HTN-APT: Computer Aid in Hypertension Management

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Hypertension-aid in physician treatment (HTN-APT) is an expert computer system that assists the physician in determining the best form of treatment for the individual hypertensive patient. The HTN-APT system aids the physician in managing the hypertensive patient by keeping a record of the patient's progress, allowing easy access to drug information, and generating recommendations and critiques about treatment options. The treatment recommendations are ranked by an analogue indication-contraindication scheme whereby each drug both singly and in combination is evaluated for patient suitability on the basis of more than 30 possible patient factors. When the computer-generated recommendations were evaluated by a group of family physicians, the HTN-APT system was found to make beneficial treatment recommendations without major judgmental error.

Hypertension-aid in physician treatment (HTN-APT) is the first expert system to aid the physician in managing the hypertensive patient by not only monitoring a patient's progress but also offering individualized treatment recommendations and critiques. The role of computers in medicine has been largely limited to business activities, databases, and specialized technologies, such as the new imaging techniques (computed tomography, magnetic resonance imaging), while the computer's potential to aid in the making of medical decisions has been neglected. Expert systems developed to assist the physician in making decisions focus on diagnosis and medical management. Systems such as MYCIN,[1] PIP,[2] EXPERT,[3] and INTERNIST-I[4] were designed to aid in the diagnostic process, whereas systems such as the Digitalis Advisor,[5] VM,[6] ONCOCIN,[7] ATTENDING,[8,9] and now APT assist with medical management. Many of the systems, through various methods of artificial intelligence, model the thought process a physician might use in making medical decisions, with the desirable result of being able to do it faster, more accurately, or more extensively.

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By weighing the positive and negative aspects of options involved in a decision, the HTN-APT program makes recommendations based on a logic process similar to that of the human mind. This decision process is used, for example, by physicians weighing the risks and benefits of a possible course of action. The HTN-APT system combines this "thinking" process with the ability to recall and manipulate large amounts of stored information to evaluate the therapeutic options for each patient.

Hypertension was chosen as the first disease to be addressed by the APT system because of prevalence, lack of therapeutic individualization, and availability of a vast amount of drug and treatment information. This information glut for antihypertensive therapy often forces physicians to become familiar with only those drugs that seem to have a general applicability to patients. Because of this limiting of the treatment options, some patients may receive suboptimal management of their hypertension.

Guides to antihypertensive therapy such as "stepped-care" achieve normotensive levels in more than 80 percent of patients but are limited because of the differences between individual drugs and the many different patient factors that can affect therapy.[10] More than 30 different patient factors, such as asthma, renal insufficiency, and diabetes mellitus, can influence the treatment decision. Ideally, each potential drug regimen should be evaluated in light of past therapy and the various patient factors so that the treatment regimen best suited to the patient can be chosen. This task could be done quickly and efficiently

with the aid of a computer system. What follows is a description of HTN-APT, which was designed to fulfill this need.

DESIGN OF SYSTEM

To be accessible to the largest number of physicians, the HTN-APT program was written in compiled BASIC for the International Business Machines series of personal computers. This user-friendly system was designed to keep records of patient information, allow easy access to drug recommendations, and generate critiques of treatment regimens through an interaction process that takes only minutes to accomplish. At the start of the program, a main menu offers the options of (1) entering information on a new patient, (2) updating a patient's information, (3) reviewing a patient's hypertension history, (4) getting treatment recommendations or critiques, or (5) accessing drug information. Most of these processes are database functions specifically designed for the management of hypertensive patients, except for the treatment recommendations and critiques, which utilize artificial intelligence techniques.

To generate drug recommendations and critiques, the HTN-APT program uses data derived from the medical literature. The informational sources used to develop the data files (a collection of related information stored on the computer disk) include *AMA Drug Evaluations,*[11] *American Hospital Formulary,*[12] and *Physician's Desk Reference,*[13] along with current medical journal articles. The HTN-APT system uses the stored information to evaluate the suitability of each drug regimen for a patient, and a ranked order listing of treatment recommendations is made. A brief critique is also generated for the patient's current treatment and for any alternative medications that a physician would like to evaluate for use in that patient.

Both the critiques and the recommendations use more than 30 patient factors (Table 1) in the evaluation of the various treatment options. Each drug in the data files has a corresponding value of appropriateness (VOA) that indicates the degree to which that drug is indicated or contraindicated for a particular factor. The VOA consists of a value between −4 and +4; a value of −4 contraindicates use of the drug, +4 indicates its use, and 0 is neutral. Each drug, therefore, has more than 30 VOAs by which it can be evaluated for patient suitability. Table 2 is an example of how the VOA is based on factors relevant to each piece of patient data, such as the percentage of drug metabolized by the liver, for the factor of liver disease.

So that treatment recommendations can be generated, each drug VOA is brought into an algorithm along with a drug field weight (DFW) and a patient field weight (PFW) for every relevant patient factor (Table 3). The DFW and PFW allow each piece of patient data to be given the appropriate emphasis for each drug being evaluated. The DFW varies the emphasis on the different drugs, such as giving nifedipine more weight than furosemide when a patient's blood pressure is evaluated. Likewise, the PFW varies the emphasis between the different patient variables, such as giving more weight to the patient's history of congestive heart failure than to the patient's race.

TABLE 1. PATIENT FACTORS EVALUATED BY HTN-APT

- Basic information
  - Age
  - Sex
  - Race
  - Height
  - Weight
  - Blood pressure
  - Potassium
  - Glucose
  - Uric acid
  - Creatinine
  - Current drug therapy
- History of any of the following
  - Asthma or wheezing
  - Bradycardia
  - Cerebrovascular disease
  - Congestive heart failure
  - Coronary artery disease
  - Depression
  - Diabetes mellitus
  - Dysrhythmia
  - Edema
  - Gout or hyperuricemia
  - Gynecomastia
  - Heart block > first degree
  - Hyperlipidemia
  - Impotency
  - Inflammatory bowel disease
  - Liver disease
  - Migraine
  - Orthostatic hypotension
  - Peptic ulcer disease
  - Peripheral vascular disease
  - Pheochromocytoma
  - Pregnancy
  - Pulmonary edema
  - Renal component of hypertension
  - Renal insufficiency
  - Renal stones (calcium)
  - Rheumatic heart disease
  - Sedation
  - Tachycardia

TABLE 2. EXAMPLES OF VALUE OF APPROPRIATENESS (VOA) FOR LIVER DISEASE

Drug name	Percent Metabolized*	VOA**
Atenolol	0	3
Nadolol	0	3
Reserpine	40	0
Guanadrel	40–50	0
Clonidine	50	0
Pindolol	60–65	−1
Timolol	80	−2
Metoprolol	85	−2
Prazosin	90–95	−3
Propranolol	Extensive	−4
Methyldopa	Extensive	−4

** Data from references 11 and 12.*
*** Scale from −4 (drug is contraindicated) to +4 (drug is indicated)*

TABLE 3. VARIABLES USED BY THE ALGORITHM

Variable	Description of Variable	Range	Examples
Patient field weight	What weight should this patient factor have when any drug is evaluated?	1 to 9	Congestive heart failure = 7 Race = 3
Drug field weight	What weight should this drug have when this patient factor is evaluated?	1 to 9	Nifedipine in blood pressure = 9 Furosemide in blood pressure = 5
Value of appropriateness	Is this drug contraindicated or indicated for this patient factor?	+4 to −4	Furosemide in congestive heart failure = +4 Atenolol in congestive heart failure = −4

TABLE 4. PARTIAL DRUG EVALUATION FOR A SAMPLE PATIENT

1. Patient: 64-year-old white woman with chronic obstructed pulmonary disease (COPD) (bronchospastic component), congestive heart failure, and pulmonary edema who is currently receiving furosemide with partial success. Normal laboratory test results. Average resting blood pressure: 180/100 mmHg
2. Database values for the patient factor variables (VOA/PFW/DFW*)

	COPD	Congestive Heart Failure	Pulmonary Edema	Current Drugs	Blood Pressure	Partial Total
Diuretic + α-blocker	1/7/5	3/7/5	1/7/4	0/5/7	2/6/7	252
Furosemide	0/7/5	4/7/5	3/7/4	1/5/9	−2/6/5	209
Diuretic plus vasodilator	0/7/5	3/7/5	3/7/4	−1/5/7	0/6/9	154
Captopril	0/7/5	4/7/5	0/7/4	0/5/9	0/6/5	140
Nifedipine	0/7/5	1/7/5	2/7/4	−2/5/9	1/6/9	55
Clonidine	1/7/5	0/7/5	−1/7/4	−3/5/9	0/6/6	−128
Methyldopa	1/7/5	−3/7/5	−1/7/4	−3/5/9	0/6/6	−233
Atenolol	−2/7/5	−4/7/5	0/7/4	−3/5/9	0/6/5	−345

3. Recommendations**
   1. Diuretic (furosemide) + α-blocker (clonidine, guanabenz, prazosin)
   2. Diuretic (furosemide)—dosage modification may be necessary
   3. Diuretic + vasodilator (nifedipine)
   4. Angiotensin-converting enzyme inhibitor (captopril, enalapril)

** DFW, drug field weight; PFW, patient field weight; VOA, value of appropriateness*
*** Based on all sample patient variables and evaluation of all possible drug regimens*

To demonstrate how the program evaluates the various treatment regimens, a partial evaluation of a sample patient is presented in Table 4 along with the recommendations that were generated. For each patient factor, a VOA, PFW, and DFW are accessed from the database, and their product is added to the running total for each drug. The drug regimens are then put in rank order, and those above a confidence threshold are recommended. The recommendations are made by general category (for example, diuretic) and also by the individual drugs within each recommended category (for example, furosemide).

There is usually more than one treatment recommendation made, so that the physician can choose from different acceptable treatment options rather than take only the "best" choice for each patient. At the physician's request, the suitability of these treatment options for the patient can be critiqued by the system. Additionally, the information necessary to prescribe any of the drugs is easily accessible. The HTN-APT system was designed to put at the physician's disposal the information necessary to continually evaluate a hypertensive patient in an effective manner.

EVALUATION

The HTN-APT system was evaluated by both primary care physicians and hypertension specialists. Their combined contributions led to the modification and upgrading of the system to its current state. Initial evaluation came in the form of comments from the physicians using the system. Most of the comments were supportive of the system, but some were concerned with the reliability of the drug recommendations. Unlike such diagnostic sys-

tems as INTERNIST-I,[4] whose function can be determined quantitatively by a compilation of how often the diagnosis was right or wrong, the HTN-APT system would be difficult to evaluate quantitatively. Qualitative evaluation, however, is possible.

For evaluation of the drug recommendations made by the HTN-APT system, the program's recommendations were compared with those made by eight family physicians for a set of 20 hypertensive patients. After recommending treatment for the sample patients, each physician was shown the recommendations made by the program and asked to compare the computer's treatment recommendations with his or her own. The categories for rating the computer's recommendations with those the physician made ranged from "definitely better" to "definitely worse." There were 157 responses (three cases had no responses), and the physicians ranked the computer's recommendations as definitely better in 5 percent, somewhat better in 18 percent, about the same in 69 percent, somewhat worse in 8 percent, and definitely worse in none of the cases. Although about two thirds of the responses were in the "about the same" category, many of the physicians commented that they were impressed by the treatment options the computer presented in those cases.

This study demonstrates the potential of the HTN-APT system in affording optimal management for a significant percentage of hypertensive patients. Additionally, the treatment options presented by the system were without significant judgmental error, as indicated by no "definitely worse" responses in the study. With the upgrading of the drug data file, the system will continue to improve in its recommendations. The ultimate evaluation of the effectiveness of the system will occur as it is used over time.

DISCUSSION

Programs that aid in the decision-making process must be able to be updated easily to stay current with the constantly expanding base of medical knowledge. The HTN-APT program does not use an if-then logic or flowchart format, which would require that the program be changed every time it needed to be updated. Instead, it simplifies the logic process and shifts the emphasis to the data, which can be easily updated. The disadvantage to this approach is that the rare or unusual variable requires that databased programs either ignore it or add another variable to the database to take it into account.

Another concern with artificially intelligent programs is that of programmer bias. In programs such as HTN-APT, which make recommendations that can have commercial consequences, any influences from the business sector should be avoided. Even with no external bias, the program creators can incorporate their ideas and concepts of medicine to some degree. This bias can be decreased if various authorities are involved and if the more generally accepted concepts are used, but there is always the risk of watering down the program so much that it becomes useless.

For any program to be acceptable to the medical community, it must be quick and easy to use. The vast majority of time required to run a program lies not with the speed of the computer but rather with the communication of information between the user and the computer. A program such as HTN-APT cannot require long lists of data to be entered or prolonged discussions to be read if repeated usage by the physician is desired. There must therefore be a compromise between completeness and efficiency, and this compromise could be a source of controversy.

Although the HTN-APT program is not perfect, it maintains easily accessible databases for modification and updating. Such programs can be viewed as intelligent references that assist the physician in an analysis of information. Their future role in medicine will depend largely on physician acceptance, demand, and the availability of quality programs.

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