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Hypertension Diagnosis and Management in Children and Adolescents: Important Updates

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Abstract

Purpose of Review This review aims to examine new literature and clinical practice guidelines on the diagnosis and management of hypertension in children along with the potential impact on clinical practice of the new recommendations.

Recent Findings Hypertension is underrecognized and underdiagnosed in clinical practice. Tools for improving diagnosis may include prompts in electronic medical records, use of a blood pressure screening table, and standardized blood pressure thresholds for adolescents. The recent AAP clinical practice guideline on the management of hypertension in children developed new blood pressure tables with lower norms that may increase the percentage of children diagnosed with elevated blood pressure and hypertension. In this high cardiovascular-risk population, therapeutic lifestyle modifications remain a fundamental management strategy.

Summary There is more evidence demonstrating the importance of identification and management of elevated blood pressure in childhood. New tools and strategies may improve recognition and treatment of hypertension as the number of children at risk increases.

Keywords Pediatric blood pressure · Pediatric hypertension · Hypertension diagnosis · Hypertension screening · Blood pressure guidelines · Hypertension management

Introduction

Blood pressure assessment is an important part of vital sign evaluation, and yet, it is frequently not done, not done correctly, or not interpreted properly. The issues are that it takes time and the right equipment to do it properly and the normative tables for comparison have been complex and cumbersome [1•]. In addition, high blood pressure is frequently asymptomatic and is unlikely the reason for the office visit so in a busy pediatric practice can easily be missed. But because hypertension is asymptomatic, it is precisely why the blood pressure needs to be measured in order to identify a treatable cardiovascular risk factor. Blood pressure can be a marker of fluid status, endocrine function, cardiac function, perinatal programming, and current and future cardiovascular disease risk. Making a diagnosis of hypertension may also lead to the identification of poor lifestyle habits, or a medication side effect, or an underlying kidney disease.

Until recently, the most current practice guideline for blood pressure management in children was the Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents sponsored by the National Heart, Lung, and Blood Institute and published in 2004 [1•]. Since this publication, there has been more research into the impact of high blood pressure on the cardiovascular health of children as well as longitudinal studies demonstrating adulthood risks of pediatric hypertension. In the most recent years, several workgroups have published updated guidelines on the management of pediatric hypertension including the American Academy of Pediatrics, Hypertension Canada, and the European Society of Hypertension [2••, 3•, 4•, 5]. While each guideline has minor differences, the major messages including the importance of measuring blood pressure in children, diagnosing hypertension, and managing elevated

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blood pressure are consistent. In the following sections, these important topics will be reviewed along with the latest evidence and practical tools to support the recommendations.

Importance of Blood Pressure Screening

Hypertension is most commonly a clinically silent condition yet can have a significant impact on the cardiovascular health of the child. Elevated blood pressure in childhood has been linked to cardiovascular changes including left ventricular hypertrophy (LVH), increased carotid intima media thickness (IMT), and increased vascular stiffness [6–8]. Around 40% of children with hypertension already have LVH on echocardiogram at presentation [9]. In addition, pathologic studies including the Bogalusa Heart Study and the Pathobiological Determinants of Atherosclerosis in Youths (PDAY) study have also demonstrated early atherogenesis in childhood and young adulthood related to elevated blood pressure [10, 11]. Additional target organ damage can be seen with 35–50% of children having hypertensive retinal vascular changes and around 25% having albuminuria at presentation that may regress with treatment [12–14]. In fact, most target organ damage is reversible with proper treatment of hypertension in children [15]. Luckily, mortality due to hypertension and cardiovascular disease is rare in children but remains the most common cause of mortality in adults worldwide [16]. Therefore, it only makes sense to identify and treat this cardiovascular risk factor at its earliest stage.

Elevated blood pressure during childhood not only has consequences on childhood cardiovascular health but also increases the risk of adulthood disease. Evidence from the Fels Longitudinal Study showed that even a single elevated systolic blood pressure reading during childhood increased the risk of both adulthood hypertension and metabolic syndrome [17•]. The risk increased sequentially with each additional childhood examination with elevated blood pressure. Analysis of the Metabolic Lifestyle and Nutrition Assessment in Young Adults cohort showed that the risk for adulthood hypertension increased with increasing adolescent blood pressure values without a discernable threshold effect [18]. This was also true within the Fels Longitudinal Cohort where the risk of adulthood hypertension in males at 35 years of age increased with increasing childhood blood pressure percentiles, including those considered normal [19]. In fact, in this population, to remain free of adulthood hypertension and metabolic syndrome, childhood blood pressure should be below the 50th blood pressure percentile [17•]. In a New Zealand birth cohort study, researchers have shown that blood pressure trajectories track from childhood into mid-adulthood and begin as early as 7 years of age [20]. It may be that controlling rates of adulthood hypertension may in part come down to management of childhood blood pressure.

Discovery of elevated blood pressure in children may also lead to identification of other cardiovascular risks as they often cluster in children and adolescents. There is a strong link between obesity and hypertension with the risk of developing hypertension being two times higher in children with obesity and four times higher in those with severe obesity compared to children of normal weight [21•]. In addition, studies have found the clustering of hypertension, hypercholesterolemia, or both in children with higher fasting glucose levels [22]. In US adolescents in the National Health and Nutrition Examination Surveys (NHANES), May et al. (2008) found a dose-response relationship with weight category and elevated blood pressure, low HDL cholesterol, and elevated serum glucose [23]. These factors in addition to low physical activity, smoking, and infrequent fruit consumption during childhood all increased the risk of adulthood increased carotid IMT in the Cardiovascular Risk in Young Finns Study [24]. Fortunately, the International Childhood Cardiovascular Cohort Consortium has also shown that if elevated childhood blood pressure resolves by adulthood, the adult carotid IMT is similar to adults where blood pressure was never elevated [25]. All of these cardiovascular risk factors are part of the American Heart Association's "Life's Simple 7" which they predict could reduce death from cardiovascular disease and stroke by up to 20% [26].

Underdiagnosis of Hypertension

Unfortunately, elevated blood pressure in children is underrecognized and underdiagnosed in clinical practice. Both the Fourth Report and the AAP Clinical Practice Guideline on hypertension (AAP CPG) recommend that all children 3 years of age and older have their blood pressure measured at clinical encounters but it would seem that this is not routinely done [1•, 2••]. In a study of consecutive children admitted to hospital, more than 50% had never previously had their blood pressure measured [27]. In a large study of children's clinics, blood pressure was measured in only 35% of all encounters and in 67% of preventive care visits [28]. Still more concerning, in a large US healthcare organization with 14,000 children, 3.6% had hypertension based on repeated elevated blood pressure measurements but 74% were undiagnosed [29•]. Even in children with the most severely elevated blood pressure in the stage 2 category, 41% went undiagnosed. From a survey of pediatricians regarding blood pressure measurement and assessment, it was found that 71% measure blood pressure only if there is a suspected risk factor for hypertension [30]. In addition, the majority admitted to looking up the blood pressure percentile only when they thought the reading may be elevated, but when given case scenarios, they often underestimated the blood pressure category with underrecognition of hypertension.

Given the difficulty with recognition of elevated blood pressure, much effort has been put into developing tools to improve hypertension diagnosis. As initial blood pressure readings are often completed by nurses, nursing assistants, or trainees who may not be familiar with pediatric blood pressure norms, the AAP CPG developed a simplified blood pressure table for screening (Table 1) [2••]. This table consists of the 90th percentile blood pressure for a child at the fifth height percentile for each age and gender and the elevated blood pressure threshold for adolescents [31]. This table is meant as a simple screening tool to flag children who may need to have their blood pressure repeated based on review of the full blood pressure tables. Use of this screening method has been shown to be the most useful of various screening methods to avoid underrecognition of elevated blood pressure in children and adolescents [32].

Many health care centers and organizations have moved to electronic medical records (EMR) for patient data collection and reporting. Building blood pressure thresholds and alerts into the EMR seems to improve the recognition of elevated blood pressure. Brady et al. [33•] incorporated an alert into the EMR of a pediatric primary care clinic that flagged all elevated blood pressures (≥ 90th percentile) as needing to be repeated manually. This tool increased the recognition of elevated blood pressure from 12.5 to 42% with the EMR alert. Others have found that a clinical decision support tool needs to be used in addition to an EMR to improve rates of blood pressure control in primary care clinics [34]. Twichell and colleagues [35] combined an app that could calculate and track the child's blood pressure percentile with their EMR and found that use of the app improved recognition of elevated blood pressure from 5 to 17%. Unfortunately, the voluntary app was only used in 5% of all encounters and 13% of encounters with elevated blood pressure and rates of recognition of elevated blood pressure remain less than optimal. There are also various electronic blood pressure apps available for phones that are able to determine blood pressure percentiles for children based on the updated AAP CPG blood pressure norms, but the important part seems to be remembering to use them.

Table 1 Simplified blood pressure screening table. Reproduced with permission from the journal *Pediatrics*, vol. 140(3), page(s) e20171904, copyright© 2017 by the AAP

Age (years)	Blood pressure (mmHg)			
	Boys		Girls	
	Systolic	Diastolic	Systolic	Diastolic
1	98	52	98	54
2	100	55	101	58
3	101	58	102	60
4	102	60	103	62
5	103	63	104	64
6	105	66	105	67
7	106	68	106	68
8	107	69	107	69
9	107	70	108	71
10	108	72	109	72
11	110	74	111	74
12	113	75	114	75
≥ 13	120	80	120	80

Diagnosis of Hypertension

The diagnosis of hypertension in children requires multiple blood pressure readings. At the first clinical encounter, if the initial blood pressure is elevated, it is recommended that the blood pressure be measured an additional two times during that visit [2••]. If initial elevated blood pressure readings are done with an oscillometric machine, it is recommended that repeat measures be completed manually by auscultation as oscillometric devices tend to overestimate blood pressure in children [36, 37]. If at the end of that visit the repeated blood pressure readings remain elevated, it is recommended that the patient return for a follow-up clinic visit to repeat the measurements again at a different occasion. If the readings remain elevated at the second encounter, the AAP CPG recommends that the patient and family be counseled on lifestyle modifications and return for a third visit to recheck blood pressure [2••]. If the blood pressure remains above the 95th percentile at the third visit, the patient is diagnosed as hypertensive. At this point, I would term the patient as having "clinic" or "office" hypertension and arrange for a 24-h ambulatory blood pressure monitoring (ABPM). The AAP CPG also recommends ABPM and/or subspecialty referral to confirm hypertension where these services are available [2••].

The reason for measuring blood pressure repeatedly before diagnosis of hypertension in children is based on ample evidence that blood pressure can be quite variable in children within and between visits. Many studies have shown that the percent of patients having elevated blood pressure reduces from around 10% at the first visit to about 2–3% by the third encounter [38, 39]. The blood pressure category or stage can also change between visits. Falkner et al. [40] showed that in children with blood pressure initially in the hypertensive range, 70% of boys and 73% of girls had only prehypertension or normal blood pressure at a 2-year follow-up. Nearly all studies show within a single encounter that the first reading is higher than subsequent readings, but there is recent research further describing this variability. One recent study showed that within visit blood pressures were more variable in younger children and in those with elevated blood pressure readings [41]. de Oliveira et al. [42] demonstrated the benefits of doing three blood pressure readings each visit and averaging

the final two blood pressure measures as the best representation of the blood pressure. Koebnick et al. [43] determined that by repeating an initial high blood pressure value during the same visit, you can avoid misclassification in 54% of these children and save them from an unnecessary follow-up visit.

There is also more attention being given to out-of-office blood pressures in the form of 24-h ABPM for diagnosis of hypertension in children and adolescents. One of the major benefits of ABPM is that you are able to identify white coat hypertension which occurs in around 20% of pediatric hypertensive clinic patients [44, 45]. White coat hypertension is defined as an elevated blood pressure measured in a clinic setting but normal blood pressure by ABPM, and it is therefore not treated with pharmacotherapy. In addition, unnecessary investigations could be avoided and studies have found an economic benefit to early ABPM [45]. In addition, the strongest correlation with cardiovascular damage in children comes from ambulatory and not clinic blood pressure [46, 47]. The difficulty lies in access to this procedure that requires child-sized-validated equipment and interpretation by a pediatric specialist. In an ideal world where ABPM was universally available, it would be the recommended approach for the diagnosis of hypertension in children as it is the gold standard method.

New Blood Pressure Norms and Classification

The determination of blood pressure status also requires comparison of measured values with appropriate blood pressure norms. The recent AAP CPG provided updated normative blood pressure tables based only on children of normal weight which differs from those from the Fourth Report which also included children with overweight and obesity [2••]. The effect of this re-analysis is that the 95th percentile blood pressures are around 1–4 mmHg lower than the Fourth Report standards [48]. Given the known effect of obesity on blood pressure, this revision has created norms more representative of a healthy population. The consequence is that, potentially, more children and adolescents will be diagnosed as having high blood pressure. Given that studies have shown evidence of target organ damage in children even in the prehypertension range by the Fourth Report standards, this adjustment seems to make physiologic sense to protect the cardiovascular health of these children [8].

The classification of blood pressure has also been modified in the current AAP CPG (Table 2) [2••]. The new categories are separated into children (1 to < 13 years old) and adolescents (≥ 13 years of age) with differences in the definitions. For children, the stages continue to be defined by blood pressure percentiles while for adolescents, the American College of Cardiology/American Heart Association adult guideline recommendations have been incorporated [49•]. The latest adult blood pressure thresholds have been used for adolescents as the adult guideline is based on hard outcome data which is absent in pediatrics, and the current adult blood pressure values are comparable to the adolescent blood pressure norms [50]. This modified classification should improve the recognition of elevated blood pressure in adolescents when only a few threshold blood pressure values need to be remembered. In addition, the transition of adolescents to adult care providers should also be enhanced if both groups are using the same blood pressure thresholds.

Impact of The New Blood Pressure Standards

There has been recent concern about the updated blood pressure norms and classification in the AAP CPG in terms of increasing the number of children identified with blood pressure abnormalities. Using NHANES data, Sharma et al. [51] determined that with the AAP CPG classification, 5.8% of the population would be reclassified to a higher blood pressure category. In this study, the percentage of children diagnosed with hypertension would increase from 2.7 to 5.8% and those with high blood pressure would increase from 11.8 to 14.2% with the AAP standards compared to the Fourth Report. The participants who were reclassified upward were more likely to be overweight or obese, have abnormal lipids, and prediabetes, suggesting the new standard is actually identifying many children with a higher cardiovascular risk [51]. Jackson and colleagues [52] with the Center for Disease Control (CDC) similarly looked at adolescents 12–19 years old in NHANES and found that when compared to the Fourth Report norms, the AAP CPG norms classified more youths with hypertension and fewer youths with elevated blood pressure. The newly reclassified hypertensive adolescents were more likely to be older, male, and have obesity. In addition to blood pressure classification, Khoury and colleagues [53•] also examined the correlation of target organ damage and hypertension by the Fourth Report and AAP CPG classification in children with type 2 diabetes mellitus and/or obesity. The prevalence of hypertension increased from 8 to 13% with the AAP CPG norms, but the sensitivity was higher for detecting target organ damage including increased carotid IMT, left ventricular mass, arterial stiffness, and diastolic dysfunction. Overall, it seems that while the prevalence of hypertension and elevated blood pressure may increase with the recent AAP CPG, the new classification is identifying a higher cardiovascular risk group that does warrant attention.

Investigation of Hypertension

The appropriate investigation of hypertension is guided by the likely etiology of hypertension within a particular population.

Table 2 AAP clinical practice guideline blood pressure categories for children and adolescents. Reproduced with permission from the journal *Pediatrics*, vol. 140(3), page(s) e20171904, copyright 2017 by the AAP

For children aged 1 to < 13 years	For children aged ≥ 13 years
Normal BP, < 90th percentile	Normal BP, < 120/< 80 mmHg
Elevated BP, ≥ 90th percentile* to < 95th percentile	Elevated BP, 120/< 80 to 129/< 80 mmHg
Stage 1 HTN, ≥ 95th percentile* to < 95th percentile + 12 mmHg*	Stage 1 HTN, 130/80 to 139/89 mmHg
Stage 2 HTN, ≥ 95th percentile + 12 mmHg*	Stage 2 HTN, ≥ 140/90 mmHg

*Percentile values should not exceed the adolescent threshold values; use whichever is lower

BP blood pressure, *HTN* hypertension

In the USA, obesity-related or primary hypertension is the most common cause beginning at around 5–6 years of age [54, 55]. The AAP CPG has reduced the number of investigations for secondary causes of hypertension and emphasized investigations for other cardiovascular risk factors [2••]. All hypertensive patients are recommended to have a urinalysis, chemistry panel including renal function, and lipid panel. In adolescents and obese patients include a hemoglobin A1c and liver enzyme screen for fatty liver. Renal ultrasound is limited to children less than 6 years of age or for those patients with an abnormal urinalysis or chemistry [2••]. Hypertension Canada and ESH continue to recommend a routine renal ultrasound for all hypertensive children and adolescents, and I include renal ultrasound in my hypertension clinic investigation pathway [3•, 5]. Even within primarily obese or adolescent populations, around 10% will have an abnormality on renal ultrasound with rates around 35% in children with secondary hypertension [54, 56, 57]. These identified renal abnormalities may influence your choice of antihypertensive medication (see below). Echocardiography to assess for cardiac target organ damage is recommended at the time of consideration of pharmacologic therapy initiation in the AAP guideline [2••]. It should also be considered to rule out coarctation of the thoracic aorta in younger children, those with reduced femoral pulses, those with a suspicious murmur, or in children with higher upper than lower limb blood pressure [58]. Additional or specific testing can be guided by the patient history, family history, physical examination, and/or results of the initial investigations.

Management of Elevated Blood Pressure

Therapeutic lifestyle modifications remain the mainstay and initial management of elevated blood pressure in children and adolescents [2••, 4•]. High dietary salt intake, which is a health concern in most populations, has been linked with elevated blood pressure and increased left ventricular mass in pediatric studies [59, 60]. Reduction of salt intake has been shown to reduce blood pressure in children and is a core recommendation in hypertension management [2••, 4•, 61]. In addition, institution of a DASH (Dietary Approaches to Stop Hypertension) diet in children with metabolic syndrome has been shown to reduce the prevalence of high blood pressure in this group [62]. In general, a DASH style diet is one that is high in fruits and vegetables, whole grains, low-fat dairy, and lean meats and low in fat, sugar, and salt. Increased exercise in children has also been shown to reduce blood pressure and improve carotid IMT and arterial stiffness [63, 64]. The exact amount and duration needed is not known as each study has used different protocols, but to increase the chances of success, your recommendations should likely be individualized for each patient and family. These interventions should not be done in isolation as there is evidence for greater benefit when both dietary modifications and physical activity interventions are combined [65]. The Hypertension Canada guidelines have incorporated this evidence and recommend the following: (1) height and weight be measured and body mass index (BMI) calculated at routine health visits, (2) achieving a BMI < 85th percentile is recommended to prevent and treat hypertension, and (3) a comprehensive approach including both dietary education and increased physical activity should be used [4•].

Pharmacologic treatment of pediatric hypertension should be considered when patients have stage 2 hypertension, are symptomatic, have target organ damage, have comorbid renal disease or diabetes mellitus, or have failed a trial of lifestyle modifications [2••, 4•]. The classes of antihypertensive medications that are approved for use in children by the Food and Drug Administration (FDA) and Health Canada are generally the newer agents including angiotensin-converting enzyme (ACE) inhibitors (e.g., enalapril), angiotensin receptor blockers (ARB) (e.g., losartan), calcium channel blockers (e.g., amlodipine), and a single beta-blocker, metoprolol. In a systematic analysis of drug trial data, Simonetti et al. [66] showed that all medications classes reduce the blood pressure by around 10 mmHg [66]. These results suggest that practitioners could prescribe whichever medications they are most comfortable using. Guidelines recommend initial mono-drug therapy with either an ACE inhibitor, ARB, or calcium channel blocker with beta-blockers as a less preferable choice due to their side effect profile [2••, 4•]. Beta-blockers are also not recommended first-line treatment in uncomplicated systolic hypertension in recent adult guidelines [49•, 67]. Beta-blockers should be used with caution in asthmatics, high-performance athletes, and patients with diabetes mellitus. ACE inhibitors and ARBs require intermittent bloodwork

monitoring of potassium and renal function, and females of child-bearing age need to be counseled on the risk of teratogenicity. The AAP CPG also includes thiazide diuretics as potential first-line antihypertensive medication while the Hypertension Canada guideline does not include this drug which has never been studied in children for hypertension [2••, 4•]. These antihypertensive medications are intended to be used in conjunction with continued efforts to improve diet and exercise.

There are a few special populations that deserve specific attention when considering pharmacologic treatment of high blood pressure. Hypertension occurs in children with diabetes mellitus with a prevalence of 4–7% in type 1 diabetes and 25–40% in type 2 diabetes [68]. These children are at risk for glomerular hyperfiltration, albuminuria, and renal failure, and therefore, ACE inhibitors and ARBs, which may reduce these negative effects, are recommended as first-line treatments [2••, 5]. Similarly, in children with chronic kidney disease, especially those with proteinuria, ACE inhibitors and ARBs are recommended as first-line treatments although the goals of therapy are lower (50th percentile blood pressure) in children with chronic kidney disease [2••, 5]. Management of the hypertensive athlete also deserves consideration as you need to balance the therapeutic benefits of exercise with the risk of worsening of the blood pressure during exertion. The AAP CPG recommends that athletes with hypertension should be assessed for (cardiac) target organ damage and that blood pressure should be treated to below stage 2 thresholds prior to competitive sport participation [2••]. The high-static sports, such as weight lifting, wrestling, and boxing, are the most concerning for raising blood pressure [69•]. In high-performance athletes, beta-blockers and thiazide diuretics are not recommended due to concerns of bradycardia, dehydration, and electrolyte disturbances and may be prohibited as doping substances in some high-level competitions [5, 69•].

Pediatricians seem more comfortable with advising on therapeutic lifestyle modifications than on prescribing antihypertensive medications [70]. Common reasons for not starting medication in a hypertensive adolescent include being unfamiliar with the drugs, concern for potential side effects, preference for referring to a subspecialist, and disbelief that adolescents will take prescribed medications [70]. Given the ever increasing list of potential medications, the concerns are understandable and so I have included some tips for prescribing antihypertensive medications (Table 3). If you know the cause of the hypertension, try to pick a drug to match the mechanism of action such as an ACE inhibitor to limit renin effects in renal scarring. To improve adherence, try to use drugs that are dosed once or twice daily. Try to avoid drugs whose side effects would create or exacerbate symptoms such as beta-blockers in asthmatics or drugs needing bloodwork monitoring in needle-phobic patients. Also, consider if the patient has another condition besides the hypertension that could be helped by a single medication such as using a calcium channel blocker in children who also have Raynaud phenomenon or a beta-blocker in children who also have migraines. Referral of patients to an expert in pediatric hypertension to help with management is also always an acceptable course of action.

Table 3 Tips for pharmacologic management of pediatric hypertension

- Try to *match* the medication to the mechanism of the hypertension if known
- Try to use medications *dosed* once or twice daily to improve adherence
- Try to *avoid* medications that could create or exacerbate undesirable symptoms
- Try to *choose* medications with desirable side effect profiles if possible

Consider:

- *ACE inhibitors or ARBs* in chronic kidney disease, renal scarring, proteinuria, diabetes mellitus, Marfan syndrome
- *Calcium channel blockers* in African Americans or patients with Raynaud phenomenon or migraines
- *Beta-blockers* in repaired aortic coarctation, stable heart failure, hyperthyroidism, Marfan syndrome, or patients with migraines or infantile hemangiomas
- *Diuretics* in chronic lung disease, glomerulonephritis, edema, hepatic fibrosis/portal hypertension

ACE angiotensin-converting enzyme, *ARB* angiotensin receptor blocker

Conclusions

In recent years, there has been publication of update guidelines for the diagnosis and management of hypertension in children based on emerging evidence. Longitudinal studies are reinforcing the importance of identifying blood pressure abnormalities in childhood. New tools and simplified blood pressure tables will make the diagnosis of hypertension simpler. Lifestyle modifications remain the core management of elevated blood pressure which is especially important given the additional cardiovascular risk factors that many of these children and adolescents have. Further research is currently underway to determine the blood pressure percentile or threshold that increases cardiovascular risks in children so that the norms and classification can be further refined. The ultimate goal is to minimize hypertensive target organ damage in childhood and reduce the risk of adulthood cardiovascular disease so that our patients may live long and healthy lives.

Compliance with Ethical Standards

Conflict of Interest Janis M. Dionne declares no conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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