

## Development of an Expert System for Aiding Migraine Diagnosis

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### ABSTRACT

**Objective:** To design and develop a prototype expert system to aid physicians in diagnosing migraines and their sub-types.

**Design:** Developmental process.

**Setting:** Since the system is Web-based, it is accessible to any physician or healthcare provider anywhere in the world.

**Methods:** The knowledge acquisition process was facilitated by a physician who served as our domain expert to identify the application's key elements. We have included the essential questions and rules that are necessary for building an expert system for aiding migraine diagnosis and distinguishing migraines from other types of headaches. The application utilises a data collection form, the C Language Integrated Production System (CLIPS), and a program with the appropriate rules, which are written in the CLIPS language. The front end and middle tier is built, and the connection between the HTML (Hypertext Markup Language) front end and the expert system shell CLIPS is established. We also created an XML (Extensible Markup Language) representation of the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM), including the disease category 346 (Migraine), and published it on the Web. The system was tested using data from six patients with a clinical diagnosis of migraine.

**Results:** For each of the six cases the system indicated that the likelihood of the diagnosis of migraine was greater than 75%, with the probability for fourteen different sub-types ranging from 0% to 97%. The time taken by the system to process the data was related to the number of questions asked and the number of sub-types embedded in the system, but was less than thirty seconds for all cases tested.

**Conclusion:** We have developed an expert system for aiding physicians in the diagnosis of migraines and their sub-types. Further development and evaluation of the clinical accuracy of the system are necessary before it can be recommended for routine clinical use.

## INTRODUCTION

Headaches in a variety of forms are one of the most common areas of complaint presenting to physicians. They present a diagnostic challenge as they can be caused by more than 100 diseases<sup>1</sup>, and accurate diagnosis of the cause is essential to optimal treatment. With respect to migraines, there are at least twenty different types and specific, individualised treatment is more effective than nonspecific therapies in relieving symptoms, preventing attacks and maintaining patient function<sup>2</sup>. However, migraines are frequently underdiagnosed or misdiagnosed as tension type headaches<sup>3-6</sup>. Consequently many patients do not receive appropriate treatment and continue to suffer attacks with associated disabling symptoms.

The International Headache Society has proposed a classification scheme for headaches including rules to diagnose migraines<sup>7,8</sup>. These, however, appear to be over-simplified and we consequently have developed a Web-enabled application using more sophisticated rules to aid diagnosis of migraines. The rules for the application are represented in the C Language Integrated Production System (CLIPS) expert system shell. CLIPS is a product development and delivery expert system tool which provides a complete environment for the construction of rule and/or object based expert systems<sup>9</sup>.

## METHODS

The CLIPS expert system shell provides a cohesive tool for handling a wide variety of knowledge with support for three different programming paradigms:

- Rule-based
- Object-oriented
- Procedural

Rule-based programming allows knowledge to be represented as heuristics, or 'rule of thumb', which specify a set of actions to be performed for a given situation. Object-oriented programming allows complex systems to be modeled as modular components, which can be easily reused later. The procedural programming capabilities are similar to capabilities found in languages such as C. CLIPS can be embedded within procedural code, called as a subroutine, and integrated with languages such as C and Java. CLIPS can easily be extended by a user through the use of several well-defined protocols, and it can be implemented in Web-based applications using the Common Gateway Interface (CGI) bin or Java servlets.

The clinical diagnosis of migraine is based on headache characteristics and associated symptoms, particularly nausea and vomiting. Figures A3 and A4 in the Appendix show the form containing the questions identified as relevant to the diagnosis. The program itself can dynamically generate the forms and these are directly filled in on the computer. Paper forms are not required but may be neces-

sary for people without direct access to a computer. If paper forms are used then data entered from the form to a computer will need to be validated and corrected, if necessary.

The International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM), classifies migraines into twenty different sub-types<sup>10</sup>. To test our system, research was performed on a subset of questions and types of migraines. We selected only ten of these questions for our research, and created the appropriate program. From the twenty known types of migraines we randomly selected fourteen types. The rules we created are based on existing criteria<sup>6-7</sup>; however, we introduced additional artificial dependencies for the purpose of testing system performance. The certainty of each diagnosis is calculated by three parameters; these parameters are chosen by the program according to certain rules related to the answers given.

**Table 1.** *Migraine Expert System Questions and Answers for six cases with a clinical diagnosis of migraine*

Question	Answers for Case					
	1	2	3	4	5	6
1 Age (in years)?	0-29	30-49	50-69	70-up	0-29	50-69
2 Gender?	female	male	female	male	male	female
3 Does your headache occur during menstruation, ovulation, menopause or oral contraceptives?	yes	-	-	-	-	-
4 Does your headache BEGIN on right side?	yes	yes	no	yes	no	no
5 How does your headache feel?	dull	aching	throbbing	unknown	aching	dull
6 Does pain interfere significantly with school activity*?	yes	no	no	no	no	no
7 Does vomiting accompany the headache?	no	yes	no	yes	yes	no
8 Does nausea accompany the headache?	yes	-	no	-	-	no
9 The number of headaches per month?	0-2	6-9	10-19	0-2	3-5	6-9
10 Can your headache be triggered by certain foods, odors, stress or weather changes?	yes	no	yes	no	no	yes

**Note:** School would apply to an adolescent or young adult in graduate school. Here we present only ten questions, but we are currently working on the comprehensive program containing the set of all available questions and rules.

These simplifications are necessary to create a prototype of the expert system for migraines, and to test the rules and performance, and to later extend the system. We also introduced additional complexity into the CLIPS rules to increase the accuracy of migraine diagnosis.

To test our system we entered answers obtained by interviewing six patients, diagnosed with migraines. The data was entered directly using an existing CLIPS interface. The user's dialogue with the CLIPS application is presented in the Appendix.

We also evaluated the execution time of the system with respect to the number of questions asked and the number of migraine types embedded in the system.

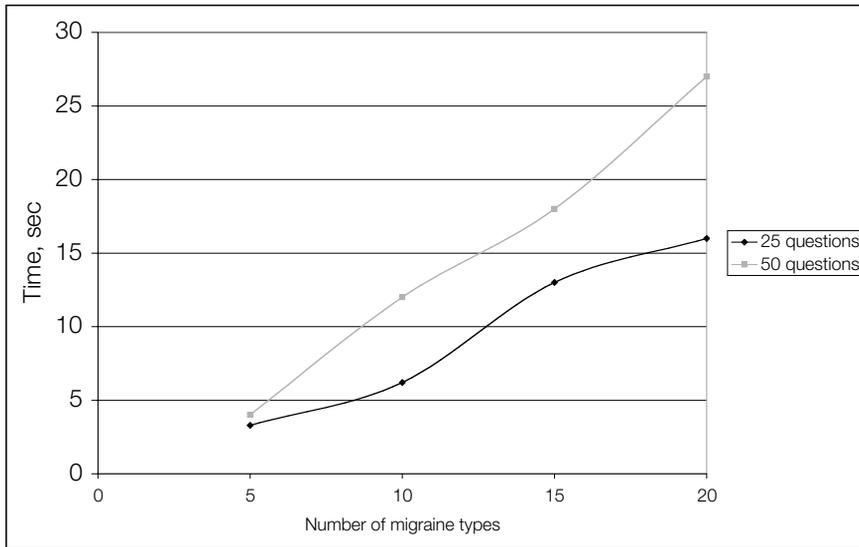
RESULTS

The results from the CLIPS system for the six patients with a known diagnosis of migraine are shown in Table 2 below: In all patients the certainty for a diagnosis of migraine is at least 75%, but the sub-diagnoses vary from 0% to 97%. For example, Patient 1 has three possible types of migraine with the certainty of Horton's neuralgia being highest (88%), and for atypical migraine being lowest (40%). Missing values for the other eleven types of migraine indicate that the certainty of such types is negligible. For the six patients evaluated, for the fourteen different types of migraine, the system helps to narrow 84 (14x6) possible diagnoses down to 48 (3+11+8+13+7+4).

The precision of the system may be improved by increasing the number of questions. As shown in Figure 1 this increases the time that the system takes to process the data. This increase in time of a few seconds is, however, of no clinical

Table 2. Certainty of a specific diagnosis for various cases

	ICD-9 Code	Migraine description	Certainty for each Case Number (%)					
			1	2	3	4	5	6
1	346.0.1	Migraine preceded by ...	-	40	92	36	-	40
2	346.0.2	Migraine with aura	-	-	-	20	20	-
3	346.1.1	Atypical migraine	40	-	-	20	20	-
4	346.1.2	Sick Headache	-	36	36	59	20	-
5	346.2.1	Cluster headache	64	20	-	36	-	-
6	346.2.2	Histamine cephalgia	-	36	36	59	-	40
7	346.2.3	Horton's neuralgia	88	20	20	20	-	80
8	346.2.4.1	Migraine abdominal	-	20	-	36	-	-
9	346.2.4.2	Migraine basilar	-	76	-	76	76	-
10	346.2.4.3	Migraine lower half	-	40	40	68	40	-
11	346.2.4.4	Migraine retinal	-	40	-	68	40	-
12	346.2.5	Neuralgia	-	40	40	20	-	-
13	346.2.8.1	Migraine hemiplegics	-	-	97	-	-	80
14	346.9	Migraine, unspecified	-	40	40	68	40	-



**Figure 1.** The execution time for the CLIPS procedure with respect to the number of questions asked and the number of migraine types embedded into the system

significance. The time to process the data is also affected by the number of migraine types embedded into the expert system. Increasing the number from the 5 most common migraine diagnoses to 20 types increases the execution time from 3 to 17 seconds (see Figure 1). Again this increase in time is of no clinical significance.

## DISCUSSION

Recent advances in understanding the pathophysiology of migraine combined with better pharmacotherapy have improved treatment of migraineurs with respect to relieving symptoms, preventing attacks and maintaining functionality. However, for patients to benefit from appropriate therapy, accurate diagnosis of migraines is essential. This is based on the history, but physicians frequently fail to ask all the relevant questions necessary to make the diagnosis. This is demonstrated by a recent study which found that the documented history was inadequate to exclude the diagnosis of migraine in two-thirds of cases in which a diagnosis of non-migraine headaches was made<sup>6</sup>. Data from other studies and surveys have also confirmed that migraines are frequently underdiagnosed or misdiagnosed as tension headaches<sup>2-5</sup>.

The system we have developed aids the diagnosis of migraines by ensuring that necessary questions to make the diagnosis are asked. The system was tested using only ten questions but twenty-three essential questions have been identified for helping to distinguish migraines from headaches. More questions should help to improve discrimination. Some of these questions may be omitted depending on

answers to previous questions. For example, the question ‘Does your headache occur during menstruation, ovulation, menopause or oral contraceptives?’ will appear only if the answers to the previous questions ‘Age (in years)?’ and ‘Gender?’ are ‘0–29 or 30–49’ and ‘Female’ respectively .

The system has been developed using the CLIPS expert system shell as this tool provides a complete environment for the construction of rule- and/or object-based expert systems<sup>9</sup>. It can include a number of features including support for modular design and partitioning of a knowledge base, static and dynamic constraint checking of slot values and function arguments, and semantic analysis of rule patterns to determine if inconsistencies could prevent a rule from firing or generating an error.

The application is intended primarily for physicians, but patients could use a modified version. This could be provided as either an online or stand-alone application, but an online approach is better for new data collection and updating rules. The procedure requires about 1 minute to physically enter the answers to the questions (but obviously takes longer to ask or read the questions), and execute the expert system. To provide likely diagnoses takes less than 30 seconds and depending on the patient’s symptoms the system can reduce the number of possible types of migraine by almost 50%. We estimate that use of such a system during a typical consultation for headaches will save several minutes of the doctor’s and patient’s time. It should also reduce the need for unnecessary investigations. Through both these mechanisms it should produce cost-savings. However, this and the system’s ability to improve migraine diagnosis including differentiating them from tension headaches remains to be proven.

## CONCLUSION

We have created a program, written in the CLIPS language for expert systems, to aid the diagnosis of migraines and to distinguish them from headaches. We have identified essential questions necessary for building an expert system that distinguishes migraines from headaches. The execution time depends on the number of migraine types embedded in the expert system. The time varies from three seconds for the five most common migraine cases to seventeen seconds for the entire set of twenty types of migraine according to the ICD-9-CM classification. We also created an XML representation of the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM), including disease category 346 (Migraines), and published it on the Web. The clinical accuracy of the system and its benefits remain to be established.

## ACKNOWLEDGEMENT

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APPENDIX

The research application prototypes were developed on both UNIX and Windows platforms using the following techniques: data mining, online transaction analytical processing

Open source and freeware tools such as Java, MySQL (Structured Query Language) database, Apache Web server, and CLIPS Expert System shell were used in the development process.

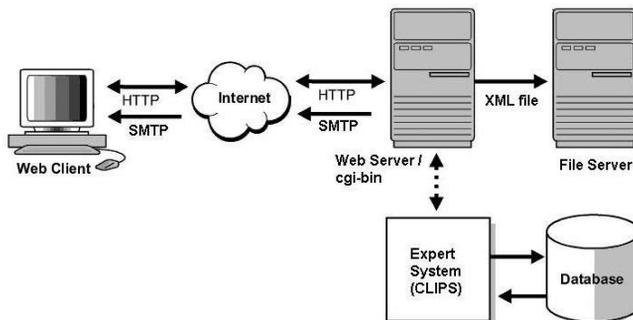


Figure A1. The Migraine / Headaches Application Schema

The graphic user interface (GUI) and presentation layer are written in HTML and JavaScript, while the Application and data manipulation layers are written in Common Gateway Interface (CGI) Perl script. In our present implementation, data is collected in the XML format as a file for future analysis and sent by e-mail (Figure A1).

```

<?xml version="1.0" encoding="UTF-8" ?>
- <ICD-9-CM>
- <topic name="Classification of Diseases and Injuries">
  <group number="1">Infectious and Parasitic Diseases</group>
  <group number="2">Neoplasms</group>
  <group number="3">Endocrine, Nutritional, and Metabolic Diseases and Immunity Disorders</group>
  <group number="4">Diseases of the Blood and Blood-Forming Organs</group>
  <group number="5">Mental Disorders</group>
- <group number="6">
  Diseases of the Nervous System and Sense Organs
- <diseases numbers="340-349">
  <diseasesclass>Other disorders of the central nervous system (340-349)
  </diseasesclass>
- <category id="346">
  <categoryname>Migraine</categoryname>
- <subcode id="346.0">
  <subcodename>Classical migraine</subcodename>
  <disease id="346.0.1">Migraine preceded or accompanied by transient focal neurological phenomena</disease>
  <disease id="346.0.2">Migraine with aura</disease>
  </subcode>
- <subcode id="346.1">
  <subcodename>Common migraine</subcodename>
  <disease id="346.1.1">Atypical migraine</disease>
  <disease id="346.1.2">Sick headache</disease>

```

Figure A2. International Classification of Diseases (ICD-9-CM) (Fragment)

Brooklyn College. Migraine Application revision 1.1.5

<b>Please enter general information:</b>	
Facility name	<input type="text"/>
Date	<input type="text"/>
<b>Patient Details:</b>	
• First Name	<input type="text"/>
• Last Name	<input type="text"/>
• Medical Record Number	<input type="text"/>
• Gender	[Gender] ▾
• Age (in years)	[Age] ▾
• Zip Code	<input type="text"/>
• Where does your headache BEGIN? (Check <u>ALL</u> that apply)	
<input type="checkbox"/> Right Side	<input type="checkbox"/> Left Side <input type="checkbox"/> Forehead <input type="checkbox"/> Back of head
• How does your headache feel? (Check the <u>SINGLE</u> answer that best describes your typical headache)	
<input type="radio"/> Throbbing	<input type="radio"/> Dull <input type="radio"/> Aching <input type="radio"/> Other
• I have about [Number] ▾ headaches per month	

Figure A3. Migraine Application HTML Form (fragment – upper part)

**Please check ALL the symptoms that usually accompany your headache:**

- Nausea
- Vomiting
- Sensitivity to bright light
- Sensitivity to loud noise
- Worsening of pain with movement
- My headaches began when I was about [Age] years old

**Please check ALL of the following that apply:**

- My headache sometimes interferes with following activity:  
 School  Work  Social  None of these

**A family history of headache:**

- Do any of your close relatives have significant headaches [?]

**Please check ALL of the following which describe your headache:**

- Can be triggered by certain foods, odors, stress or weather change
- Occurs during menstruation, ovulation, menopause or oral contraceptives administration
- Occurs with or after sustained exertion
- Begins with a visual or other warning before the headache begins
- Improves with sleep

Press to submit      Reset Parameters

Figure A4. Migraine Application HTML Form (fragment – lower part)

Note 1. Most of the questions are based on the identification of headache syndromes in accordance with the International Headache Society (HIS) or the World Health Organization’s International Classification of Diseases (ICD-10).

Note 2. School would apply to an adolescent or young adult in graduate school.

A Java extraction transformation loading (ETL) procedure was used to transform the source text file into an XML file. It was then utilised to build the XML representation of the original International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) as shown in Figure A2. The Migraines and Headaches Application Form (Figures A3 and A4) was developed and published on the Web. The Perl script simple-form.cgi takes the input from a form, sends it to a specified email address, appends information to the XML file and returns a confirmation page.

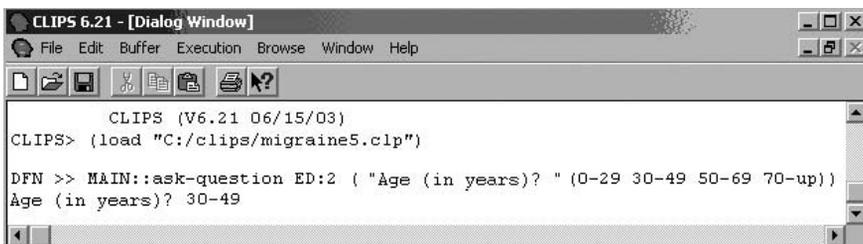


Figure A5. User’s dialogue with CLIPS application (fragment)

The answers from six patients, diagnosed with migraine, were obtained by interviewing. The data was entered directly using an existing CLIPS interface. Patients' potential diagnoses are presented in Table 2.

**Patient Case1 – Dialogue with CLIPS system:**

CLIPS: "Age (in years)?" (0–29 30–49 50–69 70-up) /\* valid answers, see Figure A5 \*/

Patient: 0–29.

CLIPS: Gender? (Male/Female)

Patient: Female.

CLIPS: Does your headache occur during menstruation, ovulation, menopause or oral contraceptives? (Yes/No)

Patient: Yes.

CLIPS: Does your headache BEGIN on right side? (Yes/No)

Patient: Yes.

CLIPS: How does your headache feel? (throbbing dull aching other unknown)

Patient: Dull.

CLIPS: Does pain interfere significantly with school activity? (Yes/No)

Patient: Yes.

CLIPS: Does vomiting accompany your headache? (Yes/No)

Patient: No.

CLIPS: Does nausea accompany your headache? (Yes/No)

Patient: Yes.

CLIPS: The number of headaches per month? (0–2 3–5 6–9 10–19 20-up)

Patient: 0–2.

CLIPS: Can your headache be triggered by certain foods, odors, stress or weather changes? (Yes/No)

Patient: Yes

