

Use of Diagnostic Tests in Adolescents With Essential Hypertension

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Objective: To describe the use of diagnostic tests in adolescents with essential hypertension.

Design: Longitudinal analysis of administrative claims data.

Setting: Michigan Medicaid program during 2003 to 2008.

Participants: Adolescents with 3 or more years of Medicaid eligibility (≥ 11 months/y) who had a diagnosis of essential hypertension and 1 or more antihypertensive medication pharmacy claims.

Main Outcome Measures: We examined adolescents' echocardiogram use and compared it with electrocardiogram (EKG) and renal ultrasonography use. We examined timing of the 3 diagnostic tests in relation to the first pharmacy claim. We examined patient demographics and presence of obesity-related comorbidities.

Results: During 2003 to 2008, there were 951 adolescents with essential hypertension who had antihypertensive pharmacy claims; 24% (226) had echocardiograms;

22% (207) had renal ultrasonography; and 50% (478) had EKGs. Males (odds ratio [OR], 1.53; 95% CI, 1.06-2.21), younger adolescents (OR, 1.69; 95% CI, 1.17-2.44), those who had EKGs (OR, 5.79; 95% CI, 4.02-8.36), and those who had renal ultrasonography (OR, 2.22; 95% CI, 1.54-3.20) were more likely to obtain echocardiograms compared with females, older adolescents, and adolescents who did not have EKGs or renal ultrasonography.

Conclusions: Guideline-recommended diagnostic tests—echocardiograms and renal ultrasonography—were equally poorly used by adolescents with essential hypertension. Sex and age differences exist in the use of echocardiograms by adolescents with essential hypertension. The decision and choice of diagnostic tests to evaluate adolescents with essential hypertension warrant further study to understand the underlying rationale for those decisions and to determine treatment effectiveness.

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ESSENTIAL HYPERTENSION IS A growing problem for adolescents because of its association with obesity, which is estimated as affecting one-third of US adolescents.¹⁻³ Current pediatric guidelines recommend obtaining basic serum and urine laboratory tests and renal ultrasonography for all pediatric patients with hypertension to rule out renal disease.⁴ The same guidelines recommend obtaining echocardiograms for all pediatric patients with hypertension to assess for target organ damage. Thirty-eight percent of adolescents with primary hypertension were found to have left ventricular hypertrophy (LVH) on echocardiograms in 1 study.⁵ Findings from echocardiograms can guide physicians' decision to treat hypertension in adoles-

cents since guidelines recommend initiating or intensifying pharmacotherapy if there is evidence of target organ damage.⁴

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Little is known about echocardiogram use among adolescents with essential hypertension and the timing of echocardiogram use in relation to the use of antihypertensive pharmacotherapy. Additionally, little is known about echocardiogram use among adolescents with essential hypertension in comparison with use of other recommended diagnostic tests (renal ultrasonography) and nonrecommended but more readily available diagnostic tests such as electrocardiograms (EKGs).

The purpose of this study was to describe patterns of echocardiogram use among adolescents with essential hypertension severe enough to warrant antihypertensive pharmacotherapy, in relation to the use of renal ultrasonography and EKGs. We hypothesized that echocardiogram use would be similar to that of renal ultrasonography but less than that of EKGs because EKGs are often more readily available to physicians at the point of care.

METHODS

STUDY DESIGN

We conducted a longitudinal analysis of Michigan Medicaid claims and pharmacy data from 2003 to 2008 for adolescents 12 to 18 years old. We identified adolescents with essential hypertension who had 1 or more antihypertensive pharmacy claims and examined echocardiogram, renal ultrasonography, and EKG use (if any). We examined timing of the 3 diagnostic tests in relation to each other (if applicable) as well as to the first antihypertensive prescription. This study was approved by the institutional review board of University of Michigan Medical School.

STUDY POPULATION

The sampling frame was adolescents 12 to 18 years of age on December 31, 2003, who were eligible for Michigan Medicaid for at least 3 of 6 years (≥ 11 months/y) during the period 2003 to 2008. We included both fee-for-service and managed care Medicaid coverage and included those with dual Title V eligibility. We excluded years where children had other insurance coverage.

We considered adolescents to have essential hypertension if they had an outpatient clinic visit claim with an *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* code for hypertension (401.x). We excluded adolescents who had 1 or more visits with an *ICD-9-CM* code for malignant hypertension, pregnancy-related hypertension, portal hypertension, pulmonary hypertension, glaucoma, and secondary hypertension; we also excluded adolescents who had 1 or more visits with an *ICD-9-CM* code for common pediatric causes of secondary hypertension such as renal disease, coarctation of the aorta, hyperthyroidism, Cushing syndrome, and pheochromocytoma. A full list of exclusion codes is found in the eTable (<http://www.archpediatrics.com>).

Using pharmacy claims including National Drug Codes for the duration of Medicaid eligibility, we identified adolescents who had 1 or more pharmacy claims for 5 common pediatric recommended antihypertensive drug classes: angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, β -blockers, calcium channel blockers, and diuretics.⁴ We excluded adolescents who had any pharmacy claims for clonidine hydrochloride or guanfacine hydrochloride to focus on 5 common antihypertensive drug classes recommended for treatment of pediatric hypertension.⁶

VARIABLES OF INTEREST

Echocardiogram Use

We considered adolescents to have had an echocardiogram if they had at least 1 claim with Current Procedural Terminology (CPT) codes 93303, 93304, 93307, 93308, 93320, 93321, 93325, or 93350 or *ICD-9-CM* procedure codes 88.72 or 37.28

or revenue code 0483 during periods of Medicaid eligibility. If the adolescent had more than 1 echocardiogram during the study period, we used the date of service of the first echocardiogram when evaluating timing of echocardiogram in relation to the first antihypertensive prescription and other diagnostic tests (renal ultrasonography and EKG).

Renal Ultrasonography Use

We considered adolescents to have had renal ultrasonography if they had at least 1 claim with CPT codes 76770, 76775, 76700, or 76705 or *ICD-9-CM* procedure code 88.76 during periods of Medicaid eligibility. If the adolescent had undergone renal ultrasonography more than once during the study period, we used the date of service of the first ultrasonography when evaluating timing of renal ultrasonography in relation to the first antihypertensive prescription and other diagnostic tests (echocardiogram and EKG).

EKG Use

We considered adolescents to have had an EKG if they had at least 1 claim with CPT codes 93000, 93005, 93010, 93040, 93041, or 93042 or *ICD-9-CM* procedure codes 89.51 or 89.52 during periods of Medicaid eligibility. If the adolescent had more than 1 EKG during the study period, we used the date of service of the first EKG when evaluating timing of EKG in relation to the first antihypertensive prescription and other diagnostic tests (echocardiogram and renal ultrasonography).

Antihypertensive Pharmacotherapy

If the adolescent had more than 1 antihypertensive pharmacy claim during the study period, we used the date of service of the first pharmacy claim when evaluating timing of the 3 diagnostic tests in relation to the first antihypertensive medication use during the study period. For adolescents who had more than 1 diagnostic test, we categorized them as having the diagnostic test before the prescription if they had at least 1 test before the first antihypertensive prescription. Similarly, we categorized adolescents as having diagnostic tests and prescription on the same date if they had at least the first diagnostic test done on the same date as the first antihypertensive prescription.

INDEPENDENT VARIABLES

Demographic variables included age at start of Medicaid eligibility during the study period categorized as younger (11-14 years) vs older (15-19 years) adolescents; race categorized as white, black, Hispanic, and other/unknown; and sex. Given that the sampling frame was age 12 to 18 years on December 31, 2003, it was possible for adolescents who were 11 or 19 years old at the start of their Medicaid eligibility to be included in the study. Independent variables also included duration of Medicaid eligibility and presence of obesity-related comorbidities, defined as having 1 or more visits with an *ICD-9-CM* code for obesity, hyperlipidemia, diabetes mellitus type 2, or metabolic syndrome.

STATISTICAL ANALYSES

Descriptive analyses included simple counts and proportions. We used χ^2 tests to assess associations between echocardiogram use, renal ultrasonography use, EKG use, and demographic characteristics. We performed multivariate logistic regression to evalu-

Table 1. Demographic Characteristics of 951 Adolescents With Essential Hypertension Who Had an Antihypertensive Prescription During 2003 to 2008

| | Overall, No. (%) (n = 951) |
|---|-------------------------------|
| Sex | |
| M | 648 (68) |
| F | 303 (32) |
| Race | |
| White | 480 (51) |
| Black | 417 (44) |
| Hispanic | 41 (4) |
| Other/unknown | 13 (1) |
| Age at first year of study eligibility, y | |
| 11-14 | 569 (60) |
| 15-19 | 382 (40) |
| No. of years of Medicaid eligibility | |
| 3 | 226 (24) |
| 4 | 212 (22) |
| 5 | 213 (22) |
| 6 | 300 (32) |
| Obesity-related comorbidity | |
| Yes | 538 (57) |
| No | 413 (43) |

ate the associations between demographic characteristics, renal ultrasonography use, EKG use, and echocardiogram use among adolescents with essential hypertension who had an antihypertensive pharmacy claim. Since it is unclear whether physicians would apply pediatric or adult guidelines for children 18 years of age, we conducted a separate sensitivity analysis for all who turned 18 years old during the study period. *P* values < .05 were considered statistically significant. All analyses were performed using SAS version 9.2 (SAS Institute Inc).

RESULTS

There were 416 878 adolescents 12 to 18 years of age enrolled in the Michigan Medicaid program of which 155 913 adolescents had at least 3 years of Medicaid eligibility (≥ 11 months of Medicaid eligibility and no other insurance for each study year) during 2003 to 2008. From this, we identified 2724 adolescents with a diagnosis of essential hypertension at an outpatient visit who had 1 or more antihypertensive prescriptions, then excluded those with secondary causes of hypertension and clonidine or guanfacine prescriptions, resulting in our final study sample of 951 adolescents.

STUDY SAMPLE CHARACTERISTICS

Sample characteristics of the 951 adolescents who met eligibility criteria are described in **Table 1**. Two-thirds were male; 60% were 11 to 14 years old at the start of Medicaid eligibility; and 44% were black; 51%, white, and 4%, Hispanic. Our sample demographics (N=951) were also similar to the Medicaid population in general with the exception of sex, where one-third of our sample were female whereas sex was more evenly distributed in the general Medicaid population.

Table 2. Characteristics Associated With ECHO, Renal Ultrasonography, and EKG Use Among Adolescents With Essential Hypertension Who Had an Antihypertensive Prescription During 2003 to 2008

| | % | | |
|---|-----------------------------|-------------------------------------|----------------------------|
| | Adolescents Who Had an ECHO | Adolescents Who Had Ultrasonography | Adolescents Who Had an EKG |
| Overall (n = 951) | 24 | 22 | 50 |
| Sex | | | |
| M (n = 648) | 26 ^a | 19 ^a | 52 |
| F (n = 303) | 19 | 27 | 47 |
| Race | | | |
| White (n = 480) | 25 | 23 ^a | 50 |
| Black (n = 417) | 22 | 19 | 50 |
| Hispanic (n = 41) | 27 | 29 | 56 |
| Other/unknown (n = 13) | 23 | 46 | 54 |
| Age at first year of study eligibility, y | | | |
| 11-14 (n = 569) | 27 ^a | 24 | 49 |
| 15-19 (n = 382) | 19 | 19 | 52 |
| No. of years of study eligibility | | | |
| 3 (n = 226) | 21 | 21 | 47 |
| 4 (n = 212) | 23 | 18 | 46 |
| 5 (n = 213) | 20 | 22 | 51 |
| 6 (n = 300) | 29 | 25 | 55 |
| Obesity-related comorbidity | | | |
| Yes (n = 538) | 24 | 24 | 51 |
| No (n = 413) | 24 | 19 | 49 |

Abbreviations: ECHO, echocardiogram; EKG, electrocardiogram.
^a *P* < .05.

More than half had an obesity-related comorbidity (57%). One-third of adolescents had 6 years of Medicaid eligibility during the study period.

OVERALL USE OF DIAGNOSTIC TESTS BY 951 ADOLESCENTS WITH ESSENTIAL HYPERTENSION AND AN ANTIHYPERTENSIVE PRESCRIPTION

During the study period, nearly one-quarter of adolescents with essential hypertension who had an antihypertensive prescription had at least 1 echocardiogram (n = 226) or 1 renal ultrasonography (n = 207) (**Table 2**). In contrast, 50% of adolescents with essential hypertension who had an antihypertensive prescription had at least 1 EKG (n = 478).

Demographic characteristics associated with diagnostic test use are also presented in Table 2. Males were more likely than females to get an echocardiogram; younger adolescents were more likely than older adolescents to get an echocardiogram. In contrast, females were more likely than males to get renal ultrasonography and white and Hispanic adolescents were more likely than black adolescents to get renal ultrasonography (Table 2). Additionally, there were no differences between younger and older adolescents in their renal ultrasonography use. Finally, unlike those who had an echocardiogram or renal ultrasonography, EKG use was not significantly associated with demographic characteristics among adolescents who had an EKG during the study period (Table 2).

Table 3. ECHO, Renal US, and EKG Use Among Adolescents With Essential Hypertension Who Had an Antihypertensive Rx

| Diagnostic Tests | All Adolescents, No. (%) | No. of Adolescents | | |
|-------------------------|-----------------------------|--------------------|----------------|-----------------------|
| | | Test Before Rx | Rx Before Test | Test and Rx Same Date |
| No tests | 362 (38) | ... | ... | ... |
| 1 Test | | | | |
| ECHO only | 28 (3) | 15 | 13 | 0 |
| Renal US only | 66 (7) | 28 | 37 | 1 |
| EKG only | 233 (24) | 108 | 103 | 22 |
| 2 Tests | | | | |
| EKG and ECHO | 121 (13) | 76 | 35 | 10 |
| EKG and renal US | 64 (7) | 37 | 24 | 3 |
| ECHO and renal US | 17 (2) | 7 | 7 | 3 |
| 3 Tests | | | | |
| ECHO, renal US, and EKG | 60 (6) | 42 | 16 | 2 |
| Total | 951 | 313 | 235 | 41 |

Abbreviations: ECHO, echocardiogram; ellipses, not applicable; EKG, electrocardiogram; Rx, prescription; US, ultrasonography.

FREQUENCY OF DIAGNOSTIC TEST USE IN 951 ADOLESCENTS

More than a third of adolescents with essential hypertension who had an antihypertensive prescription ($n = 362$) had none of the diagnostic tests—echocardiogram, renal ultrasonography, or EKG—during the study period (**Table 3**). One-third ($n = 327$) had 1 diagnostic test during the study period, mainly an EKG. Nearly one-quarter ($n = 202$) had 2 diagnostic tests; a combination of EKG and echocardiogram was most common. Only 60 adolescents (6%) had all 3 diagnostic tests during the study period (Table 3).

DIAGNOSTIC TEST USE IN RELATION TO ANTIHYPERTENSIVE PRESCRIPTIONS IN 589 ADOLESCENTS

Among 589 adolescents who had at least 1 diagnostic test during the study period, 53% had a diagnostic test before their first antihypertensive prescription; 7% had a diagnostic test and prescription on the same date; and 40% had a prescription before a diagnostic test (Table 3).

ECHOCARDIOGRAM USE

Among 226 adolescents who had an echocardiogram, 49% ($n = 111$) had the echocardiogram on the same date or before their first antihypertensive prescription. Of the 111, nearly a third ($n = 36$) had the first antihypertensive pharmacy claim within 1 month after the echocardiogram; 21% ($n = 23$), between 1 and 6 months after the echocardiogram; and 47% ($n = 52$), in more than 6 months after the echocardiogram.

RENAL ULTRASONOGRAPHY USE

Among 207 adolescents who had renal ultrasonography, 42% ($n = 87$) had the ultrasonography on the same date or before their first antihypertensive prescription. Of the 87, 22% ($n = 19$) had the first antihypertensive pharmacy claim within 1 month after the renal ultrasonography; 23% ($n = 20$), between 1 and 6 months after

the ultrasonography; and 55% ($n = 48$), in more than 6 months after the ultrasonography.

EKG USE

Among 478 adolescents who had at least 1 EKG, 60% ($n = 288$) had an EKG on the same date or before their first antihypertensive prescription. Of the 288, 34% ($n = 98$) had the first antihypertensive pharmacy claim within 1 month after the EKG; 19% ($n = 54$), between 1 and 6 months after the EKG; and 47% ($n = 136$), in more than 6 months after the EKG.

ORDER AND TIMING OF DIAGNOSTIC TESTS IN RELATION TO EACH OTHER IN 262 ADOLESCENTS

Among the subset of adolescents ($n = 181$) who had an EKG and an echocardiogram during the study period, 63% ($n = 114$) had an EKG before the echocardiogram, 27% ($n = 48$) had it on the same date as the echocardiogram, and 10% ($n = 19$) had an EKG after the echocardiogram.

Among the subset of adolescents ($n = 124$) who had an EKG and renal ultrasonography during the study period, 64% ($n = 80$) had the EKG before the renal ultrasonography, 6% ($n = 7$) had it on the same date as the ultrasonography, and 30% ($n = 37$) had the EKG after the renal ultrasonography.

Among the subset of adolescents ($n = 77$) who had renal ultrasonography and an echocardiogram during the study period, 34% ($n = 26$) had the renal ultrasonography before the echocardiogram, 19% ($n = 15$) had it on the same date as the echocardiogram, and 47% ($n = 36$) had the renal ultrasonography after the echocardiogram.

MULTIVARIATE LOGISTIC REGRESSION ANALYSES

Among all adolescents with essential hypertension who had an antihypertensive prescription, echocardiogram use was significantly associated with age, sex, EKG, and renal ultrasonography use in our multivariate logistic regression model (**Table 4**). Controlling for race/

ethnicity, obesity comorbidity status, and years of Medicaid eligibility, males, younger adolescents, adolescents who had an EKG, and those who had renal ultrasonography were more likely to get echocardiograms compared with females, older adolescents, those who did not have an EKG, and those who did not have renal ultrasonography. Our sensitivity analyses showed no statistically significant difference in use patterns of echocardiograms, renal ultrasonography, and EKGs between adolescents who turned 18 years old during the study period and their younger counterparts.

COMMENT

Although national guidelines recommend that all pediatric patients with hypertension get an echocardiogram to assess for target organ damage, only one-quarter of adolescents did so in our study. We found that a similar proportion of adolescents with essential hypertension had undergone renal ultrasonography at least once (22%), another guideline-recommended diagnostic test for adolescents with hypertension. Our study describes for the first time, to our knowledge, equally low levels of obtaining echocardiograms and renal ultrasonography, which are recommended by national hypertension guidelines, by adolescents with essential hypertension.

In contrast, we found that one-half of adolescents with essential hypertension had at least 1 EKG during the study period, a diagnostic test that is not recommended by pediatric hypertension guidelines but one that is recommended for adults with hypertension. Not only were EKGs the most commonly used diagnostic test of the 3 but EKG was more often used by itself than other diagnostic tests. When used in conjunction with echocardiograms and/or renal ultrasonography, EKGs were more often done first or on the same day as other diagnostic tests. The preferential use of EKGs seen in our study is understandable because EKGs are less expensive and often more readily available to most physicians at the point of care than echocardiograms or renal ultrasonography.⁷ Thus, EKGs may be used in lieu of echocardiograms to screen for LVH, a form of subclinical target organ damage. However, studies have shown relatively low sensitivity to diagnose LVH on EKGs compared with echocardiograms in adults.⁷⁻¹¹ In pediatric patients with hypertension, the sensitivity of detection of LVH may be only 25% to 35%.^{12,13} Thus, target organ damage cannot be ruled out based on the absence of LVH on EKGs alone.

Moreover, renal ultrasonography is useful to rule out potential causes of secondary hypertension in pediatric patients, most commonly of renal etiology, which is quite different from evaluation of target organ abnormalities using EKGs or echocardiograms. However, in our study, the most commonly used combination of diagnostic tests was EKGs and echocardiograms. Given that both diagnostic tests are typically used to evaluate target organ damage, it is unclear why physicians would order both EKGs and echocardiograms for their adolescent patients with essential hypertension. The rationale behind physi-

Table 4. Multivariate Logistic Regression of Patient Characteristics Associated With Echocardiogram Use Among 951 Adolescents With Essential Hypertension Who Had an Antihypertensive Prescription

| | Odds Ratio (95% CI) |
|---|------------------------|
| Male (reference = female) | 1.53 (1.06-2.21) |
| Age at first study eligibility | |
| 11-14 y (reference = 15-19 y) | 1.69 (1.17-2.44) |
| White (reference = black) | 1.22 (0.87-1.71) |
| Hispanic (reference = black) | 1.08 (0.49-2.40) |
| Other/unknown (reference = black) | 0.68 (0.17-2.83) |
| Has obesity comorbidity (reference = no comorbidity) | 0.93 (0.66-1.29) |
| 4-6 y of study eligibility (reference = 3 y) | 0.98 (0.64-1.51) |
| Had EKG (reference = no EKG) | 5.79 (4.02-8.36) |
| Had renal ultrasonography (reference = no renal ultrasonography) | 2.22 (1.54-3.20) |

Abbreviation: EKG, electrocardiogram.

cians' decision making and choice in diagnostic tests for management of essential hypertension in adolescents warrants further study.

Through national guidelines, experts in pediatric hypertension suggest that diagnostic tests such as echocardiograms be mandatory in the management of pediatric patients with hypertension. Patterns of EKG and echocardiogram use in our study raise questions about the level of familiarity, awareness, or agreement with pediatric hypertension guideline recommendations and the rationale behind these recommendations among physicians who provide primary care for children and adolescents (general pediatricians and family practitioners). Given that adult hypertension guidelines recommend EKG and not echocardiogram to assess cardiac end organ damage in adult patients with newly diagnosed hypertension,¹⁴ it is possible that physicians are more comfortable obtaining EKGs in their adolescent patients with hypertension according to adult hypertension guidelines instead. Thus, strategies to educate and inform pediatric primary care physicians about pediatric hypertension guidelines need to be developed to address these potential barriers to physician adherence to hypertension practice guidelines.¹⁵ Moreover, further study is warranted to determine efficient evaluation pathways and use of diagnostic tests in the management of essential hypertension in adolescents.

Finally, 60% of adolescents who had at least 1 of the 3 diagnostic tests under study—echocardiograms, renal ultrasonography, or EKGs—had the test on the same date or before the first antihypertensive pharmacy claim. It is possible that physicians used information about left ventricular mass and target organ damage from echocardiograms or EKGs or potential renal causes of hypertension from renal ultrasonography in their treatment decisions for those adolescents with hypertension. However, our findings also suggest potential missed opportunities and raise questions of timely and efficient use of these diagnostic tests in the treatment of adolescents with hypertension at high risk for developing cardiovascular disease in adulthood that warrant further study.

Our findings should be interpreted with the following limitations. First, our study population was adolescents enrolled in the Michigan Medicaid program, which has potential implications for generalizability of our results to a privately insured population. Second, actual blood pressure measurements of our study sample are unknown given that the study design used claims analysis and not medical record review. Third, limitations of pharmacy claims analysis suggest that prescription claims that were filled may potentially differ from use. Fourth, specialties of physicians ordering diagnostic tests are unknown because of lack of identifiable physician information on procedure claims such as Drug Enforcement Administration numbers used for pharmacy claims. Thus, it is unknown how diagnostic test ordering might differ between various specialties of primary care physicians and subspecialty physicians. However, our previous work describing antihypertensive prescribing patterns for the same study population found that the leading prescribers of antihypertensive medications were primary care physicians who provide care for both adults and children, mainly family practitioners.⁶ Fifth, timing of diagnostic tests could be subjective to appointment availability, patient schedule, and/or patient compliance with obtaining physician-ordered tests. Sixth, the rationale behind physicians' use of diagnostic tests in the management of adolescents with essential hypertension is unknown. Finally, we acknowledge a left-censoring issue where we cannot evaluate diagnostic tests or antihypertensive pharmacy claims before 2003.

CONCLUSIONS

Hypertension guideline—recommended diagnostic tests—echocardiograms and renal ultrasonography—were equally poorly used by adolescents with essential hypertension. Sex and age differences exist in the use of echocardiograms by adolescents with essential hypertension. The decision and choice of diagnostic tests to evaluate for target organ damage in adolescents with essential hypertension warrant further study to understand the underlying rationale for those decisions and to determine treatment effectiveness.

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