8. DISCUSSION
8. DISCUSSION

There can be few physicians so dedicated to their art that they do not experience a slight decline in spirits when they learn that their patient’s complaint is giddiness. This frequently means that after exhaustive enquiry it will not be entirely clear what it is that the patient feels wrong and even less so why he feels it.52

Dizziness is the ninth most common clinical symptom, rising to third among aged 65 to 75 years and becoming first among those aged more than 75 years195. American National Institute of Health Statistics has reported that 42% of the nation’s population goes to the physician with dizziness sometime in their lives and balance related falls account for 50% of accidental deaths in the population above 65 years116. Dizziness has a prevalence of 23% in the UK population347. It has been found that 5% of all patients going to the general practitioner (GP) and 10% of patients going to the ENT specialist or neurologist suffer from balance disorder. Exact figure of prevalence of dizziness in India is not available45.

Though one of the most common complaints, vertigo has been said to be the greatest heart sink symptom in medicine. The main reason for this problem is not the symptom but the doctor. It has been said that labyrinthine vertigo can change, in seconds, a healthy and active individual into a helpless invalid, and a rational physician into a babbling idiot. The most important step towards reaching a diagnosis is full clinical history191. “Computer-Aided Diagnosis In NeurOtology” (CADINO), an experimental program for computer-assisted diagnosis in cases of dizziness can be immensely helpful to the ENT surgeons. It takes step-by-step history of the patients and offers a list of differential diagnoses for the consideration of the attending physician. Armed with CADINO an ENT surgeon can interview the dizzy patient confidently, which even generates confidence in the patient.

The symptoms of dizziness can be difficult for the physicians to categorize. Patients may use different terms to describe their sensations of dizziness such as disequilibrium, unsteadiness, vertigo and lightheadedness. A seemingly endless number of disorders can result in symptoms of dizziness. Majority of the patients with dizziness are referred to otolaryngologists because most commonly the cause lies in the inner ear35.
The CADINO, which is an interactive computer system, has the potential to directly assist ENT surgeons or other health care professionals with clinical decision-making tasks in cases of dizziness. Study of Arya and Nunez\(^8\) demonstrates that ENT physicians experienced in the management of dizziness can diagnose cardiological, neurological, psychological, and other causes of dizziness and make appropriate onward referrals. In this study CADINO was evaluated by ENT residents and surgeons only.

In UK vertiginous patients who are referred by their general practitioner (GP) were offered appointments at hospital ENT clinics. The audit of this revealed that the mean waiting time between referral and effective management exceeded 24 weeks (22 to 27 weeks). Patients initially waited an average of 13 weeks for an ENT appointment, a further five weeks for vestibular assessment, and another six weeks to be re-reviewed at the ENT clinic with vestibular testing results, with subsequent referral for vestibular rehabilitation if required\(^{207}\). CADINO has the potential to reduce this waiting time because GP themselves can use CADINO and manage most of the dizzy patients as only 10% patients need specialists services\(^{168}\).

Most of the dizzy patients are managed at the level of general practitioner but 9% - 13% of these patients are referred to the specialists such as neurologists, cardiologists and otolaryngologists\(^{168}\). In the present era of information technology (IT), CADINO can be a boon to the Rural Health Centers because the General Medical Practitioners can also operate the Computer-based Clinical Decision Support Systems (CDSS)\(^{27}\).

Despite the obvious public health significance, dizzy patients typically have great difficulty accessing good quality health care and are generally perceived by otolaryngologists to represent one of the most frustrating and frustrated groups of patients\(^{207}\). These were the governing and motivating factors for selecting dizziness and vertigo as the neurotology domain for CADINO.

The work on entire range of patient monitoring systems and computer-assisted medical decision making is progressing rapidly. CADINO can be used simultaneously with the doctor-patient consultation. A user-friendly interface MS Word ® 2000 with hyperlinks was constructed with a comprehensive set of clinical terms. In majority of the cases the correct diagnosis appears in the differential diagnoses list. The CADINO is designed to meet the knowledge gaps of the individual ENT surgeon while dealing with dizzy patient.
HUMAN BRAIN
The size of the human brain has changed little in the past thousand years, yet the total of world knowledge has increased several thousand folds. Medical knowledge doubles every five years. We owe this increase in knowledge to how we synthesize information into knowledge and transfer it to others. The human brain is unsurpassed in its ability to perceive, focus, think, analyze, imagine and create, but it is greatly limited in its ability to store a large collection of facts permanently, to recall the facts instantaneously and precisely, and to handle multiple variables at a time. The rapid evolution of technology and clinical research makes it difficult even for the specialist to keep up. In the light of this 'Information Explosion', it has been demonstrated that physicians do not always make optimal decisions.204

CADINO is an 'expert system' meant for use in diagnostic dilemmas in cases of dizziness. As humans making complex decisions under stressful circumstances in a short time, ENT surgeons may forget to consider important diagnostic possibilities during vertigo workup. The consequences of such errors may range from nothing to life-threatening complications. CADINO is best used as a checklist after the primary decision-making has been performed.

Humans have only a limited ability to incorporate information in decision-making. In certain situations, the mismatch between this limitation and the availability of extensive information contributes to the varying performance and high error rate of clinical decision makers.241 Artificial Intelligence (AI) is the branch of computer science that focuses on the development of computer systems to simulate the process of problem solving by duplicating the functions of human brain. The objective of AI applications is to enable computers to process information, gain knowledge, and understand their environment.331

COMPUTER ASSISTED DIAGNOSES IN MEDICINE
Computers are being widely used for improving the quality of patient care. They enhance the decision-making, management, planning, and medical research.208 It is imperative for the medical practitioners to integrate information technology into medical and health care management. The technologies that primarily supported the administrative processes are
now used for medical and health care management. Computer-based patient records and electronic communication are becoming part of routine medical practice\textsuperscript{27}.

There is increasing appreciation of the role that Information Technology (IT) can play in improving the overall health delivery systems in urban and rural areas. The role of computers in medicine has been expanded rapidly and continuing at the same pace. Most computer programs available for clinical practice offer only accounting, scheduling, patient monitoring, record keeping, or bibliographic retrieval capabilities. Too little attention has been given to providing diagnostic assistance to practicing clinicians\textsuperscript{25}. The Knowledge-Based Systems (KBS) and Expert Systems (ES) help in the understanding of complex processes of medical decision-making\textsuperscript{27}. The CADINO's structured approach for clinical history taking and examination assists the ENT surgeons in understanding the complex processes involved in medical decision-making in cases of vertigo and dizziness.

The rapid evolution of technology and clinical research makes it difficult even for the ENT specialist to keep up. In the light of this 'information explosion', it has been demonstrated that physicians do not always make optimal decisions. The large amount of current medical knowledge has resulted in a situation where consultants find it difficult to assimilate and remember all the information\textsuperscript{204}. CADINO has the potential to provide a solution to this problem. The emergence of domain-independent software tools for implementing Knowledge-Based Medical Decision-Making Systems is a great boon to doctors. Problem-solving algorithms represent the intellectual core of CADINO. The behavior of CADINO results mainly from the formation of problem areas through a partitioning algorithm and the conclusion of diagnoses within problem areas, using strategy of diagnosis by exclusion.

CADINO is capable of solving problems in complex cases of vertigo and dizziness by using the knowledge and emulating the behavior of ENT specialists. The applied symbolic reasoning and its various techniques have been employed in an attempt to model the humans' thought processes and problem solving methods. CADINO can be used as powerful tools for education since they make the underlying reasoning explicit.

The current expert systems have no potential to replace the doctors but are simply an aid to them. Various expert systems have been reported on medicine such as MYCIN, ONKOCYN, DXPlain, ABEL, DIAGNOSER, EMERGE, GALEN, HDDSS, GLAUCOMA, INTERNIST, QMR, AI/RHEUM, and ONCOCIN etc. Lele\textsuperscript{204} has...
reviewed many such systems. Continuing Medical Education Association (www.medinfosource.com or www.cmea.com) has come out with some good programs such as DiagnosisPro, Iliad 4.5, and Quick Medical Reference. Others are Home Medical Advisor, DX plain, and Meditel etc. In a review article, Berner and others\textsuperscript{41} compared Iliad, QMR, DX plain, and Meditel. They found the programs fairly similar. The breadth of known diagnosis and symptoms, the depth of knowledge about a disease, and the quality of the priority ranking of the diseases in the differential diagnosis were all differentiating factors. Some of the other examples of such medical systems are: Epileptologists’ Assistant, HELP (Knowledge-Based Hospital Information System), MDDB (Dysmorphic Syndrome). Jeremiah, Orthoplanner, and RaPID are decision support systems for dental surgeons\textsuperscript{27,204}.

Medical decision support systems, which are more difficult to develop and implement help clinicians in constructing differential diagnoses or selecting therapeutic options. The knowledge base and algorithms of these computer programs provide expert-level decision-making assistance. The suitable man-machine interfaces make such programs easy and attractive to the practicing clinicians\textsuperscript{229}. After a thorough clinical history and examination CADINO system provides a list of differential diagnoses, which are of the level of an otoneurologist. ENT surgeons simply have to click on the options, which have hyperlink and take the user to next step and than ultimately to the list of differential diagnoses.

\textbf{Need}

If properly studied, piloted, and implemented, expert systems have the potential to greatly increase the quality of care in the primary care setting. The implementation of expert systems leads to increase in the quality of care and decrease in the cost. Bates and others\textsuperscript{34} studied the effect of computerized physician order entry and a team intervention on prevention of serious medication errors. They found that a well-planned physician order entry implementation had decreased serious medication errors by 55%. Gerbert and others\textsuperscript{114} have discussed decision support software to help primary care physicians triage skin cancer and conducted a pilot study. They reported earlier detection of skin cancers with fewer office visits that led to better outcomes and decreased overall costs to the system.
Kawamoto and others studied seventy Decision support systems (DSSs). DSS significantly improved clinical practice in 68% of trials. Johnston and others studied effects of computer-based clinical decision support systems on clinician performance and patient outcome. They showed improvements in clinician performance using a computer-based clinical decision support system (CDSS).

- The provision of patient- and context-specific reminders has the potential to reduce diagnostic omissions across all subject grades for a range of cases. The study of Ramnarayan and others suggests a promising role for the use of future reminder-based CDSS in the reduction of diagnostic error.

Schiffman and others conducted a systematic review of functionality and effectiveness of computer-based guideline implementation systems. Decision-support systems showed a positive effect on outcomes. The number of legitimate uses for rules-based processes in guiding physician behavior continues to grow and now includes such diverse functionality as reminders for when critical screening tests need to be performed and paging providers for abnormal laboratory results. Decision-support systems have led to such impressive statistics as a savings of $3 million per year in medication costs at a large academic teaching hospital and a 69% decrease in duplicative laboratory orders simply by informing providers of redundant orders.

**COMPUTER-ASSISTED DIAGNOSIS IN OTONEUROLOGY**

Mira and others developed 'Vertigo', an expert system (ES) aimed at the classification and diagnosis of different forms of dizziness. 'Vertigo' had been conceived mainly as a teaching tool in otoneurological departments. 'Vertigo' was tested on cases of dizziness and was than sent for the use of ENT residents during their otoneurology stage.

Auramo, Kentala and others developed an OtoNeurological Expert system (ONE) to aid the diagnostics of vertigo, to assist teaching and to implement the database for research. The database contains detailed information on the patient history, signs and test results necessary for the diagnostic work with vertiginous patients. The pattern recognition method was used in the reasoning process. Questions regarding symptoms, signs and test results are weighted and scored for each disease, and the most likely disease is recognized from the defined disease-profiles. Uncertainties in reasoning, caused by missing information, were solved with a method resembling fuzzy logic. They also
applied adaptive computer applications, such as genetic algorithms and decision trees, in the reasoning process. The six diseases were detected with high accuracy also with adaptive learning methods and discriminant analysis. They aimed to construct a hybrid program for the reasoning, where the best reasoning method for each disease was used. A follow-up should be implemented for the patients, since diagnosing sudden deafness and Meniere's disease during the first visit is often impossible. 187

The CADINO collect data and diagnose the work-up of vertigo of both central and peripheral diseases causing vertigo. Patient history and otoneurological and other examination results are used in the reasoning process. The history is interactively collected and complemented with clinical examination results. The case history data could be either mandatory or supportive. Questions are used to confirm a diagnosis and reject an unlikely disease. Supportive questions support or suppress a diagnosis, but their presence is not obligatory. The reasoning procedure of CADINO considered every question independently for different diagnoses, depending on how well they agreed with the symptom entity of a disease. Diagnostic criteria were set for each disease. In Meniere's disease, for example, the full triad (Fluctuating sensorineural deafness, spinning vertigo and tinnitus) is required. To be able to take even rare diseases into consideration CADINO tries to diminish the possibility of a wrong decision rather than maximize the likelihood of reaching only one right decision.

NEED OF CADINO
The interest in the development of CADINO system began with a desire to overcome the problems of knowledge gaps so often felt by the ENT surgeons in dealing with dizzy patients. Other motivations for developing CADINO include their potential educational value, superior patient's confidence, enhance productivity of the health care team, and its role as models of the diagnostic reasoning process.

Busy ENT consultants do not get time to keep pace with the latest developments. Expert systems try to build a bridge between medical research, which generates knowledge, and the daily practice in hospitals. There is much need of computer-aided diagnostic system in the evaluation of patients of dizziness, which is such a common complaint.
Rural people do not get the services of otoneurologists in their areas. But a GP and other clinicians can use CADINO. Thus CADINO would be a boon to the less privileged people of remote areas. Even one can easily carry Laptop consultation system. It can serve as the function of second opinion to an ENT consultant. Medical students can use it as a tutor. Physicians can expect better patient management. In the era of consumer protection, it will be a great asset to the consultants. Because the whole process is so transparent, one can easily win the confidence of the patients, which lacks so much in recent time.

The survey of 2201 respondents was commissioned by the Isabel Medical Foundation, which showed that 35% of people have experienced a medical mistake over the last 5 years. Fifty percent of the mistakes were misdiagnosis. One in 6 of the USA adult population has experience of misdiagnosis (Survey of Medical mistakes in the USA 2005 by YouGov (http://www.isabelhealthcare.com/info/images/USsurveyrelease-Final.pdf). CADINO has great potential in addressing the issue of misdiagnosis in cases of vertigo, which because of its complex pathophysiology and a plethora of causes is one of the most feared complaints among the ENT surgeons.

Wolf and others\textsuperscript{3,4} examined the degree to which attending physicians, residents, and medical students stated desire for a computer based consultation on difficult-to-diagnose patient. They studied the changes in diagnostic decision-making based on perceptions of need and helpfulness. During the CADINO evaluation study majority of the ENT faculties, surgeons and residents appreciated its clinical and educational value, as good number of dizzy patients is difficult-to-diagnose.

The knowledge-based systems in medicine have the potential to become a reality in most consultants’ offices in the future\textsuperscript{37}. CADINO might gain wider acceptance because it would actually benefit both patients and ENT surgeons.

**COMPONENTS OF “CADINO” SYSTEM**

The components of CADINO are Knowledge base, Inference engine, and User interface. The knowledge base is a collection of encoded knowledge of dizziness and vertigo that is needed to solve problems in dizzy patients. The inference mechanism uses the information in the knowledge base to generate list of differential diagnoses about dizzy
patient. While these two components are viewed here as being conceptually distinct, they are interwoven in the system.

**Knowledge Base**

The CADINO knowledge base encompasses about 100 causes of dizziness (Table 6.1 and 6.2). The knowledge base incorporates individual disease profiles, which consists of historical items, symptoms, physical signs, laboratory abnormalities and treatment. The disease profiles (Material and methods – Appendix: Clinical Features) have been derived from interaction with the professor and head ENT and authentic postgraduate level textbooks and journals of otolaryngology. An additional concern is that one disease that usually present in a classical manner may present differently in some patients. For example, perilymphatic fistula may present as transient vertigo or imbalance as well as similar to Meniere’s disease. Solution of classification problem entailed the development of algorithms that permit CADINO to construct evaluation and different causes of dizziness.

In addition to disease profiles, the knowledge base details relations among diagnoses and among manifestations. The knowledge base contains links between the related diseases, which come under similar pathophysiological states. The links are used to express causality or a predisposition. CADINO formulates and resolve problem areas serially. The total number of links among the 100 diagnoses in knowledgebase is about 1000. The manifestations of diseases in CADINO knowledge base are not independent. The knowledge base has properties of each manifestation that specify how its presence or absence may influence the differential diagnoses. During the development of CADINO, many cases, both simple and complex, were presented to the system in order to evaluate and improve the knowledge base and the diagnostic computer program. The knowledge base of CADINO was accordingly altered after such consultations. These cases were not included in the evaluation study.

**Knowledge Representation**

The process of designing computer-aided diagnostic system requires integration of various databases, integration of conventional and non-conventional data type, definition of object methods using varying existing application, run time combination of
diverse processing components, and support for arbitrary level and for advanced forms of inter-operability among components. Various methods are available for knowledge representation and the technique depends directly on knowledge domain. CADINO differs considerably from other medical diagnostic computer programs. The goal of CADINO knowledge representation method was to model the real scene of evaluation of vertigo and dizziness patient as closely as possible.

In developing CADINO, perhaps the most challenging part was to translate pathophysiological knowledge of dizziness into abstract representation that could be processed, by computer. It involves many approaches. The two distinct methods of knowledge elicitation employed in CADINO are: Classification or scaling method and the traditional interview based approach.

Problem-solving algorithms represent the intellectual core of CADINO. The behavior of CADINO results mainly from the formation of problem areas through a partitioning algorithm and the conclusion of diagnoses within problem areas, using strategy of diagnosis by exclusion.

In the past, techniques including mathematical modeling, use of Bayesian statistics, pattern recognition, and other approaches have been shown to be useful in the differential diagnosis of abdominal pain, and the diagnosis and treatment of meningitis. The capabilities of the CADINO derive from its extensive knowledge base and computer programs that provide differential diagnoses of dizziness.

Knowledge acquisition is not an exact science but doctors are better positioned to refine and develop their own procedures as they acquire new information. Such Computer-aided medical diagnosis system generates a list of hypotheses that may deserve consideration. CADINO provides checklists that enable the ENT surgeon to ensure that no diagnostic possibility has been overlooked. For the knowledge elicitation as well as knowledge representation no direct help of any computer software persons were taken.

Boolean logic, set theory and symbolic logic are used when clinician applies a branching logic, whether the symptom is present or absent. There are two types of knowledge in CADINO. 1) Declarative knowledge consists of factual knowledge of dizziness and vertigo. 2) Procedural knowledge is the skill of knowing how to use declarative knowledge. Declarative knowledge in CADINO was derived from review of postgraduate level ENT books, journals and interaction with professor and head ENT.
The various methods of Knowledge Representation employed in developing expert systems are: Algorithmic, Statistical pattern, Database comparison, Fuzzy, Production rules, Frames forming semantic network, and OAV (Object, Attribute, Value) triplets. Each method has its own advantages and disadvantages. Algorithmic decision tree is the core of CADINO system. A decision tree is an artificial intelligence program that is adaptive and is closely related to a neural network, but can handle missing or nondecisive data in decision-making.

Though not used in CADINO, several machine-learning methods had been used in the refinement of knowledge bases for removing inconsistencies and redundancies, and for simplifying decision rules. Juhola and others applied machine-learning methods based on artificial intelligence theory to the computer-aided decision making of otoneurological diseases, for example Meniere's disease. Three methods explored were decision trees, genetic algorithms and neural networks. By using such a machine learning method, the decision-making program was trained with a representative training set of cases and tested with another set. The machine learning methods were useful also for their otoneurological expert system (ONE), which was based on a pattern recognition approach. The methods were able to differentiate most of the cases tested between the six diseases included, provided that a sufficiently large training set was available.

Expressing vertigo and dizziness problem-solving knowledge as a set of algorithms in CADINO was found to be a fairly difficult task, as the diagnostic knowledge is intuitively known to the otoneurologists and found in books as descriptive data. Though a major technique of knowledge representation but not used in CADINO is the semantic net, in which facts and their relationships are shown both qualitative and quantitative. The most suitable languages for this work are LISP and PROLOG, ES-shell, Visual dbase.

When the clinician says that 'common things occur commonly' Bayes's theorem of conditional probabilities can be used. Bayesian ES for diagnosis of 'acute abdominal pain' has been proved more accurate than physicians. It needs many different indicants concurrently, which at time are clinically unrealistic. The probabilities of one location may not be usable at other locations. Other techniques of this approach are Linear Discriminant Functions and Data Base Comparisons. Large patient databases are useful for decision-making. Though Bayes's theorem was not utilized in CADINO however
similar to Bayes's theorem, CADINO assumes that only one disease process is present at a time though patients can have multiple problems at a given time. Though not employed in CADINO, Fuzzy set theory has also been used for several medical problems including kidney failure and liver impairment.

Kentala and others developed an interactive database for vertigo that could be used to assist in the diagnostic procedure and to store the data in a form of a database. The database offered the possibility to split and reunite the collected information in a desired way. The database contained detailed information about patient history, symptoms and findings in neurotological, audiological and imaging tests. The symptoms were classified into three sets of questions: vertigo (including postural instability), hearing loss and tinnitus, and provoking factors. The input information could be applied in an expert system ONE for vertigo work-up. The database was claimed to be user-friendly. Besides diagnostic purposes the database was found excellent for research purposes, and combined with the expert system it worked as a tutorial guide for medical students. The CADINO system is not a database.

Samanta explored the use of web-based knowledge acquisition for the medical domain. A suitable toolkit such as MedFrame was required to enable the medical experts to perform the knowledge acquisition tasks without support or with little support from knowledge engineer. Web-based knowledge acquisition was not tried in CADINO.

Algorithmic Method
Inductive algorithms are a potential alternative method of knowledge acquisition for expert system development. Algorithmic methods, employed in CADINO were found successful when the pathophysiology is clearly understood and categorical decisions could be made. An algorithm is a step-by-step set of instruction on how to accomplish some tasks. Information specific to the problem of dizziness and vertigo was encoded in branching logic of the CADINO program. Inferences are generated by simply executing the statements in the program.

Kentala and others retrieved data on patients with Meniere's disease, vestibular schwannoma, traumatic vertigo, sudden deafness, benign paroxysmal positional vertigo, or vestibular neuritis from the database of otoneurologic expert system ONE for the development and testing of a genetic algorithm (GA). The best rules retrieved from the
GA were described by a set of questions with the most likely answers. The most important questions concerned the duration of hearing loss and the occurrence of head injury. For rare diseases, some other reasoning process such as case-based reasoning was used.

**Decision Analysis**

Decision Analysis is a formal discipline for making decisions that in many respects resembles the informal strategies of clinicians. In CADINO it is presented as a decision tree with several pathways along each of which are several nodes or decision points. Each intervention is a decision node. The tree was progressively built, from the signs, symptoms, and diagnostic interventions of the dizzy patient. The tree was constructed in sufficient detail to make the representation realistic, and yet is constrained to prevent it from becoming unmanageably large.

Viikki and others\(^{336}\) and Kentala and others\(^{189}\) employed decision tree induction to acquire diagnostic knowledge for otoneurological diseases and to extract relevant parameters from the database of an otoneurological expert system (ONE). The records of patients with benign positional vertigo, Meniere's disease, sudden deafness, traumatic vertigo, vestibular neuritis and vestibular schwannoma were retrieved from the database of ONE, and for each disease, decision trees were constructed. Their study showed that decision tree induction was a useful technique for acquiring diagnostic knowledge for otoneurological diseases and for extracting relevant parameters from a large set of parameters. The most important questions concerned the presence of vertigo, hearing loss, and tinnitus; duration of vertigo; frequency of vertigo attacks; severity of rotational vertigo; onset and type of hearing loss; and occurrence of head injury in relation to the timing of onset of vertigo. Meniere's disease was the most difficult to classify correctly. The validity and structure of the decision trees were easily comprehended and could be used outside the expert system.

**Neural Networks**

Though not used in CADINO, neural networks have been used in medical imaging\(^{270}\), in medical signal processing and to analyze both clinical and laboratory data. Principally, neural networks simulate the function of the brain. The decision-making is based on
mathematical transformations and it occurs on a hidden level. Calculations are made on parallel manner and the decision-making simulates pattern recognition method. A drawback of neural networks is that the decisions are irrational and cannot be motivated to the user. Another problem is neural networks' difficulty to handle incomplete input data, i.e., how to define some default or expected values for unknown input parameters\(^{137}\).

In a complex medical area, which would require multilayered neural networks, the neural networks require a large amount of solved cases for the learning process. Kentala and others\(^{185}\) did not find neural networks suitable for diagnosing vertigo and they felt that a better choice would be either case-based reasoning or possibly genetic algorithms or a combination of these.

**Tools**

Commonly used tools in CMD systems are AI Languages, Tool Kits, and ES-Shells. While most AI systems are written in LISP or PROLOG, the EXPERT, a domain-independent software tool or shell, is unusual because it is written in FORTRAN. AI/RHEUM system for diseases of joints was built using EXPERT\(^{204}\). The INTERNIST system\(^{228}\) was written in LISP and assembly language. For representing drug and laboratory knowledge in a clinical event monitor deployed in an inpatient setting, CLIPS has been selected as the basis for its KB and inference engine\(^{262}\).

The Microsoft ® Word 2000 and its hyperlinks were used in CADINO. CADINO can be run on Internet Explorer and at any time can be easily converted into Macromedia Dreamweaver or Microsoft FrontPage. Rao\(^{276}\) designed a computer-based medical diagnostic system for logic formalisms of the Bayesian probabilistic belief networks. Data bank of about 35,000 disease-features is developed from text sources using MS access.

Dr. Roger Jellife developed pharmako-kinetically oriented methods for planning, monitoring and adjusting dosage regimens of powerful but potentially toxic drugs\(^{266}\). Written in Interlisp language the ONCOCIN expert system advises on-line Cancer chemotherapy protocols\(^{27}\).

HYPERTENZ\(^{258}\) the decision making program in treatment of hypertension is using the Microsoft Access language of the Access database system. Marchevsky and others\(^{220}\) have developed a rule-based expert system in EXCEL 4.0 (Microsoft, Redmond,
WA) for the automatic classification of DNA. If-Than rules were used to classify histograms.

In order to develop Expert System for the Assessment of Legal Capacity (ESALC), Hu-Z and others employed Visual Basic for Windows 3.0. They develop the ESALC for assessment of criminal responsibility capacity of mentally ill offenders. Agarwal developed 'Acuware' in Client-Server computing environment, where she used Visual Basic 5.0 as front-end and MS-Access as back-end tool. Landmarks were scanned using Adobe Photoshop and the scanned images were stored in GIF format.

Though not used in CADINO, the emergence of domain-independent software tools is a great boon to doctors, who can build expert systems for a wide variety of applications. There is practically no need of knowledge engineer during the knowledge acquisition process. CADINO was developed using hyperlink word documents and there also was no need of knowledge engineer.

The Quick Medical Reference (QMR), an experimental microcomputer-based decision support system was written using Turbo Pascal Version 5.0 (Borland International, Scotts Valley, California, USA). Its knowledge base was an extension of the Internist-1 knowledge base.

LOGIC OF CADINO

CADINO attempts to form an appropriate differential diagnosis in cases of dizziness. The most important step in the diagnosis of dizzy patients is an unhurried and detailed history. One must examine ears, cranial nerves, cerebellum, balance function, and look for nystagmus. In many cases, investigations are not required at all except audiogram. There is no indication for routine caloric testing, imaging or blood analysis, each of which should be carried out only when there are specific indications. Specialized vestibular testing is required in research projects. The CADINO takes step-by-step structured history of dizzy patients and side-by-side asks relevant positive findings of examination of ear, nystagmus, cranial nerves, cerebellum, gait, audiogram, positional, and balance tests. This usually leads to identification of a category or process to which patient’s dizziness is attributable.

We routinely construct differential diagnoses on the basis of etiology (such as infection, trauma, congenital, neoplasm, iatrogenic, idiopathic) or the site of lesion central
and peripheral vestibular diseases. An ENT surgeon or computer program thus narrows the set of possible diagnoses from all known diseases. The method of diagnosis by sets of algorithms is employed to resolve each differential diagnosis.

CADINO basically follows a symptom-based classification, which is based on presumed pathophysiological mechanisms, to evaluate the cases of dizziness. Some diseases have both central as well as peripheral vestibular features. The follow up CADINO consultations may give a new list of differential diagnoses due to the additions of new findings during the temporal profile and natural history of CNS disorders.

Dizzy patients often have difficulty describing their symptoms, so determining the cause can be challenging. Often the patients use the term dizziness to describe following different sensations: spinning or whirling, unsteadiness, lightheadedness, near faint, loss of balance, fatigue, floating feelings, head fullness, or out of body sensations abnormal sense of upright, sense of tilting, and a tendency to lean or fall to one side. These different sensations of dizziness are categorized in 4 groups: vertigo, lightheadedness, presyncope, and dysequilibrium\textsuperscript{142}. CADINO's approach is different it does not first ask about the description of dizziness. CADINO begins with the history of trauma and drugs and than subsequently associated symptoms such as ear, headache, and neurological etc.

The common differential diagnoses of vertigo, a false sense of motion such as rotation\textsuperscript{316} though include peripheral vestibular causes (labyrinth and vestibular nerve) and central vestibular causes (vestibular nuclei and their connections in the central nervous system), other nonvestibular conditions can also cause spinning vertigo\textsuperscript{84}. Certain vestibular lesions manifest as nonrotatory vertigo and do not cause spinning vertigo. Certain patients with vestibular dysfunction such as ototoxicity and acoustic neuroma feel only a sensation of imbalance or disequilibrium in the head.

Stapleton and Mills\textsuperscript{318} studied the role of open-ended questionnaire in patients with balance symptoms. Their preliminary study suggests that a tailored combination of both direct and open questions might be the most effective way to glean valid, reliable, unbiased and discriminatory information when assessing patients with balance symptoms. Prior to the CADINO's structured and guided approach patient history was taken with an open-ended approach.

Dix-Hallpike maneuver, which has a positive predictive value of 83 percent and negative predictive value of 52 percent for the diagnosis of benign paroxysmal positional
vertigo\textsuperscript{156} (BPPV), is considered by CADINO to diagnose BPPV. No laboratory tests were done initially to identify the etiology of dizziness. Laboratory tests identify the etiology of vertigo in less than 1 percent of patients with dizziness\textsuperscript{156}. The key findings of history and examination were employed in CADINO for establishing a diagnosis (Table 4.2).

The nature of dizziness may change with the passage of time. Rotatory may change to lightheadedness, tilting, or imbalance. So CADINO asks about the past history of first episode of vertigo as well as current episodes of dizziness. Though seems easy it may be difficult to know whether dizziness is continuous or intermittent. CADINO asks whether patient feels perfectly well, lightheaded or imbalance in between the episodes of rotatory vertigo.

Key information from the history such as timing and duration (Table 4.6A and 4.6B) of vertigo\textsuperscript{288}; provoking (Table 4.7) or aggravating factors\textsuperscript{106}; and associated features (Table 4.8) particularly neurologic symptoms and hearing loss\textsuperscript{18,20} were used to make the distinction between the peripheral and central causes of vertigo (Table 4.5).

When the clinical course is not running according to the expectations, it is advised to repeat the full CADINO history, starting again from the beginning and setting aside all previous thoughts on the patient. This worthwhile approach is more effective than unnecessary investigations, which usually fail to help in the management of the vertigo patients.

The onset and duration of episodes of vertigo helped CADINO in distinguishing certain causes of dizziness. Provoking factors and the events preceding the onset of vertigo were proved useful in CADINO in narrowing the differential diagnoses. Vertigo, which occurs only with positional changes, such as turning over in bed\textsuperscript{106}, bending over at the waist and then straightening up, or hyperextending the neck\textsuperscript{142}, is diagnosed as BPPV. Provoking factors such as food triggers, stress, and improper sleep, helped CADINO diagnosing migraine headaches.

CADINO inquires about the events preceding the episode of vertigo such as direct blow, scuba diving (barotrauma), heavy weight bearing, or excessive straining with bowel movements\textsuperscript{288} suggest perilymphatic fistula\textsuperscript{188}, which may present similar to Meniere's disease. The Tullio's phenomenon suggests a perilymphatic fistula, labyrinthine fistula, dehiscence of superior semicircular canal and syphilis.
Associated symptoms such as hearing loss, pain, nausea, vomiting, headache or neurologic symptoms help CADINO in differentiating various causes of vertigo. Pain usually occurs in acute middle ear and mastoid diseases, and intracranial complications of cholesteatoma. Weakness, dysarthria, vision disorders, paresthesia, altered level of consciousness, ataxia, or other sensory and motor deficits are present in cerebrovascular strokes, brain tumors, and multiple sclerosis.

Migraine patients experience typical headache (often throbbing, unilateral, sometime preceded by an aura), nausea, vomiting, photophobia, and phonophobia. Twenty-one to 35 percent of patients with migraine suffer vertigo\textsuperscript{66}.

There is no inquiry for any routine blood tests on patients with vertigo in CADINO. Routine tests for thyroid function or diabetes, in the absence of clinical indications are not good use of medical resources\textsuperscript{191}. Laboratory tests (electrolytes, glucose, blood counts, and thyroid function tests) identify the etiology of vertigo in less than 1 percent of patients\textsuperscript{156}. Blood tests for vascular risk factors, and inflammatory, infectious, and hypercoagulation disorders should be done in presence of signs or symptoms, which suggest the related conditions. In cases of Meniere’s disease, CADINO excludes syphilis, which can present like Meniere’s disease. There is no indication for exclusion of syphilis in every dizzy patient\textsuperscript{191}.

In CADINO, MRI imaging is considered in patients who have neurologic manifestations, cerebrovascular risk factors, or progressive unilateral hearing loss. Forty percent of patients with neurologic signs were reported\textsuperscript{256} to have lesions on magnetic resonance imaging of the head. In cases of isolated vertigo having cerebrovascular risk factors, 25 percent had caudal cerebellar infarcts\textsuperscript{249}. However, MRI is not indicated in cases of BPPV, vestibular neuritis or Ménière’s disease. Neuroimaging should not be done as routine screening tests for cerebellopontine angle tumors causing vertigo\textsuperscript{117}.

A wide range of vestibular investigations (such as electronystagmography, caloric and rotating chair tests) is available but they have few clinical uses\textsuperscript{191} and were not included in CADINO. The computerized systems such as force plate, which records all changes in the position of the center of gravity of the patient, were not asked in CADINO. It is difficult to justify the use of these tests for routine clinical work\textsuperscript{191}.
OUTPUT OF CADINO

CADINO employs an organized method for history taking and physical examination leading to the identification of the causes of dizziness. Its approach to patients is built on an understanding of pathophysiology of dizziness. The CADINO program provides options on patient findings necessary for diagnostic work with dizzy patients. The following steps are taken during a CADINO diagnostic consultation. In order to improve the efficiency, questions in small groups are asked by the system. The level of questioning is escalated step by step. The program changes focus from one problem area to another as per the selection of the option. This method of constructing differential diagnoses gives CADINO seemingly intelligent behavior.

CADINO assumes that only one disease process is present at a time and user can choose only one option from the given choices. But if clinician feels that patient has multiple problems at a given time and more than one options are correct, than user will have to run the program again and select the options accordingly. CADINO plays roles of an electronic textbook and a diagnostic consultant on vertigo.

When the program is started, options are displayed on the screen. One most relevant finding of the patient can be chosen directly from the menu. An interactive dialogue is then started that will lead to a possible diagnosis based on the findings of the dizzy patient. The line of inquiry is based on the users identification of one most relevant finding of the patients. The user cannot choose more than one finding. It is best to take time and choose the one most pertinent finding. Some findings have additional description, which follow that finding. Hearing loss can be conductive or sensorineural, preexisting or recent, sudden or gradual onset, and progress rapidly, gradually or fluctuating (Box 7.12). Some choices off the category menus are technically not ‘true symptoms.’ These include important vascular risk factors such as Diabetes, Hyperlipidemia, Hypertension or Smoking history.

The CADINO program begins with the general instructions and a sort of disclaimer. Once the user accepts the conditions, its first inquiry is regarding the trauma (Box 7.1), which consists of physical trauma, surgical complications and barotraumas. In cases of head injury (Box 7.2), CADINO inquires about facial palsy, CSF otorrhea, hearing loss and dizziness. The physical ear trauma (Box 7.3) consists of both pressure
and foreign bodies induced injury to the ear. In patients of barotraumas (Box 7.4), CADINO asks whether symptoms developed during ascent, descent, or in deep water. In presence of descent (Box 7.5) CADINO would like to know whether dizziness lasted for 10-15 minutes or long lasting. In cases of ‘Drug induced dizziness’ (Box 7.6), CADINO shows ototoxic antibiotics, antihypertensive, hormones, cardiac, psychiatric, and CNS medicines. Physiological dizziness (Box 7.7) consists of motion sickness and disembarkment syndrome. Otological signs and symptoms may be associated with dizziness (Box 7.8).

In the cases of otorrhea (Box 7.9) CADINO needs ear microexamination to see the findings of different types of otitis medias. Positive history of ear pain (Box 7.10) also needs ear microexamination for the findings of external and middle ear disorders, which can lead to dizziness. CADINO inquires associated features, which may be present in cases of deafness and tinnitus (Box 7.11). In certain febrile illnesses, which present with deafness / tinnitus, patients can have vestibular symptoms. In all the cases of hearing losses (Box 7.12) audiogram is important particularly in cases of noninfectious diseases of middle and inner ear. CADINO categorize headache (Box 7.13) into two types single prolonged attack or recurrent episodic attacks. In CADINO central nervous system findings include motor and sensory deficits, such as muscle weakness, ataxia, diplopia, blindness etc (Box 7.14).

The system does inquire the type and description of dizziness (Box 7.15). Disequilibrium without vertigo (Box 7.16) refers to imbalance, unsteadiness, difficulty in standing, or walking. The patients of presyncopal dizziness (Box 7.17) usually have feeling of lightheaded sensation, giddiness, generalized weakness, and pallor just before fainting or losing consciousness. Only lightheadedness (Box 7.18), which includes giddiness, floating, rocking, swimming sensation, or feeling of being removed from the body usually indicates psychiatric cause. The sensation of spinning, whirling or rotation refers to vertigo (Box 7.19). CADINO notes that the recurrent episodes of vertigo may or may not be associated with instability, imbalance, or lightheadedness in between the attacks. So if a patient has instability, imbalance, or lightheadedness in between the attacks of spinning vertigo it is not considered single prolonged continuous vertigo.

CADINO put the episodes of vertigo, which are triggered by specific head position, neck movement (Box 7.20) or other triggers into a different category (Box 7.21).
CADINO even tries to extract some findings, which may be associated with the so-called isolated episodes of vertigo (Box 7.22). If CADINO does not find any cause of vertigo, which can be diagnosed on the bases of clinical findings, it asks for some common systemic diseases and certain investigations (Box 7.23).

DISTINGUISHING FEATURES OF CADINO

CADINO differs from diagnosis decision support systems (DDSS) like QMR and Iliad\textsuperscript{129}, Dxplain (http://dxplain.mgh.harvard.edu), DiagnosisPro (http://www.diagnosispro.com), PKC\textsuperscript{6} in that it uses simple hyperlinks of word documents.

Dxplain and Quick Medical Reference (QMR) were developed two decades ago and aimed to solve medical problems. They used a complex network of clinical findings and disease names within their database. Clinicians entered a patient's clinical features through a controlled vocabulary. Diagnostic results were ranked by probability.

The order of appearance of CADINO diagnoses is in the order of importance. ENT surgeons have to use their clinical judgment to decide of these diagnoses to investigate and crucially which to treat. The ENT surgeon can quickly browse the list and decide for himself the probability. UpToDate and MDConsult are large repositories of medical knowledge (journals, textbooks, reviews). It is possible to start a search within these systems only when a diagnosis label is available. CADINO begins at an earlier point in the dizziness cases, and helps the ENT surgeons reach a diagnosis first and then aids to mobilize medical knowledge related to the disease.

CADINO system provides a set of diagnoses for each dizzy patient and tells the clinician what to do and further workup. Thus CADINO helps clinicians by providing reminders as well as mobilizing relevant medical knowledge. Although there is potential concern that ENT surgeons might over-investigate dizziness patients on the basis of CADINO advice, users seem to be able to distinguish between the 'red herrings' and the really important suggestions without much difficulty.

CADINO has the potential for a meaningful change in the quality of diagnostic decision-making in cases of vertigo. Though not studied in this project, even other clinicians can also use CADINO system when they need diagnostic assistance during the
assessments of dizzy patients. Incomplete workups would be identified. CADINO may prompt the consideration of appropriate diagnoses and lead to a complete workup.

Graber and others\textsuperscript{130} found that lack of knowledge was not an important factor in diagnostic error. Graber and Franklin\textsuperscript{130} found that cognitive factors contributed to diagnostic error in 74\% of cases. The most common cognitive problems involved faulty synthesis. Premature closure, which is the failure to continue considering reasonable alternatives after an initial diagnosis was reached, was the single most common cause. Elstein and Schwarz\textsuperscript{94} suggested the value of compiling a complete differential diagnosis to combat the tendency to premature closure. CADINO tries to address these issues and offer a complete list of differential diagnoses. So, CADINO assists in minimizing cognitive factors contributing to diagnosis error.

CADINO cannot replace ENT surgeons but just complement their natural abilities to make judgments with its vast memory, reliability and processing capabilities. Traditional continuing medical education is designed to meet the knowledge gaps of groups rather than individual physician with specific patient problems\textsuperscript{95}. CADINO is designed to meet knowledge gaps of ENT surgeons while dealing with the dizzy patients.

**EVALUATION OF CADINO**

The CADINO, an experimental computer program is meant for use as a near-patient decision support tool. It is designed for ENT surgeons to provide a checklist of likely diagnoses for patient's dizziness. It aims to reduce diagnostic errors and improve patient care. CADINO is designed to enhance the knowledge and cognitive skills of the physician to provide a checklist of reasonable, relevant dizziness diagnoses for the physician to consider. The CADINO was evaluated to highlight its strengths and weaknesses. Its clinical acumen was compared with that of, E.N.T. residents, consultants and teachers. The evaluation was not intended to validate CADINO for the clinical use.

CADINO, which is capable of making diagnoses in cases of dizziness, includes about 100 causes of dizziness (Table 6.1 and 6.2). It was developed in Microsoft \textregistered Word 2000 using hyperlinks. Prospective study of the diagnostic accuracy of CADINO consultations was done in 35 patients, 8 simulated cases and 7 case reports from journals (Table 7.1). Eleven ENT residents and 14 ENT surgeons (8 teachers and 6 senior private consultants) participated in the evaluation of CADINO (Table 7.2).
The patients in whom no cause of dizziness could be ascertained (such as vestibulopathies of unknown etiologies and presumed malingering) and who have multiple causes of dizziness (such as elderly patients) were not included in the study. The patients were followed until a diagnosis was definitively established. The diagnosis was usually established clinically if the professor was sufficiently convinced of the diagnosis to begin specific treatment. The diagnostic accuracy of the residents, faculties and program and the impact of CADINO consultation were assessed comparing the final established diagnosis.

In addition, CADINO has an invaluable role to play in medical education at any level to illustrate the art of diagnostic decision-making. After CADINO consultation, users were requested to record the rating of the educational value (Helpful, neutral, not helpful) and patient management (Helpful, neutral, not helpful). In 21 (84%) of the 25 participants rated the CADINO consultation to be educationally helpful (Table 7.3). The same proportion of participants 21 (84%) rated CADINO consultation useful for patient management.

Some of the early expert diagnosis decision support systems have undergone accuracy studies. Graber and Vanscoy found the final diagnosis in the differential diagnosis generated by Iliad and QMR 72% and 52% of the time respectively. Bavdekar and Pawar evaluated an Internet-Delivered Pediatric Diagnosis Support System (Isabel) in a Tertiary Care Center in India and demonstrated 80.5% sensitivity. Borowitz and others found that in 10% of cases, a diagnosis reminder system caused the user to consider a major diagnosis they had not considered and concluded that diagnosis reminder systems could reduce diagnostic omissions and the number of medical errors. Kentala and others developed an OtoNeurological Expert system (ONE) to aid the diagnostics of vertigo, to assist teaching and to implement the database for research. In the validation they found the expert system ONE to be a sound decision maker, by solving 65% of the cases correctly, while the physicians' mean was 69%.

During the CADINO evaluation study, residents gave correct diagnosis in their preconsultation diagnoses in 20 (62.5%) of 32 patients (Table 7.4.1). Before using the CADINO program, the faculties gave correct diagnosis in 26 (81.25%) of 32 patients. The correct diagnosis was the highest ranked CADINO diagnoses in 27 (84.38%) of 32 patients. In all 20 patients in which resident named correct diagnosis, the CADINO...
program did also. In 26 patients, both the CADINO and faculties gave correct diagnoses. Out of the 8 simulated cases (Table 7.5.1) CADINO gave correct diagnoses in 7 (87.5%).

The diagnostic sensitivity of the CADINO (Table 7.5.1, 7.5.2, 7.6.1, 7.6.2 and 7.7), 84.78% (Patients 84.38%, simulated cases 87.50%, case reports 83.33%), was approximately similar to that of faculties 81.25%, but better than that of residents, 62.5%. In this quasi-experimental study, E.N.T. consultants and teachers assessed dizziness cases and after CADINO consultation, about 85% found their correct diagnoses. CADINO reminded them to consider other clinically important diagnoses and prompted them to order an important test. No clinically significant diagnoses were omitted indicating that CADINO consultation did not result in any deleterious effects.

The decision-making ability of 'ONE' a neurotologic expert system was compared with the diagnoses of six physicians. Five of the physicians were residents and one was a specialist in the field of otolaryngology. The test patients were randomly selected from vertiginous patients referred to an otolaryngology clinic. The expert system and the physicians first had identical information on patient history, symptoms, and tests. The correct diagnoses were certified by an experienced specialist in neurotology. The expert system did better in decision-making when both the expert system and the physicians had identical information on patients. The expert system diagnosed 65% of the cases, while the physicians first diagnosed 54% of the cases. In the validation the expert system ONE proved to be a sound decision maker, by solving 65% of the cases correctly, while the physicians' mean was 69%. The six diseases were detected with high accuracy.

A study of QMR and Iliad showed "Each case took from 20 to 40 minutes to input". PKC is designed for data to be entered by the patient. A recent study "A randomized outpatient trial of a decision-support information technology tool of PKC" showed that "average Coupler session took approximately 18 minutes of employee time to coordinate". This gives an idea as to the time taken to obtain a differential diagnosis in DiagnosisPro (http://www.diagnosispro.com) and Dxplain (http://dxplain.mgh.harvard.edu). In contrast CADINO was found quite quick (Table 7.8). On average time for CADINO on a stand alone basis was shown to be less than 10 minutes because user simply selects the pertaining item and no typing/printing is needed. In CADINO there is no data entry therefore it is very quick. Users have to select from a series of options for each clinical feature.
For the initial consultations both in cases of patients and simulated cases more time was taken but in subsequent cases less time was taken because the users got familiar with the system. In cases of case reports on and average 5 minutes were taken.

CAUSES OF VERTIGO
Benign paroxysmal positional vertigo, acute vestibular neuronitis, and Ménière's disease are the most common causes of vertigo; however, other common causes include cerebrovascular disease, migraine, psychological disease, perilymphatic fistulas, multiple sclerosis, and intracranial neoplasms. Although otitis media is the most common cause of vertigo in children, it can be a manifestation of other otological and medical disorders. Vertigo in the absence of otological, neurological or medical disorders is a diagnostic dilemma for the clinicians.

The real patients, excluding simulated cases and case reports, were divided into three categories (Table 7.4.2) as described by Agostino and others. The first group consisted those patients having associated cochlear symptoms. Second group patients had isolated vertigo. Third group patients had associated CNS or medical conditions.

The type of catchments population coming to an institute determines the etiology / epidemiology of dizziness. The largest was the second group (37.5%). The commonest diagnosis (18.75%) in this group was benign paroxysmal positional vertigo (BPPV), followed by vestibular neuritis. Meniere's disease and migraine and its variants were the most common causes in first and second group respectively.

The diagnosis of Meniere’s disease was made on 3 cases (9.37%). Otitis media was seen in three cases: 1 each case of acute otitis media (AOM), otitis media with effusion (OME) and cholesteatoma. The case of ototoxicity had a preceding history of streptomycin prior to the development of vertigo. Perilymphatic fistula was diagnosed in 1 case following stapes surgery.

BPPV was diagnosed in 6 cases with isolated vertigo and Vestibular neuritis in 4 cases. A case of hyperventilation syndrome was diagnosed by reproduction of vertigo on hyperventilating (40-60 breaths per minute) for 1 to 3 minutes without any nystagmus and with normal otoneurological examination.

Migraine related vertigo was diagnosed in 3 of 10 cases of third group and was the largest number in this group. Migraine headache with or without aura was present in all
the 3 cases. Drop attacks were not seen in any case. None of the migraine patient had history of hearing loss. The CNS conditions associated with disequilibrium were diagnosed in one patient each, with cerebellar abscess, acoustic neuroma, and paraneoplastic syndrome. Vitamin B₁₂ deficiency associated with dizziness was seen in one case only. Two cases had drug-induced dizziness, caused by carbamezepine and methotrexate.

It is estimated that more than 25% of patients who present with vertigo suffer from benign paroxysmal positional vertigo BPPV²⁷³. Labyrinthine diagnoses coexisting with central neurological or cardiovascular cause are classified as multifactorial (Table 4.1b). An idiopathic diagnosis is only made after other causes had been excluded and the patient’s dizziness has resolved. Patients with neck pain or occipital headache but no features of otological or neurological disease in whom vertigo was provoked by changes in neck position are diagnosed musculoskeletal vertigo.

CADINO: CAUTIONS AND FUTURE DIRECTIONS

Without doubt CADINO would need up gradations and modifications to keep pace with the modern development. Though the video, audio, and cross-sectional photographs have been included in many computerized medical diagnostic programs, in CADINO only text related to the disease was added. At present CADINO is not an excellent patient education tool focusing on dizziness. Computerized protocols can generate patient-specific instructions for therapy that can be carried out with little interclinician variability; however, clinicians must be willing to modify personal styles of clinical management²⁴¹

At present CADINO has not been interfaced with electronic medical record (EMR) systems such as NextGen (http://www.nextgen.com/), PatientKeeper (http://www.patientkeeper.com/) and A4 Health Systems (http://www.allscripts.com/). Considering the simple nature of its algorithms, though CADINO performed quite well, it was felt that program does not yet possess sufficient reliability for clinical application.

To further improve the CADINO results, I feel that a follow-up should be implemented for the patients, to ease the diagnostic work of some difficult diseases. Diagnosing the first episode of vertigo during the first visit would be difficult because if the episodes recur repeatedly it indicates a different category of causes. In some cases where the diseases progresses over the time certain new features appear, which might
change the diagnosis such as in cases of tumors, degenerative and vascular lesions. Lack of temporal reasoning capabilities was the significant shortcoming that was highlighted during the evaluation of CADINO.

The developers of computer-aided medical decision systems should keep in mind the ethical and legal concerns especially during the process of program validation. Is there the need of users certification before the use of system, which provide patient specific advice? Who will be held legally responsible when system’s advice is faulty? Is a physician who does not use such system liable if that system’s advice might have prevented an adverse outcome? The ethical and legal issues were not the concern for CADINO right now because users as well as patients who participated were made fully aware of its experimental nature and were informed that the CADINO evaluation study was not for validating the program.

Specific deficiencies of CADINO include its inability to reason temporally, inability to construct differential diagnoses spanning multiple problem areas, and its inability to explain its thinking.

**ADVANTAGES AND RATIONALE OF USING CADINO**

The CADINO is an intelligent system with great potential for categorizing the causes of dizziness and vertigo. CADINO is easily portable and can be run on different types of economical current models of PCs. Because of its transparency it enthuses the confidence of the patients. The decisions suggested by the system are reasonable for the given patient data and knowledge base. Though evaluated in this study by ENT residents and surgeons only CADINO is designed even for medical students, general practitioners and other health workers. It is an aid to the ENT specialists to look up complex information quickly and also provides them second opinion to review the case from other angles.

CADINO is designed to remind the physicians of diagnoses they know about but may not have thought of. So CADINO enhances the physicians’ skills. It is anticipated that the CADINO system will be most useful in clinical settings with rapid turnover. It can be used in ambulatory settings and outpatient departments as a reference tool. While the CADINO system is primarily a clinical decision support system, the educational aspect of its advice cannot be underestimated. Even if the diagnostic advice might not
change practice for one patient, the knowledge gained from its advice and art of evaluation might help the next dizzy patient. CADINO helps in reducing the number of inappropriate tests done as part of a lengthy diagnostic workup. CADINO is easy to use and provides rapid advice within minutes. In this study it took on average less than 10 minutes to process the diagnostic suggestions and make meaningful clinical decisions. The only infrastructure necessary is Microsoft Office.

The CADINO system will list different diseases on the basis of symptom and signs. Within each section the diagnoses are further described on a relative rarity scale as very common, common, rare, and very rare. The physicians who are not efficient in typing can also quickly select the options with simple tap on a key or click of a mouse. The system showed good performance.

The CADINO does have the advantages of other computerized medical diagnosis (CMD) such as portability, transparency, and structured and modular history taking. The computerized decision support of CADINO is configured to contain much more detail than textual guidelines or paper-based flow diagrams for the evaluation of dizzy patients.

The rationales for using CADINO are following. ENT surgeons can now afford computer technology. Literate patients demand information and explanation regarding the diagnosis of vertigo and dizziness. There is increasing popularity of computers in public and medical professionals. There is complete and accurate evaluation of dizzy patients. CADINO could prove to be immensely helpful in consumer protection litigation and other legal matters. There could be enhanced productivity of the health care team, who manage the dizzy patients.

CADINO offers complete confidentiality of patient’s record and wins the patient’s confidence because of transparency. CADINO has the potential to educate and evaluate students, residents and other health care providers, who are interesting in managing patients of vertigo and dizziness. It could prove to be an excellent tool for clinical research in the field of balance disorders. CADINO can successfully manage ENT surgeons self perceived knowledge gap in managing dizzy patients. CADINO is a good mode of practicing Evidence Based Medicine.