Patterns of Care and Persistence After Incident Elevated Blood Pressure

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KEY WORDS

child, adolescent, hypertension, blood pressure, screening, electronic health records

ABBREVIATIONS

AOR—adjusted odds ratio

BP—blood pressure

CI—confidence interval

EHR—electronic health record

ICD-9-CM—International Classification of Diseases, Ninth Revision, Clinical Modification

KPCO—Kaiser Permanente Colorado

KPNC—Kaiser Permanente Northern California

Dr Daley conceptualized and designed the study, drafted the initial manuscript, revised the manuscript, and approved the final manuscript as submitted; Drs Sinaiko, Margolis, Parker, Sherwood, Adams, Kharbanda, Lo, O'Connor, and Magid contributed to the study conceptualization and design, critically reviewed and provided feedback on the manuscript, and approved the final manuscript as submitted; Ms Reifler conducted the data analyses, critically reviewed the manuscript, and approved the final manuscript as submitted; Ms Tavel and Ms Chandra acquired and prepared the data, contributed to data analyses, and approved the final manuscript as submitted; Dr Glanz contributed to the study design and analytic methods, critically reviewed and provided feedback on the manuscript, and approved the final manuscript as submitted; Ms Trower acquired and prepared the data, contributed to data analyses, and approved the final manuscript as submitted; and Dr Greenspan contributed to data collection, critically reviewed and provided feedback on the manuscript, and approved the final manuscript as submitted.

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WHAT'S KNOWN ON THIS SUBJECT: Screening for hypertension in asymptomatic children and adolescents occurs during routine care. For those with elevated blood pressure, a repeat measurement within 1 to 2 weeks is recommended. However, little is known about patterns of care after an incident elevated blood pressure.

WHAT THIS STUDY ADDS: In a population of 72 625 children and adolescents, 6108 (8.4%) had an incident elevated blood pressure. Among these, 1275 (20.9%) had their blood pressure measurement repeated within 1 month. However, few individuals with an incident elevated blood pressure subsequently developed hypertension.

abstract

BACKGROUND AND OBJECTIVE: Screening for hypertension in children occurs during routine care. When blood pressure (BP) is elevated in the hypertensive range, a repeat measurement within 1 to 2 weeks is recommended. The objective was to assess patterns of care after an incident elevated BP, including timing of repeat BP measurement and likelihood of persistently elevated BP.

METHODS: This retrospective study was conducted in 3 health care organizations. All children aged 3 through 17 years with an incident elevated BP at an outpatient visit during 2007 through 2010 were identified. Within this group, we assessed the proportion who had a repeat BP measured within 1 month of their incident elevated BP and the proportion who subsequently met the definition of hypertension. Multivariate analyses were used to identify factors associated with follow-up BP within 1 month of initial elevated BP.

RESULTS: Among 72 625 children and adolescents in the population, 6108 (8.4%) had an incident elevated BP during the study period. Among 6108 with an incident elevated BP, 20.9% had a repeat BP measured within 1 month. In multivariate analyses, having a follow-up BP within 1 month was not significantly more likely among individuals with obesity or stage 2 systolic elevation. Among 6108 individuals with an incident elevated BP, 84 (1.4%) had a second and third consecutive elevated BP within 12 months.

CONCLUSIONS: Whereas >8% of children and adolescents had an incident elevated BP, the great majority of BPs were not repeated within 1 month. However, relatively few individuals subsequently met the definition of hypertension. *Pediatrics* 2013;132:e349–e355

In 2004, an expert panel convened by the National Heart, Lung, and Blood Institute published updated recommendations for the recognition and treatment of high blood pressure (BP) in children and adolescents.¹ In 2011, these recommendations were incorporated, largely unchanged, into a new set of integrated cardiovascular risk reduction guidelines.² Despite these long-standing recommendations, hypertension often goes unrecognized in children.^{3,4}

Screening for hypertension in asymptomatic children and adolescents occurs during routine clinical care. When a screening blood pressure is elevated in the hypertensive range (blood pressure $\geq$ 95th percentile for age, gender, and height percentile), a repeat measurement within 1 to 2 weeks is recommended.^{1,2} Hypertension is defined as a BP $\geq$ 95th percentile on 3 separate consecutive occasions.^{1,2} Whereas several previous epidemiologic studies have examined pediatric hypertension, these investigations have typically used cross-sectional data or data from nonclinical settings^{5–9}; fewer studies have examined hypertension screening in routine clinical settings.^{3,4,10} In particular, little is known about how frequently children and adolescents have elevated BP readings during outpatient care, how soon elevated BP measurements are typically remeasured, and how well a single elevated BP predicts persistent elevation.

To address these gaps in current knowledge, we conducted a retrospective study of BP measured during outpatient care in 3 health care organizations. Our objective was to assess the patterns of care after an incident (ie, first) elevated BP measurement, including the time between an incident elevated BP and repeat measurement, and the likelihood of persistently elevated BP.

METHODS

Study Setting

This retrospective observational study was conducted in 3 large integrated health care delivery systems: HealthPartners of Minnesota, Kaiser Permanente Colorado (KPCO), and Kaiser Permanente Northern California (KPNC).¹⁰ The study period was January 1, 2007, through December 31, 2010. KPCO and KPNC ceded research oversight to HealthPartners; the human subjects review board at HealthPartners approved the study, and written consent was not required.

The 3 participating study sites use the Epic (Madison, WI) electronic health record (EHR). The EHR captures demographic data, health plan enrollment information, encounter data including diagnosis codes, and vital signs. BP values are captured in specific fields, and multiple BP measurements can be recorded in the EHR at each visit. The EHR does not display the corresponding BP percentiles.

Study Cohort

Inclusion Criteria

We used the following steps to identify a cohort of children aged 3 through 17 years with incident elevated BP. At HealthPartners and KPCO, all subjects from 2007 through 2010 were eligible for inclusion. Because KPNC was completing transition to the Epic EHR in 2007, the study population at KPNC was restricted to 2008 through 2010 and consisted of a 50% sample of subjects in 3 KPNC areas with early EHR implementation. The study included all children and adolescents with at least 2 eligible BP measurements, defined as BP measured in outpatient settings with corresponding height measurements taken within 90 days before or after the respective BP measurements.

Exclusion Criteria

A number of exclusion criteria were then applied. We excluded subjects

whose first measured BP during the study period was elevated, because these individuals may have had prevalent, rather than incident, high BP. In addition, subjects were required to have health plan enrollment for at least 6 months before their incident BP reading through 12 months after the date of their incident BP reading. Requiring 12 months of enrollment after the BP date ensured that all study subjects had equal follow-up time, and therefore equal opportunity to have repeat BP measurements taken.

Next, we used *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) codes from encounter diagnoses to exclude subjects with a previous diagnosis of hypertension (ICD-9-CM codes 401.xx through 405.xx) or elevated BP (code 796.2). We also excluded children and adolescents with comorbid conditions known to cause hypertension, including those with acute or chronic renal disease (codes 580.xx through 587.xx, 589.xx, 590.0x, 593.71, 593.72, 593.73, 593.81, V42.0, V56.x, and 866.xx), hemolytic-uremic syndrome (code 283.11), renal neoplasms (code 189.0), aortic coarctation (code 747.1x), hypertensive encephalopathy (code 437.2), cerebral edema (code 348.5), pregnancy (codes 630.xx through 677.xx, V22.xx through V24.xx, and V27.xx through V39.xx), and specific endocrine diseases including hyperthyroidism (codes 242.xx, 255.0, 255.1, 255.2, 255.3, 255.6, 194.0, and 227.0).

Identifying Elevated BP

The BPs used in this study were measured as part of routine clinical care. At the 3 study sites, BPs were measured by medical assistants or registered nurses using protocols based on published guidelines for proper BP measurement technique.^{1,11} Staff members at all sites received formal training in BP measurement at the time of their hire, and training updates were provided. At KPCO

and HealthPartners, BP was measured predominantly by using aneroid sphygmomanometers; at KPNC, BP was measured by using Welch Allyn (Skaneateles Falls, NY) oscillometric devices.

After applying the inclusion and exclusion criteria described above, we performed several additional steps to identify individuals with an incident (ie, first) elevated BP during the study period. Because national guidelines recommend measurement of BP at every health care encounter,¹ we examined BP measurements from all primary care, medical specialty, and surgical specialty settings. Measurements from emergency department and inpatient settings were excluded.

We identified all individuals with an elevated BP in the hypertensive range, defined as systolic and/or diastolic BP ≥ 95 th percentile for age, gender, and height percentile.^{1,2} BPs in the prehypertensive range were not examined. National guidelines recommend repeating an elevated BP at the time of the visit¹; in routine practice, providers are likely to make clinical decisions about BP follow-up on the basis of the repeat measurement. Therefore, when multiple BPs were measured on the same day, the last recorded BP was used in analyses.

EHR Review

To validate the accuracy of BP values in analytic data sets, the EHRs of 225 subjects (75 per site) were manually reviewed. These records were randomly sampled from among children and adolescents with BP measurements in the hypertensive range. For 97% of records reviewed, the BPs and height values were identical between the EHR and analytic data, with any differences explained by the use in analytic data of a recent height when a height was not obtained on the day of BP measurement. For 96% of manually reviewed EHRs, there were no additional BP readings documented in progress notes or in other text fields of the EHR.

Study Outcomes

The primary study outcome was the proportion of subjects with an incident elevated BP ≥ 95 th percentile who had a repeat BP measurement taken within 1 month of their incident measurement. Although national guidelines recommend follow-up within 2 weeks,^{1,2} we chose to examine follow-up within 1 month as a practical application of these guidelines. Our secondary outcome was the proportion of subjects with an incident elevated BP who met the definition of hypertension (BP ≥ 95 th percentile on 3 separate consecutive occasions)^{1,2} within 12 months after the incident measurement. BP measurements were excluded (ie, right censored) if they occurred > 12 months after the incident BP reading.

Analytic Methods

Frequencies and descriptive statistics were calculated for all variables of interest. We also conducted multivariate logistic regression to examine factors associated with the timing of repeat measurement. The dependent variable for multivariate analyses was whether a repeat BP measurement was taken within 1 month of the incident elevated measurement (yes/no); the independent variables were age, gender, BMI category, clinical setting of initial BP measurement, category of BP elevation, health care utilization rate, and study site. For these analyses, the incident elevated BP was divided into 3 mutually exclusive categories: stage 1 systolic elevation (systolic BP: 95th percentile to the 99th percentile plus 5 mm Hg), stage 2 systolic elevation (systolic BP > 99 th percentile plus 5 mm Hg), or diastolic-only elevation (diastolic BP ≥ 95 th percentile with systolic < 95 th percentile).^{1,2} The health care utilization rate was defined as the number of outpatient visits per patient in the 6 months before the incident elevated BP measurement. Analyses were performed by using SAS, version 9.1.3 (SAS Institute, Cary, NC).

RESULTS

Identifying Individuals With Incident Elevated BP

The overall population in the 3 study sites included 159 981 children and adolescents aged 3 through 17 years with at least 2 eligible BPs measured in an outpatient setting between 2007 and 2010. As shown in Fig 1, after applying study exclusion criteria 72 625 children and adolescents remained in the population. Among these individuals, 6108 (8.4%) had an incident elevated BP during the study period. The percentage with an incident elevated BP ranged from 6.9% to 9.0% across the 3 study sites.

Demographic and Clinical Characteristics

The demographic and clinical characteristics of individuals with an incident elevated BP are presented in Table 1. As shown, 1632 (26.7%) of those with an incident elevated BP were 15 to 17 years of age, and 1272 (20.8%) were 12 to 14 years of age. In addition, 1629 (26.7%) were obese (BMI ≥ 95 th percentile for age and gender) and 1101 (18.0%) were overweight (BMI: 85th to < 95 th percentile).

Elevated BP was identified from a variety of outpatient settings. As shown in Table 1, the majority of incident elevated BP readings ($n = 3382$; 55.4%) were measured at non-well-child visits in primary care. An additional 1535 (25.1%) of incident elevated BPs were measured at well-child visits in primary care, and 795 (13.0%) were measured at surgical specialty visits.

Characteristics of Incident Elevated BP Measurements

The characteristics of the incident elevated BP measurements are detailed in Table 2. As shown, 405 of 922 (43.9%) of 3- to 5-year-old and 374 of 1127 (33.2%) of 6- to 8-year-old children had diastolic-only elevation (ie, diastolic BP ≥ 95 th percentile with systolic BP < 95 th percentile).

FIGURE 1 Identification of children and adolescents with an incident elevated BP in the hypertensive range and the outcomes of subsequent consecutive BP readings, 2007–2010.

The proportion of subjects with stage 1 or stage 2 systolic elevation was greater at older ages (test for trend, $P < .001$). Among 6108 children and adolescents with an incident elevated BP, 99 (1.6%) had an ICD-9-CM diagnosis code for hypertension or elevated BP in the EHR on the date of their incident reading.

Timing of Repeat BP Measurement

Among 6108 individuals with an incident elevated BP, the next consecutive BP was measured within 1 month for 1275 (20.9%), within 2 to 6 months for 2130 (34.9%), and within 7 to 12 months for 1153 (18.9%) individuals. The remaining 1550 (25.4%) did not have a repeat BP measurement within 12 months after

their incident elevated BP reading. With the use of Kaplan-Meier analyses to account for censored data, the median time to repeat measurement was 4.7 months. Multivariate analyses of factors associated with having a repeat BP measurement within 1 month are shown in Table 3. When adjusted for other covariates, age in years (adjusted odds ratio [AOR]: 1.04; 95% confidence interval [CI]: 1.02–1.06) and previous health care utilization rate (AOR: 1.07; 95% CI: 1.05–1.09) were positively associated with having a repeat BP measurement within 1 month. Clinical setting was also strongly associated with this outcome; when the incident elevated BP was measured at a primary care well-child

visit, the odds of follow-up were lower than after any other type of visit. The presence of obesity (AOR: 1.12; 95% CI: 0.97–1.31) or stage 2 systolic BP elevation (AOR: 0.99; 95% CI: 0.76–1.30) was not significantly associated with an increased likelihood of having a repeat BP measurement within 1 month of an incident elevated BP.

Likelihood of Persistently Elevated BP

Figure 1 also provides the results of the BP measurements taken consecutively after an incident elevated BP. As shown, among 6108 individuals with an incident elevated BP, 84 (1.4%) had a second and third consecutive elevated BP measurement within 12 months, and therefore met the definition of hypertension.^{1,2} Stratifying this result by the category of initial BP elevation, 3.7% of those with stage 2 systolic BP elevation, 1.6% of those with stage 1 systolic BP elevation, and 0.3% of those with diastolic-only BP elevation had 3 consecutive elevated BP measurements.

Finally, subgroup analyses were conducted among those individuals with at least 2 additional BP measurements in the 12 months after the incident elevated measurement. Among 6108 individuals with incident elevated BP, 2998 (49.1%) had at least 2 additional BP measurements within 12 months; 84 of these 2998 (2.8%) had 3 consecutive elevated BP measurements.

DISCUSSION

In this large retrospective study of BPs measured during outpatient care, 8.4% of children and adolescents had an incident elevated BP during the study period. Only 20.9% of these individuals had their BP rechecked within 1 month, and the presence of obesity or stage 2 systolic BP elevation was not associated with an increased likelihood of follow-up within 1 month. However, when follow-up BP measurements were eventually obtained,

TABLE 1 Demographic and Clinical Characteristics of Children and Adolescents With an Incident Elevated BP, 2007–2010

Characteristic	Incident Elevated BP
Age, <i>n</i> (%)	
3–5 years	922 (15.1)
6–8 years	1127 (18.5)
9–11 years	1155 (18.9)
12–14 years	1272 (20.8)
15–17 years	1632 (26.7)
Gender, <i>n</i> (%)	
Male	3185 (52.1)
Female	2923 (47.9)
Race/ethnicity, <i>n</i> (%)	
Asian/Pacific Islander	409 (6.7)
Black	494 (8.1)
Hispanic	1169 (19.1)
White	3096 (50.7)
Other	95 (1.6)
Missing	845 (13.8)
BMI percentile, <i>n</i> (%)	
<85th	3367 (55.1)
85th to <95th	1101 (18.0)
≥95th	1629 (26.7)
Missing	11 (0.2)
Clinical setting of incident elevated BP, <i>n</i> (%)	
Primary care, well-child care	1535 (25.1)
Primary care, non–well-child care	3382 (55.4)
Ambulatory care, department not specified	122 (2.0)
Medical specialty	274 (4.5)
Surgical specialty	795 (13.0)
Health care utilization, median (25th, 75th percentile)	
Number of outpatient visits in 6 months before index date	12.0 (1.0, 4.0)

N = 6108. Incident elevated BP was defined as either systolic or diastolic BP ≥95th percentile for age, height, and gender.

a great majority of the repeated BPs were normal. Although these findings should be interpreted in the context of certain limitations, given that BPs were not measured in a controlled research setting, the observations have important implications for hypertension screening in children and adolescents in routine outpatient care.

Relatively little has been published regarding outcomes after children and adolescents have incident elevated BP in an outpatient setting. Although our findings are consistent with previous observations that hypertension is often unrecognized in childhood,^{3,4} factors other than underrecognition may also

contribute to the lack of follow-up. Providers may recognize an elevated BP but dismiss it as measurement error or a consequence of the child being upset or anxious. Providers may perceive that current BP thresholds are too low and consequently identify too many children as needing follow-up.¹²

Additionally, we observed that follow-up within 1 month was less likely after a well-child care visit than after all other types of visits. This finding was unexpected, particularly because well-child care is considered by many as “the ideal context” in which to address childhood cardiovascular health.² Also, the frequency of previous outpatient visits was associated with the timing of follow-up. These findings suggest that having a repeat BP measured after an elevated reading is primarily a consequence of having other reasons to seek care; children may be seen for concerns unrelated to BP, and have their BP measurement repeated as a matter of clinic routine.

In this investigation, relatively few children and adolescents with an incident elevated BP met the definition of hypertension within the subsequent 12 months. This observation highlights a number of challenges in the detection of hypertension in routine pediatric and adolescent care. Substantial additional resources would be expended if all individuals with an incident elevated BP returned to clinic for a repeat measurement, and only ~2%

of these individuals (or ~0.2% of the total population) would be identified as hypertensive. In addition, if clinicians find that most of their patients with a single elevated BP have normal BP on subsequent measurements, they may dismiss elevated values even among children who actually have hypertension.

These findings, particularly if replicated in other settings, have important implications for hypertension screening in children and adolescents. Repeating abnormal BP measurements at the end of the visit could improve detection, with EHR-based alerts to prompt for these repeat measurements. Automatic calculation and display of BP percentiles within the EHR could improve provider recognition of abnormal values. Improving recognition and follow-up in settings without an EHR is likely to be a greater challenge, in part because hundreds of different threshold values are used to identify elevated BP in children and adolescents.¹³ Finally, the utility of diastolic values when screening for hypertension in children and adolescents could also be reassessed. For almost one-third of subjects in this study, the incident elevated BP was characterized by an elevated diastolic but normal systolic BP, and only 0.3% of these individuals subsequently met the definition of hypertension. This finding is not altogether surprising given that essential hypertension in children and

TABLE 2 BP Characteristics of Incident Elevated BP Measurements

	Age				
	3–5 years	6–8 years	9–11 years	12–14 years	15–17 years
Number of individuals	922	1127	1155	1272	1632
Median BP, mm Hg					
Systolic	111	117	122	130	134
Diastolic	72	74	76	76	78
Category of incident BP elevation, ^a <i>n</i> (%)					
Stage 1 systolic elevation	477 (51.7)	707 (62.7)	720 (62.3)	898 (70.6)	1194 (73.2)
Stage 2 systolic elevation	40 (4.3)	46 (4.1)	59 (5.1)	85 (6.7)	118 (7.2)
Diastolic elevated/systolic normal	405 (43.9)	374 (33.2)	376 (32.6)	289 (22.7)	320 (19.6)

Subjects with an incident elevated BP reading during 2007–2010, stratified by age; *N* = 6108. Incident elevated BP was defined as either systolic or diastolic BP ≥95th percentile for age, height, and gender.

^a Represents 3 mutually exclusive categories: stage 1 systolic elevation (systolic BP: 95th percentile to the 99th percentile plus 5 mm Hg), stage 2 systolic elevation (systolic BP >99th percentile plus 5 mm Hg), or diastolic-only elevation (a diastolic BP ≥95th percentile with a systolic BP <95th percentile).

TABLE 3 Among Subjects With an Incident Elevated BP During 2007–2010, Univariate and Multivariate Analyses of Characteristics Associated With Having a Repeat BP Measurement Within 1 Month of the Incident Reading

Characteristic	Unadjusted OR (95% CI)	Adjusted OR ^a (95% CI)
Age in years	1.06 (1.05, 1.08)	1.04 (1.02, 1.06)
Gender		
Male	1.00 (Ref)	1.00 (Ref)
Female	0.94 (0.83, 1.06)	1.00 (0.88, 1.14)
Category of incident BP elevation ^b		
Stage 1 systolic elevation	1.00 (Ref)	1.00 (Ref)
Stage 2 systolic elevation	1.13 (0.87, 1.46)	0.99 (0.76, 1.30)
Diastolic elevated/systolic normal	0.91 (0.79, 1.04)	0.96 (0.82, 1.12)
BMI category		
<85th percentile	1.00 (Ref)	1.00 (Ref)
85th to <95th percentile	1.10 (0.93, 1.30)	1.06 (0.89, 1.27)
≥95th percentile	1.14 (0.99, 1.31)	1.12 (0.97, 1.31)
Clinical setting of incident elevated BP		
Primary care, well-child care	1.00 (Ref)	1.00 (Ref)
Primary care, non–well-child care	4.03 (3.27, 4.98)	3.29 (2.66, 4.08)
Ambulatory care, department not specified	3.37 (2.08, 5.45)	3.71 (2.25, 6.14)
Medical specialty	3.06 (2.14, 4.39)	2.24 (1.55, 3.24)
Surgical specialty	7.59 (5.96, 9.68)	4.60 (3.54, 5.96)
Health care utilization rate		
Number of outpatient visits in the 6 months before the index date	1.07 (1.06, 1.09)	1.07 (1.05, 1.09)

N = 6108. Incident elevated BP was defined as either systolic or diastolic BP ≥95th percentile for age, height, and gender. OR, odds ratio; Ref, reference.

^a Multivariate logistic regression analyses, adjusted for age, gender, category of BP elevation, BMI category, clinical setting of incident BP measurement, health care utilization rate, and study site.

^b Represents 3 mutually exclusive categories: stage 1 systolic elevation (systolic BP: 95th percentile to the 99th percentile plus 5 mm Hg), stage 2 systolic elevation (systolic BP >99th percentile plus 5 mm Hg), or diastolic-only elevation (diastolic BP ≥95th percentile with a systolic BP <95th percentile).

adolescents is often characterized by systolic BP elevation only,^{14,15} diastolic BP can be more difficult to measure than systolic BP,¹⁶ and oscillometric devices can vary in the accuracy of diastolic BP measurement.¹⁷

This investigation has a number of limitations. BPs were measured during routine outpatient visits; whereas standard protocols were used in all study sites, there was no independent way to verify whether BPs were measured by using the standard recommended techniques.^{1,11} It is possible that additional

BP measurements were performed after an incident elevated BP but documented only in text fields, such as progress notes within the EHR. Although our manual review of EHRs indicates that this was an uncommon occurrence, measurements from text fields would not have been available for analyses. Restricting analyses to individuals with 12 months of health plan enrollment after their incident elevated BP could introduce selection bias if those who disenrolled earlier differed from those who maintained enrollment with respect

to their risk of hypertension. It was not possible to determine how often clinicians recognized, but did not record, a diagnosis of elevated BP on the date of the incident elevated measurement. Problem lists and past medical histories were not examined, because it was not possible to determine whether the diagnoses listed represented resolved versus active issues; this approach could have potentially affected our ability to exclude those with known (ie, secondary) causes of hypertension. Finally, despite the demographic and geographic diversity of the study population, results may not generalize to other patient populations, particularly patients lacking health insurance or consistent access to routine medical care.

In summary, in this study of BP measurement during outpatient care, 8.4% of children and adolescents had an incident elevated BP. The great majority of abnormal BP measurements were not repeated within 1 month. However, relatively few individuals with an incident elevated BP subsequently met the definition of hypertension. Whereas the use of EHR-based alerts or other strategies could improve recognition, revisions to existing guidelines may also be indicated to focus resources on identifying children and adolescents most likely to have persistent hypertension.

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