Improving Diagnosis of Hypertension in Children

AHRQ R21HS024100

Final Report

Principal Investigator: Goutham Rao, MD
Co-investigators:
Leigh Baumgart, PhD
Jennifer Bello Kottenstette, MD, MPH
Nivedita Mohanty, MD
Additional Team Members:
Victoria Bauer, BS (project manager)
Sarah Rittner, MA (Alliance research manger)
Roxane Padilla, MPH (AllianceChicago)
Sara Naureckas, MD (Alliance physician champion)
Yosuke Miyashita, MD (Advisor)
Paul Epner, MBA (Advisor)
Sandra Tilmon, MPH (Alliance Data Manger)
Avisek Datta, MS (Statistician)
Kate Kirley, MD, MPH (Advisor)
Organization: NorthShore University HealthSystem
Federal Project Officer: Derrick Wyatt, RN
Dates of Project: 9/30/2015 – 3/31/2018
This project was completed with the support of the Agency for Healthcare Research and Quality (AHRQ) grant number R21 HS24100

Abstract:

Purpose: To improve the rate of correct diagnosis of hypertension in children, and improve recognition of abnormal BP in general.

Scope: Pediatric hypertension is common and serious. It is associated with an increased risk for adult hypertension as well as target organ damage in childhood which responds to timely treatment. Unfortunately, the most cases are missed. This project involves the development, implementation and evaluation of a multi-faceted program to improve diagnosis.

Methods: The Improving Diagnosis of Hypertension in Children program (IDHC) was developed through input from provider interviews, observation of nursing staff, and usability testing of clinical decision support (CDS). It includes a provider education program, training in BP measurement, a CDS system to facilitate diagnosis, and patient education. It was compared to a control intervention consisting of BP measurement training, the same CDS system, and a brief recorded hypertension lecture in a 15-month cluster trial among 6 community practices.

Results: Provider interviews revealed many barriers to diagnosis. Diagnostic rates did not improve post-intervention and were higher in the control group in both periods. However, a broader indicator of recognition of abnormal BP did improve post-intervention (13.6 %– 27.7% in control group; 10.8%-19.8% in IDHC group).

Key Words: Hypertension Children Diagnosis

PURPOSE: To improve the rate of correct diagnosis of hypertension in children, and to increase recognition of elevated blood pressure in children.

SCOPE:

Background: Hypertension in children is a serious and increasingly common condition. Prevalence estimates in the United States range from <1% to > 3%. Even a 1% prevalence represents approximately 740,000 American children.[1] While evidence for the direct relationship between childhood hypertension and adult cardiovascular disease is limited, the established impact during childhood provides a compelling rationale for timely diagnosis and treatment. Children with elevated blood pressure are at much higher risk for the development of adult hypertension.[2] Childhood hypertension is also associated with target organ damage (TOD) including left ventricular hypertrophy, increased carotid intima media thickness (CIMT), and microalbuminuria.[3,4,5] The treatment of hypertension is proven to be safe and slows the progression of and in some cases reverses TOD.[6] The first guidelines for pediatric hypertension, published in 1977, declared "hypertension in children the next frontier."[7] More than 40 years later, the diagnosis is often missed for a variety of reasons.[8,9,10] Clinicians are unfamiliar with the problem, standards for diagnosis are complex, and obtaining accurate blood pressure (BP) measurements is challenging.

Context: As noted above, hypertension in children is a common cardiovascular risk in children, associated with damage to target organs in childhood and a significant risk for adult hypertension. The research described in this project was carried out late 2015 – early 2018, a period of increasing recognition of the problem of under-diagnosis. New guidelines for the diagnosis, evaluation and management of hypertension in children were also released in 2017.[11] A framework for understanding the problem of under-diagnosis includes three categories:

(1) Poor Measurement Technique: Correct measurement of BP in children requires an appropriate-sized cuff, which is roughly the largest cuff that will fit on the upper arm with room below for the stethoscope head.[12] More precise standards for cuff size depending upon age are also available.[13] There are no studies of the performance of nursing staff (nurses, medical assistants) in children's BP measurement. However, evidence from adults indicates generally poor technique. Rabbia et al report, for example, that only 10% of 160 nurses inspected the arm size before placing the cuff, 80% placed the head of the stethoscope under the cuff (rather than correctly below), and 34% did not remove all clothing that covered the location of cuff.[14]Armstrong reports that only 61% of nurses met standards for identifying systolic BP (71% for diastolic BP).[15] (2) Incorrect Interpretation and Poor Knowledge: Hansen et al cite 2 factors in the failure of physicians to make a diagnosis of hypertension: (a) lack of knowledge of normal BP ranges in children; and (b) lack of awareness of patients' previous BP readings, since establishment of a diagnosis requires one elevated reading, followed by two additional confirmatory readings and averaging of all readings.[10] Riley et al included a knowledge survey of providers about standards for diagnosis of hypertension in their chart review study. Only 4% of 70 respondents answered 5/5 knowledge questions correctly. The mean number of correct responses was just 2.24/5.[20] An older study by Arafat & Mattoo reported that 44% of pediatricians did not know the standards for defining HTN, and also that poor knowledge about appropriate cuff size is common.[16] All these studies, therefore, demonstrate poor provider knowledge of standards for the diagnosis of hypertension in children. (3) Patient-Related Factors: As stated in our original grant proposal, it is unclear the extent to which patient-related factors influence diagnosis. For example, a clinician can be very diligent in recognizing elevated BP readings, but if a patient does not return for follow-up, the clinician may not have the opportunity to make a diagnosis. The need for multiple

follow-up readings and the associated inconvenience may play a significant role in under-diagnosis. The contribution of patient-related factors to under-diagnosis was not a focus of our proposal. Nevertheless, several providers interviewed to help guide the development of our intervention cited patient-related factors as a significant part of the problem.

Setting: The research took place within six community-based practices which are part of the Erie Family Health Center system. All Erie Family Health Centers are part of AllianceChicago, a network of organizations who collaborate on information technology innovations and related research. Participating practices included Erie Waukegan, Erie Evanston/Skokie, Erie Helping Hands, Erie West Town, Erie Division Street, and Erie Humboldt Park. The Erie network of practices serves primarily minority patients – More than 60% of children care for are either African American or Latino.

Participants: Four groups of participants were involved: (1) Children ages 3 – 18, with no exclusions based on illness or other criteria; (2) Parents of children cared for in the Erie practices who provided feedback about a patient education tool; (3) Providers who included primary care pediatricians, family physicians, and nurse practitioners; (4) Medical assistants and nurses who helped develop and participated in training to improve blood pressure measurement.

Incidence/prevalence: Reliable population-based estimates of the prevalence of hypertension in children are unavailable.[17] Within the Alliance network of practices, prior to the study, the recorded prevalence of hypertension among all children was 0.75%. We based our sample size and power on estimated actual prevalence of 5%.

METHODS: The project involved two major components: (1) Development of the "Improving Diagnosis of Hypertension in Children" (IDHC) intervention; and (2) Measurement of the impact of the intervention in a cluster randomized trial. Methods will be described with reference to the corresponding aims below:

Specific Aim #1: Design of a quality improvement program (IDHC) to improve diagnosis of HTN in children.

The following components either made up or informed the IDHC program:

1) Provider Interviews: Drs. Bello and Rao interviewed eight primary care providers about a variety of issues related to the diagnosis of pediatric hypertension. Interviews were recorded, transcribed, and analyzed using a grounded theory approach. Findings are summarized in our paper published in 2017.[18] These interviews formed the basis for the content of the IDHC program.
2) Training Needs of Nursing Staff and Educational Video: An experienced nurse and the project manager of the IDHC program completed 3 days of observations in different study sites of blood pressure measurement techniques by nurses and medical assistants. These observations formed the basis of a video-based educational program on correct measurement techniques. Senior nursing staff in each practice were charged with introducing the video and reviewing correct measurement technique with other nursing staff in each practice.
3) Advanced Clinical Decision Support (CDS) System: The practices enrolled in the study all deployed the GE Centricity Electronic Health Records (EHR) system, and had a basic decision tool for identifying BP percentiles among children. This decision support system was completely redesigned based on feedback from provider interviews. Usability testing was carried out with the

resulting product by a usability specialist. A training video was distributed to all providers on how to use the new CDS tool.

4) Patient Education Information Sheet: A patient-education sheet on pediatric hypertension was designed for parents by Dr. Bello based on accepted design principles for materials of this type. The sheet was pilot-tested and refined based on feedback from a small number of patients.
5) ECHO (Extension for Community Healthcare Outcomes) Curriculum: The ECHO model was developed in New Mexico to deliver highly specialized care to underserved, primarily rural communities. The CMS Center for Medicare & Medicaid Innovation has awarded Project ECHO a three-year $8.5 million healthcare innovation grant.[19]The purpose of ECHO is to provide primary care providers (PCPs) with advanced training to improve their knowledge and self-efficacy in management of a variety of conditions.[20] The model makes use of advanced videoconferencing between primary care providers and specialists. Case presentations are the foundation for discussions. We developed a short, 3-hour ECHO curriculum on pediatric hypertension. The content was based on learning needs identified through provider interviews.

Specific Aim #2: Implementation and evaluation of the *Improving Diagnosis of Hypertension in Children* (IDHC) program in a large network of primary care practices.

1) Randomization: We randomized six practices in the Erie Network to an IDHC intervention or control intervention (Erie Division St., Evanston/Skokie and Humboldt Park to IDHC intervention; West Town, Waukegan, and Helping Hands to control intervention). We had initially planned to randomize a larger number of practices. However, the Erie organization was the only Alliance member which expressed a strong interest in the project. The control and intervention group practices were chosen to be roughly balanced in size in terms of the number of pediatric patients registered in each. Three information sessions, held by webinar, and led by the PI were carried out for IDHC group providers.
2) Interventions: Our original scheme for the IDHC and control group interventions is shown below. Nurses and medical assistants in all practices received training in appropriate measurement technique. We found substantial deviation from accepted techniques through direct observation. We felt it was important for diagnosis to be based on the same, standard measured blood pressure in all practices.

Table 1 IDHC and Control Interventions	
IDHC Arm	**Control Arm**
Nursing staff training	Nursing staff training
Information sessions	Overview recorded web-based lecture on pediatric hypertension (from a prior program developed by the PI)
ECHO Childhood HTN curriculum	
Advanced IDHC CDS tool	

3) Data Sources and Outcomes: Apart from qualitative data, all relevant outcomes data was extracted from structured EHR data fields, de-identified and stored in a secure database for analysis. Principal outcomes were the proportion of children ages 3-17who met clinical criteria for hypertension (average of ≥ 3 readings of BP ≥ 95th percentile) or elevated blood pressure (≥ 3 readings of BP ≥90th and < 95th percentile) with a diagnosis of hypertension recorded in charts. We calculated these "diagnostic rates" over two 15 month periods (6/1/14-9/30/15, "pre-

intervention" or "baseline" period) and (8/17/2016 – 11/17/2017). We also intended to track CDS tool usage (old rudimentary tool and newer advanced tool) in each time period but this proved problematic as usage of the tool was triggered anytime a BP was entered. We were unable to overcome this technical problem.

Limitations: We successfully developed a multi-faceted intervention to improve diagnosis of hypertension, several components of which are in use today. The BP measurement training video is available to all clinicians within the Alliance. The 3-part ECHO curriculum on pediatric hypertension has become a permanent part of the larger ECHO curriculum on pediatric obesity. The advanced CDS tool is still in use. It includes prompts to encourage accurate diagnosis and also summarized guidelines for diagnosis, evaluation, and management. The patient education sheet is still available and in use. Our principal challenge was implementation of the IDHC program in community practices and accurate measurement of its effects in the cluster trial. This was primarily the result of an unforeseen lack of technical capability within AllianceChicago, limited willingness to participate among providers and practices, and changes in leadership within the AllianceChicago with a diminished commitment on the part of new leaders. These and other factors influenced our outcomes as described in more detail below:

1) One control group practice, (Erie West Town) included a number of physicians who were enthusiastic about tackling the problem of under-diagnosis (including a very active member of the project advisory committee). This clearly distorted the results, as few interventions are as effective in improving health care quality as a physician champion in an individual practice.
2) We were unable to turn on our advanced CDS system only in intervention group practices. The technical capability of turning on the CDS system selectively initially proved difficult and ultimately not possible. As noted, accurate measurement of CDS usage was also not possible.
3) The ECHO curriculum was open to all who were interested. We actively encouraged providers from the IDHC practices to participate, but ultimately, a wide variety of providers from across the Erie system and the Alliance more broadly participated.

The quantitative results described below should be interpreted in the context of these limitations.

Principal findings from both the development and evaluation phase of the project are described below:

RESULTS:

Findings from Observations of BP Measurement Technique:

We uncovered widespread problems related to cuff size, failure to repeat initially high measurements, etc. Problems were so widespread our training program for nursing staff was a complete review of BP measurement in children.

Findings from Provider Interviews:

Findings from provider interviews are described in more detail in our recent publication.[18] We successfully carried out, transcribed, and analyzed 8 interviews (6 pediatricians; 1 family physician; 1 family nurse practitioner) from 4 different Erie practices. Several important themes emerged: (1) There is a perception that the prevalence of pediatric hypertension has increased, largely due to increases in the prevalence of obesity; (2) Providers cited numerous barriers to diagnosis including patient related

factors such as the need for follow-up for serial BP measurements; (3) Providers wanted a CDS tool to assist rather than "make" a diagnosis for them; (4) Providers expressed a strong concern about poor measurement technique among medical assistants; (5) Providers were very hesitant to prescribe medication for hypertension, but were comfortable with recommending lifestyle changes; (6) Providers emphasized a substantial need for patient education materials, and noted that such materials should include recommendations for lifestyle changes. All these findings informed the pediatric hypertension ECHO curriculum and our clinical decision support system (e.g. Patient education materials were incorporated as a link within the CDS).

Principal Findings from Cluster Trial:

During the baseline period 47,669 individual children were seen in the six practices. 3446 met criteria for hypertension for a prevalence rate of 7.2%. During the follow-up intervention period, 48821 individual children were seen. 3196 met criteria for hypertension, for a prevalence of roughly 6.5%. Both prevalence rates are substantially higher than most prior estimates, possibly because of the high proportion of at risk minority (African American and Latino) children. IDHC (intervention group) and control group children differed significantly in the baseline and follow-up periods in terms of race, ethnicity, and age distribution, and also differed significantly in the follow-up period in use of oral or inhaled steroids (Tables 2 and 3).

Table 2– Baseline Demographics Stratified by Intervention Groups (n=3,446)

	Control (n=1725)	IDHC (n=1721)	P-value
Race			
White	1430 (82.9%)	884 (51.4%)	**<.0001**
Non-White	295 (17.1%)	835 (48.5%)	
Declined/Null	0 (0.0%)	2 (0.1%)	
Ethnicity			
Hispanic or Latino	1464 (84.9%)	1161 (67.5%)	**<.0001**
Not Hispanic or Latino	241 (14.0%)	479 (27.9%)	
Other/Declined	20 (1.17%)	80 (4.6%)	
Percentile Groups			
<85%	648 (37.6%)	639 (37.1%)	0.3753
85-95%	294 (17.0%)	260 (15.1%)	
>95%	452 (26.2%)	477 (27.7%)	
Unknown	331 (19.2%)	345 (20.1%)	
Gender			
Male	912 (52.9%)	886 (51.5%)	0.4148
Female	813 (47.1%)	835 (48.5%)	
Age			
<=6	923 (53.5%)	811 (47.1%)	**0.0007**
7 to 11	409 (23.7%)	478 (27.8%)	
>=12	393 (22.8%)	432 (25.1%)	
Oral Contraceptives			
Yes	1 (0.1%)	1 (0.1%)	1.0000
No	1724 (99.9%)	1720 (99.9%)	
Oral or Inhaled Steroids			
Yes	38 (2.2%)	49 (2.9%)	0.2280
No	1687 (97.8%)	1672 (92.1%)	
Stimulants			
Yes	2 (0.1%)	2 (0.1%)	1.0000
No	1723 (99.9%)	1719 (99.9%)	
NSAID Use			
Yes	22 (1.3%)	14 (0.8%)	0.1824
No	1703 (98.7%)	1707 (99.2%)	
Asthma			
Yes	18 (1.0%)	18 (1.0%)	1.0000
No	1707 (99.0%)	1703 (99.0%)	

	Control (n=1725)	IDHC (n=1721)	P-value
Diabetes			
Yes	0 (0.0%)	0 (0.0%)	1.0000
No	1725 (100.0%)	1721 (100.0%)	
Chronic Renal Disease			
Yes	0 (0.0%)	0 (0.0%)	1.0000
No	1725 (100.0%)	1721 (100.0%)	
ADHD			
Yes	7 (0.4%)	9 (0.5%)	0.6130
No	1718 (99.6%)	1712 (99.5%)	
Obstructive Sleep Apnea			
Yes	2 (0.1%)	1 (0.1%)	1.0000
No	1723 (99.9%)	1720 (99.9%)	
Hyperthyroidism			
Yes	0 (0.0%)	0 (0.0%)	1.0000
No	1725 (100.0%)	1721 (100.0%)	
Congenital Heart Disease			
Yes	0 (0.0%)	1 (0.1%)	0.4994
No	1725 (100.0%)	1720 (99.9%)	
Hyperlipidemia			
Yes	4 (0.2%)	3 (0.2%)	1.0000
No	1721 (99.8%)	1718 (99.8%)	
Cushing's Disease			
Yes	0 (0.0%)	0 (0.0%)	1.0000
No	1725 (100.0%)	1721 (100.0%)	

Table 3 – Follow up Demographics Stratified by Intervention Groups (n=3,196)

	Control (n=1794)	IDHC (n=1402)	P-value
Race			
White	1521 (84.8%)	701 (50.0%)	**<.0001**
Non-White	266 (14.8%)	696 (49.6%)	
Declined/Null	7 (0.4%)	5 (0.4%)	
Ethnicity			
Hispanic or Latino	1497 (83.4%)	918 (65.6%)	**<.0001**
Not Hispanic or Latino	296 (16.5%)	479 (34.2%)	
Other/Declined	1 (0.1%)	2 (0.1%)	
Percentile Groups			
<85%	659 (36.7%)	515 (36.7%)	0.5046
85-95%	316 (17.6%)	230 (16.4%)	
>95%	527 (29.4%)	493 (28.7%)	
Unknown	292 (16.3%)	254 (18.1%)	
Gender			
Male	929 (51.8%)	744 (53.1%)	0.4710
Female	865 (48.2%)	658 (46.9%)	
Age			
<=6	750 (41.8%)	672 (47.9%)	**0.0018**
7 to 11	543 (30.3%)	265 (26.0%)	
>=12	501 (27.9%)	365 (26.0%)	
Oral Contraceptives			
Yes	1 (0.1%)	2 (0.1%)	0.5852
No	1793 (99.9%)	1400 (99.9%)	
Oral or Inhaled Steroids			
Yes	37 (2.1%)	49 (3.5%)	**0.0130**
No	1757 (97.9%)	1353 (96.5%)	
Stimulants			
Yes	7 (0.4%)	6 (0.4%)	0.8678
No	1787 (99.6%)	1396 (99.6%)	
NSAID Use			
Yes	45 (2.5%)	31 (2.2%)	0.5842
No	1749 (97.5%)	1371 (97.8%)	
Asthma			
Yes	16 (0.9%)	11 (0.8%)	0.7423
No	1778 (99.1%)	1391 (99.2%)	

	Control (n=1794)	IDHC (n=1402)	P-value
Diabetes			
Yes	1 (0.1%)	0 (0.0%)	1.0000
No	1793 (99.9%)	1402 (100.0%)	
Chronic Renal Disease			
Yes	0 (0.0%)	0 (0.0%)	N/A
No	1794 (100.0%)	1402 (100.0%)	
ADHD			
Yes	6 (0.3%)	3 (0.2%)	0.7396
No	1788 (99.7%)	199 (99.8%)	
Obstructive Sleep Apnea			
Yes	2 (0.1%)	1 (0.1%)	1.0000
No	1792 (99.9%)	1401 (99.9%)	
Hyperthyroidism			
Yes	0 (0.0%)	0 (0.0%)	N/A
No	1794 (100.0%)	1402 (100.0%)	
Congenital Heart Disease			
Yes	2 (0.1%)	0 (0.0%)	0.5074
No	1792 (99.9%)	1402 (100.0%)	
Hyperlipidemia			
Yes	8 (0.5%)	4 (0.3%)	0.5674
No	1786 (99.6%)	1398 (99.7%)	
Cushing's Disease			
Yes	0 (0.0%)	0 (0.0%)	N/A
No	1794 (100.0%)	1402 (100.0%)	

Tables 4 and 5 describe the overall diagnosis and recognition rates of hypertension and elevated blood pressure in the baseline and follow-up periods. The rate of recognition of hypertension actually declined, but the rate of elevated BP diagnosis increased substantially. When either "hypertension" or "elevated BP" was used to identify recognition of abnormally high blood pressures, overall recognition was substantially higher in the follow-up period.

Table 4 – Correct Diagnoses of Hypertension and Elevated BP for Baseline Data

	# Correct Diagnosis	# Incorrect Diagnosis	% Correct
Correct Diagnosis of Hypertension	62	1650	62/1712 = 0.0362 = 3.62%
Correct Diagnosis of Elevated BP	138	1596	138/1734 = 0.0796 = 7.96%
Any recognition of Elevated BP	420	3026	420/3446 = 0.1219 = 12.19%

Table 5 – Correct Diagnoses of Hypertension and Elevated BP for Follow up Data

	# Correct Diagnosis	# Incorrect Diagnosis	% Correct
Correct Diagnosis of Hypertension	25	1480	25/1505 = 0.0166 = 1.66%
Correct Diagnosis of Elevated BP	308	1383	308/1691 = 0.1821 = 18.21%
Any recognition of Elevated BP	775	2421	775/3196 = 0.2425 = 24.25%

Tables 6 and 7 describe the recognition and diagnostic rates stratified by intervention. As shown, the rate of correct diagnosis of hypertension did not differ significantly between control and IDHC groups in the follow-up period. The rate of recognition of elevated BP and recording of elevated BP or hypertension for children with elevated readings was actually higher in the control group.

Table 6 – Correct Diagnoses Table of Hypertension and Elevated BP for Baseline Data Stratified by Intervention

	Control	IDHC	P-value
Correct Diagnosis of Hypertension (n=1712)			
Correct	13 (1.6%)	49 (5.5%)	**<.0001**
Incorrect	808 (98.4%)	842 (94.5%)	
Correct Diagnosis of Elevated BP (n=1734)			
Correct	94 (10.4%)	44 (5.3%)	**<.0001**
Incorrect	810 (89.6%)	786 (94.7%)	
***Any recognition of Elevated BP (n=3446)**			
Correct	234 (13.6%)	186 (10.8%)	**0.0134**
Incorrect	1491 (86.4%)	1535 (89.2%)	

Table 7 – Correct Diagnoses Table of Hypertension and Elevated BP for Follow up Data Stratified by Intervention

	Control	IDHC	P-value
Correct Diagnosis of Hypertension (n=1505)			
Correct	14 (1.6%)	11 (1.7%)	0.8858
Incorrect	850 (98.4%)	630 (98.3%)	
Correct Diagnosis of Elevated BP (n=1691)			
Correct	203 (21.8%)	105 (13.8%)	**<.0001**
Incorrect	727 (78.2%)	656 (86.2%)	
***Any recognition of Elevated BP (n=3196)**			
Correct	497 (27.7%)	278 (19.8%)	**<.0001**
Incorrect	1297 (72.3%)	1124 (80.2%)	

*Clinician records any hypertension-related diagnostic code including elevated BP, hypertension, etc. for children with 3 or more readings which are either in the elevated BP or hypertensive range. For example, if a child meets criteria for hypertension, but the clinician records "elevated BP" this counts toward recognition.

DISCUSSION: This project was the first to involve the development of a comprehensive intervention to improve diagnosis of hypertension including provider education, training to improve measurement of blood pressure, clinical decision support, and patient education. The components we have developed are still in use. As noted, the pediatric hypertension curriculum has been incorporated as a standing part of a larger ECHO curriculum on childhood obesity. Our implementation of the IDHC program in the cluster randomized trial had both successes and shortcomings. We were able to recruit six highly engaged practices. Participation in the ECHO curriculum was strong, but clearly included providers from both control group and intervention group practices.

The control group West Town practice included a number of providers who became passionate about improving diagnosis, including two members of our project advisory committee. The rates of recognition and diagnosis and recognition in the control and IDHC groups, therefore, were not what was initially expected.

We were also surprised that the rate of diagnosis declined in the study versus baseline period, though the rate of any acknowledgement by providers of abnormal BP (by recording "elevated BP" or "hypertension") improved. Through greater awareness, providers may actually have been more wary to make a definitive diagnosis of hypertension. The reasons are unclear, but in interviews, providers expressed discomfort with several tasks, including initiating pharmacotherapy.

There was a major change in leadership within our community-based partner, the AllianceChicago at the outset of the study. For this and other reasons, the expectations for key outcomes data, such as reliable

CDS usage data was not met. While the research team designed the CDS system, the Alliance clearly did not have reliable measurement of its usage for research in mind when implementing it.

CONCLUSIONS: A multi-faceted program to improve diagnosis of hypertension in children can be successfully implemented in a network of community-based practices. Insights into providers' preferences for clinical decision support, workflow, and patient education were successfully incorporated. Our intervention focused on health care providers. Undoubtedly, patient-related factors contribute greatly to missed diagnosis. Interventions which target children and parents, and especially the inconvenience of serial office-based BP measurements, should be developed.

DISSEMINATION SUMMARY:

Type	Authors	Title	Journal/Venue	Date(s)	Status
Manuscript	Rao G	Diagnosis, epidemiology, and management of hypertension in children	Pediatrics	August 2016	Published: Link (http://pediatrics.aappublications.org/content/138/2/e20153616.long)
Manuscript	Bello JK, Mohanty N, Bauer V, Rittner SS, Rao G	Pediatric hypertension: Provider perspectives	Global Pediatric Health	June 2017	Published: Link (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5464512/)
Poster presentation	Mohanty N, Rao G, Naureckas S, Bello JK, Padilla R, Tanni A, Datta A, Rittner SS, Bauer V, Baumgart L	Leveraging health information technology for evidence-based pediatric blood pressure management	American Academy of Pediatrics: National Conference and Exhibition, Chicago, IL	September 2017	Presented
Poster presentation	Rao G, Bauer V, Naureckas S, Datta A, Mohanty N, Rittner S, Padilla R, Epner P	Diagnostic paths to pediatric hypertension	9th INternational Diagnostic Error in Medicine Conference, Boston, MA	October 2017	Presented
Oral presentation	Bauer V, Bello JK, Mittal K, Chavez J, Hamlish T, Johnson D, Mohanty N, Rittner SS, Padilla R, Rao G	Exploring and improving clinicians' understanding of pediatric hypertension (Focus on ECHO curriculum)	North American Primary Care Research Group (NAPGRG) Annual Meeting, Montreal, QC, Canada	November 2017	Presented
Manuscript	Rao G, Naureckas S, Datta A, Mohanty N, Bauer V, Padilla R, Rittner SS, Epner P	Pediatric Hypertension: Factors Associated with Diagnosis and Diagnostic Paths	Diagnosis	May 2018	Submitted, editor's decision, "revise and resubmit." Will be resubmitted in June 2018.

REFERENCES:

[1] Rao G. Diagnosis, epidemiology, and management of hypertension in children. Pediatrics 2016;138(2): e20153616.
[2] Chen X, Wang Y. Tracking of blood pressure from childhood to adulthood. A systematic review and meta-regression analysis. Circulation 2008;117: 3171-80.
[3] Brady TM, Fivush B, Flynn JT, Parekh R. Ability of blood pressure to predict left ventricular hypertrophy in children with primary hypertension. J Pediatr 2008;152: 73-8.
[4] Lamotte C, Iliescu C, Libersa C, Goltrand F. Increased intima-media thickness of the carotid artery in childhood: a systematic review of observational studies. Eur J Pediatr 2011;170(6): 719-29.
[5] Assadi F. Relation of left ventricular hypertrophy to microalbuminuria and C-reactive protein in children and adolescents with essential hypertension. Pediatr Cardiol 2008;29: 580-4.
[6] Assadi F. Effect of microalbuminuria lowering on regression of left ventricular hypertrophy in children and adolescents with essential hypertension. Pediatr Cardiol 2007;28: 27-33.
[7] Blumenthal S, Epps RP, Heavenrich R et al. Report of the task force on blood pressure control in children. Pediatrics 1977;59 (5 2 Suppl): I-II, 797-820.
[8] Hansen ML, Gunn PW, Kaelber DC. Underdiagnosis of hypertension in children and adolescents. JAMA 2007;298(8): 874-9.
[9] Brady TM, Solomon BS, Neu AM, Siberry GK, Parekh RS. Patient, provider, and clinic-level predictors of unrecognized elevated BP in children. Pediatrics 2010;125(6): e1286-93.
[10] Riley M, Dobson M, Sen A, Green L. Recognizing elevated BP in children and adolescents: How are we doing? J Fam Pract 2013;62(6): 294-99.
[11] Flynn JT, Kaelber DC, Baker-Smith CM, Blowey D, Carroll AE, Daniels SR, de Ferranti SD, Dionne JM, Falkner B, Flinn SK, Gidding SS, Goodwin C, Leu MG, Powers ME, Rea C, Samuels J, Simasek M, Thaker VV, Urbina EM; SUBCOMMITTEE ON SCREENING AND MANAGEMENT OF HIGH BLOOD PRESSURE IN CHILDREN. Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents. Pediatrics. 2017 Sep;140(3). pii: e20171904. doi: 10.1542/peds.2017-1904.
[12] http://www.nhlbi.nih.gov/health/public/heart/hbp/bp_child_pocket/bp_child_pocket.pdf.
[13] Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves J, Hill MN, et al.; Subcommittee of Professional and Public Education of the American Heart Association Council on High BP Research. Recommendations for BP measurement in humans and experimental animals. Part 1: BP measurement in humans. Hypertension 2005;45:142–61.
[14] Rabbia F, Testa E, Rabbia S, et al. Effectiveness of BP educational and evaluation program for the improvement of measurement accuracy among nurses. High Blood Press Cardiovasc Prev. 2013 Jun;20(2):77-80.

[15] Armstrong RS. Nurses' knowledge of error in BP measurement technique. Int J. Nurse Pract 2002;8(3):118-26.
[16] Arafat M, Mattoo TK. Measurement of BP in children. Recommendations and perceptions on cuff selection. Pediatrics 1999;104: e30.
[17] Rao G. Diagnosis, epidemiology, and management of hypertension in children. Pediatrics 2016; 138(2). pii: e20153616. doi: 10.1542/peds.2015-3616.
[18] Bello JK, Mohanty N, Bauer V, Rittner SS, Rao G. Pediatric hypertension: Provider perspectives. Glob Pediatr Health 2017; Jun 6;4:2333794X17712637. doi: 10.1177/2333794X17712637. eCollection 2017.
[19] http://innovation.cms.gov/initiatives/Health-Care-Innovation-Awards/New-Mexico.html. Accessed 9 October 2013.

[20] Arora S, Kalisman S, Thornton K, et al. Expanding access to hepatitis C virus treatment – Extension for community healthcare outcomes (ECHO) project: Disruptive innovation in specialty care. Hepatology 2010;52: 1124-33.