# THE EFFECT OF A CLINICAL DECISION SUPPORT TOOL ON THE IDENTIFICATION OF PEDIATRIC HYPERTENSION

By

Eli M. Lourie, M.D.

A CAPSTONE

Presented to the Department of Medical Informatics & Clinical Epidemiology
and the Oregon Health & Science University
School of Medicine
in partial fulfillment of
the requirements for the degree of

Master of Biomedical Informatics

September 2013

School of Medicine

Oregon Health & Science University

CERTIFICATE OF APPROVAL

This is to certify that the Master's Capstone Project of

Eli M. Lourie

*"The Effect of a Clinical Decision Support Tool on the Identification of Pediatric Hypertension"*

Has been approved

[redacted]

Capstone Advisor

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## ACKNOWLEDGEMENTS

When I started this project last summer, I expected to be finished in time to graduate in the spring. Unfortunately, I found a number of speed bumps in my way. Bumpiest was the creation of my clinical decision support tool. I had not anticipated how difficult it would be to learn how to write code for our electronic medical record. Two months into my project, the two people with advanced knowledge on how to do this programming left my organization and I was left to fend for myself. I eventually succeeded and put the tool into production. After collecting the data and starting to write the paper, my life entered a three month period of turmoil during which it was difficult to find time to crunch the data and actually put pen to paper. I would like to express my gratitude to my advisor, Dr. David Dorr, who has shown such patience with me along the way. Now, at the end of my Odyssean journey, I can step back, take a breath, and enjoy the satisfactory feeling of a job well done. Indeed, I look at all the hard work and long hours taking classes while holding down a full time job and continuing to be involved in my kids' lives and feel immense pride.

I could never have reached this point without help from so many people. I would like to acknowledge all my professors and TAs who guided me; my fellow students with whom I collaborated on so many projects; and the administrative staff at OHSU, especially Diane Doctor and Lynne Schwabe, for helping me stay on track. Most importantly, I would never have taken my first step down the road to informatics if it wasn't for my friend and mentor, Tony Luberti. Thank you, Tony, for believing in me and showing me the way.

Lastly, I would like to acknowledge my wife, Jennifer, and my children, Jonah and Celia. Your support of my desire to learn and transform my career leaves me speechless. I love you, guys!

# ABSTRACT

**Introduction**: Pediatric hypertension has recently emerged as important clinical entity, however, it can be difficult to recognize due to the complicated process required to identify a child's blood pressure reading as high. Our objective was to determine if a clinical decision support tool could improve recognition of high blood pressure readings and hypertension.

**Methods**: We created a clinical decision support tool and inserted it into the electronic office visit in a pediatric ambulatory practice. The tool calculated, displayed and interpreted the percentiles of the patients' current and past blood pressures; and suggested an appropriate work up. Our outcome measures were number of patients with high blood pressure readings who had repeat visits within one month and who had high blood pressure placed on their problem lists. Data from the four month pre-intervention and post-intervention periods were compared.

**Results**: During the evaluation, there were a total of 2545 office visits; a blood pressure was taken at 1175 (46.1%) of those. The intervention tool was used in every office visit regardless of the presence of a blood pressure reading. Of a total of 1820 patients seen during the study, 100 (5.5%) had at least one high blood pressure reading. During the pre-intervention period, two patients had repeat readings within one month of the initial high blood pressure (4.0%) compared to seven post-intervention (12.7%) ($p = .21$). During the pre-intervention period, one patient had a problem list entry (2.0%) compared to eight post-intervention (14.5%) ($p=0.052$). Six patients had multiple high blood pressure readings, four of whom did not continue to get appropriate follow up and one who qualified for a diagnosis of hypertension but did not have it placed on their problem list.

**Discussion/Conclusions**: While not significant, the tool appeared to increase awareness of high blood pressure readings. The lack of appropriate follow up of patients with high readings is troubling; however, given more time and a larger sample size, the data may show significance. Additionally, including teaching about hypertension may increase clinicians' awareness of high readings and the need for appropriate follow up.

# INTRODUCTION

High blood pressure has emerged as an important clinical entity in pediatrics. Until the early Twenty-First Century, this importance was not recognized by the medical community due to a number of factors. Chief amongst these was the belief that pediatric hypertension was a rare disease. Studies published as recently as 2001[1] reported a prevalence of 1%. However, recent studies have estimated the prevalence of pediatric hypertension at 3.2% to 4.5 %.[2–4] While still not as prevalent as asthma (approximately 9%), pediatric hypertension is 3-4 times as prevalent as autism and epilepsy.[5]

While at one time, pediatric hypertension was believed to be chiefly due to secondary causes (e.g. kidney disease, endocrine disease, aortic coarctation), the increase in prevalence is thought by many to be related to an increase in essential, or primary, hypertension. Many researchers believe that this is directly related to the increase in childhood obesity, a common cause of essential hypertension. The presence of obesity in a child increases their risk of high blood pressure by two to three times.[4,6] In fact, obesity may more than double the prevalence rates of hypertension in children.[3,7]

In addition to the concern of increasing prevalence of pediatric hypertension, there are important long term consequences of having children with high blood pressure. Firstly, it is clear that high blood pressure in childhood leads to high blood pressure in adulthood.[7,8] According to a meta-analysis by Chen and Wang in 2008[8], "most studies found significant [blood pressure] tracking"[8(p3173)] into adulthood in both systolic and, to a lesser extent, diastolic blood pressures. More importantly, there is evidence that hypertension-related end organ damage occurs in children. In 2003, Vos et al.[9] reported that elevated blood pressure in adolescence is associated with an increased carotid intima-media thickness (cIMT), a marker for atherosclerosis (i.e. narrowing of artery walls). Perhaps most importantly, evidence suggests pediatric hypertension can increase left ventricular hypertrophy (LVH); an indicator that the heart is working harder, and a risk factor for adult hypertension outcomes. McNiece et al.[10] reported that the prevalence of LVH is 14.5% in children with Stage 1 hypertension and 30% in those with Stage 2.

While it is clear that it is important for clinicians to recognize, pediatric hypertension is a difficult diagnosis to make. According to the National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents[11] the definition of hypertension is systolic or diastolic blood pressure that is greater than or equal to 95$^{th}$ percentile for age, sex and height on at least three separate occasions. There are a number of barriers to achieving the criteria for diagnosis. Obtaining accurate blood pressure readings is one barrier to making a correct diagnosis. Children's blood pressure cuffs come in many different sizes and the use of an incorrect cuff can lead to readings that are too low or too high. Another barrier is correctly recognizing that a blood pressure reading is high. Unlike in adult medicine, high readings are not defined by a fixed number (i.e. 140/90); instead they depend on the blood pressure percentile. These percentiles can be calculated precisely using a complicated equation[11(pp571-3)] that uses the child's age, sex and height percentile as well as a number of constants. Instead of making this calculation, pediatricians have historically used tables[11(pp558-9)] to estimate whether a child's blood pressure reading is in the hypertensive range. Unfortunately, using these tables is usually not within a pediatrician's normal workflow. Because it takes extra time to locate the tables in the office, find the height percentile, and find the correct line on the table, many high blood pressure readings are not recognized. Additionally, many clinicians are not aware of a patient's previous blood pressure readings – a key element in making a correct diagnosis.[4]

Our goal in this project was to create a clinical decision support tool to make it easier to recognize high blood pressure readings and make a diagnosis of hypertension.  Our hypothesis was that better identification of high readings would lead to more repeat visits for follow up readings and to increased placement of the diagnosis of pediatric hypertension on patients' problem lists.

# METHODS

## CREATION OF THE CLINICAL DECISION SUPPORT TOOL

The CDS tool was created using Visual Form Editor[12], a program designed to create custom "forms" to work with GE Centricity EMR.[13] This program provided the infrastructure to create the user interface for the tool, as well as the ability to write custom programming using its proprietary programming language, Medicalogic Expression Language (MEL). MEL is similar to Visual Basic in its syntax which allows for programmers familiar with mainstream programming languages such a Java or C++ to quickly create clinical decision support content.

The user interface was designed with usability in mind, using the tenets laid out in the seminal paper by Bates et al.[14] The use of color was a paramount feature of the design. Throughout the form, normal readings appeared in green, hypertensive readings in red and pre-hypertensive readings in yellow. This green-yellow-red color scheme continued into the interpretation as well. Additionally, in the workup section, tasks that needed to be performed were shown in red, while those already completed were shown in green.

The tool was also designed to facilitate an optimized office workflow. One such feature in the design was one-click task completion. Many of the current forms used in Centricity EMR are designed to send the user to different modules within the EMR to complete tasks such as problem list entries or ordering of tests. The decision was made to create buttons that completed necessary tasks within the tool so the user would not need to spend unnecessary clicks performing tasks and then returning to the blood pressure form. Wherever possible, these buttons were used in the form and were color coded for easy visual recognition. Due to limitations of Visual Forms Editor specialist referrals could not be configured for one click ordering. Lastly, the form was designed to refresh its data whenever blood pressure data was entered or changed in the office visit. This assures that important changes in data were not missed due to users not performing a task, like pushing a "refresh" button.

The tool was created in four major sections. The first section, shown in Figure 1, was entitled "Today's Blood Pressure" and displayed information from the current visit. The latest blood pressure was presented along with the percentile for both the systolic and diastolic readings. Additionally, the systolic and diastolic blood pressures that would represent the 95$^{th}$ percentile and 99$^{th}$ percentile – the current patient's threshold for stage 1 and stage 2 hypertension – were presented so the user can see how close or far away from a hypertensive reading the patient is. The ability to enter a new blood pressure or height reading if necessary was also added to located in this section.

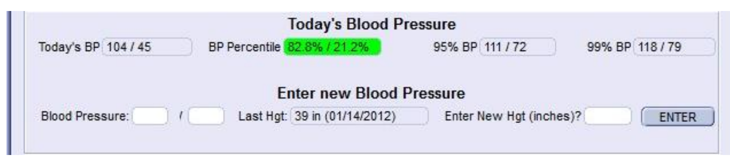


Figure 1. First section of the tool; dedicated to blood pressure readings from the day of the visit

The second section, entitled "Last 3 Blood Pressures" and shown in Figure 2, displayed the previous three blood pressures, the dates recorded and their percentiles. By displaying the last three readings, the tool easily made the user aware of previous readings and allowed the user to see if the patient has met the requirement of three high blood pressures to diagnose hypertension.

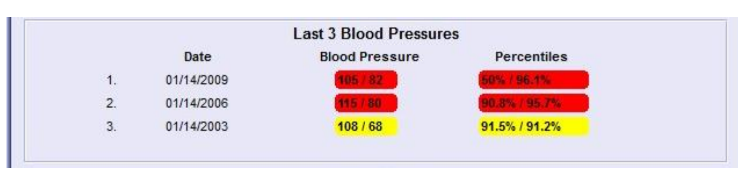


Figure 2. Second section of the tool; displaying the last three blood pressure readings and their percentiles

The third section, named "Interpretation" and shown in Figure 3, gave the user an interpretation of the recorded blood pressures. It informed the user whether the patient had hypertension, was at risk for hypertension, or was normotensive. For patients at risk, the interpretation section also reminded the user of the requirements for making a diagnosis of hypertension.

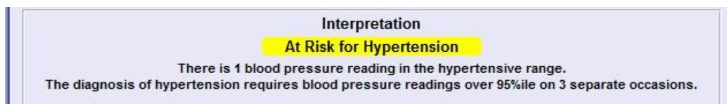


Figure 3. Third section of the tool; displaying the interpretation of the blood pressures

The final section, shown in Figure 4, contained the recommended workup. It was located just below the interpretation and recommended any needed workup of the patient. No workup was recommended for normotensive patients. For patients at risk for hypertension, the tool suggested a repeat blood pressure within one to two weeks. Patients meeting criteria for a diagnosis of hypertension have the most recommendations. First, if hypertension was not on the problem list, the user was given the option to add it with the touch of a button. Next, the form checked for the presence of an initial medical workup within the past 180 days. The recommended workup came from the guidelines published in Pediatrics in 2004.[11] The workup consisted of three parts: laboratory tests, radiology tests and specialist referrals. For the laboratory tests, the tool looked for the presence of orders or results of a complete blood count, a basic metabolic panel, lipid panel, urinalysis and urine culture. Any tests not found could be ordered with button clicks. For any parts of the workup that the tool could not search, such as renal ultrasounds, echocardiograms or specialist referrals, the tool looked for the presence of outstanding orders for those tasks. The buttons for the radiology tests and specialist referrals were colored yellow to alert the user that they must be alert to the possibility that these items are not as reliably denoted by the form as were the problem list and laboratory tests.

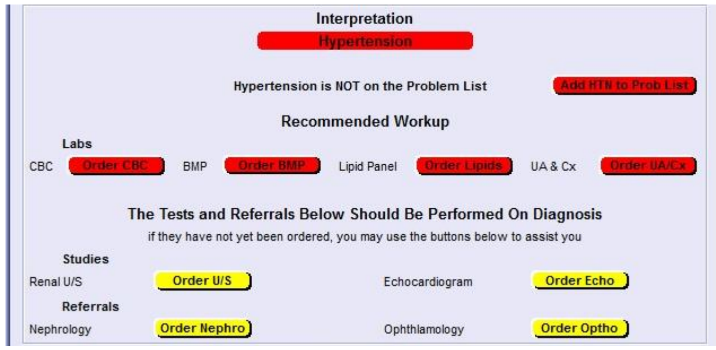


Figure 4. Fourth section of the tool; displaying the recommended workup and containing action buttons to perform needed tasks

To allow the user interface to function properly, we needed to create underlying code to run the tool. The tasks that needed to be performed were:

- Gathering the previous blood pressure and height readings
- Finding the closest height reading to a given blood pressure
- Calculating the percentiles from a given blood pressure and height
- Searching for ordered or resulted tests/referrals
- A master "Driver" function to run it all

Using Visual Forms Editor and MEL, we wrote a number of custom functions to achieve these ends. The first function, called GetSortedSignedObsArray(), was designed to collect any needed discrete data observations in an array and sort them from earliest to most recent. This function was used to collect blood pressure, height, and all necessary laboratory test data. To be able to calculate blood pressure percentiles, a second function, GetClosestHeightData(), was created to find the height reading closest to a given blood pressure. For each blood pressure, this function iterated through all height readings (which had been sorted in order of date done by the previous function) until both the blood pressure date and height date were the same or the amount of time between the blood pressure date and height dates began to increase – an indication that the dates are getting further apart. Once the closest height was found, another function, GetBPZscore(), calculated the z-score based on the standard equation and constants.[11] Lastly, a master "driver" function was created to run the tasks necessary for the form to perform. These tasks included collecting the output from the previously described functions, presenting them to the user in the appropriate color, counting the number of abnormal blood pressure readings and presenting the appropriate interpretation and workup options.

## STUDY DESIGN

The setting for this study was an inner city, academic pediatric practice. All patients ages 3 years and older seen for physician office visits between the months of November 2012 and June 2013 were included in the study. Both well and acute visits were included. The study used a simple time-series, quasi-experimental design where the four pre-intervention months were used as a control for the four post-intervention months. The clinical decision support intervention began on March 1, 2013. This intervention was part of a process improvement project within the pediatric practice for which IRB approval was waived and individual consent was not needed.

The intervention tool was introduced into the suite of EMR forms the practice used during all office visits. After interviewing the practice's clinical staff about the ideal placement of the tool within these forms, the tool was placed just after the vital signs form so that the users would be able to easily see and interact with it in their normal workflow. All clinicians were trained on the use of the form and any clinical decision support recommendations which might be presented.

Data was extracted from the Centricity EMR's Oracle database with SQL queries and placed in Microsoft Excel spreadsheets. Data collected included demographics (age at time of office visit, sex and race) and clinical data (systolic and diastolic blood pressure, height readings, and problem list entries). For each month of the study, and pre- and post-intervention periods, we counted the number of patients who had office visits, office visits with blood pressure readings, number of high readings, and presence of hypertension-related diagnosis codes on problem lists. We chose the ICD-9 codes that are generally used for hypertension which are listed in table 1. Patient-level data was collected so that we could assess the amount of time between blood pressure readings. Chart review was not performed.

**Table 1** ICD-9 codes used in querying the problem list

| ICD-9 Code | Description |
|---|---|
| 401.x | Essential hypertension |
| 402.x | Hypertensive heart disease |
| 403.x | Hypertensive chronic kidney disease |
| 404.x | Hypertensive heart and kidney disease |
| 405.x | Secondary hypertension |
| 796.2 | Elevated blood pressure without diagnosis of hypertension |

To assess the effectiveness of the tool, we chose two outcome measures that have been used in previous studies assessing physician response to high pediatric high blood pressure readings.[4,15] The primary measure was the number of patients with high blood pressure readings who had repeat measurements within one month of their high reading. Our assumption was that the tool would have recommended repeat readings to lead the user toward making a diagnosis of hypertension. Our secondary measure was the number of patients with high blood pressure who had either hypertension or high blood pressure readings indicated on their problem list. The $\chi^2$ test was used to compare the pre- and post-intervention results.

# RESULTS

During the eight month study period, 1820 patients aged 3 years and older were seen in the study practice for a total of 2545 individual office visits. Demographic details of the patient population can be seen in table 2.

**Table 2** Patient demographics

| Characteristic | Num of Patients | Percentage |
|---|---|---|
| Sex | | |
| Male | 938 | 51.5% |
| Female | 882 | 48.5% |
| Race | Num of Patients | Percentage |
| Black | 1339 | 73.6% |
| Caucasian | 308 | 16.9% |
| Hispanic | 57 | 3.1% |
| Asian | 11 | 0.6% |
| Undetermined | 105 | 5.8% |
| Age ranges | Num of Patients | Percentage |
| 3 to 5 | 479 | 26.3% |
| 6 to 8 | 424 | 23.3% |
| 9 to 11 | 348 | 19.1% |
| 12 to 14 | 278 | 15.3% |
| 15 to 17 | 244 | 13.4% |
| 18+ | 47 | 2.6% |

The patient population skewed younger with 903 patients (49.6%) under 8 years of age. The predominant race of the population was black (73.4%) followed by Caucasian (16.9%); 5.8% were of either unknown or undetermined race. A total of 2545 office visits (consisting of well and acute visits) occurred during the study period. The number of patients seen pre and post intervention was not significantly different. Blood pressure readings were taken at 1175 visits (46.1%). Specific data regarding office visits is summarized in table 3. Month to month, the percentage of visits with blood pressure readings ranged from a low of 38.9% in January to a high of 53.4% in May.

**Table 3** Monthly numbers of patients seen and blood pressure readings taken

| Time Period | Number of Patients Seen | Number of Patients with BP Readings | Number of Patients with High BP Readings |
|---|---|---|---|
| Month | | | |
| November | 335 | 176 | 19 |
| December | 309 | 130 | 9 |
| January | 378 | 147 | 16 |
| February | 296 | 128 | 6 |
| March | 334 | 139 | 12 |
| April | 336 | 158 | 21 |
| May | 331 | 166 | 10 |
| June | 246 | 131 | 12 |
| Intervention period | | | |
| Pre | 1318 | 581 | 50 |
| Post | 1247 | 594 | 55 |

The total number of patients with at least one high blood pressure reading was 100 (5.5%). Of these, only nine (9.0%) were brought back within one month for repeat readings. During the pre-intervention period, two patients had repeat readings (4.0%) compared to seven post-intervention (12.7%) (not significant, $p = .21$). A total of six patients (6.0%) had multiple high readings, only one of which (1.0%) had the necessary three high readings to make a diagnosis of hypertension. All of the other five patients with multiple high readings had two consecutive high readings. One of these had a subsequent normal reading and the other four had no further readings.

There were nine patients who had high blood pressure readings and also had either hypertension or elevated high blood pressure on their problem lists (9.0%). During the pre-intervention period, one patient had a problem list entry (2.0%) compared to eight post-intervention (14.5%) (not significant, $p=0.052$).

# DISCUSSION

The purpose of this study was to evaluate whether adding a clinical decision support tool into the normal workflow of a pediatric ambulatory practice could positively affect the approach to patients with high blood pressure. While this study failed to show significant changes in the awareness of pediatric hypertension in the pediatric practice, it did produce some encouraging data. Immediately after the implementation of the blood pressure tool, there was a three and a half fold increase in repeat readings and an eight fold increase in problem list entries. This suggests the tool did increase awareness of high blood pressure readings. One of the reasons for these findings may be the tool's ability to make the user aware of the normal blood pressure range and the previous readings for a particular patient; both of which are thought to be reasons for poor recognition of high blood pressure readings.[4]

Although we were encouraged by the apparent increased awareness of high blood pressure readings, there is still room for improvement. It was expected that displaying the blood pressure percentiles within the normal workflow of an office visit would lead to a more aggressive approach to high readings. We wanted to see post-intervention improvement compared to both pre-intervention data and to published baselines. For our baselines, we used two recent studies that looked at how pediatricians approached high blood pressure readings absent clinical decision support. The first was large retrospective study by Daley et al.[15] who reported that 20.9% of patients with a high blood pressure reading had a repeat reading within one month and 1.6% of them had a hypertension-related problem list entry. Our post-implementation repeat visit rate of 12.7% lagged behind this baseline; however, our 15% post-implementation problem list entry rate was over nine times better than Daley's. The second study used for baselines was a retrospective study by Hansen et al.[4] who found that 26% of patients who qualify for a diagnosis of hypertension had an appropriate problem list entry. In our study, we had one patient who qualified for a diagnosis of hypertension but did not have any hypertension-related problem list entries on their chart.

At this point, it is difficult to identify the reason for the lack of significant improvement. One scenario is that the tool was effective in alerting the physicians to high readings, but other circumstances led to a lack of results. It is possible that the physicians were aware of their patients' high blood pressure readings and scheduled follow up appointments to which the patients did not come. The practice where this study took place is located in a low socioeconomic area and it is common for patients to not show up for scheduled visits. Another possibility is that the physicians were aware of high readings while using the tool during the early part of the visits, but a lack of reminder in the latter part of the visit (when the assessment and plan are formulated) led to the lack of follow up. Performing chart reviews as part of our data collection would have given us a better understanding of these possibilities.

Another scenario may exist in which the tool was not effective and the patients' high blood pressure was missed. It is possible that the physicians did not take the time to look at the tool or, more troubling, saw the tool but failed to use the decision support. One survey of pediatricians published in the journal *Pediatrics* in 2004[16] found that 40% were uncomfortable with the diagnosis and treatment of pediatric hypertension and that a striking 54% were either not aware or not familiar with the latest guidelines.[11] In our study, the physicians were only given instructions on the use of the tool. It is possible that including a short didactic educational session about pediatric hypertension might increase the number of patients with high blood pressure readings that were recognized.

There are some limitations we must put on this study. First, some of these findings may be affected by sample size issues. The incidence of one patient having elevated blood pressure is 8%-10%[3,15], almost twice our result. This suggests that we had fewer than half the expected high readings. The study practice also had a predominantly African American population. Given that both high blood pressure readings and hypertension are more prevalent in black children compared to Caucasians[3], we might have expected to have even more high readings than expected. It is possible that a larger sample size and an accompanying increased number of patients with high readings would have allowed us to see a more significant change in the physicians' practice. Additionally, when evaluating the lack of follow up of high readings, performing a chart review might have helped differentiate between physician awareness and patients not returning to scheduled visits.

Another limitation may be found in our use of the presence of entries on a patient's problem list as our second outcome measure. According to Blaze Gusic, M.D., the Medical Director of the study practice[17], the physicians' usage of the EMR problem list is inconsistent. It is common to see problems that have resolved (e.g. strep throat) still remain on the problem list. It is also common to see charts not have problem list entries for existing issues (e.g. constipation). Practice physicians also claim that finding diagnosis codes using the Centricity EMR problem list search is not an easy or intuitive process.[17] It is possible that physicians who did not want to put a diagnosis of hypertension on the problem list when a patient had fewer than three high readings either had difficulty finding the diagnosis code for elevated high blood pressure or did not even try to search for it based on previous experience. Our tool did not offer a button to add a problem list entry for elevated blood pressure and including one may have increased the number of problem list entries.

An additional limitation was the use of Visual Form Editor to create the tool. A major downside of Visual Form Editor is its limited debugging capabilities, making programming more difficult. Another factor complicating the coding of the form was that certain test results and reports were not searchable using the MEL language. Specifically, radiology results and referral letters within patient charts could not be recognized by the tool. These issues forced us to have inconsistencies in the form's function which may have lead to confusion in its use.

There are a few next steps we would like to take in evaluating this clinical decision support tool. First, we would like to address outcome measures and not just process measures. If sample size increases, we will, hopefully, be able to assess how well our tool guides clinicians in appropriate work ups for patients with hypertension. There would also be a possibility of providing decision support tools for starting and maintaining anti-hypertensive medication. We would also like to address the lack of follow up for patients with high readings. One possible intervention we could pursue a chart-level alert so that both clinical and non-clinical staff will be notified that these patients need blood pressure checks and should be offered appointments at all contact points. Additionally, we could add clinical decision support elements to the assessment and plan section of the visit workflow. Lastly, in our study, we did not differentiate between patients with and without obesity. Considering the importance of obesity as a risk factor for hypertension, we would like to continue to refine the tool to also make the physicians aware of the patient's body mass index as well as their blood pressure percentiles.

# CONCLUSION

Pediatric hypertension has become an important chronic disease of childhood. Failure to recognize it early in life can lead to dire consequences, both as a child and as a hypertensive adult. In the near future, we expect the prevalence of pediatric hypertension increase because of its association with childhood obesity. With greater adoption of electronic medical records, clinical decision support tools can be used to help clinicians to better recognize high blood pressure readings and diagnose hypertension. Our study showed some encouraging trends toward achieving these ends. In the first two months with our tool in production, the practice's clinicians started to approach patients with high blood pressure readings in a manner more aligned with published guidelines. Nevertheless, it is clear that more work needs to be done in refining how such a tool might best work in a clinical practice. Not only do clinical decision support tools need to be more effective in making clinicians aware of high readings, they also need to help them close the loop on their patients most at risk.

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