Development of a Medical Expert System for the Diagnosis of Ectopic Pregnancy†

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Objective: *To developed a software-based medical expert system for supporting in the diagnosis of ectopic pregnancy.*
Material and Method: *This system was developed to facilitate the knowledge creation and inference engine. The diagnostic process used the interactive backward chaining inference algorithm. The medical knowledge base was represented as production rules which performed in tree structure. The system designed to interact with users in question information form. After that, the clinical data from medical records of patients were applied to the system by physician retrospectively.*
Results: *Thirty-two medical records of women who diagnosed ectopic pregnancy were reviewed. The mean patients' age was 27.7 years. The majority of the patients were multigravida gestation. There were twenty-one patients who did not have any risk factors of ectopic pregnancy. 31 of patients' clinical data applied to the system successfully. All of them had correspondent diagnosis with established ectopic pregnancy.*
Conclusion: *This medical expert system was found to be a good tool to facilitate the decision making in the diagnosis of ectopic pregnancy.*

Keywords: *Medical expert system, Ectopic pregnancy, Medical knowledge-based system*

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To date, many researchers have proposed various methods to improve the learning ability of medical students and healthcare providers. There are many evidences that medical informatics can facilitate the medical and paramedical education[1]; for example, a computer-based approach to teach acid/base physiology[2], an online case-based interactive approach in fluid/electrolyte pathophysiology[3] and an e-learning and online genetics for health professionals[4].

Moreover, the computer application programs are used to help in the decision making process or diseases prevention in a variety of clinical situations[5,6]. In this age of information explosion, many physicians seek the new medical information via electronic media or internet sources as same as their patients[7].

In Thailand, there are few researches in computer based learning program[8,9] especially in medical fields, so the authors aim is to develop the new system used as a teaching media in the topic of public health concerns.

Ectopic pregnancy is any pregnancy that occurs outside the uterine cavity[10]. It is the most common life threatening emergency in early pregnancy. The early diagnosis and treatment can reduce the morbidity and mortality related to this condition.

The purpose of this study is to develop the specific medical expert system for medical students and

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young physicians, which facilitates the decision making for the diagnosis of ectopic pregnancy.

Material and Method

The expert system was used as the medical information technology for the emulation of human reasoning processes and human expert problem solving[11]. The development of the new medical expert system required many steps as described below.

Medical expert system design

The process for design and development of the expert system was called knowledge engineering[12]. This process comprises several steps as follows.

Knowledge acquisition

Knowledge acquisition was defined as the method of acquiring, organizing and studying knowledge[13]. The authors had to review the standard guidelines for the diagnosis of tubal ectopic pregnancy as the first step before creating this system[10,14,15]. The initial criteria of patients were reproductive age woman, had history of sexual intercourse and no use of any contraceptive methods or had history of contraceptive failure. Then the significant clinical information of ectopic pregnancy must be identified. This clinical data was categorized into several levels: A) History taking including the chief complaint of patients and risk factor(s) for ectopic pregnancy (Table 1). B) Physical examination (PE) and per vaginal examination (PV). C) Diagnostic tests for ectopic pregnancy such as serum beta-human chorionic gonadotropin (b hCG), transvaginal sonography, fractional curettage and diagnostic laparoscopy.

Table 1. Chief complaints and risk factors of ectopic pregnancy

Chief complaint(s)	Lower abdominal pain
	Vaginal bleeding
	Missed period
	Shock/shoulder pain
Risk factor(s)	History of previous tubal surgery
	History of pelvic inflammatory disease
	Use of assisted reproductive technology
	Use of progestin only pills
	Infertility
	In utero Diethylstilbestrol exposure
	Smoking

Architecture of the medical expert system

The system contained six components which were knowledge base, inference engine, user interface unit, explanation module, knowledge acquisition unit, and blackboard. All of these units had to work together systematically (Fig. 1).

Knowledge base design

The authors used the production rule-based knowledge representation which consisted of the list of rules as IF-THEN (premise and conclusion of the rules). The relationship between each rule could be displayed in a rule-tree structure[16]. The ectopic pregnancy rules list for the main knowledge base and the repeat b hCG subgroup were shown in Table 2.

Diagnostic mechanism design

The authors reviewed the process for diagnosis of ectopic pregnancy and designed the software for diagnostic mechanism. This research used the interactive backward chaining inference[17] to prove the hypothesized ectopic pregnancy as the agenda. Fig. 2 illustrated the agenda of inference for the main knowledge base.

Medical expert system development

The authors used Borland C++ builder as a tool for the development. This system worked on Microsoft Window XP, and the CPU is Pentium IV.

This expert system contained 2 main sections, which were knowledge base editor (Fig. 3) and diagnosis mode (Fig. 4). Additionally, the system was designed to manage the knowledge such as creating, updating and editing the facts of users and physicians.

Evaluation of the system

After the system was developed, it was tested prior to using in clinical practice. The three steps of testing were performed as follows.

Table 2. The ectopic pregnancy rules list: agenda for main knowledge base and subgroup in the repeat b hCG

Agenda	Priority
Emergency surgical treatment	1
No ectopic pregnancy	2
Ectopic pregnancy	3
Repeat 48h b hCG	4
Normal pregnancy	4.1
Ectopic pregnancy	4.2

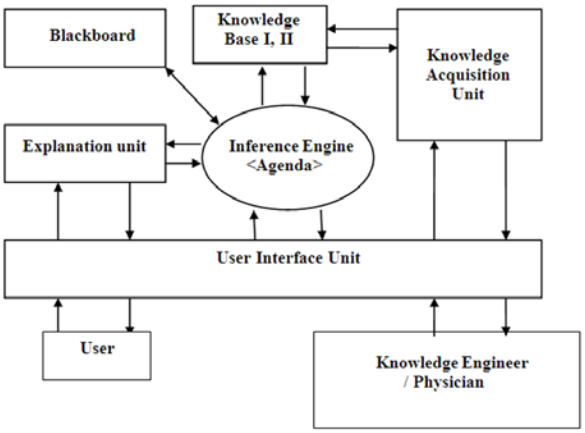

Fig. 1 Architecture of the medical expert system

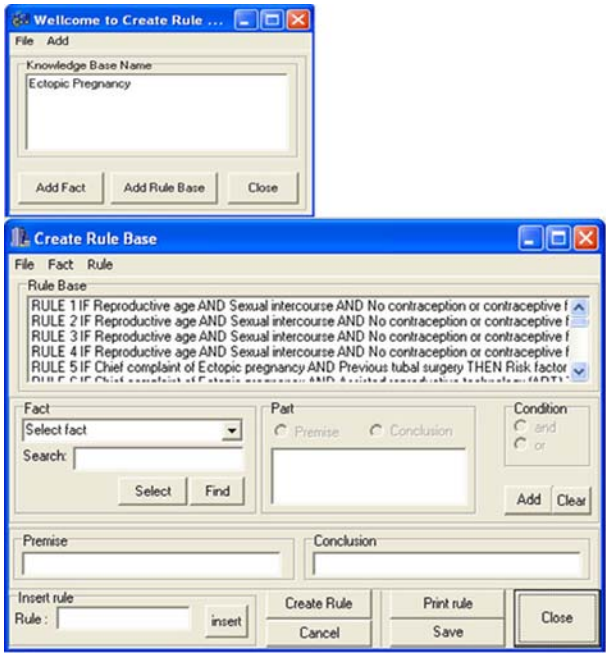

Fig. 2 Rule base editor

Debugging the operation of system

The system was checked in the backward chaining inference process by WW.

Checking the knowledge accuracy

The strategy to diagnose tubal ectopic pregnancy was followed by the standard guidelines and rechecked in the system by MK again.

Importing the clinical data into the system

The in-patient medical records with the diagnosis of ectopic pregnancy in HRH Maha Chakri Sirindhorn Medical Center were retrospectively reviewed from January 2005 to September 2007. All data obtained from the records were processed into the software systematically. The correspondence rate of diagnosed ectopic pregnancy by this expert system

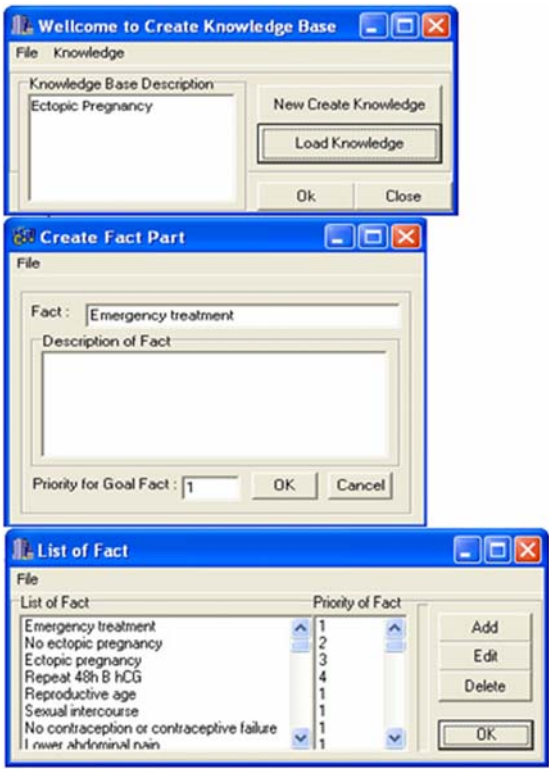

Fig. 3 Knowledge base editor of medical expert system

was calculated.

Results

There were some errors in these testing processes including the following:

1. Error of inference due to incorrect priority of agenda and rules.

2. Syntax error that occurred when the incorrect forms of a rule and fact were entered.

3. Medical expert's knowledge error, such as incorrect knowledge.

4. Incomplete elicitation of medical knowledge from the physician.

5. Semantic error of meaning between the knowledge engineer and the physician.

During 3 months of improving the system, the authors tested this software by entered the clinical data into the system. A total of 32 medical records of ectopic pregnancy patients were included in this model study. Their mean age was 27.7 years (range, 17-39 years). Twenty women were multigravida, while twelve women were primigravida. Twenty one women did not have any risk factor for ectopic pregnancy. The major presenting symptom was abnormal uterine bleeding in almost all cases. After the clinical data and investigations were imported in the model by physician systematically, 31 case-sheets were satisfied with this system and all of them correspondence with the established diagnosis. There was only one case that failed to be imported into the system because of the lack of initial clinical symptoms and signs. This patient was consulted from the surgeon in the operative theater for suspected ectopic pregnancy. Her preoperative diagnosis was acute appendicitis.

All 32 patients received the standard treatment which consisted of surgery (27 patients), methotrexate therapy (4 patients) and combined method (1 patient). The course of hospitalization was uneventful. All of them were discharged from the hospital without serious complication.

Discussion

During the past decades, researches have shown that various teaching materials can also assist the medical education. Some of these tools are electronics learning[18], computer aided instruction[19], prob-

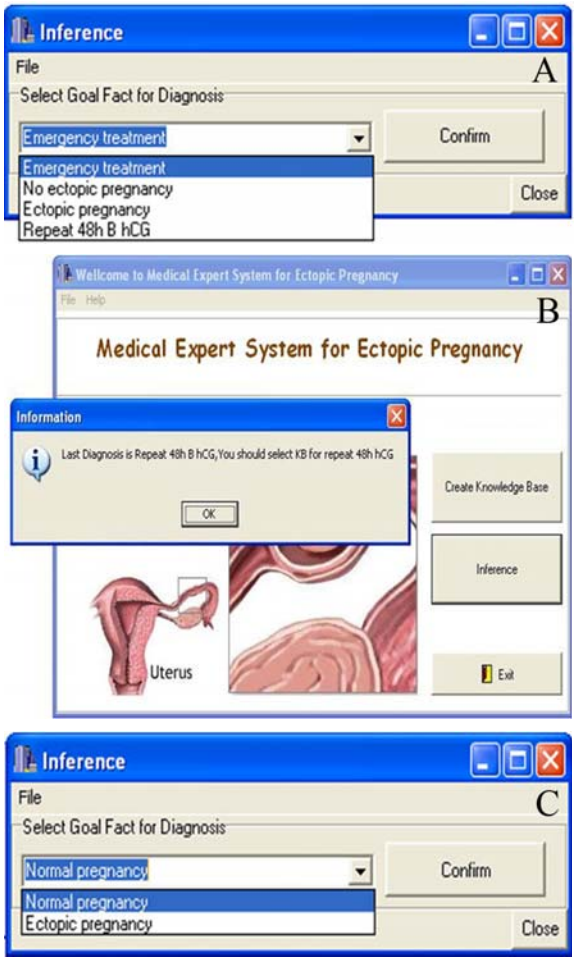

Fig. 4 The diagnosis mode of the medical expert system: the main knowledge base (A) and the inference mode for the repeat 48h b hCG (B, C).

lem-based interactive discussion[3] and simulation-based teaching materials[20,21]. Also, the medical expert system is an alternative way to support medical education[22].

The advantage of the use of production rules[23] in the medical expert system is simplicity. The production rules form a good psychological model for medical knowledge representation because they closely relate to human reasoning and modularity. Each production rule can be independently written and added to a rule base, and checked for rightness.

In this study, the diagnosis of tubal ectopic pregnancy determined by the expert system corresponds to the clinical diagnosis in 100% of the study group.

The accuracy of the system is depends on the knowledge from medical human expert and clinical data imported to the system. Because the system is run by automatic engine for inference, the efficiency of the system depends on this knowledge as well.

In the real medical practice, there are many complexities in clinical presentations more than Yes or No (IF-THEN rules). This occurred from the confusion or hesitation of the patients. As a result, the medical expert system requires the method for resolving the uncertain data such as fuzzy knowledge base and fuzzy inference mechanism[24,25].

The limitations of this study are the small sample size, the requirement to complete all steps of the system before making the diagnosis, the interference by users bias, the misdiagnosis after incorrectly entered clinical data and the limitation to apply for some specific types of ectopic pregnancy such as twin tubal pregnancy[26], combine/heterotropic pregnancy[27] and ectopic pregnancy after infertility treatment[28].

Conclusion

Our study suggests that the medical expert system for ectopic pregnancy has a high correspondence comparing to clinical diagnosis and may be used as a teaching device for medical students. Further study with larger sample size and various study population may represent the real accuracy of the system.

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การพัฒนาระบบผู้เชี่ยวชาญทางการแพทย์สำหรับวินิจฉัยการตั้งครรภ์นอกมดลูก

เมธาพันธ์ กิจพรธีรานันท์, วัชรชัย วิริยะสุทธิวงศ์

วัตถุประสงค์*: เพื่อพัฒนาโปรแกรมซอฟแวร์ระบบผู้เชี่ยวชาญทางการแพทย์สำหรับช่วยวินิจฉัยการตั้งครรภ์นอกมดลูก*

วัสดุและวิธีการ*: ระบบนี้ได้รับการพัฒนาเพื่อสนับสนุนการสร้างความรู้ และเครื่องมือประมวลผลกระบวนการวินิจฉัยใช้การอนุมานเป็นลูกโซ่แบบย้อนหลัง ความรู้ทางการแพทย์ถูกนำเสนอใหม่ในรูปแบบการสร้างกฎ ซึ่งมีลักษณะเป็นแผนผัง ระบบออกแบบให้ตอบสนองต่อผู้ใช้งานด้วยการตอบคำถาม หลังจากนั้นแพทย์นำข้อมูลทางคลินิกจากเวชระเบียนของผู้ป่วยมาใช้กับระบบนี้แบบย้อนหลัง*

ผลการศึกษา*: ทำการทบทวนเวชระเบียนของสตรี 32 ราย ซึ่งได้รับวินิจฉัยการตั้งครรภ์นอกมดลูก อายุเฉลี่ยของผู้ป่วย คือ 27.7 ปี ผู้ป่วยส่วนใหญ่เป็นการตั้งครรภ์หลังมีผู้ป่วย 21 ราย ซึ่งไม่มีปัจจัยเสี่ยงต่อการตั้งครรภ์นอกมดลูก ข้อมูลทางคลินิกของผู้ป่วย 31 ราย นำมาใส่ในระบบได้สำเร็จ ทั้งหมดได้รับการวินิจฉัยที่ตรงกันกับที่วินิจฉัยการตั้งครรภ์นอกมดลูกอยู่แล้ว*

สรุป*: ระบบผู้เชี่ยวชาญทางการแพทย์นี้เป็นเครื่องมือสนับสนุนที่ดีสำหรับการตัดสินใจวินิจฉัยการตั้งครรภ์นอกมดลูก*