

Research Submission

An Expert System for Headache Diagnosis: The Computerized Headache Assessment Tool (CHAT)

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Background.—Migraine is a highly prevalent chronic disorder associated with significant morbidity. Chronic daily headache syndromes, while less common, are less likely to be recognized, and impair quality of life to an even greater extent than episodic migraine. A variety of screening and diagnostic tools for migraine have been proposed and studied. Few investigators have developed and evaluated computerized programs to diagnose headache.

Objectives.—To develop and determine the accuracy and utility of a computerized headache assessment tool (CHAT). CHAT was designed to identify all of the major primary headache disorders, distinguish daily from episodic types, and recognize medication overuse.

Methods.—CHAT was developed using an expert systems approach to headache diagnosis, with initial branch points determined by headache frequency and duration. Appropriate clinical criteria are presented relevant to brief and longer-lasting headaches. CHAT was posted on a web site using Microsoft active server pages and a SQL-server database server. A convenience sample of patients who presented to the adult urgent care department with headache, and patients in a family practice waiting room, were solicited to participate. Those who completed the on-line questionnaire were contacted for a diagnostic interview.

Results.—One hundred thirty-five patients completed CHAT and 117 completed a diagnostic interview. CHAT correctly identified 35/35 (100%) patients with episodic migraine and 42/49 (85.7%) of patients with transformed migraine. CHAT also correctly identified 11/11 patients with chronic tension-type headache, 2/2 with episodic tension-type headache, and 1/1 with episodic cluster headache. Medication overuse was correctly recognized in 43/52 (82.7%). The most common misdiagnoses by CHAT were seen in patients with transformed migraine or new daily persistent headache.

Fifty patients were referred to their primary care physician and 62 to the headache clinic. Of 29 patients referred to the PCP with a confirmed diagnosis of migraine, 25 made a follow-up appointment, the PCP diagnosed migraine in 19, and initiated migraine-specific therapy or prophylaxis in 17.

Conclusion.—The described expert system displays high diagnostic accuracy for migraine and other primary headache disorders, including daily headache syndromes and medication overuse. As part of a disease management program, CHAT led to patients receiving appropriate diagnoses and therapy. Limitations of the system include patient willingness to utilize the program, introducing such a process into the culture of medical care, and the difficult distinction of transformed migraine.

Key words: headache diagnosis, expert systems, disease management
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Annually, over 10% of the population suffers at least one migraine headache,¹ with a significant impact on the individual's quality of life,² as well as a major economic and societal burden.³ Up to 5% of

the adult population may suffer from daily headache syndromes, with medication overuse identified in one-third of these patients.⁴ The impact of chronic daily headache on the individual and society is even greater than that of episodic migraine.

Despite significant advances in acute and preventive therapy, migraine remains underdiagnosed, and "drug rebound headache" an "unrecognized epidemic."⁵ A population-based survey found that

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only 48% of participants who fulfilled International Headache Society (IHS) criteria for migraine had been diagnosed as having migraine.⁶ Only 50% of patients who fulfill criteria for migraine and seek medical care are correctly diagnosed.⁷ The burden of undiagnosed migraine is significant: 24% of patients with undiagnosed migraine missed at least 1 day of work or school in the previous 3 months, and 45% reported at least a 50% reduction in productivity.⁶

Several authors have also proposed simplified criteria for diagnosis of migraine. These typically include some subset of IHS criteria.⁸⁻¹⁰ A variety of questionnaires to diagnose migraine have been developed, with reported sensitivities of 76–84%, and specificities of 92–99%.^{11,12} None of these instruments has come to be used commonly in clinical practice.

There have been few reports of utilizing computer technology to diagnose migraine and other primary headache disorders. Drummond and Lance utilized a computer algorithm to determine to what extent clusters of symptoms differentiated diagnoses along the “migraine-tension headache spectrum.”¹³ Andrew et al.¹⁴ and Gobel et al.¹⁵ incorporated the 1988 IHS classification system¹⁶ into a computer program. Gobel’s group later utilized the program to standardize inclusion of patients into a sumatriptan trial.¹⁷

Diagnostic headache diaries^{18,19} and structured medical records²⁰ have been incorporated into computer programs to aid in headache diagnosis. Several authors have described programs but not reported validating the instruments with diagnostic interviews.²¹⁻²³ Most of the above programs are essentially checklists of symptoms which the computer program tries to fit into a specific diagnosis.

The author (Morris Maizels) sought to develop a headache diagnostic program which would employ simple branching decisions to mimic the logic of a clinician. The Computerized Headache Assessment Tool (CHAT) was developed with the following features in mind (summarized in Table 1): completed by patients on-line; questions are systematically presented depending on prior answers (patients are only presented with relevant questions); screens for all common primary headache disorders; distinguishes chronic from episodic subtypes; recognizes medication overuse; and screens for potentially worrisome headaches. It was

Table 1.—Desired Characteristics of a Computerized Headache Diagnostic System

Diagnostic Features
• Recognize the major primary headache disorders, including migraine, tension-type headache, cluster headache, and brief headache syndromes
• Distinguish chronic from episodic subtypes of migraine, tension-type headache, and cluster headache
• Recognize medication overuse
• Screen for “worrisome” features
User-friendly
• Patient self-administered
• Rapid completion
Human Interviewer Characteristics
• Branching logic
• Subsequent questions selected based on prior answers (patient only sees relevant questions)
• Feedback answers
• Recognize and correct inconsistencies
Clinically Useful Output
• Criteria for generated diagnoses are explained in a format understandable for patients
• Hardcopy of output is suitable for physician to review with patient, and to include into a medical record

hoped that the output of the program would be in a format suitable for a physician to review with the patient, and to include in the medical record. This article describes the development of the program, the diagnostic accuracy for primary headache syndromes, and the outcomes of screening.

METHODS

Description of the Computerized Headache Assessment Tool (CHAT).—CHAT consists of 4 sections: an explanatory and disclaimer page, the interview section, feedback of answers, and diagnostic output.

The disclaimer page requires patients to confirm their understanding that the tool is intended for use in conjunction with a health care professional.

The interview section begins with 2 screens which all subjects see: the first asks the frequency of moderate-to-severe headaches, and the second the duration of these headaches. Based on these answers, the questioning branches. Patients with headaches lasting 3 hours or less next answer questions relevant to brief headache syndromes (number of attacks/day, location, quality, autonomic features, triggering). Patients with severe headaches 4 hours or longer see

a screen, which asks questions based on IHS criteria for migraine and tension-type headache (severity, laterality, throbbing vs dull, exacerbation with physical activity, associated nausea or vomiting, light or noise sensitivity). This screen also determines the frequency of milder headaches and medication usage. Patients with headaches lasting longer than 4 hours are also asked questions about their previous headaches: whether they were daily from onset or became daily suddenly or gradually; whether there were any significant events associated with headache onset or “transformation”; whether there has been a significant change in headache pattern; and how long the current headache pattern has persisted. For patients whose current headaches did not fulfill migraine criteria on the previous screen, they see an additional screen to determine whether previous headaches met migraine criteria.

Feedback. A screen summarizes the patients answers, and the patient has an opportunity to correct any answers.

Diagnostic Output.—The screen shows an “assessment” (the word “diagnosis” is not used, to reduce the subject’s reliance on the CHAT assessment without clinician review). Assessments were based on the 1988 IHS classification system,¹⁶ and the Silberstein–Lipton revised criteria for transformed migraine.²⁴ Potential assessments for headaches lasting 4 hours or longer include migraine (episodic or transformed), migrainous, episodic or chronic tension-type headache, and new daily persistent headache. The assessment includes “. . . with medication overuse” for subjects who indicated symptomatic medication use 3–4 days/week or more. For brief headache syndromes, diagnoses include cluster (episodic or chronic) and atypical cluster headache, idiopathic stabbing headache, and trigeminal neuralgia. Importantly, headaches that do not fulfill criteria of the above conditions generate an assessment of “cannot assess.” All diagnoses are followed by a brief explanation of how the diagnosis was made. Patients with daily or near-daily headaches see a caution in bold print that frequent or daily headaches require evaluation to exclude worrisome causes.

Errors and Inconsistencies.—During initial testing, it was noted that patients might indicate that headache

duration was 3 hours or less when in fact it was over 4 hours. To confirm that this answer is correct, patients with episodic headache who indicate duration as 3 hours or less see a screen that says “Do these headaches ever last more than 4 hours?” Further, for patients who are initially routed to the brief headaches screen, if they do not fulfill criteria for any of the brief headache syndromes, they are routed through the questions for patients with headaches lasting 4 hours or longer.

Study Setting.—The patient population included members of a suburban health maintenance organization. Patients completed the internet questionnaire at home or work.

Patient Selection.—A poster in the triage section of the adult urgent care (AUC) department described the study, and nurses were asked to identify headache patients and hand them a flyer. However, because of poor compliance with this method, we later mailed out a study flyer to patients who had presented to AUC with headache. A flyer describing the study was also posted in the family medicine department at the receptionist’s desk. There were no inclusion or exclusion criteria for participation, other than age over 18.

Diagnostic Confirmation.—Study participants who granted permission were contacted by telephone. A headache clinic nurse experienced in headache diagnosis performed diagnostic interviews. The interview began with the San Diego migraine questionnaire, a well-validated instrument for migraine diagnosis.¹² Patients with frequent headache were further classified by the modified Silberstein–Lipton criteria.²⁴ Patients with brief headache syndromes were classified by IHS criteria. All interviews with diagnostic uncertainty were reviewed by the author (Morris Maizels).

Patient Follow-Up.—Patients were offered follow-up appointments to their primary care physician if headaches were diagnosed as episodic migraine or tension-type headache, and to the headache clinic if headaches were diagnosed as chronic migraine or another daily headache syndrome.

Chart Review.—Medical records of patients who completed their diagnostic interview were reviewed within 6 months to determine if they had kept their

follow-up appointment, and whether any new treatments were initiated as a result.

Data Analysis.—Simple descriptive analyses were performed on the data.

This study was approved by the Institutional Review Board. Patient consent was obtained through the introductory screen online.

RESULTS

One hundred thirty-five subjects completed the online survey, 103 from AUC and 32 from primary care. Diagnostic interviews were completed on 117 subjects. Physician diagnoses were available for 98 patients from the AUC sample but not for the primary care waiting room sample. The confirmed diagnoses, CHAT assessments, and AUC physician diagnoses are shown in Table 2.

CHAT correctly identified 35/35 (100%) patients with episodic migraine and 42/49 (86%) of patients with transformed migraine. Urgent care physicians correctly diagnosed 26/30 (86.7%) of patients with episodic migraine, and recognized 27/40 (66.7%) of patients with transformed migraine as migraine, although none as a daily headache disorder. CHAT also correctly identified 12/12 patients with chronic tension-type headache, 2/2 with episodic tension-type headache, and 1/1 with episodic cluster headache. Although NDPH was correctly identified in only 3/7 (42.9%) patients, CHAT recognized 6/7 as a daily headache syndrome.

CHAT recognized medication overuse in 43/52 (82.7%) patients who met criteria for the diagnosis on diagnostic interview. Three additional assessments of medication overuse by CHAT were not confirmed.

Overall, CHAT recognized 85/90 (94.4%) cases of “any migraine,” (ie, migraine, migrainous, or TM) and 63/68 (92.6%) as a daily headache syndrome (TM, CTTH, or NDPH). The diagnostic accuracy for all headache diagnoses, including unclassifiable (but not including medication overuse) was 104/117 (88.9%).

Patient Follow-Up.—Fifty patients were referred to their primary care physician, and 42 made at least one visit for headache follow-up. Of 29 patients referred with a confirmed diagnosis of migraine, 25 made a follow-up appointment, the PCP diagnosed mi-

Table 2.—Confirmed Diagnoses, Assessments Generated by CHAT, and Physician Diagnoses From Adult Urgent Care Visits. Percentages (in Parentheses) of Correct Assessment/Diagnosis

Confirmed Diagnosis n = 117	CHAT Assessment n = 117	Physician Diagnosis n = 98
Episodic migraine 35	Episodic migraine 35 (100%)	“Migraine” 26/30 (86.7%)
Migrainous* 6	Migrainous 5 (83.3%) Probable TM*** 1	TH 1 “vascular headache” 1 no specific diagnosis 1
TM** 49	TM 42/49 (85.7%) Episodic migraine 2 CTTH 3	“Migraine” 27/40 (66.7%)
NDPH 7	atypical cluster 1 “can’t assess” 1 NDPH 3 (42.9%) TM 1	TH 2 no specific diagnosis 3
CTTH 12	CTTH 2 “can’t assess” 1 CTTH 12/12 (100%)	migraine 2 “TTH” 1 no specific diagnosis 9
ETTH 2	ETTH 2/2 (100%)	no specific diagnosis 2
Cluster headache • episodic 1	Cluster headache • episodic 1/1 (100%)	• no specific diagnosis 1
• atypical 1	• atypical 1/1 (100%)	• “rhinitis vs. cluster” 1
Unclassifiable 4	“can’t assess” 3 (75%)	no specific diagnosis 4
Medication overuse 52	NDPH 1 Medication overuse 43 (82.7%)	(none identified)

* “Migrainous” now labeled “probable migraine” by ICHD-II classification.

** “Transformed migraine,” as designated by Silberstein-Lipton criteria, not recognized in ICHD-II classification.

*** Probable transformed migraine, ie, patient could not recall whether headaches changed gradually.

TM = transformed migraine; NDPH = new daily persistent headache; CTTH = chronic tension-type headache; ETTH = episodic tension-type headache; TH = tension headache.

graine in 19, and initiated migraine-specific therapy or prophylaxis in 17. Sixty-two patients were referred for evaluation to the headache clinic, and 51 made at least one visit.

DISCUSSION

An expert systems approach to headache diagnosis, as incorporated in CHAT, achieves diagnostic precision for primary headache diagnoses. Like all of clinical medicine, accurate diagnosis depends on the accuracy of patient responses, and a skilled human interviewer is likely to elicit more accurate responses than a fixed computer program.

In our patient sample, CHAT recognized 100% of patients correctly as episodic migraine. There were 13 incorrect diagnoses for the entire cohort, of which 11 were in patients classified by interview as TM or NDPH. The diagnosis of TM and NDPH both rely on the patient's accurate recall of whether headaches began abruptly and/or became daily gradually or abruptly. The accuracy of this recall is difficult to determine. The designation of TM has been replaced in the current ICHD-II by chronic migraine and episodic migraine + CTTH. However, the difficulties of this diagnostic category led to an appendix revision of chronic migraine (appendix 1.5.1 chronic migraine), which allows for CM to be diagnosed with ≥ 15 headache days/month, of which 8 days are migraine-like.²⁵ From a clinical point-of-view, especially in a primary care setting, the distinctions of migraine from non-migraine, and frequent/daily from episodic are important. The nuances of CM and NDPH would not change clinical practice.

The ability of the program to recognize certain headaches as unclassifiable, ie, "can't assess," is an important feature of this program. This assessment is most often generated when patients entered incorrect data for headache duration (ie, patients with migraine may indicate headache duration less than 3 hours because of relief with medication).

The recognition of medication overuse is an important feature of headache evaluation, and one commonly overlooked in primary care settings. CHAT correctly recognized medication overuse in 43/52 (82.7%) patients, with 3 false positive diagnoses. The false positives occurred in part because some patients confused preventive with acute/abortive medication.

Physicians had a high rate of correct diagnosis of migraine, although the study did not determine what percent of the AUC sample identified themselves as having migraine. The label of "transformed" or chronic

migraine is not one familiar to primary care physicians. A surrogate marker to indicate whether physicians recognize headache frequency and its significance might be the use of prophylaxis. This measure was beyond the scope of the study.

CHAT is a unique system in that it combines simple human-like branching logic to determine the most appropriate diagnostic questions to ask. Recently, Sarchielli et al.¹⁹ reported on a software program which could generate ICHD-II diagnoses of all migraine subtypes, tension-type headache, cluster headache, and other trigeminal autonomic cephalgias. However, the program relies on data entered from patients' headache diaries, and is suggested as useful in tertiary headache centers rather than for primary care diagnosis.

Study Limitations and Limitations of CHAT.—Headaches were most difficult to classify, both by human interviewer and by CHAT, in patients with headache of recent onset (often associated with viral-like syndromes).

The tested edition of CHAT does not recognize many of the brief headache syndromes, specifically paroxysmal hemicranias, SUNCT, trigeminal neuralgia, and hypnic headache.

Further, CHAT cannot generate more than a single headache diagnosis. This feature would require revision to be consistent with ICHD-II which distinguishes chronic migraine from episodic migraine + CTTH.

The appropriate clinical application of CHAT would have the physician confirm the accuracy of patient replies. This may not occur, leading to the possibility of treatment based on unvalidated patient replies. However, this problem exists for any screening instrument used in medicine.

Any automated screening program must take pains to recognize potentially serious causes for headache, or caution both patient and physician users about that possibility. A later version of CHAT added the question, "Has this headache pattern been stable for the past six months?" This question has not been validated as an adequate screen for ominous headaches.

Future Development.—The criterion-based portion of this program can be readily modified to the cur-

rent ICHD-II and future iterations of headache diagnosis. The branching logic at present appears appropriate although further study may lead to future modification.

The main modification would involve deletion of “transformed migraine,” replacing it with chronic migraine, episodic migraine + CTTH, or CTTH alone. “Migrainous” would be replaced with “probable migraine,” a change not requiring any change in the logic of the program. The less common primary care headache syndromes (paroxysmal hemicranias, SUNCT, hypnic headache, etc) can readily be included, although their rarity will make validation in a general population difficult.

CONCLUSION

An internet-based headache assessment tool has demonstrated a high degree of accuracy in recognizing primary headache disorders, distinguishing chronic daily from episodic headache, and recognizing medication overuse. No other computer-assisted headache diagnostic program described in the medical literature has a similar scope of diagnosis, or demonstrated accuracy.

The major challenge of computer-assisted headache diagnosis at present is not in developing better programs, but in facilitating patients to use such programs, and encouraging their use in primary care settings. Further development might integrate online headache assessment with education about headache treatment, identification of headache triggers, and innovative online behavioral modification programs.

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