Reasoning about Therapeutic and Patient Management Plans in Respiratory Medicine by Physicians & Medical Students

by

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Jai Tirupati Balajëë !!
Gurü! ! Bhrahmä, Gurü!! Vishnü, Gurü!! Devo Maheswarä !
Gurü !! Saakchhatya Para-Bhrahmah , Tasmay Sri Guruveh Namä !!
"Upnishäd"

Dedicated to my

"Gurü"

who inspired me to see
different colors in the world

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ABSTRACT

Recently, there has been extensive research in the area of diagnostic expertise. The model of diagnostic reasoning and clinical expertise has been well documented (Patel et al., in press). This study attempts to extend this research in order to include therapeutic reasoning. Using the expert-novice paradigm, this study attempts to investigate the use of knowledge, specifically, both biomedical and clinical sciences, and the directionality of reasoning during decision making about patient management and therapeutic planning in respiratory medicine.

Subjects at four levels of expertise were given two clinical problems with the diagnosis and asked (a) to provide therapeutic plans, and (b) describe the underlying pathophysiological explanations of the diseases. Think-aloud protocols were audio-taped and analyzed using methods of protocol analysis. The results showed that the use of basic medical sciences increased as a function of expertise in the procedure-oriented decision-making tasks. The novices generated rule-based prototypical textbook descriptions based on the clinical information, and the diagnosis given in the task. In contrast, the experts' therapeutic responses showed a predominance of causal-level inferences, reflecting more backward-directed inferences than novices. Although both the novices and experts generated forward-directed inferences, the novices were unable to provide accurate and adequate explanations for their decisions. Finally, the pathophysiological explanations of the disease were generated from a different knowledge source than that used to develop therapeutic decisions.

The implications of these findings for development of theory of expertise and for education in the medical domain are discussed.

RÉSUMÉ

Des travaux de recherche approfondis ont été menés dans le domaine de l'expertise disgnostique. Le modèle de raisonnement diagnostique et d'expertise clinique est bien documenté dans la littérature (Patel et al., sous presse). Cette étude tente d'étendre ce type de recherche pour inclure le raisonnement thérapeutique. Utilisant le paradigme expert-novice, cette étude tente d'examiner en détail l'usage des connaissances acquises spécifiquement dans les sciences tant biomédicales que cliniques et la directionalité du raisonnement pendant la prise de décision concernant la façon de traiter les patients et la planification thérapeutique en médecine respiratoire.

On a donné deux problèmes cliniques avec le diagnostique à des sujets à quatre niveaux d'expertise, et on leur a demandé de fournir (a) des plans thérapeutiques et (b) une description des explications de la pathophysiologie sous-jacente des maladies. Des protocoles «penser à haute voix» furent enregistré sur magnétophone et analysés en utilisant des méthodes d'analyse de protocole. Les résultats ont démontré que l'usage des sciences médicales de base augmenta en fonction de l'expertise dans les tâches de prise de décision sur la prodédure à suivre. Les novices ont généré des descriptions de manuel prototypiques basées sur l'information clinique et le diagnostique fournis dans le problème. En contraste, les réponses thérapeutiques des experts ont révélé une prédominance d'inférences causales, reflétant plus d'inférences dirigées vers le passé que les novices. Bien que les novices comme les experts eussent généré des inférences dirigées vers l'avenir, les novices ont été incapables de fournir des explications précises et adéquates pour leur décisions. Enfin, les explications pathophysiologiques de la maladie ont été générées à partir d'une source de connaissances différente de celle utilisée pour développer les décisions thérapeutiques.

Les implications de ces conclusions tant au niveau de la théories que de la pratique de la médecine cliniques sont discutées.

PRESENTATION

Parts of the work presented in this thesis has been reported in the following:

Chaturvedi, R. K. & Patel, V. L. (1994). *Therapeutic decision making by physicians and students: role of knowledge and reasoning strategies*. Paper presented at American Educational Research Association Meeing. New Orleans, LA, April 4-8, 1994.

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CHAPTER 1

INTRODUCTION

Motivation

Motivation for this study arose from the controversy about the role of biomedical science knowledge in clinical medicine. Biomedical science knowledge is deemed to provide a framework upon which clinical knowledge can be developed. However, the precise role of biomedical knowledge in medical reasoning is still controversial (Patel, Evan, & Groen, 1990; Patel & Groen, 1986; Feltovich, 1981; Norman, 1988; Lesgold; 1984; Boshuizen & Schmidt, 1992). The results of these studies show that the general theory of expertise in the domain of medicine has two specific measures which play particular roles in reasoning and problem solving in clinical medicine. They are (a) the richness of the knowledge base and the type of knowledge used, and (b) the directionality of reasoning. Directionality of reasoning is a measure of expertise in the process of problem solving. The results of much research in different domains has indicated that, as a general trend, during problem solving directionality of reasoning is data driven in routine tasks. Similarly, research into medical decision making (Patel & Groen, 1986) suggests that expert behaviour during routine medical problem solving shows a forward-directed reasoning. This type of forward-directed reasoning (data to hypothesis) shows strong problem-solving strategies (Patel & Groen, 1991; Kassirer & Kopelman, 1990) which differentiate it from weaker approaches used by novices, such as backward-directed reasoning from hypothesis to data.

In the domain of medicine, the process of making a diagnosis is an extremely important step. However, another essential area in clinical medicine is decision making about therapeutic plans. Much research has been conducted in the domain of medicine to investigate the role of biomedical knowledge and directionality of reasoning in the area of diagnostic problem solving; the area of therapeutic decision making has yet to be investigated. This research has focused on these issues of the use of knowledge and directionality of reasoning in the area of decision making about patient management and therapeutic plans. Patel and Groen (1986, 1991) demonstrate that during clinical problem solving, experts use forward reasoning, and conclude that there is a fairly strong relationship between diagnostic accuracy and this type of forward reasoning. The question is whether this characteristic still holds when the diagnosis has already been provided and the subjects are asked to make therapeutic and patient-management decisions for the patient.

Objectives

The specific research objectives are as follows:

1. To investigate the use of basic medical science knowledge during patient-management and therapeutic planning.
2. To investigate the kinds and the nature of reasoning strategies used in generating the therapeutic plans and in providing explanations and justifications for such plans.
3. To examine the type of knowledge used during explanation of clinical problems and its relationship to patient management and therapeutic planning.
4. To study (1), (2), and (3) above as a function of problem familiarity.
5. To study (1), (2), (3) and (4) above as a function of domain expertise.

Outlines

The present study is based on the expert-novice traditions of cognitive research that have received a great deal of attention in recent years. This research presents an investigation of clinical problem solving in the context of patient management and therapeutic planning. The main purpose of this study is to extend the scope of traditional clinical problem-solving studies beyond the diagnostic stage and into the area of decision making for therapeutic planning. However, another purpose of this study is to investigate decision making processes and strategies used by subjects at different levels of their expertise when they are presented with two different types of clinical problems, i.e., a routine and a non-routine clinical problem, in real, practical situations. This study is based on the main body of cognitive research on the expert-novice paradigm conducted in many academic institutions.

The study of expertise in the domain of medicine has, in the last few decades, developed to a considerable extent. Various studies have uncovered general characteristics of medical expertise (Patel & Groen, 1986, 1990, 1991) that are consistent with those which have emerged from studies into expertise conducted in other domains (Chase & Simon, 1973; Larkin et al., 1980; Voss & Post, 1983). The review of literature was undertaken, first, to search for a theoretical framework for my research. With the foundation stone of this research laid, I have looked for the historical aspects of biomedical sciences in clinical medicine. The rationale for this brief review of the history of biomedical sciences in clinical medicine is that one of the central questions of my research is the use of biomedical science knowledge in clinical medicine, a controversial issue in the domain of medicine. Finally, the review of literature focused on research studies conducted in the domain of clinical medicine. Most of these studies have explored the area of diagnostic skills, and range from psychometrically-based studies (Rimoldi, 1961) to normative research (Feinstein, 1967) to the latest in the area of the cognitive process (Elstein, Shulman & Sprafka, 1978, Patel & Groen, 1986). In the realm of clinical medicine, the diagnostic process is an important first step towards the search for the underlying clinical problem in the patient. Another essential step in clinical medicine is the decision to provide treatment to the patient to bring his or her clinical state to the normal state. In the area of diagnosis making, two aspects are thoroughly explored. These are: the use of basic science knowledge and the directionality of reasoning. The present research has looked at similar issues in the area of decision making about therapeutics and patient-management planning. Many studies in the area of therapeutic decision making have been conducted using different parameters, mostly probability, but cognitive research in the area of decision making for therapy and patient management are limited (Elstein, et al., 1986, 1992; Moskowitz, Kuipers, & Kassirer, 1988; Pauker & Kassirer, 1975, 1980).

My research has extended into the area of decision making about therapeutic planning and patient management, and also focuses on the study of expert-novice therapeutic reasoning strategies. This research investes some characteristics of the novice with respect to what he or she lacks as compared to experts during decision making about therapeutics.

In Chapter 2, "Literature Review", I have included a brief account of some of the studies in the expert-novice tradition, especially in the areas of problem solving and medical decision making. This chapter presents an overview of problem-solving research in complex academic contexts, and has provided a general theoretical framework for my research. This problem-solving research has examined individual differences during problem-solving sessions between novices and experts. This section is followed by a brief account of the history of biomedical science in medical education. Later in the chapter, I have included an analysis of research in problem solving and decision making about therapeutics in clinical medicine. Although much has been done in directionality of reasoning, and the use of basic medical science knowledge in the area of diagnosis or clinical problem solving, research in the area of therapeutics and patient management is very limited (Elstein, et al.,1986, 1992; Moskowitz, Kuipers, & Kassirer, 1988, Pauker & Kassirer, 1975, 1980). This research focuses on decision making about a patient's therapy which is based on different issues, such as the uncertainty of the diagnosis (Moskowitz, Kuipers, & Kassirer, 1988), the risks and benefits of therapy for the patient (Elstein, et al.,1986, 1992), the costs and benefits of therapy (Pauker & Kassirer, 1975), and decision making for withholding the therapy (Pauker & Kassirer, 1980). In my research, I have investigated the issue of the use of basic medical science knowledge in the area of decision making for therapeutic planning. A brief review of literature in the area of clinical therapeutic decision making is followed by a rationale for the studies on the cognitive aspect of therapeutic decision making.

Chapter 3, "Methodology" is organized according to the standard practice of methodological presentation, beginning with a brief description of the subjects selected for the experiment at different levels of their expertise. This is followed by a detailed description of the materials used in the experiment. The two clinical cases in question are a routine asthma and non-routine pulmonary embolism, followed by explanations of each case. The rest of the section deals with the procedures and methods of analysis, including coding schemes and specific differences in the forms of knowledge used in responses. The "methods of analysis" section includes specific hypotheses to be explained.

The results are presented under three main section headings. The use of knowledge, directionality of inferences, and explanatory process together with the discussions which helps to clarify the section, followed by more general comments.

The first section on the use of knowledge presents the general results for each group. This section summarizes the results in a descriptive manner, focusing on numerical information and centering upon quantitative analysis. This quantitative analysis is divided into four groups: deals with the total number of propositions used by different groups of subjects and the mean percentage propositions of different types of knowledge used; covers the mean percentage of propositions of basic science knowledge used by different groups of subjects; presents the results of analysis conducted for the use of pathophysiological knowledge propositions by different groups of subjects; discusses the results of the trend for the use of basic science propositions at different levels of expertise during therapeutic and patient-management planning in the given two cases.

The second section on the directionality of inferences provides an account of individual protocols which offers a descriptive picture of the subjects' decision-making and reasoning processes. In this section the main focus falls upon the ongoing process of decision making with special attention paid to directionality of inferences and justification offered by the subjects during planning of therapeutics and patient management. I have used the term "directionality of inferences" in keeping with the practice of the relevant literature (Patel & Groen, 1986, 91) in both the research on scientific reasoning and on diagnostic reasoning in medicine. The section on directionality is followed by a section offering an analysis of explanatory responses given by the subjects to a question regarding the pathophysiology of the cases in the experiment. The main focus in this section is upon the use of information from the clinical stimulus text and the responses given regarding the patient-management planning during the subjects' explanations of the pathophysiology of the cases.

Finally, conclusions about the research are presented, focusing on the relevant literature previously discussed. A brief account of the limitations, potential future research, and the instructional implications of this study is provided.

CHAPTER 2

LITERATURE REVIEW

Section 1: Basic Medical Science in Medical Education

One purpose of this selective review of the literature on the history of biomedical sciences in medical education is to provide a fundamental understanding of how biomedical sciences entered the medical curriculum and began to assume an important role in medical education. Another purpose of this review is to form a connection between one of my research questions in this work regarding the issues of the use of knowledge and directionality of reasoning in the area of decision making about patient management and therapeutic plans and other studies already conducted in the domain of clinical problem solving regarding the role of basic medical sciences.

The era of Boerhaave (1668-1738, cited in Boshuizen & Schmidt, 1992) recognized the importance of basic medical sciences, i.e., anatomy, physiology, and biochemistry for medical education. However, attempts had been made to uncover the human body's internal structure (anatomy) and functions (physiology) since the era of Antonio Benivienis (1448-1502) and Jean Fernel (1502-1588). Van Leeuwenhoek (1632-1732) helped in expediting the process of studying human anatomy and physiology by inventing the first microscope. Since then research into human physical structure and its physiology has provided a great deal of knowledge which is essential in understanding the process of disease when non-equilibrium in the body systems occurs, and how these disorders get normalized. As a result of these studies, the concept and practice of medicine developed from an art into a modern science (Boshuizen & Schmidt, 1992).

In the first decade of this century some important decisions were made after the publication of the Flexner report (1910) and its recommendations. In its conclusions the report stated that there were gross inadequacies in medical curriculum across the medical schools in North America. This report recommended a division of medical education into two major areas: (1) basic science teaching or pre-clinical years, and (2) clinical teaching or clinical years. Basic science teaching includes courses in anatomy, physiology, biochemistry and bacteriology, whereas teaching in clinical years comprises courses in medicine, surgery, gynecology and other clinical subjects. According to this report, the basic science courses should be taught to the students before they enter the clinical year of their medical school program. The Flexner report also recommended that students entering medical school should have a background in basic science subjects like physics, chemistry, and biology. This report was universally well received in North American Medical Schools and changes were made in medical curriculum based on this report.

Since then not much has changed in the pre-clinical teaching program; the basic biomedical courses remain as such, for example anatomy, physiology and biochemistry. But because of developments in modern technologies such as the electron microscope, and different technological apparati for imagining the tissues and organs of the body, the physician's understanding of body physiology and anatomy has increased dramatically. These developments have helped modern physicians to understand disease etiology and pathology more completely. In addition, these technologies have expanded the content of basic science courses. As a result of vast increases in basic science knowledge, basic science subjects were taught by teachers with a background in basic science and very little clinical science knowledge (Barzansky, 1992; Neame, 1984).

In the 1950's an integrated teaching program was introduced at the Western Reserve Medical Schools. The purpose was to break down the barriers between preclinical or basic-science teaching and clinical teaching, by presenting basic sciences along with clinical teaching (Olson,1976). With the introduction of this integrated teaching program in a medical curriculum a question arose: should we reduce basic science given in current medical curriculum, or should we lengthen the time of curriculum further to accommodate more knowledge (Mann, 1976)? Nossal's response to this question was that what is needed is not more basic science but "better basic science" (Nossal, 1976). As a result of this proposal, two innovative curricula for basic science teaching were introduced: (1) the teaching of basic sciences during the clinical part of the curriculum, and (2) the teaching of basic sciences during an eight-week return to basic science following the clerkships. A similar argument given by other researchers questioned whether we should attempt to build the correspondences between basic and clinical science by more aggressive teaching or better targeted instruction (Patel, Evan, & Groen, 1989). The importance of basic science in clinical problem solving and decision making is recognized and accepted completely.

Patel and Dauphinee (1984) conducted a study to investigate the effects of a return to BSO-program (Basic Science Option) for graduating students, introduced into the McGill University Medical Curriculum in the 1970's. The major objectives of the program were to facilitate student learning in greater depth and to integrate basic science with clinical knowledge. Students undertake a three-month program in the basic-science option in the final year of their undergraduate clinical clerkship. In this study, selected students enrolled from 1978-1981 were tested on educational and attitudinal variables. Data were collected using achievement tests, questionnaires and interviews. The results of this program showed that the students were able to integrate basic science with clinical knowledge in a better way. As a result of this study, the concept of a return to basic science was recommended for consideration by medical faculties.

The importance of the biomedical sciences in the medical curriculum, and the role of these sciences in medical problem solving is still in doubt, however, in current practice, because research findings in these areas are contradictory. Most of the studies about the role of basic science in medical curriculum and clinical problem solving seem to be based on two contradictory statements: (1) that the basic sciences provide a foundation for clinical reasoning, and (2) that the physician rarely uses basic science in thinking about clinical problem solving (Schmidt et al., 1990).

Section 2: Problem Solving: Expert-Novice Paradigm

This review of literature on problem solving is selectively based on studies in the expert-novice paradigm based on cognitive theories. This will explain and clarify the framework on which many clinical problem-solving studies were conducted. Based on a similar framework, this research is extended into the area of therapeutics and patient management.

In recent years, a good deal of research has been conducted to investigate differences between expert-novice problem-solving strategies in many fields, including: physics (Larkin, 1981; Chi, Feltovich & Glaser, 1981), chess (deGroot, 1965, 1966; Charness, 1989; Simon and Gilmartin, 1973; Chase & Simon, 1973; Newell & Simon, 1972), electronic circuit diagrams (Egan & Schwartz, 1979); the game of Go (Reitman, 1976), and bridge (Engle

& Bukstel, 1978; Charness 1989) and computer programming (Card, Moran, & Newell, 1983). This research involves people at various levels of expertise in their field, i.e., novices, intermediates, experts. Some of these studies were longitudinal (the same subjects were followed from the novice stage to the stage where they became expert in their fields), but most were cross-sectional (subjects were selected from various levels of expertise within a field, and were asked to perform tasks to search for the solution to a problem). The results of these studies showed that experts use different methods of reasoning from those used by novices or intermediates. In addition, experts organize their knowledge differently (Patel & Groen, 1991). Within only a few decades a great deal of research has been done on expertise in the field of sports, chess, mathematics, physics and medicine.

A number of research projects were conducted in the discipline of physics to investigate differences between novices and experts (Larkin, 1981; Chi, Feltovich & Glaser, 1981; Chi, Glaser, & Rees, 1982). A well-structured discipline like physics, which has a well-organized knowledge structure, can be divided into many sub-domains, such as kinetics, dynamics, thermodynamics and so on. A problem-solving task in the field of physics involves three main components: (1) recognition, (2) problem representation, and (3) inference or interpretation of the problem. A physics problem solver must recognize the underlying structure of the problem, generate representations appropriately for the discovery of solutions, and make inferences on the generated representations. Recognition in physics, for example, involves theoretical knowledge of the area, generation involves the abstraction of appropriate problem-specific knowledge about presented problems from theoretical knowledge, and inferences are made efficient by strategies like working forward (Simon & Simon, 1978). These studies concluded that the novices try to formulate the equations very quickly, and try to coordinate the data in the given problem in these equations. Experts, on the other hand, take sufficient time, first to understand the problem, then to draw the diagram to represent the problem, and finally to derive an equation into which the given data of the problem would fit. Once the correct equation was constituted, the problem was solved much more quickly than the novice could manage (Chi, Glaser, & Rees,1982).

Simon and Simon (1978) compared the performance of novices and experts in the domain of physics. Their study concluded that experts solve problems much faster than novices and that experts use forward reasoning, starting with data given in the problem and then generating an equation to fit the data (working forward), whereas novices start from the goal variable and retrieve equations which contain variables given in the data (working backward).

These results about experts' practice of working forward and quickly solving the problem compelled the researchers to wonder whether the novice can be taught to work forward. The answer was not likely to be "Yes", because for working forward, a subject should have a sufficient domain-specific knowledge. This extensive domain knowledge and the ability to represent the domain problem enables an expert to work forward and find the solution to the problem quickly (Lesgold, 1988).

These studies were not only confined to the academic domain. deGroot (1965), who was a pioneer in the study of the novice and master chess players' performance, investigated differences between master and weaker chess players. In the results of his study, deGroot showed that master chess players were not different from novices or weaker players in terms of their memory and intelligence. It was observed that there were differences in master players in comparison to novice players in their abilities in choosing the number (quantitative) and quality (qualitative) of moves. deGroot found that master players considered fewer, but more accurate moves in comparison to novices. In his study, deGroot presented chess-game positions to his subjects, showed them for five seconds and then removed the pieces from their original positions. Later, the subjects were asked to reconstitute the chess board positions with the same chess pieces. Results showed that master chess players were able to reconstruct up to twenty pieces, where novices could construct only four or five. deGroot concluded that the master and novice players have differences in working memory or short term memory (STM), which was much greater in master chess players in comparison with weaker players. deGroot found that expert players were able to recognize the common board configurations as a function of their extensive experience with the game. However, in situations when deGroot presented subjects with random chess positions, he did not find any differences between novice and master players. In the studies which were conducted with randomized chess positions on the board, masters as well as weaker players were able to reconstruct the positions of only a few chess pieces. deGroot also observed that the master players were upset, and complained about these random chess board positions (Anderson, 1990).

Charness (1989) conducted another study to investigate the memory pattern in novice and expert chess players. In his study Charness showed his subjects a few chess board positions and then compared their memory of these after a delay of over thirty seconds (filled with an interfering task). Results showed that A-class (master) players showed no loss in recall over thirty-second intervals in comparison to novices, who often forgot a great deal. The results of these studies indicated that the memory advantage of expert individuals is seen not only in working memory or short-term memory (STM), but also extends to long-term memory (LTM). Conclusions were drawn that the master class players have an increased capacity for storing information about the chess positions. A number of other studies were conducted to investigate differences between expert and novice chess players; for example, Simon and Gilmartin (1973) estimated that masters may acquire in the order of 50,000 different chess patterns that they can recognize. This mastery comes after several years of devoted study and chess playing. Master players have to be able to store a great deal of information about chess. Chess players also think about the particular pattern on the board in a way that "if-this pattern" is present in the game, "then-that strategy" will be the appropriate solution, and keep this strategy always ready. This "if-this pattern" "then-that strategy" enables an expert to respond quickly and accurately. When the master players see such a pattern, they quickly respond and come up with an appropriate solution from their memory (Anderson, 1990).

A number of other studies were conducted to explore the phenomenon of superior expert memory in a variety of areas, for example, electronic circuit diagrams (Egan & Schwartz, 1979) and the games of Go (Reitman, 1976), and bridge (Engle & Bukstel, 1978; Charness 1989). These studies suggested the following about the general nature of expertise: (a) experts have a greater ability to organize information in semantically meaningful interrelated ways (Chase & Simon, 1973); (b) experts do not use much irrelevant information in their problem-solving tasks (Glaser & Chi, 1988); and (c) in routine situations, experts tend to use highly specific knowledge-based problem-solving strategies (Patel & Groen, 1986).

Section 3: Medical Cognition

These expert-novice differences identified in the studies in several scientific domains have considerable practical application to the study of clinical problem solving in the domain of medicine. These differences between expert and novice levels have thrown light on the reasoning strategies of novice physicians who engage themselves in a time-consuming search for an irrelevant diagnosis. Such irrelevant searches may entail unnecessary tests, investigations, unwanted medications and occasionally unneeded surgical procedures. In the domain of medicine various research-groups (Elstein Group; Patel & Groen Group; Schmidt, Feltovich, Norman, Lesgold; Blois; Kassirer) have conducted a considerable number of investigative studies which have established a general theory about expert-novice characteristics within the expert-novice paradigm. This general theory of expertise in the domain of medicine has two specific measures which play a particular role in reasoning and problem solving in clinical medicine. They are (a) the richness of the knowledge base and the type of knowledge used, and (b) the directionality of reasoning.

Knowledge use and Directionality of Reasoning

A first measure of expertise in diagnostic reasoning is the knowledge base that is brought into play, specifically the role of biomedical knowledge (Boshuizen & Schmidt, 1992). A number of studies have investigated the extent of basic medical science used during clinical problem-solving; for example, Patel, Evans and Groen (1988) conducted a study to investigate the differences between novice and expert physicians' reasoning strategies. In the results, the authors observed that novices reason at a different knowledge level, using familiar basic science components, whereas experts do not rely on causal or pathophysiological and biomedical science knowledge. It was concluded that the use of basic medical sciences decreases with an increase in expertise. In a subsequent study Arocha and Patel noted that students tend to reason in causal terms, whereas experts make use of the clinical components presented almost exclusively, and reason in conditional terms (Arocha & Patel, 1990).

Another measure of expertise in diagnostic reasoning is the directionality of reasoning. In physics problem-solving behaviour, Larkin et al. (1980) demonstrated that the directionality of reasoning observed in experts was data-driven (from data to hypothesis) in routine problem-solving tasks. Research in medical problem-solving (Patel & Groen, 1986) suggests that the direction of reasoning, forward from data to hypothesis, or backward, from hypothesis to data, discriminates strong problem solving strategies from weaker approaches. Patel and Groen (1986, 1991) also demonstrated that there is a fairly strong relationship between diagnostic accuracy and this type of forward reasoning. Subjects who provided inaccurate or incomplete diagnoses used a variety and mixture of both forward and backward reasoning in their explanations of the pathophysiology of the cases presented.

Medical Problem Solving

A number of studies were conducted in the context of the use of knowledge, especially basic science knowledge, in medical problem solving and diagnosis making (Lesgold, 1988; Schmidt et al., 1988; Patel & Groen 1986; Patel, Arocha & Groen, 1990; Patel, Evan and Chawla, 1987; Joseph & Patel, 1990). The research studies regarding the application of biomedical knowledge in medical diagnostic processes were conflicting. Some of the investigators found an extensive use of biomedical knowledge in expert physicians' responses (Lesgold, 1984), whereas others reported a virtual absence of references to biomedical knowledge in expert protocol (e.g. Schmidt, et al., 1988). In another study researchers found that practitioners solving a case in their area of expertise used little or no biomedical knowledge to explain the case, whereas researcher clinicians appeared to use more biomedical knowledge explanations in more detail (Patel, Arocha, Groen, 1988).

Radiology is a para-clinical area in the domain of medicine (domain not pertaining to a clinic or to the bedside; not pertaining to or founded on actual observation and treatment of patients, as distinguished from theoretical or experimental) but highly technical field of medicine, which is complex and very important in terms of its utility in diagnosis and confirmation of diseases. A significant characteristic of this field is its substantial perceptual nature, which is specific to it. Radiology is thus different from other scientific fields such as physics or mathematics. Problem solving in this field requires a combination of knowledge which should be acquired during the training period in the medical school by the problem solver, and the knowledge gained from exposure to radiological procedures during clinical practice. Lesgold et al. (1988) conducted research in the field of radiology to investigate radiological expertise and its acquisition. In this study Lesgold et al. provided x-ray films of patients to their subjects and asked them to provide a diagnosis based on those x-ray films, then collected the subjects' responses as "think aloud" protocol. In the experiment the subjects were given clues which indicated the process/nature of the problem in the x-ray films. These cues were provided to stimulate the schema of the disease showed in the x-ray film. The results of this study showed a nonlinear, U-shaped, relationship between the novice and expert subjects. The authors concluded that radiological problem solving requires a combination of different kinds of knowledge which are separate from each other in their body structure, i.e., basic biomedical sciences such as anatomy and physiology, and the pathogenesis of the diseases. Lesgold et al. also found an extensive use of basic medical sciences during problem solving in the field of radiology.

Patel, Groen and Scott (1988) studied how basic biomedical science is used in clinical reasoning. This study was motivated by the controversy concerning the role of basic sciences in the medical curriculum. A problem underlying this issue is that it is unknown how basic science is used in clinical reasoning. In this study, a total of twenty-four students were selected from first year, second year and final year (eight students were selected from each level of their medical school training); the students were provided with three texts dealing with basic science knowledge relevant to the clinical problem which the subjects were asked to read and recall the text; next the students were asked to read the clinical text (patient problem); finally, the students were asked to provide a diagnosis and an explanation of the underlying pathophysiology. The results of this study showed that when basic science information is given before the clinical problem, this information is used either incorrectly or inconsistently in explaining the clinical problem. The authors concluded that basic science knowledge and clinical science or clinical practical knowledge form two different domains with their own individual structures and therefore clinical information cannot be embedded into the basic science knowledge structure.

Patel, Evans and Kaufman (1990) carried out a study to investigate the role of biomedical knowledge in medical problem-solving strategies. This study was motivated by the facts and results from their previous studies (Patel, Groen & Scott, 1988). This later study, which was specifically designed to investigate the use of biomedical information in the explanation of a clinical problem, was designed on a two-stage model. The students were divided into two groups and the biomedical information was provided to the students in two stages: (a) the first group of students was provided with the clinical problem first, without any prior knowledge of biomedical information about the clinical problems; the basic science information was provided after the clinical case; (b) the second group of students was provided with the biomedical information prior to being presented with the clinical case. The results of this study were discussed in two sections. The first section was referred to as "data driven reasoning", and is characterized by the triggering of inferences from observation in the clinical stimulus text to hypothesis. The second section was designated as "predictive reasoning", and is characterized by the generation of inferences driven by the hypothesis (basic science information). Results of this study showed that, for all students except the final year medical students, the biomedical information interfered with the data driven reasoning process. However, the biomedical information also facilitated the process of predictive reasoning by the students. These results show that biomedical information can be of use if the student already has a schema of a disease (i.e. final year medical student).

This short review has shown that the questions "how" and "how much" basic science knowledge is used in medical problem-solving are still controversial. However, studies in this area of medical problem solving or diagnosis making are currently underway and we expect that some authentic (scientifically verifiable or demonstrable) results will emerge in the future.

Research in Area of Diagnostic Decision Making

The main goal of this review is to establish a relation between the research already done in the domain of medicine, specifically medical problem solving and decision making, and my research in the area of therapeutics and patient management.

We start with the pioneering work done by Elstein, Shulman and Sprafka (1978). Their study was an investigation of medical problem solving and decision making by physicians at different levels of expertise. This study was the first of its kind done from a cognitive perspective, using protocol analysis of real practical physician-patient interaction. The protocols were video taped. Subsequently, retrospective questions were asked of the physicians' activities, about what they were thinking at the time when they were performing the tasks of diagnosis and therapeutics decision making. The results of this study established that the physicians appear to generate hypotheses very early in the process of medical problem solving; however, there were no differences found between experts and novices except in the underlying knowledge.

Gale and Marsden (1983) carried out a similar study based on the work of Elstein, Shulman and Sprafka (1978), by using stimulated recall, asking subjects to verbalize comments after being shown a videotape of their diagnosis and decision-making performance in a real clinical situation (retrospective study). Gale and Marsden (1983) categorized subject performance in three steps: (1) pre-diagnostic interpretation, (2) diagnostic interpretation, and (3) clarifying inquiries about the patient. In this study also, Gale and Marsden (1983) did not find any difference between novices and experts. Based on the results of their study, Gale and Marsden concluded that diagnosticians, whether students or experts, make judgments as soon as patient information is presented. The authors claimed that their results do not agree with pattern matching or pattern recognition processing. Gale and Marsden argued that pattern matching requires the subject to be a passive receptor of patient information, at least until patient data match the "pattern in memory" of the subject.

Elstein et al. in a review (Elstein, Shulman & Sprafka, 1989) of their original work (Elstein, Shulman & Sprafka, 1978), summarized the main findings as follows: "Diagnostic expertise" is distinguished by the development of (1) a useful knowledge base, (2) some rules for accessing and applying the knowledge, and (3) a prototype for classifying instances (Elstein, Shulman & Sprafka, 1989). In their various studies, the authors concluded that there are differences between expert and novice reasoning strategies during problem solving. For example, the experts reason from facts to new inferences which were not present in the problem given them to solve. This type of reasoning used by domain experts during problem-solving activities has been described in many different terms by different researchers, for example, as "forward chain algorithm" (Winston & Horn, 1981), "forward reasoning" (Patel & Groen, 1986); "forward chaining" (Hunt,1989), and "working-forward" (Simon & Simon, 1978).

Although experts in the domain of their expertise use forward reasoning, their performance may also show use of backward reasoning. This mixture of forward and backward reasoning is found whenever experts solve a problem outside the domain of their expertise, in other words, when subjects are solving a problem which falls outside the area of their expertise and they do not have sufficient knowledge about the problem (Patel, Groen, & Arocha, 1990). A question that comes to mind is that, if experts who normally use forward reasoning sometimes use backward reasoning too, then do novices who normally use backward reasoning also use forward reasoning? In certain circumstances novices also use forward reasoning, as experts use backward reasoning. When there is not sufficient information available in the presented case, the expert uses backward reasoning. The utilization of forward problem-solving strategies is found to be related to the knowledge available to the problem solver. If this is true, it may not be possible to use forward reasoning by novices because of their limited knowledge background.

However, a recent study by Patel, Groen, and Norman (1993) has provided evidence that the pattern of reasoning may be linked to instructional methods used to train the subjects. These researchers carried out a study which compared problem-solving strategies used by two groups of subjects who were trained in two different curricula. One group was trained in a problem-based learning (PBL) environment during their medical training, and the second group was trained in a conventional curriculum (CC) environment. In the CC-group the basic medical sciences were taught before the beginning of clinical studies, whereas in the case of the PBL-curriculum the basic medical sciences were taught within the clinical context. The results of the study showed that the students in the PBL-group relied more on backward reasoning, whereas the students in the CC-group relied on forward reasoning, although this CC-group used a mixture of both forward and backward reasoning, and not pure forward reasoning. The main difference lies in the reasoning at different levels, because, as has been found in medicine, expert reasoning in routine situations occurs at the associative level rather than at the causal one, although both types of reasoning are possible (Patel, Groen, & Arocha, 1990).

Kassirer and Kopelman (1990) discussed two examples of a diagnostic search drawn from actual clinical cases. The authors found that the novices became involved in a search for many irrelevant alternatives, whereas the experts were highly systematic and quickly focused on the correct diagnosis. Kassirer and Kopelman showed that the novice's search is based on an unsystematic use of weak methods, while the expert's search for diagnosis is based on strong methods.

Patel and Medley-Mark (1985) investigated the relationship between the representation of textual information and accuracy in medical problem solving. In their study the authors selected thirty three volunteer students at different levels in their medical training and general physicians (internists). The subjects were presented with two real-life cases. These cases were presented to the subjects in two types of textual information; one as a sequential, organized, typical clinico-pathological format, and the other as general information from which the subject would have to make some inference to reach the diagnosis. Results of this study showed that the representation of textual information was very much related to the accuracy of the diagnosis. Another important conclusion drawn from this study was the ability to make inferences. The authors concluded that the ability to make relevant and accurate inferences was directly related to the level of expertise of the subject.

Recently, Joseph and Patel (1990) examined the role of domain-specific knowledge in the process of hypothesis generation during diagnostic reasoning. In this study there were nine volunteer subjects, all of whom were senior physicians associated with the Faculty of Medicine at McGill University. These subjects were provided with an endocrinal clinical case text in sequential segments. These clinical text segments were presented on a microcomputer one after another. After the presentation of each segment of the clinical text, the subjects were divided into two groups, one group consisting of high domain knowledge (HDK) subjects (endocrinologists), and the other of subjects with low domain knowledge (LDK) (physicians practicing in domains other than endocrinology). Results of this study showed that there were no significant differences between the groups in terms of the selection of relevant and critical cues from the case. However, some differences were seen between the HDK and LDK subjects. The HDK subjects used more relations to connect the important information in the given text in comparison to LDK subjects. The HDK subjects generated accurate diagnostic hypotheses early, when shown the case segments. The HDK subjects spent more time in confirming their hypotheses by explaining the given cues in the text, whereas the LDK subjects spent more time in hypothesis generation. Some of the LDK subjects also generated accurate diagnostic hypotheses, but they were unable to discriminate them from other hypotheses, and eliminate the latter.

Arocha, Patel and Patel (1993) studied the nature of inferences and strategies used by medical students during hypotheses generation and evaluation in clinical problem solving. They looked for the directionality of reasoning used to confirm or disprove their hypotheses. In this study, thirteen subjects with four levels of expertise were selected: (1) early novices (1st-year students just entered in medical school), (2) intermediate novices (2nd-year students with little clinical knowledge) (3) advanced novices (4th-year students finishing their medical schooling), and (4) experts (residents in the department of cardiology). Results showed that the students mainly used forward reasoning and confirmation strategies to prove their hypotheses. It was also found that the number of hypotheses generated increased sharply as the knowledge advanced. Advanced novices generated many hypotheses and then narrowed them down to a single coherent diagnostic explanation.

In another study Patel, Groen and Patel (1993) investigated the role of medical expertise in clinical reasoning about a patient's workup. In this study the authors used a complete workup of a patient who was suffering from a complex endocrinal disorder (hypokalemic periodic paralysis) which is a result of a decrease in the potassium (K^+) ions level in blood circulation. This decrease in K^+ ions occurs as a result of an increased influx of K^+ into intracellular space (inside the body cell) from the blood circulation (extracellular space). The authors selected subjects from three levels of expertise. The experts were from the area of endocrinology with several years clinical experience. The other two levels were house staff in the department of endocrinology, and final year medical students. These subjects were presented with the case description written in a typical clinico-pathological format. Thereafter, the subjects were asked to perform a series of tasks from diagnosis making to therapeutic planning. In their results the authors found that these subjects generated a basic schema or hypotheses at the beginning of the case interaction (i.e., history taking). This schema was built through a very complex process intermixed with backward and forward directed reasoning (Patel & Groen, 1986). Furthermore, when a basic schema was formed about a disorder with the help of this interaction, the subjects ordered a few tests or investigation procedures to prove or disprove their schema. The interpretation of the investigative reports is done to confirm the hypothesis made and therefore helps in proving or disproving their basis schema. Another important conclusion regarded the generation and evaluation of the hypothesis generated. The results of the study showed that the house staff generated the maximum number of hypotheses and also ordered the maximum number of tests and investigation procedures. In this study the authors concluded that hypothesis evaluation is a function of expertise, not hypothesis generation. Patel, Groen and Patel (1993) explained that house staff had a vast amount of information about the field and also relevant explanations for their order for tests and investigations, but these house staff were unable to distinguish the tests which were relevant to the particular patient in the experiment. On the other hand, the experts generated few hypotheses and also ordered few tests and investigations. The authors concluded that these expert subjects were able to filter out non-relevant information in the history presented and also to identify relevant tests for the particular patient. Conclusions were drawn that expertise in the area provided a tool to the experts to filter out non-relevant information and time-consuming searches, and enable them to reach the final goal quickly. The irrelevant information and tests in the search process for the hypothesis confused the subjects, and hindered their process towards the goal. In other words, novices are familiar with a number of tests and investigations and their use for diagnostic purposes, but it is difficult for them to identify the relevance of these tests for the patient. Experts, on the other hand, can identify and evaluate the relevance of clues and tests for the patient as a function of their expertise.

These studies were confined to the diagnostic aspect of clinical problem solving. The results were quite varied and contradictory. The generating of hypotheses and concluding of diagnoses by physicians is one part of a total workup in the delivery of health care. Therapeutic planning and patient management are other aspects of clinical medicine which are equally important, once the diagnosis has been made. My research work will investigate the use of biomedical knowledge and directionality of reasoning in the area of therapeutics and patient management in clinical problems and their relationship to expertise.

Research in the Area of Therapeutic Decision Making

The domain of clinical medicine can be divided into two main groups: (a) problem solving or diagnosis making (classifying the clinical state), and (b) decision making in selecting a correct solution for the disease (clinical state) to bring the body to a normal state. Each component requires a considerable amount of knowledge base (Deber & Baumann, 1992). In this study the main emphasis is given to therapeutic selection. Much investigation has been conducted in the area of diagnostic reasoning the cognitive studies in the domain of therapeutics and patient management are very limited (Elstein, et al., 1986, 1992; Moskowitz, Kuipers, & Kassirer, 1988).

Moskowitz, Kuipers, and Kassirer (1988) investigated how people make difficult decisions in situations involving substantial risk and uncertainty. They studied therapeutic and patient-management decision making by physicians in uncertain clinical situations. In their study they presented a medical case to their subjects the text of which was formulated from hospital medical records in a clinico-pathological format. The clinical text described a critically ill patient who was suffering from pre-leukemia. The patient was presented with complications of a fungal infection of the lung (mucomycosis), which primarily affects the patient with a compromised immune defense (weak immune system). After examinations and a further investigation were conducted on the patient, it was found that he was suffering from diffuse bilateral pneumonia (involving both lungs). Further specific investigations confirmed that the patient had a compromised immune defense and his respiratory function was impaired because of pneumonia. This clinical text was presented to three expert respirologists (specialists in lung disease). The task was to make a decision about the therapeutic and management plans for this patient. The case was presented to expert physicians in a combined "thinking aloud" and "cross examination" experiment. Verbatim transcripts were analyzed using "script analysis" to observe the decision-making process and the process of constricting. Results of the study show that physicians during therapeutics and patient-management planning account for some of the heuristic biases. Moskowitz, Kuipers, and Kassirer (1988) found that decisions were not made after gathering all the facts, but were constructed through an incremental process of planning by successive refinements. In the results, the authors found that the physicians, after looking at the patient, decided on a few subgoals about their decision plan and acted according to the condition within their subgoals. This process has the cognitive advantage of allowing a complex problem to be solved with limited problem resources.

Another study in the area of decision making was conducted by Elstein et al. (1992), about therapeutics and patient-management planning. In this study the authors investigated reasoning strategies employed by resident physicians to decide whether to prescribe hormonal replacement therapy (HRT) for menopausal women or not. This was a subject of continuing clinical controversy because of the risks and benefits of the HRT in the menopausal women. These women suffer from "flush" and anxiety symptoms along with a greater risk of osteoporosis which results in the risk of long bone fracturesbecause of lowered estrogen levels after menopause. Although the risk of fracture is reduced by prescribing the HRT, along with the symptomatic relief of the "flush" and anxiety symptoms, the risk of endometrial cancer increases in the patients. In their study Elstein et al. (1992) selected twenty-one residents in three different specialties. They were given twelve brief case descriptions of three levels of cancer-risk and two levels of osteoporosis-risk patients.

In their results the authors found a substantial variation in the decision-making process for prescribing HRT for different cases (.01 to 1.00). The standard cancer-risk (risk as in the general population) and high fracture-risk cases were the only cases in which the majority of subjects would prescribe HRT. However, even in this category it was not a unanimous decision. The variability of decision making for each case was demonstrated by the range. Regardless of the risk level for either cancer risk or risk of the fracture, there was at least one resident who was definite about prescribing HRT, and one who denied the prescibtion of HRT, although both patients were classified as a high risk for both cancer and fracture, and had hysterectomies for an early stage of endometrial cancer. In general it was also observed that the incidence of making a decision not to prescribe HRT increased if the cancer risk increased in comparison to the risk of osteoporosis fracture risk, meaning that the cancer risk was given more priority in comparison to osteoporosis or fracture risk.

Conclusions were made that differences in decision making about therapeutics and patient management with hormonal replacement therapy were not because of recall, because the cases were briefly described and the decisions were made by subjects while the clinical texts were before them. The authors concluded that the differences observed in the subjects' decision making for HRT might be because of differences in their knowledge bases or might be because of differences in their structuring of the problems and weighing of risks and benefits achieved by therapy.

Research Questions

A number of studies were conducted in the domain of clinical medicine about decision making, i.e., therapeutics and patient management. However, some questions remain open to debate, such as the use of knowledge and directionality of reasoning by physicians when they advance through therapeutic decision-making processes of clinical medicine. How do basic medical sciences affect medical learning and the acqusition of medical knowledge? How much are basic medical sciences used during therapeutic decision-making? To what extent is basic science used in the area of therapeutic decision making? Is the directionality of reasoning in the area of therapeutic decision making similar to that in the field of diagnosis making? These are a few of the important questions which are yet to be answered.

CHAPTER 3

METHODOLOGY

Subjects

A total of sixteen subjects were selected for this study. The subjects were at four levels of medical expertise. There were four experts in the domain of respiratory medicine, and four sub-experts working in a division other than respiratory medicine, namely, cardiology. There were four residents in the division of respiratory medicine, and finally, four final year students in their clinical clerkship program.

An expert is an individual with specialized knowledge of a domain. In this research, experts were board certified physicians in the area of respiratory medicine (Patel & Groen, 1991). Four experts were selected from the division of respiratory medicine; three of them were teaching clinicians with experience of approximately 20-30 years and one was a research clinician with experience of about 15 years in the domain of respiratory medicine.

A sub-expert is an individual with generic knowledge of the basic deciplines, e.g. internal medicine, but inadequate specialized knowledge, of the domain. In this research, sub-experts were designated as physicians working in areas other than respiratory medicine, namely cardiology (Patel & Groen, 1991). All sub-experts were board certified cardiologists and teaching physicians in academic hospitals with work experience of about 10-15 years, except one who had recently finished his specialty board in cardiology and joined the team of cardiologists.

Four residents were selected who were in their specialty board training in the department of respiratory medicine. Three of these residents were in the final stage of their training programme and one of the residents was a clinical research fellow.

The final year medical students were novices in relation to residents and expert physicians. They had completed four years of medical training and were a few months away from their licensing examination.

Materials

One routine (asthma) and one non-routine (pulmonary embolism) case were chosen because these disorders belong to a group which can be described at several different levels of hierarchy. For example, the routine case of asthma is a well-studied disease, involving multiple known causal factors which cause problems in the physiology and the anatomy of the lung. Although pulmonary embolism is also a well-described case, it is not very common in the daily practice of physicians. The importance of pulmonary embolism lies in its underlying complexity of disorder because of coronary-system involvement, which needs the prompt attention of physicians. In other words, the descriptions of both cases in the experiments are not vague, confusing or ambiguous; their explanations are mostly clear. Therefore, these cases are suitable for the experiment for testing the hypotheses preassumed: how physicians act during decision-making processes in practical situations without undergoing controversies regarding the classification and diagnosis of the disease. Both cases are important because for their therapeutic planning, a conceptual understanding of the underlying pathophysiology, basic science knowledge of respiratory and cardiovascular disease and system is necessary due to the commonality and complexity of the disorders.

Routine cases in the domain of medicine are clinical problems which physicians encounter regularly in their daily practice, and are also commonly found in the general population. A non-routine problem is one that does not occur in day-to-day practice and may be rare and important from the patient management point of view. Both cases were developed in a typical clinico-pathological format, i.e., history, physical examination, laboratory findings, x-ray and other supportive investigations for proof and justification of the given diagnoses of the cases. These two cases were developed in such a way that their presentation remained classical of their diagnoses, which were also given to the subjects. However, these cases were different in their complexity and in the required approaches for therapeutic planning. The cases presented to the subjects in the study are the following:

Case 1: Asthma

A 53-year-old ex-factory worker was admitted to emergency at one of the Montreal hospitals. Several years previously, he had taken early retirement after a prolonged history of increasing respiratory problems. Today, the patient presents with wheezing following a common cough and cold episode. On observation he looks agitated and cyanosed, with labored respiration.

On examination

CVS: Pulse rate is 120/minute, regular, blood pressure is 160/90 mm. Hg on lying. Pulsus paradoxus is 10 mm. Hg.
Respiratory system shows an increased respiratory rate, 28 per minute, diminished chest movements, on auscultation, diffuse wheezing all over the chest.
No clubbing, no central nervous system localizing signs are noticed.

Laboratory investigation

Arterial blood pH	7.22 (7.35–7.45)
Arterial blood pO_2	42 mm of Hg. (80-100)
Arterial blood pCO_2	67 mm. Hg. (35–45)
Arterial blood HCO_3	20 mmol/liter (24-28)
Blood glucose	5.0 mmol/liter (3.6–6.1)
Plasma urea	3.5 mmol./liter (2.9–8.9)
Plasma sodium	140 mmol./liter (136–145)
Plasma chloride	102 mmol./liter (96–106)
Hemoglobin	188 gm./liter (140–180)

PCV (Packed cell volume)	59% (40--52%)
WBC	15000/cmm. (5--10000)
ECG shows	Tachycardia (increased heart rate), regular
X-ray chest	Mild thoracic hyperinflation
Microscopic finding sputum	A few eosinophils and occasional bacteria
Macroscopic finding sputum	Thick and gelatinous in consistency

Case Representation

This case in the research experiment, as said above, presents the classical case of asthmatic patients who undergo such acute episodes whenever they come in contact with some irritant(s). For the reader's convenience, in the section of appendices a descriptive and graphical reference model of the routine and non-routine cases are provided (See appendix 1 to 5). These graphical representations are based on the information from the clinical text and designed specifically to represent problems described in the experiment. Inferential pathophysiological knowledge triggered by this information presented to the subjects lead to the stage in the experiment at which the therapeutic plans had to be prescribed. The graphical reference model presentation has developed in the form of the causal (CAU) and conditional (COND) networks (Patel & Groen, 1986).

Similarly, another reference model of inferences is included which was made from the information in the clinical stimulus text of underlying clinical problems in the experiment with the use of *Harrison's Principles of Internal Medicine*. This model of inferences represents some possible inferences which could be drawn from the given information in the clinical text. From this reference model of inferences, we can specify the appropriate inference generated by the subjects for each cue in the stimulus text, which can be used as a basis to evaluate the subjects' responses. Next, a detailed explanation of the presentation and its causal relations are provided for a further understanding of the case and its signs and symptomatology. A similar strategy was applied for explaining the non-routine case 2, pulmonary embolism.

Case Explanation

In the case described above, which was given to the subjects as a stimulus text, the history and complaints are typical of an acute episode of asthma. For example, wheezing, breathlessness and cough following a common cough and cold episode, is a typical three (triad) finding defined in the textbook representation for asthma. The introduction of common cough and cold increases the possibility of the most common triggering factor (viral infection) in chronic asthmatic patients. In a chronic patient, as described in the clinical stimulus text ("an early retirement after a prolonged history of increasing respiratory problem"), common viral infection ("following a common cough and cold episode") is a very frequent etiological or causal factor for triggering an acute attack (*Harrison's Principles of Internal Medicine*, 1991).

The discussion of *pulsus paradoxus*, tachycardia and increased systolic pressure in the clinical stimulus text, along with agitation, cyanosis, labored respiration and acidic pH, represent an acute exhercerbation or an acute attack of asthma on a long-standing disease. *Pulsus paradoxus* is an accentuation of the decrease in systolic arterial pressure accompanying the reduced amplitude of the arterial pulse which normally occurs during inspiration or inhalation of air. In a patient with respiratory tract (air ways) obstruction, the decrease in systolic arterial pressure frequently increases more than 10 mm Hg and peripheral pulse cannot be felt during inspiration. This is a critical sign in the patient's data which should be attended carefully. The acidic pH ("arterial blood pH 7.22") results from chronic retention of carbon-dioxide, CO_2 ("arterial blood pCO_2 67 mm of Hg."); this leads to increased production of carbonic acid, H_2CO_3, and a decrease in bicarbonate ions, HCO_3 ("arterial blood HCO_3 20 mmol/liter"). The combination of a decreased level of oxygen in the blood ("arterial blood pO_2 42 mm of Hg.") and increased carbon dioxide ("arterial blood pCO_2 67 mm. Hg.") adds to the seriousness of the disorder. The finding mentioned in the clinical text about the pulsus paradoxus is a critical signal of the dangerous condition of the patient, especially when it is associated with other findings, like laboured breathing, low oxygen, a high carbon-dioxide level and acidic arterial blood pH. This condition should be carefully attended to; otherwise it could lead to a life-threatening situation for the patient. However, these findings are not quite specific enough for diagnostic purposes, but are important for assessing the condition of the patient as well as for decision making about patient management and therapeutic planning.

The increase in packed cell volume ("Packed cell volume, PCV 59%") and increased amount of hemoglobin ("Hemoglobin 188 gm./liter") indicate a chronic respiratory problem (already described in the clinical text). Thick gelatinous sputum findings are also characteristic of asthma; because of an increase in respiratory efforts and labored respiration there is increased loss of water from the body through respiration (insensible respiratory loss of water) which results in increased consistency of respiratory tract secretions. On examination, the diffuse wheezing is also a characteristic finding in cases of asthma; this is a result of the passing of air through respiratory tracts narrowed because of the constriction of sensitive respiratory tract smooth muscles.

A number of atypical findings, such as increased hemoglobin ("Hemoglobin 188 gm./liter"), packed cell volume (PCV; 59%), and the history of a factory worker may possibily suggest an occupational origin of asthma which remained uncontrolled for a long time, but this history and these findings are insignificant for the presented condition of the patient. This information does not affect any significant changes in reasoning strategies regarding the present therapeutic plan; however, these findings can be of significance for followups and long-term management. The clinical symptomatology and information in the stimulus text are highly suggestive of a typical acute attack of asthma on a long-standing disorder. The x-ray finding of mild hyperinflation is not specific enough, and does not contribute much from the diagnostic point of view. The x-ray chest investigation is important in chronic asthmatic patients to rule out any possibility of oncoming complications, such as pneumothorax (a puncture of the lung leading to air between the lung and the lung covering, the pleura, and causing pressure over lungs). Hyperinflation indicates the trapping of air caused by chronic respiratory tract constriction. This trapped air appears as a darker area on an x-ray film of the lungs. This hyperinflated lung also contributes to a worsening of the respiratory problem because of a loss of elasticity of the lungs due to prolonged over-stretching. The loss in lung elasticity hinders the bringing in of fresh air (inspiration) and the exhaling of carbon dioxide from the body (expiration). This restriction in the air exchange mechanism finally leads to hypoxia (decreased level of oxygen in the blood) and breathlessness (labored respiration).

In summary the pathophysiological explanation for the presented routine case in the research is as follows: following a common cough and cold episode (a viral infection), the sensitive and hyperactive respiratory tract smooth muscle of a chronic asthmatic patient gets triggered; this leads to bronchospasm due to the constriction of the smooth muscle of the bronchial tree, and results in an increased resistance to air flow. This forceful air flow (inspiration and expiration) through narrowed air passages causes a high speed flow through the narrow bronchial tree causing resonance of bronchial walls, which results in an acute episode of wheezing, cough and breathlessness.

Case 2: Pulmonary Embolism

A healthy young man aged 35 years was admitted to one of the Montreal hospitals after a serious car accident on the highway. The patient had come to the hospital with a fractured femur-shaft. Two weeks later the patient suddenly developed breathlessness and a cough. He looked very agitated, complaining of severe chest pain.

On examination

Patient has mild fever with a temperature of 38 C.

CVS. pulse-rate 120/min. regular, blood pressure is 80/60 mm. of Hg.

Respiratory system examination reveals that he has an increased respiratory rate of 28/min. and diminished chest movements.

No clubbing, no central nervous system localizing signs were noticed.

Laboratory investigations

Arterial blood pH	pH 7.50 (7.35--7.45)
Blood pO_2	60mm.of Hg. (80--100)
Blood pCO_2	30mm. of Hg. (35--45)
Blood HCO_3	25mmol./liter (24-28)
Blood glucose	5.0mmol./liter(3.6-6.1)
Plasma sodium	135mmo/liter(136-145)
Plasma chloride	102mmol/liter(96-106)
Blood urea	3.5mmol/liter (2.9-8.9)
Hemoglobin	140gms/liter.(140-180)
PCV (Packed cell volume)	30% (40--52)
WBC count	6000/cmm. (5--10)
Total Thyroxine(By RIA, T_4)	75microg/liter(50-120)
Prothrombin time	3.0sec.(less than 2 sec)
Partial Thromboplastin Time (PTT)	30.0 sec.(25--37)
Albumin	30 gm/liter (35--50)

No abdominal mass detected on abdominal examination except a mild pain in epigastric region.

ECG. was done immediately and was found to be normal except for a tachycardia of 126 beats/mt.

X-ray chest: shows some abnormal findings, an area of consolidation (high density region), in the peripheral area of the lung.

Pulmonary-angiogram shows an abrupt "cutoff" of a vessel at a point farther away from periphery and a "negative shadow" (filling defect: Radiopaque material flows around embolus).

Case Explanation

The second case in the experiment is a non-routine case which is not common in the general population nor encountered by physicians in their every day practice, i.e. pulmonary embolism. In this case, the information, such as the history of an accident, and the episode of a sudden onset of chest pain after two weeks of hospitalization for an orthopedic management, triggers the possibility of a classical case of pulmonary embolism, which is confirmed by an angiogram report (the pulmonary angiogram shows an abrupt "cutoff" of a vessel at a point farther away from the periphery, and a "negative shadow"). The presence of hypotention ("blood pressure 80/60") indicates the seriousness of the disease and calls for immediate medical attention. Low blood pressure in the case of pulmonary embolism in a normal healthy young man indicates severe blood circulatory disturbances (hemodynamic compromise). The occurence of such a condition of low blood pressure (hypotensive crisis) in the patient shows the presence of a large embolus occluding a large central vessel of the heart, like the main branches of the pulmonary artery or vein, which is evident in the pulmonary angiography report ("negative shadow" filling defect: radiopaque material flows around the embolus").

Furthermore, upon examining the laboratory investigations in the clinical text, the subjects found the high blood pH, alkalotic ("Arterial blood pH 7.50"), and the decreased levels of partial pressure of carbon-dioxide ("Arterial blood pCO_2 30 mm. of Hg.") and oxygen ("Arterial blood pO_2 60 mm. of Hg.") in arterial blood to be an important indication of the recent onset (acute episode) of the disease. The other findings in the laboratory investigation are based on a routine work-up of the patient and are not specific enough to support the diagnosis.

The pulmonary angiogram, which is the "gold standard" investigation in diagnosing pulmonary embolism, was done and showed the presence of a large embolus with a filling defect, which indicates a large embolus impacted in a large pulmonary vessel.

Another finding, not significant though interesting regarding patient management, is epigastric pain. The interpretations of this particular finding could ignite a controversial question regarding the physician's thinking about dyspepsia, or ulcers in the stomach, or any consequences of abdominal injuries suffered during the car accident. This information diverts the physician's attention towards the above-mentioned possibilities, which could restrict the physician's decision-making action for prescribing any anticoagulation or thrombolytic therapy, because any anticoagulants or thrombolytic agents are contraindicated in patients with peptic ulcer, or abdominal injuries. These agents could aggravate the complication because they increase the risk of bleeding.

Other possible explanations for this pain are (a) referred pain from the infarct area in the lung ("chest x-ray: shows some abnormal findings, an area of consolidation [high density region], in the peripheral area of the lung") causing irritation of the diaphragm, or (b) the back flow of blood from the heart to the liver; this could arise from the large embolus preventing the further blood flow from the right side of the heart, as a result blood flows backward through the superior vena cava towards the inferior vena cava and ultimately to the liver. This back flow leads to an accumulation of blood in the liver and results in stretching and inflammation of the liver capsule, which may cause epigastric pain. These findings make this case interesting, and trigger different reasoning strategies for the management of the disorder. The other findings, like temperature, central nervous and respiratory system examination, and electro cardiography (ECG) are routine work-up.

The pathophysiological explanation for the non-routine case, pulmonary embolism, is as follows: the car accident caused a fractured femur shaft; consequently, the patient was under restricted movement as a result of fracture management, this, in turn, lead to immobilization of the leg as well as the non-ambulation of the patient. There is a well-described concept called the "Virchow's triad" which states that clot formation is driven by three main risk factors: (1) stasis in blood circulation, (2) an injury to blood vessel endothelium, and (3) a hypercoaguable state of body physiology. This concept allows physicians to generate inferences which could relate the patient's condition to its underlying causes, as in this concept of stasis, in terms of the immobilization of the leg (immobilization is an inference made as a part of fracture management). Another risk factor explained by the Virchow's triad, i.e., an injury to the blood vessel, was generated in terms of local injury to the blood vessels because of a fractured femur shaft. These factors ultimately predispose the subject to clot formation at the fracture site as well as in the deep veins of the leg (deep vein thrombosis, DVT), which is the most common cause (95%) of pulmonary embolism (*Harrison's Principles of Internal Medicine, 1991*). Immobilization leads to the possibility of deep vein thrombosis in the legs (stasis and trauma), and this strongly supports the diagnosis of pulmonary embolism, which is later confirmed by a pulmonary angiogram report. Increased pulse rate (tachycardia) is a common finding in pulmonary embolism; it is not specific and does not contribute much for the diagnosis. Hypotention suggestive of a central impact of the embolus indicates the seriousness of the patient's condition, and this is supported by the finding of epigastric pain and the pulmonary angiography report. Epigastric pain is due to the back blood pressure to the liver, causing inflammation of the liver capsule. Higher blood pH (7.5), low pCO_2 (30 mm. of Hg.) and pO2 (60 mm. of Hg.) result from the excessive wash out of carbon-dioxide as a consequence of hyperventilation (high respiratory rate, 28/minute); these are indicative of an acute onset of the disease.

Procedure

Two respiratory cases were designed in consultation with a specialist physician in the respiratory domain. The clinical cases were presented to the subjects in a typical clinico-pathological format, including history, physical examination, laboratory findings and investigation reports. Subjects were tested individually in their offices. The subjects were given two different cases and the following instructions. The diagnosis was provided for each of the cases.

The instructions are given below:

Instructions

This package contains two clinical cases in Respiratory medicine:

A) Asthma
B) Pulmonary Embolism

For Case A

(1) Read the clinical case.
(2) Provide the therapeutic and patient-management plan, with reasons supporting your choices
(3) Explain the underlying pathophysiology of the clinical problem, giving as much detail as possible.

Repeat 1 to 3 for Case B. Please think aloud at all times, and your responses will be audiotaped.

The two cases were given to subjects one after the other, first the routine case and then the non-routine case. The entire session was audio-taped and transcribed for analysis.

Methods of Analysis

Framework for Analysis

The method of analysis of verbal protocols was based on Patel and Groen (1986) and Hassebrock and Prietula (1992). The protocols were segmented into small phrases or segments.

All verbal responses were tape-recorded with an audio tape. The verbal protocols from all subjects were transcribed as such. The transcripts were divided into small and manageable segments. such as phrases or units. The emphasis was placed on keeping one thought contained within in one segment or unit. These segments or units were further coded in different groups according to the content of thought and types of knowledge used by the subjects in their response. The segments were coded for the use of three types of knowledge: (1) basic medical science (BB), (2) pathology, and pathophysiological knowledge (PP), and (3) clinical science knowledge (CC). This specific coding scheme for the analysis of the physicians' protocol is predicated upon a series of definitions which identify the types of knowledge used by subjects when they were providing therapy for patient management.

The coding scheme in this study is based on a series of definitions related to the domain of clinical medicine. These definitions will contribute to the understanding of the nature of the content of thought in the subjects' responses during the experimental task.

Definitions

Symptoms are the organic or psychological manifestations of disease of which the patient is usually aware and frequently complains. Symptoms can be divided into two main groups: (1) cardinal symptoms, such as temperature, pulse, respiration, and (2) subjective symptoms, which are perceptive only to the person or patient suffering, such as pain, pruritis (itching), headache and vertigo. Symptoms are produced due to a non-equilibrium state or an imbalance or disorder in the functioning of the system.

System is a set or series of interconnected, interdependent parts (body organs, tissues) which function together with a common purpose, and produce results which would be impossible to achieve by their (the parts) operating separately. For example, the respiratory system consists of tubular and cavernous organs that allow atmospheric air to reach the membranes, across which gases are exchanged with the blood or circulatory system. This includes the bronchial tree, the lobes of the lungs, the alveoli and capillaries. The circulatory system is the collection of channels through which the nutrient fluid of the body flows (commonly the blood circulatory system, the heart and blood vessels).

Basic medical sciences are that part of medical domain knowledge dealing with the principles of anatomy, physiology and biochemistry. *Anatomy* is the science which deals with the structure of living organisms and their parts, including internal (histology) and external (morphology). *Physiology* is the science which deals with the functioning of living organisms, for example, respiratory, circulatory, digestive, endocrinal physiology. *Biochemistry* studies the chemical processes in living organisms related to the vital processes, for example, chemistry, dealing with the respiratory process, the digestive process, and protein synthesis.

Physiopathology is the science dealing with the functioning of the body in a clinically disordered state (diseased state). *Pathophysiology* studies the etiology or causes for imbalance in the body system functioning. *Pathology* is the branch of medicine which deals with the structural and functional (pathophysiology) changes in the system (body, organs, tissue).

If anything goes wrong in the normal physiology of the body system, the body enters an imbalanced or *clinical state*. This pathophysiological knowledge is specifically used to explain the cause of disease and to stimulate clinical knowledge to search for therapeutic solutions to treat the underlying cause. This knowledge becomes oprative when a physician comes in contact with a patient or a patient's information, which contributes to explaining the causal relationship between the presented conditions (sign, symptom or laboratory data) and the underlying etiology or cause. This pathophysiological knowledge also makes possible a deeper understanding of the disease, rather than a superficial knowledge of the disease in syndromic-form or as a cluster of signs and symptoms.

Clinical Medicine deals with the study of the disease at the bedside through demonstrations of certain clinical states in the living patient suffering with some systemic disorder caused by an imbalance in the normal physiological functioning of some particular or multiple systems, along with the therapeutic solution to remove the cause of the clinical state. The *clinical state* is the state of the body produced by an imbalance in the normal body physiology and anatomy, represented in the form of clinical signs and symptoms which result from abnormalities in the body system. The clinical state can be presented in two ways: (1) with physical findings which can be seen, such as cyanosis, swollen neck veins, agitation, anemia findings etc. and (2) subjective findings, which are felt by the person suffering from the disease, but cannot be observed by a physician, such as pain (chest, heart, abdominal and so on), itching, numbness and tingling, headache, and vertigo (a feeling of rotation in the head). Signs and symptoms depend upon the abnormality of the system involved and its interrelation with other body organs or systems. For example, "Intestinal obstruction" is principally a disorder of the gastrointestinal tract (GIT-system) exhibited by the distention of the abdomen, which causes pressure on the diaphragm and involves the respiratory system. As a result, the patient with an intestinal obstruction also cause and presents signs and symptoms of the respiratory system, such as breathlessness and cough. *Investigations* are the procedures designed to demonstrate the existence or non-existence of certain condition(s) in the particular state of the system and also to prove or disprove the cause(s) for the disturbance or disorder for the particular condition of the system or body (the clinical state), and to provide assistance in the therapeutic and management plan for that clinical problem.

The task of decision making regarding the therapeutic planning for the disease in question involves a process of interpretation of the information about the patient's condition, i.e., history, physical examination, laboratory and specific investigative reports. This information helps physicians to understand the underlying causal mechanisms for the presented clinical state of the patient. Based on an understanding of the pathogenesis of the clinical condition of the patient, physicians prescribe their therapeutic plans to eliminate the causal/etiological factors of the disease (clinical state) and to return the patient to the normal state.

Codes for Knowledge Types

The subjects' response protocols were coded under the following categories:

Basic medical sciences propositions (BB): propositions that describe the normal structure of the system, anatomy, physiology, functions of the system, and the normal principles of physics, chemistry, and biochemistry.

Pathophysiological propositions (PP): include propositions which describe the causes of disturbances in the normal anatomy and functioning of the system. These causes may be physical, chemical, emotional or psychological, biological (viral, bacterial, fungal etc.), abnormal anatomy, physiology of the system and biochemistry of the body system.

Clinical science propositions (CC): propositions based on knowledge of clinical science, which describes the clinical state of the patient. These include:

(1) The disorder of the system(s) represented by or appearing in physical or subjective signs and symptoms.

(2) Pharmacological agents used to normalize the abnormal body systems, for example, medicine, or drugs used by the physician.

(3) Principles or concepts used in describing the relationship between the patient's symptomatology and the etiological factors causing the presented condition of the patient.

(4) Tests or investigations used to prove or disprove the causes for the disturbances in the system, i.e., physical examination, laboratory test, ECG., radiological test and so on.

(5) All differential diagnoses used to clarify the disturbances of the system.

Directionality of Reasoning

Therapeutic reasoning is reasoning about the plan of action for the treatment of the patient. The initial action or therapeutic plan is based on the working hypothesis (in the experiment the working hypothesis is the given diagnosis of the routine and non-routine case). A hypothetical therapeutic plan which is provided to the patient in order to achieve a certain stabilized stage in the patient's condition against the given diagnosis (data) is a product of inferences concluded from causal or pathophysiological knowledge about the given diagnosis and its relationships with the presented symptomatology, i.e., a backward reasoning strategy (Patel & Groen, 1986). In the later stages, the management plan can be modified depending on the effects of the initial therapy, which could have either beneficial or adverse effects on the patient. The modifications in the therapeutic plan are a function of further testing, specific investigations and evaluating the current presented clinical state of the patient for proving or rejecting the initial working hypothesis and measuring the effect of initial therapies. In other words, as a working hypothesis is available to a physician for the patient at hand, he or she develops a plan about the management of the patient (Ramoni, et al., 1990) based on the proposed working hypothesis. Explicitly, when a working diagnosis or an acceptable hypothesis is achieved from the patient's data, the physician develops an initial therapeutic plan against the available hypothesis(es) which he or she learned from textbooks or by experience with the specific problems of the domain. Thereafter, in the post-initial therapy stage, a process of monitoring begins. The process of monitoring observes and controls the course of the patient's condition (Ramoni, et al., 1990). The process of monitoring is also a part of the patient's management plan, assigned to verify the outcome of the therapeutic plan, and to assess the extent to which this particular initial treatment plan is achieving its goal or not. The process of monitoring the condition of the patient continues until the patient returns to normal health, which is the goal of the treatment plan.

To achieve the therapeutic goal, physicians draw inferences from their existing prior causal knowledge about the disease to execute the patient-management and therapeutic plan (backward-directed inferences). The execution of therapeutics and patient management begins as a result of inferences drawn by using strong forward-reasoning strategies (Patel and Groen, 1986), using the patient's information during the stage of clinical problem solving or making the diagnosis. These therapeutic inferences are drawn from knowledge which could relate the clinical state with the underlying cause of the presented condition, i.e., pathophysiological or causal knowledge, hence, backward-directed therapeutic inferences. This special kind of reasoning used by physicians to draw therapeutic inferences during patient management is causally driven, which allows physicians to arrive at the correct solution for the cause of the present condition of the patient. This kind of reasoning is related to "backward Chaining" types of deduction (Waterman & Hays-Roth, 1978).

The effectiveness of the procedure-oriented patient-management skilled performances depends upon the physician's pathophysiological understanding of the presented problem and the quality of inferences drawn from the pathophysiological knowledge-base for the given information about the presented patient (the patient's clinical state). The selection of the therapeutic procedures and agents depend upon the working hypothesis or diagnosis in hand, but the selection of correct and accurate therapeutic inferences depends upon well-organized causal knowledge, a deeper understanding of causal relationships with the clinical state of the patient, and the correct representation of the clinical problem in relation to presented information. This organized causal knowledge enables a physician to draw correct, balanced and accurate therapeutic inferences for the proper management of the presented case. This inferential quality and understanding of the clinical problem is a function of expertise in the domain.

Coding

In an attempt to identify the directionality of reasoning during decision making about patient management and therapy by the subjects, this research uses a paradigm called "therapeutic inferences". These therapeutic inferences drawn by the subjects in the experimental task were coded as either forward or backward inferences based on their direction towards consequent or antecedent points (Patel & Groen, 1986). The consequent point was coded as the "goal" and the antecedent(s) as the data provided in the clinical stimulus text. In the present study the consequent was to provide therapy for the presented clinical cases in the experiment. In summary, a therapeutic plan is a consequent (a hypothesis about possible management), and the patient's information or data (stimulus text or inferences made from stimulus text) is an antecedent.

As a result of these considerations, two kinds of behaviour in subjects' responses, as reflected in the protocols, were observed: one was that subjects start with their therapeutic plans about the disease and explain or justify the plans they have provided and how this therapy will help the presented patient's condition. This kind of response is termed backward inference (Patel & Groen, 1986). In other words, backward inference corresponds to an orientation or direction of arrow or flow from the therapeutic plan (consequent) to the information in the clinical stimulus text (antecedent). The second was that subjects select the information from the clinical text and, using this information, provide a therapeutic plan. This was termed forward inference (Patel & Groen, 1986). In other words, forward inference corresponds to an orientation or direction of arrow or flow from information in the stimulus text (antecedent) to a therapeutic plan (consequent).

Research Hypotheses

The present study investigates novices' and experts' reasoning about the planning of patient management and therapy for the two clinical cases presented. This study is based on the tradition of research on experts and novices in academic domains, and focuses specifically on the reasoning processes used by physicians during their therapeutic decision-making activity for the patient, rather than other cognitive studies in the domain of medicine for problem solving or diagnostic reasoning.

A number of questions can be added to previous research regarding the possible outcome of this research. The following hypotheses can be generated with regard to the patient-management and therapeutic planning aspects of investigation.

(1) Basic science knowledge will be used minimally during patient management and therapeutic planning.

Rationale: because the main therapeutic decision-making framework is based on clinical and causal knowledge and basic sciences are used as reference knowledge only.

(2). To develop a patient-management and therapeutic plan, clinical science and pathophysiological knowledge will play a major role, in contrast to biomedical science.

Rationale: because during decision making, the physician's main emphasis remains solely upon the search for the underlying cause of the disorder, and the goal of returning the imbalanced body state (clinical state) to a normal state, meaning that the selection of therapeutic planning would be from causal knowledge towards the therapeutic goal (use of causal knowledge-base).

(3). The use of basic science knowledge will be used to interpret the breach between the normal and abnormal condition of human physiology. This knowledge will not play a major role in developing the therapeutic plan.

Rationale: biomedical sciences are used as reference knowledge; this knowlege rarely used in diagnostic reasoning where the main framework is based on the presented condition of the patient, or treatment is mainly based on the clinical and causal factors causing the imbalance in the system. The basic medical sciences are used to compare the after effects of the therapies prescribed to the patient with the clinical state of the patient.

(4). The use of basic science knowledge will depend upon the subject's causal-knowledge base of the disease, which will be used for the interpretation of the results of their therapeutic plan.

Rationale: the use of basic science knowledge depends upon the subjects' understanding of the differences between the normal and abnormal states of the body. This understanding of the differentiation between the normal and abnormal states of clinical problems is achieved as a function of expertise.

(5). The use of pathophysiological knowledge will be maximised by the novices in comparision to experts.

Rationale: novices will try to explore all the causal possibilities for the clinical condition of the patient, whether they are relevant for the patient's condition or not, and explain them as much as possible, whereas experts will select only relevant possibilities and elaborate them in detail (Patel, Groen & Patel, 1993).

(6). Experts will be more elaborative in their plans in comparison to novices. Their therapeutic plans will include the explanation of deeper levels of justification. Novices, on the other hand, will plan their therapeutics at a superficial level (based on the signs and symptoms of the patient, rather than on a pathophysiological understanding).

Rationale: extensive experience in the domain and numerous encounters with a range of clinical cases from the typical to atypical enable experts to gather a wide knowledge and deeper understanding of the disease, which allows them to see the patient in a different light than a novice will. This deeper understanding of the disease provides them with an ability to search for the causal origins of the disease rather than superficial knowledge of symptomatic (syndromic) relationships.

(7). As expertise increases, the therapeutic plans will reflect more pathophysiological information (hypothesis-driven). Conversely, the novice's plan will be geared more towards the clinical or symptomatic format (data-driven).

Rationale: extensive experience and deeper understanding of the disease enable experts to search for the pathophysiological or etiological origins of the disease rather than superficial knowledge of symptomatic (syndromic) relationships.

(8). All subjects will use forward directed reasoning during therapeutic planning (once the diagnosis is given), the directionality of reasoning for patient-management decisions.

Rationale: to use the given information for solving a clinical problem and finding the correct solution, the subject must have a schema of the disease (Patel, Evan & Kaufman,1990). In this research all selected subjects had a schema of the disease because all were aware of the given problems and their management. Therefore, almost all subjects would reason in the forward direction, i.e., from given diagnosis to therapy.

(9). During decision making about patient-management, expert physicians will reason more on causal terms (backward-directed inferences) in contrast to novice students who will reason on clinical terms (forward-directed inferences).

Rationale: to prescribe a therapeutic plan physicians should know the relationships between clinical symptomatology in the presented patient and the underlying pathophysiology and normal basic physiology.

CHAPTER 4

RESULTS & DISCUSSION

Outline

In the interest of clarity the results of the experiment are presented together with a discussion. The results are presented in three main sections, the use of knowledge, the directionality of reasoning, and explanatory response. Each section will answer specific questions stated in the hypothesis section above.

The first section on the use of knowledge presents the general results for each group. This section summarizes the results in a descriptive manner, focusing on numerical information, then a comparison of novices and experts protocol followed by discussion centers on quantitative and qualitative values.

The second section on the reasoning process provides an account of individual protocol which offers a descriptive picture of the subject's decision-making and reasoning processes. In this section the main focus falls upon the ongoing process of decision-making with special attention paid to an understanding of the cases and directionality of reasoning and justification given by the subjects during planning of therapeutics and patient-management. The term "directionality of inferences" is used in keeping with the practice of the relevant literature (Patel & Groen, 1986) in both the research on scientific reasoning and on diagnostic reasoning in medicine.

The section on directionality is followed by a section offering an analysis of explanatory responses given by the subjects to a question regarding the pathophysiology of the cases in the experiment. The main focus in this section is upon the use of information from the clinical stimulus text and the responses given for the patient-management planning during the subject's explanations of the pathophysiology of the cases.

Section 1
Use of Knowledge

The first section on the use of knowledge presents the general results for each groups of subjects. This is followed by a qualitative analyses of protocols generated by the subjects.

The protocols were analyzed for the numbers and type of propositions. The raw data was subjected to statistical analysis to compare the the levels of expertise to different kinds of knowledge propositions generated. One-way ANOVA for individual knowledge propositions and found that the p-values ranged from .082 to .727 between the groups. This prompted the conclusion that the groups are not significantly different with respect to generating any kinds of knowledge propositions investigated. As the assumptions underlying this analysis are bound to influence the decisions, we wanted to test these. As the normality assumption is not easy to test with as small as four observations (sample groups), we opted to test the assumption of homogeneity of variances. In this case we used Bartlett's test, which produced a chi-square value of 6.1025 with a degree of freedom of three to be compared with a five percentage (5%) critical chi-square value of .352. Thus the homogeneity of variances was rejected, making the ANOVA procedure suspect (non-warranted, not-useful). In such cases non-parametric procedures are used to bring out any possible differences, if present. Therefore, the Kruskal-Wallis test was carried out on individual questions. This test, which is based on the ranks of observation, also produced high p-values similar to those obtained from the ANOVA method, namely .472; the ranks obtained for the resident group was ranked lowest (6.0) and the sub-expert group was ranked highest (10.6), whereas novice and expert groups were ranked between residents and sub-experts, 7.6 and 10.0 respectively. The overall ranking appeared as 8.5, which also indicated that there are no wide differences between the groups. Since there were no differences found on individual questions, MANOVA was not warranted.

Even though the statistical techniques did not detect differences between the different groups of expertise, they are not fully conclusive. The basic reasons are the small sample sizes of the study, non-random nature of the study groups, and the large variation among the subjects.

At the next level, the data was analyzed for the total number and mean percentage of propositions of different types of knowledge (basic science, pathophysiological, and clinical) used by the various groups of subjects. Raw numbers of propositions are difficult to interpret because there were large differences in the time taken and the length of the protocols generated by the subjects in completing the tasks.

Table 1 gives mean percentage number of basic science and pathophysiological knowledge propositions generated by subjects at different levels of expertise for routine and non-routine case. The variance within subjects and between groups was found to be very high, thus making the use of statistical generalizability invalid.

TABLE 1

Mean Percentage of Basic Science and Pathophysiological Knowledge Propositions Generated by Subjects at Different Levels of Experience by Case Type

Basic Science Propositions

Case	Students	Residents	Sub-experts	Experts
Routine	6.8 ±4.0	5.3 ±4.8	16.8 ±13.2	10.8 ±6.5
Non-routine	6.3 ±6.6	5.3 ±4.4	10 ±5.1	7.8 ±4.4

Overall mean and standard deviation between all individuals for routine and non-routine case was found to be 10±9.7 and 7.3±5.0, respectively.

Pathophysiological Propositions

Case	Students	Residents	Sub-experts	Experts
Routine	19.3 ±14.1	5.0 ±4.1	17.3 ±9.9	20.3 ±10.2
Non-routine	15.8 ±11.5	1.3 ±1.6	5.8 ±5.1	8.5 ±6.6

Overall mean and standard deviation between all individuals for routine and non-routine case was found to be 15.4±10.4 and 7.8±7.9, respectively.

Values are expressed in mean standard deviation (±).

Figures 1 and 2 give the mean percentage of the use of the three types of knowledge propositions by the student, resident, sub-expert, and expert groups in the routine and non-routine case management plans respectively.

The darkest column represents the mean percentage of responses for the use of basic science propositions. The figures show both the differences between the mean percentage of given propositions (BB or PP or CC) generated by different groups of subjects and differences between the use of the three kinds of propositions(BB, PP, and CC) within an single group. The figures indicate that the mean percentage of basic science (BB) propositions were generated in the smallest quantities in comparison to the other two kinds of knowledge propositions, i.e., pathophysiological (PP) and clinical (CC), during therapeutic planning, regardless of the level of expertise and case differences.

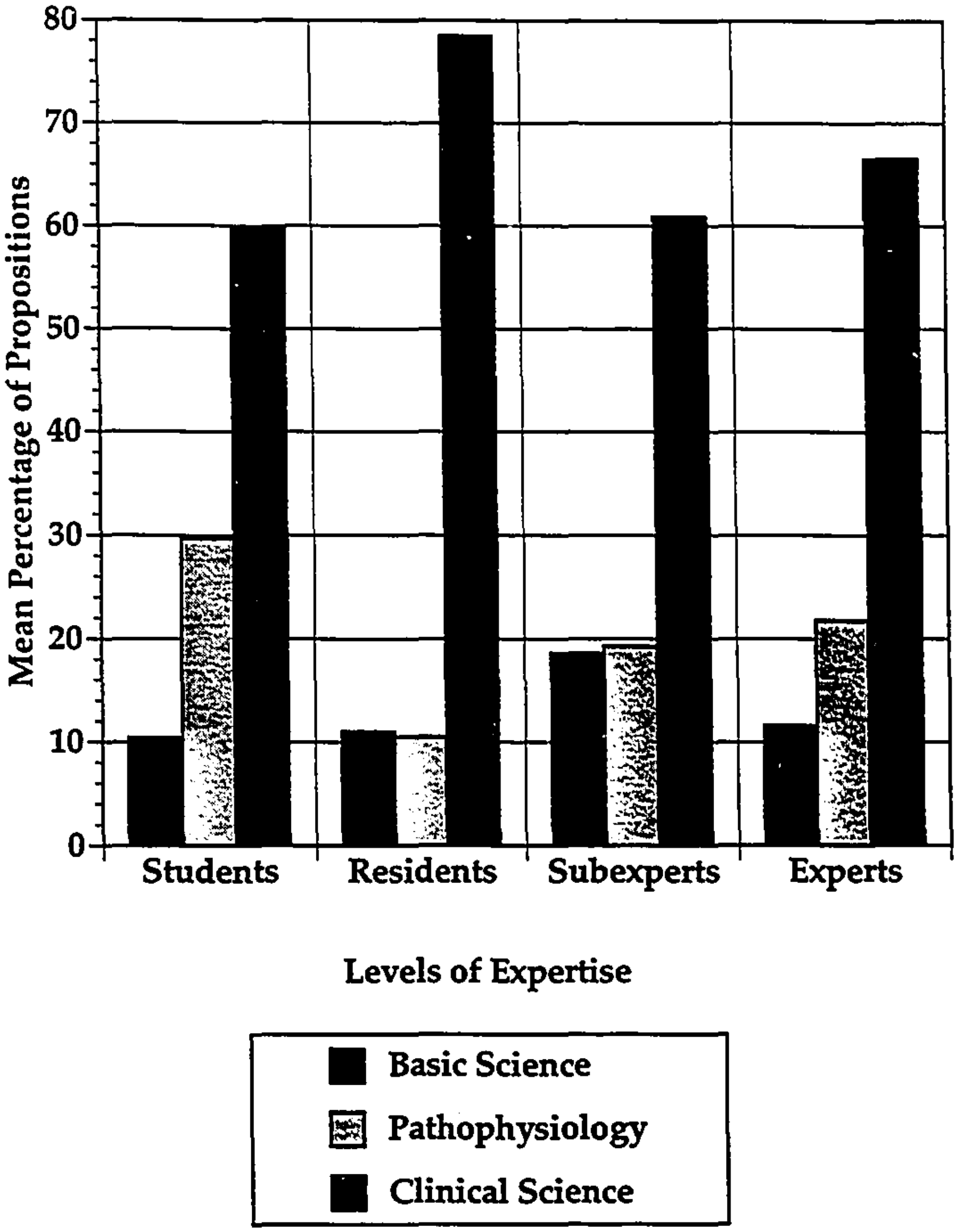

Figure 1
Mean percentage of propositions of basic science, pathophysiological and clinical science knowledge in therapeutic planning protocols for routine case of Asthma by subjects with different levels of expertise

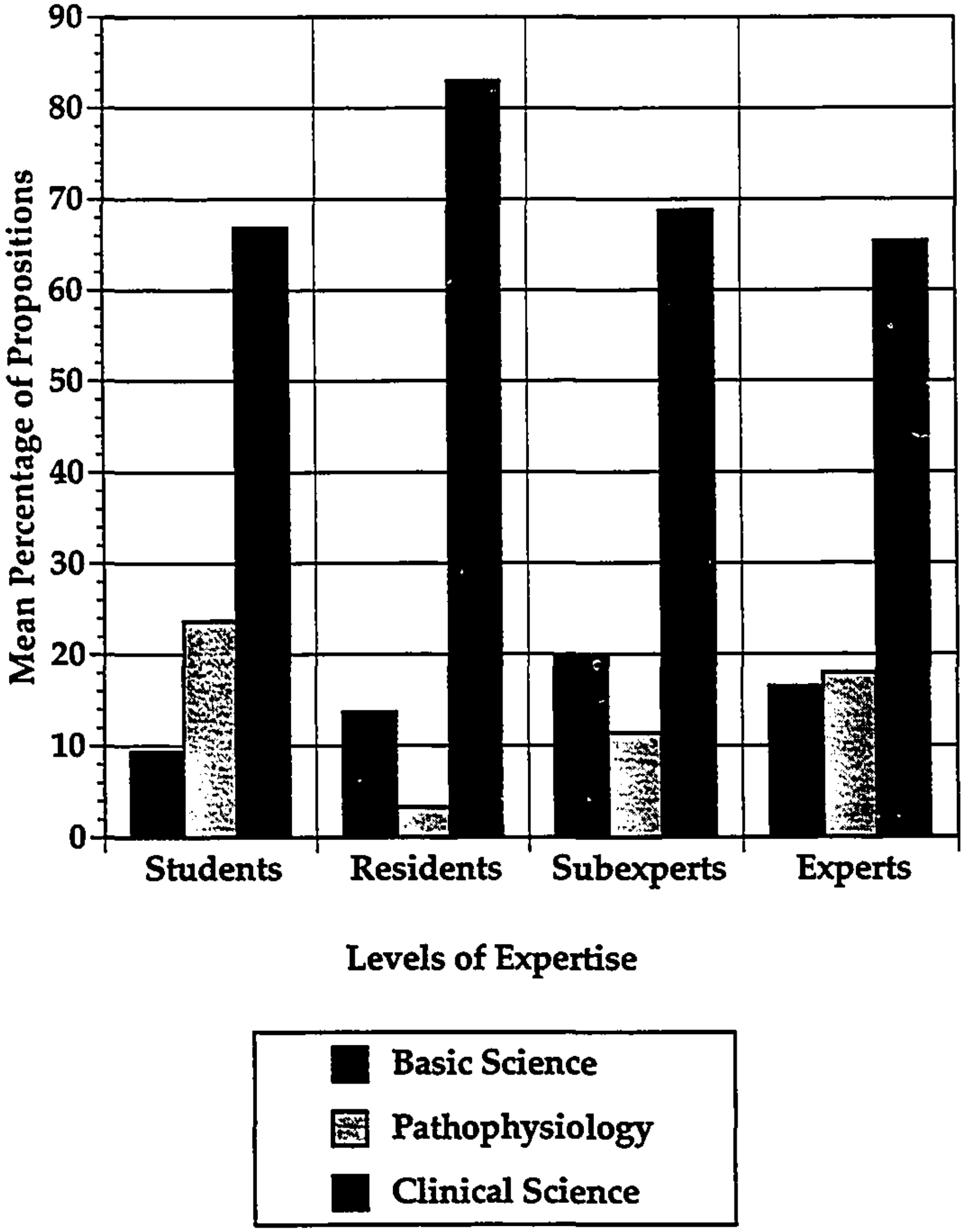

Figure 2
Mean percentage of propositions of basic science, pathophysiological and clinical science knowledge in therapeutic planning protocols for non-routine case of Pulmonary Embolism by subjects with different levels of expertise

Basic Science Knowledge

Students, residents, sub-experts and experts respectively used a 10.4, 11.0, 18.6 and 11.6 mean percentage of basic science propositions for the routine case. The generation of pathophysiological knowledge propositions by students, residents, sub-experts and experts were 29.7, 10.5, 19.3 and 21.8 respectively, whereas for clinical sciences the levels were 59.9, 78.5, 60.9 and 66.6 respectively.

This pattern of results was also true for the non-routine case, where the use of mean percentage basic science information was 9.4, 13.7, 19.8, and 16.5 by students, residents, sub-experts, and experts, respectively. The mean percentage for the use of propositions used by students, residents, sub-experts, and experts were 23.7, 3.3, 11.4, and 18.0, respectively, for pathophysiology, and 66.9, 83.0, 68.8, and 65.4, respectively, for clinical knowledge.

However, it should be noted that the use of biomedical information increases as a function of expertise in relation to both clinical cases with peak values seen at the level of sub-experts. These results show a different pattern to the ones shown in area of diagnostic problem-solving, where the use of basic medical sciences decreaseded with increased levels of expertise (Patel & Groen, 1990).

Figures 3 and 4 (next page) give the mean percentage of basic science knowledge propositions generated by expertise and by case type for routine and non-routine cases, respectively. More basic science propositions were used during therapeutic planning by all subjects in the non-routine case than the routine case.

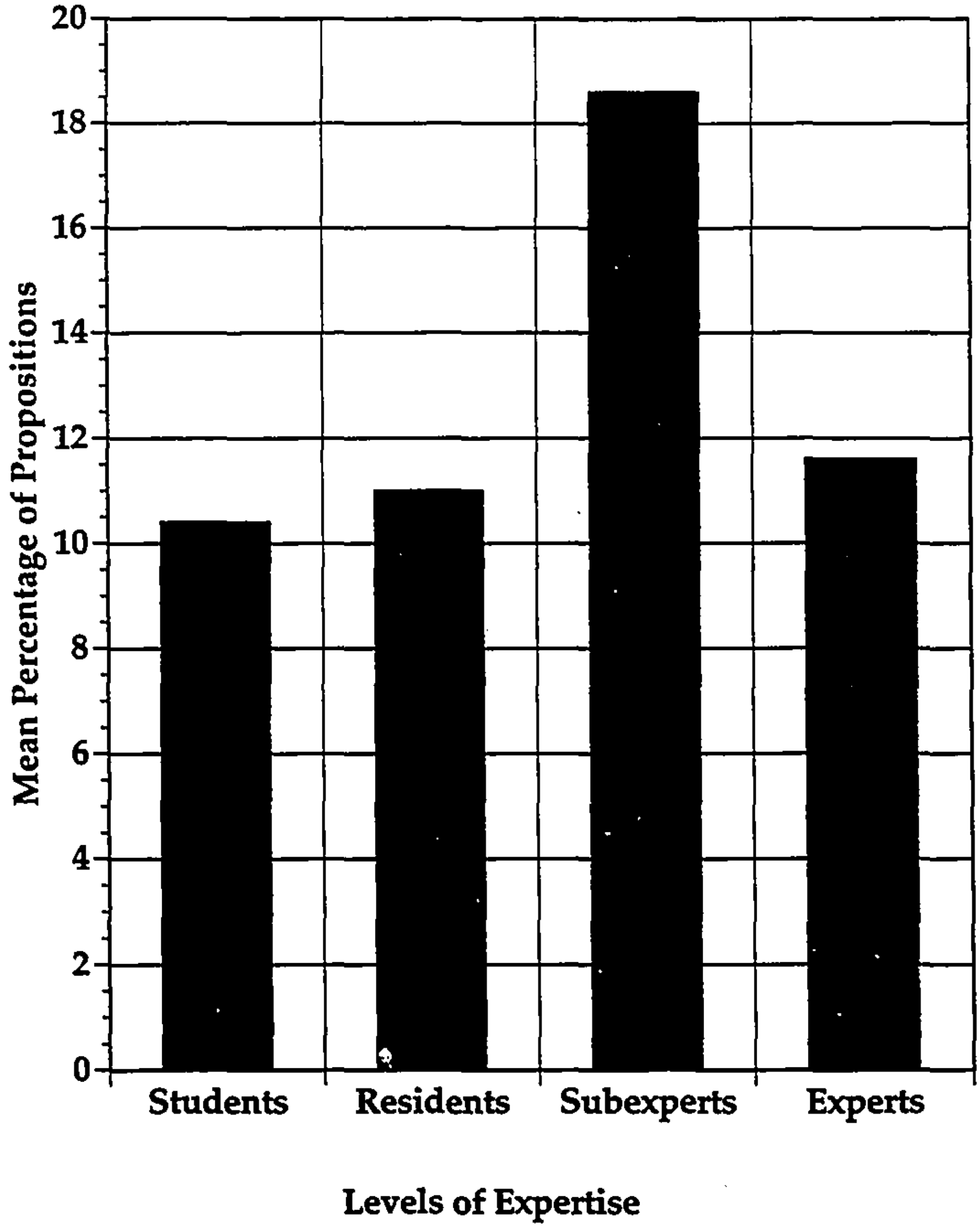

Figure 3
Mean percentage of basic science knowledge propositions generated in therapeutic planning protocols for routine case of Asthma by subjects with different levels of expertise

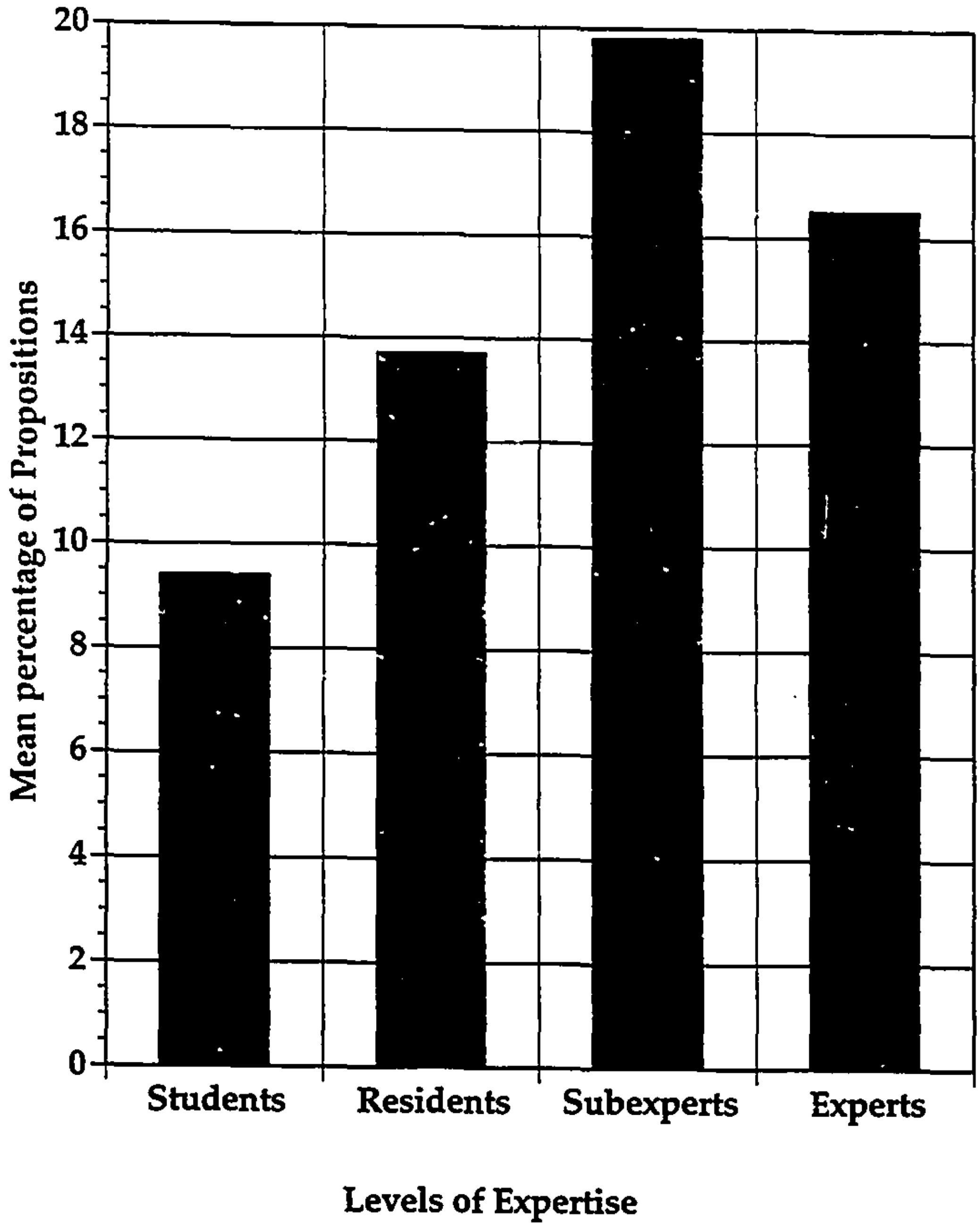

Figure 4
Mean percentage of basic science knowledge propositions generated in therapeutic planning protocols for non-routine case of Pulmonary Embolism by different levels of expertise

Pathophysiological knowledge

Figures 5 and 6 (next page) give the mean percentage of pathophysiological propositions generated by size at different levels of expertise for routine and non-routine cases, respectively. The use of pathophysiological knowledge is shown to have an U-shaped trend with its two peaks at the novices' and experts' group, who generate the most pathophysiological knowledge. Furthermore, the pathophysiological knowledge propositions were used less in the non-routine case than in the routine case by all groups.

The results could be explained on the following basis: 1) The etiological and causal factors are greater in the routine case in this study than in the non-routine case; and 2) The non-familiarity with the underlying pathophysiology of the non-routine case: in the routine case, because of complexity of the presented problem, in drawing the therapeutic inferences, physicians depended upon causal knowledge (Patel, Arocha & Groen, 1990). This was not true for the non-routine case, because although, problem being unfamiliar but presented in a very straight foreword way. There fore, the pathophysiological propositions were seen less in non-routine case than in the routine case.

Summary

Overall results show that during clinical decision-making with respect to the therapeutic plan basic science knowledge is used very little, followed by pathophysiological knowledge, and with clinical science being used the most. However, the use of basic science knowledge was seen more in the non-routine case as compared to the routine case. The use of basic science also increased as a function of expertise (except for sub-experts). This is in contrast to the results seen in the studies for diagnostic reasoning, where the use of basic science knowledge decreases as a function of expertise. A similar finding was seen in therapeutic reasoning regarding the sub-expert (researcher) tendency of using a higher amount of basic medical sciences in comparison to clinicians in the area of diagnosis-making studies. The figures duplicate the finding of an increase in the use of basic science by sub-experts.

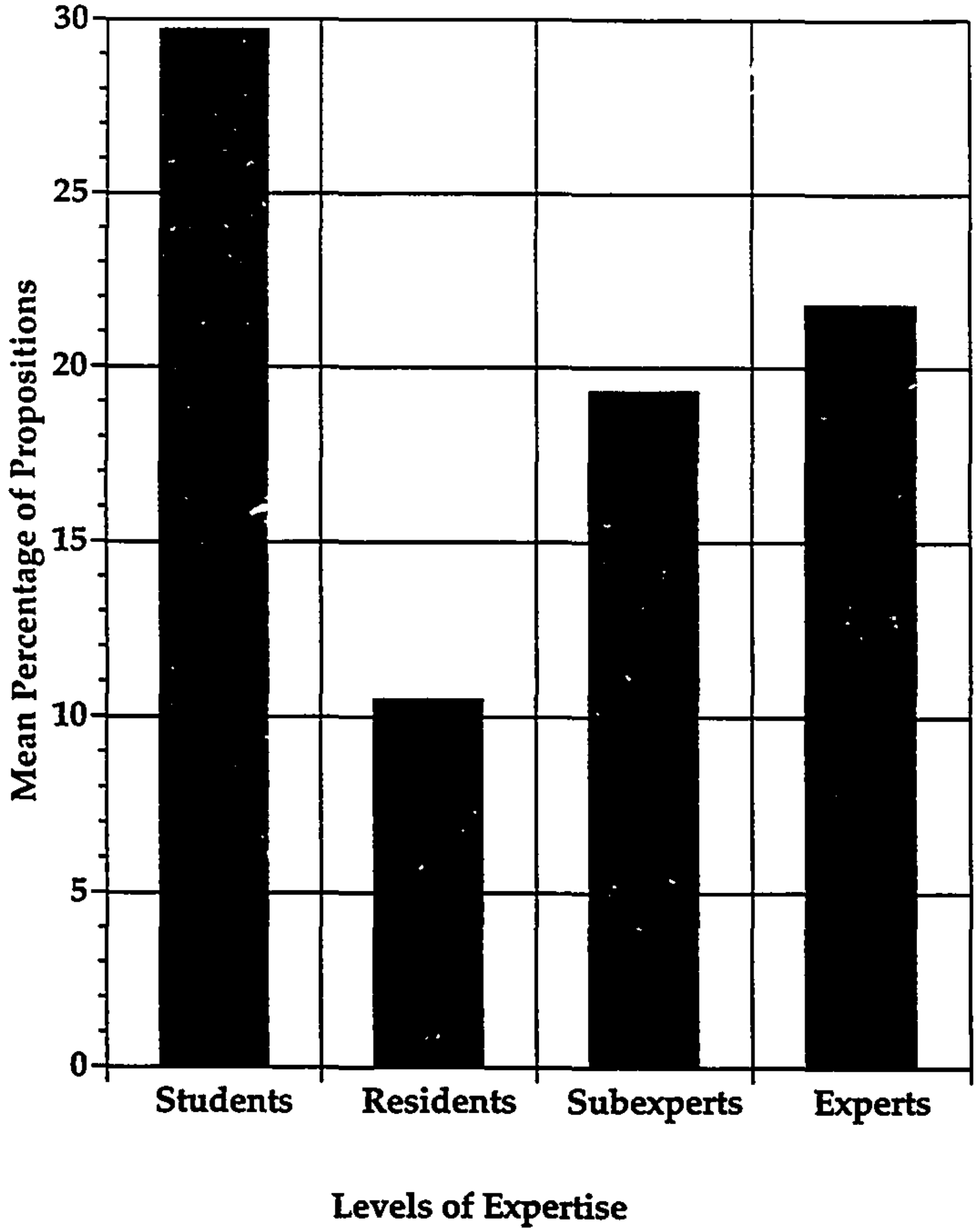

Figure 5
Mean percentage of pathophysiological knowledge propositions generated in therapeutic planning protocols for routine case of Asthma by different levels of expertise

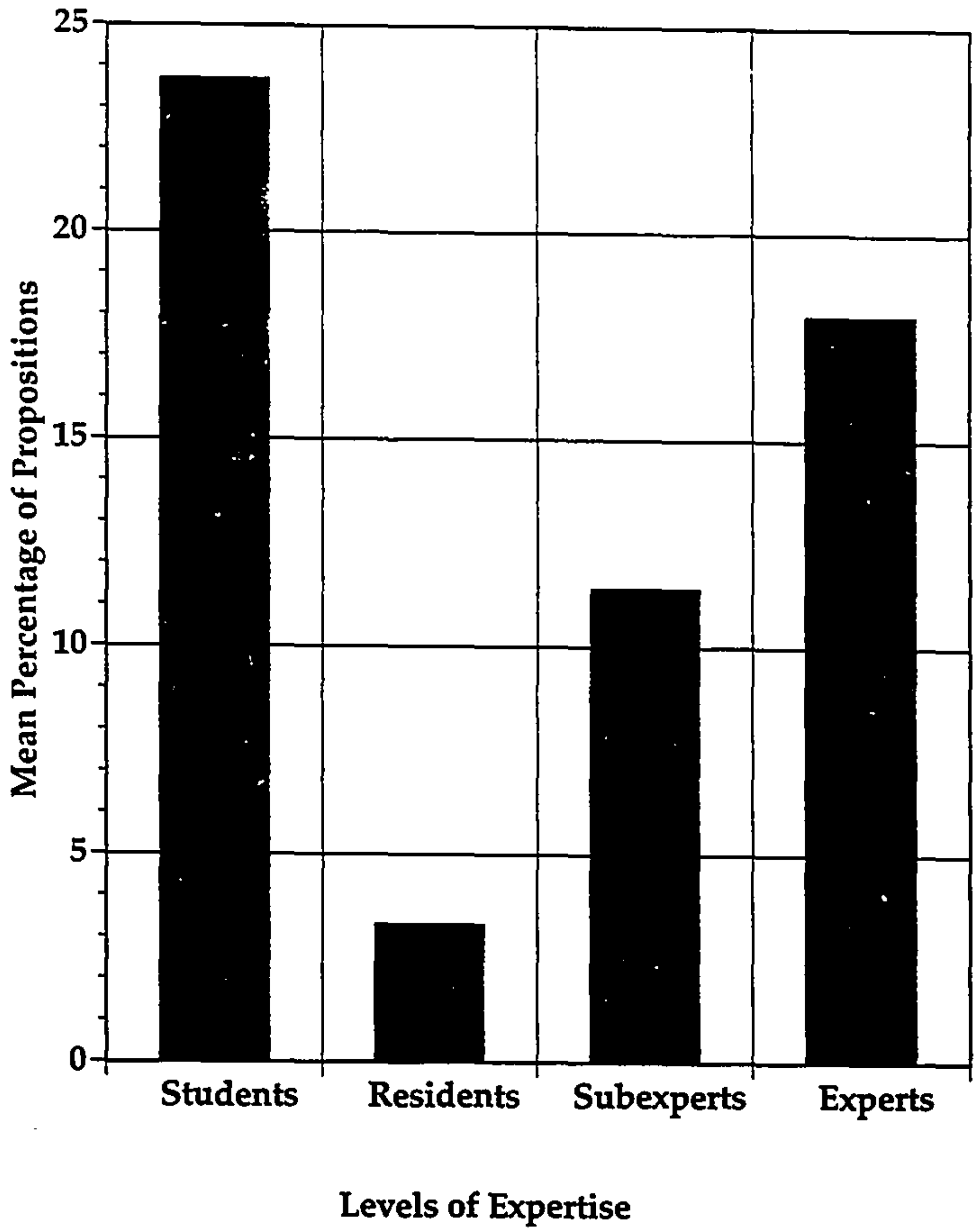

Figure 6
Mean percentage of pathophysiological knowledge propositions generated in therapeutic planning protocols for non-routine case of Pulmonary Embolism by different levels of expertise

Understanding of causal relationships to the clinical-state of the body:

In this research, in the presented routine case the information given about the pulsus paradoxus was an important issue for the management of the patient; it is an indicator of the severity and complexity of the disease, especially when it is present in association with other critical findings (as described in the methodology section), such as labored breathing, high levels of carbon-dioxide, hypoxia (low oxygen level in the blood), cyanosis and acidosis.

The following excerpts from protocols of subjects from different levels of expertise were selected to demonstrate the respective kinds and levels of understanding of basic science and pathophysiological knowledge and their relationships with the presented clinical states of the patient in the experiment. For example, the following excerpt is selected from expert 3, who is explaining the importance of the pulsus paradoxus in his decision making about the therapeutic plan for this patient:

Excerpt from the protocol for patient management
Expert 3; Case 1, Asthma

----the description of a patient shows that he is agitated and cyanosed uh!! blood pressure, pulsus is 10, the presence of the pulsus of greater than 10, indicates severe air flow obstruction, however it's absence doesn't exclude that diagnosis----

The selected excerpt shows agitation and a cyanotic state in the patient, which indicates a severe degree of air flow obstruction; this is a positive finding in an asthmatic patient. However, in his decision-making response, the expert explains that the normal reading in the text does not exclude the diagnosis presented in the experiment because it is associated with another critical finding; therefore, it reflects the seriousness of disease and indicates that the case should be handled carefully.

This selected excerpt clearly indicates the deeper understanding on the part of the expert subject of the finding of pulsus paradoxus in this particular patient, and that, though this reading is within the normal range, because of its presence with the other finding, as described in the clinical text, it should not be dealt with carelessly.

This deeper understanding of the relationships between basic sciences, pathophysiology and the clinical presentation is also seen in the sub-expert, as reflected in the following excerpt selected from the protocol for patient management and therapeutic planning from sub-expert 2:

Excerpt from the protocol for patient management
Sub-expert 2; Case 1, Asthma

------the other thing that of concern is his pulsus of 10. Usually in asthma the pulsus increases surely, which is an index of airways obstruction. In fact, it is 10. It can be a good news or bad news. One, that the FEV_1 is very high, and bad news is that, he is moving so little air uh!! that pulsus start to fall off again. I will suggest that later is more important here in that the pulsus is probably reflecting that FEV_1 is good but that there is so little air flow that the pulsus is falling. It is really suggest that in a few minutes or so if some thing is not done, pulsus ultimately will be zero and the patient will no longer take any breath, so I think that is a bad sign------

In this selected verbatim passage, sub-expert 2 further elaborates the description of pulsus paradoxus and clarifies the severity of the condition as "bad news", explaining that the presented normal reading is in fact not a normal reading: it could be that the pulsus might be on a falling trend towards the zero reading, and that later the patient will not be able to breathe at all. The excerpt in this example clearly shows that sub-expert 2 is not confused with the presented normal value for the pulsus paradoxus in the patient. Furthermore, the subject was able to interpret the clinical information and infer that it is a worsening situation for this patient. This reflects a deeper understanding of the relationships between signs and symptoms in a patient who is undergoing pathophysiological changes in the body systems.

A similar kind of recognition and more profound knowledge can be seen in the excerpt from sub-expert 1, whose explanation shows a degree of doubt about the normal finding of pulsus paradoxus in the patient presented in the experimental text. This subject further emphasizes that this pulsus paradoxus should be quite higher in the presented circumstances when associated with other critical information. The excerpt is given below:

Excerpt from the protocol for patient management
Sub-expert 1; Case 1, Asthma

--------so asthma sounds like reasonable diagnosis, but surprisingly his pulsus paradoxus is 10, which is small for this bad asthma, which can not get him into this much trouble. I expected it to be here much bigger. So taking correctly that would be a little bit surprising finding——

These explanations given by experts and sub-experts show that these experienced physicians were able to recognize the deeper level or causal relationships between signs and symptoms and basic physiological, and pathological knowledge, and coordinate the clinical information with their pathophysiological and basic science knowledge-base correctly. These physicians were not misled by the apperently normal readings, instead, they further analyzed the information, coordinated it with pathophysiological and basic science knowledge, and then drew therapeutic inferences based on this newly explored knowledge about the patient, and more thoroughly evaluated the condition of the patient. Consequently, they were able to prescribe refind and balanced therapeutic plans.

Next, we will consider examples of protocols from subjects with little or no experience in the domain of respiratory medicine, i.e., residents and students respectively. These examples were selected to demonstrate how these novice subjects (students) and residents showed negligence about exactly the same finding in the clinical case, when it was essential that they take care. The following excerpt is from the protocol of resident 2:

Excerpt from the protocol for patient management
Resident 2; Case 1, Asthma

---in the presence of pulsus paradoxus, high pulse rate, high CO_2, and acidosis I would probably intubate him early to ventilate him mechanically---

This excerpt shows that resident 2 was able to explain the critical condition of the patient which cannot be dealt with by the normal procedure of oxygenation because the presence of pulsus paradoxus together with high carbon-dioxide and low pH (acidosis) is a dangerous and life-threatening condition which needs a mechanical type of ventilation procedure. The excerpt from resident 2 clearly indicates that the subject was able to relate clinical information, the degree of seriousness of the patient's condition and the pulsus paradoxus reading in the clinical text, but did not provide in his responses any elaboration, explanation or justification to relate the underlying pathophysiological condition to the presented case.

In contrast to those of these subjects, the students' responses demonstrate the absolute absence of an appropriate understanding of the relationship between pulsus paradoxus and the clinical state in the presented patient. These subjects dealt with this critical information in the clinical text as routine text data, and did not place any significance on the pulsus paradoxus reading. For example, an excerpt from the protocol by student 1, is given below:

Excerpt from the protocol for patient management
Student 1; Case 1, Asthma

----so he is quite tachycardic 120, regular, blood pressure 160/90 on lying pulsus paradoxus is 10, an important to indicate how severe is his breathing problem? So if it is greater then 10, it is significant---

This excerpt shows that the subject, reading through the text, found an interest in the finding of pulsus paradoxus, but that he was not able to analyze the whole situation of the patient's condition, but looked upon this finding as normal because it is within the normal range. This subject was unable to associate this reading with other data, as reflected in the responses of expert physicians. This experienced group of subjects was able to identify and explain relationships between the presented data and the underlying causal factor. Findings similar to example above, revealing a surface level understanding, were also observed in the responses of other novices and less experienced subjects, such as student 4, who saw the pulsus paradoxus as normal, and residents, 1, 3 and 4 who did not even mention the pulsus paradoxus.

Summary

In these responses from the subjects it is clearly observed that novice and resident subjects were unable to understand the acuteness of the finding, or its association with other readings in the clinical text, and ignored the finding as normal value. On the other hand, senior physicians took this finding seriously and discussed it in much detail, which is clearly evident in their responses. These physicians were able to recognize the seriousness of this finding in relation to other notable data, and make a conclusive statement that this was "bad news" because it tended towards a falling line and any time it could be zero in the presence of labored breathing. Also observed was that elaborations were given more in cases of the sub-expert subjects. This may be because pulsus paradoxus is an issue of disturbances in cardio-pulmonary physiology, and in the research the sub-expert subjects were cardiologists, who were expert on this issue. Therefore, they were able to understand the issue of pulsus paradoxus at a deeper level in comparison to the other subjects.

Hypotention: Understanding of hemodynamic physiology and anatomical involvement for the selection and justification of therapeutic plans:

This section of the results aims at providing the reader with some insights into the differences in how novices and experts select their therapeutic plans based upon the emphasis on the information provided to them about the patient. To be more precise, the therapeutic decisions about pulmonary embolism are based upon the understanding of the basic physiological (hemodynamic condition) and anatomical (pulmonary vascular structure and its involvement) status of the patient. The National Institute of Health (NIH) has specified criteria regarding the use of certain kinds of therapy for specific presented states of patients in cases of pulmonary embolism. There are two basic kinds of therapeutic plans which could be prescribed in proven cases of pulmonary embolism: anticoagulants and thrombolytic agents. Anticoagulation therapy is given through two routes: parenteral and oral. Heparin is given through sub-cutaneous (or under the skin) and intravenous routes, whereas oral anticoagulating therapeutic agents include coumarin. The therapeutic agents used in this class of medication do not directly affect the blood clot which is already present in the system; however, they affect the clotting mechanisms of the human body and stop further clot formation. The other class of therapy is thrombolytic therapy, which employs therapeutic agents which dissolve the clot itself, for example, streptokinase, urokinase, tissue plasma activator (TPA). These two types of therapies have different mechanisms of action and are used in different types of clinical states of patients. For example, the anticoagulation agents alter the body coagulation mechanism and inhibit further clot formation. In contrast, the thrombolytic agents act directly on the already formed clots in the system, dissolve them and clear the passage of the obstructed blood vessel. The thrombolytic therapies are recommended by the NIH when the patient is suffering from a large hemodynamics compromise involving larger blood vessels and an extensive vascular area of the lungs, causing a severe degree of low blood pressure (hypotention), for example, a large clot occluding the large vessels obstructing more than fifty percent of the pulmonary vascular area. The anti-coagulating agents, on the other hand, are used to prevent further clot formation, particularly in patients with a high risk of pulmonary embolism, whether or not they have the clot, bed-ridden patients, and patients who have had vascular surgery. These anticoagulants have no effect on the dissolution of the clot; therefore, any dramatic improvement in a hemodynamically compromised patient should not be expected immediately with the use of these agents. These anticoagulants, however, are very important for prevention and long-term therapies in a patient with a risk of pulmonary embolism.

In the research, the patient in question was in a hemodynamically compromised (blood pressure 80/60 mm. of Hg.) clinical state with agitation and breathlessness, along with a proven case of pulmonary embolism by the positive finding in the pulmonary angiography. The task was to provide therapeutic plans for this patient. According to the basic criteria of treatment the finding of low blood pressure (hypotention) was very crucial for decision making about the therapeutic plans, i.e. selection of anticoagulation or thrombolytic therapy.

The following selected excerpts demonstrate the coordination of basic science and pathophysiological knowledge for decision making about the therapeutic plan and the selection of therapeutic agents in the non-routine case by different groups of subjects.

Excerpt from the protocol for patient management
Expert 1; Case 2, Pulmonary Embolism

---the fact is that there is hypotention, means severe hemodynamic compromise, meaning that more than the fifty percent of vascular bed is occluded by clot. This is the life threatening degree of thromboembolism---- ----I think that, certainly this patient is hypotensive and has pulmonary element. On physical examination of patient circulatory failure is not maintained at all. Patient should be admitted to the ICU, and I think that with recent history of trauma and leg fracture, I will use streptokinase or TPA. Patient have to be anticoagulated promptly with a bolus of intravenous heparin-----

As the excerpt explains, the clinical finding of low blood pressure, or hypotention, indicates that more than the fifty percent of the pulmonary vascular bed has been blocked because of a clot; this constitutes a life threatening situation for the patient. Therefore, the patient should be given agents which directly dissolve the clot, like streptokinase, or tissue plasma activator (TPA), together with agents which prevent further clotting, like heparin. The excerpt shows the subject's understanding of the basic physio-anatomical structure of the respiratory system along with the pathophysiological relationship with the clinical state of the body. The subjects were able to explain that such a condition is usually present when the large clots involve a large area of the lung leading to hemodynamic changes.

Similar suggestions and justifications were given by expert 2, with a further elaboration regarding the pathophysiological changes occurring in the patient which result in hypotention. The following excerpt is from the protocol of expert 2:

Excerpt from the protocol for patient management
Expert 2; Case 2, Pulmonary Embolism

------probably it is a most life threatening event, because of the major pulmonary embolism which put severe strain on right heart. The cardiac output was inadequate to meet energy demand of body and lead him cardiogenic shock and severe right heart failure---   -----therefore, the question immediately is to administer things which cause fibrinolysis and then you have to decide. An answer would be yes!! and I think, this is definitely indicative-----

This excerpt explains that this clot could cause cardiogenic shock (heart failure, low blood pressure or hypotention). Furthermore, the clot creates a blockage of the major pulmonary artery, preventing blood from flowing towards the left side of the heart which supplies oxygenated blood to the body, resulting in an energy deficiency; the subject explains that because of low cardiac output the circulatory system is unable to meet the energy demands of the body. Secondly, because of the block there is severe strain on the right side of the heart which normally pumps blood towards the left side: blood has to be pumped against the clot into the left side of the heart; consequently, there is severe strain on the right side of the heart and a possible failure of the right side of the heart. Such a possibility must be avoided, and a therapeutic agent which dissolves the clot immediately, like streptokinase, or tissue plasma activator (TPA), must be administered.

In the above excerpt, expert 2 explains in detail the pathophysiological events which occur when a clot obstructs the major pulmonary vessel. Similar arguments and justifications about the patient's condition were given by the other experts (3 & 4) for the selection of which kind of therapy the patient should receive.

The next examples were selected from the protocols of sub-expert subjects. On analysis we find in their explanations similar kinds of findings and recognizing abilities as were seen in the responses of the expert subjects. Some excerpts from the sub-experts protocol are given below:

Excerpt from the protocols for patient management
Sub-experts; Case 2, Pulmonary Embolism

Sub-expert 2
---------amount of pulmonary vasculature that is being interrupted in order to have a hypotention, it is estimated that you have to have a vascular interruption around 30% to 50%------
--------the NIH-criteria for using um!! thrombolytic therapy is; if more than 50% of the pulmonary vasculature interrupted, refractory hypoxemia, and refractory hypotention----

Sub-expert 3
----and the presentation with sudden respiratory distress and hemodynamic compromise which is sudden in onset----
---in presence of shock, he should get thrombolytic therapy--

Sub-expert 4
----pulmonary embolism certainly with the combination of hemodynamic instability and greater then 50% loss of vasculature are relative indications for thrombolytic therapy in pulmonary embolism---

As shown in the excerpt from the protocol of sub-expert 2, a degree of hypotention occurs when 30% to 50% of the vascular bed of the lung is blocked; in this condition, a need for thrombolytic therapy is indicated. A similar explanation was given by sub-expert 4 in his response for the treatment plan.

The selected excerpts from the sub-expert subjects show an elaborate, articulated and coordinated understanding of the physio-anatomical and pathophysiological relationship present in the clinical presentation.

Next we have selected some excerpts from the responses of the resident subjects to illustrate their understanding of the patient's condition and its relationship with the underlying cause. The excerpts from the residents' protocol generally show fewer and less elaborate explanations and justifications for selecting their therapeutic plans, as are present in the experts' and sub-experts' protocol. However, almost all residents were able to recognize the seriousness of the disease and introduced a discussion of hypotention to justify their therapeutic plans. But because of their limited experience in the domain, they were unable to elaborate and coordinate their explanations and justifications with the clinical condition of the patient, with the exception of resident 1, who has elaborated his explanation and related it to the patient's data with the inferences drawn from his basic science knowledge for explaining a hypotensive condition in the patient, as seen in the following excerpt from resident 1:

Excerpt from the protocol for patient management
Resident 1; Case 2, Pulmonary Embolism

———due to obstruction of the circulation on the right, leading to decrease in right ventricular output. As a result, left ventricle is not getting as much preload and therefore, this blood pressure is dropping—

The excerpt from the response of resident 2 shows a degree of elaboration in the selection of the therapeutic plan and the subject was able to prescribe the thrombolytic therapy to the patient based on the outline recommended by the NIH-criteria; also, his explanations were based upon the clinical trial, and its results, on those two kinds of therapies. However, the explanation did not include the pathophysiological and physio-anatomical descriptions that were seen in the protocols of the expert physicians. An excerpt from the protocol of resident 2 given below:

Excerpt from the protocol for patient management
Resident 2; Case 2, Pulmonary Embolism

———as far as the his hemodynamic status goes, he is hypotensive with tachycardia and quite agitated. So I would say he is not hemodynamically stable on the basis of his hypotention——
——recommendations of NIH-1983, regarding thrombolytic therapy suggest two regimens which are, one urokinase, and other streptokinase. The indication of that time was and still is in use; if V/Q scan difference is more then one lobe along with hemodynamic compromise—

A most interesting finding was seen in the case of the novice subjects: they used exactly the same procedures as the residents, sub-experts and expert subjects, but their explanations did not show any relationships or justification for the presented information and condition of the patient in the experiment. Excerpts from the novice subjects showed a lack of differentiation in their knowledge base between the clinical state of the patient and textbook knowledge which resulted in the prescription of rule-based procedures from textbooks.

Student 1 read through the case without placing any emphasis on any particular or critical information, such as low blood pressure, and prescribed the typical textbook therapeutic plan, heparin and streptokinase, along with a statement of strict bed rest to avoid another embolic attack. Students 2 and 4 mentioned the low blood pressure, but did not offer any elaboration, and prescribed the prototype therapeutic plan as did novice subject 1.

Student 3 was able to give some justification for using the thrombolytic therapy, explaining its use to dissolve the clot, which also reveals a kind of textbook knowledge. Later in his explanation the subject demonstrated a great deal of unfamiliarity with this thrombolytic agent. Also, the subject was unable to relate the clinical state of the patient with underlying pathology and physiological basis of the hypotention, and prescribed a therapeutic plan as exemplified below:

Excerpt from the protocol for patient management
Student 3; Case 2, Pulmonary Embolism

--------pulse rate 120 that is consistent with compensation to some blood pressure 80/60. I am hoping that, actually, no doubt, I would give him heparin. I would also give him streptokinase. Um!! I would try to dissolve the clot because it obviously has low blood pressure, he is hypotensive. He has alkalemic pH. He is very early sort of positive findings. It is quite a severe clot. Um!! I want really to get rid of it. Uh!! so I would probably give him streptokinase proper dose to get rid of this. So I will read about that then I would give him streptokinase. Once I am done, then I would anticoagulant him this disseminate the clot other way----

These excerpts clearly indicate that the experts and sub-experts drew their therapeutic inferences from an understanding of the relationships within the physio-anatomical and pathophysiological knowledge base with the clinical condition of the patient. The experts were able to analyze and coordinate the clinical state of the patient with its underlying pathophysiology, and arrive at decisions regarding which class of therapeutic agent is most suitable for the presented case.

Summary

As is shown in the excerpts from responses of subjects from different levels of expertise, there were no differences found between the novice and expert subjects in using the therapeutic procedures. Almost all the subjects in the experiment used exactly the same basic procedures in their therapeutic responses for the non-routine case as described above, i.e., anticoagulation and thrombolytic therapies. However, differences were seen in their justifications and explanations of their plans. On the one hand, the novices' explanations were typical of the prototype textbook plan: anticoagulant and thrombolytic agents with little or no justification or elaboration. On the other hand, the experts' responses involved a great many considerations and inferences drawn from their extensive knowledge of basic science, pathophysiological knowledge and their relationship with the clinical state of the patient. The experts were able to produce elaborate explanations about the hemodynamic state of the body and justification for the selection of a particular class of therapeutic agents in their therapeutic plan. This ability to abstract the important and relevant inferences from the large volume of their knowledge bases is a function of their extensive experience in the domain and deeper understanding of domain-specific problems, which allow them to relate the relevant basic science knowledge and clinical information given in the text.

This extensive familiarity with basic sciences and pathophysiological knowledge also enables them to select their therapeutic plans efficiently and refine it successfully, which ultimately benefits the patients.

Use of oxygen in asthmatic patients: Understanding of basic respiratory physiology and its control under normal and variable clinical states of the body:

As we know from the textbooks, in the normal physiological state of body breathing, the respiratory system is controlled by two main respiratory centers situated in the carotid bodies in the neck and in the medulla-oblongata, the mid-brain. These centers are regulated by the level of carbon-dioxide in the blood in the normal physiological state. If the carbon dioxide level increases sharply, the body respiratory centers are stimulated, resulting in an increased respiratory rate which washes out the carbon-dioxide from the body, bringing it to the normal level and returning the respiratory system to a normal physiological state. However, in a long-standing condition, chronic low partial pressure of oxygen in the blood , i.e., chronic hypoxia (as described in the patient in the research clinical text), the control or regulation of the respiratory centers is taken over by the low level of oxygen in the blood (hypoxic-drive), and the carbon-dioxide level plays a minor role in the regulation of the respiratory drive. Therefore, if the low oxygen level of the body is corrected quickly by the introduction of a high concentration of oxygen, the respiratory centers which had been controlled by a low concentration of oxygen, fail because of the sudden correction of the oxygen level to the normal level; this results in the failure of the "hypoxic-drive" which controlls the respiratory function in the low oxygen state of the body, and leads to respiratory failure and the ceasing of breathing resulting in the death of the patient. Therefore giving uncontrolled oxygen could be disastrous, rather than beneficial to patients.

The following excerpts from the protocols given for the routine case, asthma, by different groups of subjects, have been selected to demonstrate the differences between the different levels of subjects in terms of the understanding of respiratory physiology in the normal and pathological or clinical states of the body, and the use of this knowledge in the selection of a therapeutic agent, i.e. oxygen, for the patient. The following is an excerpt from student 1:

Excerpt from the protocol for patient management
Student 1; Case 1, Asthma

——um!! if he continues to be short of breath, and labored respiration I will admit him in the hospital. Um!! I will also start him on oxygen probably on a high rate because arterial pO_2 is only 42. I will start him on oxygen——

The response from a novice subject, student 1, shows that after reading the text, the subject drew a therapeutic inference, on the basis of breathlessness and labored respiration, that oxygen should be given to the patient because of his low partial pressure of oxygen (42 mm of Hg.).

A similar kind of explanation for the therapeutic decision was also seen in the response from another novice subject, student 4, who explained that because the patient is hypoxic the obvious prescription is oxygen. This is exemplified in the following excerpt:

Excerpt from the protocol for patient-management
Student 4; Case 1, Asthma

OK.!! oxygen, well!! definitely by mask I will get him, he is hypoxic, no doubt.

As the above selected excerpts show, the decisions by novice subjects were entirely based upon textbook, rule-based, surface therapeutic schema, which state that a particular kind of therapeutic agent is prescribed for a particular kind of condition. For example, if the patient is breathless, with a low oxygen level, then provide oxygen. The excerpts from protocols from the novice subjects also show that during therapeutic decision making, novices used a similar rule-based, top level procedure and therapeutic agent, oxygen. Although, this therapeutic agent is most useful in the acute conditions during asthmatic attack, it could be disastrous if not prescribed properly in different states and stages of low oxygen conditions, as explained before in this section.

As is apparent in the excerpts from the novices, all of the students included this oxygenation procedure in their therapeutic plan, which they learned from textbooks as a top level, rule based procedure. For example, if asthma and labored breathing are present, with a low level of oxygen in the blood (hypoxia), then oxygenation is called for. The important issue was the deeper understanding of the pathophysiological and normal physiological relationship with the clinical state of the body, and their use in decision making about therapeutic planning for the patient. As shown in the student 1 response, he used oxygenation, but in a high concentration which could be disastrous, whereas student 2 also planned to give a similar therapy slowly, but did not justify the motivation of such a decision, except to explain that the patient is a carbon-dioxide retainer which does not explain the relevant justification and physiological relationship with the current clinical state and oxygenation. Student 3 also noticed that the level of oxygen was quite low in the case, and recognized the critical condition of the patient because of low pH and high levels of partial pressure of carbon-dioxide; he planned to intubate the patient, obviously for oxygenation, but did not clarify the dose and rates for oxygenation.

These excerpts from novice protocols indicate these novice subjects' responses showed a minimal use of the basic sciences and pathophysiological knowledge base about the respiratory function and its regulatory mechanism. Novices were also unable to relate the respiratory function control under the normal and clinical state of the body and to the clinical status of the patient. This could either be because of lack of knowledge or their inability to relate their knowledge base to the clinical states of the patient during therapeutic decision making for patient management. Under certain circumstances such an inability could be dangerous, such as an uncontrolled use of oxygen in a hypoxic condition, as a rule-based therapeutic agent could result in a life-threatening condition for the patient.

Next we have selected some examples to demonstrate similar findings in the responses of subjects who were taking specialty board training in the department of medicine, and who were newly exposed to domain-specific patients, such as was described in the experiment. Following are a few excerpts from a resident and a sub-expert subjects:

Excerpt from the protocol for patient management
Resident 4; Case 1, Asthma

------OK. I will give him some oxygen, monitor his vital signs, and get the endotracheal tube ready. I will go ahead and intubate this gentle man. OK. so if his mental status is not good as I said, intubate him and I went to set up a ventilator PEEP-O_2 with respiratory rate about 16 to 20 FiO_2 of 50 to 75%

and continuously giving aerosolized bronchodialators through the endotracheal tube-----

Excerpt from the protocol for patient management
Sub-expert 1; Case 1, Asthma

-------so in term of therapeutic plan well !! first thing is that make sure he is receiving some oxygen because he is hypoxic. He also got acidosis which is primarily respiratory acidosis so giving him oxygen might help with some of with that-----

As shown in the excepts, resident 4 introduced a discussion of controlled oxygenation with the help of a mechanical ventilator, but did not justify the respiratory state of the patient and its relationship with oxygenation and the selection of his particular therapeutic plan. The other excerpt from sub-expert 2 shows that instead of concentrating on oxygenation and its use and explanation for this presented case, he misled the discussion towards mechanical ventilation. The subject was preoccupied with a dicussion of complications, mortality and morbidity of mechanical ventilation, which were of no relevance to the present task. This might stem from their limited practical experience with asthmatic patients. This is exemplified in the selected excerpt from the protocol of sub-expert 2:

Excerpt from the protocol for patient management
Sub-expert 2; Case 1, Asthma

-------If the patient is intubated, here are some most important complication that you want to avoid is barotrauma or pneumo-thorax particularly. Even air in mediastinum because, once that happens the mortality in acute asthma goes up quite dramatically. Um!! literature suggest going up from probably 2 or 3% mortality to up to around 20 to 30% mortality. So you do not want to have barotrauma.

The excerpts selected from the resident and sub-expert subjects do not show much improvement in explanations and justifications about the oxygenation procedure. However, in contrast to students, residents, and sub-experts, experts showed a great deal of concern about the control therapy of oxygen; this is explicitly evident in the excerpts selected from their protocols. This gives an indication that experts are not only aware of procedures for the disorder, but because of their extensive experience with a variety of cases and the range of their presentation, these experts were able to articulate the consequences of their therapeutic plans, from experience in their long-standing practice. For example, following are the excerpts from the expert physicians:

Excerpt from the protocol for patient management
Expert 2; Case 1, Asthma

> ——I think we need little bit more history significant for diagnosis to confirm that he has asthma or COPD. But any way!! for immediate purpose, it is evident that his arterial pO_2 is especially low and he needs oxygen. I have also noticed that he has acute respiratory acidosis his pCO_2 is 67 and 7.22 which means the giving him oxygen might be risky, and any increase in pCO_2 may even more exacerbate the respiratory acidosis. So if we give him controlled oxygen therapy using mask I think probably choose 28% oxygen——

Excerpt from the protocol for patient management
Expert 4; Case 1, Asthma

> —So far as his oxygen concentration, he should be put on a oxymeter right away. I would probably start him on about 40% oxygen by mask and see how it effects the saturation. If he does not appear to be getting progressively solemnest, then we may be give him little bit more oxygen. The fact is that we do not want to suppress his respiratory drive excessively by supplemental oxygen—

The excerpt from expert 2 shows that the subject was able to analyze the complete information given in the text, and that his decisions were made after painstakingly establishing the relationship between the clinical state of the presented case and the pathophysiological state of the respiratory system. The subject explicitly states that the patient needs oxygen, but because he is a chronic and long-standing respiratory case and has a very high carbon-dioxide level and low pH, these could present a risk to the patient if the oxygen is given uncontrolled. Therefore oxygen therapy should be started slowly and regulated. Similar kinds of explanations and justifications are observed in the responses from expert 4 in the excerpt selected above.

Summary

The responses from different levels of subjects showed clearly defined differences regarding the use and understanding of their knowledge base during decision making about patient-management planning. As seen in the results, the novices typically used a textbook knowledge-base without considering the underlying pathological state of the body, and these novice subjects were also unable to articulate therapeutic explanations with relevant justifications. In some istances potentially disastrous decisions were made by the novice subjects who were unable to differentiate between the textbook description and the presented case in the experiment. Well-defined explanations and justifications were seen in the case of expert subjects who were able to justify their therapeutic plans and also related their therapeutic decisions to their basic science as well as pathophysiological knowledge base. This understanding and ability to coordinate these knowledge bases allows them to arrive at correct and successful therapeutic plans.

Search for new information: Monitoring and evaluation of initial therapy:

Analysis of different subjects of the same group reveals that the responses from different subjects within the same group demonstrate a wide and variable range (refer to statistical analysis) between the subjects in terms of their use of knowledge during decision making and their explanations and justifications for the therapeutics and patient-management plans. However, based on the descriptive and content-specific analysis, overall group differences were obvious between the novice and expert groups of subjects.

These differences were seen in the nature of their decision-making plans. In the research experiment, the experts as well as the novice subjects were given similar instructions, diagnoses, and tasks to perform in the experiment, i.e., therapeutic and patient-management planning. In the responses it was observed that the novice responses were rule-based plans as per textbook representation, whereas the responses of experts were not rule-based or derived from the surface representation found in textbooks. Senior physicians raised a number of questions regarding the exploration of new information, such as more history and further investigations, to evaluate the present condition of the patient and to monitor the patient in the future. An example from an expert subject is given below:

Excerpt from the protocol for patient management
Expert 3; Case 1, Asthma

History of smoking
——I do not think that it says in history of fever, cough being even too young to have any abnormality due to smoking at the time of retirement. So I suppose that he has asthma before and that asthma could have been exacerbated by environment at work. May be that is why he retired now. You do not know if he has been taking any medication or not and that suppose important. Um!! then he present to emergency room with the one day history um!! of wheezing following a common cold and cough. Oh!! common cold and cough and that is very typical presentation of asthma—
Investigation procedures
—Well!! the certainly it would be nice to do, what is FEV_1 because that is the way you are going to follow the response of the patient for the treatment. So before I start any treatment even I try to do FEV_1 it take few second that would guide me—

In the excerpt from expert 3 we see that he is looking for the personal history of the patient's smoking, which is important in a case of a respiratory problem; he also searches for the occupational history which could be a factor in precipitating his asthma attack. The subject also requested the pulmonary function test which will enable him to monitor this patient following the treatment. A similar type of inquisitiveness was seen in the case of another senior physician, the subexpert. Following is an excerpt selected from the protocol of sub-expert 3:

Excerpt from the protocol for the patient management
Sub-expert 3; Case 1, Asthma

------there is no mention about smoking history but that was obviously of important because if he has a smoking history the COPD becomes more likely. Infact with this polycythemia, it becomes most likely. The other thing not mentioned in history that whether or not this factory has any occupational risk associated with it. Whether there is any specific exposure or chronic allergic exposure that might result in chronic lung disease. So we do not know these two things. It sound like from chest x-ray that there is evidence of interstitial disease. So specific relation to these are probably out. Other things you know, there are things which can precipitate air flow limitation in work place and those will be important to consider. Any way!!! as contributing factors, sounds that this age group have to consider the possibility—

As shown in the excerpts, these subjects want to start their initial therapy after evaluation of the patient's condition by knowing the present physiological status of the respiratory system of the patient through an investigation of his present flow rates (pulmonary function test), which would help in evaluating the outcome of the initial therapy prescribed to the patient at the time of admission. Furthermore, these subjects emphasized the clinical, personal and occupational history of the patient in relation to the pathophysiology and etiology of his clinical state, the diagnosis and its association to other body systems.

Other subjects, such as residents and students, begin their therapeutic plan right away based on the presented data, without exploring new information. It is evident in the less experienced physicians' responses that they inquired about information which was not very relevant for the therapeutic planning of the presented case, and offered no explicit justification. For example:

Excerpt from the protocol for patient management
Resident 1; Case 1, Asthma

--------patient required admission and should be treated fairly rapidly with ventoline as a bronchodialator and with anti-inflammatory agent trying to decrease inflammatory response. So this is why we are going to give ventoline two and the half gram dose and ventoline aerosol every twenty minute. You would in addition, administer some intravenous steroids---- ----a FEV_1 part of starting the therapy and then repeat these at hourly interval. So you are going to repeat the blood gases at the same point, as well as based on clinical status you know level of consciousness you are going to decide you are going to intubate the patient. Some one like this, I would probably admit into him in intensive care unit setting----

The excerpt from resident 1 shows that he formulated his therapeutic plan right away based on the clinical information in the text in the experiment. Though he had an understanding of the seriousness of the patient's condition, he did not spend much time in exploring the history and other information. Later in the discussion of the monitoring phase, the subject (resident 1) returned to question the respiratory system status of the patient; as a part of the initial therapy he demanded a pulmonary function test, the forced expiratory volume in first second (FEV_1) without giving a sufficient explanation or justification of this procedure at this stage of patient management. Similarly, resident 2, instead of emphasizing the important critical points in the history, focused upon the un important issue of the increased level of hemoglobin, and searched for more information to relate the causal relationship of this finding, i.e. polycythemia (see Methodology; polycythemia is not an important issue in the management of the patient in the experiment).

Resident 3 in her response, requested information on the pulmonary function test, but did not justify or explain its use in her therapeutic planning. Resident 4's response shows that this subject did not show any interest in exploring further information about the case, and provided his therapeutic plan from the clinical information and textbook representation. However, this subject had a well-defined understanding of the condition of the patient, as exemplified in the excerpt below:

Excerpt from the protocol for patient management
Resident 4; Case 1, Asthma

------clinically he is in respiratory distress. I would like to analyze quickly the blood gases, to see it is an acute or chronic process. He has respiratory acidosis and I think it looks relatively acute 40 about yes!! it is acute respiratory acidosis. So he has pH 7.22 other then that so what happens, so I should tell you what I am going to do right now. OK!!. I will give him some oxygen, monitoring him vital signs, get the endotracheal tube ready, he looks like he is potential some body perhaps all the stuff tell the nurse to bring a crash card over he potential going to be intubated----

Similarly, responses from the novice subjects (students) indicates that they also did not show any enthusiasm to explore further history, and also did not request investigations (only two novice subjects [2 and 4] demanded a pulmonary function test to evaluate the results of their initial therapies). But like residents with less practical experience, these novices also called for this information at the end of their therapeutic responses, unlike the expert subjects, who began their treatment only after a long search for information.

Summary:

. The selected excerpts show that the expert and sub-expert subjects begin their therapies only after a great deal of collecting new information about the patient's condition in order to explore the pathophysiological and etiological relationship within the present condition of the patient. However, some of the novice subjects also requested more history, investigations, and further examinations of the patient, but showed a lower degree of coordination between this requested information and therapeutic planning.

For example, on the one hand, unlike that of the experts, the information demanded by novices was either not of much relevance to the patient's present state or came very late in the process when this information would have played no role in evaluating the patient's clinical state. On the other hand, the explanations given by the novice subjects for these explorations of history and investigation reports were neither complete nor justified for use in therapeutic planning. In contrast, experts demanded information right at the beginning at appropriate time in their responses, and provided elaborate explanations and justifications for their therapeutic planning.

Flexibility in therapeutic planning:

A flexible therapeutic plan involves changing management actions according to the condition of the patient at that particular moment. For example a patient is presented at stage, S_1, and a hypothetical therapeutic action, T_1, was performed which resulted in the patient's condition moving to Stage 2 at time 2. Stage 2 may mark an important stage in the patient's condition, or it may worsen in time 2; therefore, a decision should be made according to the presented state of the patient at time 2, i.e. therapeutic action T_2.

In this part of the discussion of the use of knowledge an emphasis is placed upon flexibility in experts' nature, which distinguishes them from novices.

In the research, the experts' responses show flexible representations which are based on their extensive experience and deeper understanding of the disorder and its range of presentation. Unlike those of the novices, their therapeutic actions were not rigid and dependent on the diagnosis and symptomatology of the patient. The responses seen in the group of novice subjects show that their treatment plans were a rule-based, top level representation for a given class of disease, as described in the textbook. The flexibility in expert nature is achieved by gathering a large volume of elaborate knowledge during extended domain-specific training, extensive practice with domain-specific patients and devotion to the profession. This experience provides a tool to modify their plan according to new developments in the patient's condition with the passing of time during patient management, i.e. the monitoring phases. This experience in domain-specific problems also provides a deterrent against adhesions to textbook-based rigid therapeutic plans. This flexibility in the physicians mental representation of therapeutic plans is the key to their successful results and the benefits to the patients. It is a fact that in starting from the first stage of attending the patient and providing the initial treatment plan for a hypothetical problem, there could be a number of consequences of the therapeutic procedures and pharmacological agents. These consequences could be either beneficial or harmful, i.e. adverse reactions, allergies, complications of procedures and so on. This knowledge of after effects is not completely achieved by the theoretical textbook description; it is gained by practice and experience with patient encounters in the domain. If the physician is not able to react promptly in his or her practice to these adverse after effects during the patient's monitoring phase, after prescribing the initial therapeutic plan, life threatening consequences for the patients can result.

Such flexible behavior in the experts' character was also observed by other authors (Shanteau, 1988). In his study, Shanteau found that experts have a great ability to adjust their initial decisions in a changing environment. They are always ready to make modifications in their decisions as they advance through dynamic situations, according to the feedback they receive. This author further explained that the rigidity and acceptance of top level blind commitment in decision making for previously established decisions is a characteristic of an inexpert subject.

In general, it is seen in the response protocol for the therapeutic plans that almost all of the subjects' plans began with a detailed discussion of the patient's condition based on the given information in the clinical text, then decisions were made for the prescription of the therapeutic plan. Subsequently, subjects followed up the patient from time to time and again responded, i.e. the monitoring stage. Although in the beginning almost all of the subjects responded using similar therapeutic actions, real differences in the characters of different groups of subjects were found in the later stages, i.e. the monitoring stage of patient management.

In the research experiment, the experts' responses for therapeutic planning for the presented cases showed a great deal of flexibility and modification in their therapeutic planning. It was also found that their management plans changes course according to the condition of patient at different times after the initial therapy. The flexibility in their representation is exemplified in the following general statement: "I would give this therapy and watch how the patient responds, if he does not respond well, then I would do that". Such a flexibility is apparent in the excerpt given below, which is selected from the protocol of expert 4:

Excerpt from the protocol for patient management
Expert 4; Case 1, Asthma

————-um!! So far as his oxygen concentration, he should be given. He should be put on a oxymeter right away. I would probable start him on, may be about 40% oxygen by mask see how it effects the saturation—

---------if he does not appear to be getting progressively solemnest, then we may be give him little bit more oxygen the fact is that we do not want to suppress his respiratory drive excessively by supplemental oxygen----
-------um!! after a 15 or 20 minutes he can receive another doses of inhaled aerosol beta-agonist um!! At this point either the patient is going to be improving or not----
---If not improving then decision have to be made quite early on as to whether the patient is going to be intubated and receive mechanical ventilatory support---
---I think that his hypercapnia per say and his acidemia perse are not necessarily reasons for intubation-----
---um!! If he is developing these and subsequent blood gases show continuos detoriation, I think that it is reasonable to intubate him and commence mechanical ventilatory support----

This excerpt shows that the expert, after reviewing the case scenario, made a decision to provide a controlled 40% oxygen, then to wait for say, 15 to 20 minutes, and then provide some beta-agonist which would help in relieving the respiratory tract smooth muscle constriction. At this point the subject expected some improvement as a result of the initial therapy. However, the subject also described the contingency that if there was no improvement we would modify the treatment plan by providing an intubation and mechanical ventilatory help for the patient because of his high carbon-dioxide and low blood pH levels. It is clearly explained in the excerpt that expert 4's plan begins with a detailed discussion of the patient's condition based on the given information in the clinical text, then in his decision, a particular concentration of the oxygen was prescribed. Subsequently, the physician attended and monitored the condition of the patient from time to time, and again reacted, as seen in his response.

Next, we have selected an excerpt from a sub-expert who demonstrated similar flexibility in his therapeutic planning, as exemplified below:

Excerpt from the protocol for patient management
Sub-expert 2; Case 1, Asthma

---I would do, what you describing, that the patient has to be mechanically supported. I would probably at this point um!! intubate the patient. Although I may try a trial of non-invasive mechanical ventilation. But the patient sounds like that he has to be mechanically ventilated---

In the excerpt the subject demonstrates that in a real, practical situation he would like to intubate and mechanically ventilate this patient if the patient did not respond to the plan he had prescribed before. In contrast, novice responses about their therapeutic plans were rigid and textbook knowledge-driven. This is evident in the following excerpts:

Excerpt from the protocol for patient management
Student 4; Case 1, Asthma

-----Ok.!! oxygen, well!! definitely by mask. I will get him, he is hypoxic no doubt. Um!! he has diffuse wheezing, there is spasm of respiratory airways so we will think of bronchodialators. You want specific one, you can give ventoline um!! you can give atrovent. Um!! he got history of asthma. Is he on steroid?------

The selected excerpt from the novice subject, student 4, shows a prototype of therapeutic schema, for example, if the patient has asthma, give him a bronchodialator and steroids. The student would prescribe the oxygen because the patient is hypoxic. This is a typical example of rule-based, rigid planning without further discussion of the patient's condition. This is also shown in another novice, student 1, whose response is as follows:

Excerpt from the protocol for patient management
Student 1; Case 1, Asthma

-----He got, if he actually does have history of asthma I will try to put him on bronchodialator like ventoline and see how well he responses to that. Um!! depending on how he respond and if he is not responding to ventoline I will think about starting him on i/v steroids, solu-medrol 40 to 60---

The excerpt shows that the subject derived his therapeutic plan based on the diagnosis of asthma, and gave the patient bronchdialator, steroids and so on. The excerpt from student 1 also shows a typical textbook kind of therapeutic representation for asthma, without any elaboration of the treatment plan or the patient's condition.

Summary

These examples from the different groups of subjects provide a picture for the reader of how the rigidity in the decision-making processes of subjects changes with their increasing knowledge-base. These differences were explicitly exemplified in the excerpts' selected form the protocols given for the experimental task. It could be concluded that this flexibility in the responses of the expert subjects is a function of their extensive domain-specific experience and encounters with patients.

Discussion

Basic science Knowledge

Figure 1 shows that the basic medical science propositions were used in the least quantities in comparison to the other two types of propositions, i.e., pathophysiological and clinical science propositions. This could be explained by arguing that when a physician consults the patient's data, it stimulates the physician's causal or physiopathological knowledge base to determine "What is wrong and where does the problem lie?". This causal or pathophysiological knowledge-base enables physicians to understand the underlying cause of the presented disease of the patient. As a result of this triggering, physicians try to concentrate and limit their explanations to the link between the patient's data and underlying causal factors. Once the physician achieves success in establishing an explainable relationship between the underlying cause and the patient's presented condition, he or she subsequently makes decisions for the management plan to treat the underlying cause with an appropriate correction strategy (an initial therapeutic plan).

This discussion shows that in prescribing an initial therapeutic plan to the patient, the physicians were engaged in activities requiring either a type of knowledge which enables them to search for the underlying cause of the disease, i.e. pathophysiology, or one which allows them to search for the correction strategies for the disorder in the body by therapeutic intervention, i.e., clinical knowledge. Once an initial relationship and correction strategies are established, then a process of monitoring of the patient begins. This monitoring stage is where the notion of normal body function comes into play. In this period physicians use their knowledge of normal body functioning, i.e. basic medical sciences, to compare the condition of the patient after providing initial therapy with the normal physiological state. Here the physicians use their basic science knowledge as reference knowledge. This argument supports the results observed in figures 1 and 2, which show that the basic sciences were used in the least quantities during the decision-making process for patient management. Metaphorically, we can say basic medical science knowledge is used as a foundation stone for constructing an edifice of pathophysiological and clinical science knowledge, which are important for the purpose of clinical decision making, but don't form part of a foundation.

Basic Science Propositions: More in non-routine case

In the figures, one notes that the mean numbers of propositions of basic science were greater in the non-routine case. This may be explained by the subjects' unfamiliarity with the case. In these circumstances, when the physicians are not familiar with the presented clinical problem, they begin management first by an understanding of the case. For example, physicians first of all will try to understand which of the body systems is involved. After locating the system involved, they will then establish the symptomatic relationship between the system and the presented condition of the patient. After establishing this systemic relationship, physicians begin to investigate the causal relationships between the abnormalities in the system which are responsible for creating such a problem, i.e., the explanations for each sign and symptom, and to understand the unfamiliar case. As a result of such strategy, the physicians reach conclusions after a great deal of mixed use of different kinds of knowledge which offers assistance ranging from enabling them to find out the involved body system, i.e., basic science knowledge, to enabling them to search for the causes which are creating non-equilibrium in the system, i.e., pathophysiological knowledge, and finally, correction strategy (therapeutic plan) for the causal factors, i.e., clinical science knowledge.

In summary, in unfamiliar conditions, physicians work to search for the location of abnormality, the anatomical search; the next step is to look for causes which generate non-equilibrium in the physiological state of those locations, and then physicians try to see a relation between the pathological condition and the therapeutic to bring the body to a normal state. Therefore, the use of basic science knowledge increases in the non-routine case.

Therefore, in unfamiliar conditions basic science not only plays a role as reference knowledge but also acts as a bridge between disease pathophysiology and therapeutic planning. In contrast, in routine cases physicians become familiar with the disease pathophysiology because of encounters with these routine cases in their daily practice. Therefore, they do not resort to basic science to understand systems and their normal anatomy or physiological status in the body. In routine cases, subjects start thinking about causal or pathological knowledge directly, and its correction strategies. Basic science knowledge is used only as a reference model, and only during the monitoring phase.

We can say conclusively that basic science knowledge is used as reference knowledge, and therefore does not appear in great quantities during practical clinical reasoning during diagnosis making or therapeutic planning.

Basic Science Propositions: Use increases as a function of expertise

The explanation for the increase in the use of basic medical sciences with increasing levels of expertise may be that as the knowledge of the disease increases with the experience in domain-specific problems, the ability to understand the disease, and to differentiate and evaluate features and abnormal features in the body also increase. This evaluating power of experts enables them to differentiate among the presented signs and symptoms to determine which are relevant and which are non-relevant for the presented task. When dealing with the cases, these experts bring in their basic science understanding, differentiate normal and abnormal features in the data, choose only relevant clues, and proceed further with the designated task, i.e. therapeutic planning. This quality of evaluation is a function of expertise in the domain-specific problem. For example, an absence of pulse in the ankle could be a normal feature in a small percentage of the population or could be a sign of peripheral circulatory failure and circulatory shock. Expertise in the domain enables the experts to differentiate between this normality and abnormality by allowing these physicians to relate this feature of absent pulse to other associated findings, signs and symptoms from investigations reports. A similar observation was seen in the responses of subjects during decision making for therapeutic planning involving the experiment for the asthmatic patient (routine case). The finding of "pulsus paradoxus 10 mm of Hg." was perceived as normal by the students (novices).

We could say conclusively that the increase in the use of basic science knowledge in the non-routine case could be a function of unfamiliarity with the situation in which the novice as well as the expert attempts to understand the anatomical and physiological involvement, the abnormality of the system, which might be causing the disturbances in the systemic physiology and biochemistry and resulting in such a presentation of the patient. As a result, at first hand basic science is used to recognize the systemic anatomical and physiological involvement, and secondly as reference for establishing normality to see after effects of therapeutics. Therefore the use of basic science is evident not only as reference to evaluate therapeutic outcome, but also as knowledge to search for the proper and relevant systemic involvement.

Section: 2
Directionality of Reasoning

The section presents the general results for directionality of therapeutic inferences generated by each group of subjects during therapeutic decision-making process for routine and non-routine cases of asthma and pulmonary embolism.

Tables 2 and 3 give the mean number of therapeutic inferences generated by subjects for routine and non-routine cases, respectively.

TABLE 2
Mean of Therapeutic Inferences Generated in the Routine Case by Different Levels of Subjects

	Students	Residents	Sub-experts	Experts
Backward	3.6±1.0	7.3±4.0	10.0±5.7	9.3±3.2
Forward	13.6±6.6	9.0±7.9	9.6±1.7	4.3±3.3

Values are expressed in mean standard deviation (±).

TABLE 3
Mean of Therapeutic Inferences Generated in the Non-Routine Case by Different Levels of Subjects

	Students	Residents	Sub-experts	Experts
Backward	6.3±3.3	5.3±3.3	11.3±4.7	10.6±9.5
Forward	4.3±2.6	3.6±1.7	5.3±1.7	4.3±1.2

Values are expressed in mean standard deviation (±).

The results are also reflected in Figures 7 and 10 which present a mean number of forward and backward directed inferences generated by subjects with different levels of expertise for routine case of asthma and non-routine case of pulmonary embolism respectively. The results show that all subjects use a mixture of forward and backward directed therapeutic inferences generated by all the subjects regardless of their level of expertise. These results show a differnt pattern to the studies conducted in area of diagnostic problem-solving.

Figures 8, 9, 11, and 12 show the directionality of reasoning (inferences) in the protocols generated for patient-management and therapeutic planning. The right side of the of the figures indicate the patient-information (DATA) give in the clinical text along with inferences drawn from the given clinical text (intermediatary data) by subject. The left side of the figures represent the patient-management (HYPOTHESES generated), procedures, and therapeutic agents used during management planning.

In Figure 9, the student draws a hypothesis of intubation from the cues in patient-information. This is a forward directed therapeutic inference. But further on, the student states the he cannot intubate (hypotheses) this patient because the patient is very laboured (hypothesis to explain the clinical cues). This is backward directed inferences. In Figure 9, the students' protocols show a number of arrows from right to left (forward-directed) to be much higher compared to arrows shown in the direction from left to right (backward-directed).

In contract, in Figure 10, which is based on the experts' protocols show the oposite kind of effect. The arrows with left to right (backward-directed) shown dominance over the right to left directed arrows (forward-directed).

Similarly, Figures 11 And 12 represent the non-routine case of pulmonary embolism for students and an expert, respectively. These figures also show a similar pattern of novices' great use of forward-directed inferences over backward-directed inferences. Once again, experts have a greater tendency to use backward-directed inferences.

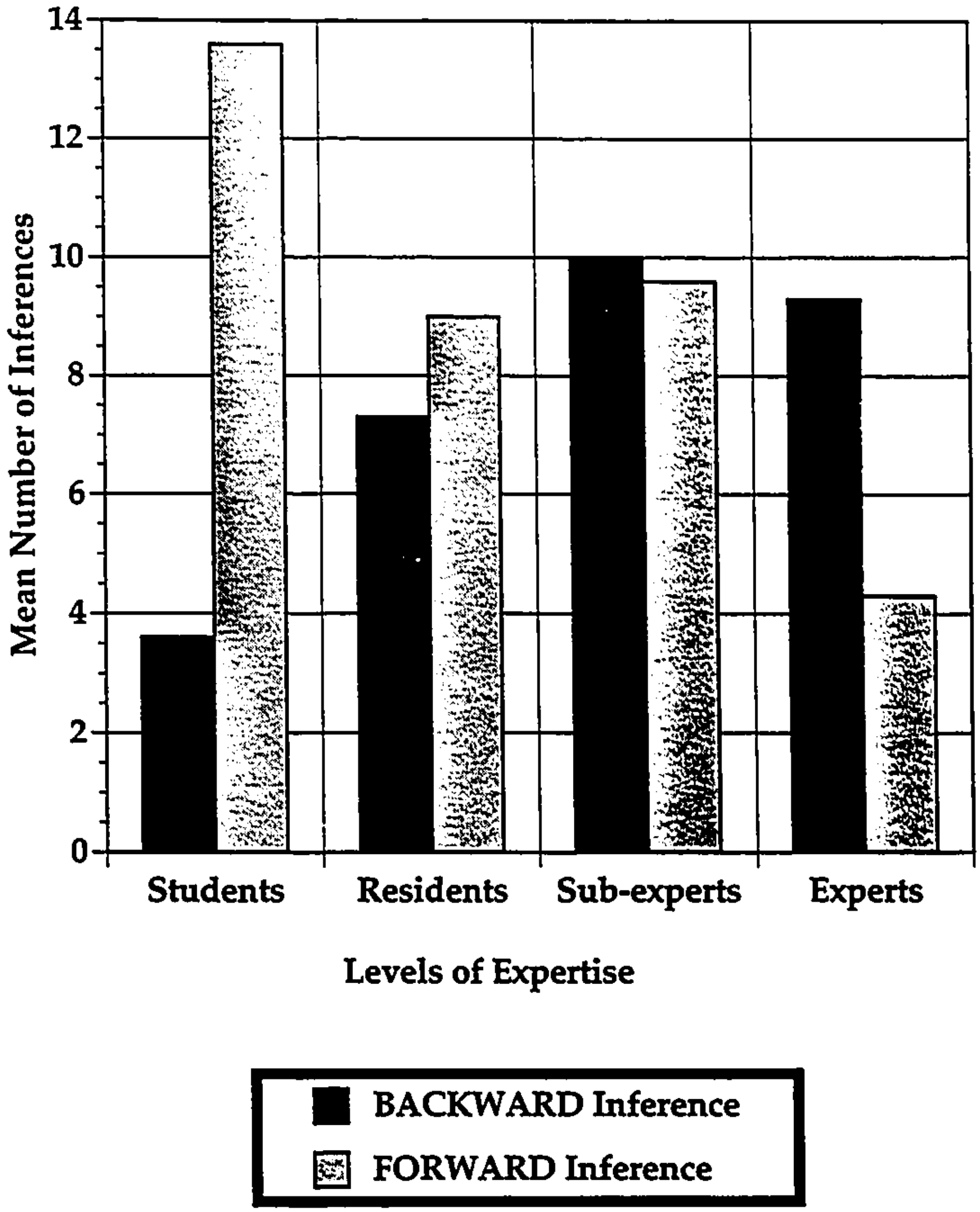

Figure 7
Mean number of backward and forward directed inferences in the protocols for therapeutic planning for routine case of Asthma by subjects of different levels of expertise

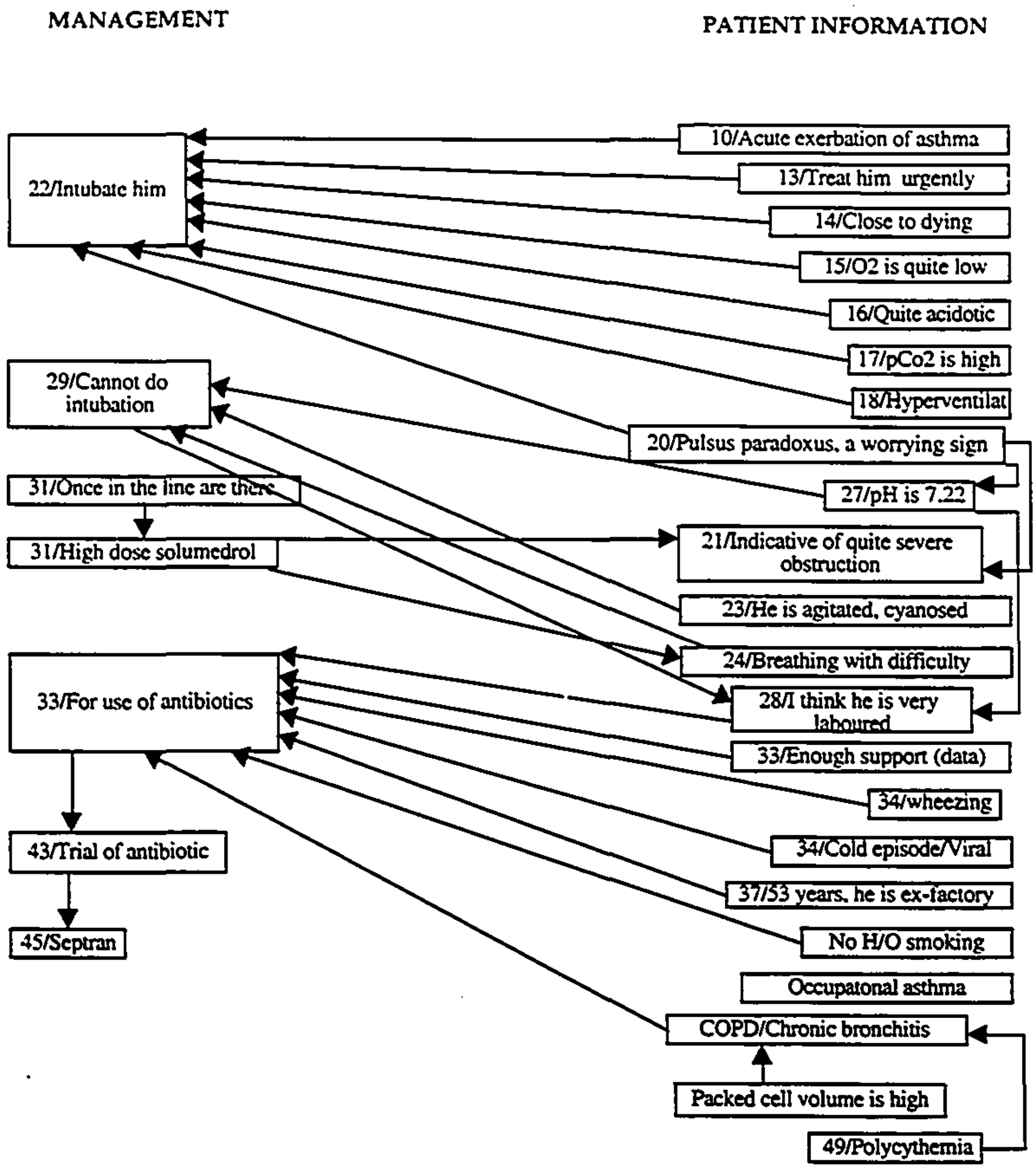

Figure 8
Directionality of inferences in the protocols for patient-management and therapeutics planning in the routine case of Asthma by student # 3
Note: The number in the blocks represent corresponding segment # in appendix 7 for the subject's protocol
Backward Inferences——Arrows Right to Left
Forward Inferences——Arrows Left to Right

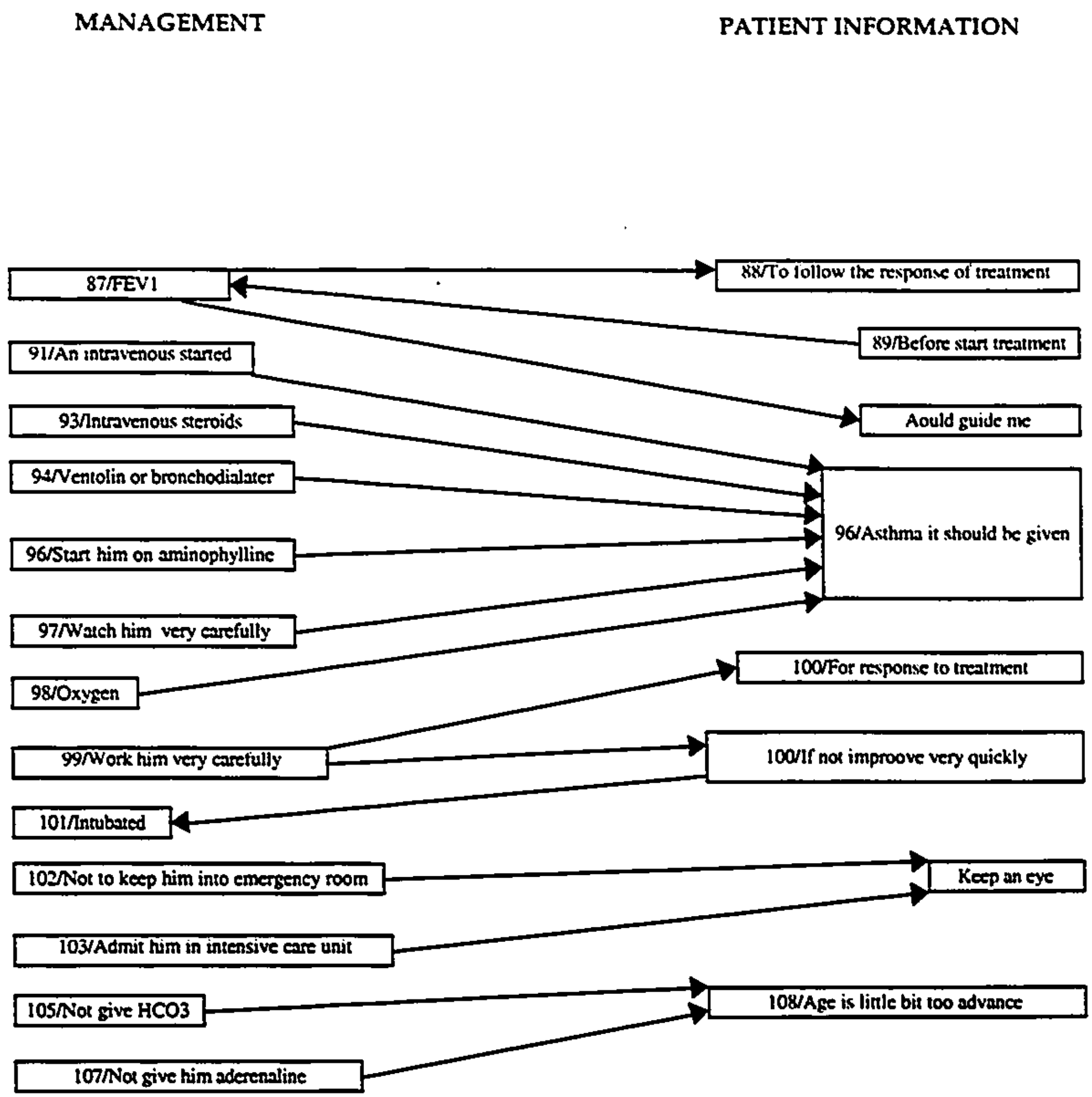

Figure 9
Directionality of inferences in the protocols for patient-management and therapeutics planning in the routine case of Asthma by Expert # 3
Note: The number in the blocks represent corresponding segment # in appendix 7 for the subject's protocol
Backward Inferences——Arrows Right to Left
Forward Inferences——Arrows Left to Right

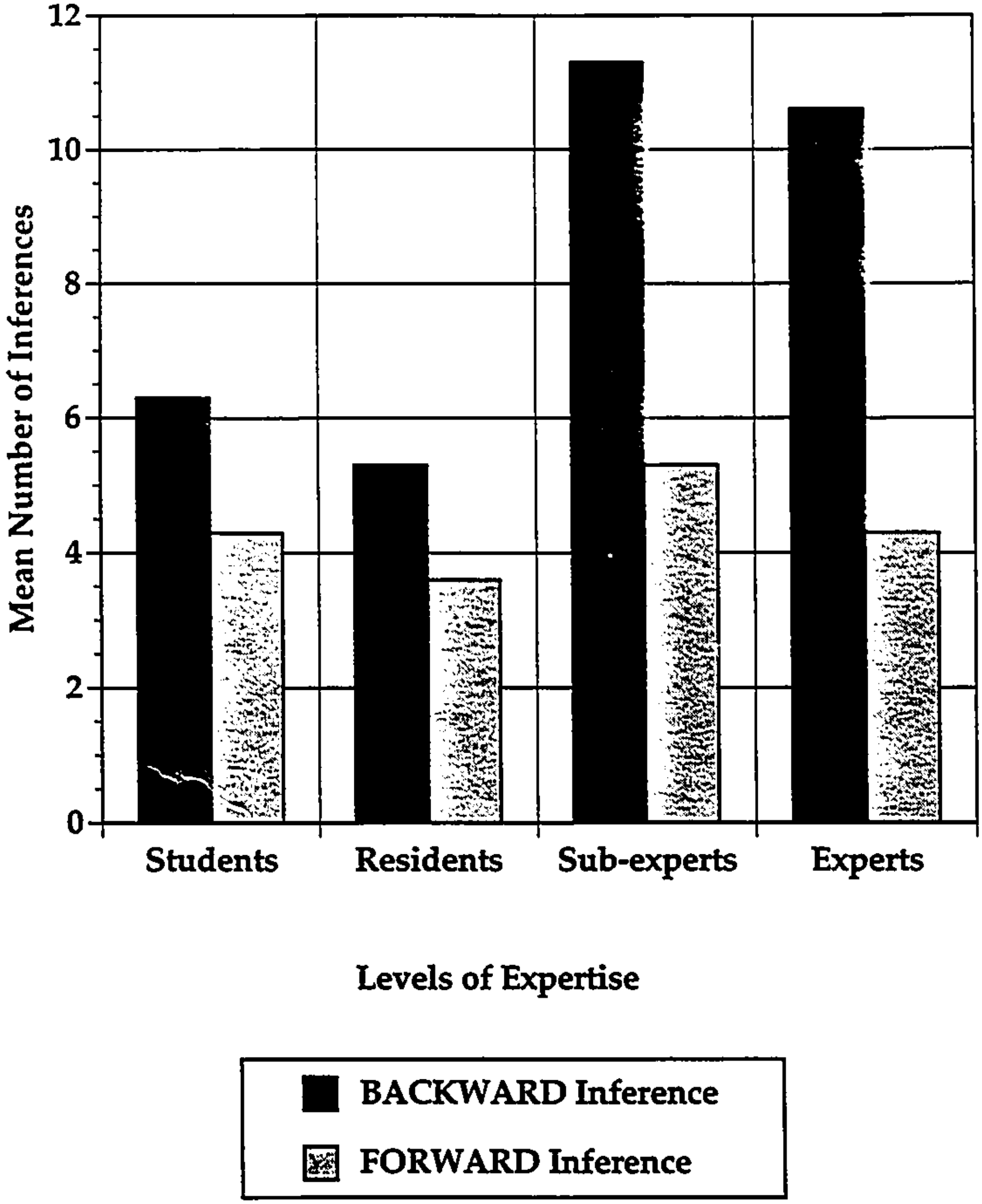

Figure 10
Mean number of backward and forward directed inferences in the protocols for therapeutic planning for non-routine case of Pulmonary Embolism by subjects of different levels of expertise

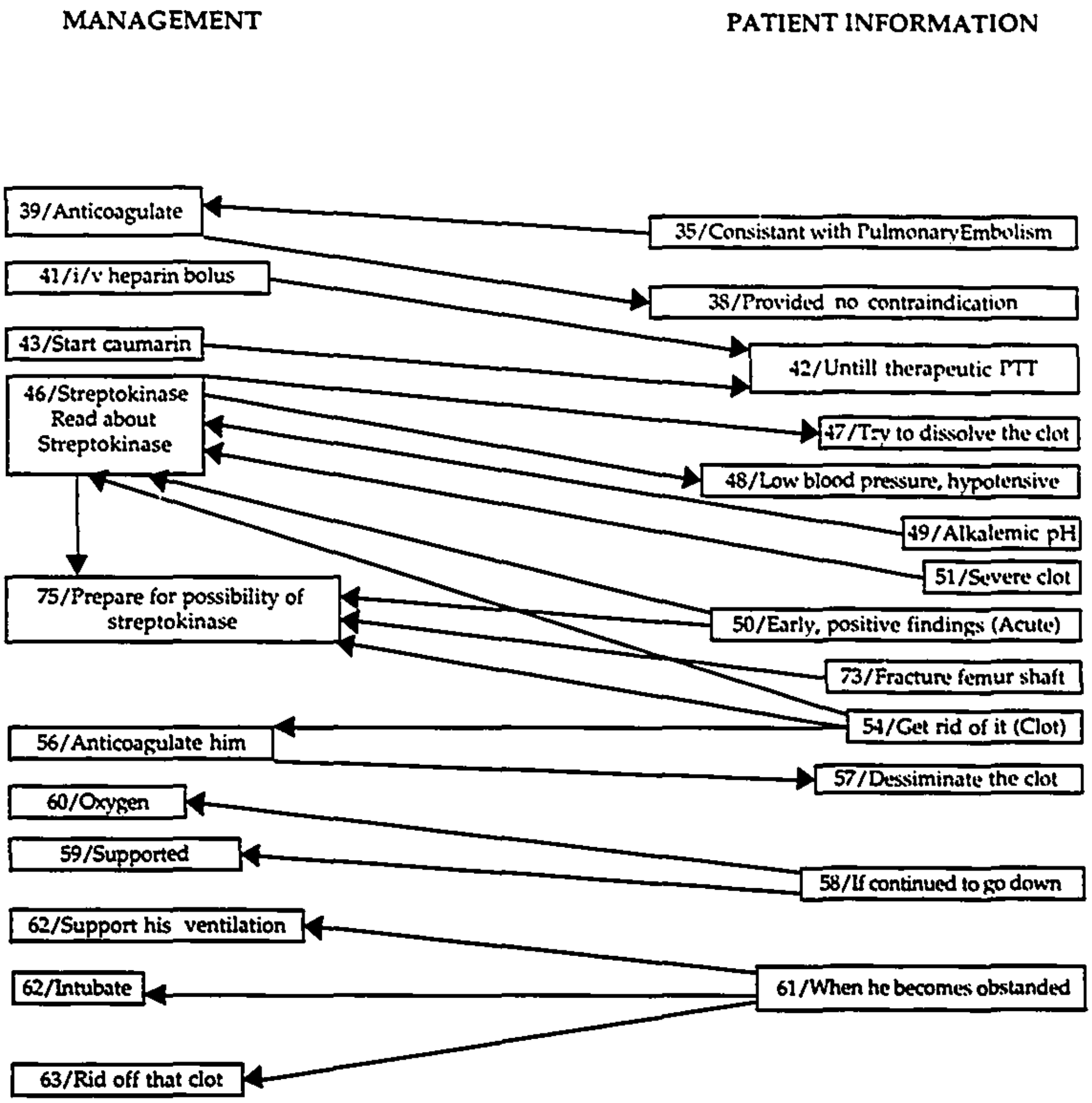

Figure 11
Directionality of inferences in the protocols for patient-management and therapeutics planning in the non-routine case of Pulmonary Embolism by Student # 3
Note: The number in the blocks represent corresponding segment # in appendix 7 for the subject's protocol
Backward Inferences-------Arrows Right to Left
Forward Inferences-------Arrows Left to Right

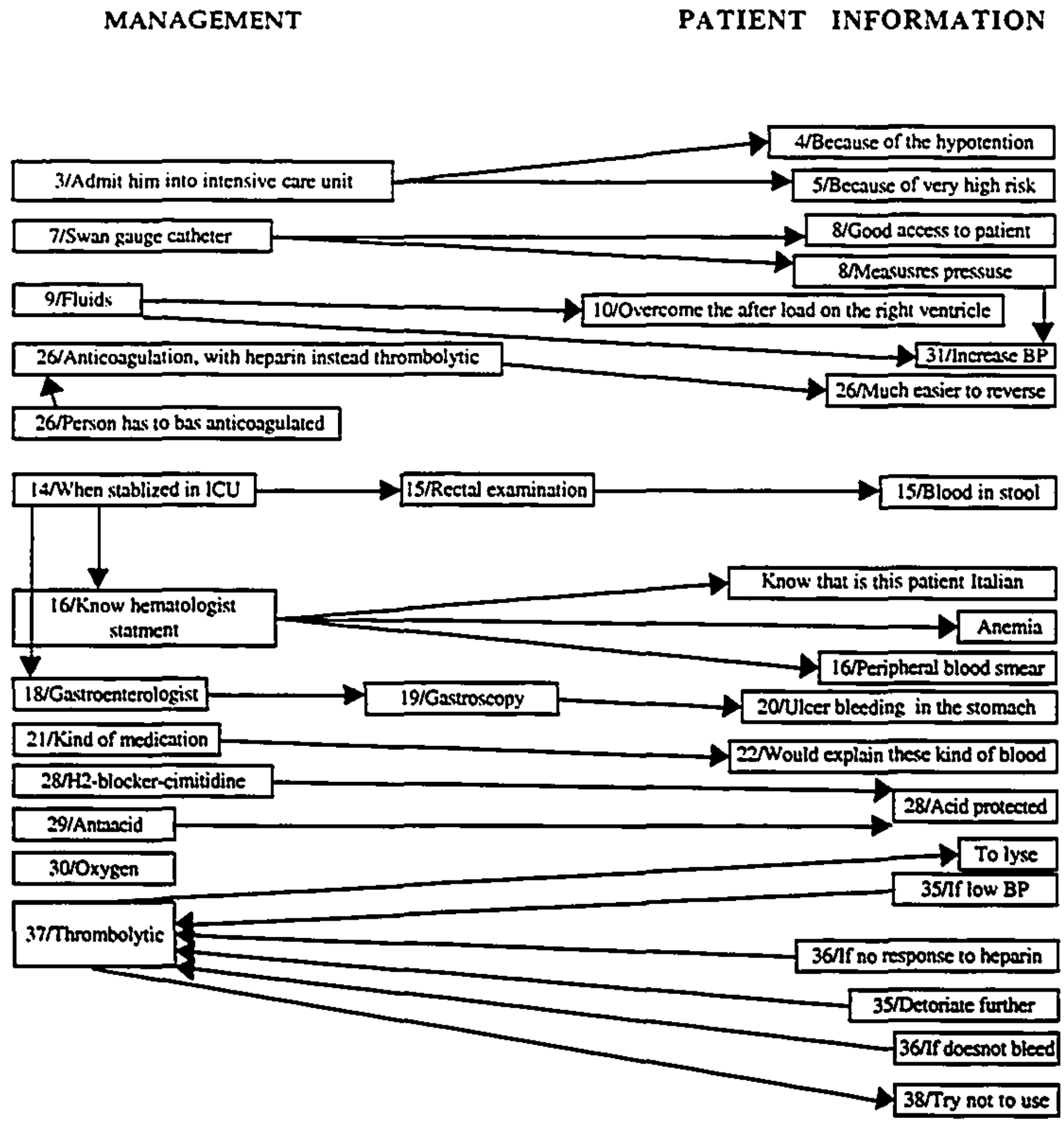

Figure 12
Directionality of inferences in the protocols for patient-management and therapeutics planning in the routine case of Pulmonary Embolism by expert # 3
Note: The number in the blocks represent corresponding segment # in appendix 7 for the subject's protocol
Backward Inferences------Arrows Right to Left
Forward Inferences------Arrows Left to Right

In the routine case of asthma, the mean number of forward directed inferences was highest within the student group (X = 13.6), and lowest within the expert group (X = 4.3). On the other hand, backward directed inferences show an increasing pattern as a function of expertise, with a peak (mean = 10.0) slightly higher than the expert seen at the level of sub-experts. In the non-routine case, the mean number of forward directed inferences remains relatively stable with increasing levels of expertise (students X=4.3, residents X=3.6, sub-experts X=5.3, experts X=4.3).

The mean range value for forward directed inferences shows a significant difference between the routine and non-routine cases (range = 9.3 and 1.7 respectively). The nature of forward directed inferences which appears to be a characteristic of novice behaviour in the area of decision-making for therapeutics and patient-management remains consistent in almost all groups of subjects when they encounter unfamiliar situations. In these non-routine conditions, both novice and expert physicians show similar tendencies (no differences were found between expert and novice groups); both generated the same mean number of forward directed inferences (X=4.3). To generate therapeutic inferences, they use the clinical clues from the patient's information (data) to generate their therapeutic plan (goal). However, the experts still use more backward directed inferences than novices in non-routine case (X=10.6 for experts versus X=6.3 for novices).

In summary, the results show that (1) forward directed therapeutic inferences were generated more by the novice than experts' group of subjects. During diagnostic reasoning, the forward directed inferences increase as a function of expertise; (2) backward directed inferences were generated more by the experts than the novices. Generation of forward directed inferences decreases with increase in expertise, and the generation of backward directed inferences increases as a function of expertise in both the routine and non-routine cases.

A Qualitative Analysis of Expert-Novice Protocols

Following are examples (excerpts) from protocols of the different groups of subjects, given for their patient management and therapeutic plans to illustrate the directionality of therapeutic inferences during decision making about treatment planning for the patient in the experiment. For example, an excerpt from a protocol of a novice subject is given below:

Excerpt from the protocol for patient management
Student 3; Case 1, Asthma

10. I think this is an acute exacerbation of asthma.
11. He may or may not have component of COPD.
12. I may treat this episode as an acute exacerbation of a potential reversible respiratory broncho-constriction problem.

The above verbatim passage shows that the subject's therapeutic plans are derived from the interpretation of clinical data and the inferences made from texual information provided in the experiment and the prior knowledge base. For example, in the selected excerpt from student 3's protocol, the subject draw an inference that this case is presented as a sudden onset of an asthma attack, and that by definition asthma is a reversible problem, and also looks into the possibility of another component of chronic obstructive pulmonary disorder. After deciding upon a potential reversible asthmatic disorder, the student further reviews the data and elaborates his decision making for therapeutic plans. The following excerpt is selected from the same subject:

Excerpt from the protocol for the patient management
Student 3; Case 1, Asthma

13.	I will treat him quite urgently
14.	This man is close to um!! dying
15.	Um!! his O_2 is quite low.
16.	He is quite acidotic.
17.	His pCo_2 is high.
18.	At least he is hyperventilating.
19.	Um!! so in terms of what I would do.
20.	He also have a pulsus paradoxus which is a worrying sign as well.
21.	Indicative of quite severe obstruction
22.	I will intubate him.

After a number of inferences and interpretations drawn from the given information, student 3 reached the conclusion that the therapy he will prescribe will be based on the assumption that there is severe respiratory tract constriction which should be treated quite urgently. Another inference drawn by the subject from the given information about the oxygen level is that the level of oxygen in the blood is very low (the levels given in the clinical text are below the normal limits). Although the blood pH is quite low (acidotic) and the level of carbon-dioxide is high, the patient has at least a high respiratory rate (a hopeful state for the patient which could be reversed, or changed to a better state) together with a high partial pressure of carbon-dioxide in the blood. The subject further looked into the text at the pulsus paradoxus, and concluded that it was a dangerous finding for the case, indicating a severe degree of obstruction. Utilizing all this texual information and inferences, the subject reached a conclusion that the patient should be intubated (endotracheal tube). As the verbatim passage shows, the subject selected and interpreted the information of low oxygen, low pH, high carbon-dioxide level associated with the pulsus paradoxus and labored breathing near fatal levels (close to dying) when he was presented with the diagnosis, and finally reached the therapeutic inference of "intubation" for his therapeutic plan. The above excerpt shows that the therapeutic inferences were drawn from the clinical data provided to the subjects. Therefore, therapeutic decisions were based on clinical terms (Arocha & Patel, 1990) derived from the given information and aimed towards the goal, i.e. therapeutics and the patient-management plan; in other words they were, forward directed inferences (Patel & Groen, 1986). An example of the selection of an alternative therapeutic plan is evident in the excerpt provided below, in which student 3 further analyzes the given information of low pH value and labored breathing and draws an inference that it will be too difficult to intubate this patient because he has labored breathing due to the severe degree of respiratory tract constriction; therefore he would prescribe a high dose of an agent which will dilate the respiratory tract. For example:

Excerpt from the protocol for patient management
Student 3; Case 1, Asthma

24.	He is breathing with difficulty, with some difficulty.
25.	I do not know, how exactly they interpret.
26.	There are various presentation.
27.	But given his pH is 7.22
28.	I think he is very labored.
29.	I probably cannot do intubation.
30.	And probably he has sudden
31.	Once there is the intravenous line in, I would fit him with high dose solumedrol.

Similar results were seen in the responses of other novice subjects, who typically derived their therapeutic schema for the presented case from the clinical data and the direct interpretation of information given to the subjects in the experiment. For example, an excerpt selected from student 2 is given below:

Excerpt from the protocol for patient management
Student 2; Case 1, Asthma

7.	Well!! the patient is not doing too well.
8.	His pulse rate is very high, and his respiratory rate
9.	He looks cyanosed
10.	His blood gases is quite poor um!! in terms of pO_2 um!!
12.	We do not have saturation here, but probably
13.	He has wheezing
14.	um!! OK. so I guess I will admit him, start intravenous um!! solumedrol

Like student 3, this subject draws her therapeutic inferences from the clinical information in the text; after reviewing the history, examination, and investigation reports, subject 2 concluded that the patient's condition was critical and that he should be admitted. Because of wheezing, she prescribes an agent, solumedrol, intravenously, which will dilate the respiratory tract and help in alleviating his wheezing problem. Similariy, the subject further reviewed the presented information and reasoned that the patient was suffering from an infection and an acute attack of asthma, therefore he would need steroids and ventoline. The justification for using these therapeutic agents is wrong, but this clearly shows that the therapeutic inferences of student 2 were drawn from the clinical information provided in the text. At this point it would not be relevant to elaborate the mistakes made by the novice subject (student 2) in her justification for the selection of the therapeutic agents because it might divert our attention from directionality of reasoning, but in short "I" could say that the response for infection should be an antibiotic rather than steroids or ventoline.

Excerpt from the protocol for patient management
Student 2; Case 1, Asthma

16.	Um!! because whatever he has superimposed on the asthma
17.	um!! I think it is that it is an asthma exhercerbation
18.	Probably an infection on top of that
19.	So he needs steroids so intravenous steroid
20.	Give him ventoline and give him atrovent

21.	He is CO_2 retainer slightly
22.	So we give him oxygen but we start off very slowly

These excerpts illustrate a reasoning strategy in which the solution is based on the given information in the problem, i.e. forward reasoning. Similarly, the therapeutic inferences drawn by the novice subjects also show a forward direction because these inferences were derived directly from the clinical text data or the interpretation drawn from the clinical information about the patient.

It could be concluded that the responses seen in the novice group for initial therapeutic action were basically derived from the given diagnosis towards the goal of patient management, namely forward reasoning (Patel & Groen, 1986).

In the next example, the excerpts selected are from the protocol of an expert subject.

Excerpt from the protocol for patient management
expert 3; Case 1, Asthma

--------86.	First thing I would do
87.	What is his FEV_1?
88.	Because that is the way you are going to follow the response of the patient for the treatment
89.	So before I start any treatment
90.	I would try to do FEV_1 it take few second that would guide me----

The above excerpt shows that expert 3, after reviewing the given information in detail, demanded an investigation procedure (pulmonary function test; Forced expiratory volume in first second, FEV_1) on the grounds that the test results or report would be able to provide information about the present respiratory status of the patient as well as assist in the evaluation of the outcomes of the therapy he is going to plan for the presented case. This excerpt indicates that the expert shows different behaviour than the novice in his response to exactly the same case, a similar task, and the same reference information. Expert 3 sought more information to increase his knowledge base for drawing therapeutic inferences. The therapeutic responses from the expert were not totally based on the information given in the experimental task, as reflected in the excerpt; rather, the decisions were based on relevant information and a deeper understanding of the presented case. Following is an excerpt from the same subject, who went further after gathering information from the text as well adding new information (ex. FEV_1):

Excerpt from the protocol for patient management
expert 3; Case 1, Asthma

91.	Um!! immediately as he comes in he should have an intravenous started.
92.	He should have the fluid.
93.	Intravenous steroids either cortico, either poly-solumedrol in a dose about 40 mg. So every 4 hourly, I mean 6 hour some thing like that to start.
94.	Then he should be given the inhaled ventolin or bronchodilater
95.	Uh!! immediately also or through nebulizer
96.	Then I would also start him on aminophylline um!! that in case there is a asthma it should be given
97.	I would watch him very carefully
98.	I would give him oxygen

After performing the pulmonary function test, the expert immediately outlines a complete therapeutic plan, for example, intravenous fluid, steroids and bronchodilators, noting that these should be given in an asthma case.

This particular excerpt shows that this expert has a therapeutic representation for a classified disorder in his knowledge base which should be given as a rule after monitoring the present status of the case. In other words, we could say that the expert in the experiment first falls back upon his knowledge base of respiratory physiology and pathophysiological changes (exemplified in his demand for a pulmonary function test) to understand the present status of the patient, and then arrives at therapeutic decisions based on the results of the new information and interpretations, rather than strictly on the data in the clinical text. Furthermore, the expert again reviewes the presented information and stresses the need for care, as reflected in following excerpt:

Excerpt from the protocol for patient management
expert 3; Case 1, Asthma

99.	I will work (watch) him very carefully
100.	Uh!! for his response to the treatment because this is a kind of person that, if he doesn't improve very quickly
101.	He might detoriate and he need to be intubated
102.	um!! I would try not to keep him into emergency room
103.	I would admit him directly to the as soon as if possible in intensive care unit
104.	We will keep an eye very carefully in the intensive care unit

In the above excerpts the same subject explains that it is very important to keep a continuous watch over this patient; the patient should be given oxygen and admitted to the intensive care unit rather than the emergency room. The patient should be monitored closely because his condition might detoriate and an endotracheal tube may be required for the proper oxygenation of the patient.

Excerpt from the protocol for the patient management
expert 3; Case 1, Asthma

105.	I will not give HCO_3
106.	You know!! I will continue with that kind of treatment to start.
107.	I will not give him adrenaline either at least at the present time
108.	Because his age is little bit too advance for that
109.	Um!! so there I would see what is his response

Later in the excerpt, it is clear that the subject also investigates an alternative line of management which is also helpful in a disorder like asthma to normalize acidic pH of blood with a counter affecting agent like HCO_3 for acidic pH, and adrenaline which acts on bronchial or respiratory tract muscle to relieve constriction as well as clear the obstruction. In his first responses the subject considered adding the therapeutic agents, bicarbonate and adrenaline, to his management plan, but then he noticed in the information that the age of the patient is "too advanced" and drew the therapeutic inference from his knowledge-base that the advanced age of the patient does not allow him to use these therapeutic agents because of their adverse effect on the heart; consequently, he withdrew his alternative therapeutic plan and decided not to prescribe these agents.

Similar findings were seen in the responses of sub-expert physicians, who also sought new information before commencing their therapeutic plans, as exemplified in the following excerpt from the protocol of sub-expert 3:

Excerpt from the protocol for patient management
Sub-expert 3; Case 1, Asthma

—it sounds like an acute episode on the background of long standing chronic respiratory disease. There is no mention about smoking history but that was obviously important. If he has a smoking history then the COPD becomes more likly infact with this polycythemia, it becomes most likely thing. The other thing that is not mentioned in history is that whether or not this factory has any occupational risk associated with it. Whether there is any specific exposure or chronic allergic exposure that might result in chronic lung disease, so we do not know these two things. It sound like from chest x-ray that there is evidence of interstitial disease so specific relation to these are probably out. Other things, you know!! there are things which can precipitate air flow limitation in work place and those will be important to concider. Any way!! as contributing factor any way sounds that this age group have to consider the possibility that cardiac dysfunction playing a role—

The above excerpt shows that before considering the therapeutic planning, the subject wanted to be more aware of the patient's present status as well as the personal, occupational and clinical history, which would help in his understanding about the etiological factors for the disorder and underlying pathophysiology in the patient's body. The subject justified his queries about smoking history so as to exclude the possibility of chronic obstructive pulmonary disease (COPD); also, occupational exposure could be a cause of allergies and chronic lung disease. This indicates that the sub-experts selected the similar line of treatment as the novices, but only after collecting a vast amount of relevant information to justify the patient's clinical state and to select the appropriate treatment. The following excerpt illustrates that even after inquiring for so much information, the subject selected a similar line of treatment as the novices:

Excerpt from the protocol for patient management
Sub-expert 3; Case 1, Asthma

--but depending on my initial diagnosis, I would give atrovent, ventolin, and steroid. Also probably put him on an antibiotics as well to cover the possibilities he might have the tracheobronchitis--

Here, the subject selected the same basic procedures as are described in the textbook for the treatment of asthma. Therefore, it could be concluded that directionality in sub-expert reasoning shows a forward kind of inference.

As was discussed in the section on the use of knowledge, the senior experienced physicians spend a lot of time collecting new information and forming a suitable therapeutic representation before prescribing their therapeutic plans. The selected excerpt from expert 3 clearly shows that his therapeutic decisions came after collecting a degree of new information in the patient's data which resulted in an increased number of backward directed inferences for their therapeutic plans. Although the directionality of therapeutic inferences in the experts' responses also show a forward orientation, like that of the novices, there was a clear difference in that the experts' sought a great deal of new information to search for the underlying cause of the disorder and to justify their procedures in their therapeutic plans.

A similar kind of analysis was conducted to look for the reasoning strategies in the different groups of subjects when they were dealing with the non-routine case and making decisions for its treatment. The following examples are selected from the protocol of student 3 during his decision-making process:

Excerpt from the protocol for patient management
Student 3; Case 2, Pulmonary Embolism

17.	Blood gas!! this time he is fairly alkalotic
18.	His pO_2 is low, his pCO_2 is low as well
19.	He is hyperventilating.
20.	Because does not have agreeable shunt what he did before
22.	He is hyperventilating in order to compensate to his lower in pCO_2
23.	and become alkalotic as a result.
24.	Um!! inspite of this, his bicarbonate is reasonably normal.
25.	Blood glucose nothing, sodium is little above, chloride
26.	Um!! renal function is fine.
27.	Packed cell volume is little low.
28.	Nothing in the white count, thyroxin is quite normal, these are the old diagnosis.
29.	Prothrombin is little.
30.	Um!! PTT is usual, albumin is low fine!!
31.	No abdominal mass
32.	ECG tachycardia OK.
33.	Um!! consolidation fine.
34.	Blood cut off negative shadow fine
35.	I find this whole, this is fairly consistent with pulmonary embolism.
36.	Um!! without positive pulmonary angiogram been really
37.	At this point, so I would anti coagulate him

This excerpt of protocol shows that the subject made a therapeutic decision to anticoagulate the patient as a result of the consideration of multiple symptoms and signs from the information in the clinical text, such as low levels of oxygen, low levels of carbon-dioxide, high pH of blood and other information. Considering these data, the subject decided to prescribe an anticoagulant therapeutic agent, which is a typical therapeutic procedure described in the textbook that does not consider the underlying cause of this presentation; this shows a forward directionality of inferences in the novice's therapeutic planning from the data to the goal or management procedures.

Excerpt from the protocol for patient management
Student 3; case 2, Pulmonary Embolism

46. I would also give him streptokinase.
47. Um!! I would try to dissolve the clot.
48. Because it obviously has low blood pressure.
49. He has alkalemic pH.
50. He is very very early (acute) sort of positive findings.
51. It is quite a severe um!! clot um!!I want really to get rid of it.
52. Uh!! so I would probably give him some streptokinase.

Subsequently, the student selected another therapeutic agent which belongs to a totally different class of drug and a different mechanism of action, in order, as the subject says, to dissolve the clot, because of low blood pressure and alkalemic blood pH (given in the clinical text). The above excerpt clearly shows that the decision regarding thereapeutic plans for the non-routine case were drawn directly from the clinical information given in the experiment, indicating a forward kind of therapeutic inference by student 3. Similar findings were seen in the responses from another novice subject, given below:

Excerpt from the protocol for the patient management
Student 2; case 2, Pulmonary Embolism

20. Um!! blood pressure is 80/60
21. Respiratory examination an increased respiratory rate and diminished chest movement
22. No clubbing no central nervous system localising sign are noticed
23. His blood gases, pH was 7.50 that a little bit alkalemic
24. pO_2 is 60
25. He has been hypoxic
26. pCO_2 is 30, HCO_3 is 25—

——so pulmonary angiogram is a high probability of pulmonary embolism–

This shows that the subject read through the data and concluded, after interpreting the report of the pulmonary angiogram that this given case has a high probability of pulmonary embolism. Consequently, as shown in the excerpt below, he prescribed heparin together with streptokinase to dissolve the clot:

Excerpt from the protocol for patient management
Student 2; case 2, Pulmonary Embolism

—um!! I would start him on heparin first with the bolus of 5000 to 10,000
39 And then 1000 units an hour and also moniter his PT, PTT every day
40. Um!! because of his pulmonary embolism
41. Also it depends on how long he develop this breathlessness and a cough
42. because of I think he needs streptokinase or some thing to dissolve clot
43. depending on how long ago it was, I will keep him in hospital on strict bed rest--

It is evident that the subjects' decisions for treatment plans were directed from the given information towards patient mananagement, indicating forward directionality in the therapeutic inferences.

Summary

One may conclude that the therapeutic inferences drawn by the experts begin with gathering new information from their knowledge-base (new information for deriving therapeutic inferences) to promote a deeper understanding of the clinical state; they then articulate a solution for patient management. This kind of approach also entails a forward directed reasoning strategy, but the addition of this new information and inferences, which serve as data for clinical decision making, changes the nature and consequences of the therapeutic response. Therefore, the direction of therapeutic inference in the expert group as well as the novice shows a forward directionality (Patel & Groen, 1986), but the examples from the responses clearly indicate that the explanations and justifications given by the novice and expert subjects reveal a different approach in their planning. For example, the explanations and justifications of therapeutic decisions in the novice group were top level, rule-based, as exemplified in the textbook, with no sense of a deeper understanding of the presented case, and were strictly dependent on the clinical information in the experimental text. This kind of superficial or surface knowlege results in incorrect and unjustified decisions (for example, student 2, steroid for infection), which are sometimes disastrous (for example, oxygen therapy by student 1). However, decisions by expert subjects about therapeutic planning were based on a deeper understanding of relationships between pathophysiological knowledge with the clinical information presented for the cases in the experiment; the decisions were well justified and explicitly explained using the expert physicians' knowledge-base with the addition of a number of new facts, and new information which is obviously beneficial for the patient. One could easily conclude that the therapeutic inferences drawn on causal terms would show dominance of backward reasoning (Patel and Groen. 1990).

Another interesting result shown in the analysis is that, although the direction of therapeutic inferences and procedures and therapeutic agents used by the subjects at different levels of expertise show a similarity in their responses, the consequent results would have been different (based on case explanations; described in the chapter on methodology). This supports the argument that the use of procedures and therapeutic agents alone is not the only important element in the clinical decision-making process; a deeper understanding of pathophysioloical and clinical symptomatology is equally important for correct therapeutic planning and its consequences, as seen in the responses by expert subjects (see the Use of Knowledge section [Patel and Groen, 1986]).

Discussion

Forward inferences in novice subjects during decision-making activity regarding the treatment plan can be explained by the novice's tendency to use a prototype management plan which is based on clinical textbooks with a minimal reference to basic science and pathophysiological knowlege. These textbooks typically mention a symptomatic therapeutic plan in the form of rules; for example, if pain is present then give an analgesic or pain-killer; if there is fever then prescribe an antipyretic. This constitutes a basic higher level therapeutic representation developed on a rule basis, i.e. "if this, then that". The novice subjects, in the beginning, have such a prototype of therapeutic representation for the disease or for particular problems. However, as the subject's understanding of the causal or pathophysiological relationship of the disease increases with experience in the domain, these individual abnormal findings (based on various symptoms) take the form of a single disease entity representing the multiple symptoms in a single class or name of the disease. This disease name represents all the signs and symptoms in the patient in one class, based on their causal relationships (this particular disease is caused by a particular kind of pathophysiology or cause, which results in such a symptomatology, i.e. signs and symptoms). This results in the creation of a new taxonomy (disease) for these symptomatologies, which represents all those signs and symptoms which are related to a particular disease and its causal or pathological entity. This modification in causal understanding about the disorder with an increasing level of expertise in the domain-specific problems also allows the physicians to change the symptomatic therapeutic representation into a global-therapeutic representation (causal or pathophysiological therapeutic representation) for that particular disease. Therefore, when experts come in contact with a patient, they look at clinical data, which they recognize as a single pattern of disease. They then derive therapeutic inferences or a representation learned for this particular disease which is based on its underlying pathophysiology and the normal physiological state knowlege-base, and apply it without considering individual symptomatology, i.e. signs and symptoms. This explains the higher number of experts' backward directed therapeutic inferences: experts generate new information and inferences from their knowlege-base, instead of depending upon the information that novices do, texual data given at hand in the experiment during patient-management planning.

In other words, when the expert physicians were provided with the diagnosis, in addition to considering the signs and symptoms in the clinical text, they took time to seek new information and to understand the actual condition of the patient, and made an attempt to go to a deeper level of understanding of the underlying pathophysiology of the disease. Only once they understood the real clinical state of the patient then did they draw their therapeutic inferences for the cause of this diagnosis or disorder. In contrast, the novices, because of their poor understanding of the causal relationship between the disease and its symptomatology, processed their therapeutic plans based only on information given them about the patient. As a result, the management plan of a novice is in the form of symptomatic treatment based on an orientation of exact data to therapeutic inference (forward directed inference), in contrast to that of an expert, whose inferences show a backward direction of therapeutic inferences, from the causal knowledge to the presented data and then to therapeutic inference.

As a result of changes in behaviour with increasing expertise, it could be argued that the generation of an increasing number of backward directed inferences is a function of expertise, specifically during the therapeutic decision-making process. This also explains the peak seen in backward directed therapeutic inferences in the case of sub-experts in the non-routine case. As explained before, the non-routine case, pulmonary embolism, lies closer to the domain of expertise of the sub-expert subjects (cardio-pulmonary researchers).

If the given information is important, the diagnosis is also an important element for the purpose of patient management and therapeutic decision making. This is because of the close relationship between the treatment and diagnosis of the disorders or diseases; a correct diagnosis leads to correct therapeutic planning. The wrong labeling of the disease can lead to a wrong management of the disease. Though it is readily apparent that a correct diagnosis will lead to correct decision making about treatment, if the underlying explanations are not adequate enough to justify the management plans, then the long-term management of the disease would disintegrate and disastrous results may ensue. The arguments for more and better understanding of biomedical sciences for therapeutic treatment and patient-management planning alone are not sufficient; explanations and justifications supporting such therapeutic decisions appear to be extremely important.

In the research, it was shown that the procedures used by novices, residents, sub-experts, and experts were often similar and invariably correct in both the routine as well as the non-routine case. Although, as seen in the results, both novices and experts used forward-directed reasoning during patient-management and therapeutic decision-making processes in both cases, it was noticed that experts were more successful in deciding on the correct procedures and therapeutic agents in comparison to the novices. This success results from their deeper understanding of causal or pathophysiological and basic biomedical sciences knowledge-bases. This was exemplified in detail in the chapter of results in the section on "The Use of Knowledge", where the excerpts selected from different groups of subjects showed that the understanding of the presented case in the experiment was greater and deeper in the group of expert physicians whether they were expert in the domain of respiratory medicine or in cardiology. These subjects showed a real coordination of their pathophysiological and basic science knowledge-bases with the clinical state of the patient in prescribing their therapeutic plans, whereas the less experienced physicians remained confined in the top level, rule-based representation as learned from textbooks and classroom lectures, although novices also reasoned in the forward direction, and prescribed similar procedures and therapeutic agents. They were not successful, however, (and were sometimes disastrous) because their knowledge-base was inadequate to support the decisions of their therapeutic plans, although they used exactly the same procedures as the experts. This research shows exactly the same reasoning during diagnosis as was shown by Patel and Groen (1986), and supports the hypothesis that forward reasoning without an adequate knowledge base can lead to unwanted situations of clinical medicine, i.e. danger to the patient's life. This research also supports the view that forward reasoning can not be specifically taught (Lesgold, 1988); rather it develops as the knowledge-base develops during medical training and through practical experience.

As was discussed previously, when correct, relevant, complete and non-confusing information was provided to the subjects, they were able to reach their decisions quickly. Also, with the assistance of a correct diagnosis most of the subjects' directionality of reasoning showed a forward orientation in their inferences in their therapeutic plans. This is exemplified in the responses in the subjects' protocols. This could be explained as follows: the non-routine case in the experiment was a straightforward case with a gold-standard investigation report of angiography showing a positive finding for pulmonary embolism, leaving no doubt or confusion in the physician's mind about the diagnosis, and therefore no requirement for a further search for the information to help decide on and draw therapeutic inferences. On the other hand, the routine case in the experiment was a long-standing respiratory case with some atypical findings, such as increased hemoglobin or polycythemia, which created some confusion in the physicians' thinking processes about the presented case, although the presented problem of polycythemia was not acute and required no immidiate correction. The subjects' work lead towards exploring new information to search out the pathogenesis or causal relationships of the atypical findings and justifying their therapeutic plans for the present case and correction strategies of this pathology. This results in the creation of more backward inferences for therapeutic planning in the routine case in comparison to the non-routine case. This explanation also supports the view that for forward reasoning accurate information is necessary.

The novice subjects, who did not show any enthusiasm for generating new data or for thinking at a deeper level about the patient's condition, drew their therapeutic inferences based upon the presented clinical information in the text (clinical term; forward reasoning), and prescribed a textbook kind of top level treatment.

These results show not only the experts' greater dependence on causal or backward therapeutic inferences in comparison to the novices, but also the experts' tendency to explore, generate and add new information, even in the presence of correct given information, which results in the generation of more backward directed inference. This exploratory and inquisitive character in experts is rewarded by the prescribing of beneficial therapeutic plans to the patient for short-term as well as long-term treatment. This deeper level of understanding about the presentation of the disease is achieved by extensive practice in the domain for a number of years, many encounters with a number of patients, and a wide range of presentations of the same disorder in different patients. This deeper understanding allows expert physicians to analyze the patient's condition according to the actual underlying pathophysiological disturbances in basic normal physiology, and then draw the correct therapeutic inferences to treat these abnormalities in the system to bring the patient from the clinical to the normal state. This deeper understanding of basic and pathophysiological sciences also allows these expert physicians to draw cause-based therapeutic inferences, instead of providing rule-based treatment, which obviously results in the correction of the actual cause, and long-term benefit to the patients, rather than time-bound symptomatic relief.

Section: 3
Explanations of Pathophysiology underlying the Clinical Cases

A detailed analysis was conducted on the explanation protocols generated by the subjects with respect to the use of information from (1) the stimulus clinical cases provided to the subjects, and (2) the therapeutic planning protocols generated by the subjects in this study. These explanatory responses were given by subjects at different levels of expertise in response to the question on providing the underlying pathophysiological explanation of the problem. These protocols were compared against the clinical text and the "think aloud" protocols on therapeutic decision making. A qualitative analysis of the items of information used by the subjects in their explanations that come from the given text and the therapeutic responses is provided on Tables 5 and 6 for routine and non-routine cases, respectively.

TABLE 4
Information Used in Explanatory Protocol
Case 1: Asthma

SUBJECTS	DATA FROM THERAPEUTIC RESPONSE FOR EXPLANATORY PROTOCOL ROUTINE CASE A	DATA FROM STIMULUS TEXT FOR EXPLANATORY PROTOCOL ROUTINE CASE B
STUDENT 1	1. Infection 2 Eosinophils	1. Cough 2. Cold
STUDENT 2	1. COPD 2. Infection	1. Cold
STUDENT 3	1. Factory worker 2. Obstruction 3. Occupational asthma 4. Pco_2 5. Pulsus paradoxus	1. Ex-factory worker 2. Eosinophils 3. Microscopic finding of sputum
STUDENT 4	1. Common cause Infection	1. Ex-factory worker 2. Eosinophils 3. Thick gelatinous sputum 4. Blood pH 5. pco_2 6. o_2 7. Pulsus paradoxus
RESIDENT 1	1. Precipitated by URTI 2. Inflammatory response	1. Eosinophils
RESIDENT 2	1. Ex-factory worker 2. Infection 3. Metabolic acidosis	1. Ex-factory worker 2. Wheezing 3. Eosinophils
RESIDENT 3	1. Broncho dilators 2. Steroids	1. sputum
RESIDENT 4	1. pH 7.22 2. X-ray	1. sputum 2. co_2 3. pH 7.22 4. Lung X-ray 5. Bicarbonate
EXPERT 1	1. History 2. Smoker 3. Chronic air flow obstruction	1. Prolong history 2. Eosinophils 3. Cold
EXPERT 2	1. airways obstruction	1. pco_2 2. Blood pco_2 3. Wheezing
EXPERT 3	1 Pco_2 2. Metabolic acidosis 3. Po_2	Nil
EXPERT 4	1. COPD 2. Occupation	Nil

TABLE 5

Information Used in Explanatory Protocol
Case 2: Pulmonary Embolism

SUBJECT	DATA FROM THERAPEUTIC RESPONSE FOR EXPLANATORY PROTOCOL NON-ROUTINE CASE A	DATA FROM STIMULUS TEXT FOR EXPLANATORY PROTOCOL NON-ROUTINE CASE B
STUDENT 1	1. Pain in chest 2. Cough	1. Pain in chest 2. Cough
STUDENT 2	1. Fracture femur shaft 2. Immobilization 3. Anticoagulant	1. Fracture femur shaft
STUDENT 3	1. Deep vein thrombosis 2. Fracture femur shaft 3. Immobilization 4. Clot 5. Cannot compensate 6. Po_2 7. Pco_2 8. Alkalotic	1. Fracture femur shaft 2. Further away from periphery 3. Po_2 4. Pco_2
STUDENT 4	1. Fracture femur shaft 2. Hypercoaguable state	1. Fracture femur shaft 2. X-ray chest
RESIDENT 1	Nil	1. Fracture femur shaft 2. Embolus
RESIDENT 2	Nil	1. co_2
RESIDENT 3	Nil	1. Two weeks
RESIDENT 4	1. Fracture femur shaft 2. Pco_2	1. Fracture femur shaft 2. Two weeks 3. Blood pressure 80/60 4. Pco_2 5. Embolus
EXPERT 1	1. Healthy	1. Femur 2. Healthy
EXPERT 2	Nil	1. Po_2 2. Car accident 3. Prothrombin time 4. Breathlessness 5. Severe chest pain 6. ECG normal
EXPERT 3	1. Heparin 2. Hypotention 3. Increased blood pressure	1. Fracture femur shaft 2. Filling defect 3. Pulmonary
EXPERT 4	1. Thrombophlabitis	1. Pulmonary

The mean number of such items of information used by all subjects is given in Tables 6 and 7.

TABLE 6
Mean Numbersof Items or Information Used from Clinical Text for Explanatory Responses Generated for Routine and Non-Routine Cases by Subjects at Different Levels of Expertise

Case	Students	Residents	Experts
Routine *	3.25±2.6	2.50±1.9	1.50±1.5
Non-Routine **	2.25±1.1	2.25±1.7	3.00±1.9

Values are expressed in mean standard deviation (±).
* Numbers correspond to Table 6 (B)
** Numbers correspond to Table 7 (B)

TABLE 7
Mean Numbers of Items or Information Used from Therapeutic Responses for Explanatory Responses Generated for Routine and Non-Routine Cases by Subjects at Different Levels of Expertise

Case	Students	Residents	Experts
Routine *	2.50±1.5	2.25±.43	2.25±.85
Non-Routine **	3.75±2.48	0.50±.86	1.25±1.08

Values are expressed in mean standard deviation (±).
* Numbers correspond to Table 6 (A)
** Numbers correspond to Table 7 (A)

The results showed that the explanations generated by individual subjects for the causality of the disorder were mostly independent of the stimulus text, and their therapeutic plan, and the clinical presentation of the disorder. All subjects used very little direct or verbatim information from the clinical text or their therapeutic planning in their explanations. The results indicate that when the subjects were asked to explain the underlying pathophysiology of the disease, they generated this explanation independently using different knowledge source.

Tables 6 and 7 give the mean number of items of information used to explain the pathophysiological explanation for routine and non-routine case respectively. In the routine case of asthma, it shows a decreasing trend as a function of expertise (subexperts were excluded for this analysis) with students (3.25), residents (2.5), and experts (1.5). There were no differences seen in non-routine case of pulmonary embolism. It is interesting to note that the information, or the items from the clinical text, or the response protocol for the therapeutic decision-making, was used to generate a relationship between the main concepts (clinical knowledge) for the disease. For example, the main concepts for the pathogenesis of the routine case are the infections or irritant dust and hyper-reactivity of the respiratory tract lining (mucosa and muscle), whereas main concept for the development of pulmonary embolism is the "Virchow's Triad". The subjects mainly selected items which could relate and justify their causal or pathophysiological explanations about the disease in the experiment.

A Qualitative Analysis of Expert-Novice Protocols

To show the difference between experts and novices' explanatory responses the following excerpts were selected from the protocol of subjects with different levels of expertise. An explanatory protocol of student 1, as given below:

Excerpt from the protocol for Pathophysiological Explanation
Student 1; Case 1, Asthma

—Asthma, it is a hyperreactivity of airways. Um!! usually there is some underlying cause like either some infection or cold triggered asthma. If he is allergic to some thing like hay or whatever. So in this case seems like his episode triggered by a upper respiratory tract infection—

The excerpt shows that the subject described asthma as a disorder of hyper-reactivity of the airways, possibily caused by infection or cold or some allergies which triggered the respiratory tract. Next, I have selected another excerpt from the same subject regarding the explanatory response for the non-routine case, as given below:

Excerpt from the protocol for Pathophysiological Explanation
Student 1; Case 2, Pulmonary Embolism

——um!! in pulmonary embolism clot usually from the femoral vein that shoots off and goes into the lung and that block off the artery—— —and patients usually gets um!! sudden stabbing pain in their chest and they are short of breath—

The excerpt shows that the subject in her explanation for the pathogenesis of the pulmonary embolism justified that this disorder is a result of the impaction of the blood clot coming from the femoral (leg) veins, which caused a sudden severe stabbing pain in the chest. Similar observations were found in the protocols of other students; for example, in the routine case, student 2 used the concept of infection, whereas student 3 explained the pathogenesis based on the concept of occupational dust and allergies. In explanatory protocols for the non-routine case, students explained the pathogenesis of the disease based on the concept of Virchow's triad by interpreting the stasis of two weeks of hospitalization and bed rest as part of fracture management, and the injury to the vessel as a result of injury to surrounding tissue during the accident leading to clot formation.

The above selected excerpts indicate that the subject attempted to relate the pathogenesis of the disorders with her pathophysiological knowledge-base with the clinical presentation by selecting or interpreting only a few items from the text.

Next, I consider an example from the explanatory protocol of resident 2, as given below:

Excerpt from the protocol for the Pathophysiological Explanation
Resident 2; Case 1, Asthma

———He is an ex-factory worker and we have to see what sounds like is an acute episode of wheezing following a upper respiratory tract infection. This suggests that he has a reactive airways. I would wonder about any occupational exposure as well other occupational exposure in a factory. But certainly he may have left with reactive airways following his occupational exposure——

In the excerpt, resident 2 used items from the clinical text, such as the history of an ex-factory worker, wheezing, respiratory tract infection (interpretation for common cough and cold) to relate the presented disorder with his explanation for the underlying pathogenesis for the presented case using the concept of hyper-reactivity because of viral infection and dust exposure from his work environment. A further excerpt, from the protocol of resident 1, is given below:

Excerpt from the protocol for Pathophysiological Explanation
Resident 1; Case 2, Pulmonary Embolism

——We say clot is formed in the leg and there is always risk factor for that endothelial damage, stasis, hypercoagubility are the risk factors being usually in the leg vein thrombus within the popliteal vein or much proximal to that in the pelvis. In this case the patient had a damage during automobile accident and get a fracture shaft femur. So you know!! there is the risk of deep vein thrombosis, dislodges, goes to right hand side circulation, goes to right heart and lodges in one of the pulmonary arterioles or arteries—

The selected excerpt shows that the subject attempted to relate the pathogenesis of the presented case by selecting some of the items from the information given in the clinical text with the pathophysiological concept of the development of thrombo-embolism, i.e. Virchow's triad, and once the subject was able to do this, he went further to elaborate the events of the progress of the disease, like the dislodging of the clot, the impaction of the clot in the pulmonary artery, and so on. Similar findings were seen in other residents' protocols, who used the same concepts for describing the causal mechanism of the disease in the experiment.

The protocols of expert subjects also show the use of similar concepts as the student and resident subjects, but in their explanations one can clearly observe that the conceptual (described earlier for the routine as well as the non-routine case) understanding was much deeper, and the explanations were much more relevant and elaborate compared to less experienced subjects. To exemplify this more elaborate response, an excerpt from the protocol of expert 1 is given below:

Excerpt from the protocol for Pathophysiological Explanation
Expert 1; Case 1, Asthma

------Pathophysiology of air flow obstruction is multi-factorial, certainly too bigger for this context. Certainly bronchospasm is an important part of pathogenesis of air flow obstruction that is a major element to cause the air way narrowing. Airways inflammation is mediated and provoked by number of entities, OK. So look at pathogenesis airways inflammation in asthma, there are a number of mediators, such as cytokines, which have origin in basophils and eosinophils. Neutrocytic responses decrease air perfusion tension of adrenaline challenge. There are number of non-allergic provoker of inflammatory which are included in these mediators, such as viral infection, inhalation of cold air and exercise. You can see, that the release of those markers of inflammation enhances inflammation. I have a clear idea of these markers on top of my head of about leukotrines D4 and E4 and like that activating factor so on I do not, I am not certain---

The selected excerpt shows that the expert explained that it is difficult to describe the complete list of pathophysiological issues for causes of asthma, but the main abnormality in an asthmatic patient is airway narrowing which is precipitated by a number of active mediators, which are secreted from basophil and neutrophil cells, for example, cytokinins, leukotrines D4 and E4. These mediators cause bronchospasm or constriction of the hyperactive respiratory tract muscles in the asthmatic patients which results in symptomatology in the patients. The above selected excerpt from the protocol of expert 1 clearly reflects a deeper understanding of the pathophysiology and pathogenesis of the asthma, in which the subject, in contrast to the novice subjects, describes a much deeper level of the causal mechanism of asthma involving the chemical mediators and their action on the respiratory tract, and ultimate results of these chemical actions. Although the explanatory protocols from the students and residents show the use of similar concepts, they do so at a very surface level, without describing the deeper underlying pathogenesis of disease. An excerpt from an explanatory protocol of expert 3 for case 1 is given below:

Excerpt from the protocol for Pathophysiological Explanation
Expert 3; Case 1, Asthma

—-Asthma is an unlucky combination of atopy and increase in airway reactivity. Um!! two abnormalities might manifest with asthma; the atopy plays a role. These people have inflammatory response around the bronchus, um!! response to some insult or stimuli. Um!! the cells through some type of complicated chain of mediators, active mediators bring the insult. These cells release all kind of several component that might contribute and will cause a tremendous amount of fatigue in airways and those will include edema. That would also include the contraction of muscle ——it happens after viral infection even in people who do not have an increase airway activity but in people with asthma this airway activity is very much increased. So the muscle responses very forcefully and closing the airway——

The above excerpt from the protocol of expert 3 also shows a deeper understanding of asthmatic pathophysiology, and this subject gives an elaborated description of chemical mediators, as did expert 2.

The excerpts from residents reflect that during the discussion of the underlying pathogenesis of the disease, the subjects neither considered the issue of therapeutic plans, nor during therapeutic planning, used the concepts of the disease. Instead they introduced a new knowledge-base to the explanatory phase of protocol. Although the therapeutic plans were based on an understanding of the underlying pathology (abnormality in the normal state of the system) of the disorder, the issue of pathogenesis and pathophysiology remains in background during decision making regarding patient management.

Discussion

As I have explained, the pathophysiological or causal explanations given for the disorders in the explanation were basically unrelated to the clinical stimulus text or the subjects' therapeutic responses and clinical knowledge, but some inferential or conceptual interrelation was clearly seen in the subjects' explanation and justification with the clinical stimulus text and their explanatory response. For example, there were two main concepts used during the pathophysiological or causal explanation of the asthma disorder, i.e., (1) hyper-reactivity of the respiratory tract, and (2) inflammatory response. A similar finding was obtained during analysis of causal explanation generated for the non-routine case. In almost all subjects, the pathophysiological explanations were generated from a main concept of risk factors for the development of the clot, which ultimately lead to embolism, i.e., the "Virchow's triad". The concept explains that clot formation is driven by three main causes: (1) stasis, (2) injury to the blood vessel, and (3) a hypercoaguable state of the body. During the explanatory response, it was clearly seen that almost all subjects tried to relate their causal explanation by inferring this stasis in terms of the immobilization of the leg (as a part of fracture management) and the injury to the blood vessel in terms of the local injury to the blood vessels because of the fractured femur shaft. These factors ultimately predispose clot formation at the fracture site and in the deep veins of the leg (deep vein thrombosis) which is the most common (in 95% of patients) cause of pulmonary embolism .

Results also showed that although the explanations from almost all subjects were virtually based on similar main concepts for the disorders, as explained earlier, the responses from the protocol of experts for the pathophysiological or causal explanation for the disorders were more elaborated and reflected their deeper understanding. It was interesting to note that the students' explanations were direct, and more inclined to find clues in the stimulus text, such as the ex-factory worker history, and consequent occupational exposure, cold, and consequent upper respiratory tract infection (surface level explanation). Students' explanatory responses did not show any description of the underlying pathophysiology of the disease, as did the experts, who introduced the issues of chemical mediator, and immune and inflammatory responses of the respiratory tract smooth muscles.

These results were consistent with previous research (Feltovich, Johnson, Mollar, & Swanson, 1984; Bordage & Zacks 1984), which has shown that diagnostic reasoning is "classically centered". Students tend to interpret cases in more common terms. In the present study, these students were in the final year of their school training, and had mostly experienced their disease knowledge in the textbooks and what was taught in the classroom, and had little exposure to real clinical cases. This flatness evident in the novices' explanations (classical centeredness) gradually disappeared as the level of expertise increased, i.e., respiratory residents' explanations started showing a deeper and more elaborate knowledge, and finally the experts' explanations demonstrated a far more detailed explanation about the underlying pathophysiology of the presented clinical cases.

As we hypothesized, the pathophysiological knowledge about the diseases has its own base which is independent of the clinical knowledge about patient management and the therapeutic plan. The pathophysiological knowledge about the disease appears only in the circumstances when a physician is particularly provoked to: (1) explain the underlying cause and its mechanism for the disease, or (2) justify the reason for choosing the therapeutic agents for the treatment or correction of the disorder. The present study supports this hypothesis in the context of decision making regarding therapeutics and patient-management plans. Similar findings were reported by Patel et al (1990) in the context of diagnostic reasoning.

CHAPTER 5

CONCLUSIONS AND FUTURE DIRECTIONS

This chapter will present a summary of the results and a general discussion within the context of the presented research about the use of basic medical science knowledge, the directionality of reasoning and the explanatory responses in relation to patient management and therapeutic planning.

Summary of Results

1. Use of Knowledge

The first objective of this research was to investigate the use of knowledge, in terms of both its nature and the extent to which it is used, during decision making about patient management and therapeutic planning. In responses offered by different groups of subjects to questions regarding therapeutic planning, a number of findings came to light. The most important were as follows:

Three kinds of knowledge were used in therapeutic responses by all groups of subjects. However, differences were found in terms of the extent of their use, which were measured in terms of the number of propositions generated by different groups of subjects with different levels of expertise. The results showed that the subjects used a large number of propositions of clinical science knowledge in comparison to the other two kinds of knowledge, i.e., basic science and pathophysiological knowledge, during their therapeutic and patient-management plan response.

Secondly, it was also clearly evident in the results that the use of basic sciences increases as the level of expertise increases, with peak levels seen in the sub-expert group of subjects. This finding contrasts with results from studies in the area of diagnostic reasoning, where the use of basic sciences decreases with increases in levels of expertise. It also shows similarities to and supports the study conducted by Patel and Arocha (1990) which compares the use of basic science knowledge between medical practitioners and research-physicians. In the present study members in the sub-expert group of subjects were selected from the division of cardiology, and were involved in cardio-physiological research. That study revealed that research physicians use more basic science knowledge during diagnostic reasoning than medical practitioners. In summary, we could explain this increasing trend as a greater ability to differentiate between normal and abnormal states in the body as a function of expertise.

It was also found that the use of pathophysiological knowledge also showed an U-shaped trend with base at level of residents' group, and peaks at levels of the students' and experts' group. This may have resulted from the novices' inability to select relevant and important information for the purpose of prescribing a therapeutic plan, and their tendency to introduce a pathophysiological explanation for every clinical presentation, whether relevant or not, for selecting a therapeutic plan because of their lack of experience about domain-specific problems. Residents, on other hand, have domain-specific knowledge and the ability to select relevant information to build a therapeutic plan; because of a lack of domain-specific practical experience, however, these residents were not able to elaborate the underlying explanations and justifications for their management plans, which were well elaborated by expert subjects (Strauss & Stavy, 1982). It was abundantly clear that all subjects used exactly the same therapeutic agents in their therapeutic plans for both cases. Later, in a qualitative analysis between expert and novice protocols, it became apperant that with the increasing use of basic science and pathophysiological knowledge the therapeutic plans became more and more refined, accurate and beneficial for the patient.

2. Directionality of Inferences

In the results section on reasoning we found that a mixture of backward and forward directed therapeutic inferences was found in all groups of subjects during their therapeutic planning action. However, the dominance of backward or forward therapeutic inferences varied from group to group. The results showed a very interesting finding which indicated a contrasting pattern not only in clinical problem solving in the domain of medicine, but also in other domains like physics, mathematics, etc. Results showed that the expert physicians demonstrated a preference for backward directed therapeutic inferences for their therapeutic decisions. On the other hand, novices depend upon forward rather than backward directed therapeutic inferences.

Secondly, experts in using backward directed inferences, were more accurate and refined in their decisions, which were highly beneficial to the patient. On the other hand, the rule-based treatment prescribed by novices on clinical terms (based on clinical symptomatology) could have caused risk to the patient. In summary we could conclude that backward reasoning, was more beneficial for therapeutic decision making than forward directionality of reasoning. These results in the area of clinical decision making (therapeutic planning) contrast sharply with those in the area of clinical problem solving (diagnostic reasoning), where forward reasoning was directly proportionate to a correct and accurate diagnosis (Patel & Groen, 1990; Kassirer and Kopelman, 1990).

3. Explanatory Responses

A detailed analysis was conducted regarding the use of clinical stimulus text information and the response to patient management and therapeutic planning data to evaluate the explanatory details of an individual subject. All explanatory responses from the subjects were compared against: (a) the clinical stimulus text, and (b) the clinical therapeutic plan response given by the individual subject. This analysis was conducted for both the cases. Results showed that the explanations generated by individual subjects for the pathogenesis of the disorder were mostly independent of the stimulus text or their therapeutic plans. The explanatory responses appear to have been generated from an independent source of knowledge base which was different from the knowledge base used to generate therapeutic responses.

In the analysis of the explanatory responses, it was also observed that the ability to distinguish and articulate the difference between the clinical state of the patient and the underlying pathophysiology, along with refinement and accuracy in therapeutic decisions, increases as a function of expertise. This research sheds light on how a relationship between causal understanding of the disease and accuracy of therapeutic decisions is established. Future research projects could explore how this relationship is established at a deeper level.

During the explanatory response analysis, it was also observed that all subjects had a surface level conceptual understanding of the pathogenesis of the disorders presented to them in the study. However, it was reflected in the experts' responses that they showed a deeper level of understanding. Sub-experts in particular were able to respond in detail about basic science and pathophysiological explanations of the disease. In other words, it could be concluded that an increasing understanding of the pathophysiology of the disease and its relationships with symptomatology coincides with increasing levels of expertise.

A number of pathophysiological concepts are related to asthma. The results showed that the novice subjects were not able to explain these concepts and pathophysiological relationships in enough detail to relate them to the presented case described in the clinical text. On the other hand, the experts' responses effectively articulated the coherence between the pathophysiological and conceptual understanding of the presented case and its symptomatology. This ability allowed expert subjects to prescribe a well balanced and beneficiary treatment to the patient.

Theoretical Models: Diagnostic Vs. Therapeutics

All subjects reasoned forward for the therapy of the known disease:

Forward reasoning is applied when the knowledge of the presented problem is adequate (Patel & Groen, 1990). But when expert physicians come across a complicated situation, or knowledge about the case becomes insufficient, or the case shows a complex nature, they fall back on a backward or causal reasoning strategy (Patel & Groen, 1990). This phenomenon of forward and backward reasoning was also present in the area of clinical decision making. The only difference found in the area of clinical decision making, in contrast to the diagnostic problem-solving model suggested by Patel & Groen (1986), is that all subjects acted initially in a forward direction from given data (diagnosis) towards the solution (therapeutic plan).

The diagnostic problem-solving model suggests that subjects at different levels of expertise act in different ways when they come across the patient's information in routine cases, i.e., experts reason forward whereas novices reason backward. In the area of decision making for therapeutics planning, the research showed that all subjects reasoned forward from the given diagnosis (data) towards the solution, i.e. providing a treatment plan (hypothetical therapeutic plan; generating of new information). Therefore, in the area of therapeutic decision making we found results which contrast with those in clinical problem solving, where the directionality of the reasoning did not show any difference between experts' and novices' reasoning directionality.

The diagnostic model also shows that, during routine problem solving, novices and experts pursue opposite directions in reasoning, i.e., experts reason forward and novices backward; but in complex situations, however, a mixture of forward and backward reasoning is evident. In circumstances where subjects used a mixture of forward and backward directed reasoning, they reached either incomplete or incorrect diagnoses. In contrast, in the area of therapeutic decision making, in both routine as well as non-routine cases, subjects showed a mixture of forward and backward directed therapeutic inferences regardless of their expertise, both with differences in the predominance of one type of inference over the other.

Accuracy and forward directed reasoning

Patel and Groen (1986, 1990), and Arocha, Patel and Patel (1993) showed that forward directed reasoning in the area of problem solving (diagnosis) in the domain of clinical medicine is highly effective in reaching accurate solutions. The results from the research in the area of therapeutic decision-making revealed the following: all subjects showed forward directed reasoning or forward directed therapeutic inferences. However, there were differences in the predominance of reasoning strategies at different levels of expertise. For example, both experts and novices used a mixture of forward and backward directed inferences during their therapeutic decision-making activities, but in their explanations experts showed a predominance of backward directed therapeutic inferences, which were drawn from their pathophysiological and basic science knowledge base, whereas novices showed a predominance of forward directed therapeutic inferences, which were drawn from patient information.

These results in the area of decision making about therapeutic planning showed a contrasting pattern to the results in the area of diagnostic reasoning explored by Patel and her colleagues (1990). The results reflect that the subjects with a dominance in backward directed inferences had a much deeper understanding of the clinical problem, and decisions about therapeutics and patient management were much more refined and accurate. Accuracy and correctness in the area of therapeutic decision making do not dependent upon a forward direction of inferences; rather they are related to the level of understanding of the underlying cause or pathophysiology of the disorder.

Causal and Clinical Term-Based Reasoning

Another comparative difference between the diagnostic problem-solving model and of therapeutic planning model was between novices' and experts' natures of reasoning. Arocha and Patel (1990) found that students reason in causal terms using more biomedical knowledge, whereas experts make use of clinical components in patient information for their clinical problem solving, i.e. during diagnosis making. The results in the present study in therapeutic decision making study showed that the bases of reasoning were exactly opposite to the those in the area of diagnostic problem solving. In the therapeutic reasoning decisions by novices were typically based on clinical information (symptomatic or clinical terms) in the presented text, whereas experts' decisions were based on a causal or deeper understanding and the analysis of the clinical data.

Converging Evidences for the Findings

The present research in the area of therapeutic decision making on the one hand shows a great contrast with results from the area of clinical problem-solving research which were discussed in section on theoretical models: diagnostic vs. therapeutic. On other hand, conclusions from a number of studies in the area of clinical problem solving gave support this research. Some of the studies which were described in the "Literature Review" chapter will be discussed in conjunction with the findings of the present research in the area of therapeutic decision making as follows:

First of all I will start with the results from the study conducted by Patel, Evans, and Groen (1989) in which they concluded that physicians showed a tendency to use basic medical science knowledge minimally during their diagnostic problem-solving exercise. The present research also indicated that the use of biomedical sciences was minimal in comparison to pathophysiological and clinical sciences. It could be concluded that biomedical sciences are used minimally during clinical medical processes, whether diagnostic problem-solving activities or during the procedures of therapeutic decision-making.

I would like to mention another study conducted by Patel, Arocha, and Groen (1988) in the context of the use of basic medical science to investigate the differences in the nature between practitioners and research physicians in their use of basic science knowledge. In their study the authors concluded that the research-physicians used more basic science in than the practitioners. This research also showed similar behavior in the members of the sub-expert group, who were cardiologists involved in cardio-pulmonary clinical research program. These sub-expert physicians used the highest number of basic medical science propositions in both the routine as well as the non-routine case in comparison to all other groups.

Next, I wish to discuss the conclusions drawn from a study conducted by Joseph and Patel (1990), in which they found that there were no differences between low domain knowledge and high domain knowledge (LDK & HDK: see Literature Review) physicians in abstracting the main concepts or the cues from the given information about the patient to explain the underlying pathophysiology of the disorder, although clear cut differences were observed in the nature of their responses. For example, the HDK subjects used more relations to connect the important information in the given text in comparison to the LDK subjects, and they generated accurate diagnostic hypotheses early, when shown the case segments.

Similarly, the results from this research also support the conclusions drawn from the study of Joseph and Patel about the explanation protocols regarding the underlying pathophysiology of the disease in the experiment. All of the subjects in the experiment were able to select main concepts for explanation of the underlying pathophysiology of both the routine and the non-routine case, regardless of their levels of expertise. But the experts' protocols showed more coherent and elaborate explanations than those of the novices.

Joseph and Patel also concluded that the HDK subjects spent more time in confirming their hypotheses by explaining the given cues in the text. Similarly, the present study also demonstrated that, in formulating their therapeutic plans, experts spent more time than novices, which was exemplified in their habit of seeking more information about the patient before prescribing their therapeutic plans.

Another area I want to draw attention to is the directionality of reasoning used by subjects at different levels of expertise. Results and conclusions drawn from a number of studies show that "forward-directed reasoning" has a strong correlation with the accuracy and correctness of solutions (Simon & Simon, 1978; Patel & Groen, 1991; Kassirer & Kopelman, 1990). The conclusions from this research raise the following question: if it is true that forward reasoning is related to accuracy, then why should we not teach such a strategy to our students (novices)? Lesgold (1988) discussed this issue in detail and concluded that the teaching of forward reasoning alone is not sufficient to derive correct solutions. Forward reasoning should be effectively supported by a strong, extensive, and elaborate domain-specific knowledge base to reach accurate answers for the problem.

This argument is well supported by the results seen in the present research, as we saw that all the subjects in the experiment used forward directed reasoning to draw their therapeutic inferences. For example, all subjects prescribed the patient-management plan based on the diagnosis given in the clinical text; in other words, they used forward directed inference regardless of their levels of expertise. But as we discussed in our result section, the plans of novice subjects were much different than those of the experts. All subjects used similar management plans and therapeutic agents, but the therapeutic inferences drawn by expert physicians were much more refined and beneficiary to the patient. In some instances it was observed that these novice subjects would have created a dangerous situation by their therapeutic plans for the patient in the given context.

These findings coincide with the other research finding that for reasoning forward, a person must have a voluminous and strong knowledge base which can effectively support the resultant solutions or inferences. In other words, the inferences drawn from an extensive knowledge base would be far more beneficial and correct compared to those arising from surface level teaching. It was observed that expert subjects draw their therapeutic inferences after a great deal of interaction between their basic science and pathophysiological knowledge bases and the clinical information in the experiment. Whereas inferences drawn by novices, though, forward directed, were based on surface or clinical terms (symptomatology). The experts were able to articulate the patient's clinical state with the help of their extensive and solid basic science and pathophysiological knowledge base. Experts, because of their large knowledge base, were able to elaborate and justify their therapeutic plans and produce a refined therapeutic plan. On the other hand, novices' plans were rule based, prototypical textbook representations, not effectively supported by explanations and justifications from their limited pathophysiological and basic science knowledge, and lead to imperfect results.

It could be concluded that the teaching of forward directed strategies without a sufficiently strong knowledge foundation would not always lead to good results or solutions, rather it could be dangerous.

The above mentioned studies were conducted in the area of clinical problem-solving or diagnostic reasoning. Although relatively little has been done in therapeutic decision making under a cognitive framework, some studies about therapeutic decision making conducted by Moskowitz, Kuiper, and Kassirer (1988) also support or agree with the results in this research in some respects. For example, in the study of Moskowitz et al. showed that expert subjects work within a limited problem space or subgoal in terms of the patient's overall condition. These experts are able to subdivide their overall therapeutic plans in terms of these subgoals. For example, when expert physicians come across the patient, they consider an initial plan at time T1 and stage 1, then act according to the condition of the patient at time T2 and stage 2. These expert subjects were able to judge whether the results of these initial treatments were progressing towards desired goals or not, and if they achieved their goal within the subgoal, they proceeded to another subgoal until they reached the final goal.

Similar results were seen in the results during patient-management plan responses by the experts in the experiment. For example, experts prescribed their therapeutic plans and then waited for some time to see the therapeutic outcome with the initial treatment, and then went further as observed in their responses as a general statement: "I would give this therapy and watch how the patient responds, if he does not respond well, then I would do that". An explanation for this is that expert physicians divided their plans into different stages and acted accordingly.

Limitations of the Study

There are a number of limitations to this study, which constrain the generalizability of the conclusions from the results in different circumstances. A few of the limitations are as follows:

Although the presented cases in the experiment fall into the category of routine and non-routine cases, the complexity in the presented problem was not well captured. These cases were simple enough for every level of subject, who were able to prescribe their therapeutic plans easily. The extension of the results to include their subjective performance with the complex cases would have provided an additional (much needed) dimension to this study.

In the present research, the emphasis was on the formulation of the clinical decision-making process about therapeutic planning by subjects with different levels of expertise. Two clinical problems were presented with their diagnoses to all the subjects participating in the study. It was difficult to separate the knowledge about the diagnosis itself from the knowledge taken from the text in order to make decisions. A control group of subjects presented with exactly the same clinical information with no diagnosis would have provided additional information to rule out the alternative treatment plan prescribed by the control group for similar clinical data of the patient.

Future Research

The present study suggests several possible extensions.

The present research showed specific phenomena regarding use of different types of knowledge. Results also indicated some similarities with those of other research conducted in the area of clinical problem solving, which suggests that the findings in this research could be generalizable. We should conduct an extended experiment with a greater number of subjects for generalization of the results.

This research could be extended to other domains of clinical medicine, such as neurology, endocrinology, and nephrology.

Medical education and instruction: In the present study expert physicians used more basic science knowledge in their therapeutic planning and were able to justify and refine their planning better, based on their biomedical science understanding, as compared to novices who were not able to explain and justify their treatment plans. This suggests that basic medical sience is very important for clinical reasoning. Therefore, it should be taught appropriately during medical trainning. Another suggestion could be that some signs and symptoms cannot be simulated or percieved from textbooks, and classroom lectures. Therefore, students should be taught with real life clinical problems.

Practice of Medicine: our belief is that this research has practical implications for the practice of medicine. It would be worthwhile to explore the extent to which a physician's decision-making process about therapeutic plans is affected by understanding of basic medical sciences and pathophysiological knowledge of the disease and systems involved. For example, decisions made for thrombolytic therapy may be affected by the individual's understanding of hemodynamics in the patient with pulmonary embolism; decision making about oxygenation with a low percentage of oxygen may be affected by an individual's understanding of the respiratory drive of human body physiology. This suggest that therapeutic plans should be taught in relation to pathophysiology of clinical problems. Since there is no evidence that this is done in medical education in a systematic way, it would be useful to investigate further whether such a strategy would help to improve therapeutic planning strategies for medical practitioners.

Expertise Vs. Experience: from the results found in the present research a question arises regarding expertise and the role of experience in the domain. There are great possibilities of extending this research to investigate this issue in the area of decision making by the selection of subjects with various lengths of experience and various levels of experience working in the same ßspecialty.

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Appendices

Appendix 1

A Descriptive Reference Model for the Cases in the Experiment (Asthma & Pulmonary Embolism)

Clinical Text
Case 1: Asthma

A 53-year-old ex-factory worker was admitted to emergency at one of the Montreal hospitals. Several years previously he had taken early retirement after a prolonged history of increasing respiratory problems. Today, the patient presents with wheezing following a common cough and cold episode. On observation he looks agitated, cyanosed, with labored respiration.

On examination

CVS: Pulse rate is 120/minute, regular, blood pressure is 160/90 mm. Hg on lying, Pulsus paradoxus is 10 mm. Hg.

Respiratory system, shows an increased respiratory rate, 28 per minute diminished chest movements, on auscultation, diffuse wheezing all over the chest.

No clubbing, no central nervous system localizing signs were noticed.

Laboratory investigation

Arterial blood pH	7.22 (7.35–7.45)
Arterial blood pO_2	42 mm of Hg. (80-100)
Arterial blood pCO_2	67 mm. Hg. (35–45)
Arterial blood HCO_3	20 mmol/liter (24-28)
Blood glucose	5.0 mmol/liter (3.6–6.1)
Plasma urea	3.5 mmol./liter (2.9–8.9)
Plasma sodium	140 mmol./liter (136–145)
Plasma chloride	102 mmol./liter (96–106)
Hemoglobin	188 gm./liter (140–180)
PCV(Packed cell volume)	59% (40–52%)
WBC	15000/cmm. (5–10000)
ECG shows	Tachycardia (increased heart rate), regular
X-ray chest	Mild thoracic hyperinflation
Microscopic finding sputum	A few eosinophils and occasional bacteria
Macroscopic finding sputum	Thick and gelatinous in consistency

Asthma

Clinical definition: A typical triad of clinical symptom, such as recurrent episodes of breathlessness, coughing, and wheezing, is characteristic for a diagnosis of asthma. This triad of clinical symptoms and signs coexist.

Pathophysiological definition: Asthma is characterized by increased responsiveness of the tracheobronchial tree to the stimuli, reversible in nature with treatment, and manifested physiologically as narrowing of the air passages and clinically as paraxysms of dyspnea, cough, and wheezing.

The problem of asthma could be divided in two common broad groups; Allergic and Idiosyncratic.

Main Segments of the Clinical Text;

History

A 53-year-old ex-factory worker was admitted to emergency at one of the Montreal hospitals. Several years previously he had taken early retirement after a prolonged history of increasing respiratory problems.

Today, the patient presents with wheezing.

On observation he looks agitated, cyanosed, with labored respiration.

Examination

Pulse rate is 120/minute, blood pressure is 160/90 mm. of Hg on lying,

ECG shows, Tachycardia, regular

Pulsus paradoxus is 10 mm. Hg.

Shows an increased respiratory rate, 28 per minute

Diminished chest movements

On auscultation, diffuse wheezing all over the chest.

No clubbing, no central nervous system localizing signs were noticed.

Laboratory investigation

Arterial blood pH	7.22 (7.35–7.45).
Arterial blood pO_2	42 mm of Hg. (80-100)
Arterial blood PCO_2	67 mm. Hg. (35–45)
Arterial blood HCO_3	20 mmol/liter (24-28)

Hemoglobin 188 gm./liter (140–180),

PCV (Packed cell volume) 59% (40–52%)

WBC, 15000/cmm. (5–10000)

X-ray chest, Mild thoracic hyperinflation.

Microscopic finding sputum, few eosinophils, occasional bacteria, thick, and gelatinous in consistency

The above selected segments or specific patient's information represent the important cues which facilitate the attending physician in taking decisions for patient management and therapeutic planning. A further detailed explanation of these data (cues) and their etiological (factor in the development of the clinical disorder) and pathophysiological importance for the presented problem is given below. This descriptive reference model of the presented problem provides help in establishing a relationship between the clinical state of the patient presented in the experiment and its underlying pathophysiology. Furthermore, this reference model also helps in understanding the graphical reference model and its causal (CAU) and conditional (COND) links for the presented symptomatology and underlying etiological factors and pathophysiology of the disease.

Description

History

A 53-year-old ex-factory worker was admitted to emergency at one of the Montreal hospitals——:

The age and work history suggest that the patient took early retirement because of an increasing respiratory problem. Physicians could assume that the patient might be suffering from some kind of occupational dust, allergens, or chemicals in his working environment which could have caused the problem of asthma.

The patient presents with wheezing following a common cough and——:

Respiratory infections are the most common stimuli that evoke acute exacerbation of asthma. Well-controlled investigations have demonstrated that respiratory viruses, especially those which are related to cold and cough, such as respiratory syncytial virus, para-influenza virus, rhino virus, influenza virus etc., are the major etiological factors. The mechanism by which viruses induce the asthma attack is unknown, but it is probable that the resulting inflammatory changes in airways mucosa produces a reduction in the firing threshold of the sub epithelial vagal receptors. Supporting evidence for this concept is derived from the fact that the airway responsiveness of normal non-asthmatic subjects to nonspecific stimuli is transiently increased after a viral infection.

Agitation:

Decrease in arterial blood oxygen partial pressure lead to cerebral hypoxia and an increased need for air which is observed as agitation in the patient.

Cyanosed state:

Reduced-Hb (Hb-R is a compound which has given up its oxygen in the tissue and is present in the venous blood) causes dark and dusky bluish discoloration of the tissue, which is called cyanosis. Cyanosis in the patient is because of an increased amount of Hb-R. This condition of cyanosis of the tissue appears when the concentration of Hb-R in the blood capillaries is increased by more than a 5 gm. percentage.

Wheezing:

Wheezing is a whistling sound associated with breathing. This sound makes the respiratory illness audibly apparent. Wheezing is produced due to the vibration of the wall of bronchi and alveoli; the passage of high velocity air through the narrowed and compressed air passages results in resonance and produces a high pitched musical sound.

Dyspnea:

Difficulty in breathing; during an asthmatic attack the respiratory tracts are narrowed due to the constriction of the hyperactive respiratory tract (bronchial) smooth muscle, especially during expiration; therefore, the patient has to breathe through a narrowed respiratory tract with increased airways resistance, resulting in very difficult, uncomfortable and labored breathing.

Examination

B lood pressure is 160/90 mm. Hg on lying:

There is mild systolic hypertension, which is common in asthmatic patients because the heart has to work against a hyperinflated chest and non-elastic lungs. This loss in the lungs' elasicity is because of the chronic over-streching of lung tissues.

Pulsus-paradoxus

Normally the arterial blood pressure falls approximately 5 mm. of Hg. on inspiration. In cases of asthma and other respiratory airways obstruction disorders, this fall exceedsthe normal limits (less than 10 mm. of Hg.)

Laboratory investigation

A decrease in arterial blood pH and an increase in partial pressure of carbon-dioxide:

Any process which hinders the ventilatory process (inspiration or expiration) leads to increased carbon-dioxide, which in turn increases the formation of carbonic acid in the system, which leads to an increase of hydrogen ions (H-ions) which are acidic ions. An increase of these H-ions in the blood results in a lower blood pH and causes systemic acidosis. In the presented routine case, the patient has obstructed airways, which hinders the ventilatory function in the patient, leading to retention of carbon-dioxide in the alveoli of the lungs and ultimately back-diffusion of carbon-dioxide into the circulating blood. This leads to an increased production of carbonic acid and decreased arterial blood pH.

Decreased partial pressure of oxygen in arterial blood:

Because of obstructed airways, inspiration is difficult so less fresh air is inspired, resulting in low oxygen in the alveoli. The low oxygen concentration in the alveoli leads to less diffusion into the blood, and a low partial pressure of oxygen in arterial blood

Increase in hemoglobin

Because of the chronic airways obstruction, there is less delivery of oxygen to the alveoli, leading to less diffusion of oxygen in the lungs, leading to low oxygen partial pressure in arterial blood; this is called "arterial hypoxemia". This patient has a long-standing case of asthma, therefore, there may be a prolonged exposure to a hypoxic condition in the blood producing system (i.e. hemopoitic system). A chronic exposure to a low oxygen condition in the hemopoitic system results in an increased production of red blood cells as a compensatory phenomenon, to carry more oxygen to the tissues by increasing the number of red blood cells which are responsible for carrying oxygen. Therefore, there is an increase in packed cell volume (PCV) in blood. This increase in hemoglobin in asthmatic patients is a compensatory phenomenon which is essential to carry oxygen to the vital organs.

X-ray chest showing hyperinflation:

Because of the chronic obstruction, air is trappe inside the lung alveoli, which gives a hyperinflated picture on the x-ray film of the lungs.

Clinical-triad and histo-pathophysiological relation

The clinical triad of asthma is basically because of the contraction of airways smooth muscle, resulting in narrowing of the respiratory air passage, mucosal thickening from edema and eosinophilic cellular infiltration as a result of immunological reaction by the release of cellular mediators. As a result of such allergic reactions, the airway lumen becomes inflamed, and inflammatory secretions form viscid plugs of mucus causing blockage of the respiratory tract, resulting in the symptomatology, i.e., breathlessness, cough and wheezing. These clinical signs and symptoms are reversible with the proper management and therapy of the patient.

Therapeutics and Patient-management

In the case of asthma, the main purpose of the treatment is to relieve the cause of the clinical triad, that is, bronchospasm. This relief in bronchospasm could be achieved in the following ways:

1. General Patient Management

1.1 Oxygenation

Oxygen therapy results in benefits if it is administered in appropriate concentrations. This will increase the alveolar oxygen concentration manyfold, and will increase the oxygen diffusion-gradient from the alveoli into the capillary.

Note: Oxygen therapy can be fatal in the chronic hypoxic condition, because the whole of the respiratory drive depends on the hypoxic-drive; if we correct the hypoxia by giving a high concentration of oxygen, the hypoxic-drive will disappear and the patient might go into respiratory failure. A continuous and repeated assessment of blood gases and the objective measurement of lung functions is very important in asthmatic patients.

1 2 Humidification and fluid management

This is done to replace the larger amount of insensible water losses that occur due to prolonged hyperventilation or an increased respiratory rate. Rehydration is done with ringer lactate, N/2 saline intravenously or as oral hydration therapy if the patient is cooperative. This fluid replacement therapy also helps in decreasing the thick and gelatinous mucous plugs in the respiratory passages.

2. Therapeutic Agents

2.1 mast-cell degradation:

This is achieved by Cromolyn sodium. This agent differs from most other anti-asthmatic medication because of its value when taken prophylactically. This agent is effective in reducing the overall level of bronchial reactivity, if taken long enough by metered-dose inhaler. This drug has no effect on already set bronchospasm and also does not have any effect on bronchial muscle tone. This drug cannot stop an already set antibody-antigen reaction. The drug inhibits the immediate and delayed reaction to inhalation of antigen. This is a very useful drug in cases of exercise-induced and aspirin-induced asthma and that induced by a variety of industrial agents.

2.2 blockage of conduction of sensation:

To achieve this action we use the local or topical anesthetic-agents. These agents block the sensory conduction along sensory or motor nerves to the airways.

2.3 inhibition of the effect of the neurotransmitters:

Acetylcholine is a neurotransmitter which is released from vagus nerve endings, providing sensation to the bronchial tree. The inhibition of these neurotransmitters can be achieved by muscarine antagonists, for example, Ipratropium, Atropine or Atrovent. These muscarine antagonists competitively inhibit the effect of acetylcholine at the muscurine receptor, and effectively block the contraction of the smooth muscle of the bronchial tree.

2.4 Direct relaxation of airway smooth muscle

Sympathomimetic agents, i.e., theophyllines, relax the contracted airway smooth muscle and inhibit the release of bronchoconstricting substances from mast cells. The exact mechanism of actions isnot known for these agents; however, these are thought to act through cyclic-AMP (c-AMP) by increasing their concentration inside the cells. Examples of these agents are Epinephrine, Ephidrine, Isoproterenol, and other beta-2 selective drugs like Albuterol and Terbutaline. Theophylline is the commonest agent which is used in almost all of the patients. Aminophylline is an agent in this group which can be given in intravenous form in emergencies as well as in oral maintenance therapy, but the cardiac adverse effect should not be ignored.

2.5 Prolonged therapy with agents that prevent late response

Corticosteroids and Cromolyn sodium are examples of these drugs. Corticosteroids are added in the therapeutic plans of patients whoser asthma is inadequately controlled by inhaled beta-agonists alone.

3. Long term Management

Prevent mast-cell degradation, and avoid triggering agents (allergic components) if known

Clinical Text
Case 2: Pulmonary-Embolism

A healthy young man aged 35 years was admitted to one of the Montreal hospitals after a serious car accident on the highway. The patient had come to the hospital with a fractured femur-shaft. Two weeks later the patient suddenly developed breathlessness and a cough. He looked very agitated, complaining of severe chest pain.

On examination

Patient has mild fever with a temperature of 38 C.

CVS. pulse-rate 120/min. regular, blood pressure is 80/60 mm. of Hg.

Respiratory system examination he found an increased RR. by 28/min. and diminished chest movements.

No clubbing, no central nervous system localizing signs were noticed.

Laboratory investigations

Arterial blood	pH 7.50 (7.35--7.45)
Blood PO_2	60 mm.of Hg. (80--100)
Blood pCO_2	30 mm. of Hg.(35--45)
Blood HCO_3	25 mmol./liter (24--28)
Blood glucose	5.0 mmol./liter (3.6-6.1)
Plasma sodium	135 mmol/liter(136-145)
Plasma chloride	102 mmol./liter (96-106)
Blood urea	3.5 mmol/liter (2.9-8.9)
Hemoglobin	140 gms./liter.(140-180)
PCV (Packed cell volume)	30 % (40--52)
WBC count	6000/cmm. (5--10)
Total Thyroxine(By RIA, T4)	75 micro gm/liter (50-120)
Prothrombin time	3.0 sec.(less than 2 sec.)
Partial Thromboplastin Time (PTT)	30.0 sec.(25--37)
Albumin	30 gm/liter (35--50)

No abdominal mass detected on abdominal examination except a mild pain in epigastric region.

ECG. was done immediately and was found to be normal except for a tachycardia of 126 beats/mt.

X-ray chest: show some abnormal findings of an area of consolidation (high density region), in peripheral area of lung.

Pulmonary-angiogram shows an abrupt "cutoff" of a vessel at a point further away from periphery and a "negative shadow" (filling defect: Radiopaque material flows around embolus)

Pulmonary-Embolism

Main Segments of Clinical Text

History

A healthy young man aged 35 years was admitted to one of the Montreal hospitals after a serious car accident on the highway.

The patient had come to the hospital with a fractured femur-shaft.

Two weeks later the patient suddenly developed breathlessness and a cough. He looked very agitated, complaining of severe chest pain.

On examination

CVS. pulse-rate 120/min. regular, ECG. was done immediately and was found to be normal except for a tachycardia of 126 beats/min.

Patient has mild fever with a temperature of 38* C.

Blood pressure is 80/60 mm. of Hg.

Respiratory system examination he found an increased RR. by 28/min.

Diminished chest movements.

blood pressure is 80/60 mm. of Hg.

Laboratory investigations

Arterial blood pH 7.50 (7.35--7.45)

Blood PO_2 60 mm. of Hg. (80–100)

Blood pCO_2 30 mm. of Hg.(35–45)

PCV (Packed cell volume), 30 % (40--52)

No abdominal mass detected on abdominal examination except a mild pain in epigastric region.

X-ray chest: show some abnormal findings of an area of consolidation (high density region), in peripheral area of lung.

Pulmonary-angiogram shows an abrupt "cutoff" of a vessel at a point further away from periphery and a "negative shadow" (filling defect: Radiopaque material flows around embolus)

Description

Serious car accident and fractured femur shaft:

Available data indicate that more than 95% of pulmonary emboli arise from thrombi in the deep venous system of the lower extremities. Therefore, every pulmonary embolism should be viewed as a complication of deep venous thrombosis (DVT), especially whenever other related factors are also present. Furthermore, it appears that the larger leg veins, those above the knee, are the most common source of those pulmonary emboli which cause clinical problems. In the case history presented, theserious car accident led to a fractured femur shaft (a lower extremity).

The management could take two forms; (a) closed-reduction, meaning that the management of the fracture is performed with a traction or a splint, or an external fixation over the fractured bone without any operative surgerical procedure; or (b) open-reduction, meaning that the patient is operated upon and the fixation of fractured bone is performed with the help of steel rods or nails in or on the bone.

The second issue of vein injury is also obvious in this kind of situation. These injuries to the veins could result from two causes; (a) as a result of the accident bone surrounding tissues and blood vessel might have suffered injury; and (b) the patient might have gone under open-surgical procedure, and surrounding vessels could have been injured during surgery.

During both of these procedures the patient is bed-ridden for a substantial time.

A two weeks stay in hospital hospital:

This temporal factor is very important in the development of the thrombosis in the lower extremities as well as in the development of pulmonary emboli. First of all, the information in the clinical history, "Two weeks later the patient suddenly-----", excludes the possibility of fat-emboli which is very common in cases of long bone fracture, like the femur (leg), or radius (arm) bone. But fat embolism usually occurs within 24 to 36 hours after injury to long bones, therefore the history of two weeks obviates the possibility of fat embolism, and gives the subjects no alternative than the diagnosis of thrombo-pulmonary embolism.

Another possibility of long-term non-ambulation is stasis of blood circulation in the deep veins of the lower extremities. This stasis because is a factor in the development of thrombosis (according to Virchows' triad; stasis, abnormalities in blood vessels, and a hypercoagulative-state are three risk factors for the development of clots). Hence, we have two factors related to the development of thrombosis: stasis and injury to the vessel.

Sudden development of breathlessness and cough:

A sudden onset of breathlessness and a cough in a healthy young man of 35 years with associated conditions, such as a fractured femur shaft, and non-ambulation for two weeks in a hospital, indicates a risk of pulmonary thrombo-embolic phenomena. This is one of the diagnostic features of pulmonary embolism. A severe persistent dyspnea is an ominous sign for pulmonary embolism, and usually indicative of severe and extensive embolic occlusion which is obvious by pulmonary angiogram as well. This symptomatology of breathlessness and cough stem from thrombo-embolism in the complete or partial obstruction of the main pulmonary artery and a large percentage of the pulmonary vasculature; this results in respiratory consequences, such as:

(A) intrapulmonary "dead-space" formation, meaning that the affected area is ventilated but not supplied with blood (not perfused) because of the obstruction of the pulmonary vasculature which results in the death of tissue due to a lack of nutrition to the area.

(B) ventilation-perfusion (V/Q) mismatch: The lung area which is not perfused (dead-space) cannot participate in the respiratory process or function, i.e., cannot exchange gases from the atmosphere (oxygen) in the blood and cannot expire carbon-dioxide into the atmosphere from the blood. Therefore, ventilation in that area is "wasted" because of no perfusion, in the respiratory physiological sense.

(C) the after effect of pulmonary embolism is constriction of the air space and airways in the affected areas of the lung (pneumo-constriction) because of the release of a protective mediator. This phenomenon of pneumo-constriction is to protect the waste ventilation or reduce waste ventilation.

Severe chest pain and agitated:

Pleuratic chest pain and sometimes hemoptysis occurs if infarction is present. The infarction is shown in the chest x-ray as a high density region in the periphery which is also indicative of pleuratic irritation due to the infarct, and results in chest pain. Another cause of chest pain is the sudden and extensive vasculature obstruction; there is sudden dilatation of blood vessels in the pulmonary vasculature which stimulates pain receptors situated in lung tissues (pain fibers) resulting in sudden pain.

Another cause of severe chest pain is the right ventricular Ischemia in cases of extensive pulmonary embolism. The agitated presentation of the patient is because of the need for air and a sudden feeling of choking.. Psychologically, also because of the severe chest pain the patient develops "an in death" feeling. Pain in pulmonary embolism could also be due to the sudden stretch of the pulmonary vessel because of the block in the artery and results in chest pain.

Pulse rate, 120/minute and ECG shows tachycardia of 126/minute:

Both correspond to each other, this is a single consistent finding in pulmonary embolism. The ECG was done immediately and was found to be normal except a tachycardia of 126 beat/minute, all suggestive of the acute onset of disease. However, in the case of an extensive pulmonary embolism, later some changes could be seen in the ECG, for example: (a) signs of right ventricular failure (b) a loud pulmonary closure sound, (c) a palpable "lift" over the right ventricle on the left sternal border, and (d) a prominent "a-wave" in Jugular venous pulse

Mild Temperature, 38*C:

A mild fever in a patient with pulmonary embolism with infarction is a rule. Infarction is well establish in the x-ray finding as a consolidated area of a high density region. Sometimes higher temperature like 39*C or 40*C are also noticed even without any evidence of infection. It is very difficult to differentiate infection and pulmonary infarction in practical situations.

Increased Respiratory Rate, 28/minute (Tachypnea):

An increase in respiratory rate is a very common symptom of pulmonary embolism. This is because of the stimulation of medullary respiratory centers in the brain via vagal nerve afferent fibres from stretch receptors (Juxta-capillary or J-receptors) in the interstitial spaces of the lung. Hyperventilation is results from air deprivation due to the sudden development of dead space

Diminished chest movements:

Diminished chest movements are because of (a) consolidation or infarct area in the peripheral region of the lungs; this consolidation results from the loss of surfactants in the alveolar surface in the affected area of the lung which are responsible for keeping alveoli expended. But because of the obstruction in blood vessels in that area causes the loss of surfactants, the alveoli collapses and leads to atelactasis, which appears as a transluscent consolidated area in the periphery of the lung in the x-ray chest report. This resuls in diminution in chest movements, and pleural surface (covering of the lungs) irritation because of infarcted (dead tissue) lungs; the patient feels pain during inspiration or expanding the chest in full. Therefore, the patient tends to expend his lung less during breathing.

Blood pressure, decreased, 80/60 mm. of Hg.:

The fall in blood pressure in cases of pulmonary embolism is suggestive of a severe, extensive and central type of pulmonary embolism causing a severe hemodynamic compromise in thebody's cardiovascular system, which is also clear in the pulmonary angiogram. This acute fall in blood pressure is also suggestive of the seriousness of disease and the need for immediate attention. A sudden fall in blood pressure is also an indication for the selection of a particular type of management plan (NIH-criteria).

Arterial blood pO2 decreased:

A decrease in arterial blood oxygen partial pressure results from many factors associated with the case of pulmonary embolism, for example

(a) ventilation-perfusion disturbances

(b) pneumo-constriction and broncho-constriction

(c) alveolar collapse due to surfactants loss

(d) cardiac failure with a lowered mixture of venous blood pO2 leading to acute hypoxia to the cardiac tissue and also, due to the obstruction in the pulmonary main vasculature, there is an acute rise in pulmonary pressures (pulmonary hypertension) which may result in right ventricular failure.

(e) Hypoxemia is due to a right to left shunt in areas of atelactasis or complete collapse.

Arterial blood pCO_2 decreased:

Because of the sudden obstruction of the pulmonary vasculature leading to an acute increase in the respiratory rate as a reflex phenomenon, hyperventilation, increased excretion or flushing out of carbon-dioxide in expiratory air leads to a decrease in arterial blood carbon-dioxide partial pressure (pCO_2).

Arterial blood pH increased, Alkalosis; 7.5:

The decrease in carbon-dioxide partial pressure in arterial blood leads to respiratory alkalosis and an increas in arterial blood pH, as a result of the decrease in carbonic acid formation in the system. This increase in pH, respiratory alkalosis, is suggestive of the acute onset of the pulmonary disorder which is also indicated in the clinical history.

Packed cell volume, decreased:

It is a well-established fact that long bone fracture may lead to a massive amount of blood loss (sometimes 2-3 litres). This is especially true in the case of a fractured femur shaft where the average blood loss is estimated at two to two and a half litres. The loss of blood volume triggers the hemopoitic system and fluid controlling system to conserve fluid in extracellular compartments, i.e., blood vessels, and this increase in volume results in a compensatory increase in plasma volume leading to hemodilution; therefore, packed cell volume is reduced.

No abdominal mass, except a mild pain in epigastric region:

Pain in the epigastric region is a somewhat tricky question. It may be associated with pulmonary embolism in the following ways: (a) referred pain from the infarcted lung near the chest wall, (pleuratic pain) to the abdominal wall, (b) the back flow of blood to the liver via the inferior vena cava from the right ventricle because of the big obstruction in the pulmonary vasculature leading to swelling of the liver capsule resulting in epigastric pain, and the last but least possible (c)an increase in the respiratory rate leading to fatigue of the abdominal muscle and pain.

X-ray chest: consolidation in peripheral area of lung:

Consolidation or infarcted area in the peripheral region of the lungs is also because of the loss of surfactants in the alveolar surface which are responsible for keeping alveoli expended. Due to the loss of surfactants because of the obstruction in blood vessels in that area, the alveoli collapse and this leads to atelactasis, and appears as a consolidated area in the periphery of the lung.

Pulmonary angiogram:

Pulmonary angiography is the gold standard test for the diagnosis of pulmonary embolism; in most cases this test gives almost 100% correct results. The clinical text presented during this experiment clearly demonstrates that the pulmonary angiogram is 100% confirmatory of pulmonary embolism showing an "abrupt cutoff sign" away from the periphery indicating that the embolism is near the central vascular system, meaning the heart and big vessels (aorta, pulmonary artery), and also showing the "filling defect" which is characteristic of a very large and extensive pulmonary embolism.

Patient-Management and Treatment

1. Specific management

1.1 intravenous Heparin is the drug of choice with a diagnosed case of pulmonary embolism. It should be started immediately unless there is any contraindication, for example, a previous history of a bleeding disorder, or stomach-ulcers.

The Heparin works in three ways in the management of pulmonary embolism. (a) It prevents further embolic phenomena (b) it promotes thrombo-embolic resolution indirectly as a result of un-opposed fibrinolysis because of no further thrombus growth, (c) it prevents the reoccurrence of embolic phenomena by preventing the further growth of thrombus.

1.2 Following a massive pulmonary embolism:

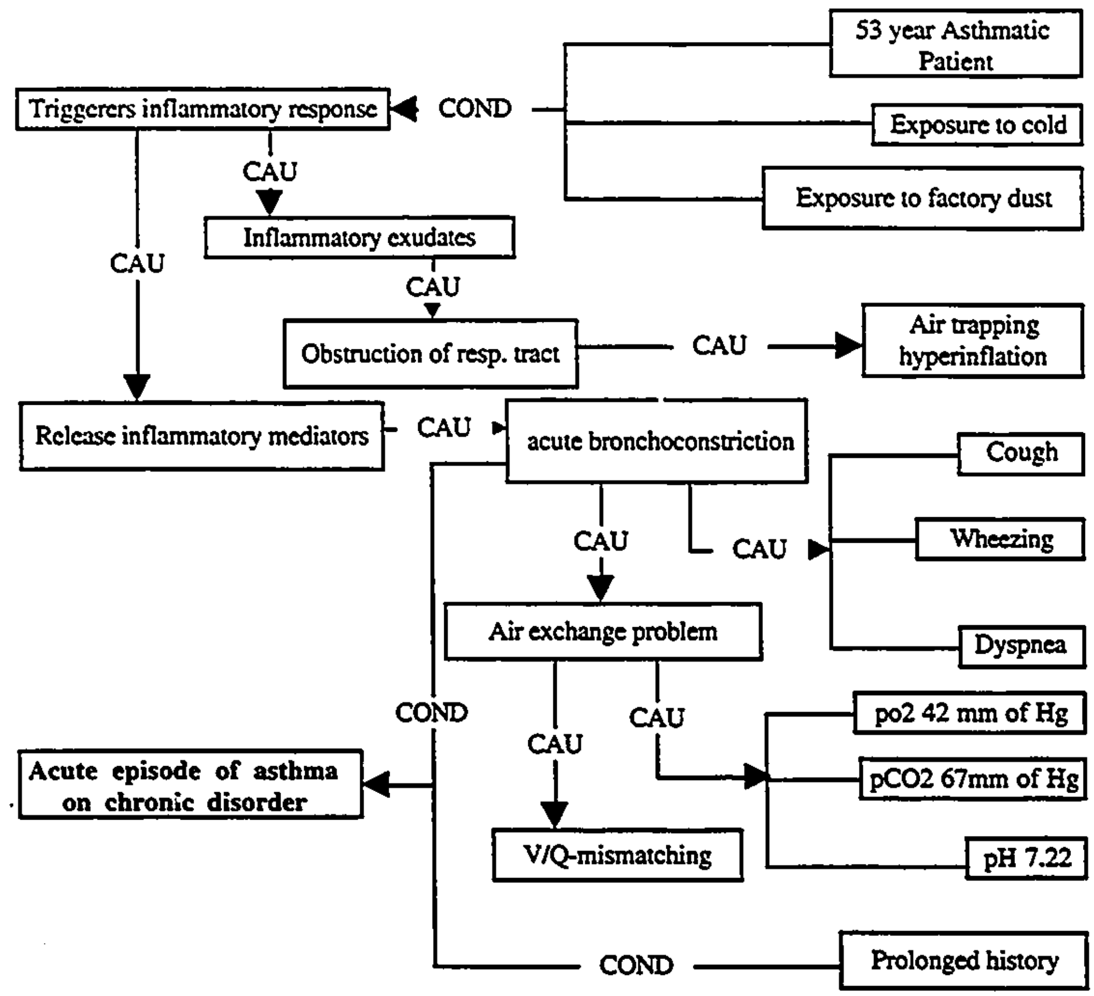
Massive embolic phenomena is evident by an acute fall in blood pressure. In these cases the approach istwo folds; (a) if blood pressure falls by 90-100 mm. of Hg, this could be managed by fluid therapies; (b) if the blood pressure fall is severely below 90 mm. of Hg. systolic, then thrombolytic therapy is required, which dissolves the clot itself; examples are Streptokinase, Urokinase, Plasma tissue activator (PTA).

Mechanism of action of Streptokinase is that it converts plasminosen into plasmin which is an active fibrinolytic enzyme which dissolves the fibrin and breaks up the clot. There are a few mild adverse effects of streptokinase, such as fever, and allergy which could be reduced by a premedicational dose of hydrocortisone.

2. Supportive measures: (a) analgesics: for obvious pleuratic chest pain (b) sedatives for agitation, and anxiety: these should be given consciously, (c) oxygen therapy if the arterial partial pressure fall below 60-65 mm. of Hg., particularly if the pCo2 is also low, oxygen therapy is recommended.

Appendix 2
REFERENCE MODEL FOR ROUTINE CASE OF ASTHMA
A Graphical Representation

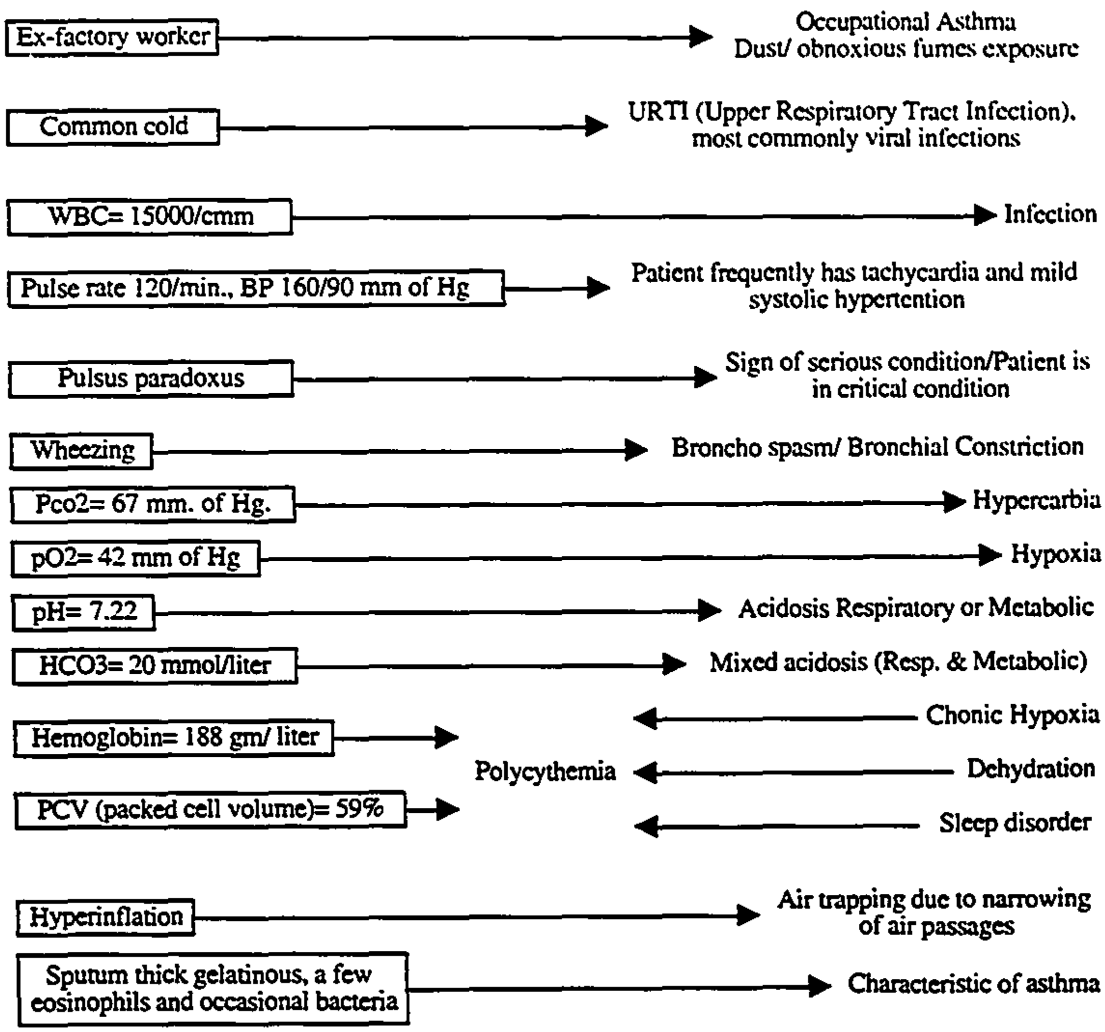
This model specifically represents the problem of asthma described in experiment
Pathophysiological definition: Asthma is characterized by increased responsiveness of tracheobronchial tree to the stimuli, reversible in nature with treatment and manifested physiologically as narrowing of air passages and clinically as paraxysms of dyspnea, cough, and wheezing



Appendix 3
Reference model of inferences for routine case of Asthma

(This reference model of inferences represent the possible inferences which could be drawn from the clinical information provided to the subjects in the experiment)

CLINICAL TEXT INFORMATION | **INFERENCES**

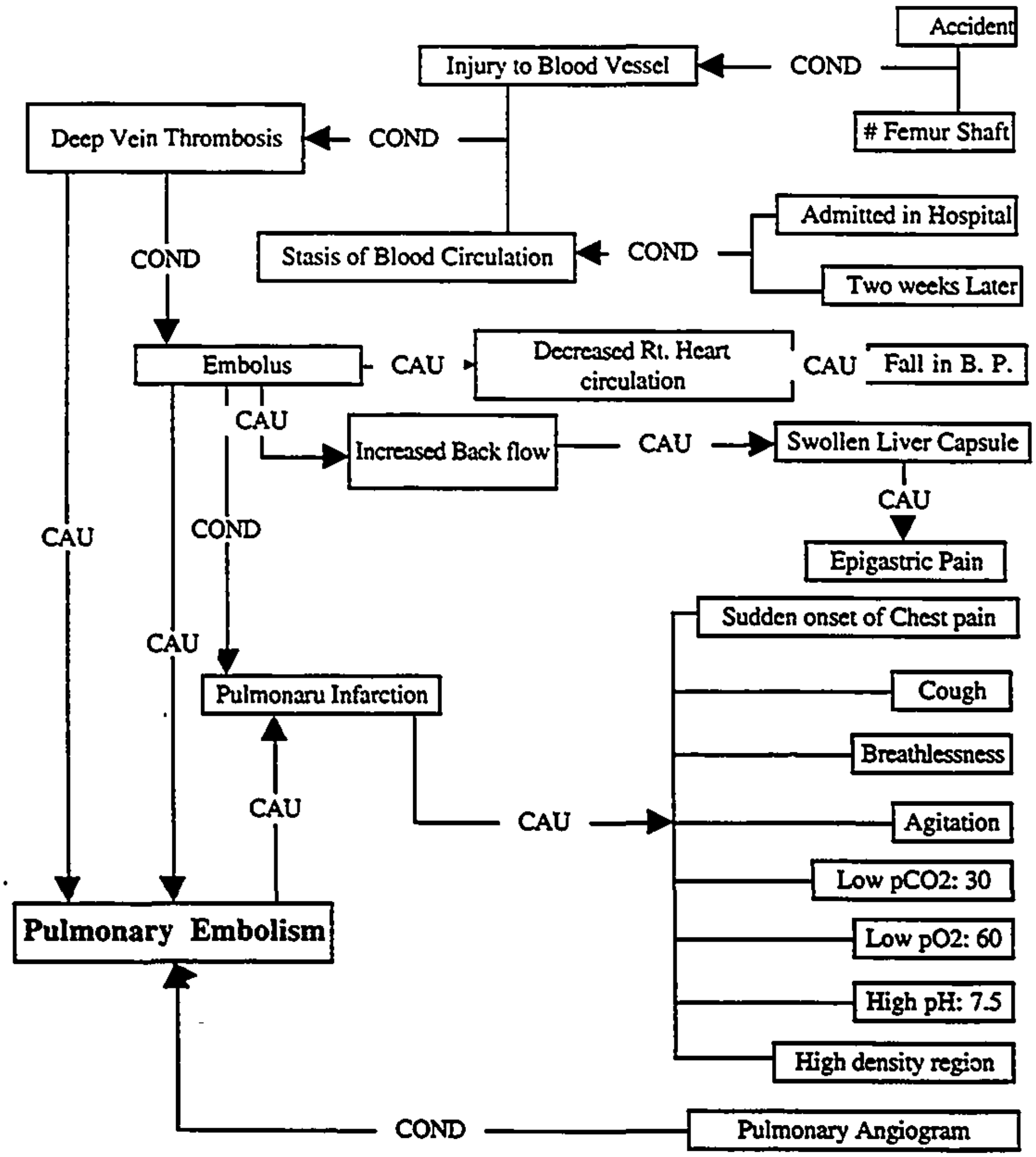


Appendix 4

REFERENCE MODEL FOR NON-ROUTINE CASE OF PULMONARY EMBOLISM

A Graphical Representation

This model specifically represent the problem of Pulmonary Embolism described in experiment



Appendix 5
Reference model of inferences for non-routine case of Pulmonary Embolism

(This reference model of inferences represent the possible inferences which could be drawn from the clinical information provided to the subjects in the experiment)

CLINICAL TEXT INFORMATION	INFERENCES
Car accident and fractured femur shaft	Orthopedic management of the fracture surgical or conservative in plaster cast
fractured femur-shaft	Local injury to tissues, muscles ,blood vessels During accident or surgery
admitted to one of the Montreal	As post-orthopedic management, lying in bed
Two weeks later	Lying in bed for two weeks; risk of developingDVT, commonest (95%) cause of pulmonary embolism
suddenly breathlessness and a cough, agitated, severe chest pain.	Typical feature of P.E., relevant history of two weeks bed confinement and risk of DVT, pulmonary angiography report
increased RR. by 28/min. and Blood pCO2 30 mm. of Hg.	Increased washing out of CO2 from the body system lead to low CO2 level
Arterial blood pH pH 7.50	High blood pH, Alkalosis/respiratory alkalosis/ Alkalotic pH because of low CO2 level
mild pain in epigastric region.	diaphram irritation, stretching of liver capsule, stomach ulcer, abdominal injury during accident
X-ray chest: high density region in peripheral area	Pulmonary infarction due to lack of blood supply
Pulmonary-angiogram shows an abrupt "cutoff" of a vessel at a point farther away from periphery and a "negative shadow"	Gold standard test for pulmonary embolism; diagnosis of pulmonary embolism is sound

Appendix 6

Use of Knowledge
During Patient-Management and Therapeutic Plans

Note: Literal reproduction of the clinical text were not coded, in particular, when the subjects read the case without producing any inferences or elaborations.

1. **Student 3**

2. **Case 1, Asthma**

3. Subject

4. BB pulsus paradoxus is elevated in asthma case

5. CC you know when you say pulsus paradoxus mean

6. pathophysiology of each of these presentation, each of these take of your text

7. no clubbing, no central nervous system signs pO_2

8. ohhhho!! you are kidding

9. Ok. um!! therapeutic and patient-management plan reasons supporting your choices

10. CC I think this is an acute exacerbation of asthma

11. CC there may or may not be component of COPD in this

12. CC I may treat as a, as an acute exacerbation of a

12. PP potential reversible respiratory broncho-constriction problem.

13. CC I will treat him quite urgently

14. CC this man is close to um!! dying

15. BB um!! his O_2 is quite low

16. CC he is quite acidotic

17. BB more, more in still pCo_2 is high

18. CC at least he is hyperventilating

19. CC um!! so in terms of what I would do

20. CC he also have a pulsus paradoxus which is a worrying sign as well

21. PP indicative of quite severe obstruction

22. CC so I suppose I need, I will intubate him

23. CCand it sound of it, he is agitated, he is cyanosed

24. CC he is breathing with difficulty, with some difficulty

25. CC I do not know, I do not know how exactly they interpret

26. CC there are various presentation

27. but given his pH is 7.22

28. CC I think he is very labored

29. CC I probably cannot do intubation

30. CC and probably he has sudden

31. CC and once in there, and once in the line are there, I would fit him with high dose solumedrol

32. CC I would do some information

33. CC also I think there is enough support using um!! antibiotics too

34. CC even though he is wheezing, common cold, cold episode

35. PP I think most case of viral even in setting of asthma

36. CC but refer to COPD exacerbation

37. PP it is certain he is 53 years, he is ex-factory worker

38. PP there is nothing about smoking

39. PP but there are two things alone and early retirement

40. prolong history of increase respiratory problem

41. PP may or may not be occupational asthma

42. CC but may probably a component of COPD as well

43. CC I think on that basis the trial of antibiotic would be warranted

44. CC it is going to be true intensive some thing

45. CC simple like septran, I think that usually used

46. CC um!! what else, and same time, it does going to be work out

47. CC which will go you will have to go high

48. PP actually, actually, which actually may reflect COPD as well

49. CC may be little bit polycythemia

50. BB um!! like I just said the packed cell volume is high

1. Expert 3

2. Case 1, Asthma

3. so this is the man who is 53 years old in age

4. CC that's do not sounds previous respiratory problems

5. CC but it is not defined

6. CC but um!! it is possible that there was asthma

7. CC since he was even though he was small in amount

8. CC I do not think that is says in history

9. um!! and fever, cough

10. PP being even too young to have any abnormality due to smoking at the time of retirement

11. CC so I suppose that he has asthma before

12. PP and that asthma could have been exacerbated by environment at work may be that is why he retired

13. CC now you do not know if he has been taken any medication for note or not and that suppose important

14. CC um!! then he present to emergency room with the one day history

15. um!! of wheezing following a common cold and cough

16. PP oh!! common cold and cough and that is very typical presentation of asthma

17. and he looks agitated and cyanosed, a labored respiration

18. CC um!! so looks like he has an acute asthmatic attack

19. PP um!! that has been brought up by common cold

20. CC um!! on physical examination there are some thing that little bit, do not make do not hang together very well

21. CC he is tachycardic as you expect with some body in acute distress

22. CC the blood pressure is little bit elevated it also goes along with and there

23. BB is no pulsus paradoxus so that; it only 10 mm. of mercury, that within limits and

24. CC so I suppose that is the best um!! index of severity in asthmatic attack

25. CC um!! that, that is of interest because it tells that probably it is not of the maximum severity

26. CC uh!! he has an increased respiratory rate as you will expect

27. BB also um!! he has diminished chest movement that you expect

28. CC and he has diffused wheezing over the chest and this is in a sense a good sign in top of a bad sign

29. PP because um!! if asthma will be with bigger severity will give you no wheezing at all

30. BB so the fact if he is wheezing still more air in and out

31. um!! um!! he has no clubbing

32. no central nervous symptom so on

33. CC now interesting, now I do not know who wrote this

34. BB but there is the key the key um!! lab test that the only one really that you need to handle this person is not present

35. BB and that is the flow rates

36. BB and he should have had a forced expiratory volume in first second (FEV_1) done

37. CC that is the first thing you have to do before the blood gas

38. CC but any way you do not have, now the arterial blood gas are of interest because they do not they do not make sense either

39. PP um!! the arterial blood pH is 7.22 and when we looked at CO_2 is certainly markedly elevated

40. CC and looking at bicarbonate is, is normal or little bit low

41. CC um!! so the acidosis he has, might be even starting to be mixed acidosis meaning, he has a metabolic

42. CC he has mainly a respiratory acidosis because of the asthma

43. BB and of interest that, that fact that he does not have pulsus paradoxus

44. CC fact that still quite a bit uh!! and then the people with asthma uh!!! can develop a metabolic acidosis

45. PP um!! probably because of the effect of high hyperinflation

46. BB and very high pressures that these people have to work within the heart

47. BB to give infusion in top of a hypoxemia to these regions

48. BB and work of breathing to give marked

49. PP um!! metabolic acidosis at time that they in vary asthma they do that

50. CC Now other thing that is of interest that the arterial pO_2 is low

51. CC that I would have expected, partly due to high CO_2

52. CC but asthmatics presenting like this guy might not necessarily have that low pO_2

53. CC so that will make me to suspect that he might have the pneumonia

54. BB that will produce mere marked ventilation-perfusion mis-match

55. PP and lower the pO_2 that obviously that makes things worse

56. CC I mean that could be because of asthma

57. CC but you should think about pneumonia

58. BB He is um!! he has high hemoglobin

59. CC and he has high packed cell volume

60. PP and these can be interpreted in two ways the number one,

61. PP interpretation to me, he could have he could certainly have dehydration

62. PP because of acuteness of the episode, may be he has fever

63. CC and he also these people who breath quite a bit a lot blood through the bleeding

64. PP another possibility that has abnormality in this either chronic hypoxemia

65. BB or an abnormality in red blood cells

66. CC but that should probably be looked into it

67. BB the white blood cells is elevated but I would expect to be elevate

68. PP just on a acute um!! very um!! episode of asthma but it self you will bring that up other possibility is that

69. PP he might have a an infection

70. CC an other possibility he has polycythemic vera

71. BB the white count should be increase also

72. CC but again those are possibilities that should be looked into after the acute episode gone, gone

73. CC the rest of the , the rest of the exam is not remarkable

74. CC and certainly doesn't help me one way or another

75. CC in summary this is a man who possibly have previous history of asthma

76. CC who as far as I can tell he was not on treatment then

77. PP following a cold he developed acute exacerbation of, of asthma that is very severe

78. CC oh!! as interesting by blood gases

79. BB but he is still keep it he still does not have pulsus paradoxus however the

80. CC blood show that, his asthma effecting not only the lung and gas exchange seen by pCO_2

81. BB but probably also the circulatory system

82. CC and he stated that have a metabolic acidosis

83. CC so the next thing that I will be very much concern is that he might have pneumonitis

84. CC even though the chest x-ray does not have tell us that he has, he has

85. PP and because of arterial pO_2

86. CC and I will be concern about that so in sense because that interpretation

87. BB Well!! the certainly it would be nice to, it would be nice,

88. BB first thing I would do

89. BB what is FEV_1 is

90. BB because that is the way you are going to follow the response of the patient for the treatment

91. CC so before I start I start any treatment

92. BB even I try to do FEV_1 it take few second that would guide me

93. CC um!! this immediately as he comes in he should have an intravenous started

94. CC he should have the fluid given to in

95. CC and in intravenous steroids either cortico, either poly-solumedrox in a dose about 40 mg. so every 4 hourly, I mean 6 hourly, some thing like that to start

96. CC then he should be given the inhaled ventoline or bronchodialater

97. CC uh!! immediately also or through nebulizer

98. CC and then I would also start him on aminophylline um!! that in case there is a asthma it should be given

99. CC I would watch him very carefully

100. CC I would give him oxygen off course

101. CC I will work him very carefully, uh!! for his response to the treatment

102. CC because this is a kind of person

103. CC that if he doesn't improve very quickly, he might detoriate and he need to be intubated

104. CC um!! I would try not to keep him into emergency room

105. CC but I would admit him directly to the as soon as if possible in intensive care unit

106. CC and we will keep an eye very very, you know!! carefully in intensive care unit

107. CC and that is fine I will not give HCO_3

108. CC and you know I will continue with that kind of treatment to start.

109. CC I will not give him adrenaline either at least at the present time

110. CC because his age is little bit too advance for that

111. CC um!! so there I would see what is his response

112. CC that is what I would do if he does not

1. Student 3

2. Case 2, Pulmonary Embolism

3. Excellent!! healthy young man 35 years one of those, serious car accident, fine!! fracture shaft two weeks later patient suddenly get breathlessness, cough, complains of severe chest pain

4. CC well! they do not say any thing one way or other, but he has a fracture femur shaft

5. and two weeks later he admitted in the hospital

6. CC since two weeks he is not doing much since they immobilized him

7. um!! he looks very agitated and he has got very severe chest pain

8. CC and acute onset, um!! so obviously pulmonary embolism is the most common in the differential

9. CC mild fever temperature of 38*, that consistent, cardiovascular pulse rate 120 also that consistent

10. some blood pressure 80/60

11. PP oooh!! that suggest quite significant of embolism

12. BB respiratory system exam, increase respiratory rate, tachypnea

13. CC this gives me probably most universal finding, what we see in pulmonary embolism

14. diminished chest movement

15. CC it can suggestive of presence of large pulmonary embolism

16. no clubbing, no central nervous system finding

17. CC blood gas this time he is fairly alkalotic

18. CC his pO_2 is low his pCO_2 is low as well

19. CC so in this case what he is doing he is hyperventilating

20. BB that because does not have agreeable shunt what he did, he before

21. BB because he did not compensated for better in compare to the last person

22. BB asthma is hyperventilating in order to compensate to his lower in pCO_2

23. CC and become alkalotic as a result

24. CC um!! inspite his bicarbonate is, is reasonably normal

25. CC blood glucose nothing, sodium, sodium is little above, chloride

26. BB um!! renal function is fine

27. BB packed cell volume is little low

28. CC nothing in the white count, thyroxin is quite normal, these are the old diagnosis

29. CC is prothrombin is little

30. CC um!! PTT is usual, albumin is low fine !!

31. no abdominal mass, no

32. ECG tachycardia OK!!

33. Um!! consolidation fine

34. blood cut off negative shadow, negative shadow fine

35. CC I find this whole, this is fairly consistent with pulmonary embolism

36. CC um!! well really there main without positive pulmonary angiogram been really

37. CC at this point, so I would, I would, I would anticoagulate him

38. CC um!! providing by do not have any any, any overt contraindication through that, and to see there is not

39. CC anticoagulate him

40. CC I would put him on anticoagulation

41. CC why would we do that immediately by starting, getting him a bolus of intravenous heparin

42. BB continuing that until I had a therapeutic, therapeutic PTT

43. CC I would probably start caumarin, right off

44. CC about, about just because I am hoping that

45. CC no actually, no doubt, I would, I would give him heparin

46. CC but I would also give him streptokinase

47. CC um!! I would try to dissolve the clot

48. CC because it obviously has low blood pressure

49. CC he is hypotensive , his alkalemic pH

50. CC he is very very early sort of positive findings

51. PP it is quite a severe clot um!! I would, I want really to get rid of it

52. CC uh!! uh!! uh!! so I would probably give him some streptokinase

53. CC some what only streptokinase

54. CC proper dose to give him thrombolytic therapy to get rid of this

55. CC so I will read about that then I would give him streptokinase

56. CC once I would done, then I would anticoagulate him

57. CC this disseminate the clot other way

58. CC if he did not, he continued to go down then will

59. CC um!! first of all, before you will get that, you have to, you have to make sure he is, he is well supported

60. CC so give him oxygen

61. CC and when he becomes obstanded

62. CC we will intubate him um!! we will support his ventilation that way

63. CC but really situate this guy really you got to rid off that clot

64. CC and you cannot do it by

65. CC this is, this is something you might think

66. CC doing retros. anyway

67. CC patient management plan the other point when did he get this embolus

68. PP he had a fracture femur shaft

69. PP um!! he is been immobilized

70. PP so that reaction he has

71. CC that he had deep vein thrombosis (DVT)

72. PP obviously that through of nervous from them

73. PP but given that he had fracture femur shaft

74. PP little late but it could have fat embolism as well

75. CC um!! so you better be prepare of possibility of streptokinase

76. CC now working um!! any way I am working on through out

77. CC because sodium and blood chloride

78. CC physical findings of deep vein thrombosis

79. CC um!! and same thing really applied following his, following his oxygenation, his blood pH

1. Expert 3

2. Case 2, Pulmonary Embolism

3. CC well the first thing I would do is to admit him into intensive care unit, and if he is not in intensive care unit

4. CC the reason for intensive unit is, is because of the hypotention

5. CC and because of very high risk of that

6. CC he has due to, that I comment before

7. CC now I think that a swan gauge catheter will be probably in orders

8. CC in order to to have a good access to this patient, in order to measures pressure accurately and

9. CC and the also, the fluids will have to be given

10. BB in order to overcome the after load on the right ventricle

11. CC and going to give anticoagulation

12. CC I think I am going to have to be very careful about to know exactly where we are at that time

13. CC I think that second thing I, I would do

14. CC um!! once the patient I find he is stable in intensive care unit

15. BB I certainly try to do rectal, rectal examination

15. BB and try to get some stool and see there is some in, blood in stool

16. BB and I would have the hematologist statement give me an opinion in peripheral smear either can give any guidance

17. PP um!! because you know, it is nice to know that this patient is Italian and he has some kind of uh!! anemia other then um!! a blood loss

18. CC um!! I would also um!! I would also try to have gastro-enterologist, give me a hand

19. BB um!! and I would as far as a gastroscopy in this person

20. CC um!! to see either is there is any ulcer or there is any bleeding in the stomach

21. PP and I would certainly examine what kind of, what kind of medication he has been on it as far as pain medication and see

22. PP that would explain these kind of blood loss, although still think that in two weeks that would have been quite a bit of blood loss

23. CC um!! now um!! I do not think that, I do not think that I am going to get away without anticoagulant in this person

24. CC I mean this person has to be anticoagulated um!! I think because of the, a, because of conscience about that I have about the the possible GI. (gastro-intestinal) and possible anemia

25. CC and inspite of having a blood pressure 80/60 and I think that I would start with heparin

26. CC now I would start with heparin instead of a thrombolytic agent because heparin is much easier to reverse

27. CC just in case patient worked to bleed if he had a you know a had a um!! an ulcer in the stomach

28. CC um!! I would certainly will give him, probably a, a, H_2-blocker so you have to, cimitidine or similar in order to keep this acid protected stomach is not responsible

29. CC I might even give him some, you know!! antacid or some thing else in order to keep this guy

30. CC uh!! I would give him oxygen

31. CC and certainly give him plenty of fluids in order to, to increase the blood pressure

32. CC all these in the intensive care unit certain certainly with, with swan gauge type of measurement

33. CC and you know hope for the best

34. CC if the guy some, some bleed

35. CC um!! if, if his blood pressure did not respond to heparin and the and he detoriated farther inspite of all kind of measures, we are using to increase blood pressure in intensive care unit and so on

36. CC you might have consider if he does, does not bleed

37. CC um!! a thrombolytic agent

38. CC as I said that I certainly would try to, would try to stay away if ever possible.

Appendix 7

Directionality of Inferences During Patient-Management and Therapeutic Plans

Note: Coding of inferences for therapeutic and patient-management planning, as forward and backward directionality were carried out for the excerpts containing clinical information and therapeutic procedure.

1. Student 3

2. Case 1, Asthma

3. Subject

4. pulsus paradoxus is elevated in asthma case

5. you know when you say pulsus paradoxus mean

6. pathophysiology of each of these presentation, each of these take of your text

7. no clubbing no central nervous system sign pO_2

8. ohhhho!! you are kidding

9. Ok. um!! therapeutic and patient-management plan reasons supporting your choices

10. I think this is an acute exacerbation of asthma

11. here may or may not be component of COPD in this

12. I may treat as a, as an acute exacerbation of a potential reversible respiratory broncho-constriction problem.

13. I will treat him quite urgently

14. this man is close to um!! dying

15. um!! his O_2 is quite low

16. he is quite acidotic

17. more, more in still pCO_2 is high

18. at least he is hyperventilating

19. um!! so in terms of what I would do

20. he also have a pulsus paradoxus which is a worrying sign as well

21. indicative of quite severe obstruction

22. so I suppose I need, I will intubate him

23. and it sound of it, he is agitated, he is cyanosed

24. he is breathing with difficulty, with some difficulty

25. I do not know, I do not know how exactly they interpret
26. there are various presentation
27. but given his pH is 7.22
28. I think he is very labored
29. I probably cannot do intubation
30. and probably he has sudden
31. and once in there, and once in the line are there, I would fit him with high dose solumedrol
32. I would do some information
33. also I think enough, there is enough support using um!! antibiotics too
34. even though he is wheezing, common cold, cold episode
35. I think most case of viral even in setting of asthma
36. but refer to COPD exacerbation
37. it is certain he is 53 years, he is ex-factory worker
38. there is nothing about smoking
39. but there are two things alone and early retirement
40. prolong history of increase respiratory problem
41. may or may not be occupational asthma
42. but may probably a component of COPD as well
43. I think on that basis the trial of antibiotic would be warranted
44. it is going to be true intensive some thing
45. simple like septran, I think that usually used
46. CC um!! what else, and same time, it does going to be work out
47. which will go you will have to go
48. high actually, actually, which actually may reflect COPD as well
49. may be little bit polycythemia
50. um!! like I just said the packed cell volume is high

1. Expert 3

2. Case 1, Asthma

3. so this is the man who is 53 years old in age

4. that's do not sounds previous respiratory problem

5. but it is not defined

6. but um!! it is possible that there was asthma

7. since he was even though he was small in amount

8. I do not think that is says in history

9. um!! and fever, cough

10. being even too young to have any abnormality due to smoking at the time of retirement

11. so I suppose that he has asthma before

12. and that asthma could have been exacerbated by environment at work may be that is why he retired

13. now you do not know if he has been taken any medication for note or not and that suppose important

14. um!! then he present to emergency room with the one day history

15. um!! of wheezing following a common cold and cough

16. oh!! common cold and cough and that is very typical presentation of asthma

17. and he looks agitated and cyanosed, a labored respiration

18. um!! so looks like he has an acute asthmatic attack

19. um!! that has been brought up by common cold

20. um!! on physical examination there are some thing that little bit, do not make do not hang together very well

21. he is tachycardic as you expect with some body in acute distress

22. the blood pressure is little bit elevated it also goes along with and there

23. is no pulsus paradoxus so that, it only 10 mm. of mercury, that within limits and so I suppose that is the best um!! index of severity in asthmatic attack

24. um!! that, that is of interest because it tells that probably it is not of the maximum severity

25. uh!! he has an increased respiratory rate as you will expect

26. also um!! he has diminished chest movement that you expect

27. and he has diffused wheezing over the chest and this is in a sense a good sign in top of a bad sign

28. because um!! if asthma will be with bigger severity will give you no wheezing at all

29. so the fact if he is wheezing still more air in and out

30. um!! um!! he has no clubbing

31. no central nervous symptoms so on, now interesting

32. now I do not know who wrote this

33. but there is the key the key um!! lab test that the only one really that you need to handle this person is not present

34. and that is the flow rates

35. and he should have had a forced expiratory volume in first second (FEV1), done

36. that is the first thing you have to do before the blood gas

37. but any way you do not have now the arterial blood gas are of interest because they do not they do not make sense either

38. um!! the arterial blood pH is 7.22 and when we looked at CO_2 is certainly markedly elevated

39. and looking at bicarbonate is, is normal or little bit low

40. um!! so the acidosis he has, might be even starting to be mixed acidosis meaning, he has a metabolic, he has mainly a respiratory acidosis because of the asthma

41. and of interest that, that fact that he does not have pulsus paradoxus doesn't

42. fact that still quite a bit uh!! and then the people with asthma uh!! can develop a metabolic acidosis

43. um!! probably because of the effect of high hyperinflation

44. and very high pressures that these people have to work within the heart

45. to give infusion in top of a hypoxemia to these regions

46. and work of breathing to give marked

47. um!! metabolic acidosis at time that they in vary asthma they do that

48. Now other thing that is of interest that the arterial pO_2 is low

49. that I would have expected, partly due to high CO_2

50. but asthmatics presenting like this guy might not necessarily have that low pO_2

51. so that will make me to suspect that he might have the pneumonia

52. that will produce mere marked ventilation-perfusion mismatch

53. and lower the pO_2 that obviously that makes things worse

54. I mean that could be because of asthma

55. but you should think about pneumonia

56. He is um!! he has high hemoglobin

57. and he has high packed cell volume

58. and these can be interpreted in two ways the number one,

59. interpretation to me, he could have he could certainly have dehydration

60. because of acuteness of the episode, may be he has fever

61. and he also these people who breath quite a bit a lot blood through the bleeding

62. another possibility that has abnormality in this either chronic hypoxemia

63. or an abnormality in red blood cells

64. but that should probably be looked into it

65. the white blood cells is elevated but I would expect to be elevate

66. just on a acute um!! very um!! episode of asthma but it self you will bring that up other possibility is that

67. he might have a an infection

68. an other possibility he has polycythemic vera

69. the white count should be increase also

70. but again those are possibilities that should be looked into after the acute episode gone, gone

71. the rest of the, the rest of the exam is not remarkable

72. and certainly doesn't help me one way or another

73. in summary this is a man who possibly have previous history of asthma

74. who as far as I can tell he was not on treatment then

75. following a cold he developed acute exacerbation of, of asthma that is very severe

76. oh!! as interesting by blood gases

77. but he is still keep it he still does not have pulsus paradoxus however

78. the blood show that, his asthma effecting not only the lung and gas exchange seen by pCO_2

79. but probably also the circulatory system

80. and he stated that have a metabolic acidosis

81. so the next thing that I will be very much concern is that he might have pneumonitis

82. even though the chest x-ray does not have tell us that he has, he has

83. and because of arterial pO2

84. and I will be concern about that so in sense because that interpretation

85. Well!! the certainly it would be nice to, it would be nice,

86. first thing I would do,

87. what is FEV_1 is

88. because that is the way you are going to follow the response of the patient for the treatment

89. so before I start I start any treatment

90. even I try to do FEV_1 it take few second that would guide me

91. um!! this immediately as he comes in he should have an intravenous started

92. he should have the fluid given to in

93. and in intravenous steroids either cortico, either poly-solumedrox in a dose about 40 mg. so every 4 hourly, I mean 6 hour some thing like that to start

94. then he should be given the inhaled ventoline or bronchodialater

95. uh!! immediately also or through nebulizer

96. and then I would also start him on aminophylline um!! that in case there is a asthma it should be given

97. would watch him very carefully

98. I would give him oxygen off course

99. I will work him very carefully

100. uh!! for his response to the treatment because this is a kind of person that, if he doesn't improve very quickly

101. he might detoriate and he need to be intubated

102. um!! I would try not to keep him into emergency room

103. but I would admit him directly to the as soon as if possible in intensive care unit

104. and we will keep an eye very very, you know!! carefully in intensive care unit

105. and that is fine I will not give HCO_3

106. and you know I will continue with that kind of treatment to start.

107. I will not give him adrenaline either at least at the present time

108. because his age is little bit too advance for that

109. um!! so there I would see what is his response

110. that is what I would do if he does not

1. Student 3

2. Case 2, Pulmonary Embolism

3. Excellent!! healthy young man 35 years one of those, serious car accident, fine!! fracture shaft two weeks later patient suddenly get breathlessness, cough, complains of severe chest pain

4. well! they do not say any thing one way or other, but he has a fracture femur shaft

5. and two weeks later he admitted in the hospital

6. since two weeks he is not doing much since they immobilized him

7. um!! he looks very agitated and he has got very severe chest pain

8. and acute onset, um!! so obviously pulmonary embolism is the most common in the differential

9. mild fever temperature of 38*, that consistent, cardiovascular pulse rate 120 also that consistent

10. compensation to some blood pressure 80/60

11. oooh!! that suggest quite significant of embolism

12. respiratory system exam, increase respiratory rate, tachypnea

13. this gives me probably most universal finding, what we see in pulmonary embolism

14. diminished chest movement

15. it can suggestive of presence of large pulmonary embolism

16. no clubbing no central nervous system finding

17. blood gas this time he is fairly alkalotic

18. his pO_2 is low his pCO_2 is low as well

19. so in this case what he is doing he is hyperventilating

20. that because does not have agreeable shunt what he did, he before

21. because he did not compensated for better in compare to the last person

22. is hyperventilating in order to compensate to his lower in pCO_2

23. and become alkalotic as a result

24. um!! inspite his bicarbonate is, is reasonably normal

25. blood glucose nothing, sodium, sodium is little above, chloride

26. um!! renal function is fine

27. packed cell volume is little low

28. nothing in the white count, thyroxin is quite normal, these are the old diagnosis

29. is prothrombin is little

30. um!! PTT is usual, albumin is low fine!!

31. no abdominal mass, no

32. ECG tachycardia OK

33. Um!! consolidation fine

34. blood cut off negative shadow, negative shadow fine

35. I find this whole, this is fairly consistent with pulmonary embolism

36. um!! well really there main without positive pulmonary angiogram been really

37. at this point, so I would, I would, I would anti coagulate him

38. um!! providing by do not have any any, any overt contraindication through that, and to see there is not

39. anti coagulate him

40. I would put him on anticoagulation

41. why would we do that immediately by starting, getting him a bolus of intravenous heparin

42. continuing that until I had a therapeutic, therapeutic PTT

43. I would probably start caumarine, right off

44. about, about just because I am hoping that

45. no actually, no doubt, I would, I would give him heparin

46. but I would also give him streptokinase

47. um!! I would try to dissolve the clot

48. because it obviously has low blood pressure

49. he is hypotensive , his alkalemic pH

50. he is very very early sort of positive findings

51. it is quite a severe um!! clot um!! I would, I want really to get rid of it

52. uh!! uh!! uh!! so I would probably give him some streptokinase

53. some what only streptokinase

54. proper dose to give him thrombolytic therapy to get rid of this

55. so I will read about that then I would give him streptokinase

56. once I would done, then I would anticoagulate him

57. this disseminate the clot other way

58. if he did not, he continued to go down then will

59. um!! first of all, before you will get that, you have to, you have to make sure he is, he is well supported

60. so give him oxygen

61. and when he becomes obstanded

62. we will intubate him um!! we will support his ventilation that way

63. but really situate this guy really you got to rid off that clot

64. and you cannot do it by

65. this is, this is something you might think doing retros....anyway

67. patient management plan the other point when did he get this embolus

68. he had a fracture femur shaft

69. um!! he is been immobilized

70. so that reaction he has

71. that he had deep vein thrombosis (DVT)

72. obviously that through of from them

73. but given that he had fracture femur shaft

74. little late but it could have fat embolism as well

75. um!! so you better be prepare of possibility of streptokinase

76. now working um!! any way I am working on through out

77. because sodium and blood chloride

78. physical findings of deep vein thrombosis

79. um!! and same thing really applied following his, following his oxygenation, his blood pH

1. Expert 3
2. Case 2, Pulmonary Embolism

3. well the first thing I would do is to admit him into intensive care unit and if he is not in intensive care unit

4. the reason for intensive unit is, is because of the hypotention

5. and because of very high risk of that

6. he has due to, that I comment before

7. now I think that a swan gauge catheter will be probably in orders

8. in order to to have a good access to this patient, in order to measures pressure accurately and

9. and the also, the fluids will have to be given

10. in order to overcome the after load on the right ventricle

11. and going to give anticoagulation

12. I think I am going to have to be very careful about to know exactly where we are at that time I think

13. that second thing I, I would do

14. um!! once the patient I find he is stable in intensive care unit

15. I certainly try to do rectal, rectal examination and try to get some stool and see there is some in, blood in stool

16. and and I would have the hematologist statement give me an opinion in peripheral smear either can give any guidance

17. because you know, it is nice to know that this patient is Italian and he has some kind of uh!! anemia other then um!! a blood loss

18. um!! I would also um!! I would also try to have gastro-enterologist, give me a hand

19. um!! and I would as far as a gastroscopy in this person

20. um!! to see either is there is any ulcer or there is any bleeding in the stomach

21. and I would certainly examine what kind of, what kind of medication he has been on it as far as pain medication and see

22. that would explain these kind of blood loss, although still think that in two weeks that would have been quite a bit of blood loss

23. um!! now um!! I do not think that, I do not think that I am going to get away without anticoagulant in this person

24. I mean this person has to be anticoagulated um!! I think because of the, a, because of conscience about that I have about the the possible GI. and possible anemia

25. and inspite of having a blood pressure 80/60 and I think that I would start with heparin

26. now I would start with heparin instead of a thrombolytic agent because heparin is much easier to reverse

27. just in case patient worked to bleed if he had a you know a had a um!! an ulcer in the stomach

28. um!! I would certainly will give him, probably a, a H_2-blocker so you have to, cimitidine or similar in order to keep this acid protected stomach is not responsible

29. I might even give him some, you know!! antacid or some thing else in order to keep this guy

30. uh!! I would give him oxygen

31. and certainly give him plenty of fluids in order to, to increase the blood pressure

32. all these in the intensive care unit certain certainly with, with swan gauge type of measurement

33. and you know hope for the best

34. if the guy some, some bleed

35. um!! if, if his blood pressure did not respond to heparin and the and he detoriated further inspite of all kind of measures, we are using to increase blood pressure in intensive care unit and so on

36. you might have consider if he does, does not bleed

37. um!! a thrombolytic agent

38. as I said that I certainly would would try to, would try to stay away if ever possible.