertension—unspecified (resistant)
V17.4	Family history/other cardiovascular diseases

Table 3.
Data Obtained from the Printout of the SpaceLabs Ambulatory Blood Pressure Monitoring System

Summary				
	Min	Mean	Max	Std Dev
Systolic	85 (1-03:54)	110	132 (1-10:34)	13.26 mm Hg
Diastolic	42 (1-02:34)	70	88 (1-12:54)	10.51 mm Hg
MAP	59	84	106	11.11 mm Hg
Heart Rate	51	73	106	11.17 BPM
Percent of Systolic Readings above period limits: 37.3 %				
Percent of Diastolic Readings above period limits: 27.1 %				
Percent of time Systolic was above period limits: 31.5 %				
Percent of time Diastolic was above period limits: 23.0 %				
Summary Period: 9:00 to 23:00				
	Min	Mean	Max	Std Dev
Systolic	93 (1-09:14)	119	132 (1-10:34)	7.79 mm Hg
Diastolic	63 (1-09:14)	76	88 (1-12:54)	6.59 mm Hg
MAP	73	91	106	6.83 mm Hg
Heart Rate	69	80	106	7.65 BPM
Percent of Systolic Readings > 120 mm Hg 47.7 %				
Percent of Diastolic Readings > 80 mm Hg 34.1 %				
Percent of time Systolic > 120 mm Hg 50.8 %				
Percent of time Diastolic > 80 mm Hg 31.9 %				
Summary Period: 23:00 to 9:00				
	Min	Mean	Max	Std Dev
Systolic	85 (1-03:54)	98	127 (1-23:14)	10.21 mm Hg
Diastolic	42 (1-02:34)	60	83 (1-23:14)	8.68 mm Hg
MAP	59	74	94	8.50 mm Hg
Heart Rate	51	63	81	9.09 BPM
Percent of Systolic Readings > 110 mm Hg 6.7 %				
Percent of Diastolic Readings > 70 mm Hg 6.7 %				
Percent of time Systolic > 110 mm Hg 3.6 %				
Percent of time Diastolic > 70 mm Hg 3.6 %				

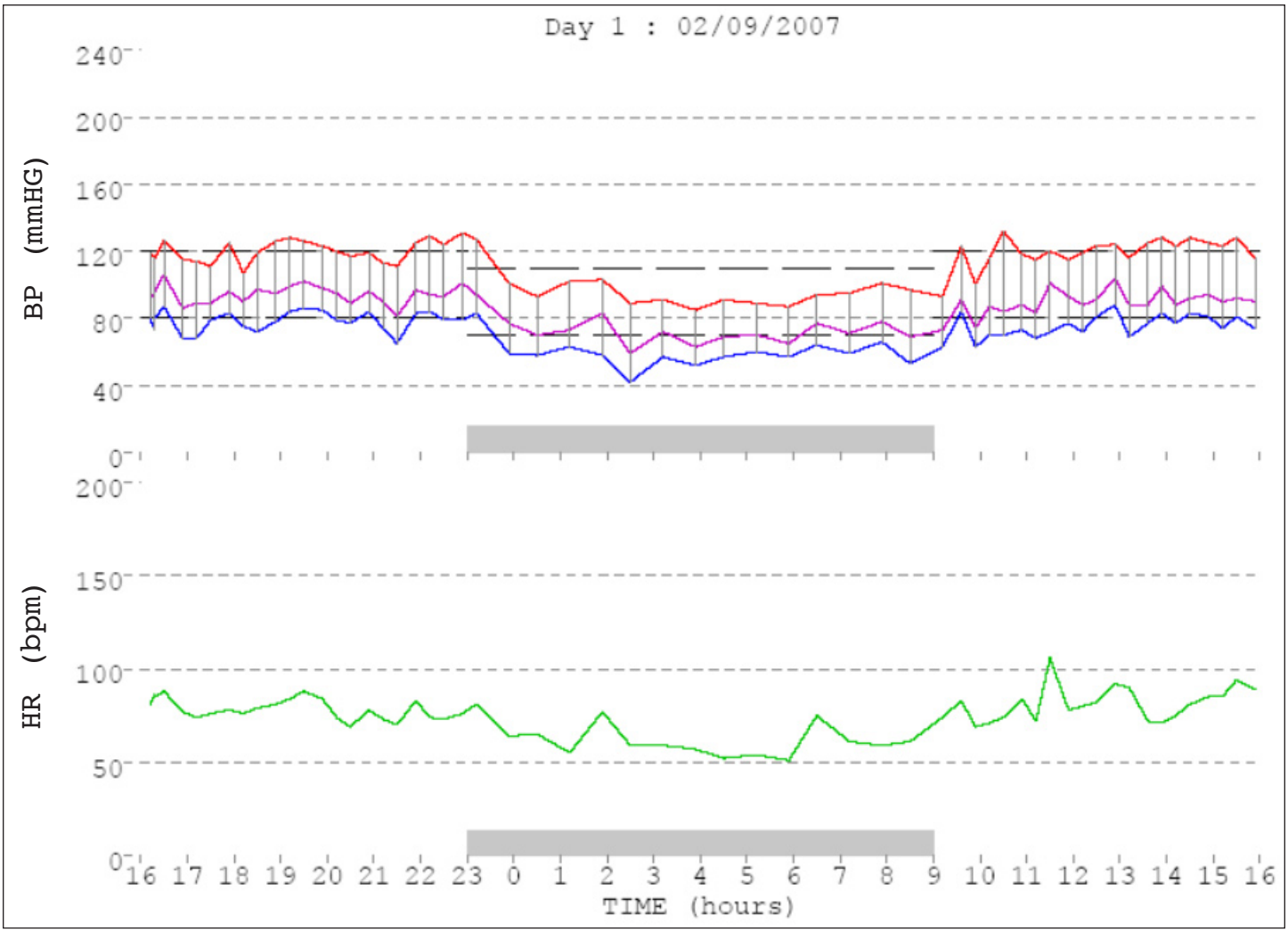

Figure 1. Data obtained from the printout of the SpaceLabs ambulatory blood pressure monitoring system.

Table 4.
Suggested Schema for Staging of Ambulatory Blood Pressure levels in Children[12]

Classification	Clinic Blood Pressure	Mean Ambulatory Systolic Blood Pressure	Systolic Blood Pressure Load (%)
Normal BP	<95th percentile	<95th percentile	<25
White-coat hypertension	>95th percentile	<95th percentile	<25
Masked hypertension	<95th percentile	>95th percentile	>25
Prehypertension	>95th percentile	<95th percentile	25–50
Ambulatory hypertension	>95th percentile	>95th percentile	25–50
Severe ambulatory hypertension (at risk for end-organ damage)	>95th percentile	>95th percentile	>50

Table 5.
American Diabetes Association Recommendations Regarding Hypertension

Family History/Other Cardiovascular Diseases
• Dietary intervention and exercise and improve glycemic and weight control
• If target BP is not reached in 3–6 months, initiate pharmacologic intervention
Systolic or Diastolic Blood Pressure Consistently above 95th Percentile in Children or >130/80 mm Hg, if 95% Exceeds That Value
• Pharmacologic intervention
Angiotensin-Converting Enzyme Inhibitors Should Be Initial Treatment

Reproducibility of 24 h ambulatory BP measurements has been demonstrated;[11] however, reproducibility of the nocturnal dipping status may not be as reliable.[20] In our experience, approximately one-third of adolescents with type 1 diabetes have an initial attenuated decline in nighttime SBP. However, of these putative nondippers who had repeat ABPM performed, almost two-thirds were found to have normal nocturnal.[16] For this reason, we rely primarily on the mean 24 h SBP and do not focus on the nocturnal dip.

Conclusion

With the advent of the recent American Heart Association recommendations for the use of ABPM in children and adolescents, more clinicians caring for children and adolescents with chronic pediatric diseases associated with hypertension, such as diabetes, will begin to incorporate ABPM into their practice. This article should provide useful information to aid the implementation of ABPM in the appropriate clinical setting.

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